JUNIPER RIDGE LANDFILL EXPANSION APPLICATION
VOLUME III
DESIGN REPORT

Submitted by:

STATE OF MAINE BUREAU OF GENERAL SERVICES,
as Owner
and
NEWSME LANDFILL OPERATIONS, LLC,
as Operator

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TABLE OF CONTENTS

Section No.	Title	Page No.

TABLE OF CONTENTS (cont'd)

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

JUNIPER RIDGE LANDFILL EXPANSION
APPLICATION
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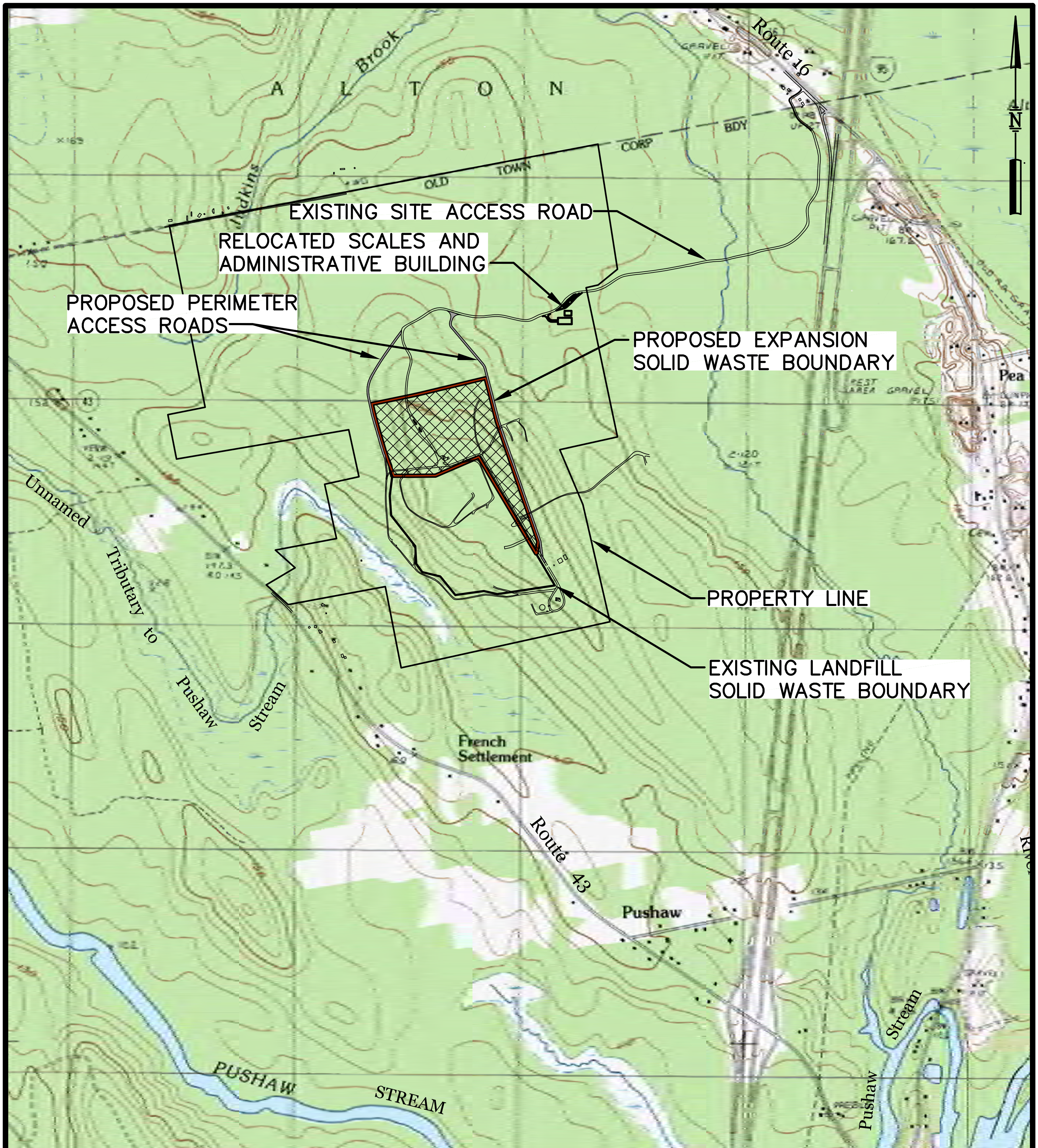
1.0 INTRODUCTION

This report describes the components of the Juniper Ridge Landfill (JRL) landfill expansion (i.e., the Expansion) and presents the design basis for those components as required of the Maine Solid Waste Management Rules (Rules) 06-096 CMR 401, Sections 2.D and F. The report discusses the site-specific factors considered during the design of the Expansion's liner, leak detection and underdrain systems, leachate collection, transport and storage systems, gas management system, and cover systems. Also addressed in this report is the phasing of the Expansion development, the proposed stormwater management and erosion control plans, the geotechnical and contaminant transport analyses, and the Expansion's construction.

1.1 Project Description

The Expansion will be located north of and adjacent to the existing JRL within the approximately 780-acre parcel of land owned by the BGS, as depicted in Figure 1-1. Access to the site is by means of a paved, two-mile-long, private road that joins Maine Route 16 in Alton, Maine. The Expansion, which in total will expand the solid waste footprint by about 54 acres, will be developed in a series of cells similar to the existing facility. BGS and NEWSME project the first expansion cell will need to be constructed during the 2018 construction season to be available for use in 2019.[1] The Expansion will provide approximately 9.35 million cubic yards of disposal capacity. The total Expansion facility site, including supporting site infrastructure (e.g., access roads, stormwater management ponds, relocated scales and office building) will be approximately 74 acres (see Figure 1-2).

[1] This assumes a filling rate of 733,400 cubic yards per year between 2015 and 2019. In addition, of the remaining permitted capacity about 664,000 cubic yards was associated with the capacity obtained by the construction of a Mechanically Stabilized Earthen Berm (MSEB). This represent about one year of disposal capacity. This capacity will be recaptured during waste filling within the expansion cells by filling against the current waste sideslopes within the current solid waste boundary.



NOTE:

BASE MAP ADAPTED FROM 7.5 MIN USGS TOPOGRAPHIC QUADRANGLE OLD TOWN, MAINE–1988

1000 0 2000 4000 FEET

FIGURE 1–1
SITE LOCATION MAP
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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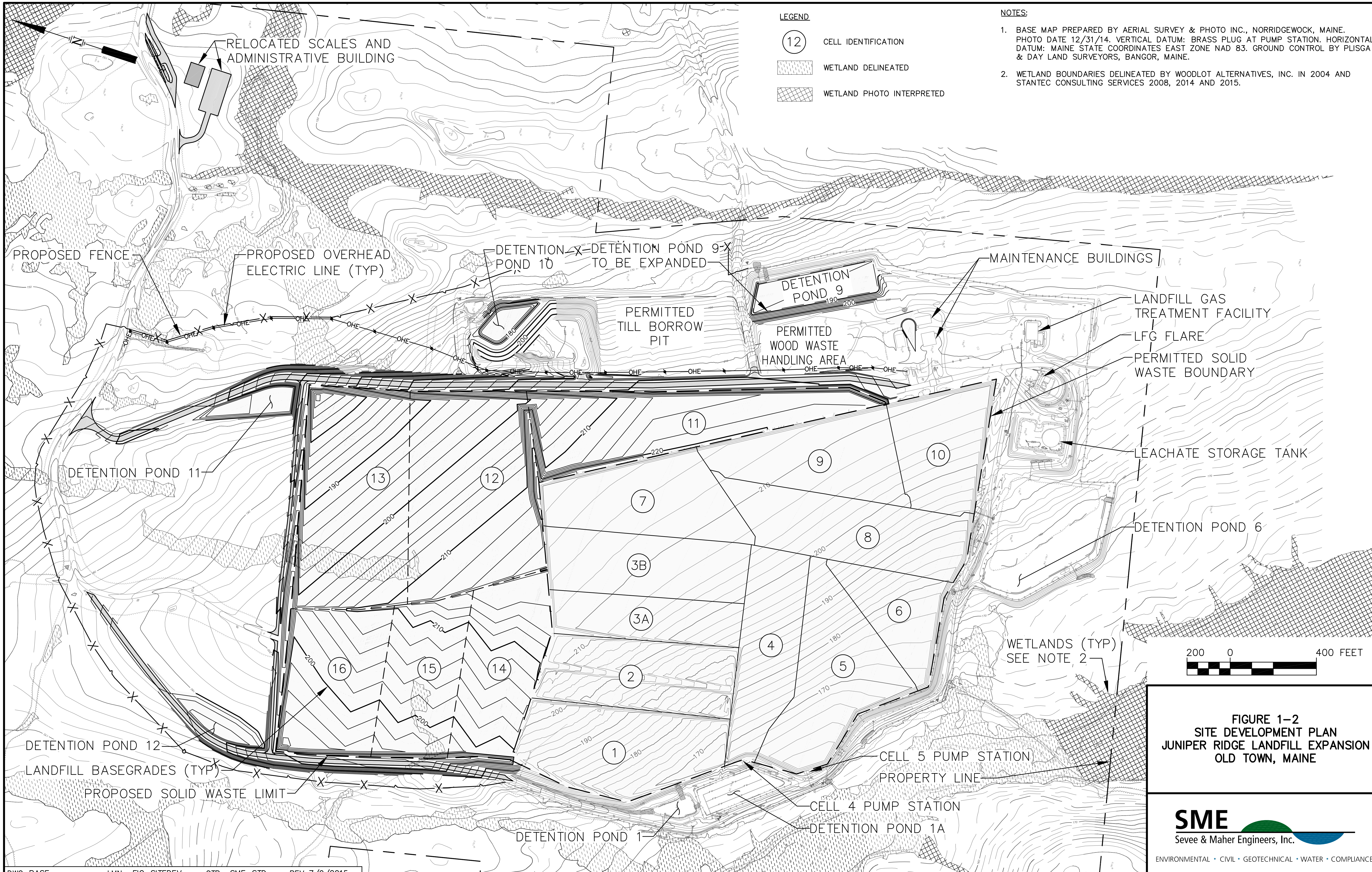

LEGEND

12 CELL IDENTIFICATION

WETLAND DELINEATED

WETLAND PHOTO INTERPRETED

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE.
2. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.

FIGURE 1–2
SITE DEVELOPMENT PLAN
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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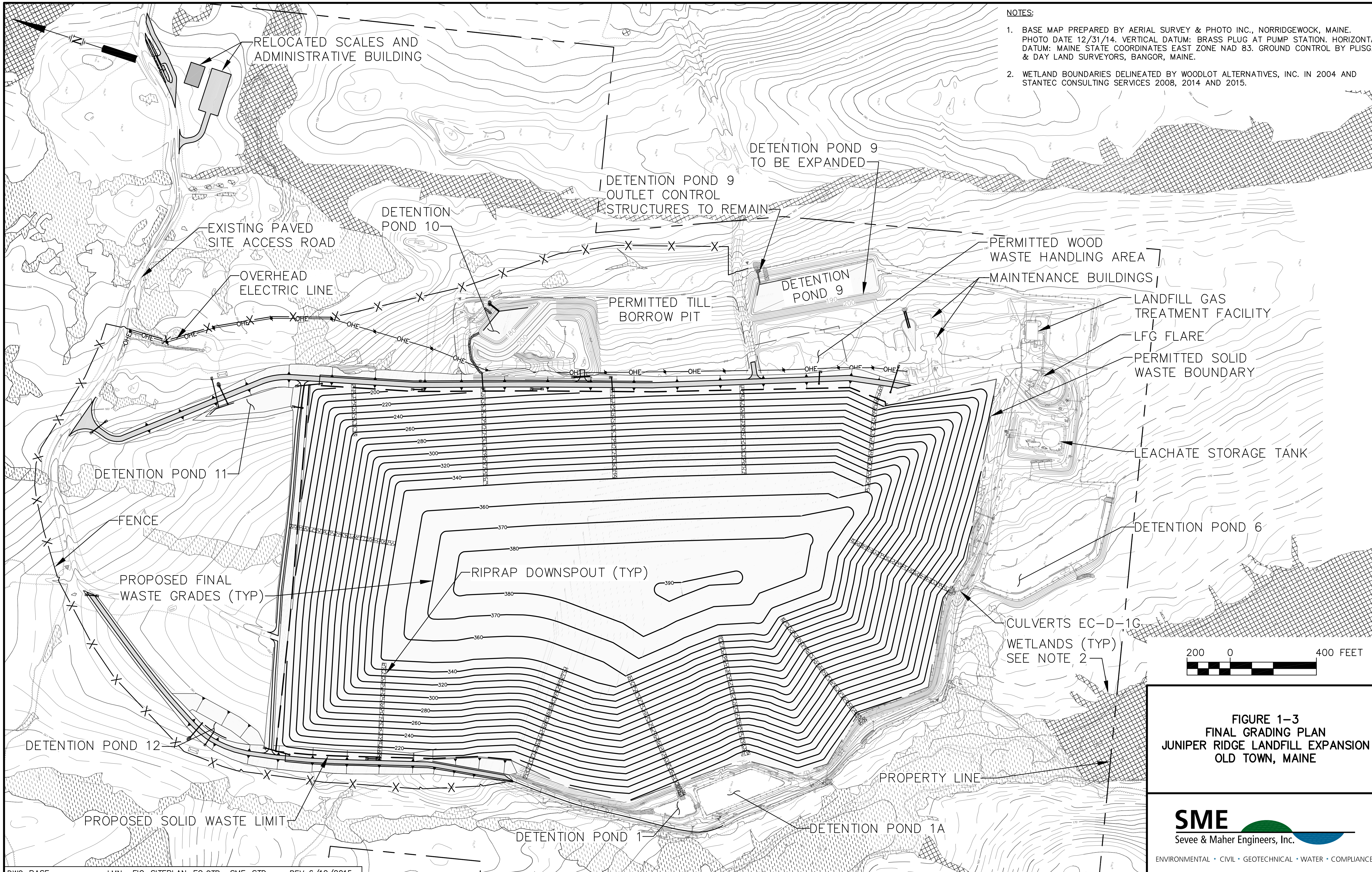
The Expansion has been designed to utilize the existing site conditions and limit potential adverse impacts to the surrounding environment, and allow the performance of the Expansion to be monitored separately from the existing facility. It has been designed as a secure solid waste landfill with two liners (a primary and a secondary), a leak detection system, leachate and gas collection and transport systems, and intermediate and final cover systems. Under the entire base of the landfill an imported soil layer, consisting of one foot of compacted clay, will be installed to provide a uniform low hydraulic conductive soil layer under the secondary liner. A granular underdrain collection system will be installed under 12.7 acres of the Expansion where the landfill base is located below the site's phreatic surface (water table). The Expansion will utilize existing site infrastructure such as the leachate storage tank, and landfill gas treatment and flare systems. These design components, combined with the site's low permeability native till soils, and excellent hydrogeologic setting as described in Volume II, provides a facility that meets the performance standards and siting criteria contained in Section 401.1 C of the Rules.

The Expansion has a maximum final grade of 390 ft-MSL with 3 horizontal to 1 vertical outer sideslopes (see Figure 1-3). This final elevation is equal to the maximum licensed elevation of the existing landfill facility. Intermediate and final cover will be placed in sequential manner over the life of the facility. The covering sequence will include areas of both the Expansion and existing landfill cells. The same waste materials currently placed within the existing landfill cells will be placed in the expansion cells. These materials included construction and demolition debris, front-end process residue, municipal solid waste ash, wood biomass ash, sludges, contaminated soil, oversized bulky waste, by-passed municipal solid waste, and other special wastes. The Expansion will only accept waste materials generated in the State of Maine. As is currently done these materials will be commingled within the landfill to maximize in-place waste densities preserving and optimizing utilization of the State's landfill resource.

The Expansion will be developed in a phased fashion over an anticipated 12-year life span. The Expansion has six operational cells, each having about two years of capacity, at a use rate of about 700,000 tons/year. The first three cells of the Expansion, the eastern cells (i.e., Cells 11 through 13) are located to the east and northeast of the existing landfill (see Figure 1-2).
Cells 11 and 12 will have temporary leachate sumps and pump stations. As the sequential cell is developed, the use of the temporary sump and pump station will be discontinued and the



NOTES:

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2. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.

FIGURE 1-3
FINAL GRADING PLAN
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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\\Nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Acad\Plans\BASE.dwg, 6/10/2015 8:56:59 AM, paf leachate flows from the previous cell will be directed to the next cell's pump station. Cell 13 has a permanent pump station, which will handle leachate from Cells 11 through 13. The last three cells of the Expansion, the western cells (i.e., Cells 14 through 16) are located to the west of Cells 11 through 13, and to the north of the existing landfill. These cells will also have both temporary and permanent leachate sumps and pump stations (see Drawing C-105 in Appendix E) that will be operated sequentially similarly to the eastern cells. The leak detection system for the Expansion cells will have an individual leak detection pump station that will remain active through the Expansion's operational and post closure periods to allow the performance of each cell to be monitored individually

A detailed discussion of the engineered components of the Expansion is contained in the remainder of this report. Appended to this report are engineering design drawings for the entire Expansion, including detailed design drawings for Cell 11, the first cell to be constructed, waste characterization data, design calculations, and construction quality control and technical specifications for the Expansion.

1.2 Report Outline

This design report has been prepared to address the applicable submittal requirements of 06-096 CMR 401, Sections 2.D and F, Sections 401.2, and 401.3 of the Rules. Section 2.0 of this report addresses the design compliance with the standards of Section 401.2D (Design Standards for Landfills) including the standards for the liner system, travel time improvement allowances, base preparation below the liner system, leachate conveyance and storage structures, seismic impact zone, and phased operations. Section 3.0 presents the information required by Section 401.2.F (Engineering Report for Landfills) including stability, settlement assessments, stability and settlement monitoring, water balance, leachate management and gas management submissions, cell development plans, a phased final cover proposal, waste storage and staging submission, waste characterization and design compatibility submission, surface water control plans, test pad submission, and special construction requirements. Section 4.0 describes the contaminant transport analysis performed for hypothetical failures of the Expansion's engineered systems. Section 5.0 addresses the various plan and profile engineering drawings prepared for this project. Section 6.0 discusses the quality assurance plan that will be implemented during construction of the Expansion. Section 7.0 discusses construction contract bid documents that will be prepared during the development of the Expansion. Section 8.0 addresses the proposed environmental monitoring program for the facility. Section 9.0 describes the facility's operations manual. Finally, Section 10.0 discusses the landfill construction procedures that will be followed during the development of the Expansion.

2.0 DESIGN STANDARDS

The design of the Expansion's engineered systems fits the existing site conditions and limits the potential for adverse impacts to the surrounding environment during the facility's operational life and the closure and post-closure periods. The Expansion's engineered systems have been designed in accordance with the design standards of Section 401.2.D, and to achieve the performance standards of Section 401.1.C of the Rules. The Expansion's construction will require both excavation and filling of the on-site native till soils to provide uniformly sloping base grades, from the approximate center of the Expansion to its perimeter. To minimize the disturbance of soil within 5 feet of bedrock at the site, excavation of areas with less than 5 feet to bedrock will be limited to grubbing of the site's uppermost vegetative and organic soil layers prior to placing soil fills or the liner systems The average till soil thickness between the landfill base grade and bedrock will be about 25 feet with the depth ranging from 2 to 62 feet. Under the entire landfill base a one-foot layer of imported clay soil will be placed to provide a uniform low permeable (i.e., less than or equal to $1x10^{-7}$ cm/sec) layer under the secondary liner. This imported soil provides a fine grained soil directly below the secondary liner that protects the secondary liner, and enhances its performance. Its physical characteristics would also retard both flow and concentration of potential contaminants in the unlikely event of the secondary liner failure (see Section 4.0). The Expansion will include the placement of an underdrain sand layer over about 12.7 acres, where the base grade is below the phreatic surface. The underdrain location is shown on Figure 2-1. The average soil depth in the area of the underdrain averages about 36 feet.

2.1 Liner System Requirements

2.1.1 Liner System. The Expansion's liner system will consist of a composite primary liner, a leak detection system, and a secondary liner. The composite primary liner will consist of the following components:

- An 80-mil high-density polyethylene (HDPE) textured geomembrane;
- A geosynthetic clay liner (GCL); and

- A 12-inch clay layer (hydraulic conductivity (K) less than or equal to $1x10^{-7}$ cm/sec).

The leak detection system will consist of the following components:

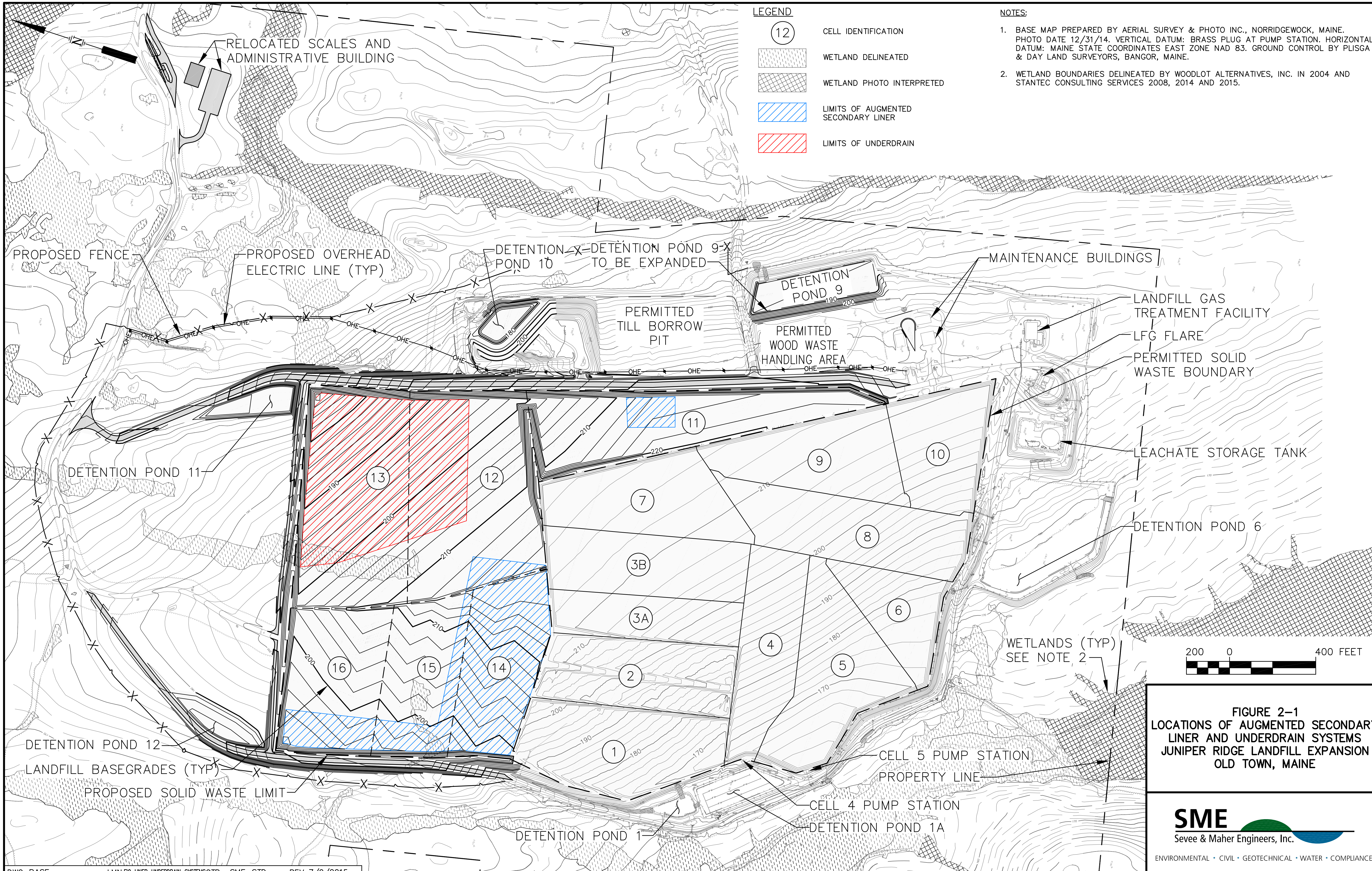
- A 12-inch layer of sand (K greater than or equal $1x10^{-2}$ cm/sec);
- A network of 6-inch diameter perforated HDPE pipe; and
- A geocomposite drainage net.

The secondary liner will consist of a 60-mil HDPE textured geomembrane. In areas where the soil depth between the bedrock and landfill base grades is less than 10 feet, that is about 11 of the 53.5 acres, the secondary liner will be augmented, with a geosynthetic clay liner and 12 inches of clay (hydraulic conductivity (K) less than or equal to $1x10^{-7}$ cm/sec) to provide a composite secondary liner. These locations are shown on Figure 2-1. The typical details for the primary and secondary liners are found on Drawing C-300 in Appendix E.

2.1.2 General Liner Design. Each component of the primary and secondary liners will have a hydraulic conductivity (K) of less than or equal to $1x10^{-7}$ cm/sec. The geomembranes used in the liner systems will meet the GRI GM-13 standards and the performance requirements contained in the site's construction technical specifications, and quality assurance manual included in Appendices A and B respectively. The HDPE geomembrane used for both the primary and secondary liners will be textured and be a full 20 mils thicker than required by the Rules.[2]

The GCLs used in the liners will consist of a sodium montmorillonite clay sandwiched between two geotextile fabrics. The specified average hydraulic conductivity for the GCL will be $5x10^{-9}$ cm/sec or less. The soil used in the liners will consist of a recompacted clay containing a minimum of 35 percent fines having a liquid limit greater than or equal to 20 and a plastic index

[2] Section 401.2.D of the Rules requires the primary and secondary geomembranes to have a nominal thickness of 60- and 40-mil, respectively.



\\Nserver\cfs\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Acad\Plans\BASE.dwg, 7/9/2015 1:54:37 PM, paf greater than or equal to 8 but less than 30. The soil will be placed in a manner that produces a homogeneous layer that eliminates soil clods and preferential flow paths, protects the geomembrane from puncture, and reduces the soil's hydraulic conductivity to the maximum extent practicable. The placement criteria for the soil will include:

- Minimum recompacted hydraulic conductivity of less than or equal to1x10^{-7} cm/sec;
- Minimum in-place density of 90 percent maximum density as measured by ASTM D 698 (standard proctor);
- Compaction techniques using kneading action to remold the soil within 0 to 4 of its optimum moisture content as determined using ASTM D 698; and
- Maximum stone size of less than or equal to 1 inch in the surface layer used for placement of the GCL and less than or equal to ½- inch in the surface layer used for placement of the HDPE geomembrane.

2.2 Improvement Allowance System

Section 401.2.D.2 of the Rules identifies improvement allowance offsets, associated with the containment system design that can be used in the calculation of the 6-year groundwater travel time to sensitive receptors performance standard specified in Section 401.1.C.1.c of the Rules. Volume II Section 7.0 of this application sets forth the travel time analysis for the Expansion. The design of the Expansion incorporates the following features and the improvement allowances associated with these features:

- Addition of a geomembrane secondary liner with a leak detection system (offset two years); and
- Use of a composite secondary liner system with a leak detection system in areas where the soil thickness between the landfill base and the bedrock is less than 10 feet (offset three years).

2.3 Base Preparation Below Liner Systems

Base preparation below the liner systems of the Expansion will include clearing and grubbing the site, general site grading to allow for positive drainage to the perimeter of the landfill for the underdrain, leak detection, and leachate collection systems. The landfill base preparation will include:

- Grading of native till subgrade to achieve the landfill base grades as shown on the Site Base Grading Plan C-102 contained in Appendix E. In fill areas the till soil will be placed in maximum of 12-inch lifts and compacted to 90 percent of its maximum dry density at moisture contents 0 to 4 percent above optimum. The native till subgrade borrow material will have sufficient quantity of fines to result in a hydraulic conductivity of less than or equal to $9.4x10^{-6}$ cm/sec when place and compacted;[3]
- Placement of a groundwater underdrain system, consisting of 12 inches of sand and 4-inch collection piping in areas where the proposed base grades are below the phreatic surface. This consists of the 12.7-acre area under a portion of Cells 12 and 13 (see Figure 2-1). The sand will have a hydraulic conductivity (K) of greater than or equal to $1x10^{-2}$ cm/sec; and
- Placement of one-foot of imported clay soils in a 12-inch lift and compacted to 90 percent of its maximum dry density at moisture contents 0 to 4 percent above optimum, and with a maximum hydraulic conductivity of $1x10^{-7}$ cm/sec.

The base materials described above will provide a firm foundation beneath the liner system and will assure that the liner design and construction standards are achieved throughout the entire thickness of the liner systems.

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[3] This is the assumed vertical hydraulic conductivity used in the travel time analysis. For the first two cells of the existing landfill the in-place till was used as a barrier soil layer for the primary liner. The test results from these construction activities showed that the hydraulic conductivity of the soils placed in this manner were less than $3.0x10^{-6}$ cm/sec.

2.4 Leachate Conveyance Systems and Storage Structure Standards

Leachate is generated from precipitation that falls onto the developed areas of the landfill and filters through the waste, or runs off the exposed waste in the active open operating area of the landfill. The Expansion's leachate conveyance systems are designed to handle these leachate sources along with any leak detection fluids and the landfill gas condensate. The landfill's leachate conveyance systems are designed in accordance with the standards identified in Section 401.2.D.4 of the Rules and include five engineered systems that collect, transport, and store leachate generated at the site. These systems include: the leachate collection, leak detection, and landfill gas condensate collection systems; the leachate transport systems that pumps leachate from the landfill cells to the storage facility; and the leachate storage tank that stores leachate on-site until it is removed from the site for treatment. The leachate collection system is designed to limit the leachate liquid depth (head) over the primary liner system to less than 12 inches, except in the leachate sumps. The leak detection system is designed to detect leaks in the primary liner within 30 days. During the first several years after construction, this system will also collect and remove residual water accumulated in the system during construction, from rain events and/or water expelled from the consolidation of the clay soils used in the construction of the primary liner. The gas condensate collection system is designed to collect and remove condensation from the gas extraction and collection systems. The leachate, leak detection, and gas condensate systems include pumping systems that pump collected fluids from their respective collection points. The condensate and leak detection systems will discharge to the leachate collection system. Fluids collected in the leachate collection system will be pumped to the on-site leachate storage tank. The tank consists of a 921,000-gallon aboveground glass-lined storage tank.

2.4.1 Leachate Collection Systems. The leachate collection design, allows leachate to drain to a collection sump at the low point of the individual landfill cells. Primary components of each cell's leachate collection system consist of the following.

- HDPE collection piping (typically 6- to 8-inch diameter pipe);
- One foot of granular drainage sand (K greater than or equal to$1x10^{-2}$ cm/sec);
- Filter stone and drainage stone located around the piping; and

- Geocomposite drainage net.

The leachate collection system has been designed to collect and convey the leachate flow from the Expansion during the operating, closure, and post-closure periods. Leachate generation rates were estimated using U.S.EPA's Hydrogeologic Evaluation for Landfill Performance (HELP) model. The HELP model assumptions and results are discussed in Section 3.2 of this Report and the model printouts included in Appendix C. Leachate collection head on the liner calculations along with leachate collection pipe sizing, spacing, and hydraulic capacity calculations for the various leachate collection components are contained in Appendix D. The piping systems are designed to withstand stresses due to dynamic and static loading conditions and climatic effects anticipated over the life of the landfill. Pipe strength calculations for buckling and deflection are contained in Appendix D-1.

The leachate collection system is designed so that the system's performance can be monitored and evaluated over the active life and post-closure life of the Expansion. The leachate level within the landfill cells will be monitored using pressure transducers located at the bottom of the cell. Each cell will have a pressure transducer installed within the cell. The leachate collection system is also designed to allow equipment access for routine cleaning, inspection, and maintenance of the primary collection pipe headers from the perimeter of the cells during the operating, closure, and post-closure periods for the Expansion. As required by the Rules, leachate collection HDPE piping will have a minimum diameter of 6 inches.

In addition, to minimize the potential clogging of leachate collection pipes and geocomposite drainage nets, the design of the leachate collection system incorporates filter design criteria for:

- Leachate collection sand to leachate collection filter stone interface;
- Leachate collection sand to geonet/geotextile interface;
- Leachate collection filter stone to leachate collection drainage stone; and
- Leachate collection drainage stone to leachate collection pipe (perforation sizing).

The layout and typical details of the leachate collection system are shown on Drawings C-105, C-300, and C-301 contained in Appendix E. Soil filter design calculations and associated soil gradation selection criteria are contained in Appendix D-2. The drainage geocomposite has also been sized to maintain the maximum head on the liner equal to the thickness of the geocomposite with factors of safety to account for long term reduction in transmissivity of the geonet due to potential creep, and chemical and biological clogging. These calculations are contained in Appendix D-3.

Directly over the drainage sand of the leachate collection system, a five-foot layer of select waste will serve as the frost protection medium and as a soft layer to protect the liner from placement of other wastes in the landfill. The frost protection/soft layer will be placed following cell construction. The frost protection/soft layer will also serve as a filter medium between other waste stream components and the sand of the leachate collection system. The frost penetration calculations for this layer are contained in Appendix D-4.

2.4.2 Leak Detection Systems. A leak detection system will underlie the Expansion's primary liner system. The leak detection system will consist of the following components (from top to bottom):

- One foot of granular drainage sand (K greater than or equal to $1x10^{-2}$ cm/sec);
- Crushed stone;
- Perforated HDPE pipe (minimum diameter 6 inches); and
- Geonet drainage composite.

The leak detection system is designed to detect leaks from the primary liner within 30 days during the active, closure, and post-closure life of the Expansion. The layout for the leak detection system is shown on Drawing C-104, and details shown on Drawing C-301 contained in Appendix E. Similar to the leachate collection system, components of the leak detection system have been designed to withstand the stresses due to dynamic and static loading conditions and climatic effects expected over the life of the landfill. Leak detection design calculations are contained in Appendix D-5.

The fluids collected in the leak detection system will gravity drain to individual collection sumps located at the low end of each cell and be pumped to the leachate collection system. Each sump is located adjacent to the leachate sumps, and will have a carrier pipe/pump arrangement so leak detection fluids can be can be removed from a cell without penetrating the secondary liner. A flow meter and sampling port will be installed on the pump's discharge line to measure both the quantity and quality of the fluid removed from the leak detection sumps. The location of leak detection pump stations are shown on Drawing C-104, contained in Appendix E. Details of the pump stations are shown on Drawings C-302 and C-303 in Appendix E.

Similar to the leachate collection system previously described, the leak detection systems will meet the following standards.

- Leak detection pipes within the cell will have a minimum pipe diameter of 6 inches and will be designed to allow equipment access for routine cleaning, inspection, and maintenance; and
- Component interfaces of leak detection systems will be designed as filters (i.e., sand to stone, sand to geosynthetic, etc.) to prevent clogging.

<u>2.4.3 Landfill Gas Condensate System</u>. The location of condensate drains are shown on Drawing C-106, in Appendix E. Condensate traps will be provided at low points in the gas conveyance pipe to remove liquid. The traps consist of U-shaped tubes filled with liquid that provide a seal between the vacuum side of the system and the atmospheric pressure side of the system. Condensate collected in the traps will drain to a primary leachate collection system pipe.

A single condensate knockout structure is proposed at the north end of the east perimeter road to remove condensate from the proposed 24-inch landfill gas diameter header. The structure, located outside the landfill limit of waste is designed to collect and pump condensate that collects in the header pipe to the leachate cleanout for Cell 13.

<u>2.4.4 Leachate Transport System</u>. The leachate transport systems for the Expansion will consist of both temporary and permanent internal cell pump stations and dual walled force

mains located in the eastern and western perimeter berms. The temporary pump stations will be used during the active life of the cell in which they are installed, and be discontinued with subsequent cell development. The temporary pump stations are required because the sequence of landfill cell development starts in areas of the Expansion with higher based grades and proceeds to areas with lower base grades. The permanent pump stations are located in the area with the lowest base grades and will be used during both the active and post-closure periods of the Expansion.

Both the temporary and permanent leachate pump stations will be internal cell pump stations that use a carrier pipe/pump and sump arrangement to remove leachate from the landfill cells without penetrating the liner system. Permanent pump stations, constructed in Cells 13 and 16 will be the same design as the existing landfill cells' pump stations (e.g., Cells 4, 5, and 8). These pump stations will use a dual carrier pipe and pump system and a valve pit located in a permanent structure. A control panel located adjacent to the valve pit of the sump pump station will control flow of leachate from the sump area into a dual-contained HDPE force main.

The temporary pump stations are designed to allow temporary storage and removal of leachate from within the cell during its active life. The four cells with temporary pumps stations are Cells 11, 12, 14, and 15. The temporary leachate collection sump/pumps system will discharge into the force main at a junction manhole in the force main. The temporary pump stations will have a single carrier pipe, in which two pumps will be located. The first pumps will be located at the bottom of the carrier pipe and handle normal leachate flows. The second pump will be a back-up pump installed to handle larger leachate flows associated with storm events. For Cells 11, 12, 14 and 15, as the next cell is developed the leachate piping from within the cells will be connected to the next cell's piping system and leachate handled by that cell's pumping system. The carrier pipes, and sumps from the previous temporary pump station will remain and the carrier pipes will then be utilized as a cleanout location for the leachate collection piping. The location of leachate pump stations are shown Drawing C-105, contained in Appendix E. Details of the pump station are shown on Drawings C-302 and C-303 in Appendix E.

Both the temporary and permanent leachate sumps and pump systems are sized using the HydroCAD Model to route stormwater flows within the active operating area of the landfill cells through the leachate sump and pumping system. During large storm events (e.g., 25-year, 24-hour storm events) the leachate generated within the active cell area will be temporarily stored within the cell until it is pumped out. For Cell 12, the cell with the largest open operating area, it will take about 46 hours after such an event to pump the stormwater flows to the leachate storage tank. The storage and pumping calculations for the sumps and force main are provided in Appendix D-6. Also included in Appendix D-6 are storage and pumping calculations for Cell 11, the first expansion cell to be constructed.

The following pumps have been selected for the Expansion's pump stations:

- Two 5-HP leachate pumps in the temporary pump stations,
- Two 10-HP leachate pumps in the permanent pump stations; and
- One 1-HP leak detection pump in the leak detection pump stations.

Pump sizing calculations for the Expansion's leachate conveyance system for the first temporary and permanent pump stations (i.e., Cell 11 and Cell 13), are contained in Appendix D-6. Sample ports will also be provided at the pump stations to allow sampling of leachate and leak detection fluids as necessary, based upon action leakage rates discussed in Section 3.3.1 of this Report. Continuous recording flow meters will also be installed at the pump stations to measure leachate flows.

The force mains will be 6- by 10-inch SDR 17 dual walled pipe. Tie-in vaults will be located at each of the connections points for the temporary and permanent pump stations, and a separate meter and air release pit will be located in the lines as shown on Drawing C-105 in Appendix E. Clean out structures will also be installed on the force mains as shown on Drawing C-105. The proposed leachate transport systems will meet or exceed the following design standards.

- The components have been designed to withstand stresses due to dynamic and static loading conditions and climate effects expected over the life of the landfill;

- Leachate transport systems have been designed so that performance can be monitored or evaluated to ensure they are operating as designed;
- Leachate transport pipes have been designed with a minimum diameter of 6 inches to allow equipment access for routine cleaning, inspection, and maintenance;
- Leachate transport systems have been designed to convey the design flows from the leachate collection (including gas collection condensate) and leak detection systems;
- Leachate transport systems have been designed to provide for sampling and flow monitoring of leachate generated at the Expansion;
- Sample locations and sampling protocol have been designed to eliminate the need for confined space entry; and
- Pressurized leachate transport systems located outside the solid waste boundary have been designed to allow leak testing and/or monitoring and inspection using dual walled pipe.

<u>2.4.5 Leachate Storage Structures</u>. The Expansion's leachate conveyance design will not require any additional leachate storage structures to be built on-site. Leachate storage for the Expansion will be provided by the existing 921,000-gallon glass-lined above-ground storage tank. The tank, its surrounding earthen berm, and site operating procedures have been designed in accordance with the criteria contained in Section 401.2.D.4.(b).[4] From this tank leachate is removed via tanker truck and disposed of at the wastewater treatment plant for the Old Town Mill owned by Expera Specialty Solutions Old Town LLC. NEWSME also has a backup agreement with the City of Brewer to accept leachate generated by JRL at its wastewater treatment plant.

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[4] The conformance of the leachate storage tank with the requirements of Section 401.2.D.4.(b)(i-vi) of the Rules was addressed with the issuance of Department Order #S-020700-WD-N-A. The conformance of the storage tank with Section 401.2.D.4.(b)(i) of the Rules is addressed in Section 3.3 of this application.

2.5 Expansion's Location Relative to a Seismic Impact Zone

The Expansion is located in a seismic impact zone as defined by Section 400.1 of the Rules. The facility structures, including its liner systems, leachate collection systems, and leachate transport systems, have been designed to withstand the maximum horizontal acceleration in lithified earth material having a 90 percent probability of not being exceeded in 50 years (construction and operation periods), and in 250 years (post-closure period). The stability assessment that addresses seismic loadings to the expansion structures is contained in Section 3.1 of this Report.

2.6 Phased Operations

The Expansion is designed for phased operations with individual cell size based upon the design waste disposal rates and an approximate two-year cell life. The Expansion's phased operations will sequence waste and cover placement to control run-on and runoff, manage leachate generation, protect the liner system, and maintain stability. The Expansion will be developed in a series of six cells, as described in Sections 1.1 and 3.5 of this document and in the Expansion's Cell Development Plans (see Volume IV Operations Manual, Appendix D).

3.0 ENGINEERING REPORT

The Expansion incorporates proven design methodologies and state-of-the-art technology. Tables 3-1 through 3-6 summarize the design selection, basis for engineering design, site-specific factors for the design, and the proposed construction procedures for the following engineered systems:

- Imported soil properties and improvement allowance systems (Table 3-1),
- Liner and leak detection systems (Table 3-2),
- Leachate collection system (Table 3-3),
- Leachate transport system (Table 3-4),
- Gas management systems (Table 3-5),
  - horizontal collection trenches,
  - vertical wells, and
  - gas transport piping; and
- Cover systems (Table 3-6),
  - daily cover,
  - intermediate cover, and
  - final cover.

The remainder of Section 3.0 provides the basis for the landfill system designs. Table 3-7 summarizes the engineered systems described above in terms of the design considerations, potential failure modes, and failure significance of their individual system components.

TABLE 3-1

IMPORTED SOIL PROPERTIES AND IMPROVEMENT ALLOWANCE SYSTEMS

Item	Design Selection	Site-Specific Factors	Basis for Engineering Design	Proposed Construction Procedure
Imported Soil Layer	• 12-inch compacted clay (K 1x10^{-7} cm/sec)	• This layer provides a uniform soil layer directly below the secondary liner.	• This layer provides a uniform layer of soil beneath the secondary liner, and enhances the liner systems performance by retarding both flow and contaminant concentration in the unlikely event of liner failure. • Increases travel time to site sensitive receptors by three years (i.e., improvement allowance 3 yrs).	• Place barrier soil - 90 percent max. dry-density - 0 to 4 percent above optimum moisture-content - K = 1x10^{-7} cm/sec - >35 percent fines - <3-inch diameter
Secondary Liner with Leak Detection System	• Leak detection system • 60-mil HDPE Liner	• About six percent of the Expansion area will have soil disturbance within five feet of bedrock. Section 401.2. D.1.b of the Rules require the use of a secondary liner in this case. • The secondary liner and leak detection system provides the ability to monitor the performance of the Expansion cells separately from the existing landfill cells • The thickness of the geomembrane is 20 mil thicker than required by Section 401.2.D.1.a of the Rules.	• Provides the ability to monitor the Expansion cells performance separately from the existing landfill cells. • Increases travel time to site sensitive receptors by two years (i.e., improvement allowance 2 yrs)	• Place 60-mil HDPE liner • Place leak detection system • 12 inches of drainage Sand K<=1x10-^{2} cm\sec. • Leak detection piping. • Geocomposite.
Augmented Secondary Liner w/Leak Detection System	• Leak detection system • 60-mil HDPE Liner • GCL • 12-inch clay barrier soil	• About six percent of the expansion area will have soil disturbance within five feet of bedrock. Section 401.2. D.1.b of the Rules require the use of a secondary liner in this case • The secondary liner and leak detection system provides the ability to monitor the performance of the Expansion cells separately from the existing landfill cells. • The thickness of the geomembrane is 20 mil thicker than required by Section 401.2.D.1.a of the Rules.	• Provides the ability to monitor the Expansion cells performance separately from the existing landfill cells • Increases travel time to site sensitive receptors by three years (i.e., improvement allowance 3 yrs)	• Place barrier soil - 12-inch lifts - 90 percent max. dry-density - 0 to 4 percent above optimum moisture-content - K = 1x10^{-7} cm/sec - >35 percent fines - <3-inch diameter • Place GCL • Place 60-mil HDPE liner • Place leak detection system

TABLE 3-2

LINER AND LEAK DETECTION SYSTEMS

Engineered System	Design Selection	Site-Specific Factors	Basis for Engineering Design	Proposed Construction Procedure
Composite Primary Liner	• 80-mil HDPE textured liner • GCL • 12-inch clay barrier soil layer	• Consistent with the existing cells' primary liner system. The thickness of the geomembrane is 20 mil thicker than required by Section 401.2.D.1.a of the Rules	• Provide containment of waste materials deposited and leachate generated at the proposed expansion • Uses proven technology for solid waste landfills (HDPE geomembranes and GCL liners) • Interface friction and internal friction angles of liner components (GCL and textured liner; needle-punch GCL with non-woven fabrics) • Ease of material placement and simplified QA/QC testing (GCL) • Meets and exceeds design criteria of Section. 401.2.D.1(a & b) of the Rules	• Place 12-inch clay barrier soil • Place GCL (non-woven geotextile) • Place 80-mil HDPE textured liner
Leak Detection Layer	• Geonet drainage composite • Granular drainage sand K $\geq 1 \times 10^{-2}$ cm/sec • Crushed Stone (¾ inch diameter) • HDPE perforated pipe (minimum dia. 6 inches) • Individual Cell collection sump with pump station flow measurement and monitoring ports	• Provides ability to monitor Expansion cells separately	• To detect leaks from the primary liner system within 30 days and to transmit flow associated with facility's action leakage rate. • Provide sampling and monitoring locations that eliminate the need for confined space entry. • Allow for equipment access for routine cleaning, inspection, and maintenance. • Improvement allowance credit	• Install sump pump and transport line • Install geonet drainage composite above secondary liner system • Install leak detection piping network • Place washed stone around leak detection pipe • Place granular drainage sand layer • Connect leak detection pump discharge line to leachate collection sump riser pipes

TABLE 3-2 (cont'd)

Engineered System	Design Selection	Site-Specific Factors	Basis for Engineering Design	Proposed Construction Procedure
Secondary Liner	• 60-mil HDPE textured liner	• Expansion of existing landfill – need to monitor separately. The thickness of the geomembrane 20 mil thicker than required by Section 401.2.D.1.a of the Rules	• Provide secondary containment to primary liner system • Uses proven technology for solid waste landfills (HDPE geomembrane)	• Place 60-mil textured HDPE liner
Augmented Secondary Liner	• 60-mil HDPE textured liner • GCL • 12-inch clay barrier soil	• Expansion of existing landfill – need to monitor separately. The thickness of the geomembrane 20 mil thicker than required by Section 401.2.D.1.a of the Rules	• Provide secondary containment to primary liner system • Uses Proven technology for solid waste landfills (HDPE liners and GCL liners) • Interface friction and internal friction angles of liner components (GCL and textured liner; needle-punch GCL with non-woven fabrics) • Ease of material placement and simplified QA/QC testing (GCL) • Meets and exceeds design criteria of Section. 401.2.D.1(a&b) of the Rules • Improvement allowance credit	• Place barrier soil layer • Place GCL • Place 60-mil textured HDPE liner

TABLE 3-3

LEACHATE COLLECTION SYSTEM

Engineered System	Design Selection	Site-Specific Factors	Basis for Engineering Design	Proposed Construction Procedure
Gravity Drain/Sump Pump System	• Geonet drainage composite • 6- to 18-inch perforated HDPE pipe network with central trunk line • Crushed stone (¾ inch diameter) • Granular drainage sand K $\geq$ 1.0x10^{-2} cm/sec • Riser pipe and inlet grates • Two 5-HP submersible pumps for temporary stations and Two 10 HP submersible pumps for permanent stations	• Cell layout and collection to provide positive drainage to the landfill perimeter and associated sump areas • Provide ability to clean major leachate lines	• Collect and convey leachate to collection sumps • Minimize leachate head on liner system • Provide long-term monitoring, maintenance, inspection, and cleaning of collection piping • Provide soil and geosynthetic filter to minimize clogging of collection system • Provide redundant design for collection system (pipe and geonet) and drainage sand • Provide redundant design for pumping system from sump and pump areas (2 pumps) • Design leachate sumps to temporarily hold stormwater flows from 25-year 24-hour storm	• Place geonet drainage composite • Place perforated pipe network • Place washed stone around pipes and in sump areas • Install riser pipes and inlet grates • Place granular drainage sand • Install sump and pump station

TABLE 3-4

LEACHATE TRANSPORT SYSTEM

Engineered System	Design Selection	Site-Specific Factors	Basis for Engineering Design	Proposed Construction Procedure
Leachate/Leak Detection Pump Station and Dual-contained Force Main	• Pump station/valve pit/control panel. • 6"x10" dual containment pipe force main. • Existing leachate storage pond and glass-lined above-ground storage tank	• See site-specific factors for leachate collection system • Existing leachate storage tank locations and force main locations	• Provide for dual containment of pressurized leachate transport line (sump and pump). • Provide locations for leachate and leak detection sampling and flow monitoring that eliminate the need for confined space entry. • Provide for equipment access for routine cleaning, inspection, and maintenance.	• Install pump station valve pit and control panel • Install dual containment HDPE force main between expansion pump stations and existing landfill's leachate collection system

TABLE 3-5

GAS MANAGEMENT SYSTEMS

Engineered System	Design Selection	Site-Specific Factors	Basis for Engineering Design	Proposed Construction Procedure
Horizontal Gas Collection Trenches	• HDPE perforated pipes bedded in stone or tire chips • spaced 40 feet vertical, 100 feet horizontal • gas wells equipped with flow control values	• Placed in waste during filling operations connected to transport piping	• To assist controlling odor during waste filling	• Install in waste as waste filling occurs • Slope a minimum slope of 5 percent • As-built locations surveyed after installation
Vertical Gas Extraction Wells	• 8-Inch PVC perforated pipe screened section encased in stone or other porous media • gas wells equipped with flow control valves	• Wells installed with 18 months of waste reaching interim cell grades space for 100-foot radius of influence	• To extract landfill gas generated by the facility to assist in controlling odors and reduce green-house gas emissions	• Drill gas wells with 30-inch bucket auger • Install PVC pipe and backfill annulus with porous media • Connect to gas transmission piping
Gas Collection Transport and Header Pipes	• Gas Headers 30-inch HDPE transport pipes 6- to 12-inch HDPE	• Headers located in perimeter berm connected to existing headers • Transport pipes run up & down waste slope at perimeter of landfill • Condensate collection provided in transport and headers.	• Headers sized for projected gas flow based on site specific gas flow modeling	• Gas headers installed during berm construction • Gas transport pipes install as waste in placed in cells

TABLE 3-6

COVER SYSTEMS

Engineered System	Design Selection	Site-Specific Factors	Basis for Engineering Design	Proposed Construction Procedure
Daily Cover	• 9-inch soil or • 9-inch soil like material (i.e., ash, CDD process fines, short paper fiber, contaminated soil)	• Generally the Facility receives enough waste materials that can be used as daily cover soil is not used.	• Minimize odors • Minimize litter, dust, other vectors	• Grade waste to drain • Place daily cover
Intermediate Cover	• 18 inches till with minimum of 35% fines) • 20-mil geomembrane (min)	• None	• Minimize leachate generation • Minimize odors • Minimize litter dust, other vectors	• Grade waste to drain • Place intermediate cover • Fertilize seed and mulch per MEDEP's BMPs (soil cover only)
Final Cover	• 12-inch medium for growing grass • 12-inch sand drainage layer • 40-mil geomembrane (textured) • 24 inches barrier soil (K < 1x10-7 cm/sec)	• Final cover system for existing landfill cells • Gas collection system of existing landfill's cover system	• Minimize infiltration of precipitation into the landfill after closure. • Provide a cover system with minimal maintenance issues that promotes drainage, minimizes erosion, protects against freeze/thaw, and minimizes the potential for disruption of continuity and function from settlement or subsidence • To protect root structure of vegetative cover.	• Grade selected waste. • Place barrier soil • Place 40-mil HDPE liner • Place sand drainage layer • Place grass growth medium

TABLE 3-7

POTENTIAL FAILURE MODES AND SIGNIFICANCE OF FAILURES IN ENGINEERED SYSTEMS

System I.D.	System Components	Design Considerations	Potential Failure Modes	Design Contingencies	Failure Significance
Underdrain system	• Sand/stone (12-inch thick layer) • HDPE perforated pipe 6-inch diameter • Geotextiles (for separation)	• Pipe size • Pipe strength • Pipe spacing • Filter design (sand/stone) • Separation geotextile design	• Pipe clogging • Pipe collapse	• Use of conservative material specification (i.e., K $\geq$ 1x10^{-2} cm/sec) • Slope of base will provide positive drainage even with collapsed pipes • Pipe bedding with stone will provide drainage even if pipe is clogged or collapsed. • Pipe burial with semi-trench condition and compacted stone backfill will increase pipe strength and minimize collapse	• Performance of underdrain in short-term (i.e. protect bedrock, dewater site) will not be affected • Performance of underdrain in long-term (tertiary back-up of liner system) would be diminished but would remain functional
Secondary & Augmented Liner Systems	• 60-mil textured HDPE liner • GCL (augmented only) • 12-inch thick clay barrier soil (augmented only)	• Interface friction angle • Internal friction angle • Anchor trench design • Connection details • GRI GM-13 geomembrane standards • Hydraulic conductivity (1x10^{-7} cm/sec min) • In-place density 90 percent maximum dry-density • Moisture-content 0 to 4 percent above optimum • Place in 9-inch lifts	• Installation damage during construction • Manufacturing defects • Premature hydration of GCL • Stability/settlement issues • Clods, voids, poor bonding of lifts • Freeze/thaw cracking • Desiccation cracking3	• Strict construction QA/QC to provide proper installation and repairs to manufacturer's or construction related defects • Proper timing of liner placement to avoid premature hydration of GCL • Use of proper anchor trench and cell development techniques to avoid stability issues with liner system • Use of composite liner with good intimate contact (HDPE/GCL) to minimize leakage if liner gets damaged during construction or operation • Use of imported barrier soil as a tertiary back-up to liner system	• Significance of failure is greatly diminished due to redundant composite liner and back-up barrier soil

TABLE 3-7 (cont'd)

System I.D.	System Components	Design Considerations	Potential Failure Modes	Design Contingencies	Failure Significance
Leak Detection System	• Sand/stone (12-inch thick) • HDPE perforated pipe (6-inch diameter) • Geonet drainage composite	• Capacity and detection time, action leakage rate • Pipe size, strength, spacing • Filter design and separation design • Connection details • Dynamic and static loading • Monitoring and maintenance	• Clogging • Settlement • Pipe collapse	• Use of redundant design components to collect and transport leachate (i.e. pipe and geonet) • Use of filter design criteria at critical material interfaces • Use of conservative material specifications and design factors of safety to account for nonperformance (i.e. K = $1x10^{-2}$ cm/sec sand) • Relatively steep drainage slopes reduce clogging potential of system	• Significance of failure minimized by design conservatism and redundancy • Slope of liner system reduces the potential of system clogging • Pipe bedding with stone will provide drainage even if pipe is clogged or collapsed. • Pipe burial with semi-trench condition and compacted stone backfill will increase pipe strength and minimize collapse
Primary Composite Liner System	• 80-mil textured HDPE liner • GCL • Clay 12 inches	• Hydraulic conductivity ($1x10^{-7}$ cm/sec) max. particle size 3", 35% fines, 90% maximum density, 0-4% moisture content, 9" lifts • GRI GM-13 geomembrane standards • Interface/internal friction angle • Anchor trench design • Connection details	• Freeze/thaw • Desiccation • Stability/settlement • Installation damage during construction • Manufacturing defects • Premature hydration of GCL	• Strict construction QA/QC to provide proper installation and repairs to manufacturer's or construction related defects • Proper timing of liner placement to avoid premature hydration of GCL • Use of proper anchor trench and cell development techniques to avoid stability issues with liner system • Use of composite liner with good intimate contact (HDPE/GCL) to minimize leakage if liner gets damaged during construction or operation • Use of composite secondary liner and leak detection system as secondary back-up to primary liner system • Use of imported barrier soil and underdrain system as a tertiary back-up to liner system • Use of frost protection layer over leachate collection system to minimize freeze/thaw effects	• Significance of failure is greatly diminished due to redundant composite primary liner, composite secondary liner with leak detection layer, and back-up barrier soil/underdrain system

TABLE 3-7 (cont'd)

System I.D.	System Components	Design Considerations	Potential Failure Modes	Design Contingencies	Failure Significance
Leachate Collection Systems	• Sand/stone (12" thick) • HDPE perforated pipe 6"-12" dia. • Geonet drainage composite	• Capacity/hydraulic head on liner system • Pipe size, strength, spacing • Filter design • Connection details • Hydraulic conductivity • Dynamic and static loading • Monitoring and maintenance	• Clogging of collection system components • Pipe failure	• Use of redundant design means to collect and transport leachate (i.e. pipe and geonet) • Use of filter design criteria at critical material interfaces • Use of conservative material specifications and design factors of safety to account for nonperformance (i.e. $1x10^{-2}$ cm/sec sand) • Slopes of liner reduce clogging potential of system	• Significance of failure minimized by design conservatism and redundancy • Slopes of liner system reduces the potential of system clogging • Pipe bedding with stone will provide drainage even if pipe is clogged or collapsed. • Pipe burial with semi-trench condition and compacted stone backfill will increase pipe strength and minimize collapse
Leachate Transport System – Sump and Pump	• HDPE dual containment force main (6x10") • Dual containment pipe leak detection • Pump station • Valve pit • Control panel • Electrical supply • Back-up power • Alarm system • Sump area	• Capacity of sump area • Monitoring and maintenance • Longevity of components • Connection to existing transport line • Pump sizing (leachate, leak detection, and underdrain)	• Clogging of sump area • Power outage (long-term) • Power surges • Pipe failure • Clogging of transport pipe • Pump failure	• Redundant design of system including: - Use of (2) sump pumps for leachate transport - Use of back-up generator - Use of dual-containment pipe • Pump leachate at minimum 2 cfs to prevent clogging of transport pipe • Use of pressure gauges to detect leaks in force main • Use of flow meter to monitor performance of system	• Significance of failure minimized by redundant design of system and ability to detect and respond to failures immediately
Gas Collection	• Sand/stone • HDPE pipe	• Capacity • Pipe size, strength, spacing	• Stability/settlement • Clogging • Pipe collapse	• Use of pipe strength design criteria and bedding installation methods to prevent pipe collapse • Install gas header pipes in perimeter berm to limit settlement of pipes • Install gas transport pipes up and down waste sideslopes to limit plugging of pipes	• Failure potential minimized by design contingencies • Significance of failure minimized by redundant design of system

TABLE 3-7 (cont'd)

System I.D.	System Components	Design Considerations	Potential Failure Modes	Design Contingencies	Failure Significance
Final Cover Systems	• 12-inch medium for growing grass • 12-inch sand drainage layer • 40-mil geomembrane (textured) • 24 inches barrier soil (K ≤1x10-7 cm/sec)	• Interface and internal friction angles • Long-term creep • Desiccation • Freeze/thaw	• Stability/settlement • Erosion	• Use of sand layer on sideslopes to over design drainage of cover system and minimize stability issues • Use of composite cover system to provide redundant barrier to precipitation infiltration • Use of material components designed to provide the maximum internal and interface friction angles to minimize stability issues • Use of thick soil cover (24 inches) over the barrier soil component of cover system to minimize effects of freeze/thaw and desiccation • Use of strict post-closure maintenance to minimize erosion issues	• Failure potential minimized by design contingencies • Significance of failure minimized by redundant design of system

The design calculations, evaluations, and drawings that support the Expansion design are contained in Appendix C through Appendix K, including the following:

- HELP model output data and leachate generation (Appendix C);
- Pipe strength design (Appendix D-1);
- Soils/stone filter design (Appendix D-2);
- Geocomposite drainage net design (Appendix D-3);
- Frost protection design (Appendix D-4);
- Leak detection design (Appendix D-5);
- Storage volume for leachate collection sumps and pump system and force main design (Appendix D-6);
- Leachate collection and underdrain pipe sizing and spacing design (Appendix D-7);
- Leachate tank storage capacity (Appendix D-8);
- Design drawings (Appendix E);
- Geotechnical calculations (Appendix F);
- Leachate quality/waste characterization (Appendix G);
- Waste compatibility test results (Appendix H);
- Landfill gas design report (Appendix I);
- Contaminant transport calculations (Appendix J); and
- Cell 11 design drawings (Appendix K).

3.1 Geotechnical Evaluation

The geotechnical evaluation performed for the Expansion included stability and settlement assessments as required by Sections 401.2.F.1 and 2 of the Rules. These assessments are based on corroborative field and laboratory data generated by site investigations and previous landfill cell construction at JRL, which established the characteristics of the existing and proposed wastes, road base fill, foundation soils, and geosynthetic components of the Expansion's engineered systems. These assessments confirmed that the Expansion will be developed in a stable area.

The slope stability assessment included the analysis of static and seismic loads; under construction, operation, and post-closure conditions; using site specific data and considered the final, as designed expansion geometry. In each case, the calculated factors of safety exceed the minimum acceptable values contained in the Rules. The assessment demonstrates that the in-place waste and foundation soils beneath and adjacent to the waste can support the loads associated with the Expansion. As part of each detailed cell design, individual slope stability assessments will be performed to evaluate construction and operational phase stability to confirm the results of this assessment.

A settlement assessment of the wastes and foundation soils in the Expansion was also performed. Based on this assessment, SME found that waste and foundation soil settlements will not affect the performance of the Expansion's base liner systems, or final cover system. The calculated tensile strains of the base liner and final cover systems are less than the maximum allowable strains recommended by the geosynthetic manufacturers; therefore, settlement is not expected to compromise the integrity of these systems, as described in Section 3.1.3.

A geotechnical monitoring plan has been prepared to monitor stability and settlement during construction and operation of the Expansion. The geotechnical monitoring plan will include inspections to observe drainage and slope conditions that could suggest the development of conditions that could promote waste slope instability and is described in Section 3.1.5.

3.1.1 Input Parameters for Geotechnical Assessments. Key parameters for assessment of slope stability and settlement include: the geometry of the waste mass and base liner system; the geotechnical properties of the waste deposit, base liner system and foundation materials; piezometric conditions (i.e., groundwater and leachate levels) within and beneath the Expansion; and the potential seismic loads that could be imparted to the Expansion by the design earthquake.

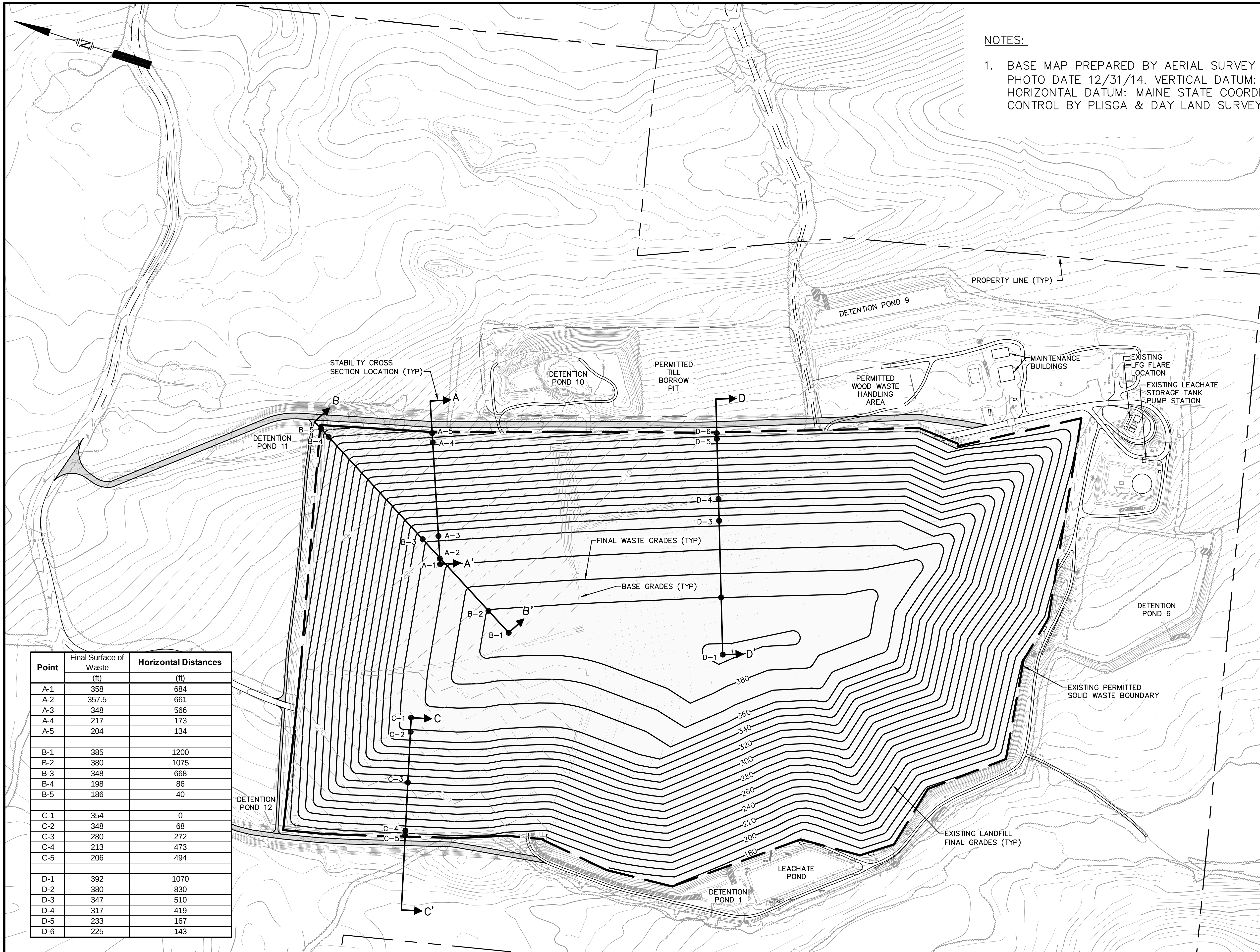
3.1.1.1 Expansion Geometry

Four cross-sections, denoted as A-A', B-B', C-C' and D-D' were selected to evaluate slope stability for the Expansion. The cross-sections are shown in Appendix F-1 and are located as shown on Figure 3-1. The cross-section locations were selected because they represent the geometries exhibiting: the steepest base liner slope angle; the steepest final sideslope angles; where the waste thickness will be greatest; and where exterior waste grades are the tallest and steepest. Cross-section A-A' is oriented generally east-west through the eastern side of the Expansion, which will be the final waste surface on the east side of the landfill; and it extends to include the eastern perimeter berm and adjacent existing ground surface. Cross-section B-B' is oriented generally north-south through the northeastern corner of the Expansion; it is parallel to the maximum base liner system slope (approximately 4 percent); and it extends to include the intersection of the northern and eastern perimeter berms and adjacent existing ground surface. Cross-section C-C' is oriented generally east-west through the western side of the Expansion, which will be the final waste surface on the west side of the landfill; it includes the tallest portion of the western perimeter berm; and it extends to the adjacent existing ground surface. Cross-Section D-D' is generally oriented east-west through the eastern side of the Expansion, which will be the final waste surface on the east side of the landfill; it extends through the high point of the Expansion; and it extends to include the eastern perimeter berm and adjacent existing ground surface. For this evaluation, the exterior sideslopes were evaluated as having operational slopes inclined at 3-foot horizontal to 1-foot vertical (3H:1V). Figure 3-2 shows cross-section A-A', based on slope stability, the remaining cross-sections are shown in Appendix F-1.

The stability cross-sections were also utilized in the settlement assessment to assess final slopes and strains in the base liner and cover systems. Figure 3-1 shows the cross-section locations and settlement assessment points.

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE.



Point	Final Surface of Waste	Horizontal Distances
	(ft)	(ft)
A-1	358	684
A-2	357.5	661
A-3	348	566
A-4	217	173
A-5	204	134
B-1	385	1200
B-2	380	1075
B-3	348	668
B-4	198	86
B-5	186	40
C-1	354	0
C-2	348	68
C-3	280	272
C-4	213	473
C-5	206	494
D-1	392	1070
D-2	380	830
D-3	347	510
D-4	317	419
D-5	233	167
D-6	225	143

LEGEND

D D' CROSS SECTION LOCATION

A-1 SETTLEMENT ASSESSMENT POINT

PROPERTY LINE

200 0 400 FEET

FIGURE 3-1
STABILITY SECTION
LOCATION PLAN
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE

DWG:P-Stability-Sections LMN: 3-1 CTB: SME-STD-HALF REV: 6/10/2015

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MATERIAL		UNIT WEIGHT (pcf)	SHEAR STRENGTH		PHREATIC SURFACE
NO.	TYPE		EFFECTIVE FRICTION ANGLE (DEGREES)	Cohesion, c (psf)	
1	Cover System	125	30	0	NONE
2	Solid Waste	74	32	0	A
3	Base Liner System	STRENGTH ENVELOPE (SEE APPENDIX F-1)			A
4	Gravel Roads	128	34	0	B
5	Foundation Soil	132	38	1000	B
6	Till Road Base	128	34	250	B

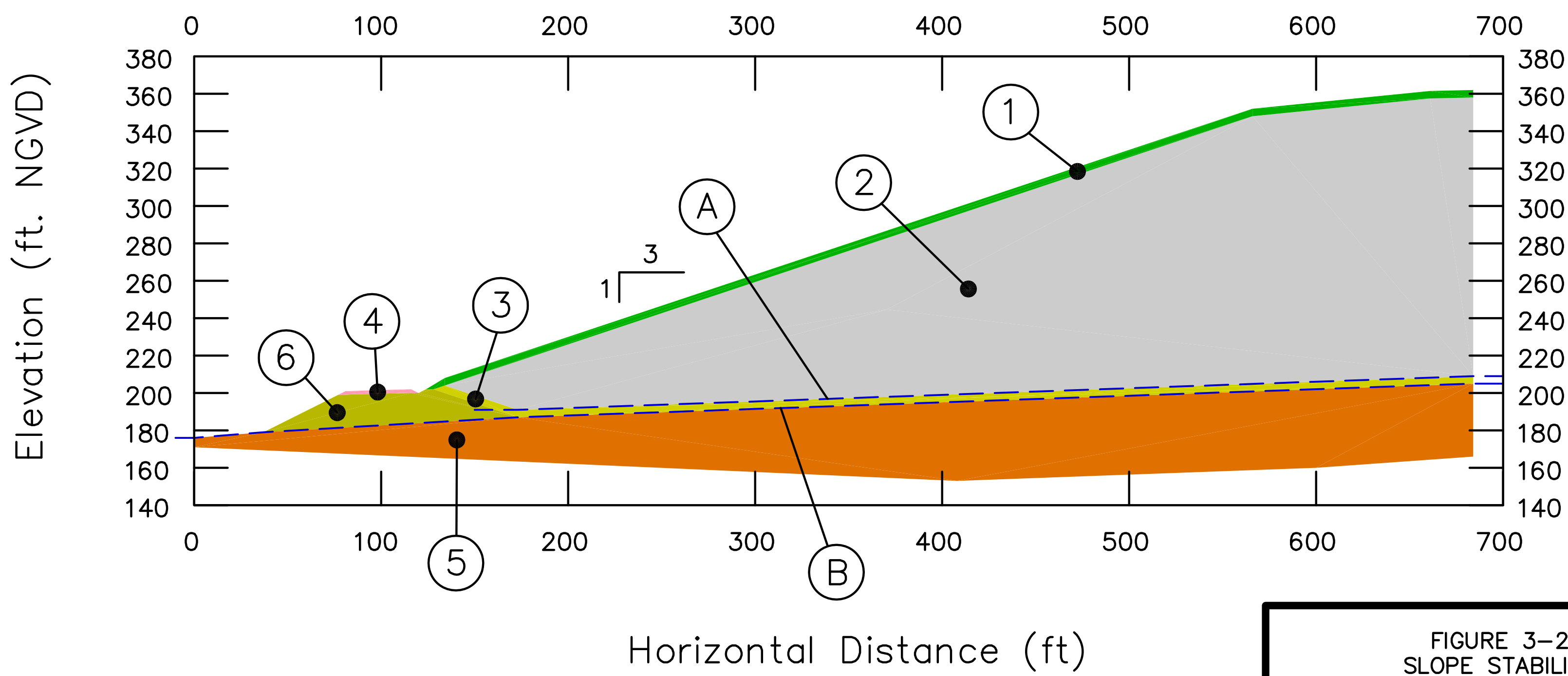

FIGURE 3–2
SLOPE STABILITY
CROSS–SECTION A–A'
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE

DWG: AA FIGURE LMN: CTB: REV: 6/10/15

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3.1.1.2 Geotechnical Properties

Selection of geotechnical properties used for the stability and settlement assessments were based on data collected from previous field and laboratory studies of the waste, base liner, and foundation soils at JRL used to assess existing landfill cell stability (SME 2014). These properties are summarized in Table 3-8:

TABLE 3-8

SUMMARY OF GEOTECHNICAL PROPERTIES

Material	Unit Weight (pcf)	Effective Friction Angle (degrees)	Cohesion, c (psf)	Settlement Factors
Cover System	125	30	0	NA
Solid Waste[1]	74	32	0	A.W.S.R. = 0.00004
Base Liner System	See Note 2			NA
Gravel Roads[3]	128	34	0	NA
Foundation Soil (Glacial Till)[3]	132	38	1000	E.C.: 2,880,000
Till Road Base[3]	128	34	250	E.C.: 1,440,000

Notes:
1. "Solid Waste" represents the current and future JRL waste streams.
2. Property values for base liner system consists of minimum specified peak and large-displacement interface shear strength envelopes for the Expansion as presented in Appendix F-2.
3. Property values based on typical granular roadway material, glacial till, and historical soil data for the JRL site (REW, 2005c)

Abbreviations:
A.W.S.R. = Average Waste Strain Rate, average strain per day by the end of the post-closure period, (at 30-years = 4.5% strain).
E.C. = Elastic Coefficient, pressure in pounds per square foot per unit of strain.
NA = Not Applicable.
pcf = pounds per cubic foot.
psf = pounds per square foot.

The waste streams proposed for the Expansion are consistent with those received by the existing landfill and consist primarily of: construction and demolition (C&D) debris; C&D process fines (used as daily cover); oversized bulky waste; bio-solids/sludge materials; and lesser amounts of ash, front-end process residuals, soils, and other miscellaneous wastes. These wastes are commingled in the landfill cells. Accordingly, 3H:1V exterior slope angles have been used in this geotechnical assessment.

3.1.1.3 Piezometric Conditions

Two potentiometric surfaces were used in the stability assessments as follows:

- The leachate in the landfill will be collected and controlled by a leachate collection system, which will maintain the level of leachate within the base liner system; therefore, a potentiometric surface coincident with the top of the base liner system was applied in the slope stability assessment to the waste and base liner system. This is identified as phreatic surface "A" on Figure 3-2.
- The potentiometric surface below the landfill base liner system will be limited to no higher than the bottom of the base liner system, by an underdrain where groundwater levels are closest to the landfill. As a conservative assumption, SME assumed that the potentiometric surface beneath the entire landfill is coincident with the bottom of the base liner system and that it approaches ground surface beyond the perimeter berms. This is identified as phreatic surface "B" on Figure 3-2.

3.1.1.4 Seismic Conditions

Seismic slope stability was evaluated for the Expansion waste deposit, base liner system, and foundation soils during the construction and operational period and the post-closure period, following the pseudo-static approach presented in RCRA Subtitle D (258) Seismic Design for Municipal Solid Waste Landfill Facilities (EPA, 1995) through the application of a site specific seismic coefficient (k_S) as required by the Rules. The Peak Ground Acceleration (PGA) applied to the landfill in this analysis (also referred to the maximum acceleration (a_{max})) in rock[5] has been assumed to be amplified through the overlying soil and waste columns by increasing it by a factor of two.[5] Then, the

[5] The term rock is used here as a general term, referring to "lithified earth," which refers to earthen materials that have been transformed into rigid rock.

maximum value of the k_s was determined as $k_S = (a_{max} * 2) /2$,[6] for analysis of the liner system and at the top of the landfill for analyses of the cover system (Hynes and Franklin in EPA, 1995). In accordance with EPA guidance (EPA 1995) the most recent seismic hazard maps are to be used. Therefore, the National Seismic Hazard Maps in Open File Report 2014-1091 (USGS, 2014) was used for this analysis. The value of k_S used in the seismic stability assessment for the Expansion are equal to the PGA values at the appropriate return frequencies and probabilities as described below.

During the construction and operational periods, Chapter 401 of the Rules states that "*the maximum horizontal acceleration in lithified earth material having a 90% probability of not being exceeded in 50 year" should be used for the PGA.* Using the 2014 USGS map (see Appendix F-3), the PGA during the construction and operational periods has been determined to be 0.07.

During the post-closure period, Chapter 401of the Rules states that "the maximum horizontal acceleration in lithified earth material having a 90-percent probability of not being exceeded in 250 years" should be used for PGA. Using the 2014 USGS map (see Appendix F-3) the PGA during the post-closure period has been determined to be 0.18.

The site is located in a seismic impact zone[7] as defined by the Rules. Therefore a seismic stability assessment was completed for the Expansion.

3.1.2 Stability Assessment. The four slope stability cross-sections (i.e., A-A' through D-D') were assessed for resistance to sliding along both rotational- and block-shaped failure surfaces through the waste, base liner system, and foundation soils. Static and pseudo-static slope stability analyses were performed for each cross-section. The computer-based slope stability

[6] "RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities," EPA/600/R-95-051, April, 1995 cites Idris (1990) as recommending an upper limit of amplification from the rock through the soils and waste mass of less than 2, a value of 2 was used to be conservative. Hayes and Franklin(1984), recommend a 50-percent reduction of k_s to account for deformation.

[7] As per Section 400.1: "Seismic impact zone" means an area having a 10 percent probability that the maximum acceleration in lithified earth materials, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10 g in 250 years as delineated by U.S.G.S. Seismic Source Zone maps.

analysis program SLOPE/W, a product of GEO-SLOPE International Ltd. of Calgary, Alberta, Canada was used to perform the slope stability calculations. Within the SLOPE/W program, moment equilibrium (the simplified Bishop's method for analysis of circular-shaped surfaces), and force equilibrium (the Spencer's method for analysis sliding block-shaped surfaces) were used to calculate factors of safety.

The lowest calculated factors of safety for slip surfaces through foundation, liner, and waste; for each of the four cross sections are presented in Table 3-9. The SLOPE/W output files for each cross section are included in Appendix F-4.

TABLE 3-9

SUMMARY OF MINIMUM CALCULATED SLOPE STABILITY FACTORS OF SAFETY

Construction and Operations						
		Static Factors of Safety				
Slip Surface Location	Surface Shape	MEDEP Required Minimum	A-A'	B-B'	C-C'	D-D'
Waste	Shallow Surficial	1.3	1.91	2.43	1.90	1.92
Liner	Block		1.73	2.01	1.75	1.82
Foundation	Circular		2.65	2.93	2.17	2.61
		Seismic Factors of Safety				
Slip Surface Location	Surface Shape	MEDEP Required Minimum	A-A'	B-B'	C-C'	D-D'
Waste	Shallow Surficial	1.1	1.54	1.88	1.53	1.55
Liner	Block		1.37	1.50	1.39	1.45
Foundation	Circular		2.14	2.26	1.75	2.07
Post Closure						
		Static Factors of Safety				
Slip Surface Location	Surface Shape	MEDEP Required Minimum	A-A'	B-B'	C-C'	D-D'
Waste	Shallow Surficial	1.5	1.81	2.33	1.81	1.84
Liner	Block		1.72	1.98	1.74	1.81
Foundation	Circular		2.65	2.90	2.17	2.54
		Seismic Factors of Safety				
Slip Surface Location	Surface Shape	MEDEP Required Minimum	A-A'	B-B'	C-C'	D-D'
Waste	Shallow Surficial	1.0	1.11	1.32	1.11	1.11
Liner	Block		1.00	1.05	1.01	1.04
Foundation	Circular		1.62	1.64	1.33	1.52

All of the seismic slope stability factors of safety were calculated to be equal to or greater than the minimum values required by the Rules.

3.1.2.1 Liquefaction and Deformation Analyses

As part of the seismic stability evaluation, an evaluation of the likelihood that site soils could liquefy during the design earthquake (i.e., liquefaction analysis) and an evaluation of the potential permanent deformation (i.e., deformation analysis) have been completed. The liquefaction analysis is provided in Appendix F-5 and shows that during the design earthquake the site soils are not expected to liquefy. The deformation analysis is provided as Appendix F-6 and shows that the final cover system is expected to deform less than 1 centimeter, which is within the acceptable range.

3.1.2.2 Sensitivity Analysis

Experience with the base liner system components used at JRL and other landfills has shown that a distinct difference in peak shear strength and post-peak shear strength (also known as large-displacement shear strength) exists for the GCL-HDPE liner interface. For other interfaces in the base liner system, the peak and large-displacement shear strengths are similar in value and thus would not appreciably affect calculated slope stability factors of safety. Although considered very unlikely, horizontal deformations (i.e., strain) of the base liner system and hence the GCL-HDPE interface can occur, potentially causing the large-displacement shear strength to be mobilized and become the limiting strength with respect to maintaining slope stability.

To understand the sensitivity of the slope stability factors of safety calculated for the Expansion base liner system with respect to the differences between peak and large displacement interface shear strengths (LD strengths), cross-sections A-A' and B-B' were also analyzed using the large-displacement shear strength envelope presented in Appendix F-2. During the post-closure period, the lowest factors of safety for potential slip surface through the base liner system, assuming design peak interface shear strength values as presented in Appendix F-2, were calculated to be 1.72 and 1.74 for cross-section A-A' and C-C', respectively. To assess the sensitivity of these two slopes to the highly unlikely scenario where LD strengths develop over the entire landfill base, these two cross-sections were analyzed with the LD strengths. The sensitivity factors of safety for cross-section A-A' and C-C' were calculated at 1.27 and 1.28, respectively (Appendix F-7). Although not specifically addressed by the Rules, the engineering community generally considers factors of safety greater than 1.0 to be sufficient when considering the conservative large-displacement failure scenario.

3.1.3 Settlement Assessment. As part of the geotechnical assessment for the Expansion, a settlement assessment was performed utilizing the planned final waste grades. This assessment was undertaken to: (1) quantify anticipated settlements of the landfill wastes and foundation soils; and (2) evaluate the effect of those settlements on the base liner system, leachate collection, and cover systems.

3.1.3.1 Foundation Settlement

Based on site investigations completed for the Expansion the foundation soils below the Expansion, consist of a dense to very dense glacial till. An elastic modulus of 2,880,000 psf was used for the intact glacial till and a modulus of 1,440,000 psf was used for the compacted till fill used to construct the berms, for evaluating potential base liner system settlements due to loads imposed by the waste deposit when the landfill geometry is at the design final grades. Settlements of the foundation soils, and thereby, the overlying landfill base liner and leachate collection systems, were calculated to range between 0.0 and 0.3 feet with the larger settlements occurring where the combination of waste thickness and foundation soil thickness were greatest in the northeastern portion of the Expansion (see Appendix F-8). Therefore, settlement of the foundation soils will not compromise the performance of the Expansion's base liner and leachate collection systems since strains on the geosynthetics are within acceptable limits and the base liner system slopes are estimated to change by less than 0.1% from the design slopes. Based on this evaluation, the leachate piping is not expected to experience differential settlements that would affect the positive drainage from the pipes as designed.

3.1.3.2 Waste and Cover Settlement

The solid waste to be placed in the Expansion will be similar in terms of composition and behavior to the waste that has been placed in the previously filled cells at JRL. Therefore projected waste settlement properties (i.e., strain rate) were calculated for the existing waste mass at JRL. A description of these calculations is provided in Appendix F-8. SME determined a site-specific strain rate of 0.00004 (ft/ft)/day, which reduces to 4.5 percent strain at 30-years (i.e., the time period from when the cover is installed and the end of the post-closure period). This value was used to evaluate the overall settlement of the JRL waste mass during the post-closure period.

Settlements between 0 to 8 feet[8] are calculated to occur during the 30-year post-closure period. Figure 3-3 shows the calculated settlement of the landfill cover system over the 30-year post-closure period. The post-closure settlements are not expected to compromise the integrity of the cover liner system for the following reasons.

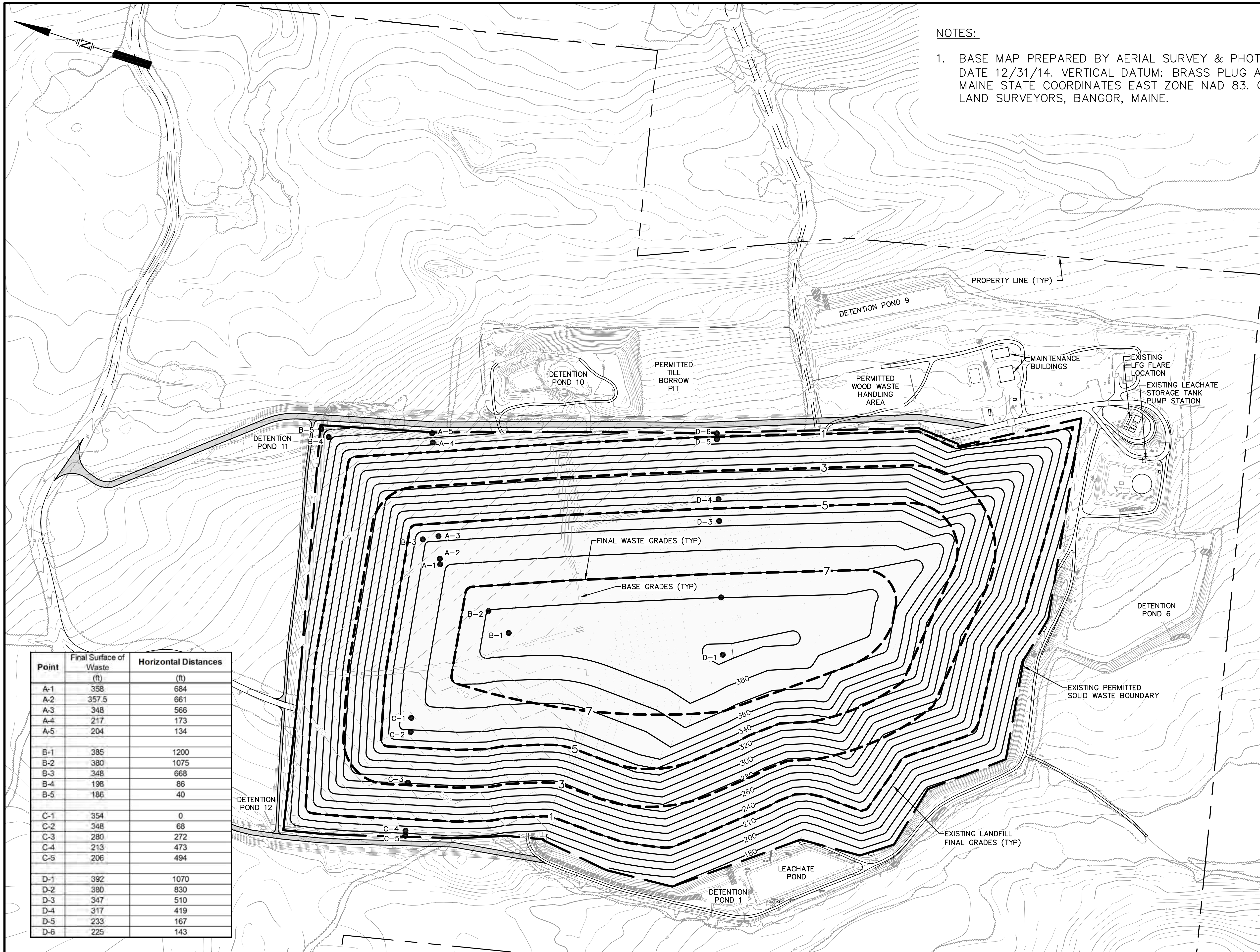
First, post-closure settlement of the waste is expected to occur in a uniform, gradual manner and thereby large, localized differential settlements that could produce high cover system liner strains are not considered likely to occur.

Second, the final cover system's initial slope angles are sufficient to accommodate the predicted post-closure settlements without a surface grade reversal, therefore maintaining positive drainage of the closed landfill surface. Calculations supporting this finding are included in Appendix F-9.

[8] No settlement of waste occurs where waste thickness approaches zero and where waste thickness is at a maximum, it is approximately 8 feet.

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE.



Point	Final Surface of Waste (ft)	Horizontal Distances (ft)
A-1	358	684
A-2	357.5	661
A-3	348	566
A-4	217	173
A-5	204	134
B-1	385	1200
B-2	380	1075
B-3	348	668
B-4	198	86
B-5	186	40
C-1	354	0
C-2	348	68
C-3	280	272
C-4	213	473
C-5	206	494
D-1	392	1070
D-2	380	830
D-3	347	510
D-4	317	419
D-5	233	167
D-6	225	143

LEGEND

- 5 — POST-CLOSURE SETTLEMENT ISOPAC LINE (FEET)
- A-1 — SETTLEMENT ASSESSMENT POINT
- PROPERTY LINE

200 0 400 FEET

FIGURE 3-3
POST-CLOSURE
SETTLEMENT ISOPAC MAP
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE

DWG:P-Stability-SectionsLMN: 3-3 CTB:SME-STD-HALF REV: 7/9/2015

\\Iserver\cfs\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Acad\Figures\P-STABILITY-SECTIONS.dwg, 7/9/2015 2:00:44 PM, paf

Finally the final cover system's slope lengths are primarily in compression, so damage to the geosynthetic components from excessive tensile strain are not expected. Tensile strains are estimated to be as high as 0.1 percent which is well below the generally accepted allowable strain of 4% for textured HDPE (Peggs et al, 2012).

3.1.4 Conclusions and Recommendations. Based on the available geotechnical data consisting of previous field and laboratory testing results completed for the waste and base liner system at the existing facility, the proposed waste types and their physical properties, and the results of the slope stability and settlement assessments completed as described above, the following conclusions have been reached:

- The results of the foundation, liner and waste static and seismic stability assessments for the Expansion meet or exceed factor of safety requirements contained in the Rules.
- Settlement of the foundation soil will not compromise the integrity or effectiveness of the landfill base liner or leachate collection system and differential settlements across the base liner and leachate collection systems will not result in slope reversals. Therefore, proper drainage of the landfill base can be expected.
- Settlement of the waste will not adversely affect the performance or integrity of the final cover system during the post-closure period.

3.1.5 Stability and Settlement Monitoring Plan. This section describes the Stability and Settlement Monitoring Plan (Plan) for the Expansion as required by the Rules. Pore-water pressure transducers will be placed at the base of each of the Expansion cells to measure hydraulic head on the liner system and to confirm design assumptions relative to the effectiveness of the leachate collection system. One pressure transducer will be placed within each operational cell as shown on the Drawing C-105 contained in Appendix E. These transducers will be connected to the JRL Pump Station Control panels to allow the pressure readings to be recorded daily. The data will be compiled and evaluated annually in conjunction with the geotechnical site inspection and reported annually to the MEDEP as part of the Annual Report.

In addition to monitoring and evaluating the pressure transducers, geotechnical inspections of the Expansion will be completed during the operation and post-closure periods to visually assess slope stability and settlement behavior. The inspections will consist of annual visual site walk-overs conducted by a qualified geotechnical engineer. The annual inspections will include, at a minimum:

- Observation of active and inactive filling slopes for cracks, sloughs, or any other displacements or seeps that could be indicative of possible forthcoming slope instability;
- Observation of any permanent and interim closed slopes for cracks, sloughs, seeps, leachate breakouts, displacements, toe-heaving, and areas of stressed vegetation that could be indicative of forthcoming slope instability;
- Observation of any water that has ponded on an active or inactive slope face or capped surface that may be indicative of slope movement or excessive settlements; and
- Review and comparison of any topographic maps prepared for the waste deposit since the last inspection.

As part of the annual inspection, a review of wastes types, quantities, location of waste placement and evaluation of pore pressure data from the Expansion will be conducted. This information will be used to assess the consistency of geotechnical parameters used in the settlement and stability assessment performed for the Expansion Application. If it is determined that the design assumptions, including the waste streams and pore pressures, have changed, then a reevaluation of the settlement and stability of the Expansion may be necessary. The geotechnical inspections will be summarized and reported to NEWSME for inclusion in the JRL Annual Report to MEDEP.

The geotechnical monitoring plan for the Expansion is included in Volume IV, Appendix N, of this application.

3.2 Water Balance Submission

SME used the U.S.EPA's Hydrologic Evaluation of Landfill Performance (HELP) Model Version 3 to simulate leachate generation rates for the expansion cells and the entire facility. The results from the model were used to identify the most critical leachate generation conditions over the life of the Expansion, and to design the leachate collection system. The HELP model simulation used both the soils and geosynthetic properties representative of the proposed containment system components (i.e., liner and leachate collection systems), and climatological data for a 34-year period from 1980 through 2014. Daily precipitation data was obtained from weather stations in Old Town and Orono, Maine. Temperature and solar radiation data were synthetically generated by the HELP model using model coefficients for Bangor, Maine.

SME completed two HELP model simulations to estimate the leachate generation rates. These conditions included: (1) an open active waste filling condition assuming 10 feet of waste and no cover and; (2) an intermediate covered condition assuming 90 feet of waste and 18 inches of soil cover. The leachate generation rates calculated for these conditions were then applied to open and intermediate covered landfill areas throughout the life of the Expansion as presented in Section 3.5 to estimate both the overall facility, and the Expansion's leachate generation rates. For the open active waste filling condition leachate generation includes both leachate collected at the base of the landfill (i.e., infiltration) and runoff from active waste filling areas. For the intermediate cover condition, the leachate generation only included leachate collected at the base of the landfill. A HELP model simulation was also run for the final cover condition. However, because this model indicates no leachate will be generated from areas with final cover because the composite cover does not allow infiltration into the waste, SME assumed a leachate generation rate for the final covered areas of 1.22 inches per year when estimating overall facility leachate generation rates.[9] The HELP model printouts and a summary sheet showing the estimated leachate generation rates over the anticipated life of the facility are included in Appendix C of this Report.

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[9] This figure is approximately 3 percent of the annual precipitation in this area. SME's experience is that in the first few years after closure there is some leachate generation from areas of a landfill on which a final composite cover has been placed and precipitation recharge removed from the landfill.

The estimated average annual daily leachate flows from the entire JRL facility during the operational period of the Expansion is about 48,000 gallons per day with the average daily flow during the peak monthly being about 57,500 gallons per day. The estimated yearly flows from the entire facility range from approximately 22.9 million gallons per year, during the operation of Cell 12 which has the largest open operational areas of the Expansion to approximately 13.8 million gallons per year during the operation of Cell 15.

The HELP model predicts that peak infiltration rates to the leachate collection system occurs in May (i.e., 2.34 inches) for the operating condition. This rate was used to size the leachate collection system drainage composite and pipe spacing, which are discussed in Section 2.4.1 of this Report.

3.3 Leachate Management Submission

The leachate management conveyance, transport and treatment systems selected for the Expansion are described in Section 2.4 of this Report. Leachate generated by the JRL will continue to be pumped to the on-site leachate storage tank, and then trucked to the wastewater treatment plant at the Old Town Mill which is owned by Expera Specialty Solutions Old Town LLC. NEWSME also has a backup agreement with the City of Brewer wastewater treatment plant. On average, currently about 30,000 gallons of leachate are hauled from the JRL site daily. During peak leachate hauling months (e.g., June 2013) this number increases to about 46,000 gallons per day. With the anticipated slight increase in leachate flows as a result of the Expansion (i.e., 48,000 average and 57,500 peak month) slightly more leachate will need to be hauled from the site. This increase represents about two to three additional trucks per day.

There are no proposed changes to the waste types received in the expansion cells. Therefore, leachate quality generated in the Expansion cells is expected to be consistent with the leachate quality currently generated at the site. A summary of the existing landfill's leachate quality is contained in Appendix G and a copy of the existing leachate disposal contracts are contained in Appendix L of Volume I of the application.

A description of the design of the various components of the leachate collection and transport systems are described in Section 2.4 of this report. The leachate and underdrain pipe sizing and spacing calculations are provided in Appendix D-7. As identified, the leachate generated at the facility will continue to be pumped to and temporarily stored in the on-site above ground leachate storage tank. The tank has an overall storage capacity of 921,000 gallons. The adequacy of the tanks storage capacity to handle the quantity of leachate generated under the most critical conditions over the life of the Expansion was evaluated and the calculations are provided in Appendix D-8. These calculations consider the following: 1) an initial static water level in the tank, consistent with common operational practices at the site; 2) the estimated average daily facility wide leachate generation rates; 3) the amount of additional leachate that would be generated from largest open operating area for the Expansion (i.e., Cell 12) during a 25-year 24-hour storm event; and 4) the typical leachate removal rate from tank. These calculations demonstrate that the existing storage tank has the capacity to meet the storage capacity requirements of Section 401.2.D.4.b.(i). Design drawings for the proposed leachate conveyance systems are contained in Appendix E.

<u>3.3.1 Action Leakage Rate/Response Action Plan</u>. A leak detection system is proposed for the Expansion to monitor the performance of the primary liner system as described in Section 2.2 of this Report. As described this system will have the capability to measure both flow and water quality from the leak detection layer. The ability to monitor both flow and fluid quality will allow NEWSME to determine if excessive leakage from the primary liner is occurring. This will be done by comparing the measured specific conductance to values calculated using selected Action Leakage Rates (ALR), leachate specific conductance and baseline measurements. The methodology to implement this monitoring is contained the Liner Action Plan (LAP) contained in Appendix P of the Operations Manual in Volume IV of this application.

<u>Design Liner Leakage Rates</u>. The amount of leachate that could leakage through the primary liner depends on several factors, including the following:

- The number and size of holes or imperfections in the geomembrane;
- The head above the primary liner;

- The uniformity of contact between the geomembrane and underlying soil/GCL; and
- The hydraulic conductivity of the material in contact with the primary liner.

Typically, two-hole or imperfection sizes are used in defining leakage rates through a geomembrane liner system. Small holes (i.e., $3x10^{-6}$ m^2), roughly equal to the thickness of the geomembrane should be considered representative of actual field conditions and more typical of operating conditions. A larger hole (i.e., $1x10^{-4}$ m^2) is used to size the hydraulic capacity of the leak detection layer.

For the Expansion, SME calculated a design leakage rates through the primary liner using the larger hole size. The frequency of imperfections in a geomembrane is associated with the degree of QA/QC associated with the manufacture and installation of the membranes. Because a detailed geomembrane QA/QC program has been developed for the project (see Appendix B), a minimal number of defects is anticipated. SME calculated total design leakage rates through the primary liner for three holes per acre (with a size of $1x10^{-4}$ m^2) to establish and impingement rate on which to design the hydraulic capacity of the geocomposite drainage net of the leak detection system. The second variable affecting flow through the primary geomembrane liner is hydraulic head on the liner. SME used a conservative hydraulic head of one foot. The last two variables that affect leakage rate through the primary liner are the hydraulic conductivity of the materials in contact with the liner and the contact conditions. Calculated flow estimates were based on the proposed base liner design. The membrane liner of the primary liner will be underlain by a GCL with a hydraulic conductivity of $5x10^{-9}$ cm/sec. Good contact conditions between the geomembrane and GCL were assumed in the calculations. Good contact is defined by Bonaparte et al. as a membrane installed with few wrinkles on top of a low hydraulic conductivity soil layer, as will be the case for the primary liner.

Based on these variables, leakage rates through the base primary geomembrane liner system were calculated. The flow rate was estimated based on analytical models developed by Giroud and Bonaparte (1989) for flow through composite liners. SME also evaluated hydraulic capacities of the leak detection system to handle the calculated flows and the time of travel for these flows in the leak detection systems. The leak detection calculations are contained in

Appendix D-5. For the conditions described above, the calculations demonstrate that the leak detection system has the capacity to both handle flows and detect leaks within 30 days, as required by the Rules. The design leakage rate for the primary liner established by these calculations was 0.26 gallons per acre per day. This value compares with the peak daily leakage rate calculated by the HELP model of 0.004 gallons per acre per day. The lower values from the HELP model are a result of the model's hydraulic head predictions being less than one foot (i.e., 0.003 ft) reflecting the design of leachate collections layer located above the primary liner, which is designed to maintain leachate head in the leachate collection system geocomposite.

The ALRs of 4.6 and 92 gallons per acre per day (gpad) has been established for the Expansion. These values are conservatively consistent with EPA guidance[10] and represent values used in the contaminant transport analysis discussed in Section 4.0 of this report. ALR represents the minimum rate of leakage that will trigger interaction between NEWSME and the MEDEP to determine the appropriate response action for the leakage. The steps in evaluating the ALRs and response actions are included in the LAP for the Expansion contained as Appendix P of the Operations Manual, Volume IV of this application.

3.3.2 Contingency Plan for Leachate Conveyance Failure Modes. The Expansion has been designed to allow for long-term access for maintenance and repair of the engineered components that make up a landfill's leachate conveyance system. In addition, all of the engineered design systems relating to leachate collection and conveyance for the Expansion have been designed using conservative design measures such that the overall performance of the system will function even with the occurrence of one or more failures to the system. As previously described in Table 3-7, potential modes of failure of the Expansion engineered leachate conveyance systems include the following:

- Leachate Collection Systems. Modes of failure for a leachate collection system include:

[10] 40 CFR § 265.302 "The action leakage rate is the maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding 1 foot.

- o clogging of collection system components,
  - geonet
  - leachate collection sand
  - leachate collection pipe failure
  - pipe collapse due to loading (static and live load conditions)
  - misalignment due to differential settlement and thermal expansion/contraction
  - freezing of the pipe

Contingencies built into the leachate collection system design to address these potential failure modes include the following:

- o Use of conservative factors of safety within the performance design calculations (i.e., head on the liner system) that address potential clogging of geonet/geotextiles,
- o Use of a combination leachate collection piping network, in addition to a leachate collection geonet and drainage sand, to collect and transmit leachate flows,
- o Use of conservative loading and installation assumptions for calculating pipe strength criteria,
- o Use of materials with more stringent material specifications for granular drainage sand (i.e., higher hydraulic conductivity) than required by Rules.
- o Use of multiple filter designs at critical interfaces of the drainage system that have potential for clogging,
- o Use of stone around leachate collection pipe to serve not only as a filter, but also to provide a conduit for leachate flow even in the event of pipe failure,
- o Use of pressure transducers within each cell to monitor leachate collection/head on the liner performance;
- o Designing the leachate collection piping layout to allow for long-term maintenance (i.e., cleaning), and
- o Grading of the landfill base to drain to the perimeter of the landfill cells.

Responses to non-performance of the leachate collection system will vary. Due to the redundancy and contingencies built into the design, it may not be possible to detect any one mode of non-performance of the leachate collection system. If multiple non-performance modes were to occur, evidence of the problem would include seepage observed along the waste sideslopes, and elevated readings at the pressure transducer locations within each cell's leachate collection sand layer. Non-performance of the geonet would likely increase head on the liner by less than an inch, because the geonet was designed with factors of safety for clogging and because of the redundant leachate drainage sand and leachate collection piping system design. Repairs to the various components of the leachate collection system such as replacement of geonet, replacement of the leachate collection sand or pipe will not be feasible after the initial operating period of the cell; however, leachate collection piping will be cleaned periodically to prevent clogging and header pipes located along the outside perimeter of the landfill may also be excavated and replaced if necessary.

- Leachate Transport System. Modes of failure for the proposed leachate transport systems include:

  - pump failure at the pump stations,
  - leak in the force main,
  - clogging of the force main, and
  - power outage.

  Contingencies built into the leachate transport system design to address these potential modes of failure include the following:

  - Periodic maintenance, cleaning, and inspections of all transport lines;
  - Availability of back-up pumps and back-up generators at the Expansion's sump and pump stations;

- Ability to pump leachate directly from the Expansion's cell sumps into haul trucks for transport to the wastewater treatment plant;
- Use of continuous recording flow meters to detect significant changes in leachate flows that would indicate non-performance of the conveyance system;
- Use of high-water alarm and loss of power alarms at the sump and pump areas;
- Use of dual-containment piping for the force main to contain potential leaks from the inner carrier pipe;
- Use of pressure gauges installed along the outer transport pipe of the dual-containment force main to indicate a leak in the force main's carrier pipe;
- Use of valves within the leachate transport piping system to control flows from select locations of the transport system; and
- Ability to visually inspect and to readily access the interior and exterior of the leachate storage structure to perform maintenance and make repairs as necessary.

The redundant nature of the leachate transport system's design will provide back-up and containment for many of the potential modes of non-performance. Some of the potential modes of non-performance could result in temporary build-up of leachate within the landfill cells (i.e., clogging of transport lines) which could result in the temporary build-up of head over the liner system. These issues can be addressed through routine maintenance, inspection, and cleaning of the various components of the transport system.

Due to the relative size and capacity of the nearby wastewater treatment plant (i.e., Old Town Mill owned by Expera Specialty Solutions Old Town) in relation to the predicted leachate flows, there are no leachate disposal limitations associated with the treatment plant facility. A copy of the current leachate disposal contract for the JRL leachate is contained in Appendix L of Volume I of the Expansion's Permit Application.

3.3.3 Leachate Conveyance Monitoring and Maintenance. Leachate generated will be measured by the use of flow meters located at each pump station. Leachate quality will be monitored in accordance with the site's Environmental Monitoring Plan contained in Volume IV Appendix I of this application. This monitoring plan was developed to comply with the requirements of Section 405 of the Rules. Leachate samples will be routinely collected directly from the on-site storage tank and the leachate and leak detection pump stations.

The Expansion's leachate collection, leak detection, and leachate transport systems will be maintained, inspected, and cleaned periodically in accordance with the site's maintenance and inspection plan as described in Volume IV Appendix O of this application. The leak detection system will be monitored in accordance with the LAP contained in Appendix P of Volume IV.

3.4 Gas Management

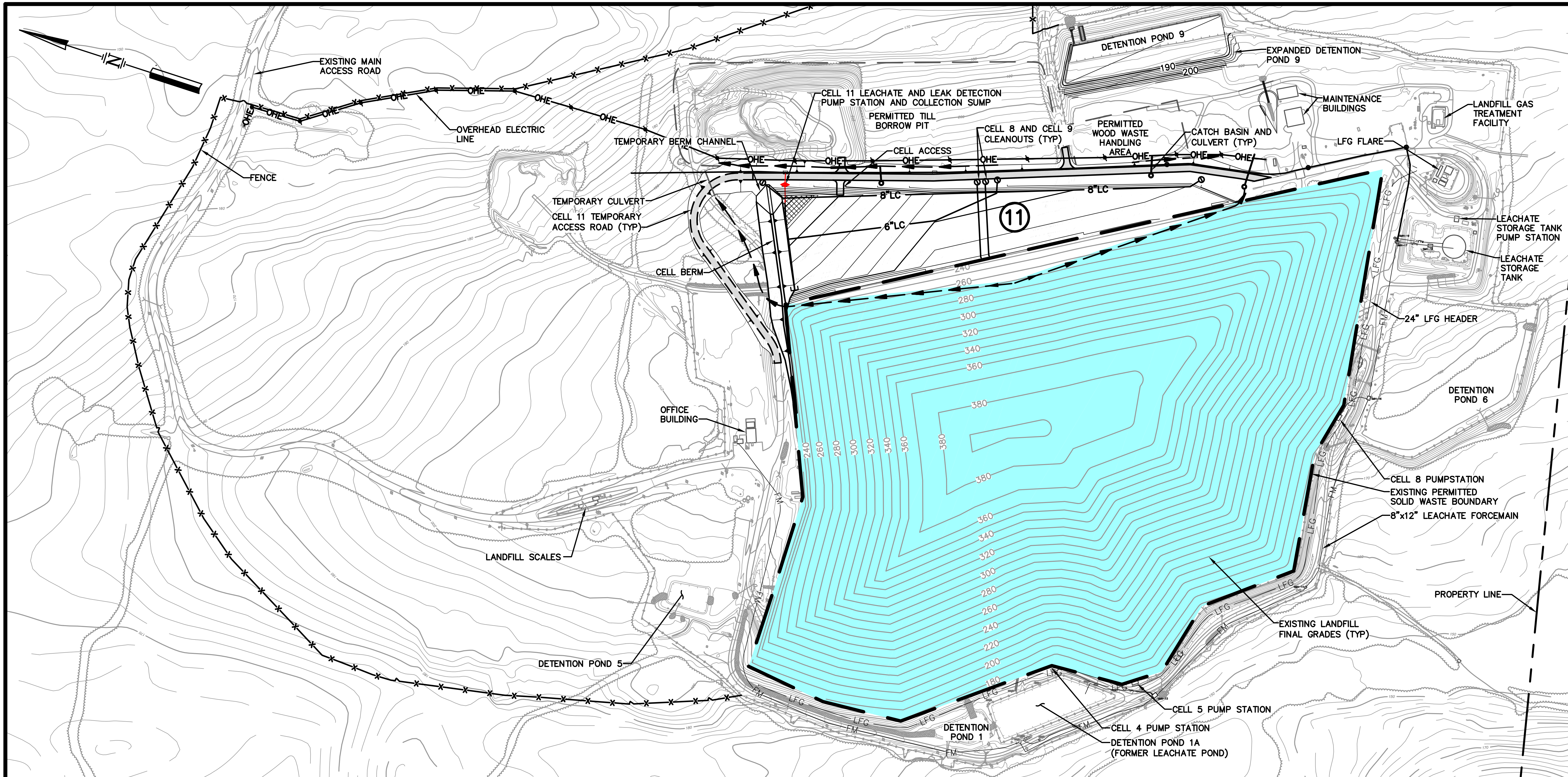
The existing active landfill gas (LFG) extraction system will be expanded to collect the landfill gas generated by the Expansion. Landfill gas will be collected and conveyed to either the permitted on-site flare or a landfill gas to energy facility. The LFG collection and control system will be designed to meet the applicable requirements in 40 CFR Part 60, Subpart WWW. This in combination with placement of intermediate and final cover over the landfill will limit the potential for landfill gas migration from the facility. The details of the landfill gas management design for the Expansion is provided in the Landfill Gas Design Report prepared by Sanborn Head & Associates, Inc. and contained in Appendix I. The Report addresses the overall landfill gas generation estimates, the proposed landfill gas extraction and conveyance systems, and the landfill gas system operations and maintenance. Appendix K includes the detailed design for Cell 11 gas management system.

3.5 Cell Development

NEWSME will construct and operate the Expansion in a sequential manner, consisting of constructing and operating a series of six landfill cells. Each landfill cell is sized to have approximately two years of capacity so construction of new cells is anticipated to occur every two years. The cell development concept also incorporates a phased final cover construction over the existing and future JRL landfill cells. The cover construction will generally occur in the years when cell construction is not occurring. The actual timing for both cells and cover construction will depend on the yearly capacity consumption reviews and the projection of when new cell disposal capacity will be needed.

3.5.1 Cell Development Plan. The cell development sequence has been established to allow NEWSME to continue to operate in the active landfill cell, while the next cell is being constructed. The cell development sequence also allows for phased intermediate and final cover placement to control leachate generation by diverting clean surface water runoff from the covered waste. Each landfill cell will have several similar attributes. These include: the landfill cells will be constructed on a firm base of compacted native till and imported clay soils; the landfill base will be sloped to drain to the perimeter of the landfill; the site access roads, surface water drainage control structures, leachate force main, and gas headers will be located in the east and west side perimeter berms; the leak detection and leachate collection piping orientation allows access for cleaning and the cells' leak detection system allows each individual cell's performance to be monitored separately from the existing and future landfill cells. Erosion and sedimentation control procedures which will be implemented for each cell are provided in the erosion and sedimentation control plan contained in Volume I, Appendix K of this application.

Cell 11 will be the first cell to be developed, will occupy approximately 9.5 acres, and will provide approximately 1,460,000 cubic yards of disposal capacity. The location and base grades for Cell 11 are shown on Figure 3-4. Cell 11 will be filled during the first several years of Expansion operations; detailed cell development plans for Cell 11 are included in Appendix D of Volume IV of this application. Cell 11 abuts the existing Cells 7 and 9. The Cell 11 liners will be seamed to these cells' liner. Cell 11 construction will include: installing erosion control



CAPACITY	1,460,000 CUBIC YARDS
OPEN CELL AREA	9.3 ACRES
OPEN SLOPE AREA	1.8 ACRES
INTERMEDIATE COVER	65.8 ACRES
FINAL COVER	0 ACRES

NOTE: ALL AREAS ARE PLAN AREAS.

175 0 350 FEET

LEGEND

- AREAS OF FINAL COVER
- AREAS OF INTERMEDIATE COVER
- (11) CELL DESIGNATION
- CLEAN STORMWATER DITCH
- CLEAN STORMWATER CATCH BASIN
- LEACHATE COLLECTION AND LEAK DETECTION PUMP STATIONS
- PERMANENT PUMP STATION
- COLLECTION SUMP
- FORCEMAIN VAULT
- LC — LEACHATE COLLECTION PIPING
- FM — LEACHATE TRANSPORT FORCEMAIN

NOTES

1. GRADES SHOWN IN CELL REPRESENT BASE CELL GRADES PRIOR TO WASTE FILLING.
2. FINAL GRADES REPRESENT TOP OF WASTE.

FIGURE 3–4
CELL 11 INITIAL CONDITIONS
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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DWG: CELL–DEV LMN: C11 CTB: SME–STD REV: 7/9/2015

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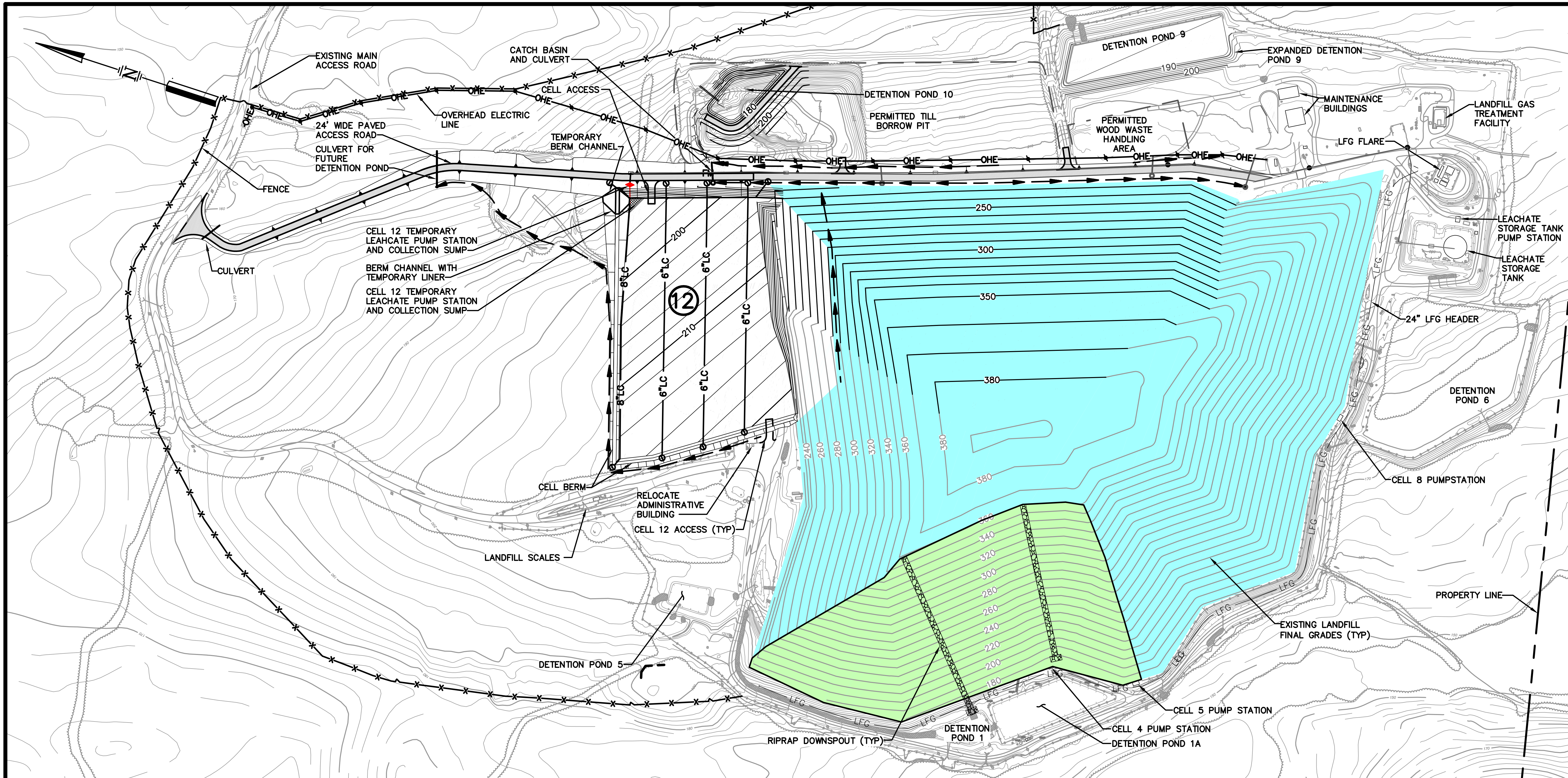
measures; relocation of utility poles and perimeter fence; expansion of existing Detention Pond 9; excavating and filling the cell area to base grades; constructing 1,800 feet of the Expansion's eastern perimeter berm and an intermediate cell berm on the north side of the cell; installing a temporary access road on the northern side of the cell from the existing site access road to the roadway on top of the perimeter berm; installing the cell's secondary liner, leak detection system, primary liner, and leachate collection systems; constructing the cells' leachate and leak detection collection sump and pump systems, approximately 2,600 feet of the eastern perimeter leachate transport force main to the on-site leachate storage tank, and a portion of the 24-inch gas header. Several of the existing Cell 7 and Cell 9 leachate collection cleanouts will be extended out to the Cell 11 perimeter berm to provide ability to clean and maintain key headers. The base grades for Cell 11 slope in an easterly and northerly direction towards the intermediate collection sump. Leachate and leak detection flows collected from Cell 11 will be pumped to the eastern perimeter force main.

Access to Cell 11 will be from the northeast corner of the cell (see Figure 3-4). The sequence of existing intermediate cover removal, waste placement, installation of leachate collection inlets, installation of gas collection piping and installing intermediate cover are described in detail in the Operations Manual, Volume IV of this application. The year following Cell 11 construction final cover will be placed over about 14.3 acres of the existing landfill cells at the location shown on Figure 3-5. Once Cell 11 filling is complete, intermediate cover will be applied to the areas of Cell 11 shown on Figure 3-5.

Cell 12 will encompass approximately 12.6 acres and provide approximately 1,500,000 cubic yards of disposal capacity. Cell 12 abuts the existing Cells 7, 3B, and 11. The liners for these cells will be seamed to the Cell 12 liners. The location and base grades for Cell 12 are shown on Figure 3-5. Cell 12 construction will include: installation of erosion control measures; constructing Detention Pond 10; removal and relocation of the existing administration building and associated utilities; excavating and filling the cell area to base grades; constructing the remainder of the Expansion's eastern perimeter berm (about 500 feet), the 24-foot wide access road (about 3,000 feet), and the intermediate cell berm on the northern and western sides of the cell; installation of the cell's underdrain, secondary liner, leak detection system, primary liner, and leachate collection system; constructing the Cell 12 pump station and collection sump;



CAPACITY	1,500,000 CUBIC YARDS
OPEN CELL AREA	12.6 ACRES
OPEN SLOPE AREA	2.5 ACRES
INTERMEDIATE COVER	60.1 ACRES
FINAL COVER	14.3 ACRES

NOTE: ALL AREAS ARE PLAN AREAS.

175 0 350 FEET

LEGEND

- AREAS OF FINAL COVER
- AREAS OF INTERMEDIATE COVER
- (12) CELL DESIGNATION
- CLEAN STORMWATER DITCH
- CLEAN STORMWATER CATCH BASIN
- LEACHATE COLLECTION AND LEAK DETECTION PUMP STATIONS
- PERMANENT PUMP STATION
- COLLECTION SUMP
- FORCEMAIN VAULT
- LC — LEACHATE COLLECTION PIPING
- FM — LEACHATE TRANSPORT FORCEMAIN

NOTES

1. GRADES SHOWN IN CELL REPRESENT BASE CELL GRADES PRIOR TO WASTE FILLING.
2. FINAL GRADES REPRESENT TOP OF WASTE.

FIGURE 3–5
CELL 12 INITIAL CONDITIONS
CELL 11 FINAL CONDITIONS
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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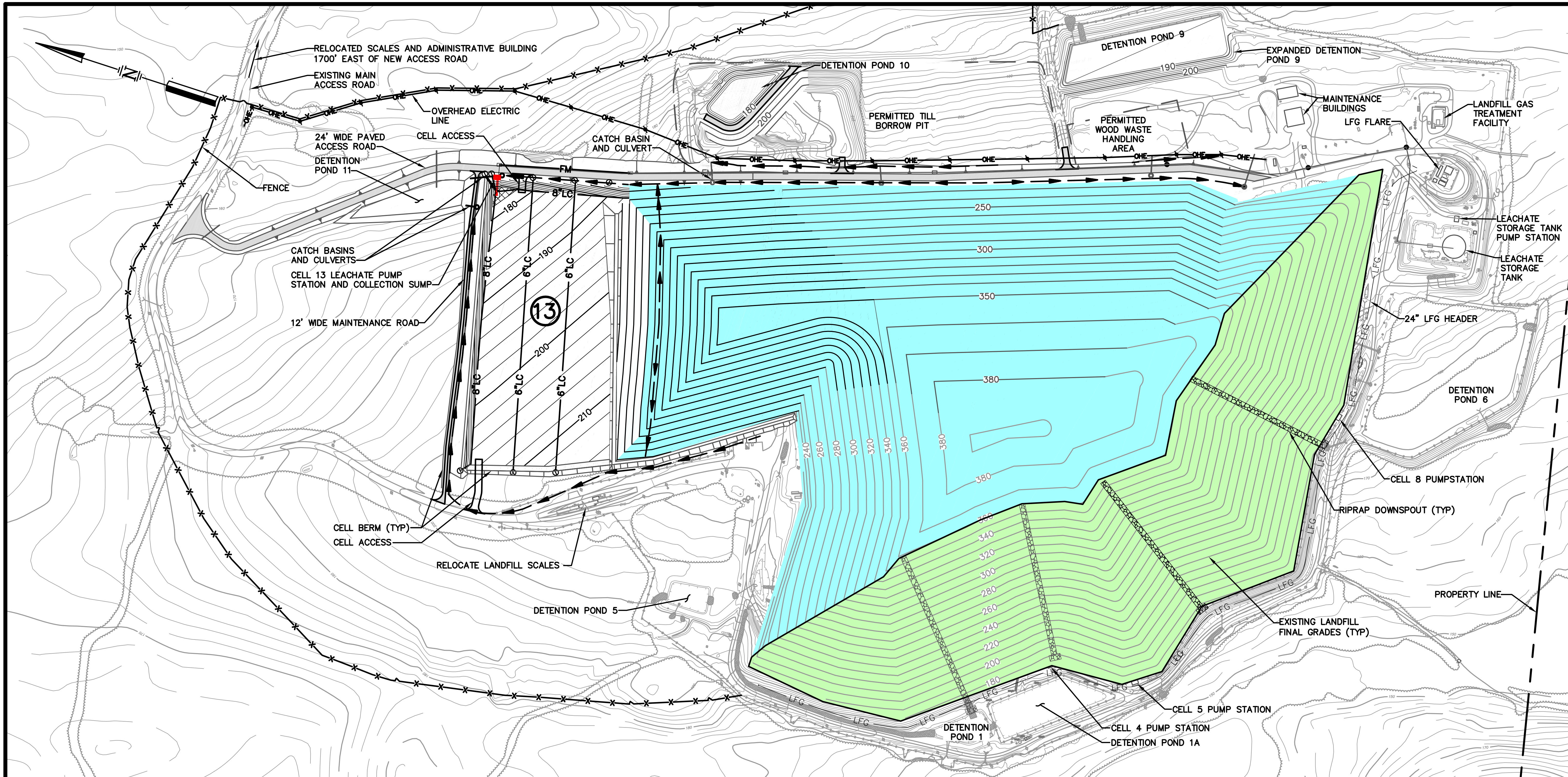
removal of Cell 11 northern temporary cell berm, connecting the Cell 11 collection sump area to Cell 12 and relocation of the Cell 11 leachate pumps to the Cell 12 pump station; and extending the eastern side transport force main to the Cell 12 intermediate pump station from the existing Cell 11 cleaning/tie-in vault (about 550 feet).

Access to Cell 12 will be from the northeast corner off the access road located on the perimeter berm, and from the southwest corner of the cell off the existing access road. The sequence of existing intermediate cover removal, waste placement, installation of leachate collection inlets, installation of gas collection piping and installation of intermediate cover at pre-determined intervals of the cell development will be the same as Cell 11 which is described in Volume IV of this application. The year following Cell 12 construction final cover will be placed over and addition 18.6 acres of the existing landfill cells so the final cover has been applied to the areas shown on Figure 3-6. Once Cell 12 filling is complete, intermediate cover will be applied to the area of Cell 12 shown on Figure 3-6.

Cell 13 will be the third cell to be developed and will be located to the north of Cell 12. Cell 13 will encompass approximately 11.8 acres and provide approximately 1,580,000 cubic yards of disposal capacity. The location and base grades for Cell 13 are shown on Figure 3-6. Construction of Cell 13 will include: installation of erosion and sedimentation control measures; constructing Detention Pond 11; relocating the scale house; excavating and filling the cell area to base grades; constructing the cell berm on the northern and western sides of the cell; and installation of the cell's underdrain, secondary liner, leak detection system, primary liner, and leachate collection systems; constructing Cell 13 permanent pump station and collection sump; connecting the Cell 12 leachate sump to the Cell 13 leachate collection system; constructing the remaining 570 feet of the eastern side force main from the Cell 13 pump station to the existing Cell 12 cleaning/tie-in vault; and installation the remaining gas header.

Access to Cell 13 will be from both the northwest corner of the cell from the existing access road located west of the cell, and the eastern side of the cell for the perimeter access road. As in previous cells, sequence of existing intermediate cover removal, waste placement, installation of leachate collection inlets, installation of gas collection piping and installation of intermediate cover at pre-determined intervals of the cell development will progress in much the same



CAPACITY	1,580,000 CUBIC YARDS
OPEN CELL AREA	11.8 ACRES
OPEN SLOPE AREA	2.2 ACRES
INTERMEDIATE COVER	54.5 ACRES
FINAL COVER	32.9 ACRES

NOTE: ALL AREAS ARE PLAN AREAS.

175 0 350 FEET

LEGEND

- AREAS OF FINAL COVER
- AREAS OF INTERMEDIATE COVER
- (13) CELL DESIGNATION
- CLEAN STORMWATER DITCH
- CLEAN STORMWATER CATCH BASIN
- LEACHATE COLLECTION AND LEAK DETECTION PUMP STATIONS
- PERMANENT PUMP STATION
- COLLECTION SUMP
- FORCEMAIN VAULT
- LC — LEACHATE COLLECTION PIPING
- FM — LEACHATE TRANSPORT FORCEMAIN

NOTES

1. GRADES SHOWN IN CELL REPRESENT BASE CELL GRADES PRIOR TO WASTE FILLING.
2. FINAL GRADES REPRESENT TOP OF WASTE.

FIGURE 3-6
CELL 13 INITIAL CONDITIONS
CELL 12 FINAL CONDITIONS
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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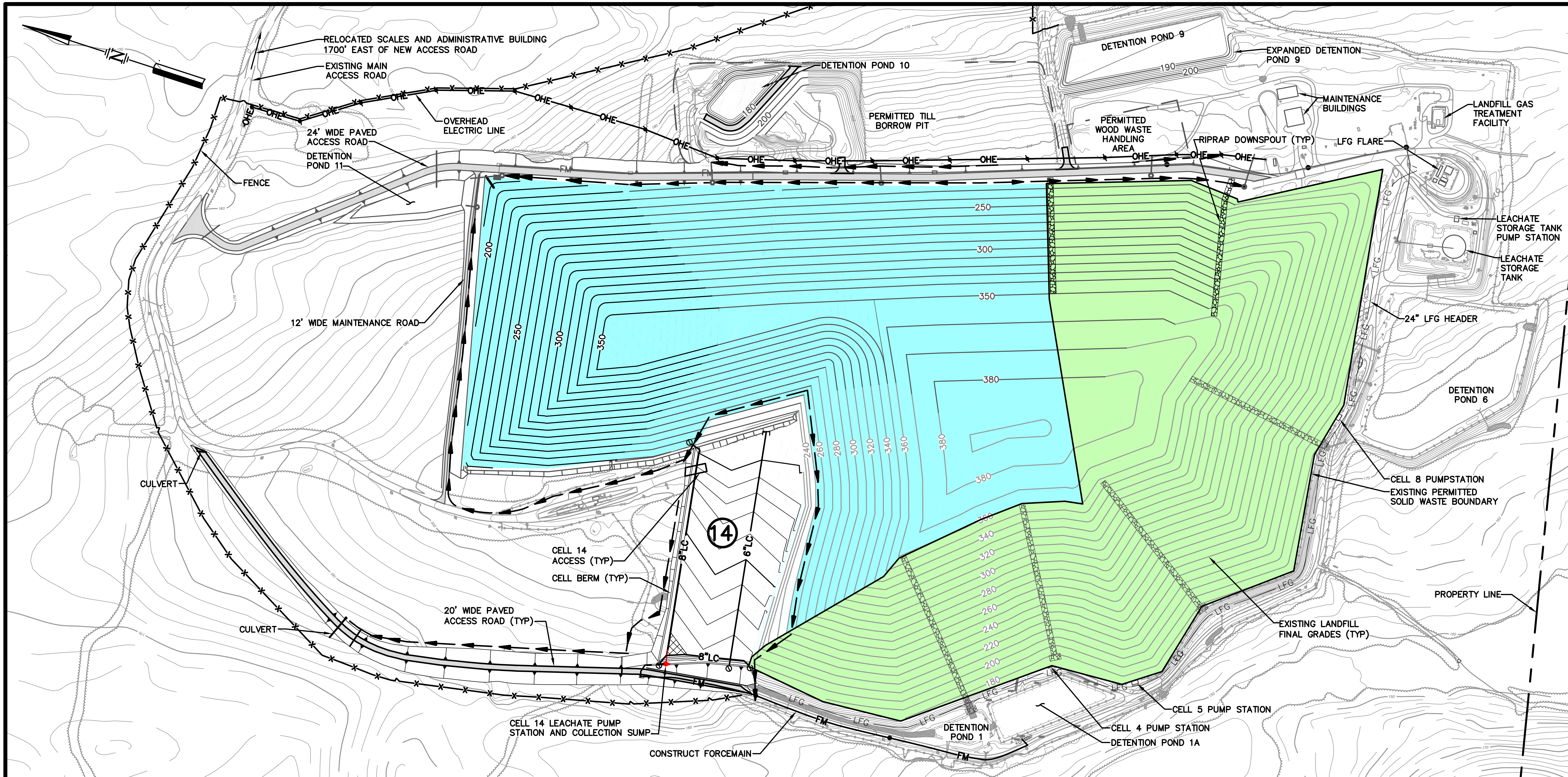
\\Nserver\cfs\Casella\OldTown\Landfill\Expansion\9.35MCY-Expansion\Acad\Figures\CELL-DEV.dwg, 7/9/2015 2:28:14 PM, paf manner. The year following Cell 13 construction additional final cover will be placed over additional 14.6 acres of the existing landfill cells so final cover has been applied as shown on Figure 3-7. Once this Cell 13 filling is complete, intermediate cover will be applied to the area of Cell 13 shown on Figure 3-7.

Cell 14 will encompass approximately 6.7 acres and provide approximately 1,670,000 cubic yards of disposal capacity. Cell 14 abuts the existing Cells 1 through 3B, and Cell 12. The liners for these cells will be seamed to the Cell 14 liner system. The location and base grades for Cell 14 are shown on Figure 3-7. Cell 14 construction will include: installation of erosion control measures; excavating and filling the cell area to base grades; constructing the Expansion's western perimeter berm (1,100 feet) and 20-foot wide access road (2,300 feet) on the western side of the cell and an intermediate cell berm on the northern end of the cell; and installation of the cell's secondary liner, leak detection system, primary liner, a temporary cell berm, and leachate collection systems; construction of the Cell 14 pump station and collection sump; and constructing 1,400 feet of new force main from the Cell 14 pump station to the existing force main at a new manhole located at the former leachate pond. The new force main will be tied into the existing 8-inch by 12-inch dual containment HDPE force main that discharges into the existing leachate storage tank.

Access to Cell 14 will be from the northeast corner off the existing access road, with the exception of the initial waste placement to construct the perimeter berm described below. As in the previous cells, the sequence of existing intermediate cover removal, waste placement, installation of leachate collection inlets, installation of gas collection piping and installation of intermediate cover at pre-determined intervals of the cell development will progress in the same manner. The year following Cell 14 construction additional final cover will be placed over an additional 13.3 acres of the existing landfill cells so final cover has been applied at the locations shown on Figure 3-8. Once this Cell 14 filling is complete, intermediate cover will be applied to Cell 14 shown on Figure 3-8.

Cell 15 will be the next cell to be developed and will be located to the north of Cell 14 and west of Cell 12. Cell 15 will encompass approximately 6.0 acres and provide approximately 1,500,000 cubic yards of disposal capacity. The location and base grades for Cell 15 are shown



CAPACITY	1,670,000 CUBIC YARDS
OPEN CELL AREA	6.7 ACRES
OPEN SLOPE AREA	1.8 ACRES
INTERMEDIATE COVER	52.2 ACRES
FINAL COVER	47.5 ACRES

NOTE: ALL AREAS ARE PLAN AREAS.

175 0 350 FEET

LEGEND

- AREAS OF FINAL COVER
- AREAS OF INTERMEDIATE COVER
- (14) CELL DESIGNATION
- CLEAN STORMWATER DITCH
- CLEAN STORMWATER CATCH BASIN
- LEACHATE COLLECTION AND LEAK DETECTION PUMP STATIONS
- PERMANENT PUMP STATION
- COLLECTION SUMP
- FORCEMAIN VAULT
- LC — LEACHATE COLLECTION PIPING
- FM — LEACHATE TRANSPORT FORCEMAIN

NOTES

1. GRADES SHOWN IN CELL REPRESENT BASE CELL GRADES PRIOR TO WASTE FILLING.
2. FINAL GRADES REPRESENT TOP OF WASTE.

FIGURE 3-7
CELL 14 INITIAL CONDITIONS
CELL 13 FINAL CONDITIONS
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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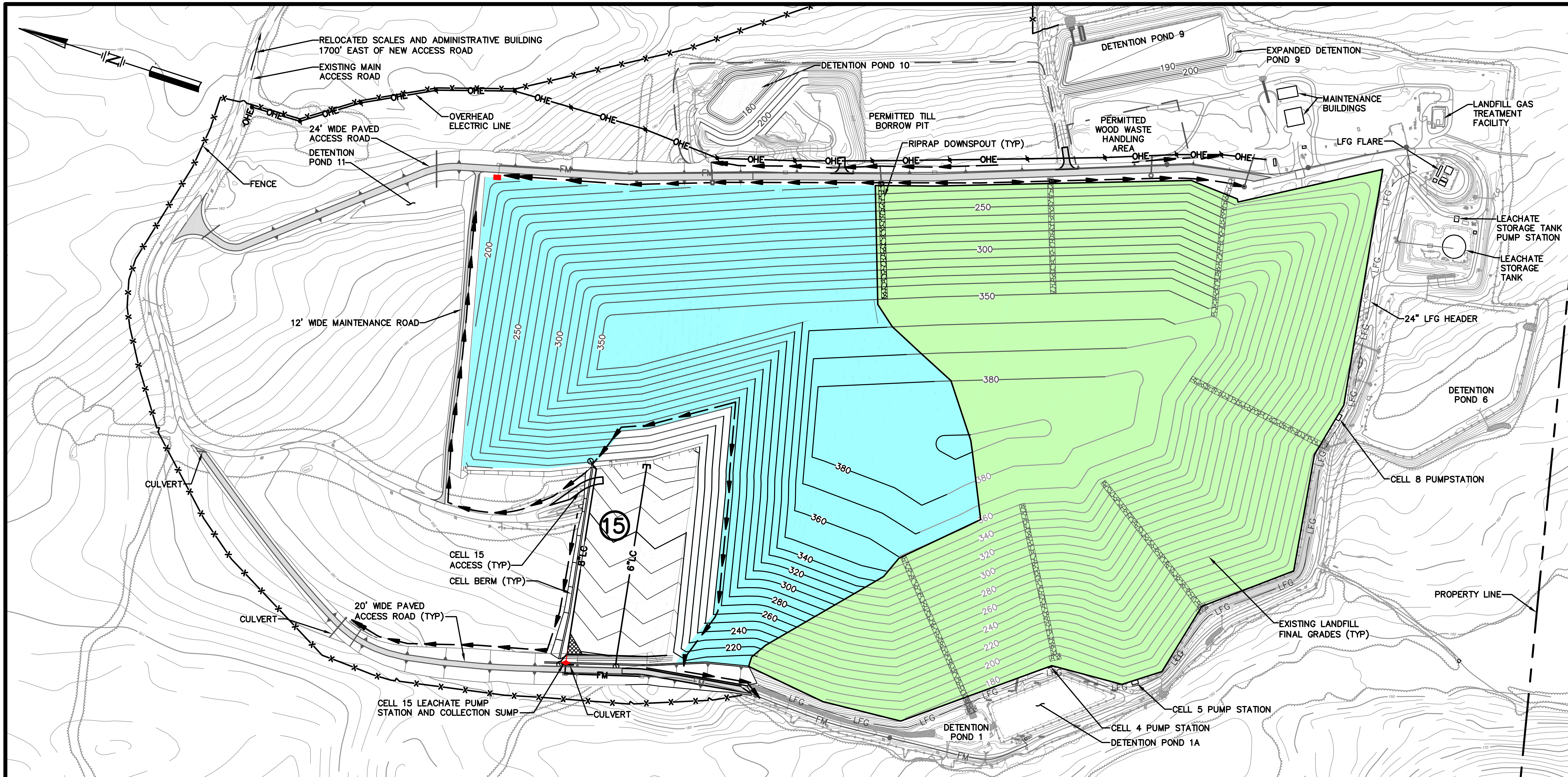

CAPACITY	1,500,000 CUBIC YARDS
OPEN CELL AREA	6.0 ACRES
OPEN SLOPE AREA	3.2 ACRES
INTERMEDIATE COVER	45.3 ACRES
FINAL COVER	60.8 ACRES

NOTE: ALL AREAS ARE PLAN AREAS.

175 0 350 FEET

LEGEND

- AREAS OF FINAL COVER
- AREAS OF INTERMEDIATE COVER
- (15) CELL DESIGNATION
- CLEAN STORMWATER DITCH
- CLEAN STORMWATER CATCH BASIN
- LEACHATE COLLECTION AND LEAK DETECTION PUMP STATIONS
- PERMANENT PUMP STATION
- COLLECTION SUMP
- FORCEMAIN VAULT
- LC LEACHATE COLLECTION PIPING
- FM LEACHATE TRANSPORT FORCEMAIN

NOTES

1. GRADES SHOWN IN CELL REPRESENT BASE CELL GRADES PRIOR TO WASTE FILLING.
2. FINAL GRADES REPRESENT TOP OF WASTE.

FIGURE 3–8
CELL 15 INITIAL CONDITIONS
CELL 14 FINAL CONDITIONS
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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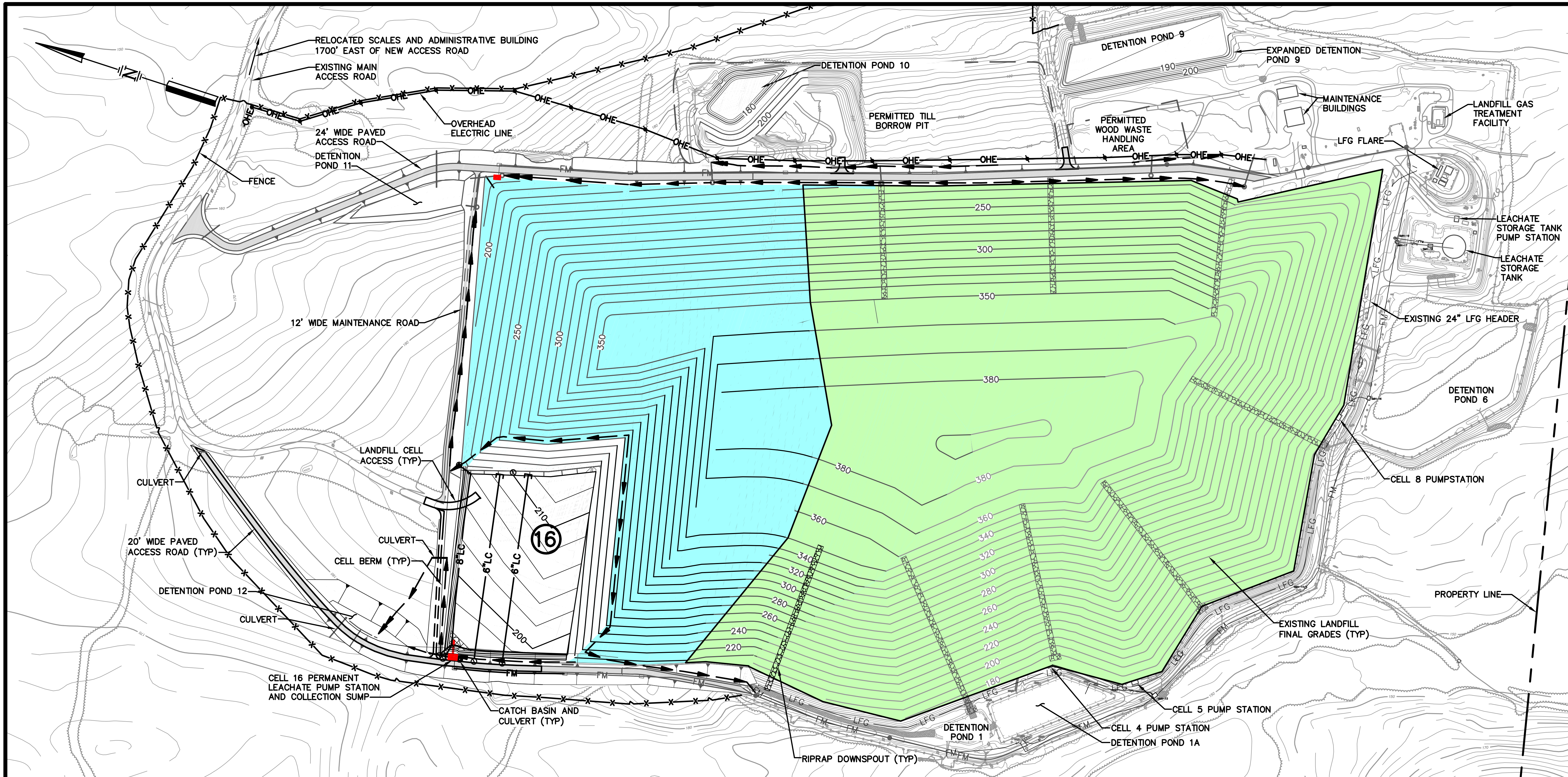
DWG: CELL–DEV LMN: C15 CTB: SME–STD REV: 7/9/2015 on Figure 3-8. Construction of Cell 15 will include installation of erosion and sedimentation control measures; excavating and filling the cell area to base grades; construction of the cell berm on the northern end of the cell; installation of the cell's secondary liner, leak detection system, primary liner, and leachate collection systems; construction of the Cell 15 pump station and collection sump; connecting the Cell 15 leachate sump to the Cell 14 leachate collection system; and constructing a new force main from the Cell 15 pump station to the existing Cell 14 cleaning/tie-in vault.

Access to Cell 15 will be from the northeast corner of the cell from the existing access road located north of the cell. As in the previous cells, sequence of existing intermediate cover removal, waste placement, installation of leachate collection inlets, installation of gas collection piping and installation of intermediate cover at pre-determined intervals of the cell development will progress in the same manner. The year following Cell 15 construction additional final cover will be placed over an additional 15 acres of the landfill so final cover has been applied as shown on Figure 3-9. Once this Cell 15 filling is complete, intermediate cover will be applied to the area of Cell 15 shown on Figure 3-9.

Cell 16 will be the last Expansion cell to be developed and will be located to the north of Cell 15. Cell 16 will encompass approximately 7.1 acres and provide approximately 1,640,000 cubic yards of disposal capacity. The location and base grades for Cell 16 are shown on Figure 3-9. Construction of Cell 16 will include: installation of erosion and sedimentation control measures; constructing Detention Pond 12; excavating and filling the cell area to base grades; cell berm on the northern end of the cell; and installation of the cell's secondary liner, leak detection system, primary liner, and leachate collection systems; construction of the Cell 16 permanent pump station and collection sump; connecting the Cell 16 leachate sump to the Cell 15 leachate collection system; and constructing 430 feet of new force main from the Cell 16 pump station to the existing Cell 15 cleaning/tie-in vault.

Access to Cell 16 will be from the northeast corner of the cell from the existing access road located north of the cell. As in the previous cells, sequence of existing intermediate cover removal, waste placement, installation of leachate collection inlets, installation of gas collection piping and installation of intermediate cover at pre-determined intervals of the cell development



CAPACITY	1,640,000 CUBIC YARDS
OPEN CELL AREA	7.1 ACRES
OPEN SLOPE AREA	2.7 ACRES
INTERMEDIATE COVER	36.6 ACRES
FINAL COVER	75.8 ACRES

NOTE: ALL AREAS ARE PLAN AREAS.

175 0 350 FEET

LEGEND

- AREAS OF FINAL COVER
- AREAS OF INTERMEDIATE COVER
- (16) CELL DESIGNATION
- CLEAN STORMWATER DITCH
- CLEAN STORMWATER CATCH BASIN
- LEACHATE COLLECTION AND LEAK DETECTION PUMP STATIONS
- PERMANENT PUMP STATION
- COLLECTION SUMP
- FORCEMAIN VAULT
- LC — LEACHATE COLLECTION PIPING
- FM — LEACHATE TRANSPORT FORCEMAIN

NOTES

1. GRADES SHOWN IN CELL REPRESENT BASE CELL GRADES PRIOR TO WASTE FILLING.
2. FINAL GRADES REPRESENT TOP OF WASTE.

FIGURE 3-9
CELL 16 INITIAL CONDITIONS
CELL 15 FINAL CONDITIONS
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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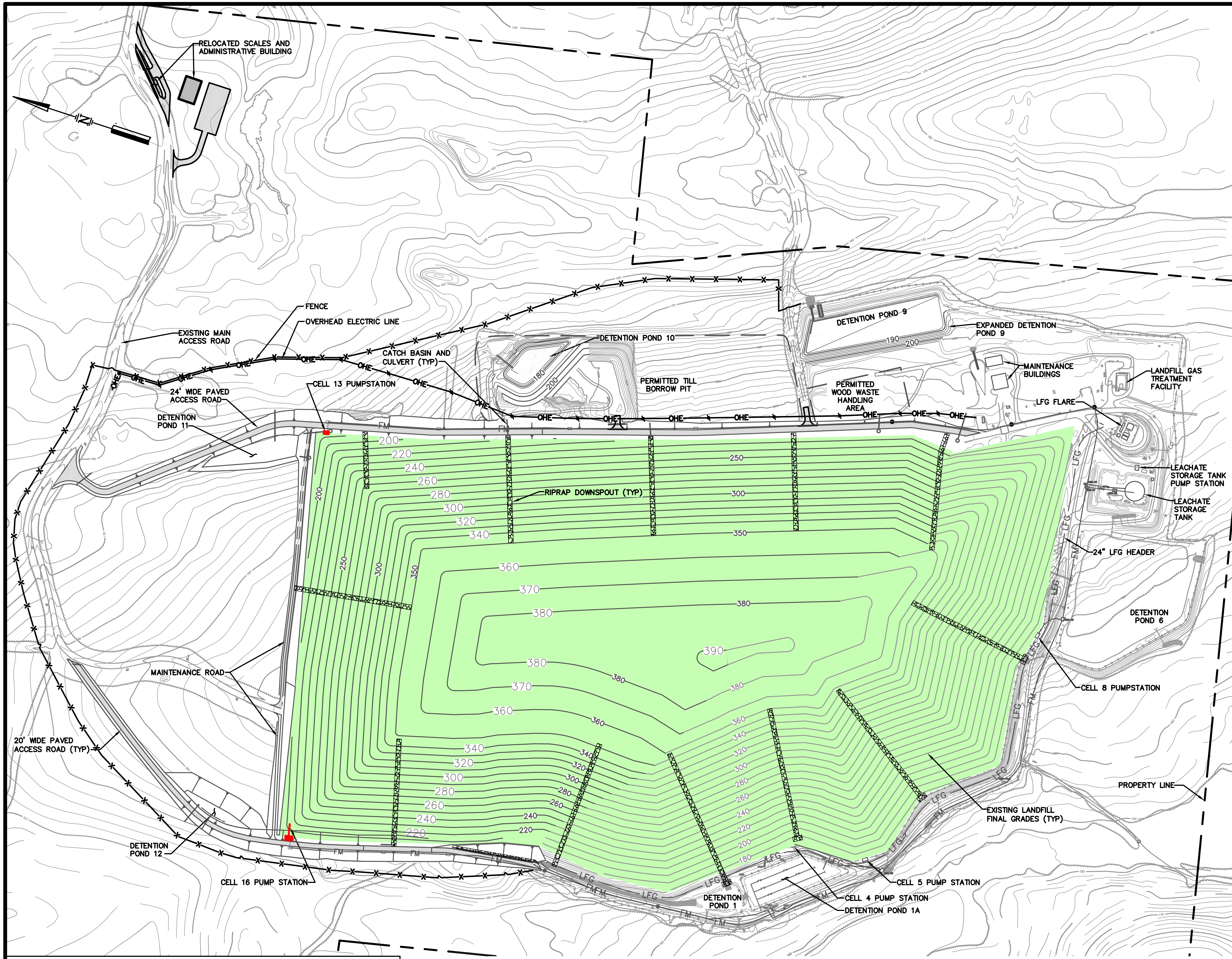
will progress in the same manner. Once this Cell 16 filling is complete, intermediate cover will be applied to the remainder of open active area of Cell 16 until final cover is placed. Following Cell 16 filling final cover will be placed over the remaining 45.5 acres of the landfill cells that have not already received final cover. This will likely occur over a several-year period. The final grading plan showing the entire landfill closed with final cover is shown on Figure 3-10. At least one year before the final phase cover placement begins, an application for final closure of the landfill containing the information required in Section 401.5.D of the Rules will be submitted to the MEDEP. Upon approval of that application the final cover will be constructed.

3.6 Phased Final Cover System

The proposed final cover system for the Expansion will use similar engineered components (i.e., textured geomembrane), and earthen materials (i.e., granular drainage sand, clays/till barrier soil, and vegetative cover soil) that will be used in the landfill construction. Placement of the proposed final cover system will comply with the similar material installation specifications, and quality control/quality assurance protocol as used for the cell construction. The final cover system proposed for the Expansion is as follows:

- 12 inches of a vegetative cover soil;
- 12 inches drainage sand;
- 40-mil HDPE textured geomembrane liner; and
- 24 inches of barrier soil layer.

As the landfill progresses and individual cells reach final grade, detailed design drawings and technical specifications will be prepared and submitted to MEDEP for review and approval prior to the placement of final cover at the site. The borrow source materials used for closure will be obtained from permitted sources. Estimated costs associated with closure construction and post-closure maintenance and care are included in Volume I Section 3.2 of this Application.



NOTES

1. GRADES SHOWN IN CELL REPRESENT BASE CELL GRADES PRIOR TO WASTE FILLING.
2. FINAL GRADES REPRESENT TOP OF WASTE.
3. SEE ATTACHED TABLE FOR SUMMARY OF STORMWATER CULVERTS, CATCH BASINS AND DITCHES.

CAPACITY	9,350,000 CUBIC YARDS
FINAL COVER	121.3 ACRES
NOTE: ALL AREA IS PLAN AREA	

LEGEND

- AREAS OF FINAL COVER
- PERMANENT PUMP STATION
- FM — LEACHATE TRANSPORT FORCEMAIN

200 0 400 FEET

FIGURE 3-10
EXPANSION CELLS FINAL DEVELOPMENT CONDITIONS
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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3.7 Waste Storage, Staging, and Burn Areas

The Expansion will not require any waste storage, waste staging, or burn areas for wood waste or construction and demolition debris. If necessary, on a temporary basis, select areas of the existing landfill will be used as a storage area for the frost protection/soft layer material that will be placed as in the bottom of the expansion cells as described in Section 2.4.1. The permitted wood waste handling area located adjacent to the maintenance facility and east of the existing landfill will continue to be used during the operation of the Expansion.

3.8 Waste Characterization and Design Compatibility

The waste types and percentage proposed for disposal in the Expansion as part of this application are the same materials which have been placed in the existing JRL cells. The design of the Expansion has assumed a total waste tonnage of 700,000 tons per year consisting of the following waste types and percentages of the total.

- WWTP and miscellaneous sludge (10 percent, includes SPF);
- Front-End Process Residuals (FEPR) (7.7 percent);
- Contaminated Soils (4.3 percent);
- Municipal solid waste ash (8.3 percent);
- Biomass and fossil fuel ash (5 percent);
- Municipal solid waste by-pass from incinerators and soft layer (3.6 percent);
- Construction/demolition debris (27.9 percent);
- Oversized bulky waste (8.6 percent);
- C & D process fines (used for daily cover) (19.7 percent); and
- Miscellaneous waste[11] (4.9 percent).

Table 3-10 is a summary of the wastes accepted at the JRL during 2014. As part of this Application, NEWSME and BGS requests MEDEP approval to continue to dispose of the same

[11] Miscellaneous wastes include oversized bulky waste, fines, contaminated soil, and spoiled food.

material types that are currently approved for disposal in the existing landfill.[12] The wastes proposed for disposal in the Expansion have been previously determined to be non-hazardous by the MEDEP and are suitable for disposal at JRL.

TABLE 3-10

SUMMARY OF WASTES ACCEPTED AT JUNIPER RIDGE LANDFILL REPORT YEAR 2014

Waste Description	Tons	Percent of Total
Burn Pile Ash and/or Hot Loads Area Ash	2,442	0.4%
Catch Basin Grit & Street Sweepings	747	0.1%
CDD Processing Residue - Bulky Waste	48,219	7.7%
CDD Processing Residue - Fines	126,152	20.1%
Coal, Oil & Multifuel Boiler Ash	22,329	3.5%
Contaminated Soil & Debris	9,624	1.5%
Crushed Glass	56	0.0%
FEPR	57,048	9.1%
Industrial WWTP Sludge	8,112	1.3%
Leather Scraps	63	0.0%
Lime Mud And Grit	2,100	0.3%
Mixed CDD	199,405	31.7%
MSW	36,878	5.9%
MSW Bypass	1,638	0.3%
MSW Incinerator Ash	54,131	8.6%
Municipal WWTP/POTW Sludge	37,892	6.0%
Non-Friable Asbestos	703	0.1%
Non-Hazardous Chemical Related	276	0.0%
Oil Spill Debris	2,434	0.4%
Pulp Mill Waste	2,585	0.4%
Sandblast Grit	221	0.0%
Short-Paper Fiber	7,841	1.2%
Spoiled Foods	831	0.1%
Sulfur Scrubbing Residues	20	0.0%
Treated Biomedical Waste	406	0.1%
Urban Fill Soil & Debris	6,452	1.0%
Wood From CDD	46	0.0%
WWTP Grit Screenings	369	0.1%
Total	629,021	100.0%

Physical and chemical characterization of the JRL's waste stream and landfill leachate have been routinely performed as part of the operation of the existing landfill. As previously discussed, there are no proposed changes in the wastes accepted in the Expansion. Therefore, there will be no significant changes to the physical or chemical characteristics of the solid waste

[12] MEDEP Permit #S-020700WD-BC-A allows JRL to accept up to 81,800 tons per year of municipal solid waste until 2018. This material is not proposed to be accepted in the Expansion.

stream requiring disposal in the Expansion. Representative copies of the JRL's waste and leachate chemical characterization are contained in Appendix G.

The existing landfill is, in itself, a case study for assessing the compatibility of landfilling the JRL's waste stream at the Expansion. There have been no significant problems in terms of physical or chemical stability associated with the commingling of the various waste streams. In fact, overall drainage and stability of the waste mass have improved with the current commingling waste placement procedures used at the site.

Finally, all of the proposed engineered components of the Expansion liner and cover systems (i.e., HDPE geomembrane, polyethylene geotextile, clay/till barrier soil, HDPE piping) have been successfully used at the existing JRL. In addition, all of the materials proposed for use in construction have been used at other solid waste disposal facilities throughout Maine, including the HDPE geomembranes, GCLs, geonets, HDPE piping. All of these materials are recognized by the MEDEP as state-of-the-art design components and in many cases are required to be used to meet the performance standards of the Rules. The MEDEP has agreed, based upon previous test results from other sites, that many of the engineered components (including HDPE geomembranes, polyethylene geotextiles, GCLs) have good chemical resistance and do not require additional testing in accordance with U.S.EPA'S 9090 testing. Copies of material compatibility testing, and data on the suitability of the materials used in landfill construction are contained in Appendix H.

3.9 Surface Water Control Plans

An Erosion and Sedimentation Control Plan meeting the requirements of Section 400.4.J, and a Stormwater Management Plan meeting the standards and submission requirements of Section 400.4.M have been prepared and are contained in Appendices J and K, respectively, of Volume I of this Application.

3.10 Test Pad Submissions

During base grade, liner and final cover construction the ability of the construction techniques used to compact the soils used in these systems will be evaluated in a manner consistent with what has been done with the construction of the existing JRL cells. The criteria that will be used to determine the adequacy of this construction technique is conformance of the finished product with the requirements of Part 3.11.B.1.b of Section 02200 of the Project Specifications. A test pad of an area of approximately 50,000 square feet will be constructed in the cell or cover area that is under construction. The test pad program will consist of placing and compacting of the clay in one, or two lifts, each with a compacted thickness of 12 inches. During placement and compaction in-place moisture/density tests will be obtained at a frequency of 15 per acre per lift. Provided the field test demonstrates an adequate compaction effort has been obtained through the entire lift thickness, the type of compaction, (e.g. compaction equipment and number of passes) will be noted in the field logs. In-place hydraulic conductivity tests will be randomly collected from the test pad area with a total of 7 hydraulic conductivity tests collected for each one-foot lift. The hydraulic conductivity tests will be performed on clay samples representative of the top, middle, and bottom of each lift. These hydraulic conductivity tests will be sent to the laboratory and the hydraulic conductivity, density, and moisture content of the in-place clay measured. If the field and laboratory tests confirm that this construction technique can achieve the project performance criteria up to four shallow test pits will be excavated in the test pad area to evaluate the remolding, and bonding of the clay through visual observations. Pictures will be used to visually document the condition of the compacted clay.

The data collected and testing results will be compiled and discussed the construction stakeholders and upon concurrence that the construction techniques are appropriate to achieve the specified in-place properties of the clay the technique will be employed for the remainder of the project. The frequency of moisture testing and hydraulic conductivity testing will be reduced to the criteria found in Section 02200 of the Specifications for the remainder of the clay layer testing program.

3.11 Special Construction Requirements

In the areas where the augmented secondary liner will be installed, (see Figure 2-1) the base grade will be box cut one-foot to accommodate the additional foot of compacted clay used in the augmented secondary liner. To minimize soil disturbance in these areas an excavator will be used to complete the cut prior to placement of the one foot of imported soils, and the one foot of clay soil that will be used to construct the secondary liner. In addition, a sand/stone underdrain system (minimum 12-inch layer) will be installed in the location shown on Figure 2-1 to aid in the dewatering of the site and to facilitate the construction of the base liner systems for areas of the Expansion developed below the phreatic surface.

4.0 CONTAMINANT TRANSPORT ANALYSIS

As required by Section 401.2.G of the Rules, the effects of hypothetical failure of various elements of the engineered leachate containment system have been evaluated. The purpose of the analysis is to assess the potential for an unreasonable threat to identified sensitive receptors (hereafter simply referred to as “receptor”) and to identify any operational or monitoring measures needed to ensure protection of those sensitive receptors. The following subsections describe the analytical methodology, the hypothetical failure scenarios evaluated, assumptions, and the results of the contaminant transport analysis. Detailed calculations are included in Appendix J of this report.

4.1 Analysis of Hypothetical Leaks

The contaminant transport analysis is based on a conceptual model, where hypothetical leakage travels in the underlying soil and/or bedrock until a receptor is reached. The leakage is modeled first assuming no engineered barriers to contaminant transport exists, (i.e., no liners), then from landfill structures (i.e., liners and leachate pipes) assuming a defined leakage conditions. In order to track assumed leachate leaks at the Expansion, an analytical three-dimensional groundwater solute transport equation was used to simulate leachate concentrations from the hypothetical leaks. Leachate constituent concentrations at each receptor, over time, were calculated using the equation. Because of the thorough characterization of groundwater flow paths at this Site and the relatively simplistic geometry of the hypothetical leak sources, an analytical rather than a numerical (e.g., computerized finite-element or finite-difference model) approach was deemed reasonable and suitable for the Expansion. The selected three-dimensional solute transport equation readily accounts for leachate plume advection and dispersion, is relatively easy to implement, and is commonly used throughout the hydrogeologic sciences. The equation was solved analytically along interpreted groundwater seepage paths beginning at a hypothetical leak location and ending at a receptor. Groundwater seepage pathways were identified during the site investigations.

The analytical three-dimensional equation simulates the most dominant mechanisms that describe the transport of leachate constituents in soil and rock: advection and hydrodynamic dispersion. Advection is the bulk flow of groundwater that transports the hypothetical leak and is controlled by the hydraulic properties of the soil and rock (i.e., hydraulic conductivity, effective porosity and hydraulic gradient). Hydrodynamic dispersion is the phenomena whereby portions of the simulated plume spread out causing a lowering of the leachate concentration as it migrates with the groundwater, similar to how dye placed in a moving river spreads out and dilutes with downstream migration. The three-dimensional analysis allowed for spreading of the groundwater leachate plume in both the longitudinal direction (i.e., along direction of seepage) and laterally (i.e., transverse to the direction of seepage). The leachate constituents are assumed not to retard during migration, absorb or adsorb onto the soil, precipitate, complex with other chemical constituents, or degrade over time or distance of travel. These phenomena typically reduce the concentrations of leachate constituents during their migration through soil and, less so, through rock fractures. Since these phenomena are known to occur to varying degrees, this assumption typically results in a conservative estimate of the constituent concentrations at a receptor. “Conservative” has the meaning that the concentration of leachate constituents at a receptor is overestimated from what would be calculated if the analysis accounted for the ignored physical and chemical phenomena that are known to reduce concentrations. The equation used in the analysis is after the approach presented by Cleary and Ungs, (1978) and as presented in Appendix J.

The purpose of the analysis was to examine the concentrations of leachate constituents at the receptors. The analysis also was used to estimate the time required for leachate constituents to reach a receptor and to reach maximum concentrations. The calculated concentrations from the analysis were compared to applicable water quality criteria. For simplicity, and as an additional degree of conservatism, the analysis does not account for dilution in surface water, or mixing with non-impacted water that would be drawn into a water supply well.

The initial concentration (C_o) of a surrogate leachate constituent was set at 1.0 (mg/L) making the results easily converted to individual leachate constituent concentrations by multiplying the source concentration, in units of mg/L, of a particular leachate constituent by the results of the three-dimensional analysis to produce an estimated constituent concentration at a receptor. In this way, the results of a single solute transport calculation can be used to evaluate concentrations of the various individual leachate constituents relative to applicable criteria.[13] Table 4-1 presents a list of concentrations of selected leachate constituents based on average leachate characteristics for existing JRL, that are anticipated to be similar to the concentration of these parameter in the expansion's leachate since the same waste are proposed for the Expansion. Corresponding applicable criteria for surface water and groundwater are also contained in Table 4-1. By examining the ratio of these two values, it can be seen in Table 4-1, that iron represents the leachate constituent that has the lowest ratio and would be the parameter that would exceed a groundwater criterion before the other constituents.

TABLE 4-1

SELECTED LEACHATE CONSTITUENT CONCENTRATIONS

Leachate Constituent[1]	Typical Leachate Concentration[2] (mg/L)	Groundwater Criteria[3] (mg/L)	Groundwater Criteria Relative to Leachate[4]	Surface Water Criteria[5] (mg/L)	Surface Water Criteria Relative to Leachate[4]
Iron	69.6	NC	NC	1.0	0.014
Nitrate	327.6	10	0.031	NC	NC
Alkalinity	2010	NC	NC	20.0	0.01
Arsenic	0.1514	0.01	0.066	0.15	0.99
Chloride	11788	NC	NC	230.0	0.02
Ammonia	662	NC	NC	16.4	0.025

Notes:
1. Selected leachate constituents are the constituents where leachate concentrations have the highest concentration relative to the groundwater and surface water criteria.
2. Average value from leachate storage tank at JRL, (LT-C4LR); samples collected between July 30, 2013 and October 21, 2014; when a constituent was not detected, the detection limit was assumed in calculating the average.
3. U.S. EPA Maximum Contaminant Level.
4. Criteria relative to Leachate, calculated as: Criteria divided by Leachate Concentration.
5. The minimum of: State of Maine, Freshwater Chronic Criteria Concentration or Acute Criteria Concentration (06-096, Chapter 584).
6. NC = No Criteria

To simulate a system of layered soils/bedrock, which have different hydraulic properties, the concentration–time profile in the first layer was solved at the layer thickness, and that

[13] Example: For a surface water sensitive receptor, a calculated result of 0.023 would indicate that the leachate constituents iron would exceed the applicable surface water criteria. The calculated iron concentrations would be 0.023 * the iron concentration in leachate of 69.6 mg/L, or 1.6 mg/L.

concentration-time profile was then used as the influent concentration-time profile entering the next layer, and so on. The concentration-time profile leaving each layer is shown in Appendix J, for each hypothetical scenario and receptor.[14]

4.2 Assumptions

The hypothetical landfill leaks were assumed to flow vertically downward through the one foot of compacted imported clay soil, the first layer modeled, which underlies the liner system. The leaks were then assumed to take one of two possible pathways after permeating the imported soil layer on their way to the receptors:

- Vertically through re-compacted native till and/or native till, with as much hydraulic gradient as is necessary to accommodate the selected leakage rate from the overlying imported soil layer; and then horizontally through bedrock; or
- Horizontally through native till.

The following assumptions were applied in the contaminant transport analysis.

1) The vertical seepage through the imported clay soil assumes the maximum acceptable hydraulic conductivity value (i.e., 1×10^{-7} cm/sec).[15]

2) The vertical seepage through the native till utilizes the mean horizontal hydraulic conductivity, instead of the mean vertical hydraulic conductivity value. The vertical conductivity was measured to be less than the horizontal conductivity during site investigations, by a factor of approximately 60. Thus, using the mean vertical hydraulic conductivity would have reduced flow rates, meaning travel

[14] The concentration-time profile leaving intermediate layers were applied to the successive layer by simplifying the concentration-time profile and manually entering values in up to eight steps to allow for manageable numerical models. The resulting concentration-time profile at each sensitive receptor then was manually interpolated as shown in Appendix J, to determine the results presented herein.

[15] The actual value is expected to be in the range of 1.9×10^{-8} to 8.3×10^{-8} cm/sec. This would increase the time of travel through this layer from approximately 3.77 years to 4.54 to 19.83 years, assuming a unit gradient condition.

times would slow by a factor of approximately 60 (e.g., for a time of six years it would be closer to 360 years) and decreasing concentrations at a given time by a similar factor or more (e.g., for a concentration of 60 mg/L it would be 1 mg/L).

3) The horizontal groundwater seepage velocity in the native till was assumed at the in situ tracer test measured value of 0.1 ft/day.[16] The horizontal groundwater seepage velocity in bedrock was assumed at the in situ tracer test measured value of 5 ft/day.[17] Groundwater seepage velocities calculated from the measured hydraulic gradients, as discussed in the travel time analysis in Section 7.0 of Volume II of the Application, result in lower seepage velocities than the tracer test values. Using the measured hydraulic gradients along with mean conductivities, and effective porosities between the assumed hypothetical leaks and receptors, would result in horizontal groundwater seepage velocities of 0.002 to 0.02 ft/day in the till; and of 0.09 to 2.6 ft/day in bedrock fractures.[18] The tracer test groundwater velocities therefore result in travel times that are shorter by at least 2 to 5 times than those calculated using the measured hydraulic conductivities, porosities and gradients. Likewise, the concentrations calculated using the tracer test velocities are higher than would be calculated using the measured hydraulic conductivities, porosities and gradients.

4) The hypothetical landfill leaks occur over large portions of the landfill base and travel to the site receptors, as follows: Receptors A and B would be affected by leakage in Cell 11; Receptor C would be affected by leakage east of the groundwater divide (i.e., Cells 12 and 13); and Receptors D through G would be affected by leakage west of the groundwater divide (i.e., Cells 14, 15, and 16). For a leaky leachate force main, a segment of pipe was assumed to fail that was hydraulically up-gradient of the receptor. The locations of the receptors and

[16] Based on till tracer testing performed by SME, as described in Section 3.2.6 of Volume II of the Application, which indicated a velocity of 11 feet/year; consequently a value of 0.1 ft/day was assumed to be conservative.
[17] Based on bedrock tracer testing performed by SME, as described in Section 3.2.7 of Volume II of the Application, which indicated a velocity of 5 ft/day.
[18] Refer to travel-time analysis in Appendix J in Volume II of the Application.

sources are shown on Figure 4-1. The leakage sources are idealized as rectangles having the dimensions illustrated on Figure 4-1, which produce plan-view areas approximating the cells they represent. SME further assumed that the horizontal leakage originates at the edge of the landfill closest to the receptor and oriented the idealized rectangular leakage area so that it was at a right angle to existing groundwater flow direction to correspond with the analytical solute transport equation used.[19]

5) For the leachate pipe failure scenario, clay dikes in the bedding stone would act to reduce the spread of leachate; and lateral flow from the perimeter berm's exterior sideslope would act as an early warning system for such leaks since the leak would be observable on the exterior sideslope of the berm. These clay dikes are approximately 150 feet apart, and in the analysis, a 300-foot section of pipe trench filled with leachate was assumed as the leakage source. Using the shorter length would reduce peak concentrations and produce similar arrival times to those produced using this assumption.

6) No recharge to groundwater beyond the Landfill was assumed.

These assumptions were intended to result in conservative calculated leachate constituent concentrations at receptors (i.e., greater that what might actually occur) and conservative arrival times (i.e., shorter arrival times than would actually occur) for the leak scenarios modeled.

4.3 Model Parameter Selection

Parameter values used in the failure analysis equations represent values within the range of measured values established during the site investigations and are summarized in Table 4-2. The sources of these values are provided in Volume II of the Application.

[19] A semi-infinite half-space was used, with the axis of flow oriented in the direction of groundwater flow and lateral distances considered where receptors are offset from the center of flow in the y- and z-directions.

LEGEND

PROPOSED		EXISTING
	GROUNDWATER SAMPLING LOCATION	
	OBSERVATION WELL LOCATION	
	SURFACE WATER SAMPLING LOCATION	
	LEAK DETECTION SAMPLING LOCATION	
	UNDERDRAIN SAMPLING LOCATION	
	TRANSDUCER LOCATION TO MONITOR GROUNDWATER LEVEL BELOW LANDFILL	
(11)	LANDFILL CELL NUMBERS	
	EXPANSION CELL LIMITS	
A	SITE SENSITIVE RECEPTOR	
	SCENARIO 1 AND 2 FLOW PATH	
	LEAKY AREA (DIMENSIONS AS SHOWN)	
	SCENARIO 3 FLOW PATH	
	300' LEAKY PIPE (SEGMENTS AS SHOWN)	

NOTE:

1. PW-08-01 TO BE CONVERTED TO MW-504A,B
2. BACKGROUND WATER QUALITY MONITORING WILL BE MONITORED AT MW-206, P-206A, MW-04-09B AND MW-04-09A

250 0 500 FEET

FIGURE 4-1
CONTAINMENT TRANSPORT ANALYSIS
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE

DWG: BASE LMN:FIG-ContainmentTransportanalysis CTB: SME-STD REV: 6/10/2015

\\Nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Acad\Plans\BASE.dwg, 6/10/2015 9:00:42 AM, paf

TABLE 4-2

HYDRAULIC PROPERTIES USED IN CONTAMINANT TRANSPORT ANALYSIS

Modeled Parameter[1]	**Vertical Flow**			**Horizontal Flow**	
	Imported Soil Layer	**Common Borrow (Berm Fill)**	**Till**	**Till**	**Bedrock**
Average Hydraulic Conductivity (k, cm/sec)	1×10^{-7}	9.4×10^{-6}	9.4×10^{-6}	9.4×10^{-6}	3.5×10^{-5}
Average Effective Porosity (n)	0.39	0.25	0.25	0. 25	0.001
Dispersivity (α, ft) for Vertical Seepage: Flow Direction, x-axis (α_x) Lateral to Flow, y and z-axes ($\alpha_y = \alpha_z$)	 0.01 0.01	 0.01 0.1	 0.01 0.1	 NA	 NA
Dispersivity[2] (α, ft) for Horizontal Seepage: Flow Direction, x-axis (α_x) Lateral to Flow: y-axis, side-to-side (α_y) z-axes, up-and-down (α_z)	 NA	 NA	 NA	 0.15 0.01 0.01	 1.2 0.4 0.02
Seepage Velocity	7.3×10^{-4} ft/day[3]	Based on hydraulic gradient produced by leak	Based on seepage from above	0.1 ft/day[4]	5 ft/day[5]

Notes:

1. All values were developed based on site-specific information and are discussed in Section 7.0 of Volume II of the Application.
2. Dispersivity is estimated as a percentage of the plume travel distance.
3. Assumes a hydraulic gradient of one.
4. Based on till tracer testing performed by SME, as described in Section 3.2.6 of Volume II of the Application, which indicated a velocity of 11 feet/year; consequently a value of 0.1 ft/day was assumed to be conservative.
5. Based on bedrock tracer testing performed by SME, as described in Section 3.2.7 of Volume II of the Application, which indicated a velocity 5 ft/day.

4.4 Hypothetical Failure Scenarios

The engineered leachate containment system includes a primary and secondary liner system, and a leak detection system beneath the waste, internal cell leachate pump stations, a force main outside the landfill and an existing leachate storage tank.[20] Based on the design of the Expansion and as required by the Rules, three hypothetical failure scenarios were evaluated: (1) complete failure of the primary and secondary engineered liner (i.e., barrier) systems; (2) continuous leakage from the primary liner system, at the design leakage rate; and (3) temporary leakage from the leachate force main (i.e., pipeline rupture). These failure scenarios were evaluated as to their impact at receptors as required by the Rules. The intent of these analyses is to identify any operational or monitoring measures needed to ensure projection of the receptors.

The three hypothetical failure scenarios are discussed below.

Scenario 1: Complete Failure of Liner System. Under this scenario, the landfill liner system, including the primary and secondary liner (engineered barrier) systems are assumed to have completely been eliminated and leachate allowed to drain directly into the underlying soils at a rate controlled by the hydraulic characteristics of the imported clay soils that will be present under the entire landfill base, assuming a hydraulic gradient of one (i.e., a unit gradient). For this scenario, a leakage rate of approximately 92 gallons per acre per day (gpad) was calculated (see Appendix J). In order to show potential impacts from a worst-case scenario with no engineered barriers, SME assumed that the leak would be continuous (i.e., goes undetected and unrepaired) for an indefinite period of time.

Based on the analysis, a plume emanating from a hypothetical total liner failure and traveling to any of the receptors would not represent an unreasonable threat to the receptors since the concentrations at six years do not exceed applicable groundwater or surface water quality

[20] Since the existing leachate storage tank will be used by the Expansion, the contaminant transport analysis associated with the tank has been previously performed and found to meet the required standards as discussed in Department Order #S-020700-WD-N-A (see findings of fact #7D).

criteria.[21] The analysis indicates that the concentration of leachate constituents at receptors reach the concentrations shown in Table 4-3 (all below applicable standards) after three or six years. Table 4-3 also shows the times required to attain concentrations equal to the applicable criteria, the times required to achieve steady-state, the maximum concentration and the time at which that would occur. The groundwater concentrations would be less than the calculated values shown in Table 4-3 at further downgradient locations or receptors (e.g., off-site groundwater and surface water). The supporting calculations are included in Appendix J.

Scenario 2: Leaky Landfill Base. Under this scenario, the secondary liner is assumed to leak and the primary liner is assumed to not be present. The hydraulic conditions (except for the leakage rate), the leakage paths and other assumptions described for Scenario 1 were applied in Scenario 2. Leakage through the secondary liner was assumed to be at a rate of 4.6 gpad, the design leakage rate, which corresponds to ten times the leakage rate through the secondary liner, assuming three design holes in the secondary liner and a one-foot head on that secondary liner system. In order to show a worst-case potential impacts, we assume that this leakage rate is continuous (i.e., goes undetected and unrepaired) for an indefinite period of time.

Based on the analysis, a plume emanating from a leaky primary liner and traveling to any of the receptors would not represent an unreasonable threat to the receptors since the concentrations at six years do not exceed applicable groundwater or surface water quality criteria.[22] In fact, the leakage rate is so low that detectable concentrations of leachate constituents would not exist at the receptors within six years of such a leak. The results are described in Table 4-3 and Appendix J.

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[21] Under actual conditions, leachate introduction into ground water would be immeasurably small due to the ability of the liner system to restrict vertical transport of leachate to rates that are at most 0.01% (assuming a minimum of 99% reduction by the primary liner and an additional 99% reduction by the secondary liner) of the rate assumed in this hypothetical scenario. Therefore, leachate concentrations in the groundwater are greatly overestimated by the analysis of this scenario.

[22] Under actual conditions, leachate introduction into ground water would be immeasurably small due to the ability of the liner system to restrict vertical transport of leachate to rates that are at most 1% (assuming a minimum of 99% reduction by the secondary liner) of the rate assumed in this hypothetical scenario. Therefore, leachate concentrations in the groundwater are greatly overestimated by the analysis of this scenario.

Scenario 3: Leaky Leachate Force Main. The dual-walled, leachate force main or pipeline in a six-foot deep trench, which flows from the leachate pump station sumps to the leachate storage tank, was assumed to rupture. In reality, a break in the force main would not result in introduction of leachate to the groundwater system because of the dual-containment design of the main, which includes a secondary containment pipe to contain leaks from a ruptured primary force main pipe. The force main's location (i.e., outside the limits of the landfill's solid waste boundary) will provide immediate access for repairs in the unlikely event of a failure.

The pipe trench is assumed to be about 28 inches wide and to have a bottom depth at approximately 6 feet below ground surface. The rupture was assumed to be observed after one week when the leachate reaches the ground surface and the leachate in the trench removed after three weeks of the leak being observed (i.e., a 30-day repair time). The leaked leachate was assumed to be confined within 300 feet length of pipe trench.[23] The escaping leachate was assumed to pass vertically through the common borrow (re-compacted native till) used to construct the berms assuming the trench was filled to ground surface, and like Scenarios 1 and 2 above, the leak then followed the same multi-layer pathways described previously. The concentration at a receptor within three years of the leak is required by the Rules not to exceed groundwater or surface water criteria for a leachate pipeline located outside the landfill liner system.

Based on our analysis and in accordance with the specifications outlined in the Rules, a plume emanating from a hypothetical leak in the proposed force main at the location indicated does not reach receptors at concentrations in excess of criteria in less than three years and, therefore, does not represent an unreasonable threat to the receptors. The results are provided in Table 4-3 and Appendix J.

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[23] Clay dikes will be constructed at 150-foot spacing along the pipe, two of these segments were assumed to fill with leachate; therefore, 300 feet was used in the analysis as a length.

TABLE 4-3

SUMMARY OF CONTAMINANT TRANSPORT ANALYSIS

Scenario[1]	Site Sensitive Receptor (Media)[2]	Parameter	Concentration, mg/L At Time of Years[6]		Time to Reach Applicable Criteria, Years	Time to Reach Steady-State, Years	Time in Years to Reach Maximum and (Concentration, mg/L)
			3	6			
Scenario 1 (Horizontal Flow in Till)	A (GW)	Nitrate		<0.00033	>30	>30	30 (0.06)
		Arsenic		<0.0000002	>30	>30	30 (0.00003)
	B (GW)	Nitrate		<0.00033	>30	>30	30 (0.33)
		Arsenic		<0.0000002	>30	>30	30 (0.00015)
	C (SW)	Alkalinity		<0.0020	>30	>30	30 (1.8)
		Iron		<0.00007	>30	>30	30 (0.063)
	D (SW)	Alkalinity		<0.0020	>30	>30	30 (<0.0020)
		Iron		<0.00007	>30	>30	30 (<0.00007)
	E (GW)	Nitrate		<0.00033	>30	>30	30 (0.66)
		Arsenic		<0.0000002	>30	>30	30 (0.00030)
	F (GW)	Nitrate		<0.00033	>30	>30	30 (0.002)
		Arsenic		<0.0000002	>30	>30	30 (0.0000009)
	G (SW)	Alkalinity		<0.0020	>30	>30	30 (<0.0020)
		Iron		<0.00007	>30	>30	30 (<0.00007)
Scenario 1 (Horizontal Flow in Bedrock)	A (GW)	Nitrate		<0.00033	>30	>30	30 (5.9)
		Arsenic		<0.0000002	>30	>30	30 (0.0027)
	B (GW)	Nitrate		<0.00033	Never	20	20 (9.8)
		Arsenic		<0.0000002	Never	20	20 (0.0045)
	C (SW)	Alkalinity		<0.0020	>30	>30	30 (<0.0020)
		Iron		<0.00007	>30	>30	30 (<0.00007)
	D (SW)	Alkalinity		<0.0020	Never	23	23 (2.2)
		Iron		<0.00007	Never	23	23 (0.077)
	E (GW)	Nitrate		<0.00033	Never	22	22 (9.8)
		Arsenic		<0.0000002	Never	22	22 (0.0045)
	F (GW)	Nitrate		<0.00033	Never	23	23 (1.3)
		Arsenic		<0.0000002	Never	23	23 (0.00061)
	G (SW)	Alkalinity		<0.0020	Never	24	24 (3.0)
		Iron		<0.00007	Never	24	24 (0.10)
Scenario 2 (Horizontal Flow in Till)[5]	A (GW)	Nitrate		<0.00033	>30	>30	30 (<0.00033)
		Arsenic		<0.0000002	>30	>30	30 (<0.0000002)
	B (GW)	Nitrate		<0.00033	>30	>30	30 (<0.00033)
		Arsenic		<0.0000002	>30	>30	30 (<0.0000002)
	C (SW)	Alkalinity		<0.0020	>30	>30	30 (<0.0020)
		Iron		<0.00007	>30	>30	30 (<0.00007)
	D (SW)	Alkalinity		<0.0020	>30	>30	30 (<0.0020)
		Iron		<0.00007	>30	>30	30 (<0.00007)
	E (GW)	Nitrate		<0.00033	>30	>30	30 (<0.00033)
		Arsenic		<0.0000002	>30	>30	30 (<0.0000002)
	F (GW)	Nitrate		<0.00033	>30	>30	30 (<0.00033)
		Arsenic		<0.0000002	>30	>30	30 (<0.0000002)
	G (SW)	Alkalinity		<0.0020	>30	>30	30 (<0.0020)
		Iron		<0.00007	>30	>30	30 (<0.00007)

TABLE 4-3 (cont'd)

Scenario[1]	Site Sensitive Receptor (Media)[2]	Leachate Parameter	Concentration (mg/L) At Time in Year(s)		Time to Reach Applicable Criteria (Years)	Time to Reach Steady-State (Years)	Time to Reach Maximum, Years (Concentration, mg/L)
			3	6			
Scenario 2 (Horizontal Flow in Bedrock)[5]	A (GW)	Nitrate		<0.00033	>30	>30	30 (<0.00033)
		Arsenic		<0.0000002	>30	>30	30 (<0.0000002)
	B (GW)	Nitrate		<0.00033	>30	>30	30 (<0.00033)
		Arsenic		<0.0000002	>30	>30	30 (<0.0000002)
	C (SW)	Alkalinity		<0.0020	>30	>30	30 (<0.0020)
		Iron		<0.00007	>30	>30	30 (<0.00007)
	D (SW)	Alkalinity		<0.0020	>30	>30	30 (<0.0020)
		Iron		<0.00007	>30	>30	30 (<0.00007)
	E (GW)	Nitrate		<0.00033	>30	>30	30 (<0.00033)
		Arsenic		<0.0000002	>30	>30	30 (<0.0000002)
	F (GW)	Nitrate		<0.00033	>30	>30	30 (<0.00033)
		Arsenic		<0.0000002	>30	>30	30 (<0.0000002)
	G (SW)	Alkalinity		<0.0020	>30	>30	30 (<0.0020)
		Iron		<0.00007	>30	>30	30 (<0.00007)
Scenario 3 (Horizontal Flow in Till)	A (GW)	Nitrate	0.00033		Never	Never	7 (0.0033)
		Arsenic	0.00000015		Never	Never	7 (0.0000015)
	B (GW)	Nitrate	0.00036		Never	Never	7 (0.0033)
		Arsenic	0.00000017		Never	Never	7 (0.0000015)
	C (SW)	Alkalinity	<0.0020		Never	Never	12 (0.0020)
		Iron	<0.000070		Never	Never	12 (0.000070)
	D (SW)	Alkalinity	<0.0020		Never	Never	11 (0.056)
		Iron	<0.000070		Never	Never	11 (0.0019)
	E (GW)	Nitrate	0.00066		Never	Never	6 (0.0029)
		Arsenic	0.00000030		Never	Never	6 (0.0000014)
	F (GW)	Nitrate	<0.00000015		Never	Never	6 (<0.00098)
		Arsenic	<0.00033		Never	Never	6 (<0.0000005)
	G (SW)	Alkalinity	<0.0020		Never	Never	11 (0.0012)
		Iron	<0.000070		Never	Never	11 (0.000042)
Scenario 3 (Horizontal Flow in Bedrock)	A (GW)	Nitrate	<0.00033		Never	Never	0.3 (0.023)
		Arsenic	<0.00000015		Never	Never	0.3 (000011)
	B (GW)	Nitrate	<0.00033		Never	Never	0.14 (0.066)
		Arsenic	<0.00000015		Never	Never	0.14 (0.000030)
	C (SW)	Alkalinity	<0.0020		Never	Never	0.5 (0.012)
		Iron	<0.000070		Never	Never	0.5 (0.00042)
	D (SW)	Alkalinity	<0.0020		Never	Never	0.45 (0.030)
		Iron	<0.000070		Never	Never	0.45 (0.0010)
	E (GW)	Nitrate	<0.00033		Never	Never	0.5 (0.0029)
		Arsenic	<0.00000015		Never	Never	0.5 (0.0000014)
	F (GW)	Nitrate	<0.00033		Never	Never	0.45 (0.033)
		Arsenic	<0.00000015		Never	Never	0.45 (0.000015)
	G (SW)	Alkalinity	<0.0020		Never	Never	0.35 (0.16)
		Iron	<0.000070		Never	Never	0.35 (0.0056)

TABLE 4-3 (cont'd)

Notes:
1. Scenarios: 1: No Liner System; 2: Leaky Liner; and 3: Leaky Force Main.
2. (GW): Groundwater criteria apply; or (SW): Surface water criteria apply.
3. < symbol indicates that the concentration is less than the value shown.
4. Transient leak does not result in a steady-state concentration.
5. Scenario 2 leakage rate is sufficiently slow that leachate constituents do not permeate the Imported Soil Layer. Therefore, only Receptors A and B were evaluated. Other receptors would show similar results (i.e., no exceedance of criteria).
6. These concentrations would not result in either practically quantifiable discharge or a statically significant change in water quality at the sensitive receptors.

Based on the above analyses, a plume emanating from hypothetical liner or leachate transport system failures would not represent an unreasonable threat to sensitive receptors. The results of the contaminant transport analyses for Scenarios 1, 2, and 3 indicate that the predicted potential impacts from the hypothetical leaks are below applicable ground and surface water standards. The parameter concentrations of leachate constituents at the sensitive receptors for the applicable three and six-year time period would not result in contamination of that receptor. Therefore, they would not represent an unreasonable threat to sensitive receptors.

4.5 Sensitivity Analysis

Anderson and Woosner, (2001) state that the purpose of a sensitivity analysis is to "quantify uncertainty in the calibrated model caused by uncertainty in the estimates of the aquifer parameters." The hydraulic conductivity, porosity and dispersivity are the primary measured parameters that affect the calculated results; therefore, these hydraulic parameters were varied such that the calculated travel time would be minimized and the concentration would be maximized. The evaluation was performed to assess the overall effect of varying the parameters for the scenario and receptor with the highest concentration from Table 4-3 (Scenario 3, horizontal flow in till, and sensitive receptor E (GW). A table summarizing the results and calculations are provided at the end of Appendix J. Based on this analysis, the results presented in Table 4-3 are considered reasonable, with the likely range of hydraulic properties producing concentrations less than applicable criteria at three years and at the maximum concentration. Similar analyses performed on the other scenarios would produce similar changes from the values presented in Table 4-3.

4.6 Conclusion

The analyses demonstrate that the Expansion complies with the requirements of Chapter 401.1.C.1.c and d and Chapter 401.2.G of the Rules in the event of a failure of engineered systems that contain leachate. The analyses presented herein support the conservative nature of the design of the Expansion and show that, even under hypothetical failure scenarios, sensitive receptors in the vicinity of the Expansion will not be unreasonably threatened by leachate leaks. Considering the conservative nature of the design of the Expansion, including the liner system (with leak detection), imported clay layer, underdrain monitoring and double-containment of leachate transport pipes, combined with the proposed monitoring program, the proposed Expansion will not pose an unreasonable threat to sensitive receptors in the vicinity of the Site. The simulations illustrate that the proposed monitoring locations and monitoring frequency (as described in the EMP) will be sufficient to detect changes in groundwater and surface water quality that may occur under potential failure conditions. As demonstrated through extensive field investigations and analyses performed as part of the application process, the proposed landfill design combined with the natural setting sufficiently inhibits transport of leachate in the overburden groundwater system and the underlying bedrock formation to receptors including on-site surface waters and hypothetical off-site water supply wells positioned at the site property boundaries. Furthermore, the currently proposed design will provide greater than six years of travel time from the base of the landfill's liner system to the sensitive receptors.

5.0 PLAN VIEW AND PROFILE VIEW DRAWINGS

Attached as Appendix E to this document, are plan and profile drawings that meet the requirements of Section 401.2.H of the Rules. Drawings attached include the following:

- Existing Site Conditions Plan;
- Site Development Plan;
- Site Base Grading Plan;
- Underdrain Piping Plan;
- Leak Detection Piping Plan;
- Leachate Collection Piping Plan;
- Gas Collection System Plan;
- Final Site Drainage Plan;
- Final Site Development Plan;
- Landfill Sections, and
- Details of the Expansion's proposed engineered systems.

Other engineering drawings for the stormwater management/erosion control systems are attached to the Erosion Control and Stormwater Management Plans contained in Volume I of this Application.

6.0 QUALITY ASSURANCE PLAN

A quality assurance plan has been prepared for the Expansion to assure that the design specifications and performance requirements for all facility components are met during construction (ref. Appendix B). The Quality Assurance Plan addresses the following items:

- Construction quality assurance (CQA) measures to be implemented;
- Relationship between the Quality Assurance Plan (QAP), construction quality control, and the construction contract bid documents;
- Responsibility and authority that organizations and/or personnel involved in permitting, design, constructing, and certifying construction of the landfill have, including a construction problem resolution process that incorporates the roles and responsibilities of all parties, including owner, manufacturer, installer, designer, QA personnel, contractor, and the MEDEP;
- CQA personnel qualifications will meet the requirements of Section 401.3(B) of the Rules, and will include certification by Geosynthetic Institute's Construction Quality Assurance – Inspector's Certification Program (CQA-ICP);
- Inspections and tests to be performed to ensure that the construction and materials conform to contractual and regulatory requirements for each landfill component including a leak location survey that will be completed on the primary geomembrane liner;
- Sampling activities, sample size, methods for determining sample locations, frequency of sampling, acceptance and rejection criteria, and methods for ensuring corrective measures are implemented;
- Recordkeeping and reporting requirements for CQA activities; and
- A list and description of all items requiring CQA certifications, including identification of the engineers responsible for the certifications.

7.0 CONSTRUCTION CONTRACT BID DOCUMENTS

Included in this report are the bid documents (for Cell 11) and technical specifications (Appendix A), a construction quality assurance manual (Appendix B), and engineering design drawings (Appendix E) that have been prepared for the Expansion. Prior to construction of any portion of the Expansion, detailed construction documents will be prepared, similar to those included in Appendix A and include contract administrative documents, detailed engineering drawings, technical specifications, QA/QC Plans, and the like. These documents will be prepared and submitted to the MEDEP for review and approval a minimum six months prior to the initiation of construction activities at the site. Included in Appendix K are the design drawings for Cell 11, the first landfill cell to be constructed.

8.0 WATER QUALITY REPORT AND PROPOSED MONITORING PROGRAM

A water quality report and proposed monitoring program prepared for the Expansion are discussed and contained in Section 6.0 of Volume II and in Appendix I of Volume IV, respectively, of this application. These have been prepared in accordance with the requirements of Chapter 405 of the Rules.

9.0 OPERATIONS MANUAL

Volume IV of this Application consists of an Operations Manual prepared in accordance with Section 401.4.A. of the Rules.

10.0 LANDFILL CONSTRUCTION

During construction of the Expansion, NEWSME will abide by the following regulatory requirements:

- Pre-Construction Conference. Prior to major construction events (i.e., cell construction, closure activities) at the Expansion, NEWSME will hold a pre-construction conference with the contractor, NEWSME's engineer, and MEDEP. The MEDEP will be given notice at least 7 days prior to the pre-construction conference.

- Quality Assurance Plan. A Quality Assurance/Quality Control (QA/QC) plan has been developed to monitor the quality of materials and procedures used in the Expansion construction. A copy of the plan is contained in Appendix B. The QA/QC Plan addresses personnel and procedures that will be used during construction of the Expansion to monitor and document materials used to meet project specification. The QA/QC Plan identifies responsibilities of parties involved in the construction (such as, owner, project manager, designer, geosynthetic manufacturer, and construction quality assurance personnel), the required construction documentation, and the QA/QC required for the material used in construction, including soil components, geomembranes, geotextiles, geonet, GCL, and piping. Specified material properties are contained in the project technical specifications.

- Liner Installation. Prior to installing any type of liner, NEWSME will evaluate the liner installation procedures and schedule in regards to climatic conditions and other site factors (such as base preparation, Quality Control Plan, technical specifications) to ensure the integrity of the installed liner system. HDPE geomembrane liners will only be installed between April 15 and November 1 and only when ambient temperatures exceed 32 degrees Fahrenheit. A cold weather installation plan will be prepared and submitted to the MEDEP for approval if liner installations are required during other times of the year.

- Changes From Approved Plans and Specifications. Prior to implementing any changes to the approved landfill design, leachate management systems, or project specifications, NEWSME will receive approval from the MEDEP through an amendment or minor revision, or through a change order approval. As provided in the Solid Waste Rules, the MEDEP will issue a response to the change order request within 5 working days or approval of the change order will be deemed automatically granted.

- Weekly Inspection Reports. NEWSME and NEWSME's consultants, and the construction quality assurance team responsible for construction inspection at the site will keep daily and weekly construction inspection reports and provide a copy to the MEDEP. The weekly reports will be issued to the MEDEP within one week after completion of each construction week. Weekly reports will summarize daily reports and include the following general information: summary of test results; summary of submittals and actions taken; summary of work progress; upcoming work items for the next two weeks; punch list items as applicable; summary of significant problems encountered and how the problems were resolved; change order status; and construction stability monitoring results, if applicable.

- Photographic Documentation. To provide photographic documentation, landfill construction photographs will be taken periodically. Copies of these photographs will be provided to the MEDEP upon request and will be contained in the final construction report.

- Record Drawings. Upon completion of landfill construction, record drawings will be prepared for the facility. Drawings will be sealed by a State of Maine Professional Engineer and will be submitted to the MEDEP within 45 days after construction completion of each cell.

- <u>Final Construction Report and Commencement of Operations</u>. Upon completion of each construction cell at the Expansion, NEWSME will submit a written request to the MEDEP to conduct an inspection of the completed construction activity for finding of compliance with the facility license. NEWSME will commence operations in the newly constructed areas of the Expansion upon MEDEP approval, or within ten working days after submitting the written request and after the MEDEP conducts or waives the need for a final construction inspection. Written certifications submitted to the MEDEP requesting inspection will be submitted as part of the final construction report. The final construction report will be prepared and submitted to the MEDEP within 45 days following construction completion of each cell of the Expansion. A copy of the final construction report will be retained by NEWSME at the JRL. The final construction report will provide written certification by the overseeing engineer that the project has been completed in substantial compliance with approved plans and specifications. The report will include a summary of all testing data as well as a narrative describing the construction project and a copy of the representative photographs and documentation of the project. The report will also include a tabulation of all problems encountered during construction and a description of how those problems were resolved, along with copies of the weekly inspection reports. Supporting documentation included in the final construction report will include laboratory test results; subgrade acceptance certification; manufacturer quality control certification; and quality assurance final reports for earthwork and geosynthetics.

REFERENCES

Anderson, M.P. and W.W. Woosner, 2001. "*Applied Groundwater Modeling, Simulation of Flow and Advective Transport"*. Academic Press, San Diego, CA.

Cleary, R.W. and Ungs, M.J. 1978 "Analytical models for groundwater pollution and hydrology" Princeton University, Water Resources Program Report 78-WR-15, 165p.

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APPENDIX A

CONSTRUCTION SPECIFICATIONS

BID DOCUMENTS AND TECHNICAL SPECIFICATIONS LANDFILL EXPANSION

JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

Submitted by:
STATE OF MAINE BUREAU OF GENERAL SERVICES
as Owner
&
NEWSME LANDFILL OPERATIONS, LLC,
As Operator

July 2015

STATE OF MAINE
GUY H. COTE, JR.
No. 5144
LICENSED PROFESSIONAL ENGINEER
6/15/15

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE

4 Blanchard Road, PO Box 85A, Cumberland Center, ME 04021 • Phone 207.829.5016 • Fax 207.829.5692 • www.smemaine.com

TABLE OF CONTENTS

BID AND CONTRACT DOCUMENTS

TECHNICAL SPECIFICATIONS

<u>DIVISION 2 – (CONT'D)</u>

BID AND CONTRACT DOCUMENTS

SECTION I

INVITATION FOR BIDS

SECTION I
INVITATION FOR BIDS

I. INVITATION FOR BIDS

Three copies of your sealed proposals for Construction of Cell 11 Expansion at the Juniper Ridge Landfill facility, will be received at the office of NEWSME Landfill Operations LLC, Hampden, Maine, until **_______ at ______**, and at that time privately opened.

The work consists of the following:

Construction of Cell 11 Expansion, including: mobilization, erosion control, dust control, site preparation, clearing, grubbing, stump grinding, topsoil stripping, abandonment and/or removal of existing structures, decommission wells, site layout, excavation and grading to meet design base grades, stockpiling of excess materials, preparation of subgrade, installation of 1-foot layer imported soil, installation of the secondary HDPE geomembrane, or augmented secondary liner consisting of: one foot of clay, GCL and HDPE geomembrane, installation of the leak detection system including: drainage geocomposite, HDPE pipe, drainage sand, cleanouts, and sampling ports, installation of the primary composite liner system including: clay layer, GCL, and HDPE geomembrane, installation of the leachate collection system including: drainage geocomposite, HDPE pipe, drainage sand, filter stone, drainage stone, drainage inlet structures, leachate collection sump and pump station, connection to the above-ground leachate storage tank force main, excavation and grading to connect the leachate collection piping to the existing system, construction of liner system tie-connections with existing systems, construction temporary geomembrane berm, perform primary liner leak survey, placement of vegetative cover soil and permanent erosion control measures, installation stormwater control structures, installation new and/or relocation of litter fence, construction of Cell 11 landfill paved and gravel access roads, landfill access ramp, chain link fence, relocation of existing above and below ground utilities, as-built/record survey and restoration of existing site roadways and site cleanup.

Plans and specifications and other contract documents may be obtained at the office of New England Waste Services of ME (NEWSME), Inc. dba Pine Tree Landfill, in Hampden, Maine.

All bids will remain subject to acceptance for 30 days after the actual date of the bid opening. Complete instructions for filing are included in the Information for Bidders.

NEWSME reserves the right to waive any informality in or to reject any or all proposals, or to accept any bid if deemed to be in the best interest of the Company to do so.

Juniper Ridge Landfill
Old Town, Maine

SECTION II

INSTRUCTIONS TO BIDDERS

SECTION II

INSTRUCTIONS TO BIDDERS

1. PROPOSALS

A. Receipt and Opening of Bids

Sealed bids will be received until ________**at** _______ at the office of NEWSME Landfill Operations LLC (NEWSME Operations) at Pine Tree Landfill, 358 Emerson Mill Road, Hampden, Maine, or at the offices of Sevee & Maher Engineers, Inc. (SME) at 4 Blanchard Road, Cumberland, Maine, and then privately opened and read. Bids delivered to SME should be accompanied by a faxed version of the bid to Wayne Boyd at NEWSME Operations (207) 862-4207. The faxed version must exactly match the delivered bid. The envelopes containing three copies of the bids must be sealed, addressed to Purchasing Department, Attn: Wayne Boyd, and designated as:

Cell 11 Expansion Construction
Juniper Ridge Landfill
Old Town, Maine
fax (207) 862-2839
phone (207) 862-4200 ext. 224

NEWSME Operations will not consider any bid not prepared and submitted in accordance with the provisions hereof and may waive any informalities or reject any and all bids. Any bid may be withdrawn prior to the above scheduled time for the opening of bids or authorized postponement thereof. Any bid received after the time and date specified shall not be considered. All bids will remain subject to acceptance for 60 days after the actual date of the bid opening.

B. Preparation of Bid

Each bid must be submitted on the prescribed form to these documents. All blank spaces in the form shall be filled, all copies shall be signed in ink in longhand, and all numbers shall be stated in writing and in figures. The complete form shall be without alterations, or erasures, and no changes shall be made in the phraseology of the form. All bid items shall be considered as a unit, and a bid on all items shall be required in order to be considered. Total base bid shall represent lump sum price to complete all work described by the bid documents. Unit price values shall be used to determine contractor’s compensation for extra work not described or shown by the bid documents. Unit prices will not vary due to changes in quantities. Individual bid items may be deleted from the project scope at the discretion of NEWSME Operations. No additional payment of any type or for any reason will be made for items covered by a lump sum price, or adjustment be made for items covered by lump sum price as a result of item deletion. Conditional bids will not be accepted.

C. Bid Documents, Drawings, and Specifications

One set of bid documents, including Drawings and Specifications, will be issued by Sevee & Maher Engineers, Inc. (SME) (termed "the Engineer") to each invited Bidder only, for the purpose of preparing a bid. No partial sets will be issued, nor will drawings or specifications be issued to firms wishing to submit material, equipment or other sub-bids to invited Bidders. The loaned sets of drawings and specifications shall be returned to the Engineer by unsuccessful Bidders, if so requested.

D. Bidder

(a) Shall carefully examine the documents, the Drawings and the Specifications, shall visit the site and fully inform himself as to all existing and controlling conditions and limitations including availability of materials and labor. A prebid telephone conference for prospective bidders will be held on ____________ **at** _________ at which time the bidder may request to visit the Juniper Ridge Landfill site. The submission of a bid shall be a representation that he has inspected the site and has familiarized himself with all of the controlling conditions. The failure or omission of any bidder to examine any form, instrument or document shall in no way relieve any bidder from any obligation in respect to his bid.

(b) Shall notify the Engineer in writing if he finds discrepancies in, or omissions from, the Drawings and/or Specifications, or is in doubt as to their meanings. If explanation is necessary, a reply will be made by an addendum issued to Bidders. No oral statement shall change the requirements of the Specifications or Drawings unless confirmed in writing.

(c) Shall state the lump sum price for which he will execute and complete each work package and the entire work in accordance with the Drawings, Specifications, and the requirements of the contract.

(d) Work extra to the contract requirements will be done, as outlined in the Bid Form (ref. Section C).

(e) Shall indicate in his bid the portions of the Contract work, if any, which will be subcontracted. The bidder is specifically advised that any person, firm, or other party to whom it is proposed to award a subcontract under this Contract must be acceptable to NEWSME Operations. A complete list of proposed subcontractors shall be included in the Contractor's bid.

(f) Shall state that he will complete the work of the contract in accordance with the Construction Schedule included as part of the Specifications.

(g) Shall sign his name in the space provided therefore. If the bid is made by a partnership or corporation, the name and address of the partnership or corporation shall be shown, together with the names of the partners or the officers. A bid made by a partnership shall be acknowledged by one of the partners, a bid made by a corporation by one of the authorized officers thereof.

(h) If awarded the contract, will be required to furnish copies of Insurance Certificates endorsed to meet the requirements of the contract.

(i) Each Bidder is urged to submit his best possible price with his bid. Bids will be evaluated and the order placed on the basis of the set of prices received in each Bidder's bid. Adjustment of original bid prices will not be considered after receipt of bids, except as required to adjust for design or scope changes.

E. Time of Completion

Bidder must agree to complete all work by the dates shown on the Bid Schedule (i.e., Cell 11 Expansion substantial completion ______________).

NEWSME Operations is in the process of securing all permits necessary to complete the project. The timing for obtaining these permits is unknown and, thus a start date for on-site construction cannot be given at this time. NEWSME Operations' goal is to obtain all necessary permits to enable the Contractor to begin the on-site work as early as possible. NEWSME Operations will keep the Contractor informed of the progress made in the project permitting. NEWSME Operations requests that the Contractor provide NEWSME Operations with a Construction Schedule identifying the major construction items and a proposed start date to have the project completed by the dates described in the Bid Schedule.

F. Condition of Work

Each bidder must inform himself fully of the conditions relating to the construction of the project and the employment of labor thereon. Failure to do so will not relieve a successful bidder of his obligations to furnish all material, equipment, and labor necessary to carry out the provisions of his Contract. Insofar as possible, the Contractor, in carrying out his work, must employ such methods or means as will not cause any interruptions of or interference with the work of any other contractor. The Juniper Ridge Landfill is an active site receiving waste materials on a daily basis. It is the responsibility of the Contractor to coordinate with the Owner with regard to use of the premises, including haul routes and vehicular access.

G. Addenda and Interpretations

No interpretation of the meaning of the plans, specifications, or other pre-bid documents will be made to any bidder orally. Every request for such interpretation should be in writing addressed to Sevee & Maher Engineers, Inc., P.O. Box 85A, Cumberland Center, Maine 04021 FAX to (207) 829-5692, to be given consideration must be received at least five days prior to the date fixed for the opening of bids. Any and all such interpretations and any supplemental instructions will be in the form of written addenda to the specifications which, if issued, will be mailed by certified mail with return receipt requested to all prospective bidders (at the respective addresses furnished for such purposes), faxed or e-mailed. Failure of any bidder to receive any such addendum or interpretation shall not relieve such bidder from any obligation under his bid as submitted. All addenda so issued shall become part of the Contract Documents.

H. Laws and Regulations

The bidder's attention is directed to the fact that all applicable State laws, municipal ordinances, and the rules and regulations of all authorities having jurisdiction over construction of the project shall apply to the Contract throughout, and they will be deemed to be included in the Contract the same as though herein written out in full.

I. Method of Award

If at the time this Contract is to be awarded, the lowest base bid submitted by a reasonable bidder does not exceed the amount of funds then estimated by NEWSME Operations as available to finance the Contract, the Contract will be awarded on the base bid only. If such bid exceeds said amount, NEWSME Operations may reject all bids or may award the Contract, reducing the amount of unit price work to keep the overall Contract amount within the available funds. NEWSME Operations shall award to the bidder it judges to be best qualified.

J. Bonds (NITC)

The General Contractor is not required to provide a Performance and Payment Bond for this project.

K. Attachment to the Bid Form

The bidder will attach to his bid form the following:

1. The name of the on-site supervisor(s) whom he proposes to supervise the work, together with a brief resume of past experience.

2. A list of similar projects the bidder has completed, including the name, address, and telephone number of person familiar with the bidder's performance.

3. A list of the equipment which he proposes to use and standard rate sheets.

4. A proposed construction schedule and manpower projection, as explained in Instructions to Bidders, Section E – Time of Completion.

5. Who the bidder proposes to use as specialty subcontractors.

6. Applicable sales and use taxes shall be included in the lump sum bid price, and the amount so included stated separately.

7. Separate quantity take-off for each bid line item.

L. Alternate Bids

The bidder is requested to quote this work in strict conformity with this document. However, if for any reason (such as bidder's method of cost accounting, a special small tool or equipment rental system, etc.) the bidder wishes to submit an alternate bid, it may be considered.

END OF SECTION

SECTION III

BID FORMS AND BID FORM ATTACHMENTS

SECTION III
BID FORM

BID FOR: CELL 11 EXPANSION CONSTRUCTION AT JUNIPER RIDGE LANDFILL FACILITY, OLD TOWN, MAINE

To: Wayne Boyd, General Manager

NEWSME Operations, LLC

358 Emerson Mill Road

Hampden, Maine 04444

Date ________________________

Proposal of ____ (hereinafter called "Bidder") a corporation, organized and existing under the laws of the State of _______________ __________, a partnership or an individual* doing business as ____, to the New England Waste Services of Maine, LLC (hereinafter called "NEWSME").

Gentlemen:

Having carefully examined the Instructions to Bidders, the Form of Agreement, the General and Supplementary Conditions, the Bid Documents and Specifications entitled Juniper Ridge Landfill Cell 11 Expansion Construction, Old Town, Maine and the contract drawings (Issued for ________), and the Quality Assurance/Quality Control Plan (__________), as well as the site upon which the work is to be performed, and all conditions affecting the prosecution of the work, including the availability of materials and labor:

THE UNDERSIGNED proposes and agrees to furnish all materials, labor, equipment, and supervision and perform all operations required to complete the entire scope of work in accordance with the Contract Specifications and Drawings, and all applicable local State and Federal Regulations, within the time set forth therein, for the following prices listed below.

The estimated quantities of materials provided by the Engineer for each bid item are approximate quantities of in-place materials based upon the Engineer's interpretation of the Contract Drawings. This information is provided for informational purposes only and shall not be considered to represent the actual amount of material required to complete the Scope of Work (i.e., quantities of waste, shrinkage, compaction, overlap, anchor trench, and incidental materials are not included). The cost for each bid item shall be based upon the Bidder's own interpretation of the existing site conditions, Contract Drawings, and technical specifications, and shall include all materials and incidental items required to complete the Scope of Work.

Errors or omissions of the Engineer's estimated material quantity listed in the Bid Form shall not entitle the Bidder to any adjustment in the Lump Sum Contract price. The Bidder shall list his own material quantities used to prepare his bid and notify the Owner/Engineer in writing of any significant discrepancies of in-place material quantities prior to submitting his bid.

Bidder hereby agrees to commence work under this Contract on or before the dates specified in his proposed schedule, provided that NEWSME has issued a Notice to Proceed and complete work on or before the completion date specified in the Contract Documents.

The pricing contained in this proposal is good until ______________.

1. BID ITEMS

A. BIDDER agrees to perform all the work, including all incidental labor, materials and equipment necessary for the satisfactory completion of the work and in full compliance with the contents and intent of the specifications and/or plans of the work, for the following prices listed below.

B. The Contract will be awarded based on the lump sum price for the total project. The lump sum price will become the contract price. To track costs associated with the project completion the contractor is required to provide cost information for the individual bid items, which make up the lump sum price. For each item the contractor shall provide information on the unit price, and the contractor's estimated quantities. The price for each item shall be the product of the contractor estimated quantities and unit prices. The Engineer' estimated quantities are provided for informational purposes only.

C. The Contract Price will be adjusted for changes to Contract Scope of Work or additional work elected by the Owner, on the basis of the unit prices provided in the Section C of BID SCHEDULE, as defined in SECTION 01025 – MEASUREMENT AND PAYMENT.

D. Interlineation, alteration or erasure may void the bid. All prices shall be typewritten or written by hand in ink.

SECTION A

General Contractor's Bid Values

Item	Description	Engineer's Est Quantity	Units	Contractor's Est Quantity	Unit Price (1)	Price
1	Mobilization/Demobilization		ls			
2	Clear and Grub (Cell 11 Area)		ac			
3	Clear and Grub (Outside Cell Area)		ac			
4	Stormwater Control Features		ls			
5	Cell 11 Berm Cut to Fill Place and Compact		cy			
6	Common Borrow Excavation Cell 11 Area (haul to stockpile)		cy			

Item	Description	Engineer's Est Quantity	Units	Contractor's Est Quantity	Unit Price (1)	Price
7	Detention Pond 9 Expansion		ls			
8	Supply and Install 6"x10" Dual Containment Force Main and Appurtenances		lf			
9	Supply and Install 24" Landfill Gas Header Pipe		lf			
10	Cell 11 Temporary Paved Access Road Construction		lf			
11	Cell 11 Gravel Access Road Construction		ls			
12	Cell 11 Permanent Paved Access Road Construction		lf			
13	Supply and install 1-foot of Imported Soil Layer		cy			
14	Supply and Install Compacted Clay for Augmented Secondary Liner		cy			
15	Supply and Install Geosynthetic Clay Liner for Augmented Secondary Liner		sf			
16	Supply and Install 60-mil HDPE Textured Geomembrane		sf			
17	Supply and Install Leak Detection Drainage Geocomposite		sf			
18	Supply and install 1-foot of Drainage Sand for Leak Detection System		cy			
19	Supply and Install Leak Detection Piping (pipe, stone, fabric)		-			
19A	6-inch SDR 11 HDPE Pipe		lf			
19B	12-inch SDR 11 HDPE Pipe		lf			
20	Supply and Install Compacted Clay for Primary Liner		cy			
21	Supply and Install Geosynthetic Clay for Primary Liner		sf			
22	Supply and Install 80-mil HDPE Textured Geomembrane		sf			
23	Supply and Install Temporary Geomembrane Berm		sf			
24	Supply and Install Leachate Collection Drainage Geocomposite		sf			
25	Supply and Install Leachate Collection Drainage Sand (inclusive of Item #23 sand necessary to construct temporary geomembrane berm)		cy			
26	Supply and Install Leachate Collection and Transport Piping (including pipe, stone, fabric, fittings, etc.)		-			
26A	6-inch SDR 11 HDPE Pipe		lf			
26B	8-inch SDR 11 HDPE Pipe		lf			
26B	24-inch SDR 11 HDPE Pipe		lf			
27	Supply and Install Leachate Collection system Drainage Stone (On Berm Sideslopes only Exclusive of that used in above items 1 through 26)		cy			
28	Cell 11 Sump Construction (exclusive of line items 1 - 27 above)		ls			
29	Cell 11 Pump Station Installation, including pump station enclosure, leak detection appurtenances, plumbing and mechanical (exclusive of line Item 37 below)		ls			
29	Erosion Control (including siltation fencing, stone check dam, geotextile, seed and mulch)		ls			
30	Dewatering and Stormwater Control		ls			
31	Litter Fence(New and/or Re-located)		lf			
32	Chainlink Fence(New and/or Re-located)		lf			
33	Dust Control		ls			
34	Well/Piezometer Abandonment		ls			
35	Construction/Record Survey		ls			
36	Leak Location Survey on Primary 80 mil HDPE Geomembrane		ls			
37	M.C. Electric (Electrical and Communication Utilities)		ls			
					Sub-Total =	
38	Sales and Use Tax		ls			
					Sub-Total =	
					Total Bid (Basis of Bid) =	

TOTAL AMOUNT OF BID : (ITEMS 1 THROUGH 38) – BASIS OF AWARD
Contract is Lump Sum with progress payments based on work completed per OWNERs survey.

Total Amount of Bid in Words____

Note (1) Unit Price based upon Contractor's Estimated Quantity

SECTION B

Geosynthetic Contractor's Bid Values

This proposal must include a breakdown of Geosynthetic Unit prices per the categories below. Attach copies of subcontractor proposals with the indicated units detailed out. OWNER may request substitutions of Geosynthetic subcontractors.

Item	Description	Engineers Est Quantity	Units	Contractor Est Quantity	Unit Price (1)	Price
1	60-mil Textured HDPE Geomembrane Supply (price from supplier)	__	sf			
2	60-mil Textured HDPE Geomembrane Install (in-place)	__	sf			
1	80-mil Textured HDPE Geomembrane Supply (price from supplier)	__	sf			
2	80-mil Textured HDPE Geomembrane Install (in-place)	__	sf			
3	Drainage Geocomposite Supply (price from supplier)	__	sf			
4	Drainage Geocomposite Install (in-place)	__	sf			
5	Geosynthetic Clay Liner (price from supplier)	__	sf			
6	Geosynthetic Clay Liner Install (in-place)	__	sf			
7	Sales and Use Tax	__	ls			
					Total Bid =	

Note (1) Unit Price based upon Contractor's / Sub-Contractor's Estimated Quantity

SECTION C

Extra Work Unit Prices

Changes in the Contract work shall be performed at the unit prices, described below. The unit prices are gross prices, including the Contractor's equipment, labor, supervision, and materials costs, entire mark-up, field or other costs, including general conditions, fringe benefits, overhead and profit.

Item Description	Units	Unit Price
Clearing and Grubbing	Acre	
Clearing	Acre	
Regrading Waste	C.Y.	
Common Excavation	C.Y.	
Excavation of Unsuitable Material	C.Y.	
Open Rock Excavation	C.Y.	
Trench Rock Excavation	C.Y.	
Aggregate Subbase Material	C.Y.	
Aggregate Base Material	C.Y.	
Clay Borrow Material	C.Y.	
Screened Till Material (on-site 3” minus)	C.Y.	
Common Borrow Material	C.Y.	
Siltation Fence	L.F.	
Bark Mulch Sediment Barrier	L.F.	
Riprap	C.Y.	
Stone Check Dam	EA	
Erosion Control Blanket (NAG S075)	S.Y.	

Item Description	Units	Unit Price
Erosion Control Blanket (NAG P300)	S.Y.	
Seed, Fert., Lime, Mulch	Unit	
Hay Bales	EA	
Topsoil (on-site source)	C.Y.	
Topsoil (off-site source)	C.Y.	
Pipe Bedding Stone	C.Y.	
Drainage Stone	C.Y.	
Filter Stone	C.Y.	
Underdrain Sand	L.F.	
Leachate Collection Sand	L.F.	
6" HDPE Pipe SDR 11.0	L.F.	
8" HDPE Pipe SDR 11.0	L.F.	
12" HDPE Pipe SDR 17.0	L.F.	
24" HDPE Pipe SDR 17.0	L.F.	
6"x10" Dual Containment HDPE Pipe SDR 17.0	L.F.	
18" Culvert	L.F.	
24" Culvert	L.F.	
Geocomposite Drainage Net (Geonet)	S.F.	
60-mil HDPE Liner	S.F.	
80-mil HDPE Liner	S.F.	
Geosynthetic Clay Liner (GCL)	S.F.	
Non-Woven Geotextile (Leak Detection Pipe)	S.F.	
Woven Geotextile (Separation Fabric)	S.F.	
Chain Link Fence	L.F.	
Litter Fence	L.F.	

1. Provide your expected start date with a Notice to Proceed of (TO BE DETERMINED)

Start Date: ________________________

2. THE UNDERSIGNED proposes the following deviations from, and additions, supplements and exceptions to the Specifications, with applicable pricing, on which the Proposal is based, there are no others, and affirms that any provisions in this Proposal inconsistent with the provisions in the Specifications which are not here expressly described or referred to will be construed as though such inconsistent provisions had not been included in this Proposal.

3. THE UNDERSIGNED agrees that any changes in the scope of the work extra to the contract requirements for which method of payments has not been otherwise established in this bid will be negotiated on a fixed lump sum basis, unit price basis or cost-plus-percentage basis, as selected by the Owner. When the fixed sum basis or unit price basis is selected for extra work, a breakdown of the sum will be provided as required by the Owner. When the cost-plus-percentage basis is selected for extra or for work performed under allowances, compensation will be paid as follows:

(a) An amount equal to the total sum of all Reimbursable Costs, as defined in the General Conditions of the Contract. A breakdown of the Reimbursable costs will be provided as required by the owner.

(b) Plus an amount equal to ____% of Reimbursable Costs, which amount shall be full compensation for all Overhead as defined in the General Conditions of the Contract.

(c) Plus an amount equal to _____% of the sum of Reimbursable Costs and Overhead, which amount shall be defined as "Fee". A breakdown of the fee will be provided as required by the owner.

(d) Extra Work by subcontractors shall not be included in Reimbursable Costs, but shall be handled separately, as stipulated in Paragraph 5. of this bid.

4. THE UNDERSIGNED agrees that only the following portions on the work will be subcontracted, and that the names of subcontractors will be submitted prior to award of contract, in accordance with the General Conditions of the Contract.

____

____

____

____

____

____

____

5. THE UNDERSIGNED agrees that extra work performed by his subcontractors shall be invoiced in the same manner described for the Contractor's extra work, and that he will compensate the subcontractors accordingly and accept as full payment the invoiced cost plus a charge of ______% for his own services in handling the extra work performed by the subcontractors. All subcontract prices and fees shall be subject to the Owner's prior approval.

6. THE UNDERSIGNED agrees to perform work of the Contract during over time periods for purposes beyond the intent of the Contract, if requested and authorized to do so by the Engineer, and be reimbursed for the additional cost to him as described in the General Conditions of the Contract.

7. THE UNDERSIGNED agrees to execute a formal contract for the entire work on the Agreement form provided for that purpose, within ten days after receiving notification of the award of the contract to him.

8. THE UNDERSIGNED agrees to substantially complete the entire work of the contract in accordance with the Construction Schedule and/or completion dates included in the Specifications.

9. THE UNDERSIGNED agrees that all applicable Federal, state and local sales and use taxes and cost of required insurance are included in the proposal as a separate bid item.

10. THE UNDERSIGNED agrees in submitting this bid that the right is reserved by the Owner to reject any or all bids. It is agreed that this bid may not be withdrawn for a period of sixty (60) days from the opening date thereof.

11. THE UNDERSIGNED acknowledges the receipt of Addendums:

No.	Date	Signature

12. THE UNDERSIGNED hereby declares as Bidder, that the only persons or parties interested in this Bid as Principals are those named herein; that this Bid is made without any connections with any other person or parties making a Bid for the same purpose; that this Bid is in all respects fair and without collusion or fraud.

13. THE UNDERSIGNED agrees that if the Contract is awarded to him this Bid will be attached as Exhibit A and made a part of the Agreement executed by him.

____
(Legal Name of Contracting Firm)

Signed By______________________________

Named Typed______________________________

Title ______________________________

Date______________________________

Telephone Number:______________________________

END OF SECTION

SECTION IV

TECHNICAL SPECIFICATIONS

SECTION IV

TECHNICAL SPECIFICATIONS

The following Technical Specifications of Cell 11 Construction are incorporated by this reference into this Section of the Contract Documents as fully as if reproduced in their entirety herein.

No.	Title
TECHNICAL SPECIFICATIONS	
DIVISION 1	GENERAL REQUIREMENTS
Section 01010	Summary of Work
Section 01012	Health and Safety Plan
Section 01025	Measurement and Payment
Section 01041	Project Coordination
Section 01060	Applicable Codes
Section 01211	Pre-Construction Conference
Section 01300	Submittals
Section 01350	Engineers Field Office
Section 01505	Mobilization
Section 01520	Monitoring Well and Piezometer Abandonment
Section 01561	Cleaning
Section 01562	Dust Control
Section 01570	Traffic Control
Section 01600	Material and Equipment
Section 01700	Contract Closeout
DIVISION 2	SITE WORK
Section 02015	Subsurface Information
Section 02100	Site Preparation
Section 02200	Earthwork
Section 02220	Erosion Control
Section 02272	Geotextiles and Drainage Geocomposite
Section 02275	Geosynthetic Clay Liner
Section 02450	Pipe Installation
Section 02451	Culverts
Section 02510	Bituminous Concrete Paving
Section 02570	Manholes, Catch basins and Drainage Structures
Section 02571	HDPE Manhole Structure
Section 02732	Leachate Collection Pump Station
Section 02771	Geomembrane Liner, High Density Polyethylene (HDPE)
Section 02772	Leak Location Survey
Section 02780	Interfacial Friction Angle Conformance Testing
Section 02800	Seeding and Mulching
DIVISION 3	CONCRETE
Section 03300	Cast-In-Place Concrete
DIVISION 15	MECHANICAL
Section 15100	HDPE Pipe and Fittings
Section 15110	Valves and Pipe Accessories
Section 15120	Hydrostatic and Low-Pressure Air Testing of Pressure Pipe

SECTION V

CONTRACT DRAWINGS
(REFER TO VOLUME III, APPENDIX E)

SECTION VI

CQA PLAN
(REFER TO VOLUME III, APPENDIX B)

SECTION VII

CONSTRUCTION AGREEMENT AND FORMS

CONSTRUCTION AGREEMENT BY AND BETWEEN

____

AND

NEWSME Landfill Operations, LLC
a subsidiary of Casella Waste Systems, Inc.

CELL 11 EXPANSION CONSTRUCTION
Juniper Ridge Landfill
Old Town, Maine
July 2015
DRAFT

{00000231.1}

CONSTRUCTION AGREEMENT

THIS AGREEMENT is entered into as of this ___ of ____, 20__, by and between _________, with an office in _______, _______ (hereinafter referred to as "Contractor"), and NEWSME Operations Landfill LLC, a subsidiary of Casella Waste Systems, Inc., with an office in Hampden, Maine (hereinafter referred to as "Owner").

RECITALS

WHEREAS, Owner desires to engage Contractor to provide various services and materials in connection with the Work (as defined herein) pursuant to the terms and conditions of this Agreement for construction of Cell 11 Expansion at the Juniper Ridge Landfill, (hereinafter referred to as the "Site"); and

WHEREAS, Contractor desires to render those services and provide such materials as described herein and has the experience, staff and resources to properly perform the Work.

NOW, THEREFORE, as consideration for the covenants, promises and representations contained herein, other good and valuable consideration and intending to be legally bound hereby, Owner and Contractor agree as follows:

1. General Terms and Conditions

I. The Work, Consideration, Definitions, the Agreement Price and Agreement Time

Contractor agrees to provide all necessary and required labor, materials, services and equipment to perform the Work in accordance with the terms of this Agreement and Owner shall pay to Contractor the firm fixed price sum Agreement Price (as defined herein) of $_______.— as adequate and complete consideration for proper performance of such Work.

A. The Work: Contractor shall undertake construction of Cell 11 Expansion at the Juniper Ridge Landfill and associated work at the Site including providing all necessary and required labor, materials, tools, equipment, incidentals, excavation, dewatering, shoring, sheeting, bracing, traffic control, safety devices and services necessary and all related work pursuant to the Contract Documents including the Technical Specifications and the Contract Drawings (herein referred to as the "Work").

B. Terms Defined: The following terms, as they may occur in the Contract Documents, shall mutually be understood by Owner and Contractor to have the following meanings:

__________ of Casella Waste Systems, Inc. is the Owner's **"Authorized Representative"** who has the authority to execute a Change Order on behalf of Owner.

"Bid and Contract Documents" or "Bid Package" shall mean bid documents entitled: ___________________________________which were prepared by Owner and were previously sent to, received, reviewed and accepted by Contractor. The Bid and Contract Documents consist of the following:

Section Number	Title
I	Invitation to Bid
II	Instructions to Bidder
III	Bid Forms and Bid Form Attachments
IV	Technical Specifications
V	Contract Drawings
VI	CQA Plan
VII	Construction Agreement and Forms

"Bid Forms" shall mean Section III of the Bid and Contract Documents and attachments thereto.

"Bid Package" shall mean the Bid and Contract Documents as defined herein.

"Change Order" shall mean Owner's written form issued after execution of this Agreement by an Authorized Representative of Owner to Contractor authorizing an addition, deletion, or revision to the Work as contained in the Contract Documents, and/or an adjustment in the Agreement Price or Agreement Time. The form of Change Order to be used is attached hereto in Section VII of the Contract Documents.

"Construction Quality Assurance (CQA) Consultant" shall mean representatives of **______________** who shall observe and document construction quality assurance activities and issue the project certification report (if applicable).

"Contract Documents" shall mean this Agreement and the documents attached thereto as referenced below:

Section Number	Title
I	Invitation to Bid
II	Instructions to Bidder
III	Bid Forms and Bid Form Attachment (Except for Bid Form "A")
IV	Technical Specifications
V	Contract Drawings
VI	CQA Plan
VII	Construction Agreement and Forms

"Contract Drawings" shall mean that portion of the Contract Documents which contains graphic illustrations with written representations thereon reflecting the character and scope of the Work (including plan sheets, details and sections). The set of Contract Drawings for the Work are entitled, "**Cell 11 Co**" which were prepared by Engineer. No Work shall be performed and no materials shall be ordered, fabricated or installed unless and until Owner issues a Notice to Proceed to Contractor. References in the Contract Documents to "Construction Drawings" shall mean Contract Drawings.

"Contractor" shall mean **_____________**, the party entering into this Agreement with Owner who shall perform the Work.

"Date of Completion" shall be the date of Substantial Completion of the Work as defined in this Agreement.

"Day" unless otherwise expressly defined in this Agreement, shall mean a calendar day beginning at midnight and continuing for twenty-four (24) hours until midnight of the following day. All days shall be considered consecutive unless otherwise indicated.

"Engineer" shall mean Sevee & Maher Engineers, Inc., the design engineer for the Work.

"Extra Work" shall mean an item of the Work not provided for in this Agreement as awarded but authorized by a Field or Change Order.

"Field Order" shall mean a written order issued by Owner which orders minor changes in the Work but which does not involve a change in the Agreement Price or the Agreement Time. The form of Field Order to be used in accordance with this Agreement is attached hereto in Section VII of the Contract Documents.

"Final Acceptance" shall be accomplished when the Work has passed Final Inspection, Substantial Completion (as defined herein) has occurred and Contractor receives a written Notice of Final Acceptance from Owner.

"Final Inspection" shall mean the last inspection of the Work by Owner.

"Final Payment" shall mean payment of the Agreement Price to Contractor by Owner for proper performance of the Work less amounts previously paid by Owner to Contractor less amounts not due to Contractor because of a change in the Scope of the Work less amounts withheld or applied by Owner pursuant to the terms and conditions of this Agreement or applicable law. Final Payment shall not be made to Contractor until and unless a Notice of Final Acceptance of the Work is sent by Owner and is received by Contractor.

"Notice to Proceed" shall mean a written notice sent by Owner to the Contractor indicating the date on which it is to commence performance of the Work.

"Owner" shall mean NEWSME Landfill Operations, LLC, a subsidiary of Casella Waste Systems, Inc., the party for whom the Work is to be performed.

"Payment Forms" shall mean application for payment forms (i.e. invoices), copies of which are attached hereto in Section VII of the Contract Documents, which must be completed by Contractor and submitted to Owner before payment may be made to Contractor hereunder.

"Site" shall be the location where the Work will be performed which is the Juniper Ridge Landfill as indicated previously in the Recitals to the Agreement and shall include all surface and subsurface conditions.

"Subcontractor" shall mean all materialmen, suppliers, vendors, agents and their respective employees and any other individual or entity, at any tier, providing labor, goods, or services to or on behalf of Contractor regarding performance of the Work.

"Substantial Completion" shall be the date, as determined by Owner, when the Work is sufficiently completed in accordance with the Contract Documents so that the Work can be utilized for the purpose for which it was intended by Owner.

"Superintendent" shall mean Contractor's employee who shall be in attendance at the Site; and who shall be a competent, full-time representative of Contractor; and who shall be the manager of Contractor's Work; and who shall meet all qualifications set forth in the CQA Plan (if included herein) and who shall have the authority to make decisions regarding the Work and sign Change Orders on behalf of Contractor.

"Facilities" shall mean all above ground and below ground pipelines, conduits, ducts, cables, wire, manholes, vaults, utilities, tanks, tunnels, attachments and any encasements containing such items which have been installed to furnish any services, facilities, utilities or materials including, but not limited to, the following: electricity; gases; water; steam; liquid petroleum products; telephone or other communications; cable television; sewage and drainage removal; traffic or other control systems.

C. Agreement Time: Work shall commence within ten (10) days after the date referenced in a Notice to Proceed for commencement of the Work, and Substantial Completion shall occur when _____________has been approved by the Engineer and the Maine Department of Environmental Protection (MDEP). (herein referred to as the "Agreement Time").

D. Agreement Price: Owner shall pay compensation to Contractor which shall be the (fixed unit price) (a price guaranteed not to exceed the ceiling price) of ____ and

__/100 dollars (_________.__) (herein referred to as the "Agreement Price").

2. Form and Intent of Contract Documents

For purposes of the Contract Documents, it shall be presumed that all materials, labor, equipment and services necessary and/or required to perform the Work or to fulfill the intent of the Contract Documents shall be performed, furnished and installed by Contractor regardless of whether they are expressly indicated in the Contract Documents. All Work shall be performed by Contractor unless expressly reflected in the Contract Documents as being performed by Owner or others.

3. Time Is of the Essence

In the performance and completion of the Work by Contractor, time shall be of the essence of this Agreement.

4. Payment

A. At the end of each month, Contractor shall submit itemized Payment Forms to Owner at the Site based upon the percentage of Work properly completed in accordance with the task breakdown on the Schedule and supported by receipts or vouchers showing payments for materials and labor, payments to Subcontractors and such other documentation as Owner may require in order to document Contractor's right to payment.

i. The percentage of Work properly completed in accordance with the Contract Documents shall be calculated on the basis of materials placed or installed (i.e. "in-place" Work).

ii. Measurement shall be the responsibility of Contractor subject to verification by Owner. Mutual agreement between Owner and Contractor on all measurements is required for each progress payment and Final Payment requested before such payment can be made.

iii. Contractor may request compensation for materials stored at the Site if the following conditions are satisfied:

a. Materials are physically located within the Site boundary;

b. Invoices from suppliers are presented as backup to a request for progress payment; and

c. Materials stored at the Site are designated as relating to a specific item required by the Contract Documents.

B. For fixed unit price or time and materials Work to be performed pursuant to a Change Order hereto, Contractor shall include a brief description of the Extra Work performed together with a summary of actual units employed and/or hours worked by Contractor's employees, engaged directly in the Extra Work, by classification and the rate (and multiplier if applicable), allocated per task(s) as identified in the Schedule. Direct non-salary expenses, such as subcontracts and other direct costs and expenses, shall be itemized separately and allocated per task(s) as identified in the Schedule. In addition to the foregoing, Contractor shall submit to Owner copies of time sheets, expense reports, receipts, and other documentation necessary to substantiate each submission of Payment Forms to Owner's satisfaction.

C. Contractor shall submit its application for payment on Payment Forms supplied by Owner. Copies of these forms are provided in Section VII of the Contract Documents.

D. Within thirty (30) days following receipt and approval by Owner of Contractor's Payment Forms, Owner shall pay Contractor ninety percent (90%) of the Agreement Price for a proportionate amount of the Work which, to the best knowledge, information, and belief of Owner, has been completed in accordance with the Contract Documents, less the aggregate of all previous payments made for such Work.

E. Upon receipt of any payment from Owner hereunder, Contractor shall pay out of such monies received any amounts which are due to Subcontractors on account of such Subcontractor's work. Contractor shall require each Subcontractor to include in its invoice to Contractor the percentage actually retained by Contractor, if any. Contractor shall, by appropriate agreement with each Subcontractor, require each Subcontractor to make payments to its Subcontractors in a similar manner. Before any payment can be made to Contractor hereunder, Contractor shall provide a waiver and release fully executed by Contractor on a Waiver and Release Form and one executed by each Subcontractor on Waiver and Release Forms for Subcontractors which are included in Section VII of the Contract Documents. In addition to, and not in limitation of, any terms or conditions of this Agreement, Contractor agrees that Owner may, in consultation with Contractor, and without obligation to do so, pay any Subcontractor (including, but not limited to, paying an amount which is made in settlement of any dispute involving Contractor and/or any Subcontractor) directly and deduct such amount from any amounts which are due to Contractor thereby reducing the total amount owed (the total Agreement Price) to Contractor for performance of the Work. In addition, Contractor agrees to hold Owner harmless from all claims, lawsuits, costs, damages, expenses and liability for Owner's actions undertaken in accordance with the terms and conditions of this Paragraph.

F. The full amount of the Agreement Price less amounts previously paid by Owner to Contractor less amounts not due to Contractor because of a change in the Scope of the Work less amounts withheld or applied by Owner pursuant to the terms and conditions of this Agreement or applicable law will be paid to Contractor by Owner within thirty (30) days following Final Acceptance of the Work, however, as a condition precedent to Owner making Final Payment, Contractor shall file with Owner all Waiver and Release Forms (Progress payment as well as Final Payment forms) for itself and its Subcontractors on forms provided by Owner in Section VII of the Contract Documents. Regardless of execution of any of the forms herein, Final Payment by Owner shall automatically constitute a waiver of all claims, liens and actions of any kind by Contractor against Owner arising out of this Agreement.

G. No payment shall be made for costs or expenses incurred by Contractor prior to issuance of a Notice to Proceed for the Work or after termination of this Agreement except as expressly provided herein.

H. If any items in any Payment Forms submitted by Contractor are disputed by Owner for any reason, including the lack of supporting documentation, Owner may temporarily delete the disputed item and pay the remaining amount of the Payment Forms. Owner shall promptly notify Contractor of the dispute and request clarification or remedial action. If any dispute is settled in Contractor's favor, Contractor shall include the settled amount on a subsequent regularly scheduled submission of Payment Forms or in a special submission of Payment Forms for the disputed item only.

I. 50% of the mobilization line item of _____________ dollars ($___________) of the Agreement Price, in this instance, $____________, shall be paid to Contractor upon successful mobilization to the Site by Contractor.

5. Payments Withheld

A. Payments otherwise due to Contractor including, but not limited to, any and all retainage, may be applied by Owner against any amounts due or claimed to be due Owner from Contractor, its subsidiaries or affiliates or may be withheld by Owner on account of any of the following: work suspected by Owner to be defective and not remedied; claims filed, or reasonable evidence indicating probable filing of claims; breach of any term or condition of the Contract Documents by Contractor and/or its Subcontractors; failure of Contractor to make payments promptly to its Subcontractors (and for Subcontractors to make payment to their Subcontractors) for material, labor or other goods or services; refusal of Contractor to accept or make payment for any part of the Work; Contractor's failure to deliver Waiver and Release Forms for itself or its Subcontractors; or a reasonable doubt that the Work can be completed for the balance of the Agreement Price then unpaid and/or within the Agreement Time. If the foregoing causes are removed, then withheld payments shall promptly be made. If the said causes are not removed within a reasonable time, Owner may rectify the same at Contractor's sole cost and expense (at no cost to Owner), and/or Owner may terminate this Agreement for cause pursuant to the terms and conditions provided herein.

6. Construction Personnel and Activities

I. Supervision and Construction Procedures

A. Contractor shall supervise, manage, control and direct the Work, using the Contractor's best skill and attention.

B. Contractor shall be responsible to Owner for all acts and omissions of the Contractor's employees, Subcontractors and all other persons performing any of the Work for Contractor.

C. Contractor shall be responsible for inspection of portions of Work already performed under this Agreement to determine that such portions of the Work are in proper condition to receive subsequent Work at no cost to Owner.

D. Construction meetings shall be held at the Site weekly or at such other frequencies as agreed to by Owner and Contractor as arranged by Owner's Project Manager. The Superintendent and all of Contractor's personnel working at the Site (as appropriate) shall attend such meetings.

7. Independent Contractor

A. The Work shall be performed and furnished by Contractor as an independent contractor and under the sole supervision, management, direction and control of Contractor in accordance with the terms and conditions of this Agreement. Contractor shall not be an agent, employee or representative of Owner for any purpose. Contractor shall have full control over its Subcontractors and employees as it may see fit to assist in performance of the Work, including, but not limited to, the hiring, firing, and supervision of any such employees of Contractor except for Owner's right of removal of employees or Subcontractors of Contractor expressly provided in this Agreement and/or permitted by applicable law.

B. Contractor further agrees that the MANNER, MEANS, METHODS, MANAGEMENT, PROCEDURES, SEQUENCES AND TECHNIQUES OF CONSTRUCTION SHALL BE UNDER THE SOLE CONTROL AND IS THE SOLE RESPONSIBILITY OF CONTRACTOR.

8. Contractor’s Superintendent

A. Contractor shall keep its Superintendent in attendance at the Site until Final Acceptance of the Work.

B. The Superintendent shall thoroughly understand the Contract Documents and shall insure that all of Contractor's employees and/or Subcontractors understand the tasks to be performed pursuant to such documents. The Superintendent shall communicate all necessary and/or required information to Contractor's employees and Subcontractors.

C. The Superintendent shall keep a daily diary of the Work performed and shall transmit copies of such diary to Owner on a weekly or more frequent basis.

D. The Superintendent shall attend all pre-construction and construction meetings and have the authority to make decisions on behalf of Contractor regarding performance of the Work.

9. Subcontractors and Employees

A. Nothing contained in this Agreement shall create any contractual relationship between Owner and any Subcontractor of Contractor. Notwithstanding the foregoing, any Subcontractor that executes a Waiver and Release Form as provided in Section VII of the Contract Documents shall be bound by the terms and conditions contained therein to Owner and others as indicated such Waiver and Release.

B. Contractor shall temporarily defer, at no cost to Owner, the prosecution of any portion of the Work that may be necessary in the opinion of Owner for the proper advancement of the work of other contractors when such deferment can be accomplished without unreasonable interference with Contractor's Work.

C. Owner must approve of any Subcontractor selected by Contractor in writing prior to performance of any Work by such Subcontractor, although such approval does not create any contractual relationship between such Subcontractor and Owner nor does such approval relieve Contractor of any of its responsibilities or liability hereunder. Owner may require Contractor to change any Subcontractor regardless of Owner's previous approval of such Subcontractor.

D. Any part of the Work performed for Contractor by a Subcontractor shall be undertaken pursuant to a written subcontract between the Contractor and such Subcontractor, which shall be prepared on a form of subcontract satisfactory to Owner in all respects. Each such subcontract shall contain at a minimum provisions that:

i. Require that such work be performed in accordance with the terms and conditions of the Contract Documents and all laws and regulations and require that the Subcontractor be bound by the terms and conditions of these Contract Documents and to assume toward Contractor all the obligations and responsibilities which Contractor, by such Contract Documents, assumes toward Owner;

ii. Waive all rights the contracting parties may have against one another or that the Subcontractor may have against Owner for damages caused by fire or other perils covered by the insurance required in the Contract Documents;

iii. Require the Subcontractor to carry and maintain insurance coverage in accordance with the Contract Documents, and to file certificates of insurance for such coverage with Contractor;

iv. Require the Subcontractor to submit all Waiver and Release Forms for itself and its Subcontractors on forms provided in Section VII of the Contract Documents for Work completed by it and by its Subcontractors as a condition precedent to the disbursement of any progress payment next due and owing;

v. Require submission to Contractor or Subcontractor, as the case may be, of applications for payment on the Payment Forms provided in Section VII of the Contract Documents together with clearly-defined invoices and billings supporting all such applications under each subcontract to which Contractor or its Subcontractor is a party;

vi. Report, so far as practicable, unit prices, lump sums, actual costs and any other feasible method for use in the determination of costs for changes in the Work in accordance with the Contract Documents;

vii. Require each Subcontractor to furnish to Contractor in a timely fashion, all information necessary for the preparation and submission of all reports, shop drawings and other submittals required herein;

viii. Require that each Subcontractor continue to perform under its subcontract in the event this Agreement is terminated and that Owner, in Owner's sole discretion, may take an assignment of said subcontract and request such Subcontractor to continue such performance;

ix. Require each Subcontractor to remove all debris created by its activities; and

x. If required by law, require each Subcontractor to submit evidence that it has a valid contractor's license that it is an equal opportunity employer and that it is in compliance with all related laws, statutes, regulations, rules, standards, orders and ordinances.

10. Operation and Maintenance Data

A. In addition to, but not in limitation of, the terms and conditions of the Contract Documents, Contractor shall deliver as applicable a minimum of three (3) complete bound instruction manuals to Owner for the materials and/or equipment incorporated into the Work. The purpose of such manuals shall be for the instruction of Owner's operating and maintenance personnel and to provide a positive source of information regarding the products, materials and/or equipment.

B. The bound instruction manuals shall include:

i. Complete instructions regarding operation and maintenance of all equipment involved including lubrication, disassembly, and reassembly;

ii. Complete nomenclature of all parts of all equipment;

iii. Complete nomenclature and part number of all replaceable parts, name and address of nearest vendor, and all other pertinent data regarding procurement procedure;

iv. Copies of all guarantees and warranties; and

v. Manufacturers' bulletins, catalog cuts and descriptive data where pertinent clearly indicating the precise items included in the Work.

11. Owner's Equipment

From time to time during the course of the Work, Owner may have its on-site earthmoving equipment available for use in aiding Contractor to perform earthwork activities. Contractor may employ the equipment when Owner indicates its availability and desire to rent it to Contractor. Contractor and Owner shall agree on payment to Owner and other terms and conditions which are mutually agreeable to both parties as a Change Order to this Agreement for Contractor's use of such equipment. Notwithstanding the foregoing, such equipment shall be priced on a load count or hourly basis as indicated in the Change Order. The Change Order must be executed by both parties hereto prior to using any of such equipment for any earthwork activity.

12. Labor

Contractor, for itself, its employees and Subcontractors, agrees that in performance of the Work provided for in the Contract Documents:

A. Contractor shall take affirmative action to ensure that applicants are employed and treated during employment without regard to their sex, race, creed, color, or national origin;

B. Contractor shall cooperate with Owner in the conduct of all labor relations affecting the Work;

C. At Owner's request, Contractor shall provide a method of identifying its employees and checking such employees into and out of the Site. Such method must be satisfactory to Owner prior to its use at the Site and shall be provided at Contractor's sole cost and expense (at no cost to Owner);

D. Contractor shall employ at the Site only those employees who work in harmony with the employees of Owner and/or other contractors and have the requisite skills and abilities to perform the Work in a safe, good and workmanlike manner. Owner may, at any time, refuse admittance to the Site or expel from the Site any employee of Contractor and/or its Subcontractor including, but not limited to, Contractor's Superintendent whose presence Owner, in Owner's sole discretion, considers undesirable; and

E. Contractor acknowledges that it is Contractor's responsibility to hire all personnel for the proper and diligent prosecution of the Work and Contractor shall use its best efforts to maintain labor peace for the duration of the Work.

13. Owner's Project Manager

Owner's Project Manager may monitor all or a portion of the Work on behalf of Owner but such monitoring shall in no manner relieve Contractor of any of its obligations, liabilities or responsibilities under the Contract Documents including, but not limited to, supervision, direction, management and coordination of the Work and shall not be used as grounds for additional payment to Contractor. Under no circumstances shall Owner, its Project Manager or other such representatives of Owner be considered to be engaged in any form of construction management activities relating to the Work.

14. Cooperation Between Trades and Progress of the Work

A. Full cooperation between all trades engaged upon the premises is mandatory. This Section of the Agreement shall be distinctly understood to bind Contractor and all of its Subcontractors to properly coordinate their Work with that of other contractors working at the Site, so that the Work may at all times proceed without interruption or delay and predetermined progress milestones contained within the Schedule are met.

B. Any loss, cost, delay, damage, or expense (including, but not limited to, all reasonable attorneys' fees, professional engineering fees and charges, sampling and testing fees, experts' fees and other consultants' fees and charges) caused by defective or improperly timed or coordinated Work shall be borne by the contractor responsible therefore, unless such loss, cost, delay, damage or expense is caused by Owner or Engineer. All remedies to repair or replace defective or damaged work shall be effected by the responsible contractor without interruption or delay to the Schedule.

C. If Contractor removes, alters, destroys, or defaces the property of Owner or the work of another contractor in the performance of the Work, Contractor shall promptly repair or replace the affected property or the Work to the satisfaction of Owner without interruption or delay to the Schedule at Contractor's sole cost and expense (including, but not limited to, all reasonable attorneys' fees, professional engineering fees and charges, sampling and testing fees, experts' fees and other consultants' fees and charges).

D. In the event of any dispute or controversy, Contractor for itself and its Subcontractors agrees that it will continue to prosecute the Work diligently to meet the Schedule within the Agreement Time pending resolution of any such dispute or controversy.

E. When Contractor repairs or replaces defective or damaged Work (in accordance with the terms or conditions of the Contract Documents, applicable law or otherwise) Contractor shall do so at Contractor's sole cost, expense, risk and account (at no cost to Owner). Contractor shall be solely responsible for all costs and expenses of investigation, construction, reconstruction and correction of the Work in accordance with the terms and conditions of the Contract Documents including, but not limited to, all reasonable attorneys' fees, professional engineering fees and charges, sampling and testing fees, experts' fees and other consultants' fees and charges.

15. Technical Components of the Work

A. Contract Drawings and Technical Specifications

i. Contractor shall perform the Work in strict compliance with the Contract Documents, including, but not limited to, the Contract Drawings and the Technical Specifications.

ii. Contractor shall have available on the Site, at all times, one copy of the Contract Drawings and Technical Specifications, including all Addenda thereto. Contractor shall also maintain at the Site, one copy of all approved Shop Drawings, Change Orders, Field Orders, submittals and the Schedule.

iii. Owner reserves the right to make minor changes to or modifications of the Contract Drawings prior to or during performance of the Work which shall be reflected thereon. The Work shall conform to such revised drawings and to such other drawings relative thereto as may be furnished by Owner in explanation of details or reflecting minor modifications during construction, including such minor modifications as Owner may consider necessary on account of conditions discovered during performance of the Work.

B. Survey

i. Owner shall provide the initial survey indicating horizontal and vertical controls and/or reference points and bench marks for the Site. Contractor shall, by its own engineer/surveyor (who shall be registered in the state where the Site is located) and instruments, make whatever measurements and alignments that are necessary to collect the survey information required in the Contract Documents to enable it to construct each element of the Work in the correct position required, corresponding to the horizontal and vertical controls and/or reference points and bench marks established by Owner's survey. If any errors are found, Contractor shall notify Owner in writing and, unless otherwise notified by Owner in writing, shall not proceed until such errors are corrected. If Contractor does proceed without such correction having been made, such action shall be construed as its acceptance of such lines, grades, and elevations, and Contractor shall be responsible for the correctness of the same. If by reason of Contractor acting without Owner's notification for Contractor to proceed in light of errors found, and it is necessary to reconstruct any part of the Work, Contractor shall uncover, remove and reconstruct such Work in accordance with the Contract Documents at Contractor's sole expense, risk and account (at no cost to Owner).

ii. Contractor shall furnish all survey stakes, all batter boards, templates, and other devices necessary for laying out all parts of the Work. All stakes destroyed by Contractor shall be replaced by Contractor.

iii. Contractor shall record all survey data including all lines and grades and shall record all test data required by the Contract Documents. All survey and test data shall be made available to Owner on a weekly basis or at times otherwise requested by Owner.

C. Shop Drawings and Samples

i. Contractor shall submit to Owner all Shop Drawings prepared or to be used by Contractor in performing the Work at least fourteen (14) days prior to commencement of the Work (unless Owner requests an expedited schedule) for Owner's review and approval. Contractor shall also submit to Owner for review and approval with such promptness as to cause no delay in the Work, all samples required by the Contract Documents or as otherwise requested by Owner.

ii. After checking and verifying all field measurements and after complying with applicable procedures specified in the Contract Documents, Contractor shall submit all Shop Drawings to Owner which shall bear a stamp or specific written indication that Contractor has satisfied Contractor's responsibilities under the Contract Documents with respect to the review of the submission. The data shown on the Shop Drawings and the background information for the sample shall be complete with respect to quantities, dimensions, specified performance and design criteria, installation protocol, catalog numbers, materials and similar data to enable Owner to review the information as required.

iii. All samples shall be checked by and accompanied by a specific written indication from Contractor that Contractor has satisfied all of Contractor's responsibilities under the Contract Documents with respect to the review of the submission. The submission shall clearly identify the material, supplier, pertinent data such as catalog numbers and the use for which the sample is intended.

iv. Before submission of each Shop Drawing or sample, Contractor shall have reviewed or coordinated each Shop Drawing or sample with other Shop Drawings and samples which pertain to the Work, with all facets of the Work itself and with the terms and conditions of the Contract Documents to insure compatibility therewith.

v. At the time of each submission, Contractor shall give Owner specific written notice of each variation that the Shop Drawings or samples may exhibit from the Work as described in the Contract Documents. In addition, Contractor shall cause a specific notation for each such variation to be made on each Shop Drawing and background information for the sample submitted to Owner for review and approval.

vi. Owner and Engineer shall review and approve with reasonable promptness Shop Drawings and samples, but Owner's and Engineer's review and approval will be only to assist Contractor in interpreting the scope of the Work in accordance with Owner's business and operational objectives and shall not relieve Contractor from any responsibility or liability for errors or omissions in the Shop Drawings. The review and approval of a separate item as such will not indicate approval of the assembly in which the item functions. Contractor shall make corrections required by Owner or Engineer and shall return the required number of corrected copies of Shop Drawings as indicated in the Technical Specifications or if no specific number is indicated, at least one (1) copy of such drawings and submit as required or requested by Owner new samples for review and approval. Contractor shall direct specific attention in writing to revisions other than the corrections called for by Owner or Engineer on previous submittals.

vii. Where a Shop Drawing or sample is to be provided hereunder, any related Work performed prior to Owner's and Engineer's review and approval of the pertinent submission will be at the sole risk, expense, account and responsibility of Contractor (at no cost or liability to Owner).

viii. All Shop Drawings, plans, drawings, specifications, and similar documents prepared by Contractor for the Work and any copies thereof shall be the sole property of Owner. Contractor shall deliver such documents to Owner at the completion of the Work or at times as may otherwise be requested by Owner.

D. All Shop Drawings shall become part of the Contract Documents after approval by Owner hereunder.

16. Substitutions

A. No item listed on the Contract Drawings, Contractor's Shop Drawings, or in the Technical Specifications by trade name or by name of manufacturer may be substituted without the prior approval of Owner. Owner reserves the sole right to accept or reject such Contractor's proposal for substitution. Contractor shall insure that any such substitution or refusal of substitution shall not cause delay or increased costs. For any substitutions, Owner and Engineer shall determine whether the substitute may be utilized and may make inquiries at Contractor's sole cost and expense to verify such claim.

B. At least fourteen (14) days prior to commencement of the Work, Contractor shall submit to Owner any proposals for substitutions, together with samples and complete data. Owner may consider but is under no obligation to consider such proposals. In either event, Owner shall render a decision to Contractor as promptly as possible. No substitutions may be made without the prior written consent of Owner evidenced by a Change Order and approved Shop Drawing.

C. All applications for substitutions shall be accompanied by a statement of credit or extra cost attributed to the substitution.

D. Contractor shall carefully verify and shall be fully responsible for determining that the materials and/or equipment it has proposed to provide and/or install are in accordance with and will fit into the confines indicated on the Contract Drawings, Contractor's Shop Drawings and/or the Technical Specifications.

E. Unless otherwise indicated, design of the Work is based upon the material or supplier's equipment named first in the list of manufacturers in the Technical Specifications contained herein. When other manufacturers are listed and are desired to be used by Owner, Contractor may be required to make modifications or adjustments to coordinate the installation of the material and/or equipment with associated elements of the Work.

17. Reports

A. Contractor shall prepare and forward to Owner at least fourteen (14) days prior to commencement of the Work, a materials and equipment report which shall include: a complete list of suppliers and/or fabricators; items to be purchased from and/or supplied by such suppliers and/or fabricators; time required for fabrication; and the scheduled delivery dates for each item to be purchased and/or supplied, leased or otherwise used for performance of the Work. As soon as available, Contractor shall furnish copies of purchase orders and other evidence of procurement to Owner.

B. Contractor shall prepare such additional reports as Owner may request.

C. During progress of the Work, Contractor shall keep at the Site, in good and legible form, a record of all work done differently from or in addition to, that shown on the Contract Drawings. Such record shall clearly and accurately describe the "as-built" conditions and dimensions in sufficient detail and accuracy to enable Owner to prepare as-built drawings of the Work. Contractor shall submit the record to Owner as soon as possible, however, all such information must be submitted to Owner in good and acceptable form prior to Final Acceptance of the Work by Owner.

D. Contractor shall submit all other submittals to Owner and others in accordance with provisions of the Technical Specifications regarding the same.

18. Dewatering

A. In addition to, and not in limitation of, any terms or conditions contained in the Technical Specifications, all Work (including, but not limited to excavation and backfilling) shall be performed under workable and dry conditions. Contractor shall be solely responsible for all dewatering in performing the Work including, but not limited to, the following:

i. Preventing surface water and subsurface or groundwater from flowing into the excavations and flooding the Site and surrounding area; and

ii. Not allowing water to accumulate in excavations; and

iii. Providing and maintaining pumps, sumps, suction and discharge lines and other dewatering system components which are necessary to properly convey water away from excavations; and

iv. Conveying water removed from excavations to existing natural channels or otherwise providing proper and appropriate disposal of such water.

B. Dewatering devices shall provide adequate filtering to prevent the removal of fines from the soil.

C. The cost of such dewatering shall already be included in the Agreement Price.

19. Inspections, Examinations and Testing

A. Access to and Testing of the Work

i. Contractor shall provide Owner, Engineer, CQA Consultant, representatives of Owner, testing agencies and governmental agencies with jurisdictional interests with proper and safe access to the Work at reasonable times for their observation, inspection and testing.

ii. Contractor shall give Owner timely notice of readiness of the Work for all required inspections, tests or approvals so as not to delay the Schedule.

iii. If federal, state or local laws, regulations, ordinances, rules, standards, orders or requirements of any public body or court having jurisdiction require any Work (or part thereof) to specifically be inspected, tested or approved, Contractor shall assume full responsibility therefore, pay all costs in connection therewith and furnish Owner and CQA Consultant with the required certificates of inspection, testing or approval.

iv. Contractor shall be responsible for and shall pay all costs in connection with any inspection or testing by Owner of a supplier of materials or equipment proposed to be incorporated into the Work, or of materials or equipment submitted to Owner for approval prior to Contractor's purchase thereof for incorporation into the Work.

v. All inspections, tests or approvals other than those undertaken directly by governmental authorities having jurisdiction shall be performed by organizations acceptable to Owner.

vi. If any Work is covered contrary to the written or oral request of Owner, it must, if requested by Owner, be uncovered for observation and replaced at Contractor's sole expense, risk and account (at no cost to Owner). Any work undertaken by Contractor pursuant to this Paragraph, must be undertaken in full compliance with the terms and conditions of the Contract Documents.

vii. If Owner considers it necessary or advisable that covered Work be observed by Owner, Engineer or CQA Consultant, or inspected or tested by others, for any reason, Contractor, at Owner's request, shall uncover, expose or otherwise make available for observation, inspection or testing as Owner may require, that portion of the Work in question, furnishing all necessary labor, material and equipment. If it is found that such Work is not in accordance with the Contract Documents, Contractor shall bear all costs and expenses (including, but not limited to, all reasonable attorneys' fees, professional engineering fees and charges, sampling and testing fees, experts' fees and other consultants' fees and charges) of such uncovering, exposure, observation, inspection, testing and of proper reconstruction of the Work to the standard necessary and/or required by the Contract Documents.

B. Inspection, Examination and Acknowledgment

i. CONTRACTOR REPRESENTS BY ITS EXECUTION OF THIS AGREEMENT THAT IT HAS HAD THE OPPORTUNITY TO INSPECT AND EXAMINE AND HAS THOROUGHLY INSPECTED AND EXAMINED THE SITE (WHERE OR UPON WHICH THE WORK IS TO BE PERFORMED), ALL APPLICABLE LAWS AND REGULATIONS, THE CONTRACT DOCUMENTS, SITE PERMIT CONDITIONS, DATA AND OTHER SUCH INFORMATION REFLECTING SURFACE AND SUBSURFACE CONDITIONS OF THE SITE EXISTING PRIOR TO PERFORMANCE OF THE WORK AND UNDER WHICH THE COMPLETED WORK SHALL OPERATE INCLUDING, BUT NOT LIMITED TO, ALL FACILITIES, THE CHARACTER, QUALITY AND QUANTITY OF MATERIAL REQUIRED, KIND OF EQUIPMENT AND FACILITIES NEEDED PRELIMINARY TO AND DURING PERFORMANCE OF THE WORK (OR IF IT HAS NOT DONE SO, WAIVES SUCH INSPECTION AND EXAMINATION AT ITS OWN RISK); THAT IT HAS OBTAINED AND CAREFULLY STUDIED (OR ASSUMES RESPONSIBILITY FOR OBTAINING AND CAREFULLY STUDYING) ALL SUCH EXAMINATIONS, INVESTIGATIONS, EXPLORATIONS, TESTS, REPORTS, DRAWINGS, STUDIES AND OTHER INFORMATION WHICH PERTAIN TO THE SURFACE, SUBSURFACE OR PHYSICAL CONDITIONS AT OR CONTIGUOUS TO THE SITE OR THAT OTHERWISE MAY AFFECT THE PROGRESS, PERFORMANCE, INSTALLATION, OPERATION OR FURNISHING OF THE WORK AS REQUIRED OR IS NECESSARY FOR THE PROPER PERFORMANCE OF THE WORK AT THE AGREEMENT PRICE, WITHIN THE AGREEMENT TIME

AND IN ACCORDANCE WITH ALL OF THE TERMS AND CONDITIONS OF THE CONTRACT DOCUMENTS; THAT IT HAS A FULL UNDERSTANDING OF THE DIFFICULTIES AND CONDITIONS WHICH MAY BE ENCOUNTERED IN PERFORMING THE WORK AND AGREES THAT THE CONTRACT DOCUMENTS ARE ADEQUATE AND REASONABLE FOR CONTRACTOR'S PERFORMANCE OF SUCH WORK. CONTRACTOR'S FAILURE TO INSPECT AND/OR EXAMINE SUCH SITE AND THE CONTRACT DOCUMENTS RESULTING IN ITS SUBSEQUENT INABILITY TO PERFORM THE WORK HEREUNDER SHALL IN NO WAY RELIEVE IT OF THE OBLIGATIONS OF THIS AGREEMENT.

ii. Contractor is responsible for reviewing all available information, data and the Contract Documents and shall confirm the location of each Facility that exists. Contractor shall take all precautions to avoid damage to all persons and property around such Facilities during performance of the Work. If Facilities must be moved to perform the Work, the cost for such moving shall already be included in the Agreement Price, otherwise, they shall be moved at Contractor's sole expense, risk and account (at no cost to Owner).

iii. Contractor agrees to advise fully all of its employees, Subcontractors and others working for Contractor at the Site, of any risks at the Site and of all necessary and/or required environmental, safety, and health procedures contained in any applicable federal, state and/or local law, regulation, ordinance, standard, rule or order (including, but not limited to all applicable OSHA requirements).

iv. Contractor acknowledges and is aware that the Site may contain residential, commercial, and/or industrial waste materials, and Contractor knowingly and voluntarily assumes all risk of injury and damage to Contractor and Contractor's property, employees, Subcontractors and others working for Contractor, caused by exposure to such waste materials while at the Site.

C. Surveys, Borings, Drawings, Studies, Test Results and Other Site Information

i. Owner shall not be responsible for furnishing surveys (except as expressly provided herein) or other information as to the physical characteristics of, legal limitations of, or utility locations for, the Site.

ii. Owner may, however, make available to Contractor, and if so Contractor is deemed to have studied the results of certain surveys, test borings, drawings, studies, test results and information that it has, if any, as to surface conditions, subsurface conditions and Site geology. Owner does not assume any responsibility whatsoever with respect to the completeness, sufficiency or accuracy of surveys or borings made; of the logs of test borings; of drawings, studies, or test results; of other investigations; or of the interpretations and conclusions made thereof; AND THERE IS NO WARRANTY OR GUARANTEE, EXPRESS OR IMPLIED, THAT THE CONDITIONS INDICATED BY SUCH SURVEYS, INVESTIGATIONS, BORINGS, LOGS, DRAWINGS, STUDIES OR INFORMATION ARE REPRESENTATIVE OF THOSE CONDITIONS EXISTING THROUGHOUT THE SITE, OR ANY PART THEREOF, OR THAT UNFORESEEN DEVELOPMENTS MAY NOT OCCUR except however, Contractor may rely on the survey for the Site which is given to Contractor by Owner and which sets the vertical and horizontal controls and identifies benchmarks for the Site.

iii. At Owner's request, Contractor shall make available to Owner the results of any Site investigation, test borings, drawings, analyses, studies, surveys, tests or other investigations conducted by or in possession of the Contractor or any of its agents or Subcontractors.

20. Compliance with Laws, Permits and Other Conditions

I. Compliance with Laws

A. In the performance of the Work hereunder, Contractor, its employees and Subcontractors agree to comply with all applicable federal, state, provincial, county and local laws, ordinances, lawful orders, rules, standards and regulations including, but not limited to, social security and income tax withholding laws, employment compensation laws, environmental, safety and health laws including those of the Occupational

Safety and Health Act (OSHA) in existence at the time of execution of this Agreement and as thereafter enacted, amended and/or modified.

B. Contractor, its employees and Subcontractors represent and warrant that they have acquired and paid for all necessary work permits (to include all required documentation to allow personnel who are not United States citizens to legally work in the United States), licenses, certificates and other forms of documentation of personnel registration and training and that their personnel have received all necessary training required to perform the Work. Contractor shall furnish copies of such documentation to Owner's Project Manager prior to commencement of performance of the Work.

C. Contractor shall be responsible for the payment of all sales, use, added value and all other federal, state and/or local taxes of any type which arise out of or are related to the Work including, but not limited to, any personal property, income, franchise, or business privilege tax assessed Contractor for conducting its operations and purchasing materials and/or equipment hereunder. All applicable taxes shall already be included in the Agreement Price.

D. Contractor shall not violate any applicable laws, regulations, ordinances, orders, rules or standards pertaining to wetlands.

E. To the fullest extent permitted by law, Contractor, on behalf of itself, its employees and its Subcontractors, agrees to indemnify, defend and hold Owner, its respective parent and/or subsidiary and/or affiliated compan(y)(ies), and their respective officers, directors, employees, agents and subcontractors harmless from any liability, penalties or damages which might be imposed by reason of an asserted or established violation of any federal, state, provincial, county and/or local law, ordinance, lawful order, rule, standard or regulation by Contractor, its employees or Subcontractors.

F. Contractor shall perform the Work in accordance with all applicable permits, certificates and licenses acquired by Owner.

II. Legal Restrictions and Waste Disposal Permit Conditions

Contractor shall not violate any zoning, setback, buffer or other locational aspects of applicable laws, codes or ordinances, or of any recorded covenants or permit conditions of any of Owner's waste disposal or other permits (including, but not limited to, those referenced in the project specifications). If Contractor observes that portions of the Contract Documents are at variance with applicable laws, statutes, ordinances, building codes, rules, regulations or permit conditions, Contractor shall notify Owner promptly in writing and any necessary changes shall be accomplished by appropriate modification to the Contract Documents.

III. Building Permits, Certificates and Licenses

A. Contractor shall procure all federal, state, county, local and all other applicable permits, certificates, bonds licenses and inspections and shall give all applicable notices and pay for all applicable governmental charges and inspection fees as required for proper performance of the Work to be performed by Contractor as applicable.

IV. Standards, Specifications, and Codes

A. Where provisions of the Contract Documents refer to or wherever the Work performed under the Contract Documents relates to the specification of the AASHTO, AIA, ASTM, NSF or other specific standards and specifications, such specifications are made a part hereof to the extent which is indicated. Where standards, specifications, codes, etc., are referred to herein, it shall be understood that such reference is to the issue in effect at the time of Contractor's performance of the Work.

B. Abbreviations for the names or designation of recognized technical societies and industry standards in general use in the Technical Specifications include but are not limited to the following:

AASHTO	American Association of State Highway and Transportation Officials
AIA	American Institute of Architects
ASTM	American Society for Testing and Materials
NSF	National Sanitation Foundation

V. Material and Workmanship

A. All materials shall be new, free from rust or other foreign matter, and of the best quality of their respective kind. The types and sources of all materials shall be subject to Owner's approval. The Work in all respects shall be performed in a good and workmanlike manner and all Work shall be performed by persons skilled in the performance of their respective duties. Such materials and workmanship shall be free from negligence.

B. Owner is privileged to reject any materials having been obtained and installed at any time and any rejected material shall be removed and replaced with approved materials or repaired in accordance with the manufacturer's recommendations by Contractor, without delay, at Contractor's sole expense, risk and account (at no cost to Owner). All materials furnished and installed under these Contract Documents shall be of approved design and manufacture and shall be limited to products regularly produced, recommended, and guaranteed for service ratings in accordance with the manufacturer's catalog data or other comprehensive literature made available to the public and in effect at the time of execution of this Agreement. In addition to the foregoing, all materials and equipment must conform to and comply with all solid waste permit conditions for the Site.

VI. Standards of Quality

If the Contract Documents including, but not limited to, the Technical Specifications and/or Contract Drawings, describe materials, devices, or equipment as those which shall be similar and equal to certain materials, devices, or equipment designated by trade or manufacturer's name and Contractor desires to use such "equal," then Contractor shall be required to demonstrate to the satisfaction of Owner that the materials, devices, or equipment it proposes to furnish are in fact, similar or equal to the quality of those designated in such documents prior to Contractor placing an order therefore or incorporating such "equal" into the Work. In addition, Contractor shall comply with all provisions of the Contract Documents regarding substitutions.

21. Patents/Copyrights

A. INTENTIONALLY OMITTED.

B. To the fullest extent permitted by law, Contractor shall indemnify, defend, and hold Owner, its parent and/or subsidiary and/or affiliated compan(y)(ies) and their respective officers, directors, employees, agents and subcontractors harmless from all costs and expenses (including, but not limited to, all reasonable attorneys' fees, professional engineering fees and charges, sampling and testing fees, experts' fees and other consultants' fees and charges) and liability of any kind for or on account of infringement or claimed infringement of any patent or any patented or unpatented invention, article, material, or process manufactured or used in the performance of the Work, incorporated into the Work or occasioned by use of the Work by Owner or another.

22. Confidentiality

A. In connection with the Work to be performed under the Contract Documents, Owner may disclose to Contractor, or Contractor may have access to, through its representatives, confidential commercial information and technical data (including trade secrets in which Owner has proprietary rights) patentable as well as unpatentable (hereinafter "Information"). All such Information, howsoever disclosed, developed, or obtained by Contractor shall not be used or disclosed to others without Owner's prior written consent unless such information is in the public sector (through no fault or breach of any term or condition of the Contract Documents by Contractor). Upon completion of the Work, or upon earlier termination of this Agreement, Contractor shall return to Owner all such prints, drawings and documents of any kind supplied by Owner, together with all copies thereof made by or for Contractor and its Subcontractors.

B. Contractor shall not release Information or discuss the Work with news media, governmental agencies, or other interested parties at any time without the prior written consent of Owner.

C. Notwithstanding the provisions of this Section of the Agreement to the contrary, Information referred to in this Section of the Agreement may be disclosed to a court of competent jurisdiction if it is legally required to be disclosed. If such Information is requested to be disclosed by such court, Contractor shall provide Owner with written notice immediately of the request for disclosure so that Owner may enforce the provisions of this Agreement, seek an appropriate protective order and/or in Owner's sole discretion, waive Contractor's compliance with selected provisions of this Agreement concerning all of a portion of such Information.

23. Liability and Guarantee

I. Protection of the Work and Safety

A. Contractor shall maintain the Work, materials and/or equipment free from injury or damage from rain, wind, water, storms, frost and/or heat. If adverse weather makes it impossible to continue performing the Work in a safe manner, in spite of employing appropriate weather precautions, Contractor shall cease performance of the Work and notify Owner of such cessation.

B. Contractor shall not permit open fires on the Site except with the prior written permission of Owner and Contractor's adherence to all applicable laws, regulations, rules, standards and orders.

C. Contractor, at its own expense, risk and account (at no cost to Owner), shall repair, replace, and maintain in service any Facilities which are damaged, broken, or otherwise rendered inoperative by Contractor or any of its Subcontractors during performance of the Work. The method used by Contractor in repairing, replacing, or maintaining such Facilities shall be approved by Owner. However, Owner's approval does not in any way relieve Contractor of any of its obligations, liabilities, and responsibilities regarding the protection, repair, replacement or maintenance of such Facilities. Contractor shall be responsible for coordination of the Work with the owners of such Facilities.

D. Contractor shall take all necessary precautions for the safety of and shall provide protection to prevent damage, injury or loss to all subcontractors [including, but not limited to, all Subcontractors (as defined herein)], visitors, invitees, and licensees on the Site; employees performing the Work and other persons who may be affected thereby or in the vicinity thereof; the Work itself (including materials and equipment to be incorporated therein); and other property at the Site or adjacent thereto such as structures and Facilities not designated for removal, relocation or replacement in the course of construction. Contractor shall comply with all applicable provisions of federal, state, local, and municipal safety laws, regulations and building codes to prevent accidents or injuries to persons on, about, or adjacent to any area where the Work is being performed.

E. Contractor shall erect and properly maintain, at all times, as necessary and required by the conditions and progress of the Work, all barricades, warning signs, scaffolding, shoring, sheeting, bracing, hazard markings (suitably illuminated) and safeguards for the protection of workmen and the public.

F. Contractor shall provide such equipment and medical facilities as are necessary to supply first aid to anyone who may be injured in connection with the Work, and shall have the capability of immediate removal and hospitalization, if required.

G. CONTRACTOR SHALL BE SOLELY RESPONSIBLE FOR THE MANNER, MANAGEMENT, MEANS, METHODS, SEQUENCES, PROCEDURES, AND TECHNIQUES NECESSARY TO PERFORM THE WORK IN A SAFE MANNER.

H. Contractor shall arrange and attend safety meetings with Owner in order to discuss any conditions at the Site perceived to be unsafe and/or any other matters relating to work safety. Meetings may be held at any time but not less frequently than weekly and may be part of the regularly scheduled construction meetings. An agenda shall be prepared for each meeting and an attendance sheet shall be signed by representatives of each party present at the meeting. Notwithstanding arranging and attending meetings, Contractor shall immediately notify Owner of any condition that is perceived to be unsafe.

II. Risk of Loss

Until Final Acceptance of the Work by Owner, all risk of loss, injury, theft, damage to or destruction of the Work including, but not limited to, materials and/or equipment contained therein (i.e. stored at the Site or incorporated into the Work) shall be borne by Contractor. Responsibility of Contractor shall extend to materials and/or equipment furnished or leased by Owner to Contractor under the terms and conditions of the Contract Documents. Contractor shall replace or repair all damaged and/or stolen work to the condition necessitated and/or required by the Contract Documents at Contractor's sole expense, risk and account at no cost to Owner.

III. Indemnification

A. To the fullest extent permitted by law, Contractor, for itself, its employees and Subcontractors shall indemnify, defend, and hold harmless Owner, its parent and/or affiliated and/or subsidiary compan(y)(ies), and their respective officers, directors, employees, agents, vendors and subcontractors from and against all claims, lawsuits, damages, losses and expenses, (including, but not limited to, all reasonable attorneys' fees, professional engineering fees, sampling and testing fees, experts' fees and other consultants' fees and charges) arising out of a breach of any terms or conditions of the Contract Documents by Contractor or its Subcontractors, errors or omissions of Contractor or its Subcontractors, or resulting from the performance of the Work; provided, that any such claim, damage, loss and/or expense resulting from performance of the Work (1) is attributable to bodily injury, sickness, disease or death (including, but not limited to, injury or death to employees and/or Subcontractors of Contractor), or to injury to or destruction of property (including the loss of use resulting therefrom) or contamination of or adverse effects on the environment (including, but not limited to, property damage to employees and/or Subcontractors of Contractor) and (2) is caused in whole or in part by the negligence, willful misconduct or strict liability of Contractor, any Subcontractor, anyone directly or indirectly employed by any of them or anyone for whose acts any of them may be liable.

B. In all claims against Owner, any person or entity indemnified hereunder, any subcontractor of Owner, anyone directly or indirectly employed by any of them or anyone for whose acts any of them may be liable, the indemnification obligation as provided herein shall not be limited in any way by any limitation on the amount or type of damages recoverable against Contractor, its employees or Subcontractors, regarding compensation or benefits payable by or for the Contractor or any Subcontractor under workers' or workmen's compensation acts, disability benefit acts or other employee benefit acts.

C. The obligations contained in this Section of the Agreement shall survive termination of this Agreement.

IV. Guarantee

A. In addition to and not in substitution or limitation of specific warranties, if any, required by law, this Agreement or the Contract Documents, Contractor warrants and guarantees for a period of one (1) year from the date of Final Acceptance of the Work by Owner that the Work to be performed and the materials and equipment to be furnished under the Contract Documents shall all be free from negligence, any errors or omissions, defects in design work done by Contractor and shall be technically correct and accurate, shall be fit and sufficient for the purposes expressed herein; that all tasks to be performed as necessary and required by the Contract Documents shall be fully and completely performed pursuant to the Contract Documents; and that all materials, equipment and finished Work shall function in accordance with the letter and intent of the Contract Documents including, but not limited to, the Technical Specifications, the Contract Drawings and the warranty representations of Contractor.

B. In addition to, and not in limitation of, any remedy provided by law, in equity, the Contract Documents or other warranties, Contractor shall repair or replace any defective or negligently produced materials or workmanship which may develop during said one (1) year period, shall be responsible for all damages, costs and expenses (including, but not limited to, all reasonable attorneys' fees, professional engineering fees and charges, sampling and testing fees, experts' fees and other consultants' fees and charges) resulting from a breach of this warranty and guarantee by Contractor and/or its Subcontractors and Contractor shall be responsible for any damage to other work caused by the repairing of such defects, at Contractor's sole expense, risk and account (at no cost to Owner). Remedial work to be performed by Contractor shall include, but not be limited to, uncovering, removal, reinstallation, inspections and testing by Owner to determine the nature and extent of such defect. Such corrective or remedial work shall be undertaken in an expeditious fashion in accordance with a schedule developed by Owner, in Owner's sole discretion, even if additional costs are incurred in completing such work on any accelerated basis. Contractor shall be responsible for all such additional costs for accelerated work as indicated above. If requested by Owner, Contractor shall furnish satisfactory evidence as to the kind and quality of materials and equipment used or to be used to repair such damage. Any such repairs or replacement and the affected Work shall be warranted by Contractor for an additional one (1) year period from the date of Final Acceptance by Owner of such repairs or replacement. At Owner's option, Owner may remedy any such defects or negligence and Contractor shall be liable for all reasonable costs arising therefrom including, but not limited to, all reasonable attorneys' fees, professional engineering fees and charges, sampling and testing fees, experts' fees and other consultants' fees and charges.

C. Contractor shall secure and deliver to Owner written warranties and guarantees from its Subcontractors reflecting the date the warranty period begins and the date upon which such warranty ends. Contractor shall transfer all manufacturer's or dealer's warranties to Owner immediately upon purchase of any materials or equipment for incorporation into the Work. Contractor shall perform no modifications to the materials or equipment or otherwise void such warranties except with the prior written consent of Owner. Contractor is responsible for the warranty of all Work, whether performed by it or by its Subcontractors at any time.

D. The warranty and remedies provided herein shall survive termination of this Agreement. Contractor shall not be entitled to an extension of the Agreement Time because of any delay in performance of the Work attributable to Owner's exercise of its rights and remedies hereunder.

V. Limitation of Liability.

NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR SPECIAL, INCIDENTAL, EXEMPLARY, PUNITIVE OR CONSEQUENTIAL DAMAGES INCLUDING WITHOUT LIMITATION LOSS OF USE, LOSS OF PROFITS OR REVENUES, OR COST OF SUBSTITUTE OR RE-PERFORMED SERVICES, SUFFERED, ASSERTED OR ALLEGED BY EITHER PARTY OR ANY THIRD PARTY ARISING FROM OR RELATING TO THIS AGREEMENT, REGARDLESS OF WHETHER THOSE DAMAGES ARE CLAIMED UNDER CONTRACT, WARRANTY, INDEMNITY, TORT OR ANY OTHER THEORY AT LAW OR IN EQUITY.

24. Waivers and Releases

A. Waivers and Releases (Upon Progress Payment and Final Payment)
Contractor, for itself and its Subcontractors, Material Suppliers, and all other persons furnishing any goods or services pertaining to the Work, hereby agrees as a condition precedent to Contractor receiving any payment under this Agreement, to furnish to Owner good and sufficient waivers and releases on Waiver and Release Forms contained in Section VII of the Contract Documents for itself, Subcontractors, Material Suppliers, and any other persons furnishing goods and/or services pertaining to the Work. These fully executed Waiver and

Release Forms must accompany all Payment Forms submitted by Contractor to Owner hereunder, and be in the form of “upon receipt of the requested amount” for the Waiver and Release forms to be valid.

B. Payments Directly to Subcontractors

Contractor agrees that Owner may, in consultation with Contractor, and without obligation to do so, pay any Subcontractor directly and deduct such amount from any amounts which are due to Contractor hereunder, thereby, reducing the total amount of the Agreement Price owed to Contractor for performance of the Work by the amount so paid to such Subcontractor. In addition, Contractor agrees to hold Owner harmless from all claims, lawsuits, costs, damages, expenses and liability for such actions taken by Owner in accordance with Section 24 of this Agreement.

25. Insurance ~~and Performance and Payment Bonds~~ (The Owner does not require the Contractor to purchase Performance and Payment Bonds for **___________**.)

A. Insurance

Contractor shall purchase and maintain such insurance as will protect it from claims set forth below which may arise out of or result from Contractor's performance of the Work, whether such Work is undertaken by Contractor or by any Subcontractor or by anyone directly or indirectly employed by any of them, or by anyone for whose acts any of them may be liable:

i. Claims under worker's or workmen's compensation, disability benefit, and/or other similar employee benefit acts;

ii. Claims for damages because of bodily injury, occupational sickness or disease, or death of its employees;

iii. Claims for damages because of bodily injury, sickness or disease, or death of any person who is not its employee;

iv. Claims for damages insured by usual personal injury liability coverage which are sustained i) by any person as a result of an injury directly or indirectly related to the employment of such person by Contractor, or ii) by any other person;

v. Claims for damages because of injury to or destruction of tangible property, including loss of use resulting therefrom; and

vi. Claims for damages because of bodily injury or death of any person or property damage arising out of the ownership, maintenance, or use of any motor vehicle.

B. The insurance required by Paragraph 1 of this Section 25 of this Agreement shall be written for not less than the limits of liability specified as follows:

COVERAGE	**REQUIREMENTS**	**MINIMUM AMOUNTS**
Comprehensive General Liability	This coverage shall be written on an occurrence basis and include, but not be limited premises-operations, blanket contractual, XCU,	$1,000,000 Each Occurrence and

	independent contractors, products-completed, operations, personal injury and broad form property damage.	$2,000,000 Annual Aggregate $2,000,000 Per Project Aggregate
Auto Liability	This coverage shall be written on an occurrence basis and include owned, hired, and non-owned vehicles.	$1,000,000 Combined Single Limit
Excess Umbrella Liability	This coverage shall be written on an occurrence basis.	$20,000,000 Combined Single Limit
Worker's Compensation Employers Liability	Statutory Worker's Compensation Coverage and Employers Liability. The employer's liability coverage shall not contain an exclusion for occupational disease.	
Pollution Liability		$5,000,000

The insurance required under this section shall name Owner as an additional insured for the indemnity obligations under this contract (with the exception of Worker's Compensation insurance). The insurance policies shall contain a provision extending coverage on a primary basis to Owner for liabilities assumed under this contract. All policies shall contain a waiver of subrogation in favor of the Owner, and Owner will arrange with respect to its insurers to waive its rights of subrogation against Contractor's insurer for this project Limits required may be satisfied by primary policies plus umbrella/excess liability.

C. A Certificate of Insurance acceptable to Owner shall be filed with Owner prior to commencement of the Work. In addition, Contractor shall insure that all coverage required above remain in full force and effect even though Contractor may have to employ blasting or drilling to perform rock excavation.

D. If Contractor's insurance is canceled or amounts of coverage are reduced through aggregate erosion for any reason, Contractor shall immediately obtain new policies with the coverage stipulated herein. If Contractor fails to procure, maintain and/or pay for such insurance, Contractor agrees that Owner may, but is not obligated to, obtain such insurance on behalf of and at the sole expense of Contractor and such costs and expenses may be withheld from amounts due the Contractor under this Agreement or may be paid to Owner directly within ten (10) calendar days after receipt of an invoice from Owner for the same. In addition, Contractor agrees to hold Owner harmless from all claims, lawsuits, costs, damages, expenses and liability for such actions taken by Owner in accordance with Section 25 of this Agreement. Failure to obtain adequate insurance coverage shall not be a basis for an extension of the Agreement Time or adjustment of the Agreement Price.

E. Contractor shall name Owner as an additional insured (hereinafter referred to as the "Additional Insured") without limitation on all coverage listed in this Section of the Agreement, except for Worker's Compensation coverage. All insurance carried by Contractor in accordance with this Section of the Agreement shall be endorsed to provide that:

i. The Additional Insured is included as an additional insured with the understanding that any obligation imposed upon the insured (including, without limitation, the responsibility of paying premiums) shall be the sole obligation of Contractor and not that of the Additional Insured or any other insured;

ii. The respective interest of the Additional Insured shall not be invalidated by any action or inaction of Contractor or any other person or entity. The Additional Insured shall remain an additional insured regardless of any breach or violation by Contractor or any other person of any warranties, declarations or terms or conditions contained in such policies;

iii. With respect to such insurance, the insurer thereunder waives all rights of subrogation against the Additional Insured, any right of set-off and counterclaim and any other right to deduction whether by attachment or otherwise;

iv. Such insurance shall be primary without the right of contribution of any other insurance carried by or on behalf of the Additional Insured with respect to its respective interest as such in the Site and the Work;

v. If such insurance is canceled for any reason whatsoever including non-payment of premium or any substantial change is made in the coverage which affects a substantial interest of the Additional Insured, such cancellation or change shall not be effective as to the Additional Insured until thirty (30) days after receipt of written notice by the Additional Insured of such cancellation or change; and

vi. Any insurance carried by the Contractor in accordance with the provisions herein shall be endorsed to provide that inasmuch as the policy is written to cover more than one insured, all terms, conditions, insuring agreements and endorsements shall operate in the same manner as if there were a separate policy covering each insured.

F. If Contractor intends to charge Owner for such insurance premiums, they shall already be reflected in the Agreement Price.

26. ~~Performance and Payment Bonds~~

The Owner does not require the Contractor to purchase Performance and Payment Bonds for ____________.

27. The Work Schedule, Deliveries and Storage

I. Scheduling

A. Contractor shall be responsible for arranging and attending a meeting with Owner to develop a detailed work schedule herein referred to as "the Schedule" which shall be more detailed and descriptive than any schedule which may have been submitted to Owner prior to the execution of this Agreement.

B. The Schedule shall not exceed the Agreement Time unless agreed upon in writing by Owner and Contractor.

C. The Schedule shall be updated during the regularly scheduled construction meetings at the Site or at more frequent times as otherwise agreed to by Owner and Contractor. The update shall include the following items as well as any additional information necessary to make an accurate and informative report:

i. Actual start dates;

ii. Actual finish dates;

iii. Percentage of the Work completed (together with the number of units installed, if applicable);

iv. Whether the Work is on schedule, and if not, a statement as to how Contractor intends to get back on schedule (together with projected changes in the Schedule required for safe completion of the Work); and

v. The remaining duration of the Work in work days (together with the number of units needed to be installed, if applicable).

D. The Schedule represents the work schedule of Contractor. Contractor accepts and agrees to abide by the Schedule as formulated herein. The Schedule supersedes all prior oral or written work schedules of any type created by Contractor or Owner for performance of the Work.

E. It shall be Contractor's responsibility to promptly notify Owner in writing of any delay which may jeopardize completion of the Work in accordance with the Schedule. If, at any time, it appears to Owner that the rate of progress of the Work is insufficient to insure completion of the Work in accordance with the Agreement Time, Owner shall notify Contractor and Contractor shall take such steps as are necessary to insure safe completion of the Work within such Agreement Time. Any additional expenses and/or costs incurred by Contractor or charges made to Owner in excess of the Agreement Price in complying with Schedule milestones (including but not limited to those incurred for overtime or additional shifts) shall be paid solely by Contractor (at no cost to Owner).

II. Deliveries

All deliveries shall be coordinated with Owner which are not specifically addressed in the Contract Documents. Owner will work with Contractor in scheduling delivery of materials to the Site.

III. Storage and Unloading

Contractor shall be solely responsible for receiving, unloading, handling and storing all materials for the Work upon delivery at the Site at Contractor's sole cost, expense (including, but not limited to drayage), risk and account (at no additional cost to Owner). Unloading must be accomplished within the Shipper's "free period" and any demurrage charges resulting from failure to do so shall be at Contractor's sole expense, risk and account (at no cost to Owner). Contractor may store material, machinery, and equipment in an area designated by Owner. Contractor is required to coordinate and relocate materials as necessary at no cost to Owner. Owner's designation of a storage area shall in no way make Owner responsible for damage to, loss or theft of such materials, machinery, and/or equipment.

28. Delays, Unknown Conditions and Suspension of the Work

A. Force Majeure

If Contractor is delayed in the prosecution or completion of the Work due solely to Acts of God or fire, floods, insurrections, riots, epidemics, acts of governmental authorities, changes in law or abnormally or unusually severe weather which are beyond the control and without the fault or negligence of Contractor and which have a material adverse effect upon Contractor's ability to complete the Work within the Agreement Time, then the Agreement Time shall be extended for a period consistent with the time by which completion is delayed. Contractor shall use its best efforts to make up any time lost by such delays, if any. Contractor shall notify Owner of any such delay and the causes therefor in writing within five (5) working days after the delay commences, otherwise Contractor will be deemed to have waived any extension of time. Contractor shall accept any extension of time from Owner in full and complete satisfaction for any increased cost or expense resulting from such excusable delay. There shall be no payment or compensation of any kind (including, but not limited to, costs, expenses and charges for standby time) to Contractor for expenses or damages arising from delay. Delays caused by the Contractor, its Subcontractors or materialmen shall not be considered reasons for an extension of time.

B. Unknown Conditions

If conditions (including, but not limited subsurface or otherwise concealed physical conditions) are encountered at the Site which are unknown physical conditions (prior to such conditions being encountered) of an unusual nature and which differ materially from those ordinarily found to exist and are not generally recognized as inherent in construction activities of the character provided for in the Contract Documents, then written notice by Contractor shall be given to Owner promptly before such conditions are disturbed and in no event later than three (3) days after the first occurrence of each condition. Owner and Engineer will promptly investigate such conditions and, if they are unknown, unusual, differ materially from those conditions ordinarily found to exist and are not generally recognized as inherent in construction activities of the character provided for in the Contract Documents and cause a material increase or decrease in the Contractor's cost of, or time required for, performance of all or any part of the Work, Engineer will recommend to Owner an equitable adjustment in the Agreement Price, Agreement Time or both. If Engineer determines that the conditions at the Site are not unknown, unusual, and do not materially differ from those conditions ordinarily found to exist and are generally recognized as inherent in construction activities of the character provided for in the Contract Documents and that no change in the terms of the Contract Documents is justified, Engineer shall so notify Owner and Contractor in writing, stating the reasons therefore. Engineer's decision in this regard shall be final.

C. Suspension of the Work

i. Owner may, at any time and without cause, suspend the Work or any portion thereof upon giving notice to Contractor. Contractor shall strictly comply with Owner's notice and shall reasonably act to minimize the cost of such suspension. Any part of the Work not suspended shall continue to be prosecuted with full diligence by Contractor.

ii. Owner may, at any time, direct Contractor to resume the Work which was previously suspended and an equitable adjustment may be made to pay for Contractor's direct actual costs and the costs of Contractor’s supplies and subcontractors, including cost of storage, demurrage, and other direct delay costs, incurred during the period of suspension and provide, if appropriate, adjustment of the Agreement Time in accordance with all other provisions of the Contract Documents relating thereto.

iii. Should Owner suspend the Work for in excess of six (6) months, and Owner and Contractor do not agree to mutually satisfactory terms to extend such suspension, such suspension shall cause this Agreement to be terminated in accordance with Section 29 of this Agreement.

iv. The right of Owner to stop the Work shall not give rise to any duty or obligation on the part of Owner to exercise this right for the benefit of Contractor or any other person or entity.

29. Agreement Termination

I. Owner's Right to Terminate for Cause

A. Owner may, without prejudice to any other right or remedy, and upon giving Contractor written notice, terminate this Agreement immediately and may (without liability being attributed to Owner) take possession of the premises and of all materials, tools, equipment, and accessories thereon and finish the Work by whatever method Owner may deem expedient for any of the following reasons:

i. Contractor is adjudged bankrupt;

ii. Contractor makes a general assignment for the benefit of its creditors;

iii. Contractor becomes insolvent;

iv. A receiver is appointed on account of Contractor's insolvency;

v. Contractor, at any time, refuses or fails to pursue the Work with due diligence; or to supply enough properly skilled workmen; or provide the proper quality and/or quantity of materials; or there is a reasonable doubt about whether the Contractor will be able to complete the Work in accordance with the Agreement Time and Agreement Price;

vi. Contractor fails to make prompt payment to Subcontractors or its workmen for material, equipment or labor;

vii. Contractor disregards any laws, regulations ordinances, permit conditions or rules of Owner; or

viii. Contractor breaches any of the terms or conditions of the Contract Documents (including, but not limited to, any provisions regarding the completion and submission of Waiver and Release Forms for Contractor and/or its Subcontractors).

B. Upon receipt of such termination notice, Contractor shall immediately discontinue the Work and deliver to Owner all permits, licenses, Contract and Shop Drawings, inspection reports, certifications or certificates obtained by Contractor relating in any way to any portion of the Work, together with a waiver and release fully executed by Contractor on a form provided by Owner in Section VII of the Contract Documents. Additionally, Contractor shall at the request of Owner, cancel any outstanding purchase orders or subcontracts or assign such purchase orders or subcontracts to Owner. Contractor shall not be entitled to receive any further payment from Owner for Work completed prior to the date of termination or any retainage until Final Acceptance of the Work pursuant to the provisions provided herein.

C. If after termination of Contractor's right to proceed for cause it is determined that there was no cause or default to terminate Contractor therefore, the rights and obligations of the parties shall be the same as if the termination had been issued by Owner under Section 29(III) of this Agreement.

II. Remedies in the Event of Owner's Termination of Contractor for Cause

A. Promptly upon termination of Contractor by Owner for cause, Owner shall make a determination of the cost of finishing the Work. Owner may finish the Work by whatever method Owner deems expedient. If the unpaid balance of the Agreement Price exceeds the expense of finishing the Work, including compensation for additional engineering, managerial, legal and administrative services, such excess shall be retained by Owner without any accounting to Contractor. If the expense of finishing the Work exceeds the unpaid balance of the Agreement Price, Contractor shall pay the difference immediately to Owner.

B. Contractor shall be liable for all costs and expenses incurred by Owner and others if Contractor is terminated by Owner for cause including, but not limited to, all reasonable attorneys' fees, professional engineering fees and charges, sampling and testing fees, experts' fees and other consultants' fees and charges. These remedies are in addition to, and not in limitation of, any remedies provided at law, in equity or otherwise pursuant to the Contract Documents of Owner.

III. Other Termination

Owner may, without prejudice to any other right or remedy, and upon giving Contractor prior written notice, unilaterally terminate this Agreement for any reason or no reason, in Owner's sole discretion. Upon receipt of such notice, Contractor shall immediately discontinue the Work unless the notice provides otherwise, and deliver to Owner all permits, licenses, certificates, drawings and all other work prepared or obtained by Contractor relating in any way to any portion of the Work, together with fully executed Waiver and Release Forms for itself and its Subcontractors. Additionally, Contractor shall, at the request of Owner, cancel any outstanding purchase orders or subcontracts or assign such purchase orders or subcontracts to Owner as requested by Owner. Owner shall pay to Contractor: i) that portion of the Agreement Price representing that portion of the Work satisfactorily completed prior to termination; ii) any direct and reasonable costs of demobilization, or termination charges associated with subcontractor and supplier demobilization and cancellation; iii) any other reasonable, necessary and direct expenses associated with such termination, and iv) a fee of seven (7%) calculated on items (ii) and (iii) above representing administrative costs incurred by Contractor and a reasonable profit thereon, less any amounts previously paid to or withheld by Contractor for such completed Work. No other amounts shall be payable to Contractor regarding such termination. In addition, the payments provided for herein shall be accepted by Contractor as its sole and exclusive compensation in the event of termination hereunder and in lieu of any and all liability of any nature whatsoever on the part of Owner.

30. The Premises and Completion of the Work

I. Substantial Completion, Final Inspection, Final Acceptance and Occupancy of the Work

A. When Contractor considers the entire Work or a designated portion thereof ready for its intended use, Contractor shall send notice to Owner certifying in writing that:

i. The Contract Documents have been reviewed; and,

ii. The Work has been inspected for compliance with the Contract Documents; and,

iii. After such inspection by Contractor, the Work has been completed in accordance with the Contract Documents; and,

iv. All equipment and systems constructed by Contractor hereunder have been tested in the presence of Owner and are operational; and

v. The Work is completed and ready for Final Inspection.

B. After receipt by Owner of such written certification that the Work is ready for Final Inspection Owner shall promptly make such Final Inspection.

C. If Owner determines that Substantial Completion i.e., the Work is sufficiently completed, in accordance with the Contract Documents, so that the Work can be utilized for the purpose for which it was intended by Owner, has not occurred, Owner will promptly notify Contractor in writing, listing the reasons for not granting Substantial Completion and:

i. Contractor shall take immediate steps to remedy the stated deficiencies and shall send a second written certification to Owner; and

ii. Owner shall reinspect the Work; and

iii. Failure by Owner to include any items on the list of reasons for not granting Substantial Completion does not relieve Contractor of the liability or responsibility of Contractor to complete all Work in a good and workmanlike manner and in accordance with the terms and conditions of the Contract Documents.

iv. If Owner determines that Substantial Completion has occurred, Owner shall issue a certificate of Substantial Completion.

v. Owner shall have the right to exclude Contractor from the Work after the date of Substantial Completion.

D. Owner may, if it finds it necessary, occupy or use a portion or portions of the Work prior to or after Substantial Completion thereof. Occupancy or use of a portion or portions of the Work shall not constitute acceptance of the Work by Owner nor relieve Contractor of its obligations and/or liabilities hereunder.

E. After Substantial Completion **<u>of all of the Work</u>** has occurred, Contractor may make application for Final Acceptance to Owner. Such application may be made only if:

i. Substantial Completion (as defined herein) has occurred (i.e., all items of correction have been completed to the satisfaction of Owner, the Work has passed Final Inspection by Owner and Owner has issued a Certificate of Substantial Completion); and,

ii. Owner has received all maintenance and operating instructions for equipment and/or systems provided hereunder, schedules, guarantees, bonds, certificates of inspection, applicable certifications, Shop Drawings, record documents and other documents required to be prepared and/or delivered to Owner hereunder; and,

iii. Owner has received all fully executed Waiver and Release Forms (including Waiver and Release Forms for Final Payment) from the Contractor and all Subcontractors (as defined herein) on Waiver and Release Forms which are attached hereto in Section VII of the Contract Documents; and,

iv. Owner has received Payment Forms for all remaining amounts due and owing but yet unpaid for the Work.

F. If Contractor has complied with all of the terms and conditions contained in Sections 30 of this Agreement for all of the Work, Owner shall issue Final Acceptance to Contractor for that part of the Work which is in compliance with all of the above.

31. Use of the Premises

A. Contractor shall comply with and enforce the rules and requirements of Owner and all applicable laws, regulations, ordinances and permit conditions with reference to deliveries, storage of equipment and/or material, enclosures, barriers, signs, advertisements, smoking, and deportment of employees on the premises.

B. Contractor shall conduct its operations at the premises in such a manner as to cause a minimum of inconvenience or disturbance to or interference with the normal and uninterrupted utilization of existing premises, Facilities, business operations and services adjacent to or in the vicinity of the premises. Operations which could prevent access thereto, interrupt, restrict or otherwise infringe upon the utilization or business operation thereof, shall be coordinated with Owner prior to the initiation of such operations. Contractor shall assure free, convenient, unencumbered and direct access to properties neighboring the Site for owners of such properties and their respective tenants, agents, invitees and guests.

C. Facilities shall not be interrupted without approval from Owner as to time and duration. No Facilities serving existing Site operations shall be discontinued until new service connections are installed (unless temporary connections are made to serve such Site operations).

D. The Work shall be performed during daylight hours. Non-daylight work must be approved by Owner in writing.

E. All personal vehicles shall be parked at a location designated by Owner. Only essential work related vehicles will be permitted on the Site.

F. All of Contractor's personnel including Subcontractors shall sign in and out daily at the Site, as required by Owner. Visitors, including delivery personnel, shall be escorted by Contractor's personnel while on Owner's property.

32. Housekeeping

A. Contractor shall maintain the Site, all roadways utilized to access the Site and all working areas in a reasonably clean and orderly condition. Contractor shall perform cleanups when necessary or as ordered by Owner. In no event shall cleanups be performed less frequently than once per week.

B. Contractor shall leave all surfaces free from any contamination resulting from performance of the Work. Upon completion or termination of the Work, Contractor shall remove from the Site and from all public and private property, at its own expense, all temporary structures and Facilities, tools, excess construction materials, fences and scaffolding which remain from its performance of the Work or operations hereunder. All waste materials, rubbish and all other debris of any kind resulting from performance of the Work or operation hereunder shall be disposed of pursuant to the provisions of this Section of the Agreement and the Contract Documents.

C. Owner shall provide a container for collection of all construction and other waste produced by Contractor, its employees and Subcontractors. Contractor shall be responsible for collection and delivery of the waste to the container and shall be responsible for maintaining the waste in accordance with all safety laws, rules, regulations, standards, ordinances, orders, Site permit conditions and precautions. Contractor warrants that such waste shall not contain any hazardous, explosive, highly flammable, infectious, pathological, radioactive, toxic or illegal waste as defined under any applicable laws, regulations or operating permits. Owner shall dispose of such waste.

33. Temporary Facilities

Contractor shall provide and secure all such temporary facilities and utilities as necessary to complete the Work. Such facilities and utilities shall include, but are not limited to, the following:

A. Pumps and hoses required to convey all water;

B. Toilets and sanitary facilities;

C. Commercial electrical power, if available;

D. Compressed air;

E. Signs, barricades, warning lights, scaffolding, shoring, sheeting, bracing and all safety devices;

F. Field office(s) and phone service; and/or

G. Temporary storage buildings.

34. Miscellaneous Terms and Conditions

A. Separate Contracts

Separate contracts may be awarded for different parts of the Work and/or for various types of Work at the Site. Contractor shall afford other contractors and Owner (if applicable) working on the Site reasonable opportunities for the receipt and storage of their materials and equipment and shall coordinate its work with theirs at no cost to Owner.

B. Additional, Omitted, or Changed Work

i. Owner may authorize minor variations in the Work from the terms and conditions of the Contract Documents including, but not limited to, the Contract Drawings and Technical Specifications which do not involve an adjustment in the Agreement Price or the Agreement Time and are consistent with the overall intent of the Contract Documents. Such authorization may be implemented by a Field Order issued to Contractor and will be binding on Contractor who shall perform the Work involved promptly. If Contractor believes that a Field Order from Owner justifies an increase in the Agreement Price or an extension of the Agreement Time, Contractor shall send a written notice to Owner requesting a Change Order described below within five (5) days after receipt by Contractor of such Field Order otherwise, Contractor shall perform all work required by the Field Order promptly and no change in the Agreement Price nor Agreement Time shall be permitted.

ii. Owner, without invalidating the Agreement may, in its sole discretion, order changes in the Work or the Contract Documents within the general scope of this Agreement consisting of additions, deletions or other revisions, with the Agreement Price and the Period of Performance being adjusted accordingly. However, if Owner orders portions or all of the Work not to be performed, Owner shall do so in writing and Contractor shall delete such work as is indicated in the notice from the Work to be performed pursuant to this Agreement and shall reduce the Agreement Price and Period of Performance in proportion to such reduction. Notwithstanding any term or condition of this Agreement, a Change Order need not be executed to reflect Owner's deletion of Work from the scope of the Work but <u>may</u> be executed to reflect such change.

iii. Unless otherwise provided herein, a Change Order requested by Contractor shall be considered by

Owner only if Contractor makes a request for a Change Order by sending written notice to Owner promptly but in no event later than five (5) days after the occurrence of the event giving rise to the request for a Change Order otherwise, Contractor shall not have a right to submit a Change Order to Owner for such event and no change in the Agreement Price nor Agreement Time shall be permitted. The notice to Owner must state the specific nature of the request. No request by Contractor for a change in the Contract Documents or adjustment in the Agreement Price or Agreement Time will be valid if not submitted in accordance with this Paragraph.

iv. If Owner considers a Change Order to be acceptable, it shall be executed by Owner's Authorized Representative. If Contractor considers a Change Order to be acceptable, it shall be executed by Contractor's duly authorized representative or Superintendent. The form of Change Order to be used hereunder is provided in Section VII of the Contract Documents. Change Orders must be fully executed by both parties hereto prior to performance of the Extra Work which is the subject of the Change Order. Any changes in the terms or conditions of the Contract Documents as authorized by a Change Order fully executed by both parties hereto shall be performed under the applicable conditions of the Contract Documents (not modified by such Change Order). Changes that result in an increase in Agreement Price shall be calculated in accordance with the following methods:

a. Firm Lump Sum - If Owner requests, Contractor shall submit a written proposal covering the Extra Work on a firm lump sum basis. Owner shall review such proposal and upon mutual agreement, a Change Order to the Agreement shall be issued; and/or

b. Fixed Unit Prices - If Owner requests, and fixed unit prices are established in Section IX of the Contract Documents, then the increase in the Agreement Price shall be computed using such prices, except, however, these fixed unit prices shall apply only for quantities fluctuation of ±20 percent of the original quantity. Quantity fluctuation in excess of ±20 percent will require a re-evaluation of the fixed unit prices. If the fixed unit prices are not established in the Agreement or Contract Documents or such re-evaluation requires that different prices should apply, then Owner and Contractor shall negotiate and mutually agree upon fixed unit prices to apply to such changed work; and/or

c. Actual Cost - If Owner requests, Contractor shall perform the Extra Work covered by any increase in the Agreement Price on the basis of the actual cost incurred plus allowances for overhead and profit as provided herein. The increase in the price shall be computed as follows:

v.. The direct cost of labor to Contractor at the rates set forth in Section IX of the Contract Documents shall be used, or, if no rates are attached, the effective rates established by any applicable labor agreement, including any surcharges contained in such labor agreement for fringe benefits, payroll taxes, and insurance shall apply. Such labor costs shall include all classifications up to and including General Foremen, but shall not include Contractor's clerical and supervisory employees, regardless of classification. Contractor shall receive an allowance of ten percent (10%) total for overhead and profit on the cost described in this Paragraph;

vi. The actual cost of materials incorporated into the Extra Work shall be used. Contractor must receive written authorization from Owner to furnish such materials prior to incorporation of such materials into the Extra Work. Contractor must establish that it has endeavored to obtain such materials at the lowest available prices and shall verify the cost of all materials by submitting the actual invoice. Material usage shall be subject to verification by Owner. Contractor shall receive an allowance of ten percent (10%) total for overhead and profit on the costs described in this Paragraph;

vii. The actual cost for the Extra Work subcontracted by Contractor will be allowed only when each Subcontractor has been approved in writing by Owner before Contractor commences such Extra Work. Only the net cost to Contractor shall be considered a cost hereunder that may be billed to Owner, it being understood that, on any actual cost work by its Subcontractor(s), that allowances for tools, supplies, overhead, supervision and profit to the Subcontractor(s) shall not exceed ten percent (10%);

viii. The actual cost of equipment rented by Contractor from third parties not affiliated with Contractor at no more than published rates (i.e., Bluebook Equipment Rates) plus operating costs, less the applicable discount associated with the area where the Work is being performed shall be used. Contractor shall receive an allowance of ten percent (10%) total for overhead and profit on the costs described in this Paragraph; and

ix. The cost of rental of Contractor-owned equipment which shall include the cost of fuel, oil, lubrication, supplies, small tools, necessary attachments, repairs and maintenance, depreciation, storage and insurance at rates which are attached hereto in Section IX of the Contract Documents shall be used. Such costs shall not exceed the rental rates as published in the most current Bluebook Equipment Rate Guide. If rates are not attached hereto, then the cost of such equipment shall be at actual cost not to exceed the rental rates published in the most current Bluebook Equipment Rate Guide. Hourly rental charges of equipment on the Site shall be on the basis of 1/176th of monthly rates. Operators of rental equipment shall be paid in accordance with the "labor" provisions of Section 34 of this Agreement.

x. For all purposes of the Contract Documents, the profit and overhead allowances provided herein shall be deemed complete compensation to Contractor for all cost attributed to or apportioned to the Extra Work. By way of illustration, overhead and profit shall be deemed to include, but not be limited to: Contractor's profit; cost of capital; supervision; clerical and non-manual labor; all tools having a replacement value of less than $200; expendable supplies; warehousing costs; local transportation of material and labor; all expenses of Contractor prior to beginning the Extra Work; preparatory work performed by Contractor prior to beginning the Extra Work; Extra Work performed by Contractor which does not meet the standards to which the Work should be performed under the terms and conditions of the Contract Documents, including the cost of correcting or replacing such Extra Work, taxes on Contractor's income, profit, franchise, occupational license, or personal property; and, fines or assessments against Contractor by any governmental authority.

xi. The compensation established herein for any change ordered by Owner shall be the sole and exclusive consideration for such change. Any increased overhead, extension of the Agreement Time, inefficiencies, and all other costs and profits are incorporated into the compensation established pursuant to this Section of the Agreement and are agreed upon by Contractor.

xii. If notice of any change affecting the Work or the provisions of the Contract Documents (including, but not limited to, the Agreement Price or Agreement Time) is required by the provisions of any bond to be given to a surety, the giving of any such notice shall be Contractor's responsibility, and the amount of each applicable bond shall be increased by any increase in the Agreement Price caused by such Change Order.

C. If a dispute arises Owner and Contractor will attempt to settle any dispute arising out of or relating to this Agreement through cooperation and negotiation in good faith. Either party may initiate such negotiations at any time upon written request to the other. Either party may demand that the dispute be submitted to mediation, by written notice to the other party. When such a demand is made, the parties shall within ten (10) days jointly make arrangements for the mediation of the dispute within the State of Maine with a mutually agreeable party ("ADR Service Provider"), whose procedures for mediation of business disputes in effect on the date of the written demand for mediation shall govern the mediation in all respects, except as modified by written agreement of the parties.

35. Right to Audit

INTENTIONALLY OMITTED

36. Notice

Any notice required under this Agreement shall be given by and shall correspondingly be deemed received as follows: personal delivery (on the date of delivery); or, telecopy [on the date of transmission (if received during normal business hours)]; or, overnight express mail (on the day after delivery to a reputable overnight delivery service or the U.S Postal Service) or by registered or certified U.S. Mail, return receipt requested, (on the third day after being post-marked by the U.S. Postal Service); if addressed to the party to whom intended, and is sent with sufficient prepaid postage or delivery fees. Notice shall be given to the parties at the following addresses:

To Owner:

One copy of notice shall also be sent to the Engineering Department of Owner to the attention of Director of Engineering at: Casella Waste Systems, Inc.
25 Greens Hill Lane
Rutland, Vermont 05701
802-770-5030 (fax)

One copy of notice shall also be sent to the Legal Department of Owner to the attention of the General Counsel at: 25 Greens Hill Lane
Rutland, Vermont 05701
802-770-5030 (fax)

To Contractor: ________________
____
____

Either party may change the location for receipt of notice hereunder by providing written notice to the other party as aforesaid.

37. Copies of Contract Documents Furnished to the Contractor

Upon execution of this Agreement, Owner may, if requested, provide one (1) copy of the Contract Documents to Contractor free of charge. Any additional copies shall be purchased for the cost of reproduction and handling.

38. Law and Severability

This Agreement is to be governed by the laws of the location of the Work. In the event that any provision(s) or portion of such provision(s) of the Contract Documents shall be void, unlawful or unenforceable, such provision(s) or portions thereof, shall be deemed stricken from the Contract Documents, but the Contract Documents shall not otherwise be affected and the remaining provisions, or portions thereof, shall continue in full force and effect.

39. Modification and Non-waiver

The parties agree that no change or modification to the Contract Documents, or any documents incorporated by reference herein or otherwise made a part of the Contract Documents, shall have any force or effect unless the change is in writing, dated and made a part of this Agreement. The execution of the change shall be authorized and signed in the same manner as this Agreement or as authorized by the Change Order provisions of this Agreement. In addition, any failure by Owner at any time or from time to time, to require the strict adherence to and performance of the terms or conditions of the Contract Documents shall not constitute a waiver by Owner nor impair Owner's right to enforce such terms or conditions or any other terms or conditions of the Contract Documents.

40. Assignment

A. Contractor may not assign or subcontract any portion of the Work, right to payment or any terms or conditions of the Contract Documents without the prior written approval of Owner. The parties agree that there are no third party beneficiaries to this Agreement.

B. No assignment, transfer, or subcontract, even though consented to, shall relieve Contractor of its obligations, responsibilities and liability under the Contract Documents.

C. Should any assignee fail to perform the Work undertaken by it in a proper manner, Owner may, at Owner's option, require Contractor to terminate such assignment.

D. Owner may, in its sole discretion, freely assign this Agreement to any of its parent, subsidiary or affiliated companies or any other individual or entity; provided, however, Owner shall remain primarily responsible for the financial arrangements set forth in this agreement.

41. Headings

All headings in this Agreement have been inserted for convenience of reference only and are not to be considered a part of this Agreement nor shall they in any way affect the interpretation of this Agreement.

42. Separate Counterparts and Telecopy

This Agreement may be executed in separate counterparts which shall collectively and separately be considered one and the same Agreement. No party shall be bound by this Agreement until Owner and Contractor have fully executed it. In addition, a telecopy or facsimile of this Agreement (including, but not limited to, executed signature pages) shall have the same legal force and effect as an original. If this Agreement is executed by telecopy or facsimile, originals of the executed Agreement shall be forwarded to both parties as soon as reasonably possible.

43. Remedies and Rights Not Exclusive

No remedies or rights herein conferred upon Owner are intended to be exclusive of any remedy or right provided by law, but each shall be cumulative and shall be in addition to every other remedy or right given hereunder or now or hereafter existing at law or in equity (including, but not limited to, the remedy of specific performance).

44. Approvals, Authorizations, Certifications, Reviews and/or Concurrences, etc. By Owner, Engineer or CQA Consultant

Any approvals, authorizations, certifications, reviews, observations, acceptances (including, but not limited to, Final Acceptance), progress payments, Final Payment, consents, inspections (including, but not limited to, Final Inspection), verifications, beliefs, monitoring, testing, opinions, indications of satisfaction, and/or concurrences by Owner, Engineer or CQA Consultant does not constitute acceptance, approval, certification nor assurance of completeness, quality, or accuracy concerning details, dimensions and quantities and shall not relieve Contractor of any obligations, responsibility or liability for Contractor's active or passive negligence, willful misconduct or strict liability, defects in workmanship, proper performance of the Work in a good and workmanlike manner, in accordance with the Contract Documents, and pursuant to the proper manner, means, methods, techniques, management, sequences and procedures of construction or safety nor shall such actions on Owner's part cause any liability or responsibility to be attributed to Owner. In addition, Contractor agrees to hold Owner indemnify, defend and hold harmless Owner from all claims, lawsuits, damages, costs, expenses (including, but not limited to, all reasonable attorneys', professional engineering, sampling and testing, experts' and other consultants' fees and charges) and liability for such actions taken by Owner as reflected in Section 34 of this Agreement.

45. Integration and Interpretation

This Agreement shall include the following documents which were previously sent to and received by Contractor in the Bid Package entitled "____" dated ____________, and which is incorporated by reference into this Agreement as fully as if set forth herein in their entirety:

A. Section Number — Title

Section Number	Title
I	Invitation to Bid (Attached)
II	Instructions to Bidder (Attached)
III	Bid Forms and Bid Form Attachments (Except for Bid Form "A")
IV	Technical Specifications

V	Contract Drawings
VI	CQA Plan (None included in the Contract Documents)
VII	Construction Agreement and Forms

B. The various Contract Documents that constitute this Agreement shall, insofar as is possible, be so interpreted as to be consistent with one another. In the event of any conflict among the terms and conditions of the Contract Documents, this Agreement shall take precedence over all other documents.

C. If a discrepancy or inconsistency exists between the Contract Drawings and the Technical Specifications, Contractor shall notify Owner immediately for a resolution. Until a resolution is made by Owner, the Contract Drawings shall have precedence over the Technical Specifications (except as provided in paragraph "D" of this Section of the Agreement).

D. Among all Contract Documents (except for the Agreement which has precedence over all documents) the more stringent specifications shall have precedence over the less stringent specifications in such documents.

E. The document of the latest date shall govern unless such order of precedence is otherwise addressed in this Section of the Agreement.

F. All references in the Technical Specifications to "Industry Codes and Standards," or to "Manufacturer's Recommended Specifications," shall be deemed to refer to the latest editions or revisions of such "Standards" and "Specifications."

46. Entire Agreement and Binding Effect

This Agreement, including any Change Orders fully executed by both parties hereto and all documents incorporated by reference herein or specifically made a part of this Agreement as expressed herein, represents a negotiated agreement between and constitutes the entire agreement and understanding between Owner and Contractor. This Agreement shall supersede any prior written or oral negotiations, representations, agreements or understandings relating to the subject matter of the Contract Documents. In addition, this Agreement shall be binding upon all parties hereto, their heirs, successors, representatives and assigns.

NEWSME LANDFILL OPERATIONS, LLC	______________________________
By: ______________________________	By: ______________________________
Name: ______________________________	Name: ______________________________
Title: ______________________________	Title: ______________________________

NOTICE OF AWARD

DESCRIPTION OF WORK: Construction of Cell 11 Expansion at the Juniper Ridge Landfill facility in Old Town, Maine.

To:

The Owner has considered the Bid submitted by you on **__________**, for the above described work in response to its Notice and Instructions to Bidders dated ____________.

It is to the best interest of said Owner to accept your Bid in the amount of **(**$**_________.-)**; you are hereby notified that your Bid has been accepted

Dated this **__ day of ________**

NEWSME Landfill Operations, LLC
Owner

By:________________________________

Title:_____________________________

ACCEPTANCE OF NOTICE

Receipt of the above Notice of Award is hereby acknowledged this ______ day of ______, 20__

By:________________________________

Title:_____________________________

NOTICE TO PROCEED

DESCRIPTION OF WORK: Construction of Cell 11 Expansion and at the Juniper Ridge Landfill facility in Old Town, Maine, including mobilization, erosion control, site preparation, clearing, grubbing, base grading, placement of underdrain system, placement of composite liner system and placement of leachate collection system, as described at the Pre-Bid Meeting on ________, ____ as described in the specifications, and as shown on Contract Drawings**.**

To:

The Owner has considered the Bid submitted by you dated **___________** for the above described work in response to its Notice and Instructions to Bidders dated _________.

The total dollar amount covered by this notice is $**_______.-.**

Dated this **__ day of ________**

NEWSME LANDFILL OPERATIONS, LLC
Owner

By:________________________________

Title:_____________________________

ACCEPTANCE OF NOTICE

Receipt of the above Notice of Award is hereby acknowledged this **______** day of **_______**, 20__

By:________________________________

Title:_____________________________

CHANGE ORDER

CONTRACTOR:

____

____

____

OWNER:

____

____

____

SITE:

____

____

____

PROJECT:

____

____

____

CHANGE ORDER NUMBER: ______________

DATE: ______________________________

CONTRACT DESCRIPTION:

(Agreement) (Addendum) by and between

____

and

____

dated ________________________________

as thereafter amended or changed pursuant to the terms of such Agreement (hereinafter referred to as the "Agreement") for the proper performance of all necessary, required and/or related Work to:

____

____

at the Site.

Contractor and Owner, intending to be legally bound hereby, agree to make the following changes to the Agreement:

I. Contractor shall provide all necessary and required labor, materials, tools, services, equipment and incidentals to

____

____

____

II. This Change Order shall incorporate by reference the terms and conditions of the Agreement as fully as if reproduced in its entirety herein.

III. Contractor shall obtain the necessary insurance coverage and Certificates of Insurance as required by the Agreement prior to performing any Work.

IV. All other terms and conditions of the Agreement shall remain the same.
V. Change Order Summary:

A. The original Agreement Price was $ ______________________

B. Net change by previously authorized Change Orders $ ______________________

C. The Agreement Price prior to this Change Order was $ ______________________

D. The Agreement Price for this Change Order is $ ______________________

E. The new Agreement Price of the Agreement (including this Change Order) is $ ______________________

F. The Agreement Time for Substantial Completion of the Work required pursuant to the Agreement and this Change Order shall (be __________, 19___ (remain unchanged).

IN WITNESS WHEREOF, the parties hereto set forth their signatures as of the date first set forth above.

WITNESS:

By: ______________________

Printed Name: ______________________

CONTRACTOR:

By: ______________________

Printed Name: ______________________

Title: ______________________

WITNESS:

By: ______________________

Printed Name: ______________________

OWNER:

____

NEWSME Landfill Operations, LLC

By: ______________________

Printed Name: ______________________

Title:

ATTACHMENT C-1

WAIVER AND RELEASE FORMS (CONTRACTOR)

WAIVER AND RELEASE FORM
(PROGRESS PAYMENT FOR CONTRACTOR)

Upon receipt of a progress payment in the sum of $___________________ for labor, services, equipment, materials, permits, licenses and/or other goods or services (the "Goods and Services") provided to NEWSME Operations Landfill LLC (the "Owner") regarding the Work performed by ___________ (the "Contractor") at the Juniper Ridge Landfill as further set forth in an agreement between Owner and Contractor, dated _____________, 20__, for _______ as thereafter amended or modified (hereafter referred to as the "Agreement"), Contractor on behalf of itself, its employees, agents, subcontractors, vendors, materialmen and suppliers, at any tier, (hereafter collectively and individually referred to as the "Releasors") does hereby, to the fullest extent permitted by law and to the extent of receipt of the amount of the progress payment reflected above hereby, waives, releases and forever relinquishes, *pro tanto*, any and all: mechanics' liens; levies of any kind; attachment liens; judgment liens; execution liens; stop notices; bond rights; claims, lawsuits, losses, damages, costs and expenses (including, but not limited to, all attorneys', professional engineering, testing and sampling, experts' and other consultants' fees and charges) (hereafter collectively and individually referred to as the "Claims") which the Releasors had previously, have at the present time or may have in the future pertaining to the Goods and Services furnished or installed in connection with the Work (as defined in the Agreement) including, but not limited to, such Claims against or concerning the following: retainage or other funds not yet paid in accordance with the terms and conditions of the Agreement, land, buildings, structures, additions, improvements or personalty constructed under the Agreement and/or arising out of the Work furnished or installed thereunder; and/or all other assets (hereafter collectively and individually referred to as the "Assets") of Owner its parent corporation, its subsidiar(y)(ies) and affiliated companies and their respective officers, directors, shareholders, agents, employees, representatives, subcontractors, their successors and assigns (hereafter collectively and individually referred to as the "Releasees").

In addition to, and not in limitation of, any term or condition contained in the Agreement, to the fullest extent permitted by law, Contractor shall indemnify, defend and hold Releasees harmless, from any Claims against Releasees or the Assets and shall fully satisfy of record any such Claims incurred by Releasees because of the Contractor's or any of the Releasors' performance of the Work and breach of any terms or conditions of the Agreement or this Waiver and Release, at Contractor's sole cost and expense (including, but not limited to, all recording, reasonable attorneys', professional engineering, experts' and other consultants' fees and charges). If Contractor fails to satisfy any such Claims of record within five (5) calendar days after Owner's request to Contractor to do so, Owner may, but is not obligated to, satisfy such Claims of record and charge all costs and expenses associated therewith (including, but not limited to, all reasonable attorneys', professional engineering, experts', recording and other consultants' fees and charges) to Contractor who shall be solely responsible to pay for such charges (at no cost to the Releasees).

This Waiver and Release Form covers a progress payment for the Goods and Services provided to Owner for Work performed through ________________ only and does not cover any retention or Goods and Services furnished or installed after that date.

WITNESS:	**CONTRACTOR:**
	______________________
By: ______________________	By: ______________________
Printed Name: ______________________	Printed Name: ______________________
	Title:

WAIVER AND RELEASE FORM
(FINAL PAYMENT FOR CONTRACTOR)

Upon receipt of Final Payment in the sum of $___________________ for labor, services, equipment, materials, permits, licenses and/or other goods or services (the "Goods and Services") provided to NEWSME Operations Landfill LLC (the "Owner") regarding the Work performed by ________________ (the "Contractor") at the Juniper Ridge Landfill as further set forth in an agreement between Owner and Contractor, dated _____________, 20__, for _____________ as thereafter amended or modified (hereafter referred to as the "Agreement"), Contractor on behalf of itself, its employees, agents, subcontractors, vendors, materialmen and suppliers, at any tier, (hereafter collectively and individually referred to as the "Releasors") does hereby to the fullest extent permitted by law:

A. Waive, release and forever relinquish any and all mechanics' liens; levies of any kind; attachment liens; judgment liens; execution liens; stop notices; bond rights; claims, lawsuits, losses, damages, costs and expenses (including, but not limited to, all attorneys', professional engineering, testing and sampling, experts' and other consultants' fees and charges) (hereafter collectively and individually referred to as the "Claims") which the Contractor had previously, has at the present time or may have in the future pertaining to such Goods and Services furnished or installed in connection with the Work (as defined in the Agreement) including, but not limited to, such Claims against or concerning the following: retainage or other funds not yet paid in accordance with the terms and conditions of the Agreement, land, buildings, structures, additions, improvements or personalty constructed under the Agreement and/or arising out of the Work furnished or installed thereunder; and/or all other assets (hereafter collectively and individually referred to as the "Assets") of Owner, its parent corporation, its subsidiar(y)(ies) and affiliated companies and their respective officers, directors, shareholders, agents, employees, representatives, subcontractors, their successors and assigns (hereafter collectively and individually referred to as "Releasees"); and,

B. Warrant that there are no amounts or Claims owed by the Contractor or the Releasors to any person or entity which could become the basis for a Claim against Releasees and in addition to, but not in limitation of, any terms or conditions contained in the Agreement, shall indemnify, defend and hold Releasees harmless, from any and all Claims whatsoever arising at law or in equity, or otherwise which Releasors may have against Releasees or the Assets by reason of any matter, cause or thing whatsoever arising out of performance of the Work, the Agreement and/or this Waiver and Release. Contractor shall fully satisfy of record any such Claims against Releasees or the Assets at Contractor's sole cost and expense (including, but not limited to, recording, reasonable attorneys', professional engineering, experts' and other consultants' fees and charges). If Contractor fails to satisfy such Claim of record within five (5) calendar days after Owner's request to Contractor to do so, Owner may, but is not obligated to, satisfy such Claim of record and charge all costs and expenses associated therewith (including, but not limited to, all reasonable attorneys', professional engineering, experts', recording and other consultants' fees and charges) to Contractor who shall be solely responsible to pay for such charges (at no cost to Releasees).

WITNESS:	**CONTRACTOR:**
	_____________________
By: ______________________	By: ______________________
Printed Name: ______________________	Printed Name: ______________________
	Title:

ATTACHMENT C-2

WAIVER AND RELEASE FORMS (SUBCONTRACTORS)

WAIVER AND RELEASE FORM
(PROGRESS PAYMENT FOR SUBCONTRACTOR)

Upon receipt of a progress payment in the sum of $___________________ for all labor, services, equipment, rental, materials, permits, licenses and/or other goods or services (hereinafter the "Goods and Services") for _____________________ _______________________________________ (attach purchase order, agreement or scope of work and mark as Exhibit A) (hereafter referred to as the "Work") which is provided to ______________ (the "Contractor") as part of the Work performed pursuant to an agreement between Contractor and NEWSME Operations Landfill LLC (the "Owner") dated ______________, 20__, for ____________ at Juniper Ridge Landfill as thereafter amended or modified (the "Agreement"), the Undersigned on behalf of itself, its employees, agents, subcontractors, vendors, materialmen and suppliers, at any tier, (hereafter collectively and individually referred to as the "Subcontractor Releasors") does hereby, to the fullest extent permitted by law and to the extent of receipt of the amount of the progress payment reflected above hereby, waives, releases and forever relinquishes, *pro tanto*, any and all: mechanics' liens; levies of any kind; attachment liens; judgment liens; execution liens; stop notices; bond rights; claims, lawsuits, losses, damages, costs and expenses (including, but not limited to, all attorneys', professional engineering, testing and sampling, experts' and other consultants' fees and charges) (hereafter collectively and individually referred to as the "Claims") which the Subcontractor Releasors had previously, have at the present time or may have in the future pertaining to the Goods and Services furnished or installed in connection with the Work including, but not limited to, such Claims against or concerning the following: retainage or other funds not yet paid in accordance with the terms and conditions of the Agreement, land, buildings, structures, additions, improvements or personalty constructed under the Agreement and/or arising out of the Work furnished or installed thereunder; and/or all other assets (hereafter collectively and individually referred to as the "Assets"), of Owner its parent corporation, its subsidiar(y)(ies) and affiliated companies and their respective officers, directors, shareholders, agents, employees, representatives, subcontractors, their successors and assigns (hereafter collectively and individually referred to as the "Releasees").

To the fullest extent permitted by law, the Undersigned shall indemnify, defend and hold the Releasees harmless, from any Claims against the Releasees or the Assets and shall fully satisfy of record any such Claims against the Releasees or the Assets at the Undersigned's sole cost and expense (including, but not limited to, all recording, reasonable attorneys', professional engineering, experts' and other consultants' fees and charges) arising out of performance of the Work and breach of any terms or conditions of this Waiver and Release by the Undersigned or the Subcontractor Releasors. If the Undersigned fails to satisfy any such Claims of record within five (5) calendar days after Owner's request to the Undersigned to do so, Owner may, but is not obligated to, satisfy such Claims of record and charge all costs and expenses associated therewith (including, but not limited to, all reasonable attorneys', professional engineering, experts', recording and other consultants' fees and charges) to the Undersigned who shall be solely responsible to pay for such charges (at no cost to the Releasees).

This Waiver and Release Form covers a progress payment for the Goods and Services provided to Contractor or Owner for the Work performed through ________________ only and does not cover any retention or Goods and Services furnished or installed after that date.

WITNESS:

By: ______________________________

Printed Name: ______________________________

CONTRACTOR:

By: ______________________________

Printed Name: ______________________________

Title:

WAIVER AND RELEASE FORM
(FINAL PAYMENT FOR SUBCONTRACTOR)

Upon receipt of Final Payment in the sum of $___________________ for all labor, services, equipment, rental, materials, permits, licenses and/or other goods or services (hereinafter the "Goods and Services") for _____________________ _______________________________________ (attach purchase order, agreement or scope of work and mark as Exhibit A) (hereafter referred to as the "Work") which is provided to _____________ (the "Contractor") as part of the Work performed pursuant to an agreement between Contractor and NEWSME Operations Landfill LLC (the "Owner") dated ______________, 20__, for ______________ at Juniper Ridge Landfill as thereafter amended or modified (the "Agreement"), the Undersigned on behalf of itself, its employees, agents, subcontractors, vendors, materialmen and suppliers, at any tier, (hereafter collectively and individually referred to as the "Subcontractor Releasors") does hereby to the fullest extent permitted by law:

A. Waive, release and forever relinquish any and all mechanics' liens; levies of any kind; attachment liens; judgment liens; execution liens; stop notices; bond rights; claims, lawsuits, losses, damages, costs and expenses (including, but not limited to, all attorneys', professional engineering, testing and sampling, experts' and other consultants' fees and charges) (hereafter collectively and individually referred to as the "Claims") which the Subcontractor Releasors had previously, have at the present time or may have in the future pertaining to such Goods and Services furnished or installed in connection with the Work including, but not limited to, such Claims against or concerning the following: retainage or other funds not yet paid in accordance with the terms and conditions of the Agreement, land, buildings, structures, additions, improvements or personalty constructed under the Agreement and/or arising out of the Work furnished or installed thereunder; and/or all other assets (hereafter collectively and individually referred to as the "Assets") of Owner, its parent corporation, its subsidiar(y)(ies) and affiliated companies and their respective officers, directors, shareholders, agents, employees, representatives, subcontractors, their successors and assigns (hereafter collectively and individually referred to as "Releasees"); and,

B. Warrant that there are no amounts or Claims owed by the Subcontractor Releasors to any person or entity which could become the basis for a Claim against Releasees and shall indemnify, defend and hold Releasees harmless, from any and all Claims whatsoever arising at law or in equity, or otherwise which Subcontractor Releasors may have against Releasees or the Assets by reason of any matter, cause or thing whatsoever arising out of the Undersigned's or Subcontractor Releasors' performance of the Work or this Waiver and Release. The Undersigned shall fully satisfy of record any such Claims at the Undersigned's sole cost and expense (including, but not limited to, recording, reasonable attorneys', professional engineering, experts' and other consultants' fees and charges). If the Undersigned fails to satisfy such Claim of record within five (5) calendar days after Owner's request to the Undersigned to do so, Owner may, but is not obligated to, satisfy such Claim of record and charge all costs and expenses associated therewith (including, but not limited to, all reasonable attorneys', professional engineering, experts', recording and other consultants' fees and charges) to the Undersigned who shall be solely responsible to pay for such charges (at no cost to Releasees).

WITNESS:	**CONTRACTOR:**
By: ______________________	By: ______________________
Printed Name: ______________________	Printed Name: ______________________
	Title:

SECTION VIII

PERFORMANCE AND PAYMENT BONDS
(NOT REQUIRED UNDER THIS CONTRACT)

SECTION IX

THE AGREEMENT PRICE
(FEES, CHARGES, RATES AND ADDITIONAL TERMS AND CONDITIONS)

TECHNICAL SPECIFICATIONS

SECTION 01010

SUMMARY OF WORK

1.01 WORK COVERED BY CONTRACT DOCUMENTS: These Contract Documents define the requirements of the construction of the Landfill Expansion of the Juniper Ridge Landfill site in Old Town, Maine. Work shall include furnishing all materials (including materials source testing as described in Section 02200), equipment, labor, and supervision, and performing all operations required to complete the work as shown on the Contract Drawings and as described in the site's Quality Assurance/Quality Control Plan and the specifications contained herein, and as evidently necessary to complete the work. Work shall include, but not be limited to, the following items:

Expansion Construction. Provide the equipment, labor, tools, materials, and supervision necessary for the successful completion of the work as detailed in the contract documents. The work includes, but is not limited to:

- Site layout;
- Clearing and grubbing of the site;
- Chipping of all stumps and wood debris (Contractor shall use or stockpile grindings for future erosion control purposes);
- Installation of all required erosion control measures including dewatering in accordance with MDEP Best Management Practices;
- Abandonment and/or removal of the existing infrastructure designated as such;
- Excavation or fill to required subgrades followed by compaction as indicated herein;
- Stockpile excess soils and materials where indicated;
- Installation of the Landfill Expansion subgrade base preparation materials;
- Installation of Landfill Expansion underdrain system including HDPE pipe, underdrain sand, and geotextile;
- Installation of the 1 foot layer of imported clay soil;
- Installation of the Landfill Expansion secondary HDPE geomembrane, or augmented secondary liner consisting of one foot of clay, GCL and HDPE geomembrane
- Installation of the Landfill Expansion leak detection system, including drainage geocomposite, HDPE pipe, drainage sand, cleanouts, and sampling ports;

- Installation of Landfill Expansion primary composite liner system including clay layer, GCL, and HDPE geomembrane;

- Installation of the leachate collection system including drainage geocomposite, HDPE pipe, drainage sand, filter stone, drainage stone, drainage inlet structures, leachate collection sump and pump station grid, connection to the above-ground leachate storage tank force main;

- Dust control as specified in the Contract Documents;

- Loam, seed and mulch all areas required by Contract Document and all areas disturbed during construction;

- Provide third-party inspection and support for leak location survey (Landfill Expansion primary liner)

- Perform layout and as-built survey by Professional Land Surveyor of finished work including, but not limited to the following locations: all pipe and conduit locations, location of the anchor trench and tie-in seams, all culvert inverts, all manhole inverts and rim elevations, and finish topography on a 50-foot grid including toe and crests of berms or dikes, establish benchmark for aerial survey target on all new precast vaults and manholes;

- Provide the services of a private utility location service (On Target) for locations of underground utilities within the property boundary and the services of Dig Safe for location of underground utilities within the public right-of-way (as necessary);

- Clean-up of the site following successful Contract completion;

- Maintain, repair, replace and remove (as necessary) all erosion control measures including, but not limited to, siltation fence, hay bales and stone check dams at the site to control erosion and sedimentation as required by the Contract Documents.

- Provide the necessary labor, equipment, materials, and supervision to assist the geomembrane installer as required including, but not limited to:

    - Unloading and field storage of the liner materials in accordance with manufacturer's recommendations,
    - Handling and deployment of the liner materials in accordance with manufacturer's recommendations,
    - Excavation and backfill of all liner anchor trenches,
    - Furnishing leachate collection sand for use in sand bags of the geomembrane anchoring system,
    - Preparation of all liner subgrade materials including moisture control, picking stones, as directed by the Engineer or CQA agent, providing a smooth rolled surface to the tolerances required by the Engineer or CQA agent, and assist in cleaning of the geomembrane liners as necessary,
    - Coordination of work schedule to accommodate the liner installation including weekend and holiday work as necessary, and allowing sufficient

turnaround time for results of destructive seam testing (typically 24 hours) prior to placing additional material over the HDPE seams, and

- Placement of a minimum 3 feet of suitable material, approved by the Engineer or CQA agent, over the liner materials before traveling on the liner with equipment other than low-pressure equipment approved by the Engineer or CQA agent.

1.02 SCHEDULE OF WORK: The timing of the work to be performed is critical. All phases of the project must be completed no later than the dates shown on the Bid Schedule. The Contractor will schedule work associated with the landfill's liner system so that exposure of the soil liner materials to the elements is minimized and that in-place geosynthetic clay liner is covered in accordance with the manufacturer's recommendations on a daily basis. The General Contractor shall also schedule construction of the landfill's liner in conjunction with the HDPE geomembrane installer's schedule. The General Contractor is encouraged to perform construction activities during normal working hours. The Contractor shall provide a detailed construction schedule to the Owner prior to beginning construction activities on-site.

1.03 CONTRACTOR USE OF PREMISES:

The Juniper Ridge Landfill is an active facility that receives wastes on a daily basis. It will be the responsibility of the Contractor to coordinate with NEWSME Operations with regard to use of premises, including haul routes and vehicular access. All details must be established prior to the preconstruction conference and shall be presented to NEWSME Operations at or before the preconstruction conference. The Contractor shall coordinate all construction activities so as not to interfere with active landfilling operations.

The Contractor shall obey all traffic, noise, and dust control policies of the Juniper Ridge Landfill, including primary access roads. The Contractor shall minimize the use of equipment engine brakes at the intersection of Route 16 and the site access road.

1.04 PROTECTION OF PROJECT WHILE UNDER CONSTRUCTION:

A. The Contractor will be responsible for providing complete protection of the contract limits of the Project during construction from any acts of nature or man, such as, but not limited to, floods, wind damage, earth slides, and slope failures. Damage to the Project caused by such acts will not be sufficient cause to increase contract costs to the Owner.

B. The Contractor shall take every precaution to ensure that no siltation of stormwater drainage courses occur when working in those areas.

C. The Contractor shall protect existing on-site structures from damage during construction, including: monitoring wells, power lines, maintenance facility, liner systems of existing cells, existing leachate collection and transport systems and LFG infrastructure, etc.

D. The Contractor shall be responsible for all repairs required to correct damage made to existing on-site structures described above resulting from any construction activity. The Contractor shall also make the necessary repairs to the existing access roads including, but not limited to, regrading the primary and secondary access roads upon completion of the contract work.

1.05 COMPLIANCE WITH ENVIRONMENTAL PERMITS:

A. The Contractor shall comply fully with conditions of the MEDEP Board Order (see Appendix 1), MEDEP NRPA Permit By Rule Conditions, MEDEP Construction General Permit, and MEDEP "Maine Erosion and Sediment Control Handbook for Construction: Best Management Practices".

1.06 USE OF REGISTERED LAND SURVEYOR:

A. The Contractor will provide for the services of a Professional Land Surveyor (PLS) to layout base grades and leachate collection and transport system structures. A letter from the PLS certifying that the proposed work has been laid out in accordance with the Contract Drawings will be issued to NEWSME upon completion of the survey work. In addition, the Contractor will retain the services of a PLS to provide all the necessary as-built survey information to the Engineer upon completion of the project. At a minimum, as-built survey information will be required for cell limits, all leachate collection and transportation structure pipe inverts, and other areas of work as directed by the Owner's Authorized Representative. Permanent benchmarks have been established at the precast concrete valve pit near the leachate pond and at the landfill's maintenance facility. The PLS shall verify existing project benchmarks and establish additional project benchmarks on all proposed concrete vaults and manholes for future use as survey control points.

1.07 SUMMARY OF OWNER-FURNISHED MATERIALS AND SERVICES

NEWSME Operations will furnish the following materials and services:

- Field quality control material testing described in Specification Section 02200 Part 3.14, including borrow source construction testing and in-place construction testing. The General Contractor is only responsible for the borrow source (both on-site and off-site) characterization testing described in Section 02200 Part 1.04 and for all failing tests performed by the Owner.
- All quality control/quality assurance tests and conformance tests associated with geomembranes, GCL, and geotextiles.
- Power for use by General Contractor.
- On-site till material for use in containment berms barrier soil, fill soil for the expanded wood storage yard, flare pad area, and expanded construction and operations laydown area (excavation, screening, hauling, and placement of suitable barrier soils materials by Contractor).

1.08 APPROVED SUBCONTRACTORS

The General Contractor shall include in his bid the services of the following subcontractors for this project.

M.C. Electric (Mike Eber 207-852-9781)
Leak Location Services, Inc., San Antonio, Texas (Daren Laine 210-408-1241)

END OF SECTION

SECTION 01012

HEALTH AND SAFETY PLAN

PART 1 - GENERAL

1.01 RELATED WORK SPECIFIED ELSEWHERE: All Division 2 work specified in this contract applies to the work specified under this contract.

1.02 DESCRIPTION: This work shall consist of preparation of a Health and Safety Plan, submitted prior to the commencement of construction, and statement of safe working procedures.

PART 2 - EXECUTION

2.01 HEALTH AND SAFETY PLAN (HASP) REQUIREMENTS:

A. The HASP shall conform to guidance contained in "Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities" NIOSH/OSHA/USCG/EPA, October 1985 and 29 CFR 1910 (FR March 6, 1989).

B. The HASP will include, but not be limited to, the following:

1. Identification of potential hazards
2. Identification of a site Health and Safety Officer
3. Identification of the support zone, decontamination zone, and exclusion zone at the site
4. Air monitoring activities
5. Medical surveillance records
6. Personnel protective equipment requirements
7. Emergency and contingency planning

PART 3 - WORK PROCEDURES:

A. All work involving excavation below grade or otherwise involving a risk of worker exposure to landfill gases, leachate, or solid waste shall be performed in accordance with applicable Occupational Safety and Health Administration (OSHA) regulations, U.S.EPA Health and Safety Regulations, and the contractor's site Health and Safety Plan.

END OF SECTION

SECTION 01025

MEASUREMENT AND PAYMENT

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

1.02 WORK COVERED BY CONTRACT DOCUMENTS:

A. The Contractor shall furnish all labor, materials, tools, equipment, and supervision necessary for complete installation of the work covered by these Contract Documents.

B. Miscellaneous work items necessary to satisfactorily complete the project; and, for which no separate payment item is included in the contract item, shall not be measured and paid for separately, but shall be considered as incidental to the Contract bid item.

C. The Contractor shall acquaint himself with all work associated with each payment item and shall have no claim for his unfamiliarity with the requirement of various items.

1.03 BASIS OF MEASUREMENT AND PAYMENT:

Item 1 – Construction of the Landfill Expansion of the Juniper Ridge Landfill

Payment for the construction of Landfill Expansion of the Juniper Ridge Landfill site as shown on the Contract Drawings and incidental items shall include all equipment, labor, tools, and materials necessary for the successful completion of the work. The work includes, but is not limited to, mobilization, installation of erosion control measures as required, site clearing, and grubbing, excavation, backfill, construction of till berms, base grade preparation, placement of underdrain system, placement of imported clay layer, placement of secondary liner system, placement of leak detection system, placement of the primary composite liner system, leak detection survey, installation of leachate collection system, and loam placement, seeding, mulching.

The cost for this item will assume that the clay for the clay barrier layer of the Landfill Expansion composite liner system will be obtained from off-site.

1.04 METHOD OF MEASUREMENT AND BASIS OF PAYMENT (UNIT PRICES – ADD):

The following section describes the method of measurement and payment for work which may be necessary in addition to the work associated with the construction of the base bid item described herein and shown on the Contract Drawings. The additional work items shall only be undertaken upon written approval of the Engineer, and do not include any work items associated with or undertaken as a result of the construction of the base bid item.

A. Clearing and Grubbing: Measurement of additional clearing and grubbing will be the actual additional acreage stripped as measured by horizontal dimensions determined by a field survey. Payment for the accepted quantities of additional clearing and grubbing will be at the unit price per acre.

B. Regrading Waste: Measurement of additional regrading of waste will be the actual waste cubic yardage regraded as measured by the number of cubic yards measured in its original position by cross-sectioning the area prior to and after excavation of the material. Volumes will be computed by the average end area method or by other methods generally recognized as conforming to good engineering practice. Payment for the accepted quantities of waste grading will be at the unit price per cubic yard.

C. Common Excavation: Additional quantities of excavation of material will be measured by the number of cubic yards measured in its original position by cross-sectioning the area prior to and after excavation of the material. Volumes will be computed by the average end area method or by other methods generally recognized as conforming to good engineering practice. Payment for the accepted quantities of additional excavation of material will be at the unit price per cubic yard, including removal from the site and disposal, if necessary.

D. Excavation of Unsuitable Material: Additional excavation of unsuitable material will be measured by the number of cubic yards measured in its original position by cross-sectioning the area prior to and after excavation of the unsuitable material. Volumes will be computed by the average end area method or by other methods generally recognized as conforming to good engineering practice. Payment for the accepted quantities of additional excavation of unsuitable material will be at the unit price per cubic yard, including removal from the site and disposal, if necessary.

E. Open Rock Excavation: Open rock excavation shall be measured by cross-sectioning the ledge surface. The depth shall be between the sectioned surface and the proposed subgrade. Volumes will be computed by the average end area method or by other methods generally recognized as conforming to good engineering practice. All over excavation shall be at the Contractor's expense. Any sections over-excavated shall be brought to grade with crushed stone or glacial till as directed by the Resident Project Representative. Horizontal limits will be as shown on the Contract Drawings or within two feet of proposed precast concrete structures.

Rock excavation shall consist of removing hard igneous, metamorphic and sedimentary rock which cannot be excavated without drilling and blasting or drilling and splitting, and all boulders having a volume of 2 cubic yards or more. Rock excavation shall be performed mechanically with jackhammer or other excavation equipment. No blasting will be allowed on-site.

Payment for the accepted quantities of open rock excavation will be at the unit price per cubic yard, including removal from the site and disposal, if necessary.

F. Trench Rock Excavation: Trench rock excavation to be paid for will be measured on the following basis: The depth will be the vertical distance from the bottom of the pipe bedding to the surface of the ledge, measured on the centerline of the pipe. The trench width shown on the plans will be taken as the pay width. All over excavation shall be at the Contractor's expense. Any areas over excavated shall be brought to grade with crushed stone.

Rock excavation shall consist of removing hard igneous, metamorphic and sedimentary rock which cannot be excavated without drilling and blasting or drilling and splitting, and all boulders having a volume of 2 cubic yards or more. Rock excavation shall be performed mechanically with jackhammer or other excavation equipment. No blasting will be allowed on-site.

Payment for the accepted quantities of trench rock excavation will be at the unit price per cubic yard, including removal from the site and disposal, if necessary.

G. Aggregate Base and Subbase Material: Additional aggregate base and subbase material to be used in the access road construction will be the number of cubic yards, in-place, based upon the length, width, and depth of the aggregate base and subbase material. Payment for the accepted quantities of additional aggregate base and subbase material will be at the unit price per cubic yard.

H. Clay Borrow: Additional clay borrow material to be used during construction will be the number of cubic yards, in-place, based upon the length, width, and depth of the clay borrow material. Payment for the accepted quantities of additional clay borrow material will be at the unit price per cubic yard. Satisfactory completion of this work shall include placement of clay, compaction, testing, and other associated work.

I. Screened Till: Additional screened till material to be used during construction will be the number of cubic yards, in-place, based upon the length, width, and depth of the screened till material. Payment for the accepted quantities of additional screened till material will be at the unit price per cubic yard. Satisfactory completion of this work shall include placement of screened till, compaction, testing, and other associated work.

J. Common Borrow: Additional common borrow material to be used during construction will be the number of cubic yards, in-place, based upon the length, width and depth of the common borrow material. Payment for the accepted quantities of additional common borrow material will be at the unit price per cubic yard.

K. Siltation Fence or Bark Mulch Sediment Barrier: Measurement for additional siltation fence or bark mulch sediment barrier shall be by the linear foot installed. The accepted quantity of siltation fence will be paid for at the contract unit price per linear foot, which shall be full compensation for furnishing, placing, maintaining, and removal of the item.

L. Riprap: Additional quantities of riprap shall be the number of cubic yards, in-place, based upon the surface area and depth of the riprap. Payment for the accepted quantities of additional riprap will be at the unit price per cubic yard. Geotextile material shall be installed under riprap as shown on the Contract Drawings. The installation of geotextile shall be incidental to the riprap pay item and no additional payment will be made.

M. Erosion Control Blanket: Measurement for additional erosion control blanket shall be by the square foot of blanket installed. The accepted quantity of erosion control blanket will be paid for at the contract unit price per square foot, which shall be full compensation for furnishing, placing, and maintaining the erosion control blanket.

N. Seeding: The quantity of additional seeding will be based on field measurement upon establishment of a satisfactory vegetative cover. Additional seeding does not include seeding of areas disturbed as a result of the construction of the base bid item. Seeding includes soil preparation, fertilizer, lime, mulch, and erosion control mesh (if required by the Resident Project Representative). Payment for accepted quantities of additional seeding will be based upon the price per unit (1,000 sq ft).

O. Topsoil: If additional topsoil from off-site sources is required, the quantity shall be based on field measurement in-place. Payment for the accepted quantities of additional topsoil will be at the unit price per cubic yard.

P. Hay Bales: Measurement for additional hay bales shall be per each hay bale installed. The accepted quantity of hay bales will be paid for at the contract unit price per hay bale which shall be full compensation for furnishing, placing, maintaining, and removal (if necessary) of the hay bale.

Q. Stone: Measurement for additional stone for pipe bedding, stone check dams, drainage stone, sump stone or filter stone shall be per cubic yard of stone placed. The accepted quantity of stone will be paid for at the contract unit price per cubic yard which shall be full compensation for furnishing, placing, and maintaining (as necessary) the stone.

R. Sand: Additional drainage sand and leachate collection sand used during construction will be the number of cubic yards in-place, based upon the length, width, and depth of the sand material. Payment for the accepted quantities of additional sand material will be at the unit price per cubic yard.

S. Culverts: Measurement for additional culvert shall be along the centerline of the pipe. Payment for the accepted quantity of additional HDPE culvert will be made at the unit price per linear foot. Culvert pay items shall include all fittings and bedding materials. No other measurement and payment associated with this item shall be made.

T. Pipe: Measurement for additional pipe shall be along the centerline of the pipe. Payment for the accepted quantity of additional pipe will be made at the unit price per linear foot. Pipe pay items shall include all fittings and bedding materials. No other measurement and payment associated with this item shall be made.

U. Geocomposite Drainage Net, Liners, and Geotextiles: Measurement for additional geocomposite drainage net, 60 and 80-mil HDPE liner, geosynthetic clay liner, non-woven geotextile, and woven geotextile shall be by the square foot of material installed. The accepted quantity will be paid for at the contract unit price per square foot. The unit price shall be for all labor, materials, materials testing, and equipment required to install the material. This work shall also include handling and storage of the material and any other associated work.

V. Chain Link Fence. Measurement for additional chain link fence shall be by the linear foot of fence installed. The accepted quantity of chain link fence will be paid for at the contract unit price per linear foot, which shall be full compensation for furnishing and placing the chain link fence.

W. Litter Fence. Measurement for additional litter fence shall be by the linear foot of fence installed. The accepted quantity of litter fence will be paid for at the contract unit price per linear foot, which shall be full compensation for furnishing and placing the litter fence.

1.05 BASIS OF MEASUREMENT AND PAYMENT (DEDUCTIONS):

A. Changes in the contract work which result in reduced work will be measured based on the information shown on the Contract Drawings and at the contract unit prices. Measurements and volumes will be computed based on methods generally recognized as conforming to good engineering practice and acceptable to both the Contractor and the Resident Project Representative.

B. Costs of any conformance or construction testing that fails to meet the specifications contained herein, shall be borne by the contractor. The price shall include the cost of the failing test and any cost to resample the failing material including any shipping and handling. The engineer on a monthly basis will forward a bill with a cost breakdown to the contractor whom shall apply these in the monthly requisition for payment as a deduction from the contract work. If the laboratory performing the tests is brought into question by the contractor or any of his sub-contractors and it is decided to send any further testing to a new laboratory, the contractor (s) shall bear the cost of all new testing that will be required to demonstrate conformance of a questionable material. These “new” costs shall not be applied to the monthly requisition for payment as a deduction.

C. The Owner shall not pay for any conformance testing beyond the initial testing required to approve a material for use on this project. The Owner shall also not pay for any conformance tests required on construction materials which are required because the Contractor chooses to supply construction materials from more lots than required to meet the square footage testing frequency contained in the specifications. This does not relieve the requirement that representative samples of material used on the job be tested from each lot. The cost for this additional testing is the responsibility of the Contractor, and will be handled as described in paragraph B.

1.06 UNIT PRICES: Changes in the contract work shall be performed at the unit prices indicated on the proposal. The unit prices are gross prices, including the Contractor’s equipment, labor, supervision, and materials costs, entire mark-up, field or other costs, including general conditions, fringe benefits, overhead, and profit.

END OF SECTION

SECTION 01041

PROJECT COORDINATION

1.01 GENERAL:

The Contractor shall be responsible for the following:

A. Coordination of all work under this contract.

B. Compliance with requirements of all public agencies having jurisdiction over construction.

C. Making arrangements, as necessary, for temporary electricity, heat, water, telephone, sanitary facilities, first aid facilities, fire protection, and storage of materials and supplies and for the timely delivery to the job site.

D. Assisting the Resident Project Representative as required in the review of construction, the testing of materials, and construction layout surveys.

E. Maintaining up to date progress records, project schedule, and as-built drawings.

F. Maintaining the project site in a neat condition. Protect all existing structures, including monitoring wells, power poles maintenance facility, liner and leachate collection systems of existing cells, etc., from damage resulting from contract work on-site.

G. Coordinating with all utilities, and notifying the appropriate owners when work is scheduled in areas that may affect existing utilities.

H. No extra payment shall be made to the Contractor for any delays caused by lack of progress, defective workmanship, or rescheduling of work by other contractors, subcontractors, or equipment and material suppliers.

I. Coordinating the work of subcontractors, equipment, and material suppliers.

J. Verifying all field dimensions, notifying the Resident Project Representative of any discrepancies. No additional payment will be allowed because of differences between field dimensions and those shown on the drawings without notifying the Engineer prior to performing the work.

K. Coordinate the installation of electric work with M.C. Electric who will work directly for the Owner.

L. Coordinate the third-party leak location survey with Leak Detection Services for the Expansion.

M. Providing a competent and authorized supervisory representative at each work location during all working hours who shall act as the agent of the Contractor. The supervisory representative shall be capable of reading and thoroughly understanding the Drawings and Specifications, with full authority to fulfill the Contractor’s duties and responsibilities on the job. If, in the opinion of the Owner, the supervisory representative or any of his successors proves incompetent, not conscientious, or not industrious, then the

Contractor shall replace the supervisory representative upon written request of the Owner.

N. The Contractor shall only employ competent individuals on the job. Whenever the Engineer or the Owner notifies the Contractor in writing that, in his opinion, any individual on the job, whether employed by the Contractor or any of the subcontractors imperils the safety of others or is incompetent, unfaithful, disorderly, or otherwise unsatisfactory, such individual shall be discharged from the Contract work and shall not be employed on it, except with the written consent of the Owner.

1.02 PREINSTALLATION CONFERENCES:

A. When required in individual specification section, convene a preinstallation conference at work site prior to commencing work of the section.

B. Require attendance of parties directly affecting, or affected by, work of the specific section.

C. Notify Engineer four days in advance of meeting date.

D. Prepare agenda, preside at conference, record minutes, and distribute copies within two days after conference to participants, with two copies to Engineer.

E. Review conditions of installation, preparation and installation procedures, and coordination with related work.

END OF SECTION

SECTION 01060

APPLICABLE CODES

1.01 GENERAL:

A. Comply with current edition of all local, State, and national codes applicable to the proposed construction including but not limited to the following.

1. OSHA - National Occupational Safety and Health Act.

2. BOCA - Building Officials and Code Administrators - "National Building Code".

3. Associated General Contractors of America - "Manual of Accident Prevention in Construction".

4. ASTM - American Society for Testing Materials.

5. AASHTO - American Association of State Highway and Transportation Officials.

6. NFPA - National Fire Prevention Association.

7. Department of Environmental Protection, "Maine Erosion and Sediment Control Handbook for Construction: Best Management Practices".

8. GRI GM-13 Standards – Geosynthetic Research Institute.

9. MEDEP Solid Waste Management Regulations.

10. MEDEP Maine General Permit for Construction Rules.

11. MEDEP NRPA Permit-by-Rule Standards.

END OF SECTION

SECTION 01211

PRECONSTRUCTION CONFERENCE

PART 1 - GENERAL

1.01 RELATED REQUIREMENTS SPECIFIED ELSEWHERE

A. Summary of work: Section 01010

1.02 DESCRIPTION

A. Preconstruction Conference:

1. After Award of Contract and prior to the Notice to Proceed, meet with NEWSME Landfill Operations LLC (NEWSME Operations), or its representative for a Preconstruction Conference.

2. The purpose of this conference is to review the principle features of work and to address questions regarding the contract and work site.

B. Minimum Agenda:

1. Review plans and specifications.

2. Distribute and discuss.

   a. List of major subcontractors.

   b. Tentative construction schedules.

3. Critical work sequencing.

4. Relation and coordination of subcontractors.

5. Designation of responsible personnel.

6. Protocol for Processing field decisions and change orders.

7. Submittal of shop drawings, project data, and submittals required by the technical specifications.

8. Use of premises:

   a. Access restrictions.

   b. Office and storage areas.

   c. Owner's requirements.

   d. Ongoing landfill operations.

9. Payment and procurements of materials.

10. Safety and first-aid procedures.

11. Testing of materials.

12. Estimates for partial payments.

13. Environmental protection.

14. Location for disposal of soil stockpile material.

15. Odor control during construction

END OF SECTION

SECTION 01300

SUBMITTALS

PART 1 – GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in the Construction Agreement and Division-1 Specification sections, apply to work of this section.

1.02 SECTION INCLUDES:

A. Submittal procedures.

B. Construction progress schedule.

C. Proposed products list.

D. Shop drawings.

E. Product data.

F. Samples.

G. Manufacturer's instructions.

H. Manufacturer's certificates.

1.03 RELATED SECTIONS AND DOCUMENTS

A. Quality Assurance/Quality Control Plan: Appendix B

B. Individual Material Sections in Division 2

1.04 SUBMITTAL PROCEDURES:

A. Transmit each submittal with Engineer accepted form.

B. No materials covered by submittals shall be stored on-site until submittal for material is approved by the Engineer.

C. No work of General Contractor which requires submittals shall proceed until submittals have been reviewed and approved by the Engineer.

D. Sequentially number the transmittal forms. Re-submissions are to have original number with an alphabetic suffix.

E. Identify Project, Contractor, Subcontractor or supplier; pertinent Drawing sheet and detail number(s), and specification Section number, as appropriate.

F. Apply Contractor's stamp, signed or initialed certifying that review, verification of products required, field dimensions, adjacent construction work, and coordination of information, is in accordance with the requirements of the work and Contract Documents.

G. Schedule submittals to expedite the project, and deliver to the Engineer. Coordinate submission of related items.

H. Identify variations from Contract Documents and product or system limitations which may be detrimental to successful performance of the completed work.

I. Provide space for Contractor and Engineer review stamps.

J. Revise and resubmit submittals as required, identify all changes made since previous submittal.

K. Distribute copies of reviewed submittals to concerned parties. Instruct parties to promptly report any inability to comply with provisions.

1.05 CONSTRUCTION PROGRESS SCHEDULE:

1.06 PROPOSED PRODUCTS LIST:

A. At least fourteen (14) days prior to commencement of the Work, Contractor shall submit to Owner on forms provided a complete list of major products proposed for use, with name of manufacturer, trade name, and model number of each product.

B. For products specified only by reference standards, give manufacturer trade name, model or catalog designation, and reference standards.

1.07 SHOP DRAWINGS:

A. Submit in the form of one reproducible transparency.

B. Shop Drawings shall be presented in clear and thorough manner.

C. After review, distribute in accordance with Article on Procedures above and provide copies for Record Documents.

D. Product Properties: If the Contractor proposes to use products which have properties different from what is required by the Specifications, he shall identify in the submittal, or subsequent written requests, which properties do not meet the Specifications and what specific alternate property is being proposed for the material. The Engineer will only consider alternatives presented in a written form. The Engineer shall review the proposal and determine if the proposed alternative property still meets the design intent of the project. The Engineer's approval of an alternate property shall be in writing and only cover the specific property, which the Contractor has requested the Engineer evaluate. Under no condition shall the Engineer's approval extend to other properties of the product in question.

1.08 SAMPLES:

A. Submit samples to illustrate functional and aesthetic characteristics of the product, with integral parts and attachment devices. Coordinate sample submittals for interfacing work.

B. Submit samples of finishes from the full range of manufacturer's standard colors, textures, and patterns for Engineer's selection.

C. Include identification on each sample, with full project information.

D. Submit the number or samples specified in individual specification sections; one of which will be retained by Engineer.

E. Reviewed samples which may be used in the work are indicated in individual specification sections.

1.09 MANUFACTURER'S INSTRUCTIONS:

A. When specified in individual specification sections, submit manufacturer's printed instructions for delivery, storage, assembly, installation, start-up, adjusting, and finishing, in quantities specified for Product Data.

B. Identify conflicts between manufacturer's instructions and Contract Documents.

1.10 MANUFACTURER'S CERTIFICATES:

A. When specified in individual specification sections, submit manufacturer's certificate to Engineer for review, in quantities specified for Product Data.

B. Indicate material or product conforms to or exceeds specified requirements. Submit supporting reference date, affidavits, and certifications as appropriate.

C. Certificates may be recent or previous test results on material or product, but must be acceptable to Engineer.

END OF SECTION

SECTION 01350

ENGINEER'S FIELD OFFICE

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

1.02 DESCRIPTION:

A. Provide and maintain a field office for exclusive use of Engineer during the entire life of Contract. Do not disturb, move or interrupt without Engineer's approval. The building shall be a separate structure, located outside of the hard hat area erected on a location approved by Owner and Engineer.

B. Construction:

1. Portable or mobile buildings or buildings constructed with floors raised above ground, securely fixed to foundations, with steps and landings at entrance doors.

2. Structurally sound, secure, weathertight enclosures for office and storage spaces.

3. Equip door to field office with a closer and a new secure lock and two keys.

4. Area: Minimum 200 square feet.

5. Provide lighting, electrical outlets, and automatic heating, cooling ventilating equipment to maintain 68 degrees.F heating and 76 degrees.F cooling.

6. Windows: Minimum four, arranged for cross ventilation, minimum total area of 10 percent of floor area, with operable sash and insect screens. Supply sufficient drinking water from approved sources.

C. Furnishings:

1. One flat top desk, 54x30 inch, with three drawers.

2. One drafting table, 36x72 inch, with one equipment drawer.

3. One standard four-drawer letter size metal filing cabinet with locks and two keys per lock.

4. One swivel arm chair.

5. Four folding chairs.

6. One drafting stool.

7. One tackboard, 36x30 inches.

8. One large metal waste basket, approximate size: 15 to 20 gallons.

9. One desk lamp.

10. One drafting table lamp.

11. One broom.

12. One dust pan.

13. Sufficient floor sweeping compound for the duration of the Work.

14. Drinking Water: Provide a sufficient supply of water for the duration of the job.

15. Portable toilet.

END OF SECTION

SECTION 01505

MOBILIZATION

PART 1 - GENERAL

1.01 GENERAL:

A. Mobilization shall include the obtaining of all permits, insurance, and bonds; moving onto the site any and all plants and equipment; furnishing and erecting plants, temporary buildings, and other construction facilities; all as required for the proper performance and completion of the work. Mobilization shall include but not be limited to the following principle items:

1. Delivery to the site of all Contractors plant and equipment required for first month operations.

2. Installing temporary construction power, wiring, and lighting facilities as required.

3. Developing construction water supply.

4. Providing a field office for the Contractor and the Engineer, complete with all needed furnishings and utility services.

5. Providing on-site sanitary facilities and potable water facilities as specified.

6. Arrangement for and erection of Contractor's work and storage yard.

7. Submittal of all required insurance certificates and bonds.

8. Obtaining all required permits.

9. Posting all OSHA required notices and establishment safety programs.

10. Having the Contractor's superintendent at the job site full time.

11. Submittal of Preliminary Construction Schedule.

12. Submittal of Borrow Source Testing Schedule.

13. Submittal of materials and equipment which shall include: a complete list of suppliers and/or fabricators; items to be purchased from and/or supplied by such suppliers and/or fabricators: time required for fabrication; and scheduled delivery dates for each item to be purchased and/or supplied, leased or otherwise used for performance of the Work. This report shall be submitted for review at least 14 days prior to commencement of the Work.

B. Field Offices and Sheds:

1. The Contractor will provide a temporary field office(s). The Contractor shall provide materials, equipment, and furnishings to adequately service the space.

2. The Contractor will coordinate the office site location with the Owner and will fill and grade the site as necessary in order to provide drainage away from the building.

3. Field office(s) shall be ready for occupancy 15 days after Notice to Proceed with the work.

4. The office shall be a portable or mobile building constructed with the floor raised above ground and placed on a solid foundation. Steps and landings shall be provided at entrances. The building shall be structurally sound, secure, and weathertight.

5. The offices shall be provided with adequate insulation, lighting, safety devices, and environmental controls (heating and cooling). The offices shall also be provided with an adequate amount of secure storage space. The offices shall be furnished with, but not limited to, chair, drafting table, a desk, filing cabinet, and book shelves.

6. The Contractor shall make available safety equipment, which shall include at minimum, hard hats and safety glasses.

7. Storage areas and sheds shall be provided as necessary. Location of storage areas and sheds shall be approved by the Owner.

8. The Contractor shall be responsible for maintaining office spaces, storage sheds, and storage areas in a neat and orderly manner.

9. At completion of work remove buildings, foundations, utility services, storage sheds, and storage areas. Areas shall be restored to pre-construction condition.

10. At a minimum, the Contractor shall provide a port-a-potty, which will be provided with regular maintenance and cleaning.

END OF SECTION

SECTION 01520

MONITORING WELL AND PIEZOMETER ABANDONMENT

PART 1 - GENERAL

1.01 Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Earthwork: Section 02200

B. Appendix C: Boring Logs

1.03 DESCRIPTION OF WORK:

A. The Contractor will sub-contract the work to a competent drilling company that is acceptable to the engineer. The drilling company will abandon the existing monitoring wells and piezometers within the proximity of the Expansion and the proposed work limits in accordance with Section 405.5.H of the Solid Waste Management Regulations of the State of Maine.

B. The approximate locations of the monitoring wells and piezometers to be abandoned are shown on the Existing Conditions Plan. The locations were established by field survey.

C. The water levels shown on the boring log at the monitoring well and piezometer locations are based on previous observations made by the field personnel and may or may not represent the groundwater surface at the time of abandonment. The water levels are presented only as an observation of the free-standing water surface in the monitoring well on the date noted.

D. The refusal depths shown on the boring logs indicate only, that in the drill foreman's opinion, sufficient resistance to the advance of the casing, auger, probe rod or sampler was encountered to render further advance impossible or impractical by the procedures and equipment being used. Although refusal may indicate the encountering of the bedrock surface, it may indicate the striking of large cobbles, boulders, very dense or cemented soil, or other buried natural or man- made objects or it may indicate the encountering of a harder zone after penetrating a considerable depth through a weathered or disintegrated zone of the bedrock.

PART 2 – PRODUCTS:

2.01 WATER:

Water used to prepare the grout mixtures should generally be potable water, and shall be compatible with the type of sealing material used. It should also be free of petroleum and petroleum products and suspended solids. The water source shall be pre-approved by the engineer and documented on the well abandonment log.

2.02 BENTONITE GROUT:

Use only commercially prepared, powdered, or granulated bentonite grout. Thoroughly mix the bentonite with potable water to form slurry before placement. Add a sufficient amount of water to the bentonite to allow proper hydration.

2.03 CEMENT-BENTONITE GROUT

A. A mixture of Portland Cement with 2- 10 percent by dry weight of bentonite clay.

B. Cement used in grout shall meet the requirements of ASTM C 150-92, Standard Specification for Portland Cement. The cement shall be Type I (API Class A) unless otherwise indicated.

C. Cement-Bentonite grout shall be mixed thoroughly by machine to provide a uniform consistency before pumping. The cement-bentonite shall be dry mixed prior to hydration. Thoroughly mix the bentonite-cement mixture with potable water to form slurry. Add a sufficient amount of water to thoroughly mix the bentonite-cement to allow proper hydration. No curing accelerator shall be used.

PART 3 – EXECUTION

3.01 WELL/PIEZOMETER REMOVAL

A. The well will be sounded (its depth measured with a weighted line or appropriate method) immediately before it is decommissioned to make sure that it contains no obstructions that could interfere with filling and sealing.

B. All materials installed in the original borehole shall be removed, including the PVC casing, the screen, the existing grout and sand pack. Any casing, which cannot be withdrawn, intact must be ripped and perforated and then augered or washed from the hole.

3.02 WELL/PIEZOMETER SEALING

A. After the removal or destruction of the casing and the sand pack the hole shall be sealed by pressure injection from the bottom to the top with bentonite grout, using a tremie pipe, to the base grade of the landfill. The Drilling contractor shall check for settling of the grout and top off if necessary with grout or bentonite chips.

B. Place the grout in one continuous operation from the bottom to the top of the well or boring, unless conditions in the well or boring dictate that the grouting operation be conducted in a staged manner.

C. Whenever work is interrupted by such events as overnight shutdown, poor weather or other delays the well or open borehole and any associated excavations shall be covered at the surface. The cover will be held in place or weighted down in such a manner that it cannot easily be moved except by equipment or tools.

3.03 WELL/PIEZOMETER ABANDONMENT REPORT

The Contractor (sub-contractor) shall complete an abandonment log for each well or piezometer abandoned during this project. Abandonment logs shall contain all the information required by the MEDEP Regulations Chapter 405 including date of abandonment, depth of instrument abandoned, type and quantities of materials used for abandonment, etc.

END OF SECTION

SECTION 01561

CLEANING

PART 1 - GENERAL

1.01 DESCRIPTION:

A. Related Requirements Specified Elsewhere:

1. Summary of Work: Section 01010.

2. Project Coordination: Section 01041.

3. Cleaning for Specific Products or Work: Specification Section for that item.

B. Maintain premises and public properties free from accumulations of waste, debris, and rubbish, caused by operations.

C. At completion of work, remove waste materials, rubbish, tools, equipment, machinery, and surplus materials, and clean all sight-exposed surfaces; leave project area clean.

1.02 SAFETY REQUIREMENTS:

A. Conduct cleaning and disposal operations to comply with local, state and federal ordinances and laws, particularly anti-pollution laws.

1. Do not burn or bury rubbish and waste materials on project site.

2. Do not dispose of wastes into streams or waterways.

PART 2 - PRODUCTS

Not Applicable

PART 3 - EXECUTION

3.01 DURING CONSTRUCTION:

A. At reasonable intervals during progress of work, clean site and public properties, and dispose of waste materials, debris, and rubbish.

B. Provide on-site containers for collection of waste materials, debris, and rubbish.

C. Remove waste materials, debris and rubbish from site and legally dispose of in an on-site area approved by the Owner.

D. The Contractor is responsible for controlling windblown and water transported waste materials that have been exposed by construction activities.

3.02 FINAL CLEANING:

A. Maintain cleaning until project is completed.

END OF SECTION

SECTION 01562

DUST CONTROL

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Site Preparation: Section 02100

B. Earthwork: Section 02200

1.03 DESCRIPTION: This work shall consist of furnishing all labor, materials, and equipment for applying water, or street sweeping for dust control in conformity with the contract drawings and as specified herein, or as required by the Resident Project Representative.

PART 2 - PRODUCTS

2.01 GENERAL: The water shall not be salt or brackish and shall be free from oil, acid, and injurious alkali or vegetable matter.

2.02 CALCIUM CHLORIDE: **Contractor shall not use calcium chloride unless granted permission to do so by Owner or Engineer.**

PART 3 - EXECUTION

3.01 SPRINKLING: Water shall be applied by approved methods and with equipment including a tank with gauge equipped pressure pump and a nozzle-equipped spray bar. Water shall be dispersed through the nozzle under a minimum pressure of 20 pounds per square inch, gauge pressure.

3.02 STREET SWEEPING: The Contractor shall sweep both internal and external roadways whenever instructed by the Resident Project Representative. The Contractor will immediately clean any soil tracked off-site and take appropriate action to remove soil from vehicle tires prior to traveling on public roads.

END OF SECTION

SECTION 01570

TRAFFIC CONTROL

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

1.02 DESCRIPTION: This work shall consist of furnishing all labor, material, and equipment for traffic control including: signs, barricades and channelization, lighting, flagmen, and other items necessary to effectively control vehicular and pedestrian traffic through the construction period at the intersection Route 16 and the Juniper Ridge Landfill access road.

PART 2 - PRODUCTS

2.01 Materials used shall meet the requirements of the Maine Department of Transportation Standard Specifications for Highways and Bridges, Revision of November 2014, and the Manual on Uniform Traffic Control Devices, 2009.

PART 3 - EXECUTION

3.01 Installation of traffic control devices shall be in accordance with the Maine Department of Transportation Standard Specifications for Highways and Bridges, Revision of November 2014, and the Manual on Uniform Traffic Control Devices, 2009.

3.02 Maintain safe operating speeds of all construction equipment and delivery vehicles at all times including, but not limited to, 15 mph on the Juniper Ridge Landfill access roads, and 25 mph along the paved entranceway of the site between the site's entrance gate and Route 16.

3.03 Stage all construction equipment at the landfill site. There shall be no vehicle staging or parking on Route 16. The use of vehicle engine brakes is forbidden on Route 16 and the entrance road to the facility.

3.04 Coordinate construction activities with the ongoing operations at the Juniper Ridge Landfill facility.

END OF SECTION

SECTION 01600

MATERIAL AND EQUIPMENT

PART 1 - GENERAL

1.01 SECTION INCLUDES:

A. Products.

B. Transportation and handling.

C. Storage and protection.

D. Product options.

E. Substitutions.

1.02 RELATED SECTIONS AND DOCUMENTS:

A. Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

B. Section 1300 Submittals

C. Quality Assurance/ Quality Control Plan: Appendix B

1.03 PRODUCTS:

A. Products. Includes; new material, machinery, components, equipment, fixtures, and systems of first quality to form the work. Machinery and equipment used for preparation, fabrication, conveying and erection of the work is not included. Products may also include existing materials or components required for reuse as so specified in the contract documents.

B. Do not use materials and equipment removed from existing premises, except as specifically permitted by the Contract Documents.

C. Provide interchangeable components of the same manufacturer, for similar components.

1.04 TRANSPORTATION AND HANDLING:

A. Transport and handle products in accordance with manufacturer's instructions.

B. Promptly inspect shipments to assure that products comply with requirements, quantities are correct, and products are undamaged.

C. Provide equipment and personnel to handle products by methods to prevent soiling, disfigurement, or damage.

1.05 STORAGE AND PROTECTION:

A. Store and protect products in accordance with manufacturer's instructions, with seals and labels intact and legible. Store sensitive products in weathertight, climate controlled enclosures.

B. For exterior storage of fabricated products, place on sloped supports, above ground.

C. Provide off-site storage and protection when site does not permit on-site storage or protection.

D. Cover products subject to deterioration with impervious sheet covering. Provide ventilation to avoid condensation.

E. Store loose granular materials on solid flat surfaces in a well-drained area. Prevent mixing with foreign matter.

F. Provide equipment and personnel to store products by methods to prevent soiling, disfigurement, or damage.

G. Arrange storage of products to permit access for inspection. Periodically inspect to assure products are undamaged and are maintained under specified conditions.

1.06 PRODUCT OPTIONS:

A. <u>Products Specified by Reference Standards or by Description Only</u>. Products meeting the standards, or description.

B. <u>Products Specified by Naming One or More Manufacturers with a Provision for Substitutions</u>. Submit a request for substitution for any manufacturer not named.

1.07 SUBSTITUTIONS:

A. Instructions to Bidders specify time restrictions for submitting Requests for Substitutions after the bidding period to requirements specified in this section.

B. Substitutions may be considered when a product becomes unavailable through no fault of the Contractor.

C. Document each request with complete data substantiating compliance of proposed Substitution with Contract Documents.

D. A request constitutes a representation that the Contractor:

1. Has investigated proposed product and determined that it meets or exceeds the quality level of the specified product.

2. Will provide the same warranty for the Substitution as for the specified product.

3. Will coordinate installation and make changes to other work which may be required for the work to be complete with no additional cost to Owner.

4. Waives claims for additional costs or time extensions which may subsequently become apparent.

E. Substitutions will not be considered when they are indicated or implied on shop drawing or product data submittals, without separate written request, or when acceptance will require revision to the Contract Documents.

F. Substitution Submittal Procedure:

1. Submit three copies of Request for Substitution for consideration. Limit each request to one proposed substitution.

2. Submit shop drawings, product data, and certified test results attesting to the proposed product equivalence.

3. The Engineer will notify Contractor, in writing, of decision to accept or reject request.

END OF SECTION

SECTION 01700

CONTRACT CLOSEOUT

PART 1 – GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

1.02 SECTION INCLUDES:

A. Closeout procedures.

B. Final cleaning.

C. Adjusting.

D. Project record documents.

E. Spare parts and maintenance materials.

1.03 RELATED SECTIONS:

A. Section 01561 - Cleaning

1.04 CLOSEOUT PROCEDURES:

A. Submit written certification that Contract Documents have been reviewed, work has been inspected, and that work is complete in accordance with Contract Documents and ready for Engineer's inspection.

B. Provide submittals to Engineer that are required by governing or other authorities.

C. Submit final Application for Payment identifying total adjusted Contract Sum, previous payments, and sum remaining due.

1.05 FINAL CLEANING:

A. Execute final cleaning prior to final inspection.

B. Clean equipment and fixtures to a sanitary condition.

C. Clean or replace filters of operating equipment.

D. Clean debris from drainage systems.

E. Clean site; sweep paved areas, rake clean landscaped surfaces.

F. Remove waste and surplus materials, rubbish, and construction facilities from the site.

G. Flush underdrain and leachate collection piping upon final tie-in to existing piping systems and remove debris from manhole collection points as necessary.

1.06 ADJUSTING:

A. Adjust operating products and equipment to assure smooth and unhindered operation.

1.07 PROJECT RECORD DOCUMENTS:

A. Maintain on-site, one set of the following record documents; record actual revisions to the work:

1. Contract Drawings.

2. Specifications.

3. Addenda.

4. Change Orders and other Modifications to the Contract.

5. Reviewed shop drawings, product data, and samples.

B. Store Record Documents separate from documents used for construction.

C. Record information concurrent with construction progress.

D. Specifications: Legibly mark and record at each product section description of actual products installed, including the following:

1. Manufacturer's name and product model and number.

2. Product substitutions or alternates utilized.

3. Changes made by Addenda and Modifications.

E. Record Documents and Shop Drawings: Provide the services of a Maine Professional Land Surveyor to survey the completed project and record the as-built coordinates and elevations of the containment dike corners, leachate collection piping valve inlets, culvert inverts, and other points as directed by the Owner or Owner’s Representative. Legibly mark each item to record actual construction including:

1. Measured horizontal and vertical locations of underground utilities and appurtenances, referenced to permanent surface improvements.

2. Measured locations of internal utilities and appurtenances concealed in construction, referenced to visible and accessible features of the work.

3. Field changes of dimension and detail.

4. Details not on original Contract Drawings.

F. Delete Engineer title block seal from all documents.

G. Submit documents to Engineer with claim for final Application for Payment.

1.08 SPARE PARTS AND MAINTENANCE MATERIALS:

A. Provide products, spare parts, maintenance and extra materials in quantities as specified in individual specification sections.

B. Deliver to project site and place in location as directed; obtain receipt prior to final payment.

END OF SECTION

SECTION 02015

SUBSURFACE INFORMATION

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Earthwork: Section 02200

1.03 DESCRIPTION:

A. Subsurface exploration has been done at the location of the project and a soils report has been compiled for the purpose of guidance in the design of the project facilities.

B. The logs are not intended to indicate subsurface conditions except at the locations of the exploration (at the time explorations were made) and any interpretation the Contractor may make is his responsibility.

C. Subsurface investigations of the site were made by Sevee & Maher Engineers, Inc. in conjunction with design of the facility to be constructed under this Contract. The results of these investigations are presented in reports which are available upon written request by the Contractor. The report presents the opinion of the Engineer and shall not be interpreted to prescribe or dictate construction procedures or relieve the Contractor in any way of his responsibility for the construction.

D. The approximate locations of the explorations made during this study have been plotted on the Existing Conditions Plan. The locations were established by field survey.

E. The water levels shown on the log at the exploration locations are based on observations made by the field personnel at the same time the explorations were made and may or may not represent the groundwater surface in the immediate vicinity of the explorations. They are presented only as an observation of the free-standing water surface in the exploration on the date noted.

F. The refusal depths shown at the exploration locations indicate only, that in the drill foreman's opinion, sufficient resistance to the advance of the casing, auger, probe rod or sampler was encountered to render further advance impossible or impractical by the procedures and equipment being used. Although refusal may indicate the encountering of the bedrock surface, it may indicate the striking of large cobbles, boulders, very dense or cemented soil, or other buried natural or man- made objects or it may indicate the encountering of a harder zone after penetrating a considerable depth through a weathered or disintegrated zone of the bedrock.

END OF SECTION

SECTION 02100

SITE PREPARATION

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Section 02200 - Earthwork

B. Section 02771 - Geomembrane Liner

C. Section 02015 – Subsurface Information

1.03 DESCRIPTION OF WORK:

A. Work specified in this section shall consist of furnishing all labor, materials, and equipment to prepare the site for subsequent improvements in conformity with the contract drawings, and as specified herein.

B. Site Preparation shall include, but is not limited to, the following:

1. Protection of existing trees.

2. Removal and selective clearing of trees and other vegetation.

3. Topsoil stripping and grubbing.

4. Removal and disposal of unsuitable subgrade materials.

5. Verification of locations and elevations of all facilities to be connected to.

6. Removing above-grade facilities.

7. Removing below-grade facilities.

8. Protection of existing utilities.

9. Protection of existing structures, buildings, and engineered systems (liner system, leachate collection system, leachate transport system, etc.) of existing cells

C. Verification of existing utilities locations and elevations:

1. The Contractor shall locate and verify the location and invert elevations at all connection points and utilities, as shown on the Contract Drawings. The Contractor shall notify the Engineer of any discrepancies. The Contractor shall be responsible for notifying and obtaining the services of Dig Safe and On-Target to locate existing utilities as necessary.

2. The existing utilities shown on the drawings are shown diagrammatically and it is not to be inferred that the locations shown are precise.

3. Coordinate with all applicable utility owners prior to excavation in areas where it is reasonable to expect the presence of existing utilities, whether shown on the drawings or not.

4. Accept responsibility for any and all damage to any existing utilities, caused by his efforts.

5. Contact the effected utility as soon as any damage is uncovered.

6. The utility shall make the determination as to who makes the necessary repairs.

7. In areas where existing underground structures are shown or suspected carefully uncover such structures to such extent as to enable the Engineer to determine what adjustments if any need to be made to accommodate the presence or removal of such structure.

1.04 JOB CONDITIONS:

A. Protection of Existing Facilities:

1. Provide protections necessary to prevent damage to existing facilities indicated to remain.

2. Protect facilities on adjoining properties and on the Owner's property.

3. Restore damaged facilities to their original condition, as acceptable to parties having jurisdiction.

B. Adjoining Property: Confine all operations to the property of the Owner. Protect abutting properties from construction activities at all times.

C. Salvageable Facilities: Carefully remove items indicated to be salvaged, and store on the Owner's premises where indicated, unless otherwise directed.

PART 2 - PRODUCTS

Not Applicable.

PART 3 - EXECUTION

3.01 GENERAL:

A. The Engineer will establish clearing lines and construction lines and designate the trees, shrubs, plants, and other items to remain.

B. Alignment stakes, grade stakes, witness stakes, boundary markers, bench marks, and tie points shall be preserved until such time as their usefulness has ceased and permission for their destruction is given by the Engineer.

C. Remove vegetation, facilities, or obstructions interfering with installation of new construction. Remove such items elsewhere on the site or premises as specifically indicated. Removal includes stumps and roots.

D. Carefully and cleanly cut roots and branches of trees indicated to be left standing, where such roots and branches obstruct new construction.

E. Mark and identify existing utilities to be connected in to.

3.02 CLEARING:

A. In areas designated by the Engineer, all trees, down timber, stubs, brush, bushes, shrubs, plants, and debris not designated to remain shall be removed and disposed of.

B. All trees and shrubs shall be cut to 6 in. from the ground.

C. Unsound or unsightly branches of trees and shrubs designated to remain, and not specified to be removed under another item shall be removed as directed. All such removing and the disposal shall be a part of and incidental to this item.

3.03 TOPSOIL STRIPPING:

A. Topsoil is defined as friable silt loam surface soil found in a depth of not less than 4". Satisfactory topsoil is reasonably free of subsoil, clay lumps, and large stones, and without weeds, roots, and other objectionable material.

B. Strip topsoil to whatever depths encountered in a manner to prevent intermingling with the underlying subsoil or other objectionable material.

C. Remove heavy growths of grass from areas before stripping.

D. Stockpile topsoil on-site in storage piles where directed by Owner. Construct storage piles to freely drain surface water. Seed and mulch stock piles, with temporary seed mixture in accordance with Contract Documents and MEDEP BMPs.

E. Dispose of unsuitable material the same as waste material, herein specified.

F. Where trees are indicated to be left standing, stop topsoil stripping a sufficient distance to prevent damage to the main root system.

3.04 GRUBBING:

A. Completely remove stumps, roots, heavy turf and other debris. **Disposal of stumps shall be by grinding or chipping**.

B. Excavate any gravel from the area and stockpile separately for use in access roads.

C. Fill depressions caused by clearing and grubbing operations with satisfactory soil material, unless further excavation or earthwork is indicated. Place fill material in horizontal layers not exceeding 12" loose depth and thoroughly compact to a density equal to adjacent original ground.

D. Excavated soil shall be stockpiled within the facility's existing permitted till borrow pit area.

3.05 DISPOSAL OF WASTE MATERIALS:

A. Removal from Owner's Property: Except as otherwise provided, all wood, trash, and debris shall be removed and disposed of by the Contractor. Disposal may be deposited on-site as directed by the Owner.

B. Wood Chipping: Wood chipping shall be done with approved equipment capable of reducing woody material to chips not over 1/4 in. in thickness nor over 8 in. long. Chips shall be distributed in a thin layer over the ground surface. Ground cover plants shall not be smothered and drainageways shall not be blocked. If the wood chipper or any auxiliary machines damage existing plants or ground surface, the Engineer may prohibit their further use.

END OF SECTION

SECTION 02200

EARTHWORK

PART 1 - GENERAL

1.01 RELATED DOCUMENTS:

A. The general provisions of the contract, including General and Supplementary Conditions and General Requirements (if any) apply to the work specified in this section.

B. The requirements set forth by the Quality Assurance/Quality Control Plan shall apply to work specified in this Section.

C. All work performed under this specification shall be performed in accordance with the Maine Department of Environmental Protection – Maine Erosion and Sedimentation Control Best Management Practices (October 2003).

1.02 DESCRIPTION: This work shall consist of survey layout, excavation, filling, and embankment construction, clay liner construction, underdrain and leachate collection sand placement, and grading including hauling, compaction, and disposal of all material encountered and necessary for construction of the project.

1.03 RELATED WORK SPECIFIED ELSEWHERE:

A. Subsurface Information: Section 02015

B. Site Preparation: Section 02100

C. Erosion Control: Section 02220

D. Geotextiles and Drainage Geocomposite: Section 02272

E. Pipe Installation: Section 02450

F. Corrugated Metal Pipe: Section 02451

G. Seeding and Mulching: Section 02800

H. Geosynthetic Clay Liner: Section 02275

I. Bituminous Pavement: Section 02510

J. Manholes, Catch Basins, and Drainage Structures: Section 02570

K. Cast-in-Place Concrete: Section 03300

1.04 REFERENCES

The publications listed below are part of this Technical Specification to the extent referenced. The publications are referred to in the text by the basic designation only.

A. American Association of State and Highway and Transportation Officials (AASHTO):

1. AASHTO T 104 — Soundness of Aggregates by Use of Sodium Sulfate of Magnesium Sulfate
2. AASHTO T-289 — Determining pH of Soil for Use in Corrosion Testing
3. AASHTO T-236 — Direct Shear Test Of Soils Under Consolidated Drained Conditions

B. The American Society for Testing and Materials (ASTM):

1. ASTM D 422 — Standard Test Method for Particle-Size Analysis of Soils;
2. ASTM D 698 — Laboratory Compaction Characteristics of Soil Using Standard Effort
3. ASTM D 2216 — Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
4. ASTM D 2434 — Standard Test Method for Permeability of Granular Soils (Constant Head)
5. ASTM D 6938 — Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
7. ASTM D 4318 — Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
8. ASTM D 3080 — Standard Test Method for Direct Shear of Soils Under Consolidated Drained Conditions
9. ASTM D 5084 — Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

1.05 QUALITY ASSURANCE

A. All work pertaining to this Section shall be done according to the requirements outlined in the Quality Assurance/Quality Control Plan (Appendix B).

B. Codes and Standards: Perform excavation work in compliance with applicable requirements of governing authorities having jurisdiction.

C. Borrow Source Characterization Testing **(By Contractor)**:

1. The following borrow source characterization testing shall be performed on the materials used for the project’s earthworks construction. The testing program will assure that borrow materials from on-site or off-site sources meet the requirements of this specification. Borrow source testing shall be performed prior to delivering off-site material to the site and prior to using on-site material for landfill construction. Changes in the borrow source and/or material properties shall be avoided. The Contractor shall employ a soils testing laboratory acceptable to the Engineer to perform soil testing of borrow source materials. Borrow source characterization will be performed in accordance with the Maine Department of Environmental Protection (MDEP) Solid Waste Management Regulations Chapter 401 Appendix A, or as directed by the Engineer.

Borrow source characterization testing on soil materials shall be done at the following frequencies:

TABLE 2-1

BORROW SOURCE CHARACTERIZATION TESTING

Borrow Material	Testing	Method	Frequency[1]
Underdrain and Drainage Sand[2]	Moisture Density[2]	ASTM D 698-91	1/2500 cy
	Remolded Hydraulic Conductivity	ASTM D2434-68	1/5000 cy
	Grain Size	ASTM D 422-63	1/2500 cy
	Moisture Content[3]	ASTM D 2216-92	1/2500 cy
	Calcium Carbonate[4] Content	ASTM D 4373 or approved equivalent	2 per Source
Drainage Stone	Grain Size	ASTM D 422-63	1/2500 cy
	Calcium Carbonate[4] Content	ASTM D 4373 or approved equivalent	2 per Source
Filter Stone	Grain Size	ASTM D 422-63	1/2500 cy
	Calcium Carbonate[4] Content	ASTM D 4373 or approved equivalent	2 per Source
Sump Stone	Grain Size	ASTM D 422-63	2 per Type
	Calcium Carbonate[3] Content	ASTM D 4373 or approved equivalent	2 per Source
Tire Chips (Type B)	Grain Size	ASTM C 136-05	2 per Source
Clay	Moisture Density	ASTM D 698-91	1/2500 cy
	Remolded Hydraulic Conductivity	ASTM D 5084-90	1/5000 cy
	Grain Size	ASTM D 422-63	1/2500 cy
	Moisture Content	ASTM D 2216-92	1/500 cy
	Atterberg Limits	ASTM D 4318-93	1/2500 cy
Common Borrow	Grain Size	ASTM D 422-63	1/2500 cy
	Moisture/Density	ASTM D 698-91	1/2500 cy
Structural Backfill	Grain Size	ASTM D 422-63	1/2500 cy
	Moisture/Density	ASTM D 698-91	1/2500 cy
Pipe Bedding	Grain Size	ASTM D 422-63	1/2500 cy
Aggregate Base and Aggregate Sub-Base	Grain Size	ASTM D 422-63	1/2500 cy
	Moisture/Density	ASTM D 698-91	1/2500 cy

<u>Note:</u>

1. Minimum of two tests per source.
2. Drainage Sand material includes both Leak Detection and Leachate Collection system sand.
3. Underdrain and Leak Detection Sand layers only.
4. Equivalent methods used to determine calcium carbonate content include Whole Rock Geochemistry ME XRF06 and ME ICP06.

1.06 SUBMITTALS:

A. The Contractor shall supply representative materials for testing as required by the Engineer. The Contractor shall schedule his operation and submissions so the Engineer has sufficient time to perform testing. Failing tests of materials quality, gradation, or field density will be charged to the Contractor and deducted from payments, in accordance with Part 1.05 of Section 01025.

B. Test Reports: Submit 2 copies of the borrow source test reports directly to the Engineer from the Contractor's testing subcontractor, with copy to the Contractor. If borrow source testing indicates a significant change in material index properties during the construction of the landfill liner, the in-place material testing specifications described herein should be modified.

1.07 JOB CONDITIONS:

A. Site Information: Data on indicated subsurface conditions are not intended as representations or warranties of accuracy or continuity between soil borings. It is expressly understood that Owner and/or Engineer will not be responsible for interpretations or conclusions drawn therefrom by Contractor. Data are made available for the convenience of Contractor.

Additional test borings and other exploratory operations may be made by Contractor at no cost to Owner.

B. Existing Utilities: The Contractor shall provide the services on On Target or Dig Safe to locate existing underground utilities in the areas of work, as necessary, or as required by law. If utilities are to remain in place, provide adequate means of protection during earthwork operations.

Should uncharted, or incorrectly charted, piping or other utilities be encountered during excavation, consult the Utility Owner immediately for directions. Cooperate with Owner and utilities companies in keeping respective services and facilities in operation. Repair damaged utilities to satisfaction of utility owner.

Do not interrupt existing utilities serving facilities occupied and used by Owner or others, except when permitted in writing by Engineer and then only after acceptable temporary utility services have been provided.

Demolish and completely remove from site existing underground utilities indicated to be removed. Coordinate with utility companies for shut-off of services if lines are active.

C. Use of Explosives: Blasting at the Juniper Ridge Landfill site is not permitted.

D. Protection of Persons and Property: Barricade open excavations occurring as part of this work and post with warning lights. Operate warning lights as recommended by authorities having jurisdiction. Protect structures, utilities, sidewalks, pavements, and other facilities from damage caused by settlement, lateral movement, undermining, washout, and other hazards created by earthwork operations. The Contractor shall comply with all applicable rules, procedures and regulations regarding safety as defined by all local, state, and federal agencies, including but not limited to, NEWSME Operations' safety procedures, State of Maine Labor Department Rules, and the Occupational Safety and Health Act (OSHA) Regulations.

E. Work related to geomembrane HDPE and geosynthetic clay liner installation:

The earthwork contractor shall provide the necessary labor, materials, equipment, and supervision to perform the following work in conjunction with the installation of the geomembrane HDPE liner and the geosynthetic clay liner.

- Excavation and backfill of all liner anchor trenches;
- Preparation of all liner subgrade materials including moisture control, picking stones as directed by the Engineer or CQA agent, providing a smooth rolled surface to the tolerances required by the Engineer or CQA agent;
- Coordination of work schedule to accommodate the liner installation including weekend and holiday work as necessary, and allowing sufficient turnaround time for results of destructive seam testing (typically 24 hours) prior to placing additional material over the HDPE seams;
- Placement of a minimum 3 feet of suitable material, approved by the Engineer or CQA agent, over the liner materials before traveling on the liner with equipment other than low-pressure equipment approved by the Engineer or CQA agent; and
- All other conditions noted in Section 00110 “Summary of Work”.

PART 2 - PRODUCTS

2.01 SOIL MATERIALS:

A. Roadways and Parking Lots:

1. Aggregate Subbase Material: Aggregate subbase shall be gravel consisting of hard, durable particles which are free from vegetation, lumps, or balls of clay, and other deleterious substances. Gravel subbase shall not contain particles of rock which will not pass the 6-in. square mesh sieve. The gradation of the portion which will pass a 3-inch sieve shall meet the grading requirements of the following table:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
1/4”	25-70
#40	0-30
#200	0- 7

(M.D.O.T. 703.06 Type D)

2. Aggregate Base Material: Shall be crushed gravel consisting of hard durable particles which are free from vegetable matter, lumps or balls of clay, and other deleterious substances. Gravel base shall not contain particles of rock which will not pass the 2-inch square mesh sieve. The gradation of the base materials shall meet the grading requirements of the following table:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
1/2”	45-70
1/4”	30-55
#40	0-20
#200	0- 5

(M.D.O.T. 703.06 Type A)

B. Structures:

1. Structural Backfill: Backfill placed within 5 ft of structures shall consist of a well graded sand free of vegetable matter, lumps, or balls of clay and other deleterious substances. The gradation shall meet the grading requirements of the following table:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
3”	100
#40	0- 70
#200	0- 10

Structural backfill shall not contain particles of rock which will not pass the 3-inch square mesh sieve.

C. Pipe Bedding Stone (Solid Wall Pipe):

Pipe Bedding Stone: Stone shall be obtained from rock of uniform quality and shall consist of clean, angular fragments of quarried rock free from soft disintegrated pieces or other questionable matter. The material shall meet the following gradation requirements:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
¾”	100
½”	85 -100
3/8”	0 - 15

D. Landfill:

1. Clay Borrow: Clay for landfill liner barrier soil, and imported soil layer shall be silty clay soil free of organic matter, debris, and frozen material. Cobbles and rock fragments larger than 1/2-inch in diameter shall not be permissible. Clay shall be capable of meeting the gradation and hydraulic conductivity requirements of this specification:

a) The specification for screened clay, 1/2" minus shall be as follows:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
½ "	100
#40	90-100
#200	75-100

b) Remolded Hydraulic conductivity (ASTM D 5084-90) maximum $\leq 1 \times 10^{-7}$ cm/sec.

c) Liquid limit: $\geq$ 20
Plasticity index: $8 \leq$ P.I. ≤ 30

2. Drainage Stone: Shall be screened and washed stone free of organic matter, silt, or clay lumps, and deleterious material. The stone shall contain no more that 15% calcium carbonate as determined by ASTM D 4373 or equivalent method approved by Engineer (i.e., whole rock geochemistry methods). The material shall meet the following gradation requirements:

a) Pipe Drainage Stone: $D_{50} \geq 3/4$"

Sieve Designation	percent by Weight Passing Square Mesh Sieve
2"	100
1-1/2"	80-100
1"	50- 85
1/2"	0- 50
#4	0- 15
#10	0- 5

b) Leachate Sump Stone: will consist of rounded durable screened and washed stone or washed tailings meeting the calcium carbonate requirements above.

Sieve Designation	percent by Weight Passing Square Mesh Sieve
4"	100
2"	0

3. Filter Stone: Shall be screened and washed stone free of organic matter, silt, or clay lumps, and deleterious material. The stone shall contain no more that 15% calcium carbonate as determined by ASTM D 4373 or equivalent method approved by Engineer (i.e., whole rock geochemistry methods). The material shall meet the following gradation requirements:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
1”	100
No. 4	30-100
No. 20	0-20
No. 40	0-5

4. Underdrain Sand: Clean sand, free from organic matter, graded to meet the following criteria for the appropriate designation. Underdrain sand will have a hydraulic conductivity not less than $1x10^{-3}$ cm/sec and average of $1x10^{-2}$ cm/sec as determined by ASTM D 2434. The sand shall contain no more that 15% calcium carbonate as determined by ASTM D 4373 or equivalent method approved by Engineer (i.e., whole rock geochemistry methods).

   Gradation Requirements:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
1”	100
1/2”	90-100
#4	70 – 100
#10	50 - 85
#20	35 – 70
#60	0- 40
#200	0- 5[1]

1.Based on the portion passing the U.S. Standard Size No. 4.

5. Drainage Sand: Must meet the underdrain sand gradation stated above and have a remolded hydraulic conductivity average $1x10^{-2}$ cm/sec, minimum $5x10^{-3}$ cm/sec. as determined by ASTM D2434. The sand shall contain no more that 15% calcium carbonate as determined by ASTM D 4373 or equivalent method approved by Engineer (i.e., whole rock geochemistry methods).

6. Tire Chips: Type B shredded tire chips graded to meet the following criteria for the appropriate designation. Shall be free of contaminants such as oil, grease, gasoline, diesel fuel, etc. that could create a fire hazard. No remains of tires that have been subjected to a fire. Tire chips shall be from fragments of wood, wood chips and other fibrous organic matter. Tire chips shall have less than 1% (by weight) of metal fragments that are not at least partially encased in rubber. Metal fragments that are partially encased in rubber shall protrude no more than 1 inch from the cut edge of the tire shred on 75% of the pieces (by weight) and no more than 2 inches on 90% of the pieces (by weight)

Gradation Requirements:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
18”	100
12”	90
8”	75
3”	50
1-1/2”	25
#4	1

F. Miscellaneous Materials:

1. Common Borrow: Shall be earth, suitable for embankment construction. It shall be free of frozen material, perishable rubbish, peat, organic matter, large rock fragments, or other unsuitable material. AASHTO M145 Classifications A-1 through A-5 may be used. Use of other materials as common borrow is at the discretion of the Engineer and only in approved areas.

2. Topsoil: Shall be in accordance with Section 02800 – Seeding and Mulching.

3. Riprap: Shall be in accordance with Section 02220 – Erosion Control.

4. Frost Protection Layer: Suitable frost protection material shall include bark, wood chips, sawdust, municipal solid waste, and/or other materials approved by the Owner and the MEDEP.

2.02 ON-SITE MATERIAL

A. Material on the site is the property of NEWSME Operations and may only be used with the approval of the Engineer. The Contractor will complete all borrow source testing requirements specified in Table 2-1, if they wish to use any on-site material.

B. Material not incorporated in the work because it is unsuitable will be hauled away and disposed of at the Contractor's expense.

1. Material designated to be saved by the Engineer will be stockpiled using MEDEP Erosion Control BMPs for construction, at a location shown on the drawings or designated by the Engineer.

2. Unsuitable material shall consist of grubbings or other materials which contain rock of size exceeding specifications, organic materials, frozen materials, or other materials of a deleterious nature as deemed by the Engineer.

PART 3 - EXECUTION

3.01 INSPECTION: Examine the areas and conditions under which excavating, filling, and grading are to be performed and notify the Engineer, in writing of conditions detrimental to the proper and timely completion of the work. Do not proceed with the work until unsatisfactory conditions have been corrected in an acceptable manner.

3.02 EXCAVATION: Excavation consists of removal and disposal of material encountered when establishing required grade elevations. All excavation shall be unclassified and shall include any and all material encountered. No extra compensation shall be allowed for excavation work covered by the bid proposal.

A. Excavation for Structures: Conform to elevations and dimensions shown within a vertical tolerance of one-half (1/2) in. and extending a sufficient horizontal distance from footings and foundations to permit placing and removal of concrete formwork, installation of services, other construction, and for inspection.

Excavation for footings and foundations shall extend to the depth necessary to remove all fill material above the native soils. When the footing and foundation grades extend into native soils, the native soil shall be excavated to the foundation grades specified on the plans.

In excavating for footings and foundations, take care not to disturb bottom of excavation. Excavate by hand to final grade just before concrete reinforcement is placed. Trim bottoms to required lines and grades to leave solid base to receive concrete.

Rock shattered due to drilling or ripping operations shall be removed. Excess rock excavation shall be filled with Class A or Class B concrete.

B. Excavation for Pavements: Conform to subgrade elevations and dimensions shown, within a vertical tolerance of one (1) in.

C. Excavation for Trenches: Conform to elevations and dimensions within a vertical tolerance of one (1) in. Excavate to the uniform width shown or required for the particular item to be installed. Provide adequate working space for compactive equipment.

Excavate trenches to the depth indicated or required. Carry the depth of trenches for piping to establish the indicated flow lines and invert elevations and provide suitable bedding. Pipe bedding as specified in paragraph 2.01C.

Where rock is encountered, carry the excavation six (6) in. below the required elevation and backfill with a 6" layer of crushed stone or gravel prior to installing pipe.

Grade bottoms of trenches as indicated, notching under pipe joints to provide solid bearing for the entire body of the pipe.

Do not backfill trenches until authorized by the Engineer. Use care in backfilling to avoid damage or displacement of pipe systems.

D. Site Excavation: Conform to elevations and dimensions shown within a vertical tolerance of one-tenth (0.1) of a foot. During the excavation to base grade, excavating equipment and trucks are to be kept off the subgrade to minimize disturbance of the subgrade. Excavate to a depth to provide for any subsequent loam, sod, or other specified surface material.

E. Excavation of Unsuitable Material: Shall consist of the excavation and removal of all fill materials including loose, uncompacted soils material, buried rubber tires and waste, buried vegetation and other organic or inorganic debris shown on the plans, encountered during the prosecution of the work, or as directed by the Engineer. The excavation shall extend to the limits and depth necessary to remove fill and unsuitable material as directed by the Resident Project Representative.

F. Muck Excavation: Muck excavation shall consist of the excavation and disposal of saturated and unsaturated mixtures soils and organic matter not suitable for foundation or embankment material, regardless of moisture content.

3.03 STABILITY OF EXCAVATIONS: Slope sides of excavations to comply with local codes and ordinances having jurisdiction. Shore and brace where sloping is not possible because of space restrictions or stability of material excavated.

Maintain sides and slopes of excavations in a safe condition until completion of backfilling.

3.04 SHORING AND BRACING: Provide materials for shoring and bracing, such as sheet piling, uprights, stringers, and cross-braces, in good serviceable condition.

Establish requirements for trench shoring and bracing to comply with local codes and authorities having jurisdiction.

Maintain shoring and bracing in excavations regardless of time period excavations will be open. Carry down shoring and bracing as excavation progresses.

Provide permanent steel sheet piling or pressure treated timber sheet piling wherever subsequent removal of sheet piling might permit lateral movement of soil under adjacent structures. Cut off tops as required and leave permanently in place.

3.05 MATERIAL STORAGE: Stockpile satisfactory excavated materials where directed, until required for backfill or fill. Place, grade, and shape stockpiles for proper drainage. Seed and mulch stockpiles in accordance with MDEP BMPs as necessary.

Locate and retain soil materials away from edge of excavations.

Dispose of excess soil material and waste materials as herein specified.

3.06 COLD WEATHER PROTECTION: Protect excavation bottoms against freezing when atmospheric temperature is less than 35^{o}F.

3.07 WINTER CONSTRUCTION OF EMBANKMENTS AND CLAY BARRIERS: Frozen material shall not be placed in the embankment or clay barriers. The construction of embankments may continue during cold weather only when all frozen material in the top of the embankment or the existing ground is moved to the waste storage area, or removed from the site, before placing additional material.

Compaction shall be in accordance with the specified method of embankment and clay barriers construction. When the prevailing temperatures are below 30 deg.F, all material used in embankment construction and clay barriers shall have a moisture content at the time of compaction equal to or less than the optimum moisture content.

The embankment shall not be constructed upon frozen material except that such construction of embankments outside the building area may be allowed providing the total depth of the added fill, including gravel bases, plus the depth of the frozen material beneath does not exceed 5 ft. Frozen material may be left in the embankment only if it has been compacted as specified prior to freezing. The Contractor shall not resume construction of any embankments built in this manner until all frozen material has thawed. If test holes are required to make this determination they shall be dug and backfilled with satisfactory compaction at the Contractor's expense. Before additional material is added, uncompacted material on the surface of such embankments shall be either recompacted in accordance with the specified method of embankment construction or removed. Clay layers shall not be constructed upon frozen material. The Contractor shall be responsible for protecting any clay barrier material placed from freezing. If previously placed clay material freezes, it shall be removed, thawed, and then replaced.

3.08 CLOSING ABANDONED UNDERGROUND UTILITIES: Close open ends of abandoned underground utilities, indicated to remain, permanently with closures sufficiently strong to withstand pressures which may result after closing.

Close open ends of metallic conduit and pipe with threaded galvanized metal caps or plastic plugs, or other suitable method for the type of material and size of pipe. Do not use wood plugs.

Close open ends of plastic PVC pipe abandoned in-place with a permanent plastic PVC plug. Pipe end is to be backfilled with bedding sand.

Close open ends of concrete and masonry utilities with not less than 8" thick brick masonry bulkheads, constructed to completely fill the opening.

Wet brick before laying. Lay brick in mortar so as to form a full bed with ends and side joints in one operation. Joints shall be more than three-eighths (3/8) in. wide. Protect fresh masonry from freezing or from rapid drying, as necessary, and maintain protection until mortar has set.

3.9 BACKFILL AND FILL:

A. General: Place acceptable soil material in layers to required subgrade elevations, for each area classification listed below.

1. In excavations, use satisfactory excavated or borrow material.

2. Under grassed areas, use satisfactory excavated or borrow material.

3. In pipe trenches, use material specified in typical trench section.

4. Landfill Base: Use satisfactory regraded fill material, till soils excavated from on-site, and/or clay borrow meeting the requirements of SWMR Ch. 401.2.D(3).

B. Backfill excavations as promptly as work permits, but not until completion of the following:

1. Acceptance by Engineer of construction below finish grade including, but not limited to, dampproofing, waterproofing, and perimeter insulation.

2. Inspection, testing, approval, and recording locations of underground utilities.

3. Removal of shoring and bracing, and backfilling of voids with satisfactory materials. Temporary sheet piling driven below bottom of structures shall be removed in a manner to prevent settlement of structures or utilities, or cut-off and left-in-place if required.

4. Removal of trash, debris, frozen and/or unsuitable materials.

C. Placement and Compaction: Place backfill and fill materials in layers not more than 12" compacted depth for material compacted by heavy compaction equipment, and not more than 6" in loose depth for material compacted by hand-operated tampers. Except for clay as noted below.

Before compaction, moisten or aerate each layer as necessary to provide the optimum moisture content. Compact each layer to required percentage of maximum dry density for each area classification. Do not place backfill or fill material on surfaces that are muddy, frozen, or contain frost or ice.

Prior to the placement of a layer of clay material in the landfill, at test pad program shall be completed to demonstrate that he compaction techniques used can achieved the required performance standards. The test pad shall include: an area of approximately 50,000 square feet within the cell or cover area. The test pad program will consist of placing and compacting the clay in one, or two lifts, each with a compacted thickness of 12 inches. During placement and compaction in-place moisture/density tests will be obtained at a frequency of 15 per acre per lift. Provided the field test demonstrates an adequate compaction effort has been obtained through the entire lift thickness, the type of compaction, (e.g. compaction equipment and number of passes) will be noted in the field logs. In-place hydraulic conductivity tests will be randomly collected from the test pad area with a total of 7 hydraulic conductivity tests collected for each one-foot lift. The hydraulic conductivity tests will be performed on clay samples representative of the top, middle, and bottom of each lift. These hydraulic conductivity tests will be sent to the laboratory and the hydraulic conductivity, density, and moisture content of the in-place clay measured. If the field and laboratory tests confirm that this construction technique can achieve the project performance criteria up to four shallow test pits will be excavated in the test pad area to evaluate the remolding, and bonding of the clay through visual observations. Pictures will be used to visually document the condition of the compacted clay.The data collected and testing results will be compiled and discussed the construction stakeholders and upon concurrence that the construction techniques are appropriate to achieve the specified in-place properties of the clay the technique will be employed for the remainder of the project

Mating of new clay lifts with previously placed clay lifts shall be done by excavating the mating edge of the existing clay lifts in a stepped manner. Each step shall have a vertical height no greater than 12 inches and a horizontal width of 4 to 6 feet. The surface of each of the steps in the old clay layer shall be scarified to maximize bonding between the new and old sections.

Place backfill and fill materials evenly adjacent to structures, to required elevations. Take care to prevent wedging action of backfill against structures by carrying the material uniformly around structure to approximately same elevation in each lift.

Equipment such as bulldozers and sheepsfoot drum rollers will be used during the placement and compaction of the clay liner. Grading of the clay material will utilize laser survey technology to eliminate the need for grade stakes. The type of equipment, operating speed, and number of passes to adequately compact the clay soils shall be determined by ability of equipment to achieve performance requirements and is to be approved by the Engineer. In addition, extra precaution will be taken with the equipment used for placement and compaction to avoid sudden turns, stops, or starts that could disturb the clay liner. Similar equipment and precautions will be utilized during the placement of sand above the HDPE geomembrane. The equipment used in placement of materials on top of the geomembrane shall be approved by the Engineer.

A smooth drum roller is to be used to seal the lifts. Sealing the lifts will encourage runoff from storms, thus limiting development of excessively moist or wet lenses of soil within the barrier layer. The lift surface shall be scarified or otherwise roughened by tracking with a bulldozer prior to placing the next lift of material to promote good bonding between lifts.

At the completion of the clay and prior to the installation of HDPE geomembrane, the clay surface shall be proofrolled with 3 passes of a smooth drummed 10-ton vibratory roller.

Equipment used to construct the landfill shall be approved by the Engineer prior to or during the pre-construction meeting.

3.10 GRADING:

A. General: Uniformly grade areas within limits of grading under this section, including adjacent transition areas. Smooth finished surface within specified tolerances, compact with uniform levels or slopes between points where elevations are shown, or between such points and existing grades.

B. Compaction: After grading, compact subgrade surfaces to the depth and percentage of maximum density for each area classification.

3.11 COMPACTION:

A. General: Control soil compaction during construction providing minimum percentage of density specified for each area classification.

B. Percentage of Maximum Density Requirements: Compact soil within 4 percent above the optimum moisture content, to not less than the following percentages of maximum dry density (determined in accordance with ASTM D 698).

1. Landfill:

a) Subgrades: Compact subgrades below clay layer to at least 90 percent of maximum dry density.

Fill soil approved to be left in place shall be proofrolled prior to clay placement. Proofrolling shall include a minimum of three passes of a heavy vibratory compactor. The type and weight of the compactor shall be approved by a qualified geotechnical engineer. The engineer shall recommend removal of any unsatisfactory fill material, approve compaction equipment, and observe the compaction effort.

b) Clay Layers: Compact clay layer material to achieve the following properties:

Remolded Hydraulic Conductivity	$\leq 1 \times 10^{-7}$ cm/sec at 90 percent standard proctor density
Moisture Content	0-4 percent above optimum

Compaction test frequency of clay material will be at 9/acre/lift.

c) Embankments and Anchor Trench: Compact soil at least 90 percent of maximum dry density. Embankments compaction test frequency: 1 test/100 lf/lift. Anchor trench compaction test frequency at Engineer's discretion.

d) Underdrain Sand: Compact sand to at least 90 percent of maximum dry density. Compaction test frequency at Engineer's discretion.

2. Footings and Foundations:

a. Footings founded on native sands: Compact subgrade with at least six complete passes of an approved vibratory plate.

b. Compact each layer of base material to at least 95 percent of maximum dry density.

3. Structural Slabs: Compact each layer of backfill material to at least 95 percent of maximum dry density.

4. Adjacent to Structures: Compact each layer backfill or fill material to at least 92 percent of maximum dry density.

5. Lawn or Unpaved Areas: Compact each layer backfill or fill material to at least 85 percent of maximum dry density.

6. Pavements: Compact subgrade and each layer of gravel borrow, subbase material, and base material to at least 95 percent of maximum dry density.

7. Pipe Trenches: Compact bedding material and each layer of backfill to six (6) inches over pipe to at least 90 percent maximum dry density.

C. Moisture Control: Where subgrade or a layer of soil material must be moisture conditioned before compaction, uniformly apply water to surface of subgrade, or layer of soil material, in proper quantities to prevent free water appearing on surface during or subsequent to compaction operations.

Remove and replace, or scarify and air dry, soil material that is too wet to permit compaction to specified density.

Soil material that has been removed because it is too wet to permit compaction may be stockpiled or spread and allowed to dry. Assist drying by discing, harrowing, or pulverizing until moisture content is reduced to a satisfactory level.

To control clay layer desiccation during dry conditions, the liner will be moisture conditioned as described above and a 4-mil plastic cover will be temporarily placed over the clay. Alternate plans to control clay layer desiccation shall be approved by the Project Manager.

3.12 BASE AND SUBBASE COURSES:

A. General: This work consists of placing aggregate base and subbase material, in layers of specified thickness, over subgrade surface and geotextile fabric.

See Section 02510 for paving specifications.

B. Grade Control: During construction, maintain lines and grades including crown and cross-slope of subbase course.

C. Placing: Place subbase and base course material on prepared surfaces in layers of uniform thickness, conforming to indicated cross-section and thickness. Maintain optimum moisture content for compacting materrial during placement operations.

When a compacted subbase course is shown to be 6" thick or less, place material in a single layer. When shown to be more than 6" thick, place material in equal layers, except no single layer more than 12" or less than 3" in thickness when compacted.

3.13 VEGETATIVE COVER:

A. General: This work consists of placing vegetative cover soil of the specified thickness on prepared subgrade in all areas disturbed by construction and not otherwise surfaced or covered by structures and shall be in accordance with Section 02800 – Seeding and Mulching.

B. Material: Use suitable loam stripped from site where possible.

C. Placing and Grading: Place loam at the locations at specified thickness. Grade and rake loam to remove all foreign material and rocks over two (2) inches. Leave the surface uncompacted to receive the seeding operations.

3.14 FIELD QUALITY CONTROL **(Testing Services by Owner)**:

Quality Control Testing During Construction: The Owner will perform quality control testing of materials used in the work (i.e., borrow source construction testing and in-place construction testing, in accordance with the Maine Department of Environmental Protection (MDEP) Solid Waste Management Regulations Chapter 401 Appendix A). The Contractor shall supply representative materials for testing as required by the Owner's Representative. The Contractor shall schedule his operation and submissions so the Owner's Representative has sufficient time to perform material quality control testing. Failing quality control tests of materials will be charged to the Contractor and deducted from payments. Quality control procedures outlined in the site’s Quality Assurance/Quality Control Plan (Revision November 2006), shall be implemented by the Contractor during construction at the landfill. The Contractor will allow the Owner’s testing service to examine and test subgrades and fill layers before further construction work is performed. Test results meeting the requirements of 3.09 herein, shall be obtained prior to placing additional materials.

A. Borrow Source Construction Testing: The following borrow source quality control testing of the screened till, clay, granular drainage material, and underdrain material as a minimum shall be required. Samples to be tested will be collected by the Owner's Representative. Samples will be taken from material that has arrived on-site in accordance with ASTM D420 and C702.

TABLE 3-1

BORROW SOURCE CONSTRUCTION TESTING

Material	Tests	Frequency
Clay - Soil Material	Moisture Density ASTM 698	1/2,500 cy
	Grain Size ASTM 422	1/2,500 cy
	Moisture Content ASTM D 2216	1/500 cy
Underdrain and Drainage Sand [1]	Moisture Density ASTM 698[2]	1/2,500 cy
	Grain Size ASTM D 422	1/1,000 cy
	Moisture Content ASTM D 2216[2]	1/500 cy
Drainage Stone	Grain Size ASTM D 422	1/500 cy
Filter Stone	Grain Size ASTM D 422	1/500 cy
Sump Stone	Grain Size ASTM D-422-3	1/500 cy

1. Drainage Sand material includes both Leak Detection and Leachate Collection system sand.
2. Underdrain and Leak Detection sand layers only.

B. In-Place Construction Testing: The following in-place construction quality control testing shall be performed.

TABLE 3-2

IN-PLACE CONSTRUCTION TESTING

Material	Tests	Frequency
Clay Soil Layer	Density ASTM D 6938	9/acre/lift
	Moisture Content ASTM D 6938	9/acre/lift
	Moisture Content ASTM D 2216	1/9 nuclear method test
	Undisturbed Hydraulic Conductivity ASTM 5084	5/acre/lift
	Thickness	5/acre/lift
	Lift Interface Bond and Remolding	5/acre/lift
Underdrain and Drainage Sand[1]	Density ASTM D 6938[2]	5/acre/lift
	Moisture Content ASTM D 6938[2]	5/acre/lift
	Thickness	5/acre/lift
	Remolded Hydraulic Conductivity ASTM D 2434	5/acre/lift
Embankments	Density ASTM D 6938	1/100/LF/LIFT
Retained Fill (Common Borrow)	Density ASTM D 6938	1/lift/100 LF
	Moisture Content ASTM D 3017	1/lift/100 LF

1. Drainage Sand material includes both Leak Detection and Leachate Collection system sand.
2. Underdrain and Leak Detection Sand layers only.

Perform field density tests in accordance with ASTM D1556 (sand cone method), ASTM D2167 (rubber balloon method), or ASTM D6938 (Nuclear Device), as applicable.

1. Measurement of Soil Thickness and Soil Characteristics: The Contractor shall maintain daily logs of measurements of soil lifts, soil characteristics, and other observations. The thickness of clay liner and the underdrain sand layers shall be recorded at the required frequency. The thickness of the coarse aggregate shall be recorded once per 100 lineal feet of material placed.

2. The Owner's Representative shall identify test locations. The Contractor shall assist the Owner's Representative in obtaining the required samples. The location of in-place clay and drainage sand layer tests shall be determined by gridding the placement area plan into 75-foot squares. A total of 8 squares will constitute an acre. Each grid intersection will be assigned a number and a random number generator will be used to select the locations to be tested for each lift. Test sample locations for in-place hydraulic conductivity, moisture density, and thickness will be selected in this manner. The Owner's Representative shall maintain daily logs of measurements of soil lifts soil characteristics and other observations. The thickness of the drainage stone shall be recorded at 100-foot intervals.

3. Sampling clay for hydraulic conductivity will entail collecting the clay sample with a thin-walled tube. The tube will be jacked slowly into the 9-inch clay lift to a depth $\geq$9 inches using a hydraulic jack. The tube will be removed by slowly twisting the tube 360° while slowly pulling the tube from the clay. Once successfully sampled, the tube ends are capped and taped. If the samples are not to be tested immediately, the ends will be sealed by waxing both ends of the clay sample. The tube is then labeled with the site name, sample location, date, and time. Samples shall be transported vertically to the Owner's contracted testing laboratory. Samples will be tested for hydraulic conductivity according to ASTM 5084-90.

4. Deficient Areas of Work: Contractor placed subgrades and fills that are found deficient by inspection and/or failing quality control testing will be reworked. Subgrades and clay borrow that are below specified density or thickness, or outside the specified hydraulic conductivity range will be corrected at the Contractor's expense and the Contractor will reimburse the Owner for additional testing expenses. The Owner has the option of retesting the area in question prior to the Contractor taking corrective action. The deficient area is defined as the area encompassing half the distance surrounding sampling points which satisfactorily meet the testing requirements. The Contractor can elect to rework a rejected area; if it fails again the Contractor must remove the failing material and start anew with new material. The reworked area will be inspected and tested until the area is in conformance. An area which has been rejected for nonconformance due to deficient specified thickness or grading requirements may be reworked by the Contractor until it meets the specification, provided this work does not cause the rejected block to deviate from the other requirements of conformance.

5. Clay Sample Holes:

Holes formed in the clay layer by the removal of thin-walled tube samples and moisture density testing, or for other testing or sampling, shall be backfilled by the Contractor to previous grade. The backfill will consist of either bentonite chips or compacted clay such that the hydraulic conductivity requirements for the clay layer are satisfied.

3.15 SLAB AND FOUNDATION WALL BACKFILL

Take at least 2 field density tests, at location and elevation as directed by Engineer.

3.17 MAINTENANCE

A. Protection of Graded Areas: Protect newly graded areas from traffic and erosion. Keep free of trash and debris.

Repair and re-establish grades in settled, eroded, and rutted areas to specified tolerances.

Control of clay liner desiccation shall be in accordance with Section 3.09(C).

B. Reconditioning Compacted Areas: Where completed compacted areas are disturbed by subsequent construction operations or adverse weather, scarify surface, re-shape, and compact to required density prior to further construction. This work shall be performed at no additional cost to the Owner.

3.18 DISPOSAL OF EXCESS AND WASTE MATERIALS:

Remove waste materials, including unacceptable excavated material, trash and debris, and dispose of it in areas designated by Owner/Engineer.

END OF SECTION

SECTION 02220

EROSION CONTROL

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section. The Juniper Ridge Landfill, MEDEP approved Erosion and Sedimentation Control Plan.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Site Preparation: Section 02100

B. Earthwork: Section 02200

C. Seeding and Mulching: Section 02800

1.03 DESCRIPTION OF WORK:

A. The Contractor shall provide all materials, equipment, and labor necessary for the dewatering of excavations and the removal and/or diversion of surface water from the construction area, and installation of siltation and erosion control structures as shown on the plans and according to these Specifications, and in accordance with the MEDEP "Best Management Practices" – March 2003 for erosion and sedimentation control.

B. The Contractor shall provide all materials, equipment, and labor necessary (for the duration of the Contract) for the dewatering of excavations and the removal and/or diversion of surface water from the construction area, and installation of siltation and erosion control structures as shown on the plans and according to these Specifications, and in accordance with the MEDEP "Best Management Practices" – March 2003 for erosion and sedimentation control. The Contractor shall maintain a dewatering and stormwater control system so that no sediment impacted waters are discharged west of the access road at the southwestern end of the site.

C. The Contractor shall build all drains and do all ditching, pumping, bailing, and all other work necessary to keep the excavation clear of groundwater, or storm water during the progress of the work and until the finished work is safe from damage. The Contractor shall make provisions on the site to detain and filter water from the excavation operation so that sediments from the dewatering operation are contained. In no case will direct discharge from the dewatering operations to off-site drainage facilities be allowed.

D. The Contractor shall perform all inspections and documentation required by the project's MEDEP Maine General Construction Permit.

E. The Contractor shall provide temporary seeding, mulching, or other protective coverings to exposed earth surfaces and stockpiles which will be exposed to rain or wind elements for a period of greater than seven days.

F. The Contractor shall provide siltation fences, riprap, and/or stone check dams in the newly constructed drainage ditches for temporary sediment control as shown on the Contract Drawings.

G. At the completion of landfill construction activities, the Contractor shall provide permanent seeding, mulching, or other protective landscape coverings to exposed earth surfaces effected by construction activities, and a shown on the Contact Drawings, and as specified in Section 02800.

H. The Contractor shall be responsible for inspection, maintenance, and/or repair of all temporary erosion and sedimentation control measures during construction, including temporary erosion and sedimentation control measures installed by others and used during this project. Inspections will be undertaken by qualified personnel to ensure that controls are correctly functioning, and that additional erosion control measures are in installed if needed. Such inspections will occur bi-weekly and after each significant rain fall event (1 inch or more within a 24 hour period) during construction until permanent erosion control measures have been properly installed and the site is stabilized. Trapped sediment shall be removed when the height of the sediment is greater than one-half the depth of the erosion control measure.

1.04 SEDIMENT CONTROL GUIDELINES:

A. Maine Erosion and Sedimentation Control BMPs, January 2006.

B. State of Maine Department of Environmental Protection Natural Resources Protection Act Permit by Rule Standards Chapter 305 (effective February 1989, revised April 1992).

C. MEDEP - Maine Construction General Permit requirements.

1.05 SUBMITTALS:

A. The Contractor shall furnish to the Engineer, in writing, his plan for dewatering excavations and diverting surface water before beginning the construction work for which the dewatering or diversion is required. Acceptance of this plan will not relieve the Contractor of responsibility for completing the work as specified.

B. Manufacturer’s product data sheets, material certifications, and standard manufacturing quality control test data for products listed in Part 2 of this specification.

1.06 PRODUCT DELIVERY, STORAGE, AND HANDLING:

A. Packaged Materials: Deliver packaged materials in containers showing weight, analysis, and name of manufacturer. Handle material in accordance with manufacturer’s recommendations. Protect materials from deterioration during delivery, and while stored at the site.

PART 2 - PRODUCTS

2.01 SILTATION FENCE:

A. Siltation fence shall be preassembled fence consisting of synthetic filter fabric reinforced with a supporting mesh and mounted on wood or metal stakes.

B. The fence shall be Envirofence as manufactured by Mirafi, Spun Bond as manufactured by Trevira, or Propex Silt Stop as manufactured by Amoco or approved equivalent.

2.02 EROSION CONTROL BLANKET:

A. Shall be placed on newly topsoiled and seeded areas as indicated on the Contract Drawings. The matting type shall be that which is specified on the contract drawings, or an approved equal.

2.03 RIPRAP STONE:

1. Riprap shall be a graded mixture of angular stones such that 50 percent of the mixture by volume shall be greater than the stated D_{50} size as indicated on the Contract Drawings.

   Stones used for riprap shall consist of sound durable angular rock which will not become disintegrated by exposure to the action of water or weather. Either field stone or rough unhewn quarry stone may be used. Stones shall weigh from 10 lbs to 200 lbs except that when available suitable stones weighing more than 200 lbs may be used. Approximately 50 percent of the stones by volume shall exceed a unit weight of 25 lbs. Stone particle size may not be greater than 1.5 times the stated D_{50} size.

2. Exposed Stone: The exposed stones for riprap shall be angular and as nearly rectangular in cross-section as practicable. Rounded boulders or cobbles will not be permitted.

3. Bedding Stone: Material for bedding shall be aggregate base material conforming to Specification 02200, Earthwork; Section 2.01A.2.

4. Riprap Geotextile Filter: The geotextile used in the construction of riprap ditches, spillways, aprons, and plunge pools shall meet Specification 02272 Part 2.01.A (5a).

2.04 STONE CHECK DAMS:

A. Stone for check dams shall consist of a mixture of angular stones having a particle size of between 2 inch and 3 inch. The check dams shall be installed at locations as indicated on the drawings and shall be constructed as detailed on the drawings.

B. Exposed Stone: The exposed stones for the check dams shall be angular and as nearly rectangular in cross-section as practicable. Rounded stone will not be permitted. The stone shall consist of durable stones that will not disintegrate by exposure to the action of water or weather.

PART 3 - EXECUTION

3.01 GENERAL

A. The Contractor shall provide for the diversion of clean surface water from uncapped open areas of the landfill for the duration of the construction project.

B. The Contractor shall provide all materials, equipment, and labor necessary (for the duration of the Contract) for the dewatering of excavations and the removal and/or diversion of surface water from the construction area, and installation of siltation and erosion control structures as shown on the plans and according to these Specifications, and in accordance with the MEDEP "Best Management Practices" – January 2006 for erosion and sedimentation control. The Contractor shall maintain a dewatering and stormwater control system so that no sediment impacted waters are discharged west of the access road at the southwestern end of the site.

C. The Contractor shall provide for the dewatering of excavations and the diversion of surface water from the construction areas and install siltation and erosion control measures as necessary in accordance with MEDEP BMPs.

D. The Contractor shall build all drains, dikes, and sediment basins, install all siltation fencing, mulches, grasses, seeding, ditches, channels, riprap, grading, and all other work necessary to control water pollution, surface runoff, and soil erosion.

E. The Contractor shall provide temporary seeding, mulching, or other protective coverings to exposed earth surfaces or stockpiles which will be exposed to rain or wind elements through the fall and winter seasons.

F. The Contractor shall maintain all facilities necessary to control water pollution, surface runoff, and soil erosion until permission is given by the Engineer to discontinue the use of the facilities.

3.02 EROSION CONTROL PROVISIONS:

A. The discharge from pumping operations during dewatering operations shall be contained by a dike so constructed as to prevent siltation and the area of the outlet pipe shall be protected against erosion by flowing water by the construction of a rock or timber apron.

B. Prior to removal of sediment control dikes all retained silt or other materials shall be removed and placed within landfill limits in areas not susceptible to erosion, at no additional cost to the Owner.

3.03 REMOVAL OF TEMPORARY WORKS:

A. After the temporary works have served their purposes, the Contractor shall remove them or level and grade them to the extent required to present a sightly appearance and to prevent any obstruction of the flow of water or any other interference with the operation of or access to the permanent works.

3.04 PLACEMENT OF EROSION CONTROL BLANKET: Erosion control blanket shall be placed at locations indicated on Contract Drawings. The anchoring of the blanket shall be in accordance with manufacturer's recommendations or as directed by the Engineer or Owner's Representative.

3.05 PLACEMENT OF RIPRAP: Riprap shall be placed full depth in one operation without special handwork, shall be approximately true to the required slope line and grade, and be uniform in appearance. Larger stones shall be placed at the base of the slope. The stones shall be placed on close contact with the longer axis perpendicular to the plane of the slope and so as to stagger joints. The openings between the stones shall be filled with spall, or gravel and rocks securely rammed into place. Placement of riprap shall include the placement of all bedding materials and geotextiles required as shown on the Contract Drawings.

3.06 MAINTENANCE AND ACCEPTANCE:

A. The Contractor shall be responsible for inspection and maintenance of all temporary erosion and sedimentation control measures during construction. Inspections will be undertaken by qualified personnel to ensure that controls are correctly functioning, and that additional erosion control measures are in installed if needed. Such inspections will occur bi-weekly and after each significant rain fall event (1 inch or more within a 24 hour period) during construction until permanent erosion control measures have been properly installed and the site is stabilized. Trapped sediment shall be removed when the height of the sediment is greater then one-half the depth of the erosion control measure.

END OF SECTION

SECTION 02272

GEOTEXTILES AND DRAINAGE GEOCOMPOSITE

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

B. Requirements set forth by the project's Quality Assurance/Quality Control Plan shall apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Earthwork: Section 02200

B. Erosion Control: Section 02220

C. Geomembrane Liner: Section 02771

D. Interfacial Friction Angle Conformance Testing: Section 02780

1.03 DESCRIPTION:

A. Furnish and install woven, non-woven geotextiles, or geonet, whichever is called for at the locations and in the manner shown on the drawings or as directed by the Engineer.

1.04 SUBMITTALS:

A. If brand name materials other than those suggested in this Section are proposed for use, furnish certified copy of laboratory test results and material sample as evidence that the material is similar and equal in strength, durability, and permeability.

B. Submit, 2 copies plus number of copies required by the contractor, of quality control documentation described in 1.05 A, B and C herein, and 6-1 and 7-1 of Appendix B - Quality Assurance Quality Control Plan. .

1.05 QUALITY CONTROL

A. Manufacturer's Experience: The manufacturer supplying the geosynthetic materials shall satisfactorily demonstrate previous experience by letter of certification. Certification shall indicate that the manufacturer has produced, and has in service in similar applications for a period of not less than one (1) year, at least fifteen (15) million sq ft of geotextiles and drainage net meeting these Specifications.

B. Installer's Experience: The Installer proposing to install the lining shall satisfactorily demonstrate previous experience by letter of certification. Certification shall indicate the Installer's successful past installation of at least 5,000,000 sq ft of geotextiles and drainage net.

C. Prior to the installation of any geotextile and drainage geocomposite, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (resin supplier's name and resin production plant) and identification (brand name and number) of the resin used to manufacture the geotextile.

2. Copies of the quality control certificates issued by the resin supplier.

3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geotextile meets the Manufacturer's resin specifications.

4. Reports on quality control tests conducted by the Manufacturer to verify that the geotextile manufactured for the project meets the project specifications.

5. A statement indicating that the reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness.

6. A list of the materials which comprise the geotextile, expressed in the following categories as percent by weight: base polymer, carbon black, other additives.

7. A specification for the geotextile which includes all properties contained in the project specifications measured using the appropriate test methods.

8. Written certification that minimum average roll values given in the specification are guaranteed by the Manufacturer.

9. For non-woven geotextiles, written certification that the Manufacturer has continuously inspected the geotextile for the presence of needles and found the geotextile to be needle free.

10. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for:

    <u>Geotextile</u>

    a. Mass per unit area
    b. Grab tensile/elongation
    c. Trapezoidal tear strength
    d. Mullen burst
    e. Puncture
    f. Apparent opening size
    g. Water permeability

    <u>Geonet</u>

    a. Density
    b. Carbon Black
    c. Thickness

Drainage Geocomposite

a. Transmissivity
b. Ply adhesion
c. Tensile strength

Quality control tests shall be performed in accordance with the test methods specified in Section 2.01B and 2.01C for at least every 100,000 ft^2 (10,000 m^2) of geonet and geotextile produced.

The Manufacturer shall identify all rolls of geotextiles and drainage geocomposite with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
4. Roll dimensions

1.06 CONFORMANCE TESTING:

The geocomposite will be sampled by the Geosynthetic CQA or his agent(s), at the manufacturer or upon delivery to the site. Conformance samples shall be collected in accordance with the project's Quality Assurance Quality Control Plan. The Geosynthetic CQA shall assure that conformance test samples are obtained for the geocomposite at a rate of 1 test per 100,000 square feet of each geotextile and geocomposite with a minimum of once per lot, for testing, to assure conformance to the specification. A lot consists of a group of material which is manufactured from a specific batch of raw materials (e.g., HDPE resin, or bentonite clay). The manufacturer shall identify the consecutively numbered rolls of material that are inclusive within a lot. It is not required that all rolls included in a lot be supplied to the project, as long as the specified certification test results are supplied by the manufacture to bracket the rolls delivered to the project. Conformance tests shall be performed in accordance with the test methods specified in Section 2.01B and 2.01C. Interfacial friction angle testing shall be done according to Section 02780 and at a frequency as indicated in Section 02780.2.01(D).

The contractor or sub-contractor shall coordinate information on manufacture and delivery of the geocomposite with the Geosynthetic CQA to assure that sampling and testing occur in a timely manner as to avoid construction delays.

Any further testing required to assure conformance shall be the responsibility of the contractor in accordance with 1.05 (C) of Section 01025. The testing laboratory and the results shall be acceptable to the Engineer.

Geocomposite conformance testing shall include the following:

1. Geotextile

Mass per unit area
Grab tensile/elongation
Trapezoidal tear strength
Mullen burst
Puncture

2. Drainage Geocomposite

Transmissivity
Ply adhesion
Tensile strength
Interfacial friction angle (ref. Specification Section 02780)

(a) Between drainage geocomposite and drainage sand

(b) Between drainage geocomposite and textured HDPE geomembrane

PART 2 - PRODUCTS

2.01 MATERIALS:

A. Woven Geotextile:

1. Synthetic fibers woven to provide a strong, water permeable material.

2. Fiber shall be made from polypropylene.

3. Edges: Selvaged to prevent raveling.

4. Geotextile shall be resistant to rot, mildew, insects, rodents, salt water and other biological and chemical substances commonly encountered in the ground.

5. Woven Geotextiles:

a) Roadway Stabilization Geotextile: The geotextile used in construction of the landfill access roads shall be Mirafi HP-270.

b) Riprap Geotextile Filter: The geotextile used in construction of riprap ditches and or riprap spillways shall be Mirafi® Filterweave (FW) 700 as produced by Ten Cate Nicolon or approved equal.

c) Underdrain Pipe Geotextile: The geotextile used to wrap the underdrain pipe and stone shall be Mirafi® Filterweave (FW) 300 as produced by Ten Cate Nicolon or approved equal.

B. Non-Woven Geotextiles:

1. Produced by heat bonding, needle punching or by the use of external adhesives.

2. The network of fibers shall be bonded so the fibers will retain their relative position with respect to each other.

3. Fibers may be made from polypropylene.

4. Geotextile shall be resistant to rot, mildew, insects, salt water, rodents and any other biological and chemical substances commonly encountered in the ground.

5. Non-Woven Geotextiles:

a) 6 oz/sy: The geotextile used as a filter fabric and heat bonded to both sides of the HDPE drainage net shall meet the Minimum Average Roll Values (MARV) listed below.

Property	Unit	Test Method	MARV
Weight	oz/yd^2	ASTM D 5261-92	6
Grab Strength	lbs	ASTM D 4632-91	150
Trapezoid Tear Strength	lbs	ASTM D 4533-91	60
Mullen Burst Strength	psi	ASTM D 3786-87	305
Puncture Strength	lbs	ASTM D 6241	90
Apparent Opening Size	Std Sieve	ASTM D 4751-95	70
Permittivity	Sec^{-1}	ASTM D 4491-99a	1.6
UV Resistance	% min. 500 hr	ASTM D 4355	70

b) 8 oz/sy: The geotextile used for leak detection piping and riprap downspouts shall meet the Minimum Average Roll Values listed below:

Property	Unit	Test Method	MARV
Weight	oz/yd^2	ASTM D 5261-92	8
Grab Strength	lbs	ASTM D 4632-91	225
Trapezoid Tear Strength	lbs	ASTM D 4533-91	90
Puncture Resistance	lbs	ASTM D 6241	600
Apparent Opening Size	Std Sieve	ASTM D 4751-95	80
Permittivity	Sec^{-1}	ASTM D 4491-99a	1.26
UV Resistance	% min. 500 hr	ASTM D 4355	70

C. Drainage Geocomposite:

1. Fabric wrapped high density polyethylene (HDPE) geonet drainage media.
2. Geonet: Two overlapping strands of HDPE.

3. Geotextile fabric heat-bonded to both sides of geonet and conform to the properties listed in Subsection 2.B.5.a. Fabric shall be bonded to the geonet so that it lies flat on the geonet, free of wrinkles and folds.
4. The geotextile shall be bonded to the geonet over 100 percent of the surface. Any material not meeting this requirement will be rejected for use on this project.
5. Geotextile extends a minimum of 2 inches beyond the edge of the geonet. The fabric edge shall be true and even to the edge of the geonet.
6. Drainage geocomposite conforming to the following properties:

Note A: Drainage geocomposite shall have a minimum calculated required transmissivity of 3.2 $x10^{-4}$ m^2/sec at a normal pressure of 10,000 psf and a gradient of 0.02.

The minimum calculated required transmissivity $_{(qreqd)}$ has been determined as follows:

$$q_{reqd} = q_{design} [FS_d x RF_{IN} x RF_{CR} x RF_{CC} x RF_{BC}]$$

Where; q_{design} Minimum calculated design transmissivity for geocomposite shall be as given below:
q_{design} = 4.9 $x10^{-5} m^2$/sec @ 10,000 psf and 0.02gradient

FS_d Factor of Safety for drainage = 3
RFIN Intrusion Reduction Factor = 1.0[1]

Property	Unit	Test Method	Value
Specific Gravity (geonet)	gm/cm^3	ASTM D 1505-96	0.93 5
Melt Flow Index (geonet)	gm/10 min.	ASTM D 1238-95	0.30
Thickness (geonet)	mil	ASTM D 5199	200-330
Percent Carbon Black (geonet)	%	ASTM D 1603-94	2-3
Transmissivity $_{(qreqd)}$	m^2/sec	ASTM D 4716-87	See Note A.
Ply Adhesion	lbs/in	ASTM D 7005-03	1.0 min
Tensile Strength at Yield MD	lbs/in	ASTM D 638,5034-95	50

RFCR Creep Reduction Factor = 1.1[1]
RFCC Chemical Clogging Reduction Factor = 1.4[1]
RFBC Biological Clogging Reduction Factor = 1.4[1]

Notes

1. These Reduction Factor (RF) values were assumed in this analysis, based on published data for a wide range of GCD materials. Project specific RF values can be applied during the material approval process if supporting documentation is provided by the manufacturer and approved by the project engineer.

Each type of drainage geocomposite shall meet the following requirement:

$$q_{100} \geq q_{reqd}$$

Where;

q100 Flow rate of the geocomposite tested in accordance with ASTM D4716 for all manufacturers quality control and quality assurance conformance testing, with the following conditions:

- performed with boundary condition of Ottowa Sand and liner;
- test duration = 100 hours;
- performed at a normal pressures of 10,000 psf;
- tested at hydraulic gradient of 0.02; and
- oriented in the machine direction.

D. Interfacial Friction Angle:

1. Between drainage geocomposite and leachate collection sand.

2. Between drainage geocomposite and textured HDPE geomembrane.

3. Interfacial friction angle properties shall be in accordance with the test methods specified in Section 02780.

PART 3 - EXECUTION

3.01 PREPARATION OF BASE FOR GEOTEXTILE: Subgrade surfaces shall be properly graded and compacted as called for. All sharp or protruding objects shall be removed from the subgrade surface prior to fabric placement. Geotextile fabric shall not be placed until the foundation preparation is completed and the subgrade surfaces have been inspected and approved by the Engineer.

3.02 INSTALLATION:

A. Geotextile installation shall be in accordance with manufacturer's recommendations and shall include the following considerations:

1. Place in the manner and at the locations shown on the drawings.

2. At the time of installation, geotextile shall be rejected if it has defects, rips, holes, flaws, deterioration or damage incurred during manufacture, transportation or storage.

3. Geotextile used for the underdrain of the liner system shall be sewn together continuously to provide proper separation of soil materials.

B. Drainage Geocomposite Placement:

1. Place in the manner and at the locations shown on Drawings.

2. At the time of installation, drainage net shall be rejected if it has defects, rips, flaws, deterioration, or damage incurred during manufacture, transportation, or storage.

3. Join adjacent sheets of geonet with plastic ties spaced at minimum of 5 feet on-center. Adjoining sheet ends shall be heat bonded.

4. Place long dimensions perpendicular to the contours of the sideslopes (i.e. up and down). Lay smooth and free of tension, stress, folds, wrinkles, or creases.

5. Provide a minimum width of 4 in. of overlap for each joint of the geotextile.

6. Geotextile used in the Drainage Geocomposite shall be heat bonded at all overlays.

7. Place so that the upstream strip of geotextile will overlap the downstream strip.

C. Protection of Geotextile and Drainage Net:

1. Upon delivery to the site, geotextiles shall be set up off the ground and be wrapped with a plastic tarp or stored inside a trailer or building to prevent dust clogging.

2. Exercise necessary care while transporting, storing and installing the geotextile to prevent damaging it.

3. Protect from prolonged direct exposure to sunlight.

4. Repair all damaged areas of the geotextile by placing another piece of geotextile of sufficient size to extend a minimum of 1.0 foot beyond the limits of the damage in all directions over the damaged area.

5. Do not leave exposed more than seven (7) days without being covered by backfill.

6. Overlap successive pieces of geotextile a minimum of 1.0 foot.

7. When required, sew overlaps and repairs to damaged geotextile using a portable machine to provide seam strengths of at least 90 percent of the filter fabric strength.

END OF SECTION

SECTION 02275

GEOSYNTHETIC CLAY LINER

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

B. The requirements set forth by the Quality Assurance/Quality Control Plan shall apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Earthwork: Section 02200

B. Geotextiles and Drainage Geocomposite: Section 02272

C. Geomembrane Liner: Section 02771

D. Interfacial Friction Angle Conformance Testing: Section 02780

1.03 DESCRIPTION:

A. Furnish and install a geosynthetic clay liner (GCL) as part of the composite liner in the landfill. Sufficient liner material shall be furnished to cover all areas shown on the drawings including overlaps at field seams and anchor trenches. The GCL manufacturer shall provide the service of a technical representative as described in Section 3.02.A for a minimum of 1 working day.

B. All material shall be furnished from no more then 3 lots. A lot is defined as a group of consecutively numbered rolls of material from the same manufacturing line or batch.

1.04 SUBMITTALS:

A. A plan showing the proposed liner layout.

B. All required manufacturer's quality control certifications as described in GR1-GCL3 “standard specification for Test Methods, Required Properties, and Test Frequencies of Geosynthetic Clay Liners” and in para. 8.1 of Appendix B – Quality Assurance Quality Control Plan, including, but not limited to, the following:

- verification that clay component of the finished product is 70 to 90 percent sodium montmorillonite clay of bentonite deposits;
- verification that the proper mass per unit area of bentonite clay has been added to the finished product;

- verification that the actual geotextiles used in the finished product meet the manufacturer's specification based on the minimum average roll value (MARV) concept;

- verification that needle-punched non-woven geotextiles have been inspected continuously for the presence of broken needles using an in-line metal detector.

- manufacturer supplying the GCL shall demonstrate previous experience by letter of certification. Certification shall indicate that the manufacture has produced, and has in service in similar applications for a period of not less than one (1) year, at least five (5) million sq.ft. of GCL material, meeting these Specifications.

- manufacturer's Quality Control Certification for the tests described in Table 2.01A.

1.05 CONFORMANCE TESTING:

The GCL will be sampled by the Geosynthetic CQA or his agent(s), at the manufacturer or upon delivery to the site. The Geosynthetic CQA shall assure that conformance test samples are obtained for the GCL at a rate of 1 test per 50,000 square feet of GCL with a minimum of once per lot, for testing, to assure conformance to the specification. On site samples should be taken from selected rolls by removing the protective wrapping and cutting a full width 3-foot long sample from the outer wrap of the selected rolls. The rolls should be immediately rewrapped and replaced in the shipping trailers or in the temporary field storage area. Test samples should be identified by type, style, lot, and roll numbers. The machine direction should also be noted on the samples with a waterproof marker. A lot consists of a group of material which is manufactured from a specific batch of raw materials (e.g., HDPE resin, or bentonite clay). The manufacturer shall identify the consecutively numbered rolls of material that are inclusive within a lot. It is not required that all rolls included in a lot be supplied to the project, as long as the specified certification test results are supplied by the manufacture to bracket the rolls delivered to the project. The interfacial and internal friction angle tests shall be performed at the frequency defined in Section 02780.

The contractor or sub-contractor shall coordinate information on manufacture and delivery of the GCL with the Geosynthetic CQA to assure that sampling and testing occur in a timely manner as to avoid construction delays.

Any further testing required to assure conformance shall be the responsibility of the contractor in accordance with 1.05 (C) of Section 01025. The testing laboratory and the results shall be acceptable to the Engineer.

GCL Conformance testing shall include the following:

A. Bentonite mass per unit area per ASTM D 5993;

B. Free swell of clay component per ASTM D 5890

C. Hydraulic conductivity per (ASTM D 5887-99).

D. Grab Strength and Peel Strength (ASTM D 6768-02 and 6496-99, respectively)

E. Interfacial Friction Angle (ASTM D 6243): Testing for interfacial friction angle properties shall be done on the following interfaces:

1. Between HDPE textured geomembrane and non-woven side of GCL.

2. GCL internal.

3. Between woven side of GCL and compacted clay.

The interfacial friction angle tests shall be performed according to Section 02780 and at a frequency as indicated in Section 02780.2.01(D). Test results must meet the minimum requirements stated in Section 02780.3.01.

PART 2 - PRODUCTS

2.01 MATERIALS:

A. The GCL liner shall be Bentomat ST as produced by CETCO and meet the following properties.

Material Property	**Test Method**	**Required Values**	**Manufacturer's Test Frequency**
Bentonite Swell Index	ASTM D 5890	24 mL/2g min.	1 per 50 tons
Bentonite Fluid Loss	ASTM D 5891	18 mL max.	1 per 50 tons
Bentonite Mass/Area[2]	ASTM D 5993	0.75 lb/ft^2 (3.6 kg/m^2)	1 per 5,000 yd^2
GCL Grab Strength	ASTM D 6768-02	22.5 lbs/in.	1 per 30,000 yd^2
GCL Peel Strength	ASTM D 6496-99	2.5 lbs/in.	1 per 5,000 yd^2
GCL Index Flux	ASTM 5887-99	1x10^{-8} m^3/m^2/sec.	1 per 30,000 yd^2
GCL Hydraulic Conductivity	ASTM 5887-99	5x10^{-9} cm/sec.	1 per 30,000 yd^2
GCL Hydrated Internal Shear Strength	ASTM D 6243	See Section 02780 (3.01)	
GCL Non-Woven Side vs HDPE Textured Geomembrane Shear Strength	ASTM D 6243	See Section 02780 (3.01)	
GCL Woven Side vs Compacted Clay Shear Strength	ASTM D 6243	See Section 02780 (3.01)	

B. The geotextiles used in the manufacture of the GCL shall be made up from polypropylene fibers. Any and all substitutions shall be approved by the Project Manager prior to their use.

C. The liner shall be manufactured by the mechanical bonding of the needlepunch process to enhance the friction characteristics of the liner and to maintain the integrity of the liner under hydration. No glues or adhesives shall be used in lieu of the needlepunch process so as to retain these characteristics.

Needled GCLs are those which, by the process of a needling board (similar to that used in the manufacture of standard nonwoven geotextiles) have fibers of a nonwoven geotextile pushed through the bentonite clay core and integrated into the woven geotextile.

D. The GCL shall have a hydraulic conductivity equal to or less than $5x10^{-9}$ cm/sec at 5 psi confining stress.

PART 3 - EXECUTION

3.01 SHIPPING AND HANDLING:

A. Covering of the Rolls:

1. Manufacturers should clearly stipulate the type of protective covering and the manner of cover placement. The covering should be verified as to its capability for safe storage and proper transportation of the product.

2. The covering should be placed around the GCL in a workmanlike manner so as to effectively protect the product on all of its exposed surfaces and edges.

3. The central core should be accessible for handling by forklift vehicles. Handling of the GCL during shipment (i.e. loading, transport, and unloading) shall be performed using techniques approved by the manufacturer.

4. Clearly visible labels should identify the name and address of the manufacturer, trademark, date of manufacture, location of manufacture, style, roll number, lot number, serial number, dimensions, and weight in accordance with ASTM D 4873.

B. Storage at the Manufacturing Facility:

1. GCLs should always be stored indoors until they are ready to be transported to the field site.

2. Handling of the GCL should be such that the protective wrapping is not damaged. If it is, it must be immediately rewrapped by machine or hand; in the case of minor tears it may be taped.

3. Placement and stacking of rolls should be done in a manner so as to prevent thinning of the product at points of contact with the storage frame or with one another.

C. Shipment:

1. The GCLs should be shipped by themselves with no other cargo which could damage them in transit during stops or while off-loading other materials.

2. Method of loading GCLs rolls, transporting them, and off-loading them at the job site should not cause any damage to the GCL, its core or its protective wrapping.

3. Any protective wrapping that is damaged or stripped off the rolls should be repaired immediately or the roll should be moved to an enclosed facility until its repair can be made to the approval of the quality assurance personnel.

4. If any clay has been lost during transportation or from damage of any type, the outer layers of the GCL should be discarded until undamaged product is evidenced. The remaining roll must be wrapped in accordance with the manufacturer's original method to prevent hydration or further damage to the remaining roll.

D. Storage at the Site:

1. Handling of the GCLs should be done in a competent manner such that damage does not occur to the product nor to its protective wrapping.

2. The location of temporary field storage should not be in areas where water can accumulate. The rolls should be stored on high, flat ground or elevated off the ground so as not to form a dam creating the ponding of water. It is recommended to construct a platform so that GCL rolls are continuously supported along their length. GCL stored outdoors should be covered completely by tarps or other protective materials.

3. The rolls should not be stacked so high as to cause thinning of the product at points of contact (i.e. no higher than 3 rolls high). Furthermore, they should be stacked in such a way that access for conformance testing is possible.

4. If outdoor storage of rolls is to be longer than a few weeks, particular care (e.g. using tarpins) should be taken to minimize moisture pick-up or accidental damage. For storage periods longer than one season, a temporary enclosure should be placed over the rolls or they should be moved within an enclosed facility.

3.02 INSTALLATION:

A. The manufacturer shall provide the service of a technical representative during start-up. Start-up service provided by the manufacturer shall include transportation, lodging, expenses, materials, and equipment. Start-up service shall be provided by the manufacturer for a minimum of 1 working day.

B. General: The Contractor shall schedule a pre-installation conference as specified in Section 01041, Part 1.02. Prior to ordering GCL material, the Contractor shall submit, for the Project Manager's approval, a description or drawing of the method of sheet layout, detailing the orientation of sheets and the direction of the overlap between sheets. During installation of the GCL, the Installer shall label each sheet immediately after deployment, with the roll number, panel number, and date it was installed.

Installation of the GCL shall include the following considerations:

1. The GCL shall be installed with the woven-coated side contacting the compacted clay and the non-woven side contacting the 80-mil geomembrane. Place in the manner and at the locations shown on the drawings.

2. Rolls shall be handled utilizing a 3 inch schedule 80 steel pipe through the core and slings or straps attached to the ends of the pipe (core pipe). The core pipe shall be suspended from a spreader bar so that the edges of the liner are not damaged by the suspending straps or chains.

3. Work on the slopes shall be undertaken before the bottom to permit drainage in the event of rainfall. Panels may be pulled up from the bottom of the slope to the anchor trench or anchored first and the roll slowly lowered down the slope. Seams shall be perpendicular to the toe of the slope at all times. Seams at the base of the slope shall be a minimum of 5 feet away from the toe of the slope. Roll end seams or joints will not be allowed on the sideslopes.

4. Seam areas or runs shall be flat and clear of any large rocks, debris or ruts. Contacting surfaces shall be clean and clear of dirt or native soil with all edges pulled tight to maximize contact and to smooth out any wrinkles or creases. Overlaps shall be a minimum of 6 inches and verified by QA/QC personnel. A proper seam shall cover the lap line and leave the match line exposed.

5. Seams shall be augmented with granular bentonite to insure seam integrity. Granular bentonite shall be spread evenly from the panel edge to the lap line at a minimum rate of 1/4 pound per lineal foot. This rate of application will be assured by using one 50-pound bag of granular bentonite (evenly spaced along the seam) per roll of GCL. Accessory bentonite shall be of the same type as the material within the composite liner itself. Fasteners, anchor pins or adhesives may be used on seams to keep panels in place during backfill operations if necessary. All butt seams shall have a minimum of 2 foot overlap.

6. The contractor shall only work on an area that can be completed in one working day. Completion shall be defined as the full installation of the liner and placement of the 80-mil textured HDPE geomembrane to cover the GCL. Prior to deployment of the GCL, the subgrade (i.e. clay) will be smooth rolled to provide a smooth surface free of debris, roots and angular rocks. The GCL subgrade will be inspected and certified by the CQA personnel prior to placement of the GCL. Deployment of the GCL will be visually inspected to assure that no potentially harmful objects are present (e.g. stones, cutting blades, small tools, sandbags, etc.).

7. For any penetrations or structures the liner will contact, a small notch shall be cut along the edge of the area. The liner shall be brought up to the appurtenance and trimmed to fit snugly. The contractor shall hand apply and compact a pure bead or dry mixture of 1 part bentonite to 4 parts soil (by volume), blended dry, into half of the notch. The liner shall then be inserted into the notch, with the remaining area in the notch refilled with the 1 to 4 mixture and compacted.

8. For protection and proper performance, the primary geomembrane liner (80-mil HDPE textured liner) shall be applied immediately over the liner. During the liner application, a care shall be taken to avoid sharp turns and any quick stops or starts so as to avoid pinching or moving the liner.

9. Large rips, or tears shall be repaired by placing a patch over the defect, with a minimum overlap of 12 inches on all edges. Accessory bentonite shall be placed between the patch and the repaired material at a rate of 1/4 pound per lineal foot of edge. Prematurely hydrated GCL shall be removed and replaced with new GCL in accordance with the repair procedures described above.

10. Overlap joints and seams shall be measured as a single layer of geotextile.

11. Securely anchor GCL as shown on the drawings.

12. Soil cover shall be placed over the GCL using construction equipment that minimizes stresses on the GCL. A minimum thickness of 1 foot of cover should be maintained between the equipment tires/tracks and the GCL at all times during the covering process. This thickness recommendation does not apply to frequent traffic areas or roadways for which a minimum thickness of 2 feet is required.

13. During deployment of the GCL the material shall not be dragged over the subbase

C. Protection of Bentonite Geocomposites:

1. Exercise necessary care while transporting and installing the geocomposite to prevent damaging it.

2. Stored rolls shall be on a flat dry surface and to avoid any unnecessary stress on the packaging.

END OF SECTION

SECTION 02450

PIPE INSTALLATION

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

A. The requirements set forth by the Quality Assurance/Quality Control Plan shall apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Earthwork: Section 02200

B. Erosion Control: Section 02220

C. Manholes, Catch Basins, and Drainage Structures: Section 02570

D. HDPE Pipe and Fittings: Section 15100

1.03 REFERENCE:

A. ASTM D2774-01 Standard Practice for Underground Installation of Thermoplastic Pressure Piping

1.04 DESCRIPTION OF WORK:

A. Work of this Section shall consist of furnishing all labor, materials, and equipment to install and test leachate collection, leachate transport, and leak detection pipes and culverts. Only the appropriate portions of this section pertaining to the specific contract work identified in Section 01010 "Summary of Work" or as directed by the Engineer, will apply.

1.05 SUBMITTALS:

A. The Contractor shall furnish the name of the pipe and fittings manufacturer to the Engineer prior to commencing the work. Pipe of the same manufacturer shall be used throughout the project.

B. The Contractor shall submit to the Engineer a Construction Schedule for pipe installation.

PART 2 – PRODUCTS

Not Applicable.

PART 3 - EXECUTION

3.01 INSTALLATION:

A. All materials shall be stored and handled in accordance with the manufacturer's recommendations.

B. Excavate, backfill and compact soils in accordance with Section 02200.

C. Sewer Grade Defined:

The sewer grade shown on the drawings, and referred to in the specifications is as follows: When a gravel or concrete foundation is used, it is the underside of the gravel or concrete indicated on the plans. When neither a gravel nor concrete foundation is used, it is the underside of the barrel of the pipe covered by this Contract.

D. Pipe Jointing:

All joints shall be made in a dry trench and in accordance with the manufacturer's recommendations and the best practices for class of pipe installed. The ends of the pipe shall be wiped clean with a dry cloth before making the joint.

E. Pipe Installation:

1. The pipe shall be accurately installed to the line and grades to the satisfaction of the Engineer. The line and grade may be adjusted by the Engineer from that shown on the drawings to meet field conditions and no extra compensation shall be claimed therefore. Whenever the nature of the material excavated is such as to render it unsuitable for bedding or backfill material, the Contractor shall furnish suitable material as otherwise provided in these specifications.

2. Dewatering: Remove any standing water in trench before pipe or bedding installation.

3. Perforated pipe shall be installed as shown in the Contract Drawings. Perforations shall be installed in the correct orientation as shown on Contract Drawings.

4. For trench conditions, the pipe shall be bedded in stone pipe bedding placed on a flat trench bottom. The bedding material shall be worked (chinked) under the haunches manually to assure proper support. The bedding material shall completely fill the trench and extend for a minimum of 6 inches above and below the top and bottom of the pipe, respectively, or as indicated in the Contract Drawings. Suitable backfill material shall be placed above the pipe bedding material in 9-inch lifts and compacted to 90 percent maximum density. The Contractor shall place warning tape along the length of the trench installation one foot below finish grade.

5. Maximum lengths of fused pipe to be handled as one section shall be places according to manufacturer's recommendations as to pipe size, pipe DR and topography so as not to cause excessive gouging or surface abrasion; but not to exceed 400 feet.

6. Temporarily cap pipe sections longer than a single length (40 feet) on both ends during placement and on leading end of fusion operations, thereby preventing unnecessary intrusion of soil.

7. Complete tie-ins within the trench where possible to prevent overstressing of the pipe and connection.

8. Notify ENGINEER prior to pipe installation in trench to allow time for ENGINEER'S inspection.

9. Contractor shall maintain proper trench width during pipe installation as shown on the Contract Drawings. In areas where the Contractor's trenching operation exceeds the typical section, the Contractor may be required to use a higher strength class pipe in lieu of the designated class pipe at no additional cost to the Owner.

10. Allow sufficient time to adjust to trench temperature prior to testing, segment tie-ins or backfilling pipe.

11. Coordinate pipe installation adjacent to access roads with OWNER to limit impediment of the landfill operations or operations of other Contractors.

F. Pipe Cutting:

1. Where required, sections of pipe may be cut to provide shorter sections of pipe necessary for the construction. The cutting of the pipe shall be done in accordance with the pipe manufacturer's recommendations and subject to the approval of the Engineer. Note: For dual-contained pipe, field cutting and fitting is not recommended due to the extreme importance of the conductor being centralized in the containment pipe. For tie-ins with this pipe the Contractor shall notify the pipe manufacturer of special length pipes required at the onset of the job to avoid delays.

2. When permitted and allowed by the pipe manufacturer, the pipe material shall be cut by using a saw or milling process, approved by the pipe manufacturer and not by using any impact device, such as a hammer and chisel, to break the pipe. The pipe shall be cut, not broken. The cut end of the pipe shall be square to the axis of the pipe and any rough edges ground smooth.

G. Valve Installation: All valves shall be installed in accordance with the specifications for the pipe to which they are to be connected. Valve joints shall be made up in accordance with the Contract Drawings. The valves shall bear no stresses due to loads from the adjacent pipe. All valves shall be inspected before installation and they shall be cleaned and well lubricated before being installed in the line.

H. Inspection:

Pipe installation shall be subject to inspection by the Engineer for quality, adherence to line and grade, jointing, and proper backfill. Any joint not satisfactory to the Engineer shall be removed and remade to his satisfaction at the Contractor's expense. No pipe shall be backfilled until it has been approved by the Engineer. Prior to backfilling, the contractor shall obtain as-built top of pipe coordinates and elevations at grade changes, fittings, and at least every 50 feet along the length of pipe.

3.02 PIPE INSULATION:

A. Buried Trench Condition: Install 2-inch thick x 4-ft wide Styrofoam SM insulation as manufactured by Dow Chemical Co., or approved equal, between pipe and culvert or over pipe when noted on plans or as directed by the Owner's Representative. Install over the pipe when there is less than 5 ft of cover between the top of pipe and original ground grade. Install 6 in. above the pipe unless otherwise shown on Drawings, and provide 6-in. sand blanket above and below insulation.

3.03 SPECIAL REQUIREMENTS:

A. Flexible Pipe: In the case of the installation of polyvinyl chloride pipe and HDPE, strict adherence should be made to the general pipe installation requirements (3.01-D), so that the total deflection in these pipes does not exceed 5.0% of the pipe diameter being installed.

B. Assembling Push-On Joints: Push-on joints shall be made up by first inserting the gasket into the groove of the bell and applying a thin film of special nontoxic gasket lubricant uniformly over the inner surface of the gasket which will be in contact with the spigot end of the pipe. The chamfered end of the plain pipe shall be inserted into the gasket and then pushed past it until it seats against the bottom of the socket.

C. Assembling Mechanical Joint Retainer Glands: Surfaces against which the gasket will come in contact shall be thoroughly brushed with a wire brush prior to assembly of the joint. The gasket shall be cleaned. The gasket, bell, and spigot shall be lubricated by being washed with soapy water. The gland and gasket, in that order, shall be slipped over the spigot, and the spigot shall be inserted into the bell until it is correctly seated. The gasket shall then be seated evenly in the bell at all points, centering the spigot, and the gland shall be pressed firmly against the gasket. After all bolts have been inserted and the nuts have been made up fingertight, diametrically opposite nuts shall be progressively and uniformly tightened all around the joint to the proper tension by means of a torque wrench.

The correct range of torque as indicated by a torque wrench and the length of wrench (if not a torque wrench) used by an average man to produce such range of torque, shall not exceed the values specified in the tabulation titled TORQUE RANGE VALUES.

TORQUE RANGE VALUES

Range of torque	60 to 90 ft-lb
Length of wrench	10 in.

If effective sealing of the joint is not attained at the maximum torque indicated above, the joint shall be disassembled and thoroughly cleaned, then reassembled. Bolts shall not be overstressed to tighten a leaking joint. Set screws for retainer glands shall be torqued as recommended by the manufacturer.

END OF SECTION

SECTION 02451

CULVERTS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: The general provisions of the Contract, including General and Supplementary Conditions and General Requirements (if any), apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. Earthwork: Section 02200

B. Erosion Control: Section 02220

C. Pipe Installation: Section 02450

1.03 DESCRIPTION OF WORK:

A. Work Included: Provide and install corrugated metal pipe and corrugated HDPE pipe of the type(s), size(s) and in the location(s) shown on the Contract Drawings and as specified herein.

B. Work Not Included: Temporary drainage devices used by the Contractor for construction purposes.

1.04 SUBMITTALS:

A. The Contractor shall furnish the name of the manufacturer and manufacturers product brochure and literature to the Resident Project Representative prior to commencing work. Pipe of the same manufacturer shall be used throughout the project.

B. The Resident Project Representative may request the Contractor to submit manufacturer's certification that the product meets the requirements of this Specification.

1.05 DELIVERY, STORAGE AND HANDLING:

A. Exercise care when handling corrugated pipe to prevent damage to pipe and finish.

B. Immediately remove damaged materials and replace at no additional cost to the Owner.

C. Store materials above ground on platforms, skids, or other adequate supports.

PART 2 - PRODUCTS

2.01 MATERIALS:

1. For new access road construction, provide aluminized steel corrugated metal pipe, or corrugated polyethylene pipe as indicated on the plans:

   a. AASHTO M 274, Type II.

   b. AASHTO M 36, Type I.

2. Size and length as shown on Drawings and as specified herein.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Pipe:

1. Accurately lay to the line and grades to the satisfaction of the Resident Project Representative.

2. The line and grade may be adjusted by the Resident Project Representative from that shown on the Drawings to meet field conditions and no extra compensation shall be claimed therefore.

3. Granular Pipe Bedding: As specified in Section 02200.

4. Provide proper facilities for lowering the sections of pipe where pipe is to be placed.

5. Securely attach each section to the adjoining section by the approved method for the type of joint used.

6. Paving or Partial Lining of Pipes: Coincides with the flow line.

7. Elliptical Pipe: Placed so that major axis are within 5 degrees of the appropriate planes, horizontal or vertical as the case may be.

8. Sections of Corrugated Pipe: Join by enclosing joints with coupling bands of the same material as the pipe.

9. Pipe Grade Defined: The pipe grade shown on the Drawings, and referred to in the Specifications is as follows: When a gravel or concrete foundation is used, it is the underside of the gravel or concrete indicated on the plans.

B. Fittings:

1. Antiseep collar shall be installed as shown in the Contract Drawings.

3.02 INSPECTION:

A. Pipe installation shall be subject to inspection by the Resident Project Representative for quality, adherence to line grade, jointing, and proper backfill.

B. Any joint not satisfactory to the Resident Project Representative shall be removed and remade to his satisfaction at the Contractor's expense.

C. No pipe shall be backfilled until it has been approved by the Resident Project Representative.

END OF SECTION

SECTION 02510

BITUMINOUS CONCRETE PAVING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and general provisions of Contract, including General and Supplementary Conditions, (if any), apply to work of this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Earthwork: Section 02200

B. State of Maine, Department of Transportation, Standard Specifications Highways and Bridges, Revision of December 2002, hereafter designated as MDOT Specifications.

1.03 DESCRIPTION: Furnish all labor, materials, and equipment to construct plant mix bituminous concrete in conformity with the Contract Drawings and as specified herein.

1.04 QUALITY ASSURANCE:

A. Qualifications of Bituminous Concrete Producer: Use only materials which are furnished by a bulk bituminous concrete producer regularly engaged in production of hot-mix, hot-laid bituminous concrete.

B. Qualifications of Testing Agency: Use only recognized commercial testing laboratories with not less than 5 years experience in conducting tests and evaluations of bituminous concrete materials and design.

1.05 SUBMITTALS:

A. Mix Design: Provide the Resident Project Representative with a job mix formula for each course used in the work.

B. Test Reports: Provide two copies of each test described below at the frequency determined in para. C.

1. Aggregate Material: Submit laboratory test reports that confirm aggregates used in the bituminous mix conform to Section 703 of the MDOT Specifications.

2. Asphalt Cement: Submit laboratory test reports that bituminous material used in the bituminous mix conforms to Section 702 of the MDOT Specifications.

3. In-Place, Compacted Bituminous Concrete Mix: Submit laboratory test reports of samples cut from the in-place, compacted pavement indicating the percentage of theoretical maximum density (TMD), based on laboratory specimens of the mix combined in the proportions of the job mix formula.

C. Frequency of Testing:

1. Aggregate Material: Submit laboratory test reports of the stockpiled aggregates initially used in the mix and additional test reports for each change of source.

2. Asphalt Cement: Submit laboratory test reports for asphalt cement used in the initial mix and additional test reports for each change of source.

3. In-Place, Compacted bituminous Concrete Mix: Submit laboratory test reports at frequencies not less than one of the following:

   a. Every 300 tons placed.
   b. Each day's placement.
   c. Each course, each day's placement.

PART 2 - PRODUCTS

2.01 MATERIALS:

A. Aggregates: Conform to Section 703 of MDOT Specifications.

B. Asphalt Cement: Conform to Section 702 of MDOT Specifications.

PART 3 - EXECUTION

3.01 INSTALLATION:

A. Place Mix Hot Bituminous Pavement: Produce and place pavements in conformance with Section 401 of MDOT Specifications.

B. Pavement Repair:

1. Saw edges of existing pavement to provide a vertical bonding face.

2. Grind surface course 12 inches either side of repair.

3. Apply a tack coat to the ground edges.

4. Apply 3 in. of bituminous concrete paving, consisting of 2 in. base course (Grading "B") and 1 in. wearing course (Grading "C").

5. Roller compact both surfaces, compacting the final wear course to meet existing pavement surfaces exactly.

END OF SECTION

SECTION 02570

MANHOLES, CATCH BASINS, AND DRAINAGE STRUCTURES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS:

A. Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

B. The requirements set forth by the Quality Assurance/Quality Control Plan shall apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Earthwork: Section 02200

B. Erosion Control: Section 02220

C. Pipe Installation: Section 02450

1.03 DESCRIPTION OF WORK: Work specified in this section shall consist of furnishing all labor, materials, and equipment to construct manholes or catch basins, in conformity with the contract drawings and as specified herein.

1.04 SUBMITTALS: The Contractor shall submit to the Engineer shop drawings of all precast units. Manufacturer's information shall be submitted for joint sealants and waterproofing. Manufacturer shall provide floatation design shop drawings and calculations, including anti-floatation extended base slabs as necessary, for proposed manholes. Manufacturer shall assume groundwater levels equal top of ground elevations and provide for a 1.2 floatation factor of safety.

PART 2 - MATERIALS

2.01 PRECAST MANHOLE AND CATCH BASIN SECTIONS: Precast sections shall be manufactured in accordance with the latest ASTM Specification Designation C-478. Precast manholes shall be reinforced for H-20 loading (4,000 psi concrete).

2.02 MORTAR: Cement mortar shall be prepared in the following manner:

A. The cement shall be Type II. The mix shall be one (1) part cement to three (3) parts clean, well graded, hard, durable sand. Hydrated lime may be added to the mixture in an amount not to exceed 15% by weight of the cement. The amount of water shall be only the amount necessary to make a workable mix.

2.03 BRICK: Brick for manholes shall meet the latest AASHTO Specification Designation M-91

2.04 WATERPROOFING: Waterproofing for manholes shall be:

A. Asphalt conforming to ASTM Designation D-41, or

B. Cement base coating suitable for brush coat application.

2.05 FRAMES AND COVERS:

A. All castings shall be made of clean, even grain, gray cast iron. The castings shall be smooth, true to pattern and free from projections, sand holes, warp, and other defects which would interfere with the use of, or impair the serviceability of the castings.

B. The horizontal surface of the cover seat and under surface of the cover which rests upon the cover seat shall be machined on all frames and cover intended for vehicular traffic. After machining it shall be impossible to rock any cover after it has been seated on its associated frame.

C. The iron used for castings shall conform to ASTM Designation A-48 for Class 30 gray iron.

D. Unless otherwise shown on the Drawings, all castings shall be coated with coal tar pitch varnish, to which sufficient oil has been added to make a smooth coating, tough and tenacious when cold, not tacky and not brittle.

E. Manufacturer's name and catalog figure number must be cast on each frame and cover. The word SEWER or STORM must be stamped on the manhole covers as appropriate.

F. Catch basin grates shall be as shown on contract drawings or approved equal.

2.06 INLET GRATES:

A. Inlet grates shall be Heavy Duty Bar Guards manufactured by Agri Drain or equal.

B. Guards will be constructed of ½" steel rod and be protected by a powder coat finish.

2.07 HDPE LINER: All inner surfaces of the leachate handling structures shall be provided with a cast-in-place, 2-mm HDPE Studliner® as manufactured by GSE or equal. The HDPE shall be gray in color. All pipe openings in the lined sections shall have similar lining. Pipe boots shall be constructed to seal HDPE pipe to HDPE liner. Joints shall be extrusion welded with the same material according to manufacturer's direction. Welded joints shall be spark tested for leaks. If concrete is insufficiently green to test then Copper wires will be inserted prior to welding joints. Leaks found in the joint shall be repaired according to manufacturer's direction.

2.08 ENTRANCE HATCH: The access hatches shall be Model APS 300 (or equal) of the sizes shown and installed as indicated on the Contract Drawings. The manufacturer shall guarantee proper operation and against defects in material or workmanship for a period of five years. The hatch shall be of aluminum as manufactured by U.S.F. Fabrication Inc, Hialeah, Florida, or equal. The hatch cover shall be single leaf, watertight self-draining type. Door leaf shall be ¼ inch thick aluminum diamond pattern plate capable of withstanding a 300 psf live load. The frame shall be extruded aluminum with an integral anchor flange and door seat on all four (4) sides. The door leaf shall be equipped with a minimum of two stainless steel hinges with stainless steel pins, spring operators to afford easy operation, and an automatic hold-open arm with release handle. Hatch shall be provided with recessed padlock hasp. Installation shall be in accordance with the manufacturers attached instructions. The access hatch shall be fitted with a permanently installed fall through prevention net system that is easily retractable to allow full access to the space. The safety net shall be manufactured from high strength polyester net that has been tested and certified to meet the current OSHA standard 1926.502 (c)(4)(i) drop test.

PART 3 - EXECUTION

3.01 FABRICATION:

A. The tongue and groove of manhole and catch basin sections shall be formed of concrete so as to receive a pre-molded bituminous seal. Sections shall be set so as to be vertical and in true alignment.

B. Each section of the precast manhole and catch basin shall have two (2) lift points for the purpose of handling and installing.

C. Holes for pipes shall be cast in the base section so that there is a clear distance of 4-1/2" minimum between the inside bottom of the base section and the pipe invert.

D. The joint for the pipe at the base section shall be a wedge style Kor-N-Seal series 106 boot as manufactured by Telleborg or equal.

E. The inner HDPE liner of the leachate transport manholes shall be welded at each manhole section-joint and at pipe boot construction in accordance with manufacturer’s instructions.

3.02 INSTALLATION (As shown on the Contract Drawings):

A. General:

1. The excavation shall be properly dewatered while placing bedding material and setting the base or placing concrete. Waterstop shall be used at the horizontal joint of cast-in-place manholes. Base shall be placed on a 6" layer of compacted stone bedding.

2. Inlet and outlet stubs shall be connected and sealed as shown on the Drawings.

3. Barrel sections and cones of the appropriate combination of heights shall then be placed, using manufacturer's recommended procedure for sealing the horizontal joints, and as shown on the Drawings or the remaining barrel of the manhole shall be cast above the base.

4. A leakage test shall then be made as described in "Leakage Tests."

5. Following satisfactory completion of the leakage test, the frame and cover shall be placed on the top or some other means of preventing accidental entry by unauthorized persons, children, animals, etc., until the Contractor is ready to make final adjustment to grade.

B. Waterproofing: The waterproofing of the exterior surfaces of manholes shall be one of the following methods:

1. Bituminous Coating: After the concrete or cement plaster has set, two coats of an approved bituminous waterproofing material shall be applied to all outside surfaces of manholes. Waterproofing material shall be applied by brush or spray at approximate rate of 70 sq. ft./gal., in accordance with the manufacturer's instructions. Time shall be allowed between coats to permit sufficient drying so that the application of the second coat has no effect on the first.

2. Cement Base Coating: Cement base coatings delivered in sealed containers shall be mixed in accordance with the manufacturer's recommendations and applied with a stiff brush in 2 coats. Each coat shall be applied at the rate of 2 lb. per sq. yd.

C. Frames and Covers: Frames shall be set on mortared brick courses true to grade and concentric with the opening. All voids beneath the bottom flange and in the brick courses shall be completely filled to make a watertight fit. A ring of mortar at least 1 inch thick shall be placed around the outside of the bottom flange, extending to the edge of the manhole all around its circumference. The bricks and mortar shall not extend beyond the top of precast concrete cone section.

D. Inlet Grates: Inlets shall be set on mortared brick courses true to grade and concentric with the opening. All voids beneath the bottom flange and in the brick courses shall be completely filled to make a watertight fit. The bricks and mortar shall not extend beyond the top of precast concrete cone section.

E. Each pipe boot annulus shall be sealed with Sikadur 32 Hi-Mod grout as manufactured by Sika Corporation, as shown on the Contract Drawings.

3.03 ALTER EXISTING MANHOLE AND PUMP STATION: When altering existing catch basins or manholes, the structure shall be dismantled sufficiently to allow reconstruction in accordance with the applicable requirements as shown on the Drawings for complete pump station and manholes. Each altered manhole or pump station shall be cleaned of all accumulated silt, debris or foreign matter prior to final acceptance of work.

3.04 VACUUM LEAKAGE TESTS:

A. General:

1. To be observed by the Engineer on each sewer manhole.

2. A vacuum test made as described below. Manhole to pipe connection must be a flexible connector to perform this testing.

B. Preparation for Test:

1. After the manhole has been assembled in place, fill lifting holes and point with an approved non-shrinking mortar.

2. Perform test prior to placing the shelf and invert and before filling and pointing the horizontal joints, and before backfilling.

3. If the groundwater table has been allowed to rise above the bottom of the manhole, it must be lowered for the duration of the test.

4. Plug pipes and other openings into the manhole and the plugs braced to prevent blow out.

C. Test Procedure:

1. Test immediately after manhole assembly.

2. Use manhole vacuum test equipment equal to NPC Systems, Inc., Milford, New Hampshire.

3. Set tester in place.

4. Inflate compression band to seal base to structure.

5. Draw a vacuum of 10-in. Hg.

6. Close the valve.

7. Minimum test times for various manhole sizes. Less than 1 in/hg drop for the sizes listed below.

MH Depth (feet)	4' Diameter MH	5' Diameter MH	6' Diameter MH
15 feet or less	50 sec.	1 min. 5 sec.	1 min. 20 sec.
15 to 30 feet	1 min. 20 sec.	1 min. 45 sec.	2 min. 10 sec.

8. If leakage occurs fill those points with non-shrink grout, allow to set and retest.

9. Rejected Manholes: Disassemble, reconstruct or replace as directed by the Engineer.

D. Backfilling: The test may be conducted either before or after backfilling around the manhole. However, if the Contractor elects to backfill prior to testing, for any reason, it shall be at his own risk, and it shall be incumbent upon the Contractor to determine the reason for any failure of the test. No adjustment in the leakage allowance will be made for unknown causes such as leaking plugs, absorption, etc., i.e., it will be assumed that all loss of water during the test is a result of leaks through the joints or through the concrete. Furthermore, the Contractor shall take any steps necessary to assure the Resident Project Representative that the water table is below the bottom of the manhole throughout the test.

END OF SECTION

SECTION 02732

LEACHATE COLLECTION AND LEAK DETECTION
PUMP STATIONS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS:

A. The general provisions of the Contract, including General and Supplementary Conditions and General Requirements (if any), apply to the work specified in this Section.

B. The requirements set forth by the Quality Assurance/Quality Control Plan shall apply to the work specified in this Section.

1.02 DESCRIPTION: The work of this Section includes furnishing all labor, materials, tools, and equipment necessary to furnish and install a complete leachate and leak detection pumping stations, as shown on the Drawings. The system shall be complete with submersible pumps, motors, motor controls, electrical wiring and conduits, piping and valves, liquid level sensors, lift out assembly, and other necessary appurtenances. Some of the electrical components of the pump stations will be supplied by an Owner Approved Electrical Contractor (OAEC) as specified below. The OAEC will be responsible for the installation of supplied components.

1.03 RELATED WORK SPECIFIED ELSEWHERE:

A. Site Preparation: Section 02100

B. Earthwork: Section 02200

C. Erosion Control: Section 02220

D. Pipe Installation: Section 02450

1.04 DESIGN CRITERIA:

A. The materials and equipment covered by this specification are intended to be standard materials and equipment of proven ability. Equipment shall be designed and constructed in accordance with the best practice of the industry and shall be installed in accordance with the manufacturer's recommendations and the Contract Documents. The specifications call attention to certain features but do not purport to cover all details entering into the construction of the equipment.

B. To provide for continuity of the pump station's electrical and control systems with the owner's existing SCADA system, the electrical and control systems for the pump station will be supplied by Owner Approved Electrical Contractor (OAEC). A description of these systems is provided in this specification for the purpose of providing the supplier of pumps, level sensors, and associated piping and fittings with an indication of the type of electrical and control systems that will be used in this pump station. The control logic function and all other control components used in each control system shall be performed by solid-state components, which shall be standard catalog items of the system manufacturer, with proven field performance. The system manufacturer for system expansion or renewal parts purposes shall stock at least one module of each type used in each system. The modules shall be of a compatible, integrated control family with a full range of control/protective/alternation/telemetry capabilities and associated housings, enclosure system and appurtenances to perform a variety of functions as required by this project and foreseeable expansion. It is the intention of this specification to disallow non-standard, "one of a kind", experimental, unproven combinations of equipment. The level/pressure sensing equipment shall be standard products manufactured by the control supplier in order to assure proper system interconnections and reliable, long-term operation.

Equipment shall be designed and constructed in accordance with the best practice of the industry and shall be installed in accordance with the manufacturer's recommendations and the Contract Documents. The specifications call attention to certain features but do not purport to cover all details entering into the construction of the equipment.

1.05 PRODUCT HANDLING: All materials and equipment shall be shipped, stored, handled and installed in such a manner as not to degrade quality, serviceability or appearance. The equipment shall be stored in a clean, dry location free from construction dust, precipitation and excess moisture. If stored for more than two weeks, the equipment shall receive all maintenance considerations required by the manufacturer for proper storage of the equipment.

1.06 WARRANTIES:

A. The complete pumping system as a whole, inclusive of all provided components, parts, equipment, controllers, instrumentation, assemblies and accessories shall be warranted to be free of defects in material and workmanship for a period of sixty (60) months from date of start-up by the manufacturer or authorized representative or eighteen (18) months, if start-up services are performed by others.

B. If any portion of the system fails due to either materials or workmanship during the applicable period, the manufacturer shall repair, substitute or replace the item at no-charge based on the item's being returned freight pre-paid with a returned materials authorization (RMA) to the system manufacturer for evaluation. The repaired, substituted or replaced item shall be promptly returned to the Owner freight prepaid by the manufacturer. The system manufacturer will not be liable for a fair wear and tear through service in application or damage to any item caused by abnormal operating conditions, accident, misuse, power surges, ungrounded equipment, acts of God, unauthorized alteration, modification or repair.

C. The manufacturer shall provide reasonable assistance and troubleshooting by telephone at no cost to the Owner. On-site technical assistance by an engineer or service technician shall be available with compensation to the manufacturer based on time, materials and expenses with pro-rated credit to be issued if a warranty consideration is determined to be merited.

1.07 SUBMITTALS: Shop drawings, brochures, and samples shall be submitted for all items to be furnished in accordance with the provisions of the General Conditions. Submittals shall include at least the following:

A. Shop Drawings: A complete set of drawings shall be supplied to insure successful installation and operation of the control system. The shop drawings shall consist of all of the following:

1. Sufficient detail to evaluate compliance with these specifications.
2. A detailed component list including manufacturer and catalog number.
3. A custom wiring diagram for this specific application to facilitate and insure accurate field connections to the control panel by electrical installation personnel.
4. A description of operation for the control system.
5. An enclosure dimension print.

B. Brochures and/or catalog cuts.

C. Performance curves.

D. Complete master wiring diagrams and elementary or control schematics, including required coordination with other electrical control devices operating in conjunction with the pumping station. Due to the complexity of the control functions, it is imperative the above drawings be clear and carefully prepared to facilitate interconnections with other equipment. Standard preprinted sheets or drawings simply marked to indicate applicability to this contract will not be acceptable.

1.08 Operation and Maintenance Manual of the pumping station including equipment and components.

1.09 Attention is directed to Part 2 of these Specifications wherein certain Special Mechanical and Electrical Equipment requirements are specified. These requirements are a part of this Section and relate to:

A. Substitution of equipment.

B. Special requirements for pumps.

C. Electric motor.

D. Noise specification for machinery and equipment.

E. Operation and maintenance manuals.

F. Manufacturer's services.

G. Spare parts.

H. Special tools.

I. Certifications.

J. Warranties.

1.10 DESIGN CONDITIONS:

Pump Application	HP	Flow Rate (GPM)	TDH Range (Ft)	SDR 17 Carrier Pipe Diameter (Ft)
Permanent Leachate Pump Station	10	150	71-91	2 to 3
Temporary Leachate Pump Station	5	150	35-60	2
Leak Detection Pump Station	1	30	37	1

PART 2 - PRODUCTS

2.01 LEACHATE PUMPS AND CARRIAGE SYSTEM:

A. Pumps:

1. The contractor shall furnish and install one complete leachate transfer pumping system, including two pumps, as manufactured by Leachator™ Pumping Systems, Inc. of Cumming, Georgia (1-800-640-9208) or Engineer-approved equal.

2. Pumps shall be of centrifugal, submersible design suitable for primary landfill leachate. The pump shall be coupled to a submersible motor that is non-overloading throughout the operating curve of the pump. Pump shall be supplied with a 300 series stainless steel strainer allowing up to a 1/4" solid to pass.

3. Permanent Leachate Pumps shall be Leachator™ LPS150MSTGXX100-05. Temporary Leachate Pumps shall be Leachator™ LPS150MGSTXX050-02. Both permanent and temporary pumps shall supplied with 100 feet of jacketed power cable and rated for a minimum duty performance as specified above.

4. Motor horsepower shall be as identified above, and shall operate on 460 volt, 3 phase, 60 hertz supply power.

5. Major pump components shall be of high strength, light weight aluminum alloy casting, with smooth surfaces devoid of blow holes or other irregularities. All exposed nuts or bolts shall be AISI type 300 series stainless steel construction. All exterior metal surfaces coming into contact with the pumpage, other than stainless steel shall be protected by a factory applied two-part epoxy coating. All O-rings shall be Viton.

6. The cable entry seal design shall preclude specific torque requirements to insure a watertight and submersible seal. The cable entry shall consist of a single cylindrical elastomer grommet, flanked by washers, all having a close tolerance fit against the cable outside diameter and the entry inside diameter and compressed by the body containing a strain relief function, separate from the function of sealing the cable. The assembly shall provide ease of changing the cable when necessary using the same entry seal.

7. The pump motor shall be induction type with a squirrel cage rotor, shell type design, housed in an air filled, watertight chamber, NEMA B type. The stator windings and leads shall be insulated with moisture resistant Class H insulation rated for 180°C (356°F).

. The stator shall be heat-shrink fitted into the stator housing. The motor shall be designed for continuous duty handling pumped media of 40°C (104°F) and capable of up to 15 evenly spaced starts per hour.

The rotor bars and short circuit rings shall be made of cast aluminum. The motor and pump shall be designed and assembled by the same manufacturer.

The combined service factor (combined effect of voltage, frequency and specific gravity) shall be a minimum of 1.15. The motor shall have a voltage tolerance of plus or minus 10%. The motor shall be designed for operation up to 40°C (104°F) ambient and with a temperature rise not to exceed 80°C. A performance chart shall be provided showing curves for torque, current, power factor, input/output kW and efficiency. This chart shall also include data on starting and no-load characteristics.

The power cable shall be sized according to the NEC and ICEA standards and shall be of sufficient length to reach the junction box without the need of any splices. The outer jacket of the cable shall be oil resistant chloroprene rubber. The motor and cable shall be capable of continuous submergence underwater without loss of watertight integrity to a depth of 65 feet.

The motor horsepower shall be adequate so that the pump is non-overloading throughout the entire pump performance curve from shut-off through run-out.

8. The pump shaft shall rotate on two ball bearings, single row angular upper and double row angular lower . Motor bearings shall be permanently grease lubricated.

9. Each pump shall be provided with a tandem mechanical shaft seal system consisting of two totally independent seal assemblies. The seals shall operate in a lubricant reservoir that hydrodynamically lubricates the lapped seal faces at a constant rate. The lower, primary seal shall be tungsten carbide/tungsten carbide. The upper seal shall be tungsten carbide/tungsten carbide.

10. Shaft shall be constructed of stainless steel ANSI 431.

11. The Impeller shall be of 3 vane closed impeller constructed of high chrome alloy cast iron ASTM 532.80 Alloy IIIA, hardened for high wear resistance to 60 Rc hardness.

B. Carriage System:

1. The pumps shall be mounted in a patented 300 series stainless steel carriage for use in a 24 inch HDPE / SDR 17 riser pipe with a constant inside diameter set at a 3 to 1 slope.

2. The carriages shall provide a low center of gravity and all wheels shall remain in contact with contour of the riser pipe. The wheels shall be constructed of non-

corrosive material with self-lubricating qualities and must be able to travel over welding beads, typically found in riser pipe fabrications.

3. The level sensors shall be carriage mounted and capable of being removed or replaced without disassembly of the pump assembly.

4. A safety/retrieval cable assembly with properly sized cable clips, snap hooks, and anchor eye bolt constructed of 300 series stainless steel shall be provided for each pump/carriage.

C. Discharge Hose:

1. Discharge hose shall be 3” Nitrile Synthetic rubber construction flexible hose having a rated working pressure of 150 PSI and a temperature range of -35 to +200 degrees Fahrenheit.

2. Hose suitable for leachate service shall be provided in a length commensurate with the dimensional requirements of the application and field fitted by installing contractor.

D. Discharge Hose Fittings:

1. All hose fittings shall be 300 series stainless steel and shall be suitable for the application. All hose bands shall be hi-torque 300 series stainless construction.

E. Discharge Exit Fittings:

1. A riser side exit disconnect fitting shall be provided, that will allow quick connection/disconnection of the pump discharge hose from the riser exit, and allow the pump to be removed without interference of the stationary fittings. The exit arrangement shall thread through the riser pipe as to provide gas tight connection.

2. All fittings shall be 300 series stainless steel construction.

3. The exit connections will penetrate the riser wall approximately 6”, no more than 18”, from the top of the riser pipe by means of 300 series stainless steel, male threaded exit nipple.

2.03 LEAK DETECTION PUMP:

A. Pumps:

The leak detection pump shall be a Prosser Model 1-0.34-1 HP 3450 rpm 460 volt 3 phase motor or equal. The pump shall be designed to pump waste water or leachate with 0.25” inch diameter solids without damage during operation The pump shall be designed so that the shaft power required (BHP)/(kW) shall not exceed the motor rated output throughout the entire operating range of the pump performance curve.

All major parts of the pumping unit(s) including casing, impeller, motor cover and intermediate brackets shall be manufactured from recyclable, application appropriate resins. The need for a protective coating shall not be required. All exposed fasteners shall be stainless steel and shall have stainless steel mating anchors integrally cast into the mating part. All units shall be furnished with a NPT discharge companion flange.

Impellers shall be of the multi-vane, semi-vortex, solids handling design and shall be slip fit to the shaft. The motor shaft shall be machined to provide a positive drive of the impeller. The pump casing shall incorporate an air relief valve.

All units shall be furnished with a dual inside mechanical shaft seal located completely out of the pumpage, running in a separate oil filled chamber. The oil chamber shall be fitted with a device that shall provide positive lubrication of the top mechanical seal, (down to one third of the standard oil level). The device shall not consume any additional electrical power. Units shall have silicon carbide versus silicon carbide seal faces. Mechanical seal hardware shall be stainless steel.

The pump motor(s) shall be 1 Hp, 460 V 3 Phase and shall be NEMA MG-1, Design Type B equivalent. Motor(s) shall be rated at full load amps Motor(s) shall have a 1.15 service factor and shall be rated for 20 starts per hour. Motor(s) shall be air filled, copper wound, class F insulated with built in thermal and over amperage protection. Motor shaft shall be 403 stainless steel and shall be supported by two permanently lubricated, high temperature ball bearings, with a B-10 life rating at best efficiency point of 60,000 hours. The bearings shall be single row, double shielded, C3, deep groove type ball bearings. Bearing seats shall be anodized steel or cast aluminum. Motor casing shall be 304 Stainless Steel.

The pump power cable shall be suitable for submersible pump applications The cable entrance shall incorporate built in strain relief, limited tightening plate, and shall feature a vulcanized, one piece, combination three way mechanical compression sealing/fatigue reducing boot The cable entrance assembly shall contain a anti-wicking block to eliminate water incursion into the motor due to capillary wicking should the power cable be accidentally damaged.

The pump, including the bearings, mechanical seals, and motor must be capable of running in the absence of pumpage for the period of at least 24 hours without damage.

B. Leak Detection Pump Carriage System:

The specified pumps shall be mounted in a stainless steel or non-corrosive, durable carriage. The carriage shall be designed for sideslope riser leachate applications. The carriage must remain in contact with the inside diameter of the riser pipe to assure a straight path of travel of the pump to the base of the riser pipe and shall prevent the pump from twisting movement due to the starting torque of the motor. The carriage must easily remove the pump in the field should the pump require service. The pump and carriage shall be capable of entry into a lead 12-inch SDR 17 for pumps, riser pipe and must be able to travel over welding beads (0.625 inch) and perforations which are common to leachate collection riser pipe fabrication. A safety/retrieval cable of 1/4-inch stainless steel with required fittings shall be provided for each pump.

C. Pump Cord: Heavy-duty S.O.W. cord shall be used for all electrical connections from the pumps to the control panels.

2.03 CONTROL PANEL:

A. General: (SUPPLIED BY OAEC) The pump manufacturer shall provide a completely self-contained duplex motor control panel and a simplex motor control panel. The control panel shall provide short circuit and overload protection for each pump. On the duplex leachate collection system an automatic alternator with manual override switch shall be provided to manually select the lead pump duty between the two pumps on successive cycles. The control panel shall conform to National Electrical Manufacturer's Association (NEMA), Joint Industry Council (JIC), and National Electrical Code (NEC) specifications, and shall be Underwriters' Laboratories (UL) listed. The panel shall be factory wired and tested.

B. Enclosure: (SUPPLIED BY OAEC) The motor controls and circuit breakers shall be housed in a NEMA 4X enclosure. The enclosure shall be constructed of 14-gauge steel with continuous seam welds. The enclosure shall be provided with tamperproof double-door system consisting of a bland outer door and a second inner door on which all operating controls are located. The controls shall incorporate a "dead front" type of installation. Finish shall be baked enamel, white inside, gray outside. A padlock hasp shall be provided. The control enclosure shall be housed within the warehouse.

C. Phase Failure/Undervoltage Monitor: (SUPPLIED BY OAEC) A phase-loss/unbalance/reversal and undervoltage protection assembly shall be provided with adjustable nominal voltage setting and three extractor type line voltage fuses. This device shall drop-out pumps if all phases drop below 90 percent or if one phase drops below 80 to 83 percent nominal voltage. This device shall have a 1/2-second drop-out delay and adjustable restoration time delay of up to five minutes.

D. Pump Circuit Breaker: (SUPPLIED BY OAEC) A thermal magnetic molded case industrial type circuit breaker shall be supplied as branch circuit protection for each leachate pump. The circuit breaker must have a minimum ampere interrupting capacity of 14,000 symmetrical RMS amps at 480 VAC. l Each circuit breaker toggle shall be operator accessible from the front of the dead front inner door. Each circuit breaker shall include an inner door interlocked, rotary type, padlock compatible operator handle.

E. Pump Motor Starters: (SUPPLIED BY OAEC) A NEMA rated, full-voltage across the line magnetic motor starter with overload sensing in each phase to provide overcurrent and running protection shall be provided for each pump motor. Overcurrent protection shall be provided by accurately sized, replaceable, overload heater elements. Resetting of the overload shall be provided via an inner door mounted reset pushbutton. 120 VAC control power shall be provided for the motor starter coil.

Primary Leachate Pump	**HP**	**CB Size**	**MS Size**	**Controlled By**
Lead	5 or10	20 AMP	0	Leachate level sensing
Lag	5 or10	20 AMP	0	Leachate level sensing

Leak Detection Pump	**HP**	**CB Size**	**MS Size**	**Controlled By**
Lead	5 or10	20 AMP	0	Liquid Level sensing

F. Pump Selector Switch: (SUPPLIED BY OAEC) A door-mounted, 1-3/16" diameter "hand-off-auto" 3-position, rotary, oil tight, heavy duty type selector switch shall be furnished for each pump.

G. Pump Run Indicating Light: (SUPPLIED BY OAEC) A door-mounted, 1-3/16" diameter oil tight type pilot light operated from a respective starter auxiliary contact, shall be furnished for each pump, to indicate a "pump running" condition. Each pilot light shall be transformer, press-to-test type with replaceable bulb.

H. Pump Running Time Meter: (SUPPLIED BY OAEC) A door-mounted running time meter, measuring hours and tenths of hours of operation up to 99999.9 hours, shall be furnished for each pump. This shall be a 120-VAC device operating from the control voltage by an auxiliary contact of the motor starter.

I. Control Power Transformer: (SUPPLIED BY OAEC) A 480/120 VAC transformer with primary fusing and secondary protection shall be provided for all 120 VAC powered devices, including the motor starter pilot circuits. The secondary side of the transformer shall be protected by the single pole circuit breaker described below.

J. Control Power Circuit Breaker: (SUPPLIED BY OAEC) A control power circuit breaker shall be provided. The breaker shall be operable through the inner door of the control panel to provide a disconnect means and short circuit protection for any 120 VAC (or less) devices not powered from motor starter circuits.

K. Convenience Receptacle: (SUPPLIED BY OAEC) An inner door-mounted, 120 VAC duplex, ground fault interrupter (GFI) type, convenience receptacle rated at 15 amperes shall be supplied for the operation of a trouble light, drill, etc. It shall be protected by a separate circuit breaker accessible from the inner door.

L. Condensation Protective Heater: (SUPPLIED BY OAEC) A 100 Watt, 120 VAC, strip type, condensation protective heater and high temperature cutout thermostat shall be supplied in the control panel.

M. Leachate Pump Liquid Level Pump/Alarm Controllers (2): (SUPPLIED BY OAEC) This specification is intended to cover a complete and operational automatic pump and alarm control system that responds to the leachate level pressure excursions.

Each system shall sense the liquid level and pressure over a calibrated range, display it on local display on the face of the controller.

Each pump/alarm controller shall accept a single, level-proportional analog input signal (4-20 milli-amp) and provide level-differential automatic operation of the pump(s) and alarms.

Each controller shall display the sensed control level on a display as manufactured by Precision Digital. The level shall be displayed in a 0 to 10-foot range or range as required, with 3 inch resolution.

Each controller shall operate directly with the level sensing transducer. The controller shall include transducer excitation voltage regulation, signal spanning and offsetting and adjustable "quelling" (rate-of-change limiting).

Each controller shall include abnormal level alarm annunciation circuitry with a front accessible alarm silence pushbutton and rear terminal block connection for an external audible alarm and silence pushbutton.

It is the specific intention of this functional requirement that standard controllers will be employed with features as herein described and that they be a fully-integrated assembly. That is, the furnishing of similar functions using a multiplicity of setpoint modules, extensive relay/timer logic to accomplish control sequences or generic programmable logic controllers with custom software is specifically precluded by this specification and will not be acceptable.

N. Leachate Level Sensing Submersible Transducers: Each leachate level shall be sensed by a submersible level transducer. In addition to these two transducers, the contractor shall supply one spare transducer to the Owner. Each transducer shall be able to read in 0.1-ft increments and be a 3-wire type to operate from a supply voltage of 10.5 to 24 VDC and produce a 4-20 milli-amp instrumentation signal in direct proportion to the measured level excursion over a factory-calibrated range. Each transducer shall have internal and external transient protections. One complete set of spare transducers with cable shall be supplied to the project.

Each transducer shall be of the solid-state head-pressure sensing type, suitable for continuous submergence and operation and shall be installed in accordance with manufacturer's instructions.

Transducer housings shall be constructed of Type 316 stainless steel, with a bottom diaphragm measuring 7/8-inch-diameter of heavy-duty, limp, foul-free, molded Teflon (TM) bonded to a synthetic rubber back/seal.

A hydraulic fill liquid behind the diaphragm shall transmit the sensed pressure to a solid-state variable-capacitance transducer element to convert the sensed pressure to a corresponding electrical value. The sensed media shall exert its pressure against the diaphragm which flexes minutely so as to vary the proximity between an internal ceramic diaphragm and a ceramic substrate to vary the capacitance of an electrical field created between the two surfaces. A stable, hybrid, operational amplifier assembly shall be incorporated in the transducer to excite and demodulate the sensing mechanism. The transducer shall incorporate laser-trimmed, temperature compensated, high quality components and construction to provide a precise, reliable, stable output signal directly proportional to the sensed pressure over a factory-calibrated range.

Each transducer element shall incorporate high over-pressure protection and be designed to withstand intermittent over-pressures five times the full-scale range being sensed. Metallic diaphragms shall not be acceptable in that they are subject to damage or distortion. Sensing principles employing LVDTs, resistive or pneumatic elements shall not be acceptable.

The internal pressure of each lower transducer assembly shall be relieved to atmospheric pressure through a heavy-duty urethane jacketed hose/cable assembly, and breather system mounted in the pump control panel. Each sealed breather system shall compensate for variations in barometric pressure and expansion and contraction of air due to temperature changes and altitude as well as prevent fouling from moisture and other corrosive elements. Transducer levels shall be set as follows:

Leachate Collection Sump Pump:

Pump #1 “On” Elevation	3’ Above sump floor.
Pump #2 “On” Elevation	5’ Above sump floor.
Pumps “Off” Elevation	1’ Above sump floor.

Leak Detection Sump Pump:

Pump #1 “On” Elevation	2’ Above sump floor.
Pump “Off” Elevation	1’ Above sump floor.

Each transducer assembly shall be installed where directed by the Engineer and connected with other system elements and placed in successful operation. Each shall be provided with input power and output signal transient protection, associated control elements as specified herein and in accordance with manufacturer’s instructions.

Each submersible level transducer shall be a Bulletin A1200, Model 241GSCL as manufactured by U.S. Filter/Consolidated Electric Company of St. Paul, MN.

O. Intrinsically Safe Transducer Control Modules (2): An intrinsically safe barrier shall be provided for each transducer and be mounted in the control panel. Each barrier shall have been tested, approved and labeled by an independent, 3rd party testing lab (i.e. UL, FM, CSA) with the specific submersible level transducer furnished for this application. Each barrier shall render the level sensing system suitable for use in Class 1, Division 1, Groups A, B, C and D, Class 2, Division 1, Groups E, F and G, and Class 3, Division 1 hazardous locations.

Each intrinsically safe barrier shall be a Bulletin A1000, Model IS1-3 as manufactured by U.S. Filter/Consolidated Electric Company of St. Paul, MN.

P. Relays: (SUPPLIED BY OAEC) Relays associated with the control apparatus shall be of the plug-in base type with transparent cover. Relays shall be provided with contacts rated for 10 amp., at 250 VAC. All relays shall be of the same manufacturer for all apparatus furnished.

This Specification does not apply to pre-manufactured modules which contain micro type relays to facilitate their operation.

Q. Local Alarm System: (SUPPLIED BY OAEC) An enclosure top-mounted, alarm light including a high impact resistant, red Lexan lens shall be included. The alarm light shall operate on 120 VAC power and shall flash on a transducer abnormal level or pump cutout alarm condition. The alarm light shall include a latch-in circuit for an alarm condition, requiring manual reset via an inner door mounted, pushbutton.

R. Pump Cutout/Restore Logic: (SUPPLIED BY OAEC) Logic shall be incorporated into the control to provide leachate cutout/restore based on the liquid level in the storage tank.

The pump cutout/restore logic shall include an inner door-mounted, 1-3/16-inch-diameter oil-tight-type pilot light to indicate a “pump cutout” condition. The pilot light shall be transformer, press-to-test type with replaceable bulb. The cutout logic shall also include an operator initiated, manual reset capability with inner door-mounted pushbutton, to allow the pumps to operate after the level in the storage tank has receded.

2.04 STATION WIRING (SUPPLIED BY OAEC):

A. The pumping station control panels shall be completely wired and tested at the factory. The wiring shall be in accordance with the National Electrical Code and as hereinafter specified. Control wiring shall be color coded. All job connections required to conveniently replace control components shall be made at approved type terminal blocks with engraved bakelite marker strips or similar approved means.

B. All wiring shall be of annealed 98 percent conductivity, soft drawn copper. Wire insulation shall be either Type THWN or Type XHHW. With the exception of control and signal leads, no wire smaller than No. 12 AWG, shall be used.

C. All wiring between the control panel and junction box shall be in watertight galvanized rigid steel conduit. Liquidtight flexible metal conduits shall be used for sewage pump motor terminations. Where galvanized finish is removed for threading, a protective finish shall be applied.

D. Heavy-duty S.O.W. Chord shall be used for all electrical connections from the pumps to the control panels.

2.05 FLOWMETER (SUPPLIED BY OAEC):

A. The flowmeters shall be MAG meters as manufactured by Krohna America, Inc., with instantaneous and cumulative reading capability.

B. A digital display shall be located in the pump station control panel.

2.06 ATMOSPHERE MONITORING (SUPPLIED BY OAEC):

A. Gas monitors shall be Ultima XA combustible monitor and Ultima XA hydrogen sulfide monitor, as manufactured by MSA. Each unit shall have a NEMA 4X general purpose enclosure, mounted within the 7 to 30 VDC power supply (3-wire), 4-20 mA signal output, status LEDs and internal relays (3 alarm, 1 trouble). Each unit shall come with its own calibration kit and calibration gas. One controller shall be supplied for calibration and configuration.

PART 3 - EXECUTION

3.01 INSTALLATION:

A. All materials and equipment shall be installed in a neat, workmanlike manner.

B. All wiring of the equipment shall be as specified in National Electrical Contractors Association Standard of Installation, and National Electrical Manufacturers Association WD1 and WD6.

C. Package Pumping Unit: Installation of the pumping station shall be done in accordance with written instructions provided by the manufacturer and as approved.

3.02 PAINTING: Shop painting and the surface preparation is a part of the work specified in this Section and shall be as specified in finish painting.

3.03 CLEANUP: Prior to startup and field testing, all foreign matter shall be removed from the pump chamber piping and pumps. Spillage of lubricants used in servicing the system shall be cleaned from all equipment and concrete surfaces.

3.04 MANUFACTURER'S SERVICES AND SUPERVISION: A minimum of two days shall be provided for installation and startup. The services of a factory trained, qualified representative shall be provided to inspect the completed installation, make all adjustment necessary to place the system in trouble-free operation and instruct the operating personnel in the proper care and operation of the equipment.

3.05 MANUFACTURER'S TRAINING: A minimum of one day shall be provided for manufacturer's training.

3.06 LUBRICATION REQUIREMENTS: All lubricating oils required for the first year of operation shall be provided for each station.

3.07 INSPECTION AND TESTING: Each entire package pumping system shall be field tested as a system using clean fresh water prior to the acceptance of the station. The pumps shall be operated continuously at the design conditions for at least 15 minutes. All systems, controls, and sequences shall be operated and demonstrated as operating as approved. The Contractor shall perform all tests and shall be responsible for all necessary temporary connections, testing equipment, and utilities and shall provide and dispose of all water used. A factory trained representative shall be present for the testing.

A. Field supervisor: The manufacturer will furnish a suitably qualified technician to inspect the completed installation, make necessary adjustments and instruct operating personnel in the proper care and operation of the equipment, prior to the final acceptance of the pumping station. <u>No distributor, representative or agent acting on behalf of the manufacturer shall be approved to complete start up services. This task must be reviewed and completed by a direct employee of the manufacturer.</u>

B. Field Test: When the pumping facility is complete and ready for operation, then the station shall be inspected and tested for compliance to the contract documents. Test of equipment shall be made by the contractor in the presence of the Engineer, electrical sub contractor, equipment manufacturer and the owner. The equipment tests shall include, but will not be limited to the following:

1. Pumps and motors: Pumps shall be run at design conditions. A determination shall be made of the pumping capacity. Performance of the pumps shall meet the specified criteria when field tested.

2. Electrical: Readings shall be made of the voltage and amperage draw and recorded on the manufacturers start up form. This form should be kept by the manufacturer, Engineer, Contractor and Owner for future reference.

3. Controls: Control primary elements shall be tested to determine satisfactory performance for starting and stopping at the proper liquid levels. Pump sequence and alarm functions will also be tested.

4. Equipment: Equipment shall be operated to determine that the pump is located in the correct position in the riser assembly. A check will be conducted to ensure that there is no overloading of the pump or any overheating in any of the

controls. A check will be conducted for any abnormal vibration that may be evident in the discharge plumbing. Pump will be raised and reset to ensure correct placement in riser pipe.

5. Inspection: An inspection of all mechanical and electrical equipment, controls, piping, valves, fittings, brackets, mountings, seals, conduit, painting and component features shall be made while the station is being tested to determine performance and compliance with design requirements and the specification.

6. Structure: The station shall be inspected for performance, structural soundness and water tightness.

7. Repairs, adjustments and replacement: The contractor shall make any and all necessary repairs, adjustments and replace any component parts until performance has been demonstrated to the satisfaction of the Engineer. The contractor shall bear the cost of any repair, adjustment and replacement.

8. Pump and Controls manufacturer must submit to the Engineer for review a full synopsis outlining occasions where the pump assembly has been:

    a. Run without damage
    b. Operated under conditions whereby solids have been passed through the pump assembly without degrading the pump performance or damaging the pump or motor assembly.

END OF SECTION

SECTION 02771

GEOMEMBRANE LINER HIGH DENSITY POLYETHYLENE (HDPE)

PART 1 - GENERAL

1.01 RELATED DOCUMENTS:

A. Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

B. The requirements set forth by the Quality Assurance/Quality Control Plan shall apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Project Coordination: Section 01041

B. Earthwork: Section 02200

C. Geotextiles and Drainage Geocomposite: Section 02272

D. Geosynthetic Clay Liner: Section 02275

E. Interfacial Friction Angle Conformance Testing: Section 02780

1.03 DESCRIPTION OF WORK: Extent of flexible membrane lining work is shown on the contract drawings. 80 mil textured HDPE geomembrane shall be installed as part of the primary liner system and 60 mil textured HDPE geomembrane shall be installed in the secondary liner system.

1.04 SUBMITTALS:

A. Submit 2 copies plus the number of copies required by the contractor of quality control documentation described in 1.05 herein and para. 5.1 of Appendix B – Quality Assurance Quality Control Manual.

B. Prior to ordering HDPE material, the Contractor shall submit, for the CQA Project Manager's approval, a description or drawing of the method of sheet layout, detailing the orientation of sheets and the direction of the overlap between sheets.

1.05 QUALITY CONTROL DOCUMENTATION: (Furnished by Liner Manufacturer and Liner Installer)

A. Manufacturer's Experience: The manufacturer supplying the membrane shall be GRI certified and shall satisfactorily demonstrate previous experience by letter of certification. Certification shall indicate that the manufacturer has produced, and has in service in similar applications for a period of not less than one (1) year, at least ten (10) million sq ft of HDPE material meeting these Specifications.

B. Installer's Experience: The Installer proposing to install the lining shall satisfactorily demonstrate previous experience by letter of certification. Certification shall indicate the Installer's successful past installation of at least 10,000,000 sq ft of HDPE membrane lining.

Installation shall be performed under the direction of a single installation supervisor who shall remain on site and be in responsible charge throughout the liner installation, including subgrade acceptance, liner layout, seaming, testing and repairs, and all other activities contracted for with the Installer. The installation supervisor shall have supervised the installation of at least 10,000,000 sf of polyethylene geomembrane. Actual seaming shall be performed under the direction of a master seamer who may be the same person as the installation supervisor, and who has a minimum of 1,000,000 sf polyethylene geomembrane seaming experience using the same type of seaming apparatus as that specified in this project. **No seaming may be done by any individual with less than 500,000 sf of polyethylene geomembrane seaming experience.** The installation supervisor or master seamer must be on site whenever seaming is being performed.

C. QUALITY CONTROL DURING MANUFACTURE: Random sampling shall be performed by the Manufacturer throughout the production run at the frequencies indicated below for each of the listed properties for the geomembrane to be delivered to the site.

	Test	Frequency
Thickness	ASTM D 5994	1 per roll
Asperity GM 12	GM 12	1 per 2 rolls
Oxidative induction time	ASTM D 3895 ASTM D 5885	1 per 200,000 lbs
UV resistance	GM11 ASTM D 5885	1 per formulation
Oven Aging at 85°C	ASTM D 5721 ASTM D 3895 ASTM D 5885	1 per formulation
Carbon black content	ASTM D 1603-95	1 per 20,000 lbs
Carbon black dispersion	ASTM D 5596	1 per 45,000 lbs
Force per unit width at yield	ASTM D 6693-01	1 per 20,000 lbs
Force per unit width at break	ASTM D 6693-01	1 per 20,000 lbs
Elongation at yield	ASTM D 6693-01	1 per 20,000 lbs
Elongation at break	ASTM D 6693-01	1 per 20,000 lbs
Tear resistance	ASTM D 1004-94a	1 per 45,000 lbs
Puncture resistance	ASTM D 4833	1 per 45,000 lbs
Density	ASTM D 792-91	1 per 200,000 lbs
stress crack resistance	ASTM D 5397	per GRI GM 10

Value must meet the requirements specified in Table 1 of Part 2.

The Resin Manufacturer shall provide certification to the Geomembrane Sheet Manufacturer that the resin meets or exceeds the specifications for Density, Environmental Stress Crack and Melt Index.

Sheet thickness shall be monitored continuously during manufacture and shall be nominal thickness ±10% across the sheet.

Rolls not satisfying the specifications shall be rejected. The Manufacturer shall provide certification of testing as described in Part 2.

1.06 CONFORMANCE TESTING:

The geomembrane will be sampled by the Geosynthetic CQA or his agent(s), at the manufacturer or upon delivery to the site. The Geosynthetic CQA shall assure that conformance test samples are obtained for the geomembrane at a rate of 1 test per 50,000 square feet of geomembrane with a minimum of once per lot, for testing, to assure conformance to the specification. A lot consists of a group of material which is manufactured from a specific batch of raw materials (e.g., HDPE resin, or bentonite clay). The manufacturer shall identify the consecutively numbered rolls of material, that are inclusive within a lot. It is not required that all rolls included in a lot be supplied to the project, as long as the specified certification test results are supplied by the manufacture to bracket the rolls delivered to the project. The interfacial and internal friction angle tests shall be performed at the frequency defined in Section 02780.

The contractor or sub-contractor shall coordinate information on manufacture and delivery of the geomembrane with the Geosynthetic CQA to assure that sampling and testing occur in a timely manner as to avoid construction delays.

Any further testing required to assure conformance shall be the responsibility of the contractor in accordance with 1.05 (C) of Section 01025. The testing laboratory and the results shall be acceptable to the Engineer.

Geomembrane Conformance testing shall include the following:

Thickness	ASTM D 5994
Asperity	ASTM D 7466
Carbon black content	ASTM D 1603-94
Carbon black dispersion	ASTM D 5596
Force per unit width at yield	ASTM D 6693-01
Force per unit width at break	ASTM D 6693-01
Elongation at yield	ASTM D 6693-01
Elongation at break	ASTM D 6693-01
Tear resistance	ASTM D 1004 - 94a
Puncture resistance	ASTM D 4833
Interface friction angle between drainage geocomposite and geomembrane	ASTM D 5321-92
Interface friction angle between Geosynthetic clay liner and the Geomembrane	ASTM D 6243-98

These conformance tests shall be performed in accordance with the test method specified. The Contractor shall supply the materials required to perform the conformance testing.

1.07 SPECIAL PRODUCT WARRANTY: (Furnished by Liner Installer)

A. Manufacturer's Guarantee: The manufacturer of the membrane liner shall enter into agreement with the Owner guaranteeing the membrane as follows:

The manufacturer warrants the HDPE liner which is manufactured, sold as first quality, and installed with technical assistance and/or by an approved installation contractor to be (1) furnished free of manufacturing defects in workmanship or material for a period of one year from the time of delivery with the basis for judgment of defects being the applicable product specifications in effect at the time the order was placed unless modified by mutual written agreement; (2) shall withstand normal weathering due to the effects of normal service for a period of forty (40) years from the date of delivery. "Normal service" does not include physical damage caused by acts of God, casualty, or catastrophe such as (but not limited to) earthquakes, fire, explosion, floods, lightning, piercing hail, tornadoes, corrosive air pollution, mechanical abuse by machinery, equipment, people or animals, or excessive flexures, pressures or stress from any source other than faulty installation, and (3) immune to chemical attack and degradation by chemicals, specified in the manufacturer's chemical resistance literature, as compatible with, and as not having an adverse effect on the membrane; and (4) resistance to specific chemicals when tested for them by the manufacturer at the request of the Owner.

Should defects or weathering degradation within the scope of the above warranty occur, the manufacturer shall refund to the purchaser-user the pro-rata part for the unexpired term of the warranty of the purchaser-user's original cost of such product, or will supply repair or replacement materials at the then-current price. In the event the manufacturer supplies repair or replacement materials, against the then- current price, the manufacturer will credit the lesser of (1) the pro-rata part of the original sales price of the material so repaired or replaced for the unelapsed period of the warranty, or (2) the pro-rata part of the then-current price of the material so repaired or replaced to the unelapsed period of the warranty. The warranty shall continue in effect on the repaired or replaced material for the unelapsed term of the original warranty. To enable the manufacturer's technical staff to properly determine the cause of any alleged defect and to take appropriate steps to effect timely corrective measures if such defect is within the warranty, any claim for alleged breach of warranty will be made and presented in writing to manufacturer and the installing Contractor within thirty (30) days after the alleged defect was first noticed.

PART 2 - PRODUCTS (Furnished by Installer)

2.01 TEXTURED HIGH DENSITY POLYETHYLENE (HDPE) MEMBRANE:

A. General: The materials supplied under these Specifications shall be first quality products designed and manufactured specifically for the purposes of this work, and which have been satisfactorily demonstrated by prior use to be suitable and durable for such purposes. The materials supplied shall not be manufactured from more than three different lots (resin batches), unless the manufacturer agrees to perform conformance testing on the additional lots. Conformance testing shall be performed in accordance to Part 4.

B. Description of 80-mil HDPE Material: The membrane shall be a high density polyethylene (HDPE) of 80-mils thickness containing no additives, fillers or extenders. The lining material shall be manufactured a minimum of 15 feet seamless widths, and have the following physical characteristics:

TABLE 1

Test	Test Designation	Requirement
Sheet thickness, textured	ASTM D 5994	±10% for individual for 8 out of 10 values ±15% for individual for any of the 10 values
Asperity height	GM 12 ASTM D 7466	16 mil (min. average)
Tensile strength yield	ASTM D-6693-01	min. 168 lb per in. width
Tensile strength at break	ASTM D-6693-01	min. 120 lb per in. width
Elongation at yield	ASTM D-6693-01	min. 12%
Elongation at break	ASTM D-6693-01	min. 100 %
Tear resistance	ASTM D-1004-94A	min. 56 lb
Puncture resistance	ASTM D 4833	min. 120 lb
Oxidative induction time		
(standard)	ASTM D 3895	100 minutes
(high pressure)	ASTM D 5885	400 minutes
Oven aging at 85°C		
(standard OIT)	ASTM D 3895	55% retained at 90 days
(high pressure OIT)	ASTM D 5885	80% retained at 90 days
Ultra Violet Resistance	GM 11, ASTM D-5885	min. 50% retained @ 1600 hrs.
stress crack resistance	ASTM D-5397	500 hrs
Carbon black content	ASTM D-1603-95	2 to 3%
Carbon black dispersion	ASTM D-5596 and GRI GM 13	9 in category 1 or 2 1 in category 3

Test	Test Designation	Requirement
Interfacial Friction Angle		
Between drainage geocomposite and geomembrane	ASTM D 5321-92 (see Section 02780)	See Section 02780 3.01
Between geosynthetic clay liner (non-woven side) and geomembrane	ASTM D 6243-98 (See Section 02780)	See Section 02780 3.01

In addition, the 80-mil geomembrane shall be produced as to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter, and shall not have striations, roughness, pinholes or bubbles on the surface.

C. Description of 60-mil HDPE Material: The membrane shall be a high density polyethylene (HDPE) of 60-mils thickness containing no additives, fillers or extenders. The lining material shall be manufactured a minimum of 15 feet seamless widths, and have the following physical characteristics:

TABLE 2

Test	Test Designation	Requirement
Sheet thickness, textured	ASTM D 5994	±10% for individual for 8 out of 10 values ±15% for individual for any of the 10 values
Asperity height	GM 12 ASTM D 7466	16 mil (min. average)
Tensile strength yield	ASTM D-6693-01	min. 126 lb per in. width
Tensile strength at break	ASTM D-6693-01	min. 90 lb per in. width
Elongation at yield	ASTM D-6693-01	min. 12%
Elongation at break	ASTM D-6693-01	min. 100 %
Tear resistance	ASTM D-1004-94A	min. 42 lb
Puncture resistance	ASTM D 4833	min. 90 lb
Oxidative induction time		
(standard)	ASTM D 3895	100 minutes
(high pressure)	ASTM D 5885	400 minutes
Oven aging at 85°C		
(standard OIT)	ASTM D 3895	55% retained at 90 days
(high pressure OIT)	ASTM D 5885	80% retained at 90 days
Ultra Violet Resistance	GM 11, ASTM D-5885	min. 50% retained @ 1600 hrs.

Test	Test Designation	Requirement
stress crack resistance	ASTM D-5397	500 hrs
Carbon black content	ASTM D-1603-95	2 to 3%
Carbon black dispersion	ASTM D-5596 and GRI GM 13	9 in category 1 or 2 1 in category 3

Test	Test Designation	Requirement
Interfacial Friction Angle		
Between drainage geocomposite and geomembrane	ASTM D 5321-92 (see Section 02780)	See Section 02780 3.01
Between clay borrow and geomembrane		(See Section 02780)

In addition, the 60-mil geomembrane shall be produced as to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter, and shall not have striations, roughness, pinholes or bubbles on the surface.

D. Factory Bonded Seam: Calendered HDPE sheeting may not be fabricated into large sections at the factory.

E. Extrusion Joining Resin: Resin for extrusion joining sheets shall be HDPE produced from the same material as the sheet resin. Physical properties shall be the same as those of the resin used in the manufacture of the HDPE liner. The resin shall be supplied in black and/or natural color. Natural resin shall be colored black through addition of 2.0 to 3.0 percent master batch colorant before use.

F. Documentation: Prior to delivery of the geomembrane to the job site, the Installer shall be required to provide the Owner with a written certification that the product to be delivered was extruded from the specified resin. The manufacturer shall provide clear and concise quality control certificates for each batch of resin and each shift's production of geomembrane, and shall follow the quality control testing program as described in Part 4. These quality control certificates shall be signed by responsible parties employed by the Manufacturer, and shall be supplied to the Owner. No geomembrane will be permitted to be delivered until the Owner has in his possession such certification. The manufacturer shall permit conformance test sampling by an independent party to be performed at the manufacturing plant prior to shipment if requested.

G. Roll Identification: Each roll shall have permanently affixed both inside and outside the roll the following information: name of manufacturer; date of manufacture; resin batch code; thickness of the material; roll number; roll length; and roll width. Unlabeled rolls will not be used and shall be returned to the manufacturer at the Contractor’s expense.

2.02 MISCELLANEOUS MATERIALS: (Furnished by Installer)

A. Pipe Boots, Vents, and Patches: All such devices shall be of the same material as the lining or a compatible approved equal.

B. Mechanical Fastenings: Mechanical fastenings shall be of the material, size, and type as detailed on the plans or approved shop drawings.

PART 3 - EXECUTION

3.01 GENERAL: The Contractor shall schedule a pre-installation conference as specified in Section 01041, Part 1.02. During installation of the geomembrane, the Installer shall label each sheet immediately after deployment, with the roll number, panel number, and date it was installed.

3.02 SHIPPING AND HANDLING: Each roll shall be individually packaged in heavy cardboard or wooden crate fully enclosed and protected to prevent damage to it during shipment, prominently identified in the same fashion as the sheet within and showing the date of shipment. Until installed, the rolls shall be stored indoors in their original unopened crates; if outdoors, they shall be stored on pallet and shall be protected from the direct rays of the sun under a light-colored heat-reflective opaque cover in a manner that provides a free-flowing air space between the crate and cover.

3.03 SURFACE PREPARATION:

A. Conditions: Surfaces to be lined shall be smooth and free of all angular rocks, stones greater than ½-inch, sticks, roots, sharp objects or debris of any kind. The surface shall provide a firm, unyielding foundation. No standing water or excessive moisture shall be allowed.

B. Acceptance: The Geosynthetic CQA and the Installer shall certify in writing to the Resident Project Representative that the surface to be lined is acceptable. Submittal of written acceptance may proceed incrementally according to installation schedule. No geomembrane shall be placed on subgrade deemed unsuitable by the Installer/or Engineer or the Geosynthetic CQA.

3.04 ANCHOR TRENCH: Excavation, backfill and compaction of the anchor trench will be the responsibility of the General Contractor. The anchor trench shall be excavated along the lines shown on the design drawings. The length of open trench should not exceed the amount of liner to be placed in a two (2) day period unless approval has been provided by Owner or Owner's testing agency.

The anchor trench may be partially backfilled during geomembrane panel placement, however the anchor trench shall not be compacted until the geomembrane has experienced sufficient expansion/contraction cycles. Compaction of the anchor trench backfill shall be performed using manually operated compaction equipment. Backfill shall be placed in lifts not greater than 12 inches in loose thickness and shall be compacted to at least 90% of the maximum dry density according to ASTM D 698. This backfill shall be compacted 1” minus impervious borrow. Borrow shall be placed at, or 4 percent above optimum. Owner's testing agency shall approve backfill material prior to anchor trench placement, and must be notified prior to compaction.

3.05 FIELD SEAMS: The Geosynthetic QARE can, at his sole discretion, not allow any individual seamer or seaming equipment to be used for the project, based on observations made in the field. The Geosynthetic QARE will notify the Contractor of the individual or seaming equipment which may not be used on the project and the reason or steps necessary to demonstrate the person or equipment acceptance on the job. The Contractor shall have no recourse for this decision against the Owner, Engineer, or other parties.

A. No horizontal seams shall be allowed on the sideslopes of the cell.

B. Layout: Overlap panels in shingle style from high to low elevation. Minimum panel length shall be 70 feet.

C. Preparation: All areas which are to become seam interfaces shall be cleaned of dust and dirt. When extrusion joining is required, the slick surfaces of the HDPE sheet which are to become seam interfaces shall be prepared by sanding or grinding (perpendicular to the seam) to a depth of less than .005 in. before joining the sheets. Field joints shall not take place unless the sheet is dry.

D. Seaming Methods: Installer shall submit to the Owner prior to construction a list of the seaming equipment and testing equipment, including manufacturer and model number to be used on-site. Field seams shall be made by overlapping adjacent sheets the appropriate amount and using one of the following seaming techniques:

<u>Hot Air/Hot Wedge</u>: Hot air/hot wedge technique shall be made by either a nozzle which directs hot air between the sheets or a hot metal surface in contact between the sheets. Each seaming unit must include a thermometer giving the temperature of the machine at the nozzle or metal surface. The seaming unit shall maintain a recordable temperature determined by on-site conditions and shall not vary more than, 50 deg.F above, or below the recommended seaming temperature. The adjacent geomembrane sheets shall be overlapped 6 inches. The overlapped sheets are then pressed together by mechanical means. Seaming equipment that makes a split hot wedge seam will be the preferred method of seaming; single hot wedge seaming will be allowed only with the approval of the Owner.

<u>Extrusion Bonding</u>: Extrusion and fusion bonding will be limited to areas where hot wedge cannot be used, such as pipe boots, and to any necessary repairs. The use of extrusion and fusion bonding as the primary seaming method will be allowed only with the approval of the Owner. The adjacent sheets to be seamed shall be overlapped a minimum of 3 inches. The joining procedure shall consist of softening the liner material by heated air. The temperature of the air impinging on the sheet for this purpose, shall range from, 420 deg.F to 680 deg.F. The exact temperature used shall be determined by the installation supervisor. Directly following the application of heat, a one and one-half inch minimum width strip of the same high density polyethylene resin from which the sheet is made shall be extruded between the overlapped sheets. The temperature of the resin as it emerges from the extrusion die shall range from, 428 deg.F to 536 deg.F. The overlapped sheets shall be firmly pressed together by mechanical means to form the extrusion joint.

<u>Fusion Bonding</u>: Extrusion and fusion bonding will be limited to areas where hot wedge cannot be used, such as pipe boots, and to any necessary repairs. The major seaming of the liner will be done with hot wedge. Fusion bonding shall be by means of a homogeneous overlap extrusion fusion process which provides continuous dynamic

integration of the extrudate bead with the lining material. The composition of the extrudate shall be identical to the lining material. The seaming unit shall be capable of continuously monitoring and controlling the temperature of the extrudate and the zone of contact where the machine is actually fusing the lining material. Temperature of the extrudate shall range from, 428 deg.F to 536 deg.F.

E. Tie-in Seams and Cross-Seams (Butt Seam): Seaming of geomembrane at new/new geomembrane that has become soiled and new/old geomembrane connections shall be properly prepared prior to seaming. All tie-in seams shall be pressure washed steam-cleaned and/or scrubbed to remove dirt or other deposits on the geomembrane. No seaming will take place on dirty or soiled geomembrane. The CQA shall inspect the tie-in preparation prior to seaming. The installer shall trial weld representative samples taken from the seaming area. Passing trial welds shall be attained in accordance with Section 4.03(B).

F. Seaming Wrinkles: Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle, back into the panel so as to affect a flat overlap. The cut fishmouths or wrinkles shall be seamed as well as possible, and shall then be patched with an oval or round patch extending a minimum of 6 inches beyond the cut in all directions.

G. Repairs: Any required repair of scratches >5% of the sheet thickness and small holes in the liner surface shall be made with the extrusion hand welder. Liner material shall be cleaned of all dirt, dust and other foreign material, all smooth HDPE surfaces roughened, air heated to the prescribed temperature, and a strip of HDPE resin extruded over the hole to produce an extruded welded repair.

H. Quality of Workmanship: All joints, on completion of the work, shall be tightly bonded. Any lining surface showing injury due to crimping, scuffing, penetration by foreign objects, scratching by welding equipment, or distress from rough subgrade shall, as directed by the Engineer, be replaced or covered and sealed with an additional layer of HDPE of the proper size. The Installer shall inspect the final installation and any defects shall be repaired and tested until satisfactory.

I. No seaming shall be allowed if the Geosynthetic CQA is not on-site.

3.06 PIPE BOOTS, VENTS, MECHANICAL FASTENINGS, and PATCHES: The geomembrane shall be installed around any pipes, concrete structures or other penetrations through the geomembrane in accordance with the detailed Specifications shown on the Drawings. Prior to the start of construction, the Installer may provide, for the approval of the Owner, alternate installation methods or details to successfully perform geomembrane termination.

All clamps, bolts, nuts, gaskets or other materials used to secure the geomembrane shall be compatible with and have a lifespan at least equal to that of the geomembrane.

Care shall be taken to protect the underside of the geomembrane from damage due to settling at any underbedding to concrete transition.

Extreme care shall be taken while welding around any penetration or similar structure since destructive testing is not likely to be possible in such areas. All seaming in these areas shall be performed by the Installer's Master Seamer and the operations shall be observed on a full time basis by the Geosynthetic CQA. Non destructive electric spark test of both the skirt and sleeve of the pipe boot shall be performed as described in Section 4.03(B) of this specification.

3.07 SEAMING WEATHER CONDITIONS:

A. Normal Weather Conditions: The normal required weather conditions for seaming are as follows:

1. Ambient temperature between 32°F (0°C) and 104°F (40°C).

2. Dry conditions, i.e. no precipitation or other excessive moisture, such as fog or dew.

3. No excessive winds.

The Geosynthetic CQA shall verify that these weather conditions are fulfilled and notify the Project Manager in writing if they are not. Ambient temperature shall be measured by the Geosynthetic CQA in the area in which the panels are to be placed. The Project Manager will then decide if the installation is to be stopped or special procedures used.

B. Cold Weather Conditions: To assure a quality installation, if seaming is conducted when the ambient temperature is below 32°F (0°C), the following conditions must be met:

1. Geomembrane surface temperatures shall be determined by the Geosynthetic CQA at intervals of at least once per 100 foot of seam length to determine if preheating is required. For extrusion welding, preheating is required if the surface temperature of the geomembrane is below 32°F (0°C).

2. Preheating may be waived by the Project Manager based on a recommendation from the Geosynthetic CQA, if the Installer demonstrates to the Geosynthetic CQA's satisfaction that welds of equivalent quality may be obtained without preheating at the expected temperature of installation.

3. If preheating is required, the Geosynthetic CQA shall inspect all areas of geomembrane that have been preheated by a hot air device prior to seaming, to assure that they have not been overheated.

4. Care shall be taken to confirm that the surface temperatures are not lowered below the minimum surface temperatures specified for welding due to winds or other adverse conditions. It may be necessary to provide wind protection for the seam area.

5. All preheating devices shall be approved prior to use by the Project Manager.

6. Additional destructive tests (as described in Section 5.5.6.2 of the Quality Assurance Plan (QAP)) shall be taken at an interval between 500 feet and 250 feet of seam length, at the direction of the Geosynthetic CQA.

7. Sheet grinding may be performed before preheating, if applicable.

8. Trial seaming, as described in Section 5.5.4 of the QAP, shall be conducted under the same ambient temperature and preheating conditions as the actual seams. Under cold weather conditions, new trial seams shall be conducted if the

ambient temperature drops by more than 5°F from the initial trial seam test conditions.

9. All snow and ice shall be removed from the liner using plastic shovels. The CQA will also have authority to suspend installation activities during severe weather conditions.

C. Warm Weather Conditions: At ambient temperatures above 104°F, no seaming of the geomembrane shall be permitted unless the Installer can demonstrate to the satisfaction of the Project Manager that geomembrane seam quality is not compromised.

Trial seaming, as described in Section 5.5.4 of the QAP, shall be conducted under the same ambient temperature conditions as the actual seams.

At the option of the Geosynthetic CQA, additional destructive tests (as described in Section 5.7 of the QAP) may be required for any suspect areas.

3.08 QUALITY CONTROL DURING INSTALLATION:

A. Site Test Equipment: The Installer shall maintain on site, in good working order, the following items:

Field Tensiometer: The tensiometer shall be motor driven and have jaws capable of traveling at a measured rate of 2 in./min. The tensiometer shall be equipped with a gauge which measures the force in unit pounds exerted between the jaws.

Vacuum Box: The vacuum box shall consist of a rigid housing with a transparent viewing window on top and a soft, closed- cell neoprene gasket attached to the bottom of the housing. The housing shall be equipped with a bleed valve. A separate vacuum source shall be connected to the vacuum box such that a negative pressure can be created and maintained between 4 and 8 psi. The vacuum box shall be equipped with a vacuum gauge capable of registering a minimum of 10 psi in increments of ¾ psi. A sudsy solution consisting of soap and distilled water shall be dispensed on the seam immediately ahead of the vacuum box.

Air Pressure Test Equipment: This method shall apply only when the split hot wedge seaming method is used. Equipment shall consist of an air pump capable of generating and maintaining a positive pressure of between 30 and 40 psi. A manometer capable of reading up to 40 psi attached to a needle or nipple shall be used to pressurize the air channel in the seam.

Alternative testing methods shall be submitted to the Owner or his Authorized Representative for approval prior to commencement of testing.

B. Non-Destructive Testing:

Thickness: Prior to deployment geomembrane rolls or upon deployment of individual panels, the Geosynthetic CQA shall randomly check the thickness at a minimum of twice (once per side) per 100 linear feet, in conformance with the specification in Section 2.01.

Test Seams: Test trial seams shall be made at a minimum every 4 hours to verify that adequate conditions exist for field seaming to proceed. Each seamer shall produce a test seam at the beginning of each shift. In addition, if a seaming operation has been suspended for more than 1 hour or if a breakdown of the seaming equipment occurs, a test seam shall be produced prior to resumption of seaming operations.

Test seams shall be made in the field on pieces of the approved geomembrane. Each test seam shall be at least 4 ft long by 1 ft wide and with sufficient overlap for peel testing in the field tensiometer.

Five samples, 1 in. wide shall be taken across the seam using an approved template. The samples shall be tested in the field tensiometer, three in peel and two in shear and shall meet the requirements of Section 3.08(C).

If the seam fails to pass, the seaming apparatus shall not be used for field seaming until any deficiencies have been corrected. This shall be verified by the production and successful testing of two consecutive test seams.

Vacuum Testing: All extrusion welded and solid fusion welded seams shall be evaluated using vacuum box testing in accordance with test method ASTM D 5641. Any seam overlap will be trimmed prior to testing.

A sudsy solution shall be applied to the test section and the vacuum box placed over the section. The bleed valve is then closed and the vacuum valve opened. Once a tight seal has been established (3 to 8 psi), the test section shall be visually examined for a period of not less than 15 seconds to determine whether bubbling of the soapy solution is occurring. The vacuum box is then moved and the process is repeated on the next adjacent section. A minimum 3 in. overlap shall be provided between all test sections.

All locations where bubbling of the sudsy solution was observed shall be clearly marked for repairs with a high visibility marker and recorded by number on field test reports. Any failed portion of seam shall be repaired by cap strip in accordance with Section 4.03(E).

Air Pressure Testing: All hot air/hot wedge seams shall be evaluated using air pressure testing. The seam shall be sealed off at one end and air passed through insuring an open passage. Once the seam is proven continuous the second end of the seam shall be sealed. If a seam end will be an integral part of the geomembrane the sealing shall be done in such a way that it does not harm the geomembrane. The seam should be pressurized to 30-35 psi. The feed valve shall be closed and the pressure sustained for a period of not less than 5 minutes. If a pressure loss of greater than 2 psi is observed or if the required pressure cannot be reached then the seam shall be rejected.

All faulty areas along the seam shall be identified and repaired by cap strip in accordance with Section 3.08(D). Vacuum testing shall be allowed on split wedge welds only when the faulty area cannot be isolated using air pressure testing. Any overlapping material must be removed prior to vacuum testing. All holes created during air pressure testing shall be sealed on completion of the test and vacuum tested.

All seams shall be non-destructively tested by the Installer over their full length to verify the integrity of the seam. Non-destructive testing shall be performed concurrently with field seaming. Prefabricated field seams which will be inaccessible after installation, such as those under structures or fastened to penetrations, shall be tested prior to final installation. All non-destructive testing shall be observed and documented by the Geosynthetic CQA.

Approved non-destructive testing procedure is as above. Alternate procedures shall be submitted for approval to the Geosynthetic CQA prior to the commencement of non-destructive testing.

Membrane Penetrations: Accessible pipe boot seems for all membrane penetrations shall be vacuum tested as described above. Areas not accessible to vacuum testing shall be non-destructively tested using an electric spark test. The electric spark test shall employ a continuous length of 24 gauge copper wire, placed under the geomembrane seam within 1/4-inch of the edge. A portable pulse-type detector, equipped with a brush-type electrode, charged with a low amperage current of 20,000 to 30,000 volts, will be advanced along the seam at approximately 20 to 30 feet per minute. Seam defects are detected when a spark arks from the sire to the electrode, closing the circuit and sounding an audible alarm. All seam defects shall be repaired and retested as described herein. Alternative testing methods shall be submitted to the Geosynthetic CQA and the MEDEP for approval prior to commencement of testing.

C. Destructive Testing:

Destructive testing of field seams shall be performed at selected locations in order to verify the criteria given in section "Test Seams". All sampling and testing shall be done concurrently with field seaming so that verification of field seam properties is made as the work progresses and corrective action implemented.

Test samples shall be taken at an average frequency of one test location per 1,000 ft of seam for dual-wedge seams and one test per 500 ft of seam for extrusion seams. A minimum of one test sample shall be taken from each seam that connects to existing geomembrane liner. More frequent sampling shall be performed at the discretion of the Geosynthetic CQA based on field trial welds, destructive seam test results, weather conditions, inspection of seams, and overall seaming performance. Sample locations shall be determined by the Geosynthetics CQA. The Installer shall not be informed in advance of the locations where the seam samples will be taken.

The Geosynthetic CQA may increase the amount of destructive testing based on the results of previous testing. Additional samples may also be required when the Geosynthetic CQA has reason to suspect the presence of excess crystallinity, contamination, faulty seaming equipment or any other reason affecting seam quality.

The test sample shall measure approximately 12 in. wide by 48 in. long with seam centered lengthwise along the sample. Five one-in. wide coupon strips shall be cut using an approved template from the ends of the sample. These coupons shall be tested by the Installer in the field tensiometer in both peel and shear in accordance with section "Test Seams". The remainder of the sample shall be cut into two 12-in. lengths, and one 18-in. length. The 18-inch sample shall be taken by the Geosynthetic CQA for independent laboratory testing; of the remaining two, one shall be given to the Installer for his own records or testing, and one shall be kept by the Owner for permanent record.

Samples shall be cut by the Installer under the direction of the Geosynthetic CQA. Each sample shall be indelibly numbered and identified. The sample number and location shall be recorded by the Installer on the panel layout drawing and on the sheet where the sample was taken.

The results of laboratory testing shall be made available to the Installer by the Geosynthetic CQA not more than 48 hours after the samples have been received by the testing facility. The results of laboratory testing shall determine the acceptability of a seam. Laboratory testing shall be performed in accordance with the methods given in ASTM D 6693 and ASTM D 6392 and meet the following criteria:

Test	Test Designation	Requirement
Bonded Seam Strength (Shear)	ASTM D-6392-99 and ASTM D-6693	4 of 5 coupons must be greater than 90% of parent material strength with none less than 70% of parent material strength* and have an acceptable mode of rupture
Peel Adhesion (both tracks)	ASTM D-6392-99, and ASTM D-6693	4 of 5 coupons on each side of the weld must be greater than 60% of parent material strength* or 70% of the specified value, whichever is greater, with none less than 50% of parent material strength* and have an acceptable mode of rupture

* Parent material strength shall be defined as the maximum yield tensile strength value in the cross machine direction of the manufacturers roll certification testing for all the geomembrane rolls delivered the site and the conformance test results. The Geosynthetic CQA is responsible for reviewing both the conformance and roll certification test results to determine the parent material strength value. The Geosynthetic CQA Project Manager and the MEDEP shall approve the parent material strength value.

Tests for peel adhesion and Shear shall be in a free condition (not 90^{o} or 180^{o}). Acceptable Locus of break codes for the specimen rupture mode shall be the following:

For Dual Wedge Seams: BRK, SE1, SIP and AD-BRK ≤ 25% adhesion failure;

For Extrusion Welds: SE1, SE2, SE3, BRK1, BRK2, HT, SIP, AD-WLD if strength is achieved, AD-BRK ≤ 25% adhesion failure.

Any seam that fails laboratory testing shall be repaired in accordance with section 3.08(D). The costs of repairing and retesting areas which failed destructive tests shall be the responsibility of the Installer.

The area from which the destructive test sample was taken shall be repaired without delay in accordance with the procedures given in section 3.08(D).

D. Inspection and Acceptance: As the work progresses, the Geosynthetic CQA shall document all locations requiring repair work and shall verify and document that all repairs have been successfully made by the Installer.

A field seam shall only be considered acceptable when bounded by two destructive test locations which have passed laboratory testing and applicable non-destructive testing. The following procedures shall apply in the event that a seam fails laboratory testing:

The Installer may reconstruct the seam with cap strips between the previous passing test location and the next passing test location (up to a maximum 75 feet) and retest, or;

The Installer may elect to trace the extent of an unacceptable seam to some intermediate location. This shall involve taking 1-in. template-cut cross-sections from the seam at a minimum distance of 10 ft in both directions from the failed test location. These samples shall be tested in the field tensiometer in both shear and peel in accordance with section "Test Seams". If one or both of these samples fail the field test, tracing along the seam shall continue at minimum 10-ft increments until a passing result is recorded in both directions from the failed test location. At these locations large samples shall be cut for laboratory testing as in section "Destructive Testing". If laboratory testing verifies the acceptability of the seam at these locations, the Installer shall reconstruct the seam (with cap strips) between the two passing test locations. If laboratory testing shows the seam to be unacceptable, the Installer shall further trace the unacceptable seam until acceptable test results are recorded in both directions.

Reconstructed seams shall be capped by cutting out the unacceptable seam, at least 6 inches each side of the seam and a minimum 6" beyond the defect, and patching with an acceptable material.

Reconstructed seams less than 150 ft in length shall be non-destructively tested in accordance with section "Non-Destructive Testing (3.08(B)". Reconstructed seams greater than 150 ft in length shall be destructively tested in accordance with section "Destructive Testing (3.08(C)."

The entire geomembrane surface shall be examined by the Geosynthetic CQA to confirm that it is free of any defects, holes, blisters, undispersed raw materials, or contamination by foreign matter. The geomembrane surface shall be cleaned by the Installer, if required so that it is free of dust, mud, debris or any other material which may inhibit a thorough examination of the surface. Any suspect areas shall be clearly marked by the Geosynthetic CQA and non-destructively tested in accordance with section "Test Seams."

E. Overburden: The Geosynthetic CQA shall monitor all overburden soils over the geomembrane liner and geocomposite. The Geosynthetic CQA shall identify any large wrinkles which may have been built into the geomembrane. Any such wrinkle not built in to accommodate thermal contraction of the geomembrane prior to placement of the overburden shall be cut, repaired and tested by the Installer.

The Geosynthetic CQA shall identify any slope toe, declivity, or other surface transitions which might result in bridging of the geomembrane during placement of the overburden. Any such area shall be cut, repaired and tested by the Installer.

Equipment used for placing and compacting the overburden shall not be driven directly on the geomembrane. Such equipment shall be closely monitored during placement to ensure that no damage occurs.

A minimum thickness of 1 ft of cover shall be maintained between the geomembrane and light earth moving equipment. Such equipment shall have a maximum ground pressure of 5 psi. Equipment shall have no cleats and no turning of any equipment shall be allowed on the initial 1 ft of cover. A minimum thickness of 3 feet of cover shall be maintained between the geomembrane and all rubber-tired earthmoving equipment.

In all cases, the placement of overburden shall be done with caution and in a manner which is least likely to cause wrinkles in, or damage to, the geomembrane.

For grades greater than 2 percent, all soil shall be placed in an upslope direction.

3.09 COMPLETION OF WORK:

A. The installation of the geomembrane shall be considered totally complete when:

1. The installation of the lining system, or section thereof, is finished.

2. Verification of the adequacy of all seams and repairs, including associated testing, is completed.

3. All documentation of installation is completed.

4. The leak location survey has been performed on the primary geomembrane liner in accordance with ASTM D7007 (Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials), any leaks found have been repaired appropriately by the liner installer and a report documenting the results of the survey has been reviewed and approved by the Geosynthetic CQA Project Manager.

5. The Geosynthetic QARE is able to recommend acceptance.

6. The Owner and/or his Authorized Representative is satisfied that the geomembrane has been installed in accordance with the above Specifications.

END OF SECTION

SECTION 02772

LEAK LOCATION SURVEY

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

B. Requirements set forth by the Quality Assurance/Quality Control Plan shall apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Geomembrane Liner: Section 02771

B. Drainage Geocomposite: Section 02272

C. Earthwork: Section 02200

1.03 DESCRIPTION:

A. Leak Detection Survey to be performed by Leak Location Services, Inc. of San Antonio Texas

B. The General Contractor and liner installation subcontractor shall furnish all labor, material, and equipment to support the Leak Survey crew, including line surveys, water, water truck with a driver, hose, electrical (110VAC. 5A) source/supply, a supervised crew that will prepare the soils for the leak survey, and any repairs of the geomembrane.

C. The leak location contractor shall furnish all labor, materials and equipment to perform the leak survey and any necessary reporting.

1.04 SUBMITTALS:

Leak location contractor shall submit: a location plan and or profile of proposed electrode placement; a drawing showing any necessary points to be surveyed prior to arriving on site; any necessary additional requirements; and a proposed schedule beginning at arrival on site.

1.05 QUALITY CONTROL PERFORMANCE TEST:

After excavating the leachate collection sand and removing a 2-foot diameter circle of drainage geocomposite, a test hole with a diameter of 0.25 inches shall be made in the geomembrane. A drill or other suitable instrument shall be used to remove rather than displace the material in the hole. The drill bit must be reciprocated within the hole to remove burrs from the edges or bottom side of the test hole. The test hole must be made in an area where the geomembrane has intimate contact with the supporting sub-grade or GCL.

If electrodes are installed under the geomembrane (not necessary in single liner systems), the test hole shall be placed at the farthest position away from any electrode, but at least 50 feet from the edge of the geomembrane

The Contractor will survey and document the location of the test hole relative to site benchmarks. Leak location measurements shall be made and recorded along closely spaced parallel lines in the vicinity of the test hole. This data shall be analyzed to determine the leak detection distance for detecting the 0.25-inch test hole.

PART 3 - EXECUTION

A. Preparation: Any electrodes to be installed under the geomembrane shall be installed prior to the geomembrane. Leaks must be filled with moisture or earth material to be detected. To accomplish this, the following must occur at least 24 hours prior to the start of the survey:

   Uniformly wet the earth materials covering the geomembrane with water to field capacity. All leachate collection sand or stone shall be kept a minimum of 5 feet from the anchor trench for the duration of the Leak Test and there shall be a dry area located between the sand/stone and the edge of the geomembrane. The drainage inlet structures shall be constructed after the completion of the leak location survey to avoid masking of a potential leak signal. Any metal materials that will potentially interfere (mask a potential leak) with the leak survey including liner battens, couplings shall be insulated prior to the leak survey.

B. Leak Survey: The leak location data shall be taken on survey lines spaced no farther apart than twice the leak detection distance determined for a 0.25 inch diameter leak in the performance test. The measurement electrode spacing shall be no less than that used for the performance test. The spacing between measurements shall be no more than that used for the performance test.

   Data shall be recorded, plotted and analyzed for leak signals. The positions for these leak signals shall be located and the leaks excavated and repaired by the liner installer at the contractor's expense. Additional leak location survey data shall be collected near the located leak after the leak is repaired and electrically isolated to ensure no additional leaks are present. The survey data shall be repeated on the two closest survey lines for a distance extending at least 20 feet before and beyond the leak signal. If another leak signal is detected, this process shall be repeated until no additional leaks are detected.

C. Reporting: The daily results of the work shall be communicated to the owner's representative. A list of locations of the leaks found will be submitted to the Owners Representative after completion of the field work and before the survey personnel leave the site. A report documenting the electrical leak location surveys shall be submitted within 14 days of the completion of each leak survey. The reports shall document the methodology used to locate and repair the leaks, a description of the size and nature of the liner defect, and a diagram of the cell showing the approximate leak locations.

END OF SECTION

SECTION 02780

INTERFACIAL FRICTION ANGLE CONFORMANCE TESTING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS:

A. Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

B. The requirements set forth by the Quality Assurance/Quality Control Plan shall apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Project Coordination: Section 01041

B. Geotextiles and Drainage Geocomposite: Section 02272

C. Geosynthetic Clay Liner: Section 02275

D. Geomembrane Liner (High-Density Polyethylene (HDPE)): Section 02771

E. Earthwork: Section 02200

1.03 DESCRIPTION OF WORK: The work in this Section includes all labor, materials, tools, and equipment necessary to perform conformance interfacial friction angle testing for the following interfaces:

1. Drainage sand and drainage geocomposite.
2. HDPE textured geomembrane and drainage geocomposite.
3. HDPE textured geomembrane and GCL
4. GCL internal
5. GCL and compacted clay

1.04 QUALITY CONTROL: (furnished by Geosynthetic Laboratory)

A. Geosynthetics Quality Conformance Laboratory (QCL) Experience. The testing laboratory performing the interfacial friction angle conformance testing shall be accredited by the Geosynthetics Accreditation Institute for interfacial friction angle testing and shall have satisfactorily demonstrated previous experience by letter of certification. Certification shall indicate the testing laboratory's experience with the materials to be tested and any limitations the materials may evoke on the testing program.

B. Test Method. The Geosynthetics QCL shall perform the required interfacial friction angle testing in accordance with ASTM 5321-02 and ASTM D 6243-98 for all GCL interfacial friction angle testing.

C. Test Reports. The Geosynthetics QCL shall provide test results to the project manager within 5 days of receipt of test samples. Test results shall be in the form of figures that present shear force versus displacement and shear stress versus normal stress. Both the peak strength and the large displacement strength shall be plotted. The laboratory shall report any influences or conditions that may have affected the test results. The laboratory shall indicate the correlation coefficient of the best fit lines drawn through the strength data, and the resulting peak strength and large displacement strength values for adhesion and friction angle.

PART 2 – MATERIALS AND TESTING CONDITIONS

2.01 MATERIAL SAMPLING:

A. Materials to be tested shall be obtained from materials that will be placed into service at the Juniper Ridge Landfill site.

B. Sample size shall be determined by the Geosynthetic QCL requirements.

C. Soil components used in the laboratory testing shall be obtained from the borrow source or from soil stockpiles to be utilized in the construction of the soil components of the landfill.

D. Sample and testing frequency for geosynthetics components shall be as indicated below.

Interface	**Testing Frequency**
Drainage sand/drainage geocomposite	2 tests
HDPE textured geomembrane/drainage geocomposite	2 tests
HDPE textured geomembrane/GCL	2 tests
GCL internal	1 tests
GCL/compacted clay	2 tests

Test frequency represents minimum number of tests. Additional tests may be required at the discretion of the CQA project manager.

2.02 TESTING CONDITIONS:

The following testing conditions shall be utilized for interfacial friction angle testing:

A. Use 12-inch by 12-inch-square direct shear apparatus as defined by Test Method ASTM 5321-92 and ASTM D 6243-98 for all GCL interfacial friction angle testing.

B. Test specimens shall be fully secured to the direct shear apparatus to prevent premature slippage.

C. Use site-specific soils and materials.

D. Test all geosynthetics in the direction parallel to the length of the roll (machine direction).

E. Orient surface texturing of HDPE textured geomembrane so that machine direction is oriented parallel to the direction of movement of the testing apparatus.

F. Soil components shall be remolded into the testing apparatus according to the project earthwork specification Section 02200.

G. Tests shall be run wet.

H. The seating pressure, seating time, normal pressure(s), consolidation time and strain rate for each interface to be tested shall be as indicated below:

Table 3.1

Interface	**Seating Stress** (psi)	**Soak Time** (hrs) (prior to application of normal stress)	**Normal Stress(es) (psf)**	**Consolidation Time After Application of Normal Pressure (hrs)**	**Shear Force Displacement Rate (in/min.)**
Drainage sand and drainage geocomposite	NA	1	1,440, 4,320, 7,200, 16,000, 20,000	4	0.2
HDPE textured geomembrane and drainage geocomposite	NA	NA	1,440, 4,320, 7,200, 16,000, 20,000	4	0.2
HDPE textured geomembrane and GCL (nonwoven geotextile side)	1	48	1,440, 4,320, 7,200, 16,000, 20,000	24	0.004
GCL internal	1	48	1,444, 4,320, 7,200, 16,000	24	0.004
GCL (woven geotextile side) and compacted clay	1	48	1,440, 4,320, 7,200, 16,000, 20,000	24	0.004

All tests shall be run out to 20 percent strain in the shear displacement direction. The large-displacement strengths shall be defined as the strength occurring at maximum horizontal test strain.

PART 3 –REQUIREMENTS

3.01 The geosynthetic materials tested shall demonstrate their adequacy for use in the construction of the landfill by meeting or exceeding the following requirements:

A. The interfaces listed below shall have test results for peak strength and large displacement strength that plot above the “average minimum strength envelope” as defined by Table 3.2.

Between drainage sand and drainage geocomposite.
Between HDPE textured geomembrane and drainage geocomposite.
Between HDPE textured geomembrane and GCL (non-woven)
Between GCL (woven) and compacted clay

Table 3.2

Normal Stress (psf)	Peak Shear Stress (psf)	Large Displacement Shear Stress (psf)
1,440	830	463
4,320	1,811	924
7,200	2,315	1,480
16,000	3,855	3,179
20,000	4,555	3,951

B. The internal shear strengths listed below shall have test results for peak strength and large displacement strength that plot above the “average minimum strength envelope” as defined by Table 3.3.

GCL Internal

Table 3.3

Normal Stress (psf)	Peak Shear Stress (psf)	Large Displacement Shear Stress (psf)
1,440	1,500	430
4,320	3,000	870
7,200	4,000	1,060
16,000	6,000	1,793

3.02 REVIEW OF TEST RESULTS:

The Geosynthetics CQA project manager shall review all test reports to determine if the test results meet the minimum requirements stated above.

3.03 RETESTING:

The owner, contractor, installer, and the manufacturer may elect to retest failed tests. Testing may be done at the same laboratory or an independent laboratory. The testing laboratory shall be approved by CQA project manager and the testing conditions shall be in accordance with ASTM 5321-92, ASTM D 6243-98 for all GCL interfacial friction angle testing, and this section. Testing shall be done at contractor’s installer’s, or manufacturer’s expense. Test results shall be reviewed by the CQA project manager.

END OF SECTION

SECTION 02800

SEEDING AND MULCHING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section. All work performed under this specification shall be performed in accordance with the Maine Department of Environmental Protection (MEDEP) Maine Erosion and Sedimentation Control Plan: Best Management Practices (BMPs) (March 2003).

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Earthwork: Section 02200
B. Erosion Control: Section 02220
C. Erosion and Sedimentation Control Details Drawings C-308

1.03 DESCRIPTION OF WORK: Work specified in this section shall consist of furnishing all labor, materials, and equipment to perform seeding and mulching work in conformity with the contract drawings and as specified herein. Excavation, filling, and grading required to achieve elevations shown on the Drawings are not specified in this Section. Refer to Section 02200, Earthwork. Topsoil shall be placed to a compacted depth of 4 inches over exterior cell containment dikes and all disturbed areas (excluding the landfill's access road). Topsoil shall receive seed, fertilizer, lime, and mulch per these specifications. Only work described in Section 01010 "Summary of Work" or specifically identified by the Owner's Representative should be considered part of this Contract.

1.04 QUALITY ASSURANCE: If subcontracted, subcontract the seeding work to a single firm specializing in landscape work.

A. Source Quality Control:

1. General: Ship landscape materials with certificates of inspection as required by governmental authorities. Comply with governing regulations applicable to landscape materials.

2. Analysis and Standards: Package standard products with manufacturers certified analysis. For other materials, provide analysis by recognized laboratory made in accordance with methods established by the Association of Official Agricultural Chemists, wherever applicable or as further specified.

3. Topsoil: Before delivery of topsoil, furnish written statement giving location of properties from which topsoil is to be obtained, names and addresses of owners, depth to be stripped, and crops grown during past 2 years, if requested by the Engineer.

4. Grass Seed: All seed shall be certified as to mixture, germination, and purity, as being in conformity with the following requirements:

a. Each variety of seed shall have a percentage of germination of not less than 80, a percentage of purity of not less than 85, and shall have not more than one percent of weed content.

b. All seed shall be from the same or previous year's crop unless recent tests by an approved testing agency demonstrate that older seed meets the above requirements.

5. Inspection: The Engineer reserves the right to inspect any plant materials either at the place of growth or at the site before planting, for compliance with requirements for name, variety, size, and quality.

1.05 SUBMITTALS

A. Certification: For information only, submit 2 copies of certificates of inspection as required by governmental authorities, and manufacturer's or vendors analysis for soil amendments and fertilizer materials. Submit other data substantiating that materials comply with specified requirements at the request of the Engineer.

Submit seed vendor's certified statement for each grass seed mixture required, stating botanical and common name, percentage by weight, and percentages of purity, germination, and weed seed for each grass seed species at the request of the Engineer.

1.06 PRODUCT DELIVERY, STORAGE, AND HANDLING:

A. Packaged Materials: Deliver packaged materials in containers showing weight, analysis and name of manufacturer. Protect materials from deterioration during delivery, and while stored at the site.

1.07 JOB CONDITIONS: Contractor must examine the subgrade, verify the elevations, observe the conditions under which work is to be performed and notify the Engineer's of unsatisfactory conditions. Do not proceed with the work until unsatisfactory conditions have been corrected in an acceptable manner.

Proceed with and complete the landscape work as rapidly as portions of the site become available, working within the required seasonal limitations.

A. Seeding Seasons: Unless variance is requested in writing and approved by the Engineer, seeding shall be done within the following dates:

Seeding: April 1 - September 15

PART 2 - PRODUCTS

2.01 TOPSOIL (STRIPPINGS): Loam or approved topsoil removed within the confines of the project area shall be segregated into piles, cleaned sufficiently and reused in accordance with Section 02200, Earthwork. If quantity of stockpiled topsoil is insufficient, or quality is not in accordance with the requirements for new topsoil, the Contractor shall provide additional new topsoil from approved sources off the site as required to complete landscape work.

Provide new topsoil as required which is fertile, friable, natural loam, surface soil, reasonably free of subsoil, clay lumps, brush, weeds and other litter, and free or roots, stumps, stones larger than 2" in any dimension, and other extraneous or toxic matter harmful to plant growth. Mulch peat or other excessively acidic soil shall not be used. Sand, silt, and clay contents comprising existing or new topsoil shall fall within the following ranges.

Sand	50%-70%
Silt	2%-40%
Clay	10%-28%

Submit representative soil samples of topsoil from offsite sources to qualified soil testing laboratory to ascertain what amendments may be necessary to obtain proper tilth, nutrient characteristics, and pH balance in accordance with the following. Provide amendments as necessary at rates indicated on the soil test in accordance with the following criteria:

Organic Matter: Greater than 3% organic matter (by weight)

pH range: 6.0 to 7.5. If pH is less than 6.0, lime shall be added in accordance with soil test results and seed requirements.

Phosphorus/Potassium: Low to medium range

Soluble Salt: Not greater than 500 ppm

Obtain topsoil from local sources or from areas having similar soil characteristics to that found at project site. Obtain topsoil only from naturally, well-drained sites where topsoil occurs in a depth of not less than 4"; do not obtain from bogs or marshes.

A. Soil Amendments:

1. Lime: Natural limestone containing not less than 90% of total carbonates, ground so that not less than 100% passes a 10-mesh sieve, not less than 90% passes a 20 mesh sieve, and not less than 50% passes a 100 mesh sieve.

2. Fertilizer: Fertilizer shall contain available elements in conformity with the standards of the Association of Official Agricultural Chemists. The fertilizer shall indicate the weight, contents and guarantee analysis shown thereon or on a securely attached tag, as applicable. The selection of fertilizer shall be based on the minimum phosphorus required by the soil as determined by the chemical analysis of soil samples. The Contractor shall be responsible for sampling and testing topsoil to determine amount of phosphorus required for growing of grass.

   a. Granular fertilizer shall be a commercial grade fertilizer containing the following percentages of available nutrients by weight:

Nitrogen	10 percent
Phosphoric Acid	10 percent
Potash	10 percent

   b. Water soluble fertilizer shall be completely soluble in water and contain the following percentages of available nutrients by weight. It shall contain a coloring agent.

Nitrogen	16 percent
Phosphoric Acid	To Be Determined by Contractor
Potash	16 percent

The Engineer may approve the use of other fertilizers providing they contain an equivalent amount of nutrients in an acceptable form.

2.02 GRASS MATERIAL:

A. Grass Seed: Provide fresh, clean, new-crop seed complying with the tolerance for purity and germination established by the Official Seed Analysts of North America. Provide seed of the grass species, proportions and minimum percentages of purity, germination, and maximum percentage of weed seed, as specified. Apply seed at the rate of 120 lbs/acre.

The seed mixtures shall consist of seeds proportioned by weight as follows:

Tall Fescue	54 lbs/acre
Creeping Red Fescue	25 lbs/acre
Red Top	5 lbs/acre
Ladino Clover	13 lbs/acre
Annual Ryegrass	8 lbs/acre
Birdsfoot Trefoil	5 lbs/acre
Timothy	10 lbs/acre

2.03 MISCELLANEOUS LANDSCAPE MATERIALS:

A. Mulch for Seeded Areas:

1. Hay or straw mulch shall consist of long fibered hay or straw, reasonably free from noxious weeds and other undesirable material. No material shall be used which is too wet, decayed, or compacted as to inhibit even and uniform spreading. No chopped hay, grass clippings or other short fibered material shall be used unless directed.

2. Cellulose fiber mulch shall consist of natural wood, recycled paper of humus cellulose fiber containing no materials which will inhibit seed germination or plant growth. Sufficient non-toxic water soluble green dye shall be added to provide a definite color contrast to the ground surface to aid in even distribution. Cellulose fiber mulch shall be supplied in moisture resistant, sealed bags marked with the manufacturer's name, the air dry weight, and composition of the contents.

B. Mulch Binder: Material for mulch binder may be binder or tackifier of a type acceptable to the Engineer and may be diluted with water to assure even distribution. Other types of approved mulch binders may be used when authorized by the Engineer.

PART 3 - EXECUTION

3.01 TOPSOIL PLACEMENT: Placement of topsoil shall be performed in a uniform manner, with no clumps or clods. It shall be the Contractor’s responsibility to restore to the line, grade, and surface all eroded areas with approved material and to keep topsoiled areas in acceptable condition until turf is established and accepted by the Engineer.

A. Grading: Previously established grades on the areas to be topsoiled shall be maintained according to the approved plan.

B. Liming: Where the pH of subsoil is 6.0 or less, ground agricultural limestone shall be spread in accordance with the soil texture or the vegetative establishment practice being used.

C. Bonding: After the areas to be topsoiled have been brought to grade, and immediately prior to spreading the topsoil, the subgrade shall be loosened by discing or scarifying to a depth of at least 2 inches to ensure bonding with subsoil.

D. Placement: Topsoil shall not be placed while in a frozen or muddy condition, when the subgrade is excessively wet, or in a condition that may otherwise be detrimental to proper grading or proposed sodding or seeding. The topsoil shall be uniformly distributed to a minimum compacted depth of 4 inches. Any irregularities in the surface resulting from topsoil placement or other operations shall be corrected in order to prevent the formation of depressions and/or water pockets. It is necessary to compact the topsoil enough to ensure good contact with the underlying soil and to obtain a uniform firm seedbed for the establishment of a high maintenance turf. However, undue compaction is to be avoided as it increases runoff velocity and volume, and prevents seed germination.

3.02 SEEDING:

A. Do not use wet seed or seed which is moldy or otherwise damaged in transit or storage.

B. Rates of Application: Rates of application for limestone, fertilizer, and grass seed shall be in accordance with Drawing C-308 of the Construction Drawings.

C. The hydraulic spray method shall be used for seeding all areas unless alternative methods are approved by the Engineer.

D. Application Procedure:

1. Hydraulic Spray Method: The hydraulic spray method of sowing seed shall be done with an approved machine operated by a competent crew. Seed and fertilizing materials shall be mixed with water in the tank of the machine and kept thoroughly agitated so the materials are uniformly mixed and suspended in the water at all times during operation. The spraying equipment must be designed and operated to distribute seed and fertilizing materials evenly and uniformly on the designated areas at the required rates. If the Engineer finds the application uneven or otherwise unsatisfactory, he may require the hydraulic spray method to be abandoned and the balance of the work done as specified under another method.

E. Mulching:

1. Cellulose fiber mulch shall be applied as waterborne slurry. The cellulose fiber and water shall be thoroughly mixed and sprayed on the area to be covered so as to form a uniform mat of mulch at the rate of not less than 60 pounds of mulch material per 1,000 square feet unit of area.

Cellulose fiber mulch may be mixed with the proper quantities of seed, fertilizer, and agricultural limestone as required, or may be applied separately the next day after seeding.

2. Hay or straw mulch shall be spread evenly and uniformly over any designated areas or as directed by the Engineer in the field so to avoid damage to seeded areas. Unless otherwise directed, mulch shall be applied at the rate of 2 to 3 tons per acre or 3 bales (90 to 130 lbs) per 1,000 square feet. Too heavy application of mulch shall be avoided. Lumps and thick mulch material shall be thinned.

   Unless otherwise authorized, the mulch shall be anchored in place by uniformly applying an acceptable mulch binder at a rate of 10 to 13 gallons per 1000 sq. ft. Application of a concentrated stream of mulch binder will not be allowed. Asphalt mulch binder may be omitted when authorized and when there is a danger of the asphalt defacing the surface of nearby structures, houses, vehicles or other objects. Other methods of anchoring mulch may be used subject to the approval.

3.03 MAINTENANCE AND ACCEPTANCE:

A. Seeded Areas:

1. Maintain seeded areas by watering, fertilizing, weeding, mowing, trimming, and other operations such as rolling, regrading and replanting as required to establish a smooth, acceptable grass growth, free or eroded or bare areas.

2. Seeding, April 1 to September 15, Inclusive: The Contractor shall maintain each seeded area until acceptance of the individual area. Maintenance shall consist of providing protection by erecting necessary signs and barriers and by repairing damaged areas as directed. Damaged areas and areas which do not produce a satisfactory stand of grass shall be repaired to re-establish the condition and grade of the area prior to the original seeding and then refertilized, reseeded and remulched as specified to produce satisfactory results.

   Areas fertilized and seeded by the hydraulic method will be accepted only upon attainment of a reasonable thick uniform stand of not less than 80 percent coverage of permanent grasses, free from sizeable thin or bare spots.

3. Seeding, September 16 to March 31, Inclusive: Areas not seeded or which do not obtain satisfactory growth by October 1, will be seeded with Aroostook Rye or mulched at rates previously specified herein. After November 1, or the first killing frost, disturbed areas shall receive dormant seeding (at double the regular seeding rate) in accordance with MEDEP BMPs and Drawing C-308.

4. Seeded areas will be accepted only upon attainment of a reasonably thick, uniform stand of not less than 90 percent coverage of permanent grasses, free from sizable thin or bare spots.

3.04 CLEANUP AND PROTECTION: During landscape work, store materials and equipment where directed. Keep pavements clean and work area in an orderly condition.

Protect landscape work and materials from damage due to landscape operation, operations by other contractors, and trades and trespassers. Maintain protection during installation and maintenance periods. Treat, repair, or replace damaged landscape work as directed.

3.05 RESTORATION: All paved, sod covered, or planted areas, structures, and substructures not specifically provided for in the contract disturbed by the Contractor during the execution of the work shall be restored by the Contractor, in a manner satisfactory to the Engineer, to their original conditions at no additional cost to the Owner.

END OF SECTION

SECTION 03300

CAST-IN-PLACE CONCRETE

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: The general provisions of the Contract, including General and Supplementary Conditions and General Requirements (if any), apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Earthwork: Section 02200

B. Manholes, Catchbasins, and Drainage Structures: Section 02570

1.03 DESCRIPTION:

A. Furnish and install cast in place concrete shown on the Drawings, and specified herein.

1.04 QUALITY ASSURANCE:

A. All concrete shall conform to applicable requirements of the ACI Standards for design and construction of concrete work.

B. All concrete shall be minimum 3000 psi at 28 days unless otherwise specified.

1.05 SHOP DRAWINGS:

A. Provide Shop Drawings in accordance with Section 01340.

1.06 TESTING:

A. Sampling and testing will be provided by the Owner.

PART 2 - PRODUCTS

2.01 MATERIALS:

A. Concrete:

1. Cement:

a. Portland cement conforming to the Requirements of Standard Specifications of the American Society for Testing Materials, Designation C-150, as revised, Type II.

b. Use an air entraining admixture conforming to ASTM C-260.

2. Aggregate:

   a. Conform to the Standard Specifications for Concrete Aggregates, ASTM Designation C-33, as revised.

   b. Sand: Medium with a fineness modulus of 2.60 - 2.90.

   c. Coarse Aggregate: Not to exceed 1-1/2 inches for mass concrete and 3/4 inch for reinforced slabs.

3. Water: Potable supply.

B. Reinforcing Steel:

1. As herein used, designates the bars, and rods incorporated in the concrete, but does not include any structural shapes.

2. Fabrication and placing of all reinforcing steel shall conform to the requirements of the American Concrete Institute, "Building Code Requirements for Reinforced Concrete" (ACI-318).

3. Reinforcing Steel: Round, deformed steel bars of the intermediate grade Billet Steel, ASTM Specification A-15 with deformations to ASTM Specification A-305.

4. Wire: Conform to the requirements of the "Standard Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement," ASTM Specification A-82.

5. Bars: Cold bent and accurately formed to the dimensions indicated on the Drawings.

6. Stirrups and Ties:

   a. Bent around a pin having a diameter not less than two times the minimum thickness of the bar.

   b. Bends for Other Bars: Make around a pin having a diameter not less than six (6) times the minimum thickness of the bar.

   c. Do not straighten or rebend in a manner that will injure the material.

   d. Bars with kinks, or bends not shown on the drawings, shall not be used.

   e. Heating of any bars will be permitted <u>only</u> when the entire operation is approved by the Engineer.

PART 3 - EXECUTION

3.01 INSTALLATION:

A. Forms:

1. Design, furnish and erect as necessary to install concrete.

2. Of sufficient strength and rigidity to resist, without bulging, the weight of the concrete, and smooth and free of all irregularities.

3. Form material: Suitable for forms and adequate to retain the concrete to the designed dimensions; tied, clamped, and bolted together as necessary, to prevent the leakage of mortar.

4. Falsework: Rigidly braced against lateral movement, in such a manner that accurate alignment will be assured.

5. Provide for all openings, beams, rebates, chases, slabs, etc., as may be required.

6. Set all sleeves, inserts, etc., for other trades as furnished by them, and in the locations designated by them, and hold by substantial templates.

7. Properly treat with form coating.

8. Forms for Exposed Concrete: Surfaces equal in smoothness to metal or new plywood and joints tightly fitted.

9. Construct all wall forms with clean-out panels, suitably located along the base.

10. Thoroughly clean of foreign material just prior to the placement of concrete.

11. Fit all external corners of exposed concrete with 3/4-inch chamfer strips, except where specifically dimensioned on the drawings.

12. Remove only when approved by the Engineer, and only when the concrete has obtained at least 60 percent of the design strength and is also sufficient strength to support its own weight and the live loads to be placed thereon including backfill.

13. Repair any damage caused by removal of forms.

B. Placement of Reinforcing Steel:

1. When delivered to the job site, pile on wood blocking off the ground and away from earthwork or trenching operations, and cover if necessary to prevent rusting or splashing with mud.

2. Before being positioned, remove loose mill and rust scale and any coatings, including ice, that would destroy or reduce bond with the concrete.

3. Where there is delay in depositing concrete, reinspect and clean when necessary.

4. Placement of Bars: In accordance with the "Recommended Practice for Placing Reinforcing Bars," as published by the Concrete Reinforcing Steel Institute.

5. Accurately position and secure against displacement by using annealed iron wire ties, or suitable clips, and support by suitable approved metal supports, bolsters, chains, spacers, or hangers.

6. Methods of Support: Approved prior to placement of reinforcing steel.

7. Brick supports for reinforcement in slabs laid on grade: Not permitted.

8. Maximum spacing of ties at intersections: Sixteen (16) inches.

9. Splices: Lap splice with bars placed in contact and wire securely.

10. Proposed splices not shown on the drawings. Obtain the Engineer's approval as to location and character of the splices.

11. Avoid splices at points of maximum stress, and if approved at those locations, lap-weld or form as otherwise directed.

C. Depositing Concrete:

1. Do not place until forms and reinforcing are inspected by the Engineer, but such does not constitute a review of structural adequacy of the forms which shall be the responsibility of the Contractor.

2. Place mass concrete where it is to remain immediately after mixing, in no case later than 40 minutes after mixing, distributing it over the area to be covered in layers as directed by the Engineer.

3. Take special care to spade and otherwise thoroughly work the concrete at and near the base of the walls.

4. Work along faces of forms so as to give a smooth surface, free from voids, or loose aggregate.

5. Limited vibrating may be permitted under the supervision of the Engineer.

6. No segregation will be allowed.

7. Provide spouts or suitable openings in forms where required.

8. Conduct vibration by internal type mechanical vibrators operated only by experienced employees.

9. Thoroughly rod and tamp about embedded materials to secure proper adhesion and to avoid displacement of such materials.

D. Curing:

1. Accomplish by keeping the work wet and covering the concrete surfaces, after stripping and finishing, with wet burlap or some other similar material which will hold water.

2. Keep wet continuously for at least seven (7) days.

3. At no time during these 7 days expose directly to the sun and wind.

4. Accomplish to the complete satisfaction of the Engineer.

E. Protection:

1. Heat water and/or aggregate and/or the concrete and/or protect against freezing, to the satisfaction of the Engineer.

2. Do not place on a subgrade that is frozen or contains frozen materials.

3. After being deposited in the forms, keep at a temperature of 50°F, or more, for at least five (5) days.

3.02 INSPECTION

A. Notify the Engineer of form stripping so as to inspect the concrete work before any sealing, finishing, or backfilling are allowed.

B. Replace all defective concrete work with suitable work or repair to the satisfaction of the Engineer.

END OF SECTION

SECTION 15100

HDPE PIPE AND FITTINGS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

The requirements set forth by the Quality Assurance/Quality Control Plan shall apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Earthwork: Section 02200

B. Pipe Installation: Section 02450

C. Manholes, Catch Basins, and Drainage Structures: Section 02570

D. Valves and Pipe Accessories: Section 15110

1.03 REFERENCES:

1. ASTM F-714-03, "Polyethylene Pipe SDR-PR Design"
2. ASTM D 638, "Standard Test Method for Tensile Properties of Plastics"
3. ASTM D1248-02, "Class C Polyethylene Moulding and Extrusion Materials"
4. ASTM F 1248, "Determination of Environmental Stress Crack Resistance (ESCR) of Polyethylene Pipe"
5. ASTM D 2657, "Guideline for Polyolefin Thermoplastic Butt Fusion Heat Welding"
6. ASTM D 2837, "Method for Obtaining Hydrostatic Design Basis for Thermal Plastic Pipe Materials"
7. ASTM D3035-03a, "Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter"
8. ASTM D 3350-02a, "Standard Specification for Polyethylene Plastics Pipe and Fittings Materials"
9. ASTM F 1473-01e1, "Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins"
10. ASTM D 4218-96(2001), "Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique"

1.04 DESCRIPTION OF WORK:

A. Work of this Section shall consist of furnishing all labor, materials, and equipment to install and test leachate collection, leachate transport, and underdrain pipes as shown on the Contract Drawings. Only the appropriate portions of this section pertaining to the specific contract work identified in Section 01010 "Summary of Work" or as directed by the Engineer, will apply.

1.05 SUBMITTALS:

A. The Contractor shall furnish the name of the pipe and fittings manufacturer, to the Engineer prior to commencing the work. Pipe of the same manufacturer shall be used throughout the project.

B. The Contractor shall submit to the Engineer a Construction Schedule for pipe installation.

C. The Contractor shall submit manufacturer's technical product data including chemical resistance data and installation instructions for piping joints and fittings.

D. The Contractor shall submit the Quality Control Documentation as specified in Section 10 of the QA/QC Plan, and, if required, a certificate from the pipe manufacturer certifying the product meets the requirements of this specification.

E. The Contractor shall submit to the Engineer documentation demonstrating the pipe welding technicians are certified by the MANUFACTURER to weld HDPE pipe. The Contractor shall provide the Engineer with butt-fusion procedures, pressures, and temperature for each size and class of pipe used. These procedures, pressures, and temperatures shall be used consistently throughout the project in accordance with the pipe manufacturer's recommendations.

1.06 MANUFACTURER'S QUALITY ASSURANCE:

A. The pipe and fittings manufacturer shall have an established quality assurance/quality control program responsible for inspecting and testing incoming materials and outgoing product. At a minimum incoming polyethylene materials shall be inspected and tested for density per ASTM D 1505, melt flow rate per ASTM D 1238, and contamination. All incoming materials shall be certified by the supplier.

B. The pipe and fittings manufacturer shall have an established QA program responsible for assuring the long term performance of materials and products. Representative samples of PE materials shall be tested against the physical property requirements of this specification. Each extrusion line and molding machine shall be qualified to produce pressure rated products by taking representative production samples and performing sustained pressure tests in accordance with ASTM D 1598.

C. All outgoing products shall be inspected for diameter, wall thickness, length, straightness, out-of-roundness, concentricity, toe-in, inside and outside surface finish, markings, and end cut. Quality Control (QC) shall perform tests for density, melt flow rate, carbon content, and carbon dispersion. All fabricated fittings shall be inspected for fusion quality and alignment. The pipe and fitting manufacturer shall maintain internal QA/QC records, and shall provide QA/QC information upon request of the Engineer. .

1.07 PACKAGING DELIVERY AND HANDLING:

The pipe and fitting manufacturer shall package products for shipment in a manner suitable for safe transport by commercial carrier. When delivered, a receiving inspection shall be performed, and any shipping damage reported to the pipe and fittings manufacturer. Pipe and fittings shall be handled, installed and tested in accordance with manufacturer's recommendations, and the requirements of this specification.

PART 2 – PRODUCTS

2.01 HDPE PIPE AND FITTINGS

A. Physical Properties:

Property	Unit	Test Method	Value
Material Listing	-	PPI TR-4	PE 4710
Cell Classification	-	ASTM D 3350	PE 445574C
Density	g/cm^3	ASTM D 1505	0.941 to 0.955
Melt Index	g/10 min	ASTM D1238	<0.15
Flexural Modulus	psi	ASTM D 790	>110,000 and < 160,000
Tensile Strength (yield)	psi	ASTM D 638	3000-3500
Slow Crack Growth Resistance	hours	ASTM F 1473	100
Hydrostatic Design Basis	psi	ASTM D 2837	1600 @ 23˚ C
UV Stabilizer	% Carbon Black	ASTM D 1603	2 to 3
Elastic Modulus	psi	ASTM D 638	110,000 to <160,000
Thermal Expansion	1/˚ F	ASTM D 696	8×10^{-5}
Molecular Weight Category	-	-	Extra High

B. General:

1. Materials used to manufacture pipe, fittings, and centralizers supplied under this specification shall be high density, extra high molecular weight polyethylene pipe. The pipe and fittings shall be designated PE 4710 using the cell classification system per ASTM D 3350. The pipe and fittings shall be made from the same resin base that meets this specification, and provides a minimum Hydrostatic Design Basis (HDB) of 1,600 psi as determined by ASTM D 2837.

2. The HDPE pipe and fittings should be produced by the same manufacturer, from identical materials that meet the requirements of this specification. Exceptions shall be pre-approved by the Engineer.

3. Density of base resin shall be within the limits of 0.941 to 0.955, ASTM D-1505 (Test Methods).

4. The HDPE pipe manufactured from materials meeting the specifications of this section shall have an Environmental Stress Crack Resistance of no failures in 10,000 hours (ESCR: Fo >10,000) when tested in accordance with ASTM F 1248.

5. Outside diameter of pipe shall conform to International Standard Organization (ISO) recommendations for outside diameters (IPS pipe size).

6. The pipe shall contain no recycled compound except that generated in the manufacturer's own plant from resin of the same specification from the same raw material.

7. Perforated pipe shall be provided as indicated on the Contract Drawings. Perforations shall be oriented as shown on the Contract Drawings.

8. HDPE Fittings, molded or fabricated, shall have the same pressure rating and strength as the pipe to which joining is intended. At the point of fusion, the outside diameter and minimum wall thickness of the fitting shall match the outside diameter and minimum wall thickness specifications of ASTM F714 for the same size pipe to which it is joined. Dual-wall containment fittings shall be fabricated by the manufacturer of the pipe. The manufacturer shall de-rate the fittings used for this project, as necessary. Bends, tees, and wyes shall be manufactured by mitered fabrication and shall meet the pressure rating of the piping system (100 psi). The manufacturer shall have written specifications for all standard mitered fittings establishing Quality Control criteria and tolerances. All dual-wall containment fittings shall have a Quality Control label as approved by the manufacturer. Fitting markings shall include a production code from which the location and date of manufacture can be determined. Upon request, the manufacturer shall provide an explanation of his production code.

9. Centralizers shall be used to support the dual-wall conductor pipe inside the containment pipe and maintain the specified annulus between the conductor pipe and containment pipe in both dual-wall containment fittings and pipe runs. The centralizers shall allow for the passage of fluid flow in the event of conductor pipe failure. Centralizers shall be attached to both the conductor and the containment pipe. Centralizers shall be spaced as recommended by the pipe manufacturer. Spacing of the pipes and centralizers shall be described in the manufacturer's submittal and approved by the Owner's Representative.

10. Marking: Each standard and random length of pipe and fitting in compliance with this standard shall be clearly marked with the following information:

    a. ASTM Standard Designation
    b. Pipe Size
    c. Class and Profile Number
    d. Production Code
    e. Dimension Ratio

11. Dimensions: Pipe Size and DR Rating shall be as shown on the Contract Drawings.

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL:

A. Pipe may be rejected for failure to conform to Specifications for the following:

1. Fractures or cracks sufficient to impair strength, durability or serviceability of pipe.

2. Defects indicating improper proportioning, mixing, or molding.

3. Damaged ends,

4. Contractor shall provide a pyrometer to record and verify the temperature of heating plate surface (at min of three locations) once every two hours. Maintain records of these temperature measurements including, temperature, date, time and fusing technician, for the duration of the project. Provide the Engineer with a copy of the temperature measurements.

B. Acceptance of fittings, stubs, or other specifically fabricated pipe sections(e.g. butt-fusion joints) shall be based on visual inspection at the job site and documentation of conformance to these Specifications.

C. Prior to backfilling, the contractor shall obtain as-built top of pipe coordinates and elevations as grade changes, fittings, and at least every 50 feet along the length of pipe.

3.02 PIPE JOINTING

A. All materials shall be stored and handled in accordance with the manufacturer's recommendations.

B. All joints shall be made in a dry trench or area that is protected from adverse weather or dust, and in accordance with the manufacturer's recommendations and the best practices for class of pipe installed. The ends of the pipe shall be wiped clean with a dry cloth before making each joint.

C. Butt Fusion Joints:

1. Pipes: Join to one another and to HDPE fittings by thermal butt-fusion in accordance with ASTM D2657. Dual-wall containment piping systems shall be manufactured to allow for simultaneous joining with conventional fusion equipment without the use of an *annular* heating iron.

2. The tensile strength at yield of the butt-fusion joints shall not be less than the pipe.

3. The Contractor shall utilize fusion equipment approved by the pipe manufacturer and personnel trained by the pipe manufacturer representative for all fusion welding.

D. Flange Jointing:

1. Use when connecting or transitioning to flanged steel pipe in manholes or pump stations

2. Connect slip-on type 316 stainless steel backup flanges and nuts and bolts to flange adapters

3. Butt fuse fabricated flange adapters to pipe.

4. Observe the following in connection of flanged joints:

   a. Align flanges or flange valve connection to provide tight seal. Provide nitrile-butadiene gaskets if needed to achieve seal. Gaskets are required all flanged connections.
   b. Place U.S.

5. Make Flanged connections according to Section 02450.

E. Electro-Fusion Joints:

1. Electro-fusion couplings shall be installed per manufacturer's specifications.

2. Joints using electro-fusion couplings shall be performed in the trench so as not to overstress the joint and achieve proper alignment.

F. Stainless Steel Repair Clamp Joints:

1. Stainless steel repair clamps shall be installed per manufacturer's specifications.

2. Joints using stainless steel repair clamps shall be performed on connections to existing leachate collection pipes when conditions have been determined to be too wet for electro-fusion coupling installation. Connections shall be in the trench so as not to overstress the joint and achieve proper alignment.

G. General Fusion Procedures Dual Containment Pipe:

1. Several important parameters need to be considered when fusing:

   a. Temperature: The required temperature for fusing is recommended to be 500°F, ±10° (260°C, ±6°). Should the temperature be less than that specified, then additional heating time should be allowed. The manufacturer’s policy is to provide two 2-foot (0.6m) segments of pipe to allow a test fusion which ensures the proper fusion parameters are being utilized.

   b. Airborne Contaminants: Airborne contaminants can settle on the polyethylene material, heating plate, and cutter. The fusion operator should use extreme care to ensure that all airborne contaminants are removed prior to the facing operation.

c. Cleaning of Pipe Ends: It is extremely important to remove all dirt, mud, grit, oil, water, etc. from the pipe ends. Any contamination can and will transfer to the faces of the heating iron and face plate. Avoid wiping the pipe areas after the facing operation. If shavings or other debris must be removed, use only a clean cotton cloth, as contaminated rags or use of solvents can leave harmful deposits on the fusion zone.

d. Chip Removal: Due to the fact that the annular space between the conductor and containment pipe allows limited area for the facing ribbons, the annular cavity should be monitored to ensure that chips do not build up and prevent proper facing. Remove all ribbons and chips from the annular and conductor cavities prior to heating the pipe ends.

e. Machine Clearances: The end user should take due care to ensure that clearance between obstructions and the fusion joint are sufficient to allow use of their particular machine. The varying conventional fusion machines available will require different amounts of clearance space to perform the required fusion. If any questions exist in this area, contact the manufacturer's technical services department.

f. The heating iron configuration needs to be reviewed to ensure adequate surface area exists to heat both the inner and outer pipe. Some fusion machines do not encompass the range of inner and outer pipe diameters that are available.

g. Maintenance of the fusion machine is the operator's responsibility. It is recommended the heating iron temperature for the entire surface be checked, at a minimum, on a daily basis with a pyrometer for uniform temperature.

h. The fusion pressure should be calculated by using the recommended interface pressure of 75 psi (0.52 MPa) multiplied by the interfacial areas of the inner and outer pipes combined. The Contractor shall provide a calculation for proposed fusion pressure performed in accordance with the pipe manufacturer's recommendations.

H. Pipe Cutting:

1. Dual containment pipe is manufactured to specific lengths. Due to the extreme importance of the conductor being centralized in the containment pipe, field cutting and fitting is not recommended. In the event that the end user cannot exactly specify the required length, the manufacturer should be alerted to this fact so that they can offer special lengths that may be required to allow the final tie-in. The feature should be recognized at the job onset in order to prevent final tie-in delays.

2. When permitted, sections of pipe may be cut to provide shorter sections of pipe necessary for the construction. The cutting of the pipe shall be done in accordance with the pipe manufacturer's recommendations and subject to the approval of the Engineer. Pipe cutting of dual-containment pipe shall be performed at the risk of the Contractor and shall not relieve the Contractor from obtaining proper fusion of the piping system.

3. When permitted, the pipe material shall be cut by using a saw or milling process, approved by the pipe manufacturer and not by using any impact device, such as a hammer and chisel, to break the pipe. The pipe shall be cut, not broken. The cut end of the pipe shall be square to the axis of the pipe and any rough edges ground smooth.

I. Inspection: Pipe installation shall be subject to inspection by the Engineer for quality, adherence to line and grade, jointing, and proper backfill. Any joint not satisfactory to the Engineer shall be removed and remade to his satisfaction at the Contractor's expense. No pipe shall be backfilled until it has been approved by the Engineer.

3.03 PIPE INSTALLATION

A. Install pipe according to Section 02450 of these specifications for trench conditions. .

3.04 FIELD TESTING OF PRESSURE PIPE: (N.I.T.C.)

A. Hydrostatically pressure test dual containment conductor pipe prior to placing into service in accordance with specification Section 15120.

B. The containment pipe of the dual containment force main shall be air tested to a pressure of 8 psig.

END OF SECTION

SECTION 15110

VALVES AND PIPE ACCESSORIES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS: Drawings and General Terms and Conditions as outlined in Section 1 of the Construction Agreement and Division-1 Specification sections, apply to work of this section.

The requirements set forth by the Quality Assurance/Quality Control Plan shall apply to the work specified in this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE:

A. Pipe Installation: Section 02450

B. Manholes, Catch Basins, and Drainage Structures: Section 02570

C. HDPE Pipe and Fittings: Section 15100

1.03 REFERENCE:

A. ASTM A536-84(1999)e1, "Standard Specification for Ductile Iron Castings"

B. ASTM A126-95(2001), "Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings"

C. ASTM A743/A743M-03, "Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application"

1.03 DESCRIPTION OF WORK:

A. Work of this Section shall consist of furnishing all labor, materials, and equipment to install valves, fittings and other appurtenances. Only the appropriate portions of this section pertaining to the specific contract work identified in Section 01010 "Summary of Work" or as directed by the Engineer, will apply.

B. Accept valves on site in shipping containers with labeling in place. Inspect for damage.

1.04 SUBMITTALS:

A. Product Data: Submit Manufacturers shop drawings, technical product data, installation instructions and catalog information for each valve fitting or accessory.

B. The Contractor shall submit the Quality Control Documentation as specified in the QA/QC Plan contained in Appendix B of this document. .

C. Manufacturer's Installation Instructions: Submit hanging or support methods and joining procedures.

PART 2 – PRODUCTS

2.01 BALL VALVES:

A. General: Provide ball valves for the pipe size as indicated on Contract Drawings.

B. Description:

1. Valves for sizes 4" diameter to 8" diameter shall be KTM Model EB100, full bore, metaltite seats as manufactured by Tyco International. Valves for size 12" diameter shall be KTM Model EO1100 as manufactured by Tyco International.

2. The ball shall be 316, stainless steel.

3. Seals and O-rings shall be constructed of Viton® where possible and applicable.

4. Flanges shall be drilled according to ANSI B16.5, Class 150.

2.02 PLUG VALVES:

A. General: Provide plug valves for the pipe size as indicated on the Contract Drawings.

B. Description:

1. Plug valves shall be PEC Eccentric Plug Valves as manufactured by DeZURIK. The valve shall have a cast iron body with a stainless steel plug.

2. The plug shall be 316, stainless steel. The body can be either cast iron or stainless steel provided it meets the pressure requirement.

3. Seals and O-rings shall be constructed of Viton® where possible and applicable.

4. Flanges shall be drilled according to ANSI B16.5, Class 150.

2.03 CHECK VALVES:

A. General: Provide check valves for the pipe size as indicated on the Contract Drawings.

B. Description:

1. Check valve shall be a rubber flapper swing check valve as manufactured by APCO and be capable of 100 psi operating pressure.

2. The flapper material shall be Viton A®.

3. The body shall be stainless steel and the inside shall be unlined.

4. Check valves shall be equipped with a backflow device.

5. The flanges shall be drilled according to ANSI B16.5, Class 150.

2.04 RESILIENT SEATED GATE VALVES:

A. Resilient seated Gate Valves shall be ductile iron body, bronze mounted, with 18-8, 304 stainless steel bolts, resilient wedge gate with two inch operating nut and a PIV single flange (lug) connection. Valves shall conform in every respect to AWWA C509 Valve shall be MJ-PIV, F-Series Resilient Wedge Valve as Manufactured by Clow or approved equal. Valves shall open left.

B. Valves shall be provided with "O" rings. The design of the valve shall be such that the seal plate can be fitted with new "O" rings while the valve is under pressure in a fully open position.

C. Valves shall have a 100 percent solids thermoset or fusion bonded epoxy protective coating, holiday-free in the waterway, which shall meet all requirements of AWWA C550. The epoxy coating shall not impart taste or odor to the water. The coating shall be a product acceptable to the National Sanitation Foundation (NSF) for use in potable water and shall be so listed in the most current NSF summary of approved products under ANSI/NSF Standard 61. The coating shall be applied and cured in strict conformance with the coating manufacturer's cautions and instructions. The coatings shall be applied by the valve manufacturer under controlled factory conditions and field application is strictly prohibited.

2.05 PIV INDICATOR POST:

A. Indicator post shall be used to actuate and indicate the closed or open status of remotely installed PIV valves.

B. Indicator post and any necessary extensions shall be supplied and installed as shown on the contract drawings. Indicator post supplied shall open in the same direction as the valve and indicate as such. All bolts shall be 316, stainless steel.

2.06 FITTINGS:

A. Fittings shall be flanged ductile iron. All fittings shall be cement lined, and coated as specified hereinbefore for ductile iron pipe. Fittings greater than 12 inches shall conform to ANSIA21.10 (AWWA C110) and fittings 12 inches or less shall conform to ANSI A21.11 (AWWA C111). Compact fittings shall be Class 150 conforming to ANSI A21.53 (AWWA C153) and shall be cement lined in compliance with AWWA C104 for fittings 12 inches or less. Compact fittings greater than 12 inches are not acceptable. Fittings shall come complete with gaskets, and 316 stainless steel bolts.

B. Plugs, caps and blind flanges shall be stainless steel and shall conform to the weights and dimensions shown and be provided complete with all necessary gaskets and 316 stainless steel bolts.

C. All fasteners (nuts and bolts) shall be 316, stainless steel and shall be the correct size and dimensions for the size flanges and size of pipe.

2.07 CONCRETE:

A. Concrete used for any purpose such as, but not limited to thrust restraints, encasements, and chimneys shall have a minimum compressive strength of 3000 psi and conform to the specifications contained in Section 03300, Cast-in-Place Concrete.

2.08 STAINLESS STEEL REPAIR CLAMPS:

A. Repair clamps shall be as manufactured by Romac Industries.

2.09 PRESSURE TRANSMITTERS:

A. Pressure transmitters shall be installed to monitor the interstitial space of the dual containment system. They shall have an operating pressure range from 0 to 150 psi. The pressure transmitters shall be MBS 33, Cable type, 4 – 20 mA output, as manufactured by Danfoss.

B. The interstitial space shall be accessed by installing a threaded insert through the end termination or side wall of the containment pipe inside the manhole. The pressure transmitter shall be installed into this threaded insert or a coupling. This shall be done on the lowest end elevation of the pipe run.

C. Threaded connections shall be installed using Teflon tape, or approved sealant.

2.10 PRESSURE GAUGE:

A. Pressure gauges shall be furnished and installed as shown on the contract drawings

B. Pressure shall be transmitted to the gauge by a (diaphragm seal) completely sealed fluid so as no leachate is in contact with the gauge. Fluid shall be a 50 percent mixture of ethylene glycol and water. Pressure gauges shall be protected from excessive line pressures by a stainless steel ball valve installed between the pressure sensor and the pressure gauge.

C. Pressure gauges shall be pressure type with an appropriate operating range and a 4-1/2 inch dial. Gauges shall be ½ inch bourdon tube type and calibrated in psi and the dial shall so indicate. Gauges accuracy of plus of minus ½ percent. Pressure ranges shall be 0 PSIG to 150 PSIG unless otherwise indicated.

2.11 PRESSURE TRANSDUCER:

A. Pressure transducers shall be installed in the leachate collection sand layer of the Cell 6 liner system to measure the pressure head acting on the Geomembrane in the location shown on the contract drawings.

B. The pressure transducers shall have an operating pressure range from 0-5 psig and shall be Esterline's Series 700 4-20mA Open Face Model (Part Number 700-140-0005).

C. The pressure transducers shall be accessorized with the Esterline Option-009 Surge Protection Kit and the Series 810 Vent Filter (Part Number 810).

PART 3 - EXECUTION

3.01 GENERAL:

A. All materials shall be stored and handled in accordance with the manufacturer's recommendations.

B. Verify piping system is ready for installation.

C. Provide non-conducting dielectric connections wherever jointing dissimilar metals.
D. Install valves with stems upright or horizontal, not inverted.

E. Install valves as shown on contract drawings for shut-off and to isolate equipment, part of systems, or vertical risers.

F. Valves and Fittings shall be braced against movement by installation of yoke and stanchions as applicable.

G. Inspection: Pipe installation shall be subject to inspection by the Engineer for quality, adherence to line and grade, jointing, and proper backfill. Any joint not satisfactory to the Engineer shall be removed and remade to his satisfaction at the Contractor's expense. No pipe shall be backfilled until it has been approved by the Engineer.

END OF SECTION

SECTION 15120

HYDROSTATIC AND LOW PRESSURE AIR TESTING OF DUAL CONTAINMENT PIPE

PART 1 – GENERAL

1.01 SCOPE

A. The work of this section includes the furnishing of all labor, tools, equipment, and materials and performing all operations necessary to perform hydrostatic pressure tests of the leachate transport dual-containment conductor pipe (inner pipe) and lower pressure air test of the dual-containment pipe (outer pipe).

1.02 JOB CONDITIONS

A. The work of this section shall be coordinated with the Owner. All work shall be in accordance with this specification and ASTM F 2164-02 Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressured. Where conflicts appear between these specifications and ASTM F 2164 the more stringent requirement shall apply. All pressure and leakage testing shall be done by the Contractor in the presence of the Owner's Representative.

PART 2 – PRODUCTS

2.01 MATERIALS

A. The temporary pump connections shall be made up of components compatible with test pressures.

B. The Contractor shall provide all necessary equipment (i.e., pumps, flanges, valves, bracing, bulkheads, gauges, etc.) to perform the hydrostatic and low pressure air tests.

PART 3 – EXECUTION

3.01 GENERAL

A. The Contractor shall conduct a hydrostatic pressure test for the dual-containment pipe system on the conductor pipe. Low pressure air testing shall be performed on the containment pipe.

B. It shall be the responsibility of the Contractor to ensure that appropriate safety precautions are observed during hydrostatic testing.

C. Hydrostatic and low pressure air tests shall be conducted in the presence of the Owner's Representative in order to qualify for acceptance.

3.02 HYDROSTATIC PRESSURE TEST PROCEDURES

A. Air Removal: Following flushing, and before applying the specified test pressure, air shall be completely expelled from the pipes and valves. After all air has been expelled, the air blowoffs can be closed, and the test pressure applied.

B. Inside of Trench: Fill the pipeline with water after it has been laid; bleed off any trapped air. Subject the lowest element in the system to the hydrostatic test pressure, and check for any leakage. Test pressures shall be based on the elevation of the lowest point of the pipe in the test section and shall be corrected to the elevation of the test gauge as directed by the field representative.

C. Procedures:

1. The test procedures consist of two steps: the initial expansion and the test phase. When test pressure is applied to a water-filled pipe, the pipe expands. During the initial expansion of the pipe under test, sufficient make-up water must be added to the system at hourly intervals for three hours to maintain the test pressure. After about four hours, initial expansion should be complete and the actual test can start.

2. When the test is to begin, the pipe shall be full of water and subjected to a constant hydrostatic test pressure. The test phase should not exceed three hours, after which time any water deficiency must be replaced and measured. Add and measure the amount of make-up water required to return to the test pressure and compare this to the maximum allowance shown below.

3. An alternate leakage test consists of maintaining the test pressure (described above) over a period of four hours, and then dropping the pressure by 10 psi (0.69 MPa). If the pressure remains within 5 percent of the target value for one hour, there is no leakage in the system. Under no circumstances shall the total time under test exceed eight (8) hours. If the test is not complete within this time (due to leakage, equipment failure, etc.), the test section shall be permitted to "relax" for eight (8) hours prior to the next test sequence.

Nominal Pipe Size (inches)	**U.S. Gals/100 feet of Pipe[2]**			**Nominal Pipe Size (inches)**	**U.S. Gals/100 feet of Pipe[2]**		
	1-Hour	**2-Hour**	**3-Hour**		**1-Hour**	**2-Hour**	**3-Hour**
2	0.08	0.12	0.15	20	2.80	5.50	8.00
3	0.10	0.15	0.025	22	3.50	7.00	10.50
4	0.13	0.25	0.40	24	4.50	8.90	13.30
5	0.21	0.41	0.63	28	5.50	11.10	16.80
6	0.30	0.60	0.90	30	6.20	12.60	19.10
8	0.50	1.00	1.50	32	7.00	14.30	21.50
10	0.75	1.30	2.10	36	9.00	18.00	27.00
12	1.10	2.30	3.40	42	12.00	24.00	36.00
14	1.40	2.80	4.20	48	15.00	27.00	43.00
16	1.70	3.30	5.00	54	18.00	30.00	50.00
18	2.20	4.30	6.50				

Notes 1. mm = 0.03937 2. multiply by 11.53 to convert to liters/100 meters of pipe

D. Examination: Any exposed pipe, fittings, valves, and joints shall be carefully examined during the test. Any damaged or defective pipe, fittings, or valves discovered following, or as a result of the pressure test, shall be repaired or replaced with sound material. If faulty materials are removed and replaced, the pressure testing procedure shall be repeated until satisfactory to the Owner's Representative.

E. Hydrostatic Test Pressure: The hydrostatic test pressure used for the conductor pipe shall be 100 psi. Test pressure gauge shall have a maximum range of 120 psig with minor gradations no greater than 0.5 psig.

3.03 LOW PRESSURE AIR TEST – CONTAINMENT PIPE

A. The Contractor shall be responsible for furnishing all labor, materials and equipment so that such tests can be accomplished at the times and locations the Engineer deems necessary.

B. Test Procedures:

1. For making low-pressure air tests, the Contractor shall use equipment specifically designed and manufactured for the purpose of testing sewer pipelines using low-pressure air. The equipment shall be provided with an air regulator valve or air safety valve so set that the internal air pressure in the pipeline cannot exceed eight (8) psig.

2. Pneumatic plugs shall have a sealing length equal to or greater than the diameter of the pipe to be tested. Pneumatic plugs shall resist internal test pressure without requiring external bracing or blocking.

3. All air used shall pass through a single control panel.

4. Low-pressure shall be introduced into the sealed line until the internal air pressure reaches four psig. higher than the maximum pressure exerted by groundwater that may be above the invert of the pipe at the time of the test. However, the internal air pressure in the sealed line shall not be allowed to exceed eight psig.

5. At least two minutes shall be allowed for the air pressure to stabilize in the section under test. After the stabilization period, the low-pressure air supply hose shall be quickly disconnected from the control panel. The time required in minutes for the pressure in the section under test to decrease 1 psig, shall not be less than that shown in the following table:

Pipe diameter in inches	Minutes
6	4.0
8	5.0
10	6.5
12	7.5
14	9.0
15	9.5
18	11.5

[For larger diameter pipe: Minimum time = 7.7 x Dia. (ft)]

6. When the pipeline to be tested contains more than one size of pipe, the minimum allowable time shall be based on the largest diameter pipe in the section.

3.04 ACCEPTANCE:

A. The Owner reserves the right to accept the pipeline in sections after the satisfactory tests have been made and approved, and to make full use of any part or parts of the system after acceptance of those parts.

B. Until such time as the entire contract has been accepted by the Owner, the Contractor shall be held responsible to rectify any leaks, errors, or other poor workmanship which may be discovered and shall make any necessary repairs, alterations, or adjustments as may be required to properly complete the work.

END OF SECTION

APPENDIX B

CONSTRUCTION QUALITY ASSURANCE MANUAL

QUALITY ASSURANCE/
QUALITY CONTROL PLAN
LANDFILL EXPANSION

JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

Submitted by:
STATE OF MAINE BUREAU OF GENERAL SERVICES
as Owner
&
NEWSME LANDFILL OPERATIONS, LLC,
As Operator

JULY 2015

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TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

Section No.	Title	Page No.

QUALITY ASSURANCE/QUALITY CONTROL PLAN

1.0 GENERAL

1.1 Scope

This Quality Assurance/Quality Control Plan (QAP) addresses the quality assurance and quality control of the installation of all facility components used by NEWSME Landfill Operations, LLC (NEWSME Operations) at the Juniper Ridge Landfill (JRL) in Old Town, Maine. Facility components included in this QAP include the following engineered systems: underdrain system, composite liner system, leachate collection system, leachate transport system, leachate storage systems, gas management systems, and stormwater management systems.

In the context of this plan, quality assurance refers to means and actions employed to assure conformity of the facility component production and installation with the project-specific QAP, drawings, specifications, and contractual and regulatory requirements. Quality assurance is provided by a party independent from production and installation. Quality control refers only to those actions taken to ensure that materials and workmanship meet the requirements of the plans and specifications. Quality control is provided by the manufacturers and installers of the various components of the facility, and by compliance with applicable sections of the construction specifications contained in the contract documents.

The scope of this QAP applies to characterization of manufacturing, shipment, handling, and installation of facility components. This QAP does not address design guidelines, installation specifications, or selection of facility components. The technical specifications define the quality of materials and workmanship used on the construction of the facility

The QAP is the means to assure the level of material and workmanship used in the construction of the facility components meets or exceeds the requirements of the design specifications and drawings. This QAP was developed based on U.S.EPA guidance included in "Construction Quality Assurance for Hazardous Waste Landfill Disposal Facilities", U.S.EPA/530-SW-86-031, October 1986, and "Quality Assurance and Quality Control for Waste Containment Facilities", U.S.EPA/600/R-93/182 September 1993.

1.2 Parties

The parties discussed in this section are associated with the ownership, design, manufacture, transportation, installation, and quality assurance of the facility components. The definitions, qualifications, and responsibilities of these parties are outlined in the following subsections.

1.2.1 Site Owner/Landfill Operator.

1.2.1.1 Definitions

The Owner of the Juniper Ridge Landfill site is the State of Maine acting through the State Planning Office. The operator of the JRL is NEWSME Landfill Operations, LLC (NEWSME Operations). Funding for the Expansion Project is by NEWSME Operations. The NEWSME Operations contact person for this project is Wayne Boyd.

1.2.2 Project Manager/Resident Project Representative.

1.2.2.1 Definitions

The Project Manager/Resident Project Representative (RPR) is the official representative of NEWSME Operations; in this plan, the term Project Manager/RPR shall apply equally to "Construction Coordinator", i.e., the individual responsible for coordinating construction and quality assurance activities for the project. Project Manager/RPR may also be referred to as the “Owner’s Representative” in other parts of these Bid Documents and Specifications.

1.2.2.2 Responsibilities

The Project manager is responsible for construction quality assurance activities. The Project Manager/RPR is responsible for the organization and implementation of the QAP for the project as outlined in Section 1.1 of this plan.

The Project Manager/RPR shall serve as communications coordinator for the project, initiating the resolution, pre-construction, and construction meetings outlined in Section 1.3. As communications coordinator, the Project Manager/RPR shall serve as a liaison between all parties involved in the project to ensure that communications are maintained.

The Project Manager/RPR shall also be responsible for proper resolution of all quality assurance issues that arise during construction.

1.2.2.3 Qualifications

The selection of the Project Manager/RPR is the direct responsibility of NEWSME Operations. Qualifications for this position include familiarity with the following:

1. Applicable QAPs.
2. General knowledge of the construction materials and techniques necessary to construct the facility.
3. Applicable regulatory requirements.
4. Company policies and procedures for project management.

1.2.3 Designer.

1.2.3.1 Definitions

The Designer is the individual and/or firm responsible for the preparation of the design, including plans and project-specific technical specifications for the facility components and systems. The Designer may also be referred to as the “Engineer” in other parts of these Bid Documents and Specifications.

1.2.3.2 Responsibilities

The Designer is responsible for performing the engineering design and preparing the associated drawings and specifications for all the components of the landfill facility. The Designer is responsible for approving all design and specification changes and making design clarifications necessitated during construction of the landfill and associated facilities. The Designer may attend the resolution and pre-construction meetings outlined in Section 1.3 of this plan upon the request of the Project Manager/RPR.

1.2.3.3 Qualifications

The Designer shall be a qualified engineer, certified or licensed as required by regulation. The Designer shall be familiar with all the landfill components and applicable regulatory requirements.

1.2.3.4 Submittals

The Designer shall submit the project design drawings and specifications to NEWSME Operations. The Designer shall submit completed design clarification forms to NEWSME Operations in a timely manner upon request.

1.2.4 Construction Quality Assurance Agent and Quality Assurance Resident Engineer

1.2.4.1 Definitions

The Construction Quality Assurance Agent (CQA) is a firm independent from NEWSME Operations that shall be responsible for observing and documenting activities related to the quality assurance of all phases of the landfill and associated construction activities, on behalf of NEWSME Operations. The required staffing level will be a function of the Installer's schedule.

In this QAP the term Quality Assurance Resident Engineer (QARE) shall be used to designate the engineer in charge of the project-specific quality assurance work. In this QAP the terms “construction Quality Assurance Agent (CQA)” and “Quality Assurance Resident Engineer” are interchangeable. In some cases the duties of the QARE described below may be shared by two individuals: A Quality Assurance Managing Engineer located at the headquarters of the CQA, and a Quality Assurance Resident Engineer located at the site. The personnel of the CQA also include Quality Assurance Monitors who are located at the site for construction observation and documentation. Construction Quality Assurance Agent and Quality Assurance Resident Engineers will also be described in this QAP by the specific tasks they oversee; specifically, Soils (i.e., Construction) QARE/CQA or Geosynthetic QARE/CQA.

1.2.4.2 Responsibilities

The QARE is responsible for observing and documenting activities related to the quality assurance of the production and installation of all landfill components. The QARE is responsible for implementation of the project QAP prepared by the Project Manager/RPR and coordination of the on-site and off-site materials testing program. The QARE is also responsible for issuing a final certification report, sealed by a registered professional engineer, as outlined in Section 2.0 of this QAP.

The specific duties of the QARE personnel are as follows:

1. The QARE:

   a. Reviews all design drawings and specifications.

   b. Reviews other site-specific documentation, including proposed layouts, and manufacturer's and installer's literature.

   c. Develops a site-specific addendum for quality assurance of materials and construction techniques (if necessary) with the assistance of the Project Manager/RPR.

   d. Administers the QAP, e.g., assigns and manages quality assurance personnel, reviews all field reports, and provides engineering review of all quality assurance related issues.

   e. Reviews changes to design drawings and specifications as issued by the Designer.

   f. Acts as the on-site (resident) representative of the Project Manager/RPR.

   g. Familiarizes Geosynthetic Quality Assurance Monitors with the site and the project QAP.

   h. Attends quality assurance related meetings, e.g., resolution, pre-construction, daily, weekly.

   i. Reviews Manufacturer and Installer certifications and documentation and makes appropriate recommendations.

   j. Reviews the Installer's personnel qualifications for conformance with those qualifications pre-approved for work on site.

   k. Manages the preparation of the as-built drawing(s).

   l. Provides on-site testing of soils for compaction, using Nuclear Methods.

   m. Sampling of on-site soils and other materials and coordinates testing.

   n. Reviews Geosynthetic Quality Assurance Monitor's daily reports, logs and photographs.

   o. Notes any on-site activities that could result in damage and/or delays.

   p. Reports to the Project Manager/RPR, and logs in the daily report, any relevant observations reported by the Geosynthetic Quality Assurance Monitors.

q. Prepares his own daily report.

r. Prepares the weekly report of construction activities.

t. Oversees the marking, packaging, and shipping of laboratory test samples.

u. Reviews the results of laboratory testing and makes appropriate recommendations.

v. Designates a qualified Quality Assurance Monitor to represent the QARE whenever he is absent from the site while operations are ongoing.

w. Reports any unapproved deviations from the QAP to the Project Manager/RPR.

x. Prepares the final certification report.

y. Verifies that the supporting soil has met requirements set in Section 4.3 and overburden soil placement requirements set in Section 4.4.

z. Complete geotechnical/monitoring program form, as presented in the site's Geotechnical Monitoring Plan.

2. The Quality Assurance Monitor:

a. Monitors, logs, photographs and/or documents all construction operations. Photographs shall be taken routinely and in critical areas of the installation sequence. These duties shall be assigned by the QARE.

b. Monitors the following operations for all construction activities.

(1) Material delivery.
(2) Unloading and on-site transport and storage.
(3) Sampling for conformance testing.
(4) Material placement.
(5) In-place conformance testing.
(6) Visual inspection by walkover.
(7) Construction stability.

c. Monitors and documents construction operations, including:

(1) Subgrade preparation, testing, and approval.
(2) Placement, testing, sampling, and approval of soil materials used to construct the landfill.
(3) Placement of geosynthetic materials that are not related to the landfill liner system.
(4) Installation and testing of piping systems and associated appurtenances.

(5) Installation and testing of pump stations and associated equipment.
(6) Installation and testing of the leachate storage and associated plumbing and equipment.
(7) Installation of the loading rack and loading arm.

1.2.4.3 Qualifications

The CQA shall be pre-qualified by NEWSME Operations. The CQA shall be experienced in quality assurance of landfill facilities. The CQA shall be experienced in the preparation of quality assurance documentation including: quality assurance forms, reports, certifications, and manuals.

The Quality Assurance Managing Engineer shall be a degreed engineer and be registered as a professional Engineer in the State of Maine. The Quality Assurance Resident Engineer shall be specifically experienced in the landfill construction techniques and shall be trained by the CQA in the duties of a QARE.

Quality Assurance Monitors shall be quality assurance personnel who have been specifically trained in the quality assurance of landfills.

The Geosynthetic Quality Assurance Monitor shall be certified by the National Institute for Certification in Engineering Technology (NICET), the Geosynthetic Institute's Construction Quality Assurance – Inspectors Certification Program (CQA-ICP) or equivalent or work under the direct supervision of a NICET or CQA-ICP certified professional.

1.2.4.4 Submittals

Pre-qualification: To be considered for pre-qualification, the CQA must provide the following information:

1. Corporate background and information.

2. Quality assurance capabilities:

   a. A summary of the firm's experience with landfill construction.

   b. A summary of the firm's experience in quality assurance, including installation quality assurance of similar landfill construction projects.

   c. A summary of quality assurance documentation and methods used by the firm, including sample quality assurance forms, reports, certifications, and manuals prepared by the firm.

   d. Resumes of key personnel.

Pre-installation: Prior to beginning work on a project, the CQA must provide the Project Manager/RPR with the following information:

1. Resumes of personnel to be involved in the project including QARE, and Quality Assurance Monitors.

2. Proof of professional engineering registration for the engineer to be designated as the Quality Assurance Managing Engineer (QAME).

3. Proof of the required quality assurance experience of the quality assurance personnel.

1.2.5 Geosynthetic Manufacturer

1.2.5.1 Definitions

The Manufacturer is the firm responsible for production of any of the various geosynthetic liner system components outlined in this QAP.

1.2.5.2 Responsibilities

Each Manufacturer is responsible for the production of its geosynthetic product. In addition, each Manufacturer is responsible for the condition of the geosynthetic until the material is accepted by the Project Manager/RPR upon delivery. Each Manufacturer shall produce a consistent product meeting the project specifications. Each Manufacturer shall provide quality control documentation for its product as specified in this QAP.

1.2.5.3 Qualifications

Each Manufacturer shall be pre-qualified by NEWSME Operations. Each Manufacturer shall provide sufficient production capacity and qualified personnel to meet the demands of the project. Each Manufacturer shall have an internal quality control program for its product that meets the requirements presented in this QAP.

1.2.5.4 Submittals

Pre-qualification: A Manufacturer shall meet the following requirements and submit the following information to be considered for pre-qualification:

1. Corporate background and information.

2. Manufacturing capabilities:

    a. Information on plant size, equipment, personnel, number of shifts per day, and capacity per shift.

    b. Daily production quantity available for NEWSME Operations' facilities.

    c. A list of material properties including certified test results, to which are attached geosynthetic samples.

    d. A list of at least 15 completed landfill or surface impoundment facilities totaling the minimum area (see project specification) identified in the project specifications, for which the Manufacturer has manufactured a geosynthetic. For each facility, the following information shall be provided:

        (1) Name and purpose of facility, its location and date of installation.

(2) Name of owner, project manager, designer, fabricator (if any) and installer.
(3) Type of geosynthetic, surface area of geosynthetic manufactured.
(4) Available information on the performance of the lining system and the facility.

3. The Manufacturer's quality control manual, including a description of the quality control laboratory facilities.

4. The origin (supplier's name and production plant) and identification (brand name and number) of resin used to manufacture the product.

Pre-installation: Prior to the installation of any geosynthetic material, a Manufacturer must submit to the Project Manager/RPR all quality control documentation required by the appropriate section of this QAP. This documentation shall be reviewed by the Geosynthetic Construction Quality Assurance Agent as outlined in Section 1.2.4 of this QAP before installation can begin.

1.2.6 Geosynthetic Installer.

1.2.6.1 Definitions

The Geosynthetic Installer is the firm responsible for installation of the geosynthetics. The Installer may be affiliated with the Manufacturer.

The Superintendent is responsible for the Installer's field crew. The Superintendent shall represent the Installer at all site meetings and shall be responsible for acting as the Installer's spokesman on the project.

The Master Seamer shall be the most experienced seamer of the Installer's field crew. The Master Seamer shall provide direct supervision over less experienced seamers.

1.2.6.2 Responsibilities

The Geosynthetic Installer shall be responsible for field handling, storing, deploying, seaming, temporary restraining and all other aspects of the geosynthetics installation. The Installer may also be responsible for transportation of these materials to the site and for anchor systems, if required by the project specifications. The Installer shall be responsible for submittal of the documentation listed in Section 1.2.5.4.

1.2.6.3 Qualifications

The Geosynthetic Installer shall be pre-qualified and approved by NEWSME Operations. The Installer shall be able to provide qualified personnel to meet the demands of the project. At a minimum, the Installer shall provide a Superintendent, Seamers and a Master Seamer as described below.

The Superintendent must be qualified based on previously demonstrated experience, management ability, and authority. The Superintendent, unless otherwise approved by the Project Manager/RPR, shall have previously managed, at a minimum, two installation projects which entailed the installation of at least a combined total of 10,000,000 sq. ft of polyethylene geomembrane.

For geomembrane installation all personnel performing seaming operations shall be qualified with not less than 500,000 sq. ft of polyethylene geomembrane seaming experience. The Master Seamer shall have experience seaming a minimum of 1,000,000 sq. ft of polyethylene geomembrane using the same type of seaming apparatus to be used at the site.

1.2.6.4 Submittals

Pre-qualification: To be considered for pre-qualification, the Geosynthetic Installer shall submit the following information:

1. Corporate background and information.

2. Description of installation capabilities:

    a. Information on equipment (numbers and types), and personnel (number of superintendents, number of crews).

    b. Average daily production anticipated.

    c. Samples of field geomembrane seams and a list of minimum values for geomembrane seam properties.

3. A list of at least ten completed facilities, totaling a minimum of 10,000,000 sq. ft for which the Installer has installed geosynthetics. For each installation, the following information shall be provided:

    a. Name and purpose of facility, its location, and date of installation.

    b. Name of owner, project manager, designer, manufacturer, fabricator (if any), and name of contact at the facility who can discuss the project.

    c. Name and qualifications of the Superintendent(s) of the Installer's crew(s).

    d. Type of geosynthetic, and surface area installed.

    e. Type of seaming and type of seaming apparatus used.

    f. Duration of installation.

    g. Available information on the performance of the lining system and the facility.

4. The Geosynthetic Installer's quality control manual.

5. A copy of a letter of recommendation supplied by the geomembrane manufacturer.

Pre-installation: Prior to commencement of the installation, the Installer must submit to the Project Manager/RPR:

1. Resume of the Superintendent to be assigned to this project, including dates and duration of employment.

2. Resume of the Master Seamer to be assigned to this project, including dates and duration of employment.

3. A panel layout drawing showing the installation layout identifying field seams as well as any variance or additional details which deviate from the engineering drawings. The layout shall be adequate for use as a construction plan and shall include dimensions, details, etc.

4. Installation schedule.

5. A list of personnel performing field seaming operations along with pertinent experience information.

6. All geosynthetic quality control certificates as required by this QAP (unless submitted directly to the Project Manager/RPR by the Geosynthetic Manufacturer).

7. Certification that extrudate to be used is comprised of the same resin as the geomembrane to be used.

This documentation shall be reviewed by the Geosynthetic Construction Quality Assurance Agent, as outlined in Section 1.3.3 of this QAP, before installation of the geosynthetic can begin.

Installation: During the installation, the Installer shall be responsible for the submission of:

1. Quality control documentation recorded during installation.

2. Subgrade surface acceptance certificates for each area to be covered by the lining system, signed by the Geosynthetic Installer.

Completion: Upon completion of the installation, the Installer shall submit:

1. The warranty obtained from the Manufacturer.

2. The installation warranty.

1.2.7 Geosynthetic Quality Assurance Laboratory

1.2.7.1 Definitions

The Geosynthetic Quality Assurance Laboratory (QAL) is a firm, independent from the Geosynthetic Manufacturer(s) and Geosynthetic Installer responsible for conducting tests on samples of geosynthetics taken from the site.

1.2.7.2 Responsibilities

The Geosynthetic QAL shall be responsible for conducting the appropriate laboratory tests as directed by the Geosynthetic QAE. The test procedures shall be done in accordance with the test methods outlined in this QAP and/or the project specifications. The Geosynthetic QAL shall be responsible for providing test results as outlined in Section 1.2.7.4.

1.2.7.3 Qualifications

The Geosynthetic QAL shall have experience in testing geosynthetics and be familiar with American Society for Testing and Materials (ASTM), Federal Test Method Standard (FTMS), National Sanitation Foundation (NSF), and other applicable test standards. The laboratory shall be GAI-2AP certified. The Geosynthetic QAL shall be capable of providing verbal results of destructive seam tests within 24 hours of receipt of test samples and shall maintain that standard throughout the installation. The Geosynthetic QAL shall be approved by the Project Manager/RPR or NEWSME Operations.

On-site laboratory facilities may be used by the Geosynthetic QAL, provided they are appropriately equipped and approved by the Geosynthetic QARE and the Project Manager/RPR.

1.2.7.4 Submittals

The Geosynthetic QAL shall submit destructive seam test results to the Geosynthetic QARE in written form within 48 hours of receipt of test samples unless otherwise specified by the Project Manager/RPR. Geomembrane destructive test results shall typically be provided verbally to the Geosynthetic QARE within 24 hours of receipt of test samples.

Written test results shall be in an easily readable format and include references to the standard test methods used.

1.2.8 Soils Quality Assurance Laboratory

1.2.8.1 Definitions

The Soils Quality Assurance Laboratory (SQAL) is a firm, independent from the contractor responsible for conducting tests on construction soils materials taken from the site.

1.2.8.2 Responsibilities

The Soils QAL shall be responsible for conducting the appropriate laboratory tests as directed by the Soils QARE or CQA. The test procedures shall be done in accordance with the test methods outlined in this QAP and/or the project specifications. The Soils QAL shall be responsible for providing test results as outlined in Section 1.2.8.4.

1.2.8.3 Qualifications

The Soils QAL shall have experience in testing geosynthetics and be familiar with American Society for Testing and Materials (ASTM), Federal Test Method Standard (FTMS), and other applicable test standards. The Soils QAL shall be capable of providing verbal results of destructive seam tests within 24 hours of receipt of test samples and shall maintain that standard throughout the installation. The Soils QAL shall be approved by the Project Manager/RPR and/or NEWSME Operations.

On-site laboratory facilities may be used by the Soils QAL, provided they are appropriately equipped and approved by the Soils QARE/CQA and the Project Manager/RPR.

1.2.8.4 Submittals

The Soils QAL shall submit soil test results to the Soils QARE in written form within 5 days of receipt of test samples unless otherwise specified by the Project Manager/RPR. Soil test results shall typically be provided verbally to the Soils QARE/CQA within 24 hours of receipt of test samples, or a time period as dictated by the testing requirements. Written test results shall be in an easily readable format and include references to the standard test methods used.

Written test results shall be in an easily readable format and include references to the standard test methods used.

1.3 Communication

To guarantee a high degree of quality during the construction process and assure a final product that meets all project specifications, clear, open channels of communication are essential. This section discusses appropriate lines of communication and describes all necessary meetings.

1.3.1 Lines of Communication. The Soils QARE/CQA and the Geosynthetic QARE shall be capable of direct communication with the Project Manager/RPR at all times. The project manager shall be capable of direct communications with NEWSME Operations and the MEDEP at all times.

1.3.2 Resolution Meeting. Following permit approval and the completion of the construction drawings and specifications for the project, a resolution meeting may be held. If a resolution meeting is required, it is recommended that the meeting be held prior to bidding the construction work and include the parties when involved, typically including the Project Manager/RPR, Designer, Soils QARE/CQA, Geosynthetic QARE, and a NEWSME Operations representative. If necessary, this meeting can be held in conjunction with the pre-construction meeting.

The purpose of this meeting is to establish lines of communication, review construction drawings and specifications for completeness and clarity, begin planning for coordination of tasks, anticipate any problems which might cause difficulties and delays in construction, and review the QAP. Aspects of the design shall be reviewed during this meeting so that clarification and/or design changes may be made before the construction work is bid. In addition, the guidelines regarding quality assurance testing and problem resolution must be known and accepted by all.

The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

1.3.3 Pre-Construction Meeting. A pre-construction meeting shall be held at the site prior to the start of earthwork and geosynthetic deployment. Typically, the meeting shall be attended by the Project Manager/RPR, Designer, Geosynthetic Installer, Soils QARE/CQA, Geosynthetic QARE, and a NEWSME Operations representative. NEWSME Operations or their agent shall notify the MEDEP of the pre-construction meeting 7 days prior to the meeting date so that an MEDEP representative may attend if desired.

Specific topics considered for this meeting include review of the project QAP for any problems or additions. In addition, the responsibilities of each party should be reviewed and understood clearly. The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

1.3.4 Progress Meetings. A weekly progress meeting shall be held between the Contractor, Soils QARE/CQA, Geosynthetic QARE, Geosynthetic Installer's Superintendent, Project Manager/RPR, and any other concerned parties. This meeting shall discuss current progress, planned activities for the next week, issues requiring resolution, and any new business or revisions to the work. The CQAs shall log any problems, decisions, or questions arising at this meeting in his weekly report. If any matter remains unresolved at the end of this meeting, the Project Manager/RPR shall be responsible for the resolution of the matter and the communication of the decision to the appropriate parties.

2.0 DOCUMENTATION

An effective QAP depends largely on identification of the construction activities that shall be monitored, and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The QAREs/CQAs shall document that all requirements in the geosynthetic portions of the project QAP have been addressed and satisfied.

The QAREs/CQAs shall provide the Project Manager/RPR with signed descriptive remarks, data sheets, and checklists to verify that all monitoring activities have been carried out. The QAREs/CQAs shall also maintain at the job site a complete file of the documents which comprise the QAP, including plans and specifications, checklists, test procedures, daily logs, and other pertinent documents.

2.1 Daily Reports

2.1.1 Geosynthetics Quality Assurance. Each Geosynthetic Quality Assurance Monitor shall complete a daily report and/or logs on prescribed forms, outlining all monitoring activities for that day. The precise areas, panel numbers, seams completed, and approved, and measures taken to protect unfinished areas overnight, shall be identified. Failed seams or other panel areas requiring remedial action shall be identified with regard to nature of action, required repair, and precise location. Repairs completed must also be identified. Any problems or concerns with regard to operations on-site should also be noted. This report must be completed at the end of each monitor's shift, prior to leaving the site, and submitted to the Geosynthetic QARE.

The Geosynthetic QARE shall review the daily reports submitted by the Geosynthetic Quality Assurance Monitors, and incorporate a summary of their reports into the Geosynthetic QARE's daily report. Any matters requiring action by the Project Manager/RPR shall be identified. The report shall include a summary of the quantities of the geosynthetics installed that day. This report must be completed daily, summarizing the previous day's activities and a copy submitted to the Project Manager/RPR at the beginning of the work day following the report date.

2.1.2 Construction Quality Assurance. Each Construction Quality Assurance Monitor shall complete a daily report and/or logs on prescribed forms outlining the monitoring activities undertaken for that day. The activities undertaken, materials used, location, time, testing done, samples taken, and test results obtained shall be documented. Failed areas shall be identified and the remedial action taken noted. Any problems and/or concerns regarding failed areas shall be noted. The monitor(s) shall also note the equipment used and the work force provided, and any subcontractors, provided during the daily operations. The report must be completed at the end of each monitor’s shift, prior to leaving the site, and submitted to the Soils QARE/CQA.

The Soils QARE/CQA will review daily reports submitted by the CQA monitor(s) and incorporate a summary of their reports into the Soils QARE’s/CQA’s daily report. Any actions requiring action by the Project Manager/RPR shall be clearly identified. The report shall include a summary of quantities of materials installed that day. This report must be completed daily, summarizing the previous day’s activities and a copy submitted to the Project Manager/RPR at the beginning of the work day following the report date.

2.1.3 Report Forms and Installation Logs. Each Quality Assurance Monitor shall document construction activities as described above on the pertinent forms or logs attached to the end of this Section.

2.2 Testing Reports

2.2.1 Geosynthetics Testing Reports. The destructive test reports from all sources shall be collated by the Geosynthetic QARE. This includes field tests, Installer's laboratory tests (if performed), and Geosynthetic QAL tests. A summary list of test samples pass/fail results shall be prepared by the Geosynthetic QARE on an ongoing basis, and submitted with the weekly progress reports.

2.2.2 Soils Testing Reports. The on-site testing and laboratory test reports from all sources shall be collected by the Soils QARE. This includes field tests and laboratory tests. A summary list of test samples of pass/fail results shall be prepared by the Soils QARE on an ongoing basis, and submitted with weekly progress reports.

2.2.3 Miscellaneous Test Reports. On-site testing of pressure pipe, manholes, pump stations, leachate storage tank, and other equipment shall be reported on a separate Equipment Test Report Log. Test reports shall be submitted to the Soils QARE/CQA as the equipment is tested, and shall be included in weekly progress reports.

2.3 Progress Reports

Progress reports shall be prepared by the CQAs/QAREs and submitted to the Project Manager/RPR. These reports shall be submitted every week, starting the first Friday of construction on-site. This report shall include: test results, submittals and action taken; summary of work progress; upcoming work items for the next two weeks; punchlist items; summary of problems encountered and how the problems were resolved; change order status; and construction stability monitoring results, if applicable. Other items may include delays caused by weather conditions or material shortages. A copy of these progress reports shall be forwarded to the MEDEP within one week after the completion of each construction week.

All CQA’s/QARE’s daily reports for the period should be appended to each progress report.

2.4 Record Drawings

2.4.1 Geosynthetic Record Drawings. Record drawings shall be prepared by the Geosynthetic QARE. The Record drawings shall include, at a minimum, the following information for geomembrane.

1. Location, as accurate as possible, of each panel relative to the site benchmarks (furnished by the Project Manager/RPR).

2. Identification of the seams and panels with appropriate numbers or identification codes (see Section 5.4.1).

3. Location of patches and repairs.

4. Location of destructive testing samples.

5. Pertinent as-built details, such as penetrations and anchor trenches, etc.

The record drawings shall illustrate each layer of geomembrane, and, if necessary, another drawing shall identify problems or unusual conditions of the geotextile or geonet layers. In addition, applicable cross-sections shall show layouts of geonets, geotextiles or geogrids in sump areas or any other areas which are unusual or differ from the design drawings.

2.4.2 Construction Record Drawings. Record drawings shall be prepared by the CQA Agent. The record drawings will incorporate the record drawings prepared by the Geosynthetic and Soils QARE. The record drawings shall include the above, plus the following information:

1. Horizontal and vertical location of base grades, top of 24-inch clay layer, and top of primary HDPE geomembrane liner, relative to the site benchmarks (furnished by the Project Manager/RPR).

2. The contractor will record changes to pertinent details and supply this information to the Soils QARE/CQA. The Soils QARE/CQA will show changes to the details on the record drawings.

3. Horizontal and vertical location of all external landfill components such as: pump stations; force mains; manholes; roadways; electrical conduits; utilities; gas collection system piping; and leachate storage facilities. These shall be located relative to the site benchmarks.

Record drawings shall be stamped by a Maine registered professional engineer in employ of the CQA.

2.5 Final Certification Report

A final certification report shall be submitted to NEWSME Operations upon completion of the work. This report shall summarize the activities of the project, and document the aspects of the quality assurance program performed. A copy of the report will be submitted to the MEDEP as part of the construction documentation report.

The final certification report shall include, at a minimum, the following information:

1. Parties and personnel involved with the project.

2. Certification, sealed and signed by a registered professional engineer.

3. Record drawings, sealed and signed by a registered professional engineer.

4. A narrative summary of the Geosynthetics QARE observation of the geosynthetic installation and handling activities, including placement of overburden soil.

5. A narrative summary of all phases of the landfill construction and associated facilities.

6. Copies of applicable specifications.

7. Written clarifications and interpretations of the specifications.

8. Change Orders to specifications.

9. Minutes from pertinent construction meetings.

10. Geosynthetics manufacturer's quality control documentation, certifications, warranties, and guarantees.

11. Copies of the following geosynthetics quality assurance records: conformance testing results; certificates of subgrade acceptance; temperature logs; panel deployment logs; trial seam logs; destructive testing results; non-destructive testing logs; repair logs and diagrams; CQA daily and weekly reports.

12. Copies of the following site construction quality assurance records: field compaction testing results; soil material conformance testing results; submittals; pipe testing records; pump station testing records; leachate storage tank leak testing records; and CQA daily and weekly reports.

13. Copies of photographs taken to document the progression of site construction activities.

The report shall include written certification by the Geosynthetic QARE and the Quality Assurance Managing Engineer that the installation was completed in accordance with the project QAP except as noted to the Project Manager/RPR.

3.0 LINING SYSTEM ACCEPTANCE

3.1 Geosynthetic Lining System

Upon written recommendation by the Geosynthetic QARE, the Project Manager/RPR shall consider accepting the geosynthetic lining system. The conditions of acceptance are described below. The Installer and Manufacturer(s) will retain all ownership and responsibility for the geosynthetics in the lining system until acceptance by NEWSME Operations.

The geosynthetic lining system shall be accepted by NEWSME Operations when:

1. The installation of the lining system, or section thereof, is finished.

2. Verification of the adequacy of all seams and repairs, including associated testing, is completed.

3. All documentation of installation is completed.

4. The leak location survey has been performed on the primary geomembrane liner in accordance with ASTM D7007 (Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials), any leaks found have been repaired appropriately by the liner installer and a report documenting the results of the survey has been reviewed and approved by the Geosynthetic CQA Project Manager.

5. The Geosynthetic QARE is able to recommend acceptance.

6. The Owner and/or his Authorized Representative is satisfied that the geomembrane has been installed in accordance with the above Specifications.

The Geosynthetic QARE shall certify that the installation did proceed in accordance with the geosynthetic portions of the project QAP, except as noted to the Project Manager/RPR. This certification shall be provided in the final certification report as outlined in Section 2.5.

3.2 Landfill Facility Systems

Upon written recommendation by the CQA's Quality Assurance Managing Engineer, the Project Manager/RPR shall consider accepting the landfill systems. The conditions of acceptance are described below. The Contractor will retain all ownership and responsibility for the newly constructed landfill and associated facilities until acceptance by NEWSME Operations.

The landfill facility systems shall be accepted by NEWSME Operations when:

1. The installation of the landfill soil and geosynthetic lining system, landfill piping systems, pump stations, leachate transport and storage facilities, or sections thereof, are finished.

2. Verification of the adequacy of the materials placed, equipment supplied, facilities constructed, including all associated testing, is complete.

3. All documentation of installation is completed.

4. The CQA's Quality Assurance Managing Engineer is able to recommend acceptance.

The CQA's Quality Assurance Managing Engineer shall certify that installation has proceeded in accordance with the project QAP except as noted to the Project Manager/RPR. This certification shall be provided in the final certification report as outlined in Section 2.5.

4.0 SOIL COMPONENTS

4.1 Borrow Materials

Clay: For use in the imported soil and clay liner, must meet requirements for gradation, Atterberg limits, remolded hydrogeologic, and moisture content.

Underdrain Sand: For use in the underdrain systems, must meet requirements for gradation and remolded hydraulic conductivity.

Leachate Collection Sand: For use in the leak detection and leachate collection systems, must meet requirements for gradation and remolded hydraulic conductivity specified in Section 02200.

Leachate Collection Sump Stone: For use in the leachate collection system, must meet requirements for gradation.

Drainage Stone: For use in the underdrain and leachate collection systems, must meet requirements for gradation.

Access Road Base and Subbase Material: Must meet requirements for gradation.

Common Borrow: Must meet requirements as defined by Maine Department of Transportation (MDOT) Section 703.18.

Impervious Borrow: (N.I.T.C.) Must have greater than 35 percent by weight passing the No. 200 U.S. standard sieve.

Riprap: Must meet size requirements as defined by the specifications Section 02220.

The soils used in the construction of the Juniper Ridge Landfill (JRL) facility shall meet the CQC requirements outlined in the specifications. Changes in the materials must be approved by the Project Manager/RPR prior to placement.

Clay borrow used for imported soil layer and liner construction will come from an off-site clay pit and/or from any existing clay cover that is to be removed. The Soils QARE/CQA will be required to inspect and approve the use of the clay cover soils for liner construction. The recycled clay must meet the clay borrow requirements as defined by the specifications.

The following quality control procedure is incorporated into the project specifications to assure that the clay borrow source(s) delivered to the site meets the project specifications and provides the data to define quality control acceptance criteria. The procedure is to use the individual moisture density curves and associated hydraulic conductivity test from clay borrow source testing program to guide the clay placement.

4.2 Material Delivery, Storage, and Processing

Material used in the construction of JRL facility will require proper handling in order to assure that the specified design properties are not compromised. The Soils QARE/CQA must observe hauling operations and inspect materials as they are delivered. Loads shall be periodically inspected to assure that contamination is not occurring. Truck dump bodies shall be in clean condition prior to a change of material being handled. Hauling personnel shall be informed by the Contractor of the need to clean dump bodies when appropriate. The Soils QARE/CQA may elect to obtain samples for quality assurance testing. Testing under these circumstances will be at the contractor's expense.

Storage of materials shall be in such a manner so that the material properties will remain uncompromised by contamination until they are used. The Soils QARE/CQA shall instruct the contractor of a storage location. The contractor is responsible for keeping materials from being contaminated. The contractor must take measures to assure stockpiled materials meet the specifications as they are installed. The Soils QARE/CQA may elect to obtain samples for quality assurance testing.

Processing of soil materials at the site may be necessary. Clay material stripped from existing landfill cover and to be used as liner material may require processing. Processing may entail removal of large stones or organic material. Other processing may include homogenization of clay by mixing and stockpiling, and adjustment of clay moisture. The Soils QARE/CQA should monitor these activities and perform quality assurance testing as necessary.

4.3 Subgrade Preparation

Subgrades shall be properly prepared and compacted to the requirements outlined in Part 3.09 of Section 02200 and Part 3.06 of Section 02332 of these specifications. The Soils QARE/CQA is responsible for inspection of the subgrade and identifying areas which will require further compaction. Testing will be done as needed to assure that the subgrade can adequately support the subsequent compacted liner materials. Water should be added or removed to assure optimum compaction effort.

Soil approved to be left in place shall be proofrolled prior to clay layer placement. Proofrolling shall include a minimum of three passes of a heavy vibratory compactor. The type and weight of the compactor shall be approved by a qualified geotechnical engineer.

Unacceptable subgrade material is to be removed and replaced with a suitable compacted common borrow. Common borrow used to fill the subgrade is to be approved by the Soils QARE/CQA. Subgrade below any proposed geosynthetics shall be inspected by the Geosynthetic QARE and the installer. The Geosynthetic QARE will inform the contractor of subgrade deficiencies. The contractor will provide the necessary construction effort to alleviate any subgrade deficiencies. The Geosynthetic QARE and installer will re-inspect the subgrade. The installer will complete a Subgrade Acceptance form which documents the subgrade acceptance.

4.4 Placement, Remolding, and Compaction

4.4.1 Soil Material Placement. Placement of soil into a fill is to be done according to the specifications. For embankment and excavation fills, loose lift thicknesses shall not exceed 12 inches for material compacted by heavy compaction equipment, and not more than 6 inches in loose depth for material compacted by hand-operated tampers. For clay lifts, the loose lift thickness shall not exceed 9 inches. The Soils QARE/CQA will be responsible for implementation of clay placement guidelines as set forth in these specifications. The CQA Monitor(s) will observe the placement of clay in order to verify the clay is placed as required. The contractor is responsible for documentation of loose lift of clay thickness, drainage sand, and drainage stone as directed in the specifications. The contractor will provide this documentation to the Soils QARE/CQA on a weekly basis.

Placement of soil materials to compact will not be allowed in weather conditions that adversely affect material compaction. The contractor is responsible for protection of materials being placed and should take necessary measures to protect the materials.

Clay lifts to be installed up to old or previously placed clay lifts shall be matched-in by stepping the clay layers. Prior to placement of a new lift of soil, the surface of the previous compacted lift of soil liner should be roughened to promote a good bond between new and old lifts. CQA Monitor shall inspect lift surface to assure the surface is properly prepared.

Extreme care is required when placing soil materials over geomembrane liner. Prior to the commencement of sand placement, the contractor must provide the Soils QARE/CQA with a written plan stating the sequence of sand placement over the geomembrane. The plan should state where the site will be accessed; placement of haul roads, how sand is spread, and the personnel and equipment that will be utilized. The minimum thickness of sand over the geomembrane for low ground pressure equipment shall be one foot. Minimum thickness for rubber-tired equipment is three feet. The Soils QARE/CQA will observe the hauling of fully loaded vehicles over three foot sand haul roads and may require additional sand over the liner if conditions warrant. The contractor is responsible for maintaining sand haul roads so that damage does not occur to the geomembrane and/or the underlying clay layer. The CQA Monitor(s) will observe vehicle operation on sand haul roads to assure the operation is smooth (without sudden stops, quick turns, or hopping).

Equipment used for placement of the 12-inch sand blanket over the geomembrane shall have a ground pressure of no more than 5 psi. Equipment shall have no cleats and is not allowed to make tight, sudden turns.

Sand placed on the sideslope shall be placed by working from the toe of the slope to the top of the slope. The CQA Monitor will observe spreading of sand on sideslopes to assure no damage is done to liner materials and that liner materials are not slipping on the sideslopes. Equipment working on the sideslopes is not to make sudden stops, especially in the downhill direction.

Drainage stone placed within limits of the liner system shall be spread so that no damage occurs to the liner system. Stone placed over piping and lifts less than 18 inches in thickness shall be placed with an excavator, bucket loader, or similar type equipment. CQA Monitor will inspect drainage stone for contamination periodically, as lift is placed.

<u>4.4.2 Remolding and Compaction</u>. Proper remolding of soil materials is dependent upon the correct moisture content of the soil and the compaction effort. The Soils QARE/CQA will be responsible for being familiar with the soil properties being used for the soil components at the NEWSME Operations Landfill facility. Soils QARE/CQA shall have soils materials tested when their properties are in doubt. For the clay material the soil moisture/density relationship will be defined from test results from borrow source or conformance testing. The Soils QARE/CQA should be directly involved with the test pad and be knowledgeable of soil materials and workability. The contractor shall be responsible for notifying the Soils QARE/CQA of any changes in soil materials or borrow source. The CQA Monitor shall observe clay or soil placement to assure material meets the requirements set forth by the specifications. The Soils QARE/CQA may elect to perform additional testing, beyond what is required by the specifications, in order to define the soil properties and determine their acceptability.

Prior to compaction of clay soils the contractor will supply the Soils QARE/CQA with a plan detailing where the soil materials will be obtained, how and where they are to be placed within the new phase, method of moisture adjustment, equipment to be used, and measures of protection from the weather elements. Remolding the clay begins after proper scarification of the existing surface, followed by clay placement as described in Section 4.4.1 of this section. The loose clay lift is then compacted. The equipment used and the number of passes required to meet the project specifications shall be determined at the beginning of the clay placement with a minimum of three passes. The CQA Monitor will observe the compactive effort and periodically document the number of passes taken on a given section of soil liner. The surface of the clay will then be sealed by smooth roller. The CQA Monitor will measure the moisture/density by nuclear method, as outlined in Section 4.6.1.2 of this plan. Upon passing test results, the CQA Monitor will sample the clay, if necessary, and inform the contractor of the results. Non-passing test results will immediately be reported to the contractor. The contractor can request the area be retested or the area will be reworked by adjusting soil moisture and compactive effort. The CQA Monitor should observe these adjustment measures to assure that they are applied uniformly throughout the failed area. After reworking the soil lift the CQA Monitor will retest the lift. If the moisture density tests pass, the CQA Monitor may sample the area for hydraulic conductivity if required, and the contractor may resume normal lift construction. Non-passing results on the second trial suggest the material is deficient and must be removed and replaced with other suitable material. The area will be reworked until passing test results are obtained. The CQA Monitor shall document the efforts required to acquire passing test results in deficient areas.

The compaction requirements of other soil and subgrade materials used for construction of the JRL facility are outlined in the specifications. The CQA Monitor must document the testing of these materials. Deficient areas are to be reworked until passing test results are obtained. The CQA monitor will observe the placement of the clay layer to document that previous compacted clay lifts are scarified prior to placement of the next loose lift of clay. The CQA monitor will also document through visual observations that the clay clods are broken up as part of the compaction effort. The CQA will have the authority to require areas of the clay to be reworked if either inadequate lift bonding or lack of break-up, of the clay clods is observed.

4.5 Protection

Soil materials used in the construction of the soil components of the landfill require protection to assure that the quality of the material remains within the specified requirements during and after placement into the system. The CQA shall review the contractor's planned measures to protect the soil components. Protection measures must address soils being stockpiled for subsequent use in the landfill, soils in the process of being placed, and soils already placed. At a minimum, protection measures shall address wet weather conditions, dry weather conditions (desiccation), freezing temperatures, and cross contamination of materials during and after placement. The contractor shall be responsible for implementing protection measures required to assure soil components remain in accordance to the specifications. The CQA shall oversee implementation of the protection measures.

4.6 Quality Assurance Testing and Documentation

4.6.1 Construction Quality Assurance (CQA) Agent Responsibilities. The CQA will direct the sampling and testing of all soil materials to be used in the construction of the landfill components. The CQA will observe and document, borrow site material resources and on-site utilization of the soil materials. Duties shall include but not be limited to sampling, testing, observing, and documenting soil material utilization. The CQA shall also approve methods of construction and the equipment used to place and work the soil materials.

4.6.1.1 Quality Assurance Testing

The CQA shall implement the soil testing plan as defined by the construction specifications and the quality assurance manual. Borrow materials shall be sampled and tested by CQA at the required frequency as defined by the QAQC Plan and construction specifications. Tests performed on each soil component shall be approved by the CQA. Borrow materials from the point source shall be sampled and tested at frequency indicated on Table 2-1 of Section 02200 of the Specifications.

4.6.1.2 Quality Control Testing

Quality control testing of borrow materials to be used in the construction of the landfill shall be sampled and tested at the frequency indicated in Table 3-1 of Section 02200 of the project specification. Samples shall be obtained from stockpiles to be shipped to the site or from shipments arriving on-site. The quality control testing of clay borrow shall be sampled, tested, and approved by the CQA at the required frequency as defined by this QAP and the construction technical specifications (ref. Table 2-1, Specification Section 02200).

4.6.1.3 Standard In-place Testing

The tests indicated on Table 3-2 of Section 02200 of the project Specifications shall be performed to document the clay barrier soil meets the specified in-place properties. This testing shall be performed by the CQA.

4.6.2 Sampling Procedures

4.6.2.1 Borrow Site Characterization

Sampling of a borrow site to be mined for soil components to be utilized in the construction of the landfill shall be overseen by the Soils QARE/CQA. The sample size and location shall be dependent upon the material being mined, the amount to be mined, and the frequency of Construction Quality Control (CQC) testing required. The sample size will be as directed by the CQC testing laboratory and as approved by the Soils QARE/CQA. The frequency of sampling shall be as indicated in Table 2-1 of Section 02200 of the project specifications, or as directed by the Soils QARE/CQA.

4.6.2.2 Construction Testing of Borrow Source Materials

Soil materials processed or unprocessed that are to be used as part of the landfill shall be sampled at stockpiles or from truck loads arriving on-site prior to being installed into the landfill. Samples shall be taken under direction of the Soils QARE/CQA. The frequency of sampling shall be as indicated in Table 3-1 of Section 02200 of the project specifications, or as directed by the Soils QARE/CQA. The sample size will be as directed by the CQC testing laboratory and as approved by the Soils QARE/CQA.

4.6.2.3 In-Place Construction Test Samples

Samples of soil materials placed as components of the landfill shall be sampled as directed by the Soils QARE/CQA. In-place sampling locations shall be chosen by establishing a 75-foot square grid pattern over each lift, sample location shall be randomly picked from the grid nodes. Sample grid patterns shall be staggered in each successive lift so that locations vary from lift to lift.

Should a failing test occur, the Soils QARE/CQA shall define the limit of the failing area by taking additional samples halfway between the passing test and the failing test. This procedure will be continued until the limits of the failing area are defined by passing test results.

Sampling or testing that requires penetration of in-place barrier soils will require the contractor to patch or fill the sample hole. The method of filling or patching of these holes shall be approved by the Soils QARE/CQA. The Soils QARE/CQA shall document such repairs.

4.6.3 Documentation. All observations, results of field tests performed on-site or off-site and laboratory tests, shall be recorded on suitable data record sheets. At a minimum, the inspection data record sheets shall include the following:

1. Description or title of the inspection activity.
2. Location of the inspection activity or location from which the sample was obtained.
3. Type of tests done or to be done.
4. Recorded observation or test date.
5. Results of the inspection or testing with reference to specifications.
6. Person involved in the inspection.
7. Signature of the CQA resident engineer and review by the CQA Project Manager.

Data record sheets to be utilized in the CQA program shall be approved by the CQA Project Manager.

5.0 GEOMEMBRANES

5.1 Quality Control Documentation

Prior to the installation of any geomembrane material, the Manufacturer or Installer shall provide the Project Manager/RPR with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number), and production date of the resin.

2. Copies of the quality control certificates issued by the resin supplier.

3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geomembrane meets the specifications.

4. Reports on quality control tests conducted by the Manufacturer to verify that the geomembrane manufactured for the project meets the project specifications.

5. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 2 percent by weight.

6. A list of the materials which comprise the geomembrane, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.

7. A specification for the geomembrane which includes all properties contained in the specifications measured using the appropriate test methods.

8. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.

9. Quality control certificates, signed by a responsible party employed by the Manufacturer. Each quality control certificate shall include roll identification numbers, sampling procedures, and results of quality control tests. At a minimum, results shall be given for those properties stated in Section 02771 Part 1.05.C of the project specifications:

   These quality control tests shall be performed in accordance with the test methods and frequency as specified in GRI GM 13, and Specification Section 02771 Part 1.05.C.

The Manufacturer shall identify all rolls of geomembranes with the following:

1. Manufacturer's name
2. Date of manufacture
3. Resin batch code
4. Product identification
5. Thickness
6. Roll number
7. Roll dimensions

5.1.1 Product Review: The Project Manager/RPR shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.

2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.

4. Roll packages are appropriately labeled.

5. Certified minimum properties meet the specifications.

5.2 Conformance Testing

Upon delivery of the rolls of geomembrane, the Geosynthetic QARE shall assure that conformance test samples are obtained for the geomembrane. These samples shall then be forwarded to the Geosynthetic QAL for testing to assure conformance to the specifications.

If the Project Manager/RPR desires, the Geosynthetic QARE or his agent, can perform the third-party conformance test sampling at the manufacturing plant. This may be advantageous in expediting the installation process for very large projects.

The conformance tests shall be performed in accordance with the test methods specified in Section 02771 Part 1.06 of the project specifications and consistent with GRI Test Method GM17.

5.2.1 Sampling Procedures: The rolls to be sampled shall be selected by the Geosynthetic QARE. Samples shall be taken across the entire width of the roll and shall not include the first 3 feet (1 m). Unless otherwise specified, samples shall be 3 feet (1 m) long by the roll width. The Geosynthetic QARE shall mark the machine direction on the samples with an arrow.

A lot consists of a group of materials which is manufactured from a specific batch of raw materials (e.g., HDPE resin, or bentonite clay). The manufacturer shall identify the consecutively numbered rolls of material, which are inclusive within a lot.

Unless otherwise specified, samples shall be obtained at one sample per 50,000 ft^2 (4,650 m^2) of geomembrane. Conformance tests shall be done on the samples and the results of tensile strength properties in the cross machine direction shall be utilized to establish the parent material strength.

5.2.2 Test Results. All conformance test results shall be reviewed and accepted or rejected by the Geosynthetic QARE prior to the deployment of the geomembrane.

The Geosynthetic QARE shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager/RPR. The Geosynthetic QARE shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different approved independent laboratories at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager/RPR.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager/RPR, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If the two additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

5.3 Subgrade Preparation

5.3.1 Surface Preparation: The earthwork contractor shall be responsible for preparing the supporting soil for placement of the geosynthetic layers. The Geomembrane shall be deployed on top of the Geosynthetic Clay Liner (GCL)

As indicated in Section 5.3.1.1 below the Installer shall certify in writing that the sub-surface on which the geomembrane will be installed is acceptable. A certificate of acceptance shall be given by the Installer to the Geosynthetic QARE prior to commencement of geomembrane deployment in the area under consideration. The Project Manager/RPR shall be given a copy of this certificate by the Geosynthetic QARE.

After the supporting soil has been accepted by the Installer, it is the Installer's responsibility to indicate to the Project Manager/RPR any change in the supporting soil condition that may require repair work. The Project Manager/RPR may consult with the Geosynthetic QARE regarding the need for repairs. If the Geosynthetic QARE concurs with Installer, the Project Manager/RPR shall assure that the supporting soil is repaired.

At any time before or during the geomembrane installation, the Geosynthetic QARE shall indicate to the Project Manager/RPR any locations which may not be adequately prepared for the geomembrane.

5.3.1.1 Clay Liner Surface Preparation

The earthwork contractor shall be responsible for preparing the supporting clay liner soils for placement of the secondary geomembrane.

Before the geomembrane installation begins, the Geosynthetic CQA shall verify that:

1. All lines and grades are verified.

2. An Owner's Representative verify that the supporting soil meets the density specified in the project specifications.

3. The surface to be lined has been rolled, compacted, or handworked so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade.

4. The surface of the supporting soil does not contain stones which may be damaging to the geosynthetics.

5. There is no area excessively softened by high water content.

The Installer shall certify in writing that the surface on which the geomembrane will be installed is acceptable. A certificate of acceptance shall be given by the Installer to the Geosynthetic CQA prior to commencement of geomembrane deployment in the area under consideration. The Project Manager shall be given a copy of this certificate by the Geosynthetic CQA.

After the supporting soil has been accepted by the Installer, it is the Installer's responsibility to indicate to the Project Manager any change in the supporting soil condition that may require repair work. The Project Manager may consult with the Geosynthetic CQA regarding the need for repairs. If the Geosynthetic CQA concurs with Installer, the Project Manager shall assure that the supporting soil is repaired.

At any time before or during the geomembrane installation, the Geosynthetic CQA shall indicate to the Project Manager any locations which may not be adequately prepared for the geomembrane.

5.3.1.2 GCL Surface Preparation

The geosynthetic installer shall be responsible for preparing the GCL for installation of the overlying primary geomembrane.

Before the geomembrane installation begins, the Geosynthetic CQA shall verify that:

1. All GCL seams have been completed in accordance with the specifications.

2. Repairs to the GCL are complete and secure.

3. The GCL surface is free of large wrinkles and folds and lies flat to the underlying surface.

4. GCL panels have been identified and as-built information collected.

The Installer shall verbally verify with the Geosynthetic CQA that the surface on which the geomembrane will be installed is acceptable. At any time before or during the geomembrane installation, the Geosynthetic CQA shall indicate to the Installer any locations which may not be adequately prepared for the geomembrane. The Installer shall repair said areas to the satisfaction of the Geosynthetic CQA.

5.3.1.3 Gas Collection Sand Surface Preparation (N.I.T.C)

The earthwork contractor shall be responsible for preparing the supporting soil for placement of the secondary sideslope geomembrane.

Before the geomembrane installation begins, the Geosynthetic CQA shall verify that:

1. All lines and grades are verified.

2. An Owner's Representative verify that the supporting soil meets all the gas collection sand requirements specified in the project specifications.

3. The surface to be lined has been machine-graded, or handworked so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade.

4. The surface of the supporting soil does not contain stones which may be damaging to the geomembrane.

5. There is no area excessively softened by high water content.

The Installer shall certify in writing that the surface on which the geomembrane will be installed is acceptable. A certificate of acceptance shall be given by the Installer to the Geosynthetic CQA prior to commencement of geomembrane deployment in the area under consideration. The Project Manager shall be given a copy of this certificate by the Geosynthetic CQA.

After the supporting soil has been accepted by the Installer, it is the Installer's responsibility to indicate to the Project Manager any change in the supporting soil condition that may require repair work. The Project Manager may consult with the Geosynthetic CQA regarding the need for repairs. If the Geosynthetic CQA concurs with Installer, the Project Manager shall assure that the supporting soil is repaired.

At any time before or during the geomembrane installation, the Geosynthetic CQA shall indicate to the Project Manager any locations which may not be adequately prepared for the geomembrane.

5.3.1.4 Geocomposite Surface Preparation

The geosynthetic installer shall be responsible for preparing the geocomposite surface for installation of the overlying primary geomembrane. The primary geomembrane shall be deployed on top of the geosynthetic clay liner (GCL).

Before the geomembrane installation begins, the Geosynthetic CQA shall verify that:

1. All geocomposite seams have been completed in accordance to the project specifications.

2. Repairs to the geocomposite are complete and secure.

3. The surface of the geocomposite is free of large wrinkles and folds, and lies flat to the underlying secondary geomembrane.

The Installer shall verbally verify with the Geosynthetic CQA that the surface on which the geomembrane will be installed is acceptable.

At any time before or during the geomembrane installation, the Geosynthetic CQA shall indicate to the Installer any locations which may not be adequately prepared for the geomembrane. The Installer shall repair said areas to the satisfaction of the Geosynthetic CQA.

<u>5.3.2 Anchor Trench</u>: The Geosynthetic QARE shall verify that the anchor trench has been constructed according to the design drawings and specifications.

If the anchor trench is excavated in a clay material susceptible to desiccation, the amount of trench open at any time should be minimized. The Geosynthetic QARE shall inform the Project Manager/RPR of any signs of significant desiccation associated with the anchor trench construction.

Slightly rounded corners shall be provided in the trench so as to avoid sharp bends in the geomembrane. Excessive amounts of loose soil shall not be allowed to underlie the geomembrane in the anchor trench.

The anchor trench shall be adequately drained to prevent ponding or softening of the adjacent soils while the trench is open. The anchor trench shall be backfilled and compacted as outlined in the project specifications.

Care shall be taken when backfilling the trenches to prevent any damage to the geosynthetics. The Geosynthetic QARE shall observe the backfilling operation and advise the Project Manager/RPR of any problems. Any problems shall be documented by the Geosynthetic QARE in his daily report.

<u>5.4 Geomembrane Deployment</u>

<u>5.4.1 Panel Nomenclature</u>: A field panel is defined as a unit of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of roll cut in the field.

It shall be the responsibility of the Geosynthetic QARE to assure that each field panel is given an identification code (number or letter-number) consistent with the layout plan. This identification code shall be agreed upon by the Project Manager/RPR, Installer and Geosynthetic QARE. This field panel identification code shall be as simple and logical as possible. In general, it is not appropriate to identify panels using roll numbers since roll numbers established in the manufacturing plant are usually cumbersome and are not related to location in the field. The Geosynthetic QARE shall establish a table or chart showing correspondence between roll numbers and field panel identification codes. The field panel identification code shall be used for all quality assurance records.

The Geosynthetic QARE shall verify that field panels are installed at the locations indicated on the Installer's layout plan, as approved by the Project Manager/RPR.

5.4.2 Panel Deployment Procedure: The Geosynthetic QARE shall review the panel deployment progress of the Installer (keeping in mind issues relating to wind, rain, geosynthetic clay liner hydration, and other site-specific conditions) and advise the Project Manager/RPR on its compliance with the approved panel layout drawing and its suitability to the actual field conditions. Once approved, only the Project Manager/RPR can authorize changes to the panel deployment procedure. The Geosynthetic QARE shall verify that the condition of the supporting soil does not change detrimentally during installation.

The Geosynthetic QARE shall record the identification code, location, and date of installation of each field panel.

5.4.3 Deployment Weather Conditions: Geomembrane deployment shall not proceed at an ambient temperature below 32^{o}F (0^{o}C) or above 104^{o}F (40^{o}C) unless otherwise authorized, in writing, by the Project Manager/RPR. Geomembrane placement shall not be performed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of excessive winds. Geomembrane deployment shall not be undertaken if weather conditions will preclude material seaming following deployment.

The Geosynthetic QARE shall verify that the above conditions are fulfilled. Ambient temperature shall be measured by the Geosynthetic QARE in the area in which the panels are to be deployed. The Geosynthetic QARE shall inform the Project Manager/RPR of any weather related problems which may not allow geomembrane placement to proceed.

5.4.4 Method of Deployment: Before the geomembrane is handled on site, the Geosynthetic QARE shall verify that handling equipment to be used on the site is adequate and does not pose risk of damage to the geomembrane or underlying geosynthetic clay liner. During handling, the Geosynthetic QARE shall observe and verify that the Installer's personnel handle the geomembrane and geosynthetic clay liner with care.

The Geosynthetic QARE shall verify the following:

1. Any equipment used does not damage the geomembrane or geosynthetic clay liner by handling, trafficking, excessive heat, leakage of hydrocarbons, or other means.

2. The prepared surface underlying the geomembrane or geosynthetic clay liner has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement.

3. Any geosynthetic elements immediately underlying the geomembrane or geosynthetic clay liner are clean and free of debris.

4. All personnel do not smoke or wear damaging shoes while working on the geomembrane or geosynthetic clay liner, or engage in other activities which could damage the geomembrane or geosynthetic clay liner.

5. The method used to unroll the panels does not cause excessive scratches or crimps in the geomembrane and does not damage the supporting soil or geosynthetic clay liner.

6. The geomembrane or geosynthetic clay liner is not dragged over surfaces that may damage the panels. Rub sheets shall be used to prevent damage to geosynthetic materials if dragging is necessary.

7. The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels).

8. Adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind. In case of high winds, continuous loading, e.g., by sand bags, is recommended along edges of panels to minimize risk of wind flow under the panels.

9. Direct contact with the geomembrane is minimized, and the geomembrane is protected by geotextiles, extra geomembrane, or other suitable materials, in areas where excessive traffic may be expected.

10. The method used to place the panels does not result in bridging.

11. That adequate field trial seams be run on seams that connect new geomembrane with existing geomembrane.

The Geosynthetic QARE shall inform the Project Manager/RPR if the above conditions are not fulfilled.

5.4.5 Damage and Defects: Upon delivery to the site, the Geosynthetic QARE shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. The Geosynthetic QARE shall advise the Project Manager/RPR, in writing, of any rolls or portions of rolls which should be rejected and removed from the site because they have severe flaws, and/or minor repairable flaws.

The Geosynthetic QARE shall inspect each panel, after placement and prior to seaming, for damage and/or defects. The Geosynthetic QARE shall advise the Project Manager/RPR which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels, or portions of damaged panels, which have been rejected shall be marked and their removal from the work area recorded by the Geosynthetic QARE. Repairs shall be made using procedures described in Section 5.8.

5.4.6 Writing on the Liner: To avoid confusion, the Installer and the Geosynthetic QARE shall each use different colored markers that are readily visible for writing on the geomembrane. The markers used must be semi-permanent and compatible with the geomembrane.

5.5 Field Seaming

5.5.1 Seam Layout: Before installation begins, the Installer must provide the Project Manager/RPR and the Geosynthetic QARE with a panel layout drawing, i.e., a drawing of the facility to be lined showing all expected seams. The Geosynthetic QARE shall review the panel layout drawing and verify that it is consistent with accepted state-of-practice. No panels may be seamed without the written approval of the panel layout drawing by the Project Manager/RPR. In addition, panels not specifically shown on the panel layout drawing may not be used without the Project Manager/RPR's prior approval.

In general, seams should be oriented parallel to the line of maximum slope, i.e., oriented along, not across, the slope. In corners and odd-shaped geometric locations, the number of seams should be minimized. No horizontal seam should be less than 5 feet (1.5 m) from the toe of the slope, or areas of potential stress concentrations, unless otherwise authorized by the Project Manager/RPR.

A seam numbering system compatible with the panel numbering system shall be used by the Geosynthetic QARE.

5.5.2 Accepted Seaming Methods: Approved processes for field seaming are extrusion welding and fusion welding. Proposed alternate processes shall be documented and submitted by the Installer to the Project Manager/RPR for approval. Only apparatus which have been specifically approved by make and model shall be used. The Project Manager/RPR shall submit all documentation regarding seaming methods to be used to the Geosynthetic QARE for review.

5.5.2.1 Extrusion Process

The Geosynthetic QARE shall log ambient, seaming apparatus, and geomembrane surface temperatures at appropriate intervals and report any noncompliances to the Project Manager/RPR.

The Geosynthetic QARE shall verify that:

1. The Installer maintains on-site the number of spare operable seaming apparatus decided upon at the pre-construction meeting.

2. Equipment used for seaming is not likely to damage the geomembrane.

3. Prior to beginning a seam, the extruder is purged until all heat-degraded extrudate has been removed from the barrel.

4. Clean and dry welding rods or extrudate pellets are used.

5. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.

6. Grinding shall be completed no more than 1 hour prior to seaming.

7. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.

8. The geomembrane is protected from damage in heavily trafficked areas.

9. Exposed grinding marks adjacent to an extrusion weld shall be minimized. In no instance shall exposed grinding marks extend more than 1/4 inch from the seamed area.

10. In general, the geomembrane panels are aligned to have a nominal overlap of 3 inch (75 mm) for extrusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.

11. No solvent or adhesive is used unless the product is approved in writing by the Project Manager/RPR prior to use (samples shall be submitted to the Project Manager/RPR for testing and evaluation).

12. The procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any temporary welding apparatus is controlled such that the geomembrane is not damaged or degraded.

5.5.2.2 Fusion Process

The Geosynthetic QARE shall log ambient, seaming apparatus, and geomembrane surface temperatures at appropriate intervals and report any noncompliances to the Project Manager/RPR.

The Geosynthetic QARE shall also verify that:

1. The Installer maintains on-site the number of spare operable seaming apparatus decided upon at the pre-construction meeting.

2. Equipment used for seaming is not likely to damage the geomembrane.

3. For cross seams, the edge of the cross seam is ground to an incline prior to welding.

4. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.

5. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.

6. The geomembrane is protected from damage in heavily trafficked areas.

7. A movable protective layer is used as required by the Installer directly below each overlap of geomembrane that is to be seamed to prevent buildup of moisture between the sheets and prevent debris from collecting around the pressure rollers.

8. In general, the geomembrane panels are aligned to have a nominal overlap of 6 inches (152 mm) for fusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.

9. No solvent or adhesive is used unless the product is approved in writing by the Project Manager/RPR prior to use (samples shall be submitted to the Project Manager/RPR for testing and evaluation).

5.5.3 Seam Preparation: The Geosynthetic QARE shall verify that prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris or foreign material of any kind. If seam overlap grinding is required, the Geosynthetic QARE must assure that the process is completed according to the Manufacturer's instructions within one hour of the seaming operation, and in a way that does not damage the geomembrane. The Geosynthetic QARE shall also verify that seams are aligned with the fewest possible number of wrinkles and "fishmouths".

Seaming operations to existing liner systems shall be done with care. Existing liner system shall be prepared by pressure wash to assure clean surface. Trial seams shall be done on all seams connecting new liner with existing liner systems.

5.5.4 Trial Seams: Trial seams shall be made on fragment pieces of geomembrane liner used on the project to verify that conditions are adequate for production seaming. Such trial seams shall be made at the beginning of each seaming period, or at least once each four hours, for each production seaming apparatus used that day. Also, an additional trial seam is required after any change of operator, equipment shutdown, significant idle time, or significant weather change. Additional trial seams due to idle time or weather are at the discretion of the Geosynthetic QARE. Each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as actual seams.

Trial seams shall be made on liner that will be used in production seaming, such as: new textured liner to new textured liner; new textured liner to existing textured liner; smooth liner to textured liner.

The trial seam shall be at least 4 feet (1.2 m) long by 1 foot (0.3 m) wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as indicated in Section 5.5.2.

Five samples shall be cut from the trial seam with a 1 inch (25 mm) wide die. The samples shall be cut by the Installer at locations selected randomly along the trial seam. The samples shall be tested in peel and shear using a field tensiometer. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. If a sample fails, the entire operation shall be repeated. If the additional sample fails, the seaming apparatus and seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved. The Geosynthetic QARE shall observe all trial seam procedures.

5.5.5 General Seaming Procedures: During general seaming, the Geosynthetic QARE shall be cognizant of the following:

1. For fusion welding, it may be necessary to place a movable protective layer of plastic directly below each overlap of geomembrane that is to be seamed. This is to prevent any moisture buildup between the sheets to be welded and prevent debris from collecting around the pressure rollers.

2. If required, a firm substrate shall be provided by using a flat board, a conveyor belt, or similar hard surface directly under the seam overlap to achieve proper support.

3. Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of 6 inches (152 mm) beyond the cut in all directions.

4. If seaming operations are carried out at night, adequate illumination shall be provided.

5. Seaming shall extend to the outside edge of panels placed in the anchor trench.

6. All cross seam tees should be extrusion welded to a minimum distance of 4 inches on each side of the tee.

7. No field seaming shall take place without the Master Seamer being present.

The Geosynthetic QARE shall verify that the above seaming procedures (or any other procedures agreed upon and indicated in the project manual) are followed, and shall inform the Project Manager/RPR of any nonconformance.

5.5.6 Seaming Weather Conditions:

5.5.6.1 Normal Weather Conditions

The normal required weather conditions for seaming are as follows:

1. Ambient temperature between 32^{o}F (0^{o}C) and 104^{o}F (40^{o}C).

2. Dry conditions, i.e., no precipitation or other excessive moisture, such as fog or dew.

3. No excessive winds.

The Geosynthetic QARE shall verify that these weather conditions are fulfilled and notify the Project Manager/RPR in writing if they are not. Ambient temperature shall be measured by the Geosynthetic QARE in the area in which the panels are to be placed. The Project Manager/RPR will then decide if the installation is to be stopped or special procedures used.

5.5.6.2 Cold Weather Conditions

To assure a quality installation, if seaming is conducted when the ambient temperature is below 32^{o}F (0^{o}C), the following conditions must be met:

1. Geomembrane surface temperatures shall be determined by the Geosynthetic QARE at intervals of at least once per 100 foot of seam length to determine if preheating is required. For extrusion welding, preheating is required if the surface temperature of the geomembrane is below 32^{o}F (0^{o}C).

2. Preheating may be waived by the Project Manager/RPR based on a recommendation from the Geosynthetic QARE, if the Installer demonstrates to the Geosynthetic QARE's satisfaction that welds of equivalent quality may be obtained without preheating at the expected temperature of installation.

3. If preheating is required, the Geosynthetic QARE shall inspect all areas of geomembrane that have been preheated by a hot air device prior to seaming, to assure that they have not been overheated.

4. Care shall be taken to confirm that the surface temperatures are not lowered below the minimum surface temperatures specified for welding due to winds or other adverse conditions. It may be necessary to provide wind protection for the seam area.

5. All preheating devices shall be approved prior to use by the Project Manager/RPR.

6. Additional destructive tests (as described in Section 5.7) shall be taken at an interval between 500 feet and 250 feet of seam length, at the discretion of the Geosynthetic QARE.

7. Sheet grinding may be performed before preheating, if applicable.

8. Trial seaming, as described in Section 5.5.4, shall be conducted under the same ambient temperature and preheating conditions as the actual seams. Under cold weather conditions, new trial seams shall be conducted if the ambient temperature drops by more than 5^{o}F from the initial trial seam test conditions.

9. All snow and ice shall be removed from the liner using plastic shovels. The Geosynthetic QARE will also have authority to suspend installation activities during severe weather conditions.

5.5.6.3 Warm Weather Conditions

At ambient temperatures above 104^{o}F, no seaming of the geomembrane shall be permitted unless the Installer can demonstrate to the satisfaction of the Project Manager/RPR that geomembrane seam quality is not compromised.

Trial seaming, as described in Section 5.5.4, shall be conducted under the same ambient temperature conditions as the actual seams.

At the option of the Geosynthetic QARE, additional destructive tests (as described in Section 5.4) may be required for any suspect areas.

5.6 Nondestructive Seam Testing

5.6.1 Concept. The Installer shall nondestructively test field seams over their full length using a vacuum test unit, air pressure test (for double fusion seams only), or other approved method. Vacuum testing and air pressure testing are described in Sections 5.6.2 and 5.6.3, respectively. The purpose of nondestructive tests is to check the continuity of seams. It does not provide quantitative information on seam strength. Nondestructive testing shall be carried out as the seaming work progresses, not at the completion of field seaming. At a minimum of once every 4 hours of seaming and when operation has been suspended for greater than one hour or if breakdown of seaming equipment occurs, weld samples will be tested in peel and shear in accordance with the destructive test requirements of the contract documents.

For all seams, the Geosynthetic QARE shall:

1. Observe nondestructive testing procedures.

2. Record location, data, test unit number, name of tester, and outcome of all testing.

3. Inform the Installer and Project Manager/RPR of any required repairs.

5.6.2 Vacuum Testing. The following procedures are applicable to vacuum testing.

1. The equipment shall consist of the following:

    a. A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, a porthole or valve assembly, and a vacuum gauge.

    b. A pump assembly equipped with a pressure controller and pipe connections.

    c. A rubber pressure/vacuum hose with fittings and connections.

    d. A sudsy solution of soap and water.

    e. A bucket and wide paint brush, or other means of applying the sudsy solution.

2. The following procedures shall be followed:

    a. Energize the vacuum pump and reduce the tank pressure to approximately 3.0 to 8.0 psi gauge.

    b. Wet a strip of geomembrane approximately 12 inches by 48 inches (0.3 m x 1.2 m) with the soapy distilled water solution.

    c. Place the box over the wetted area.

    d. Close the bleed valve and open the vacuum valve.

    e. Assure that a leak-tight seal is created.

f. For a period of not less than 15 seconds, apply vacuum and examine the geomembrane through the viewing window for the presence of soap bubbles.

g. If no bubble appears after 15 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 inches (76 mm) overlap, and repeat the process.

h. All areas where soap bubbles appear shall be marked and repaired in accordance with Section 5.8.

5.6.3 Air Pressure Testing. The following procedures are applicable to double fusion welding which produces a double seam with an enclosed space.

1. The equipment shall consist of the following:

   a. An air pump (manual or motor driven), equipped with pressure gauge capable of generating and sustaining a pressure between 30 and 35 psi (206 and 241 kPa) and mounted on a cushion to protect the geomembrane.

   b. A rubber hose with fittings and connections.

   c. A sharp hollow needle, or other approved pressure feed device.

2. The following procedures shall be followed:

   a. Seal both ends of the seam to be tested.

   b. Insert needle or other approved pressure feed device into the air channel created by the fusion weld.

   c. Insert a protective cushion between the air pump and the geomembrane.

   d. Energize the air pump to a pressure between 30 and 35 psi (206 and 241 kPa), close valve, allow 2 minutes for pressure to stabilize, and sustain pressure for at least 5 minutes.

   e. If loss of pressure exceeds 2 psi (15 kPa) or does not stabilize, locate faulty area and repair in accordance with Section 5.8.

   f. Cut opposite end of tested seam area once testing is completed to verify continuity of the air channel. If air does not escape, locate blockage and retest unpressurized area. Seal the cut end of the air channel.

   g. Remove needle or other approved pressure feed device and seal.

5.6.4 Test Failure Procedures. The Installer shall complete any required repairs in accordance with Section 5.8. For repairs, the Geosynthetic QARE shall:

1. Observe the repair and testing of the repair.

2. Mark on the geomembrane that the repair has been made.

3. Document the repair procedures and test results.

5.7 Destructive Seam Testing

5.7.1 Concept. Destructive seam tests shall be performed at selected locations. The purpose of these tests is to evaluate seam strength. Seam strength testing shall be done as the seaming work progresses, not at the completion of all field seaming.

5.7.2 Location and Frequency. The Geosynthetic QARE shall select locations where seam samples will be cut out for laboratory testing. Those locations shall be established as follows:

1. A minimum frequency of one test location per 1,000 feet of seam length performed by each welder. This minimum frequency is to be determined as an average taken throughout the entire facility.

2. Test locations shall be determined during seaming at the Geosynthetic QARE's discretion. Selection of such locations may be prompted by suspicion of overheating, contamination, offset welds, or any other potential cause of imperfect welding.

The Installer shall not be informed in advance of the locations where the seam samples will be taken.

5.7.3 Sampling Procedures. Samples shall be cut by the Installer at locations chosen by the Geosynthetic QARE as the seaming progresses so that laboratory test results are available before the geomembrane is covered by another material. The Geosynthetic QARE shall:

1. Observe sample cutting.

2. Assign a number to each sample, and mark it accordingly.

3. Record sample location on layout drawing.

4. Record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in Section 5.8. The continuity of the new seams in the repaired area shall be tested according to the project specifications.

5.7.4 Sample Dimensions. At a given sampling location, one sample will be taken by the installer with minimum dimensions of seam width by 48 inches in length. Field seam testing shall be performed in accordance with Section 02771 on a total of five coupons. Two coupons shall be cut one end and three from the opposite end using a 1-inch wide die with the seam centered parallel to the width of the coupon. If all coupons pass the field seam testing requirements as specified in Section 02771, a sample for laboratory testing is cut from the sample. The sample is cut into three parts and distributed as follows.

1. One portion to the Installer for optional laboratory testing, 12 inches x 12 inches (0.3 m x 0.3 m).

2. One portion for Geosynthetic QAL testing, 12 inches x 18 inches (0.3 m x 0.5 m) and

3. One portion to the Project Manager/RPR for archive storage, 12 inches x 12 inches (0.3 m x 0.3 m).

Final determination of the sample sizes shall be made at the pre-construction meeting.

5.7.5 Field Testing. The five 1 inch (25 mm) wide coupons mentioned in Section 5.7.4 shall be tested in the field using a tensiometer and shall not fail according to the criteria in the project specifications. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. If the test passes in accordance with this section, the sample qualifies for testing in the laboratory. If it fails, the seam should be repaired in accordance with Section 5.8. Final judgment regarding seam acceptability, based on the failure criteria, rests with the Geosynthetic QARE. Both tracks are to be tested in peel.

The Geosynthetic QARE shall witness all field tests and mark all samples and portions with their number. The Geosynthetic QARE shall also log the date and time, ambient temperature, number of seaming unit, name of seamer, welding apparatus temperatures and pressures, and pass or fail description, and attach a copy to each sample portion.

5.7.6 Laboratory Testing. Destructive test samples shall be packaged and shipped, if necessary, under the responsibility of the Geosynthetic QAL in a manner which will not damage the test sample. The Project Manager/RPR will be responsible for storing the archive samples. Test samples shall be tested by the Geosynthetic QAL.

Testing shall include properties as defined in the specifications. The minimum acceptable values to be obtained in these tests are indicated in the specifications. At least 5 specimens shall be tested in each shear and peel. Specimens shall be selected alternately by test from the samples (i.e. peel, shear, peel, shear...).

The Geosynthetic QAL shall provide verbal test results no more than 24 hours after they receive the samples. The Geosynthetic QARE shall review laboratory test results as soon as they become available, and make appropriate recommendations to the Project Manager/RPR.

5.7.7 Destructive Test Failure Procedures. The following procedures shall apply whenever a sample fails a destructive test, whether that test is conducted by the Geosynthetic QAL, or by field tensiometer. The Installer has two options:

1. The Installer can repair the seam between any two passing test locations.

2. The Installer can trace the welding path to an intermediate location (at 10 feet (3 m) minimum from the point of the failed test in each direction) and take a sample with a 1 inch (25 mm) wide die for an additional field test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the tests, then the seam is repaired between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be repaired.

All acceptable repaired seams shall be bound by two locations from which samples passing laboratory destructive tests have been taken. Passing laboratory destructive tests of trial seam samples taken as indicated in Section 5.5.4 may be used as a boundary for the failing seam. In cases exceeding 150 feet (50 m) of repaired seam, a sample taken from the zone in which the seam has been repaired must pass destructive testing. Repairs shall be made in accordance with Section 5.8.

The Geosynthetic QARE shall document all actions taken in conjunction with destructive test failures.

5.8 Defects and Repairs

5.8.1 Identification. All seams and non-seam areas of the geomembrane shall be examined by the Geosynthetic QARE for identification of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be cleaned by the Installer if the amount of dust or mud inhibits examination.

5.8.2 Evaluation. Each suspect location both in seam and non-seam areas shall be nondestructively tested using the methods described in Section 5.6 as appropriate. Each location which fails the nondestructive testing shall be marked by the Geosynthetic QARE and repaired by the Installer. Work shall not proceed with any materials which will cover locations which have been repaired until appropriate nondestructive and laboratory test results with passing values are available.

5.8.3 Repair Procedures. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be agreed upon between the Project Manager/RPR, Installer, and Geosynthetic QARE.

1. The repair procedures available include:

    a. Patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter.

    b. Spot welding or seaming, used to repair small tears, pinholes, or other minor, localized flaws.

    c. Capping, used to repair large lengths of failed seams at the discretion of the Geosynthetic CQA.

    d. Removing bad seam and replacing with a strip of new material welded into place.

2. For any repair method, the following provisions shall be satisfied:

    a. Surfaces of the geomembrane which are to be repaired using extrusion methods shall be abraded no more than one hour prior to the repair. The extrudate shall cover all the grinding area.

    b. All surfaces shall be clean and dry at the time of the repair.

    c. All seaming equipment used in repairing procedures shall meet the requirements of the QAP.

d. Patches or caps shall extend at least 6 inches (150 mm) beyond the edge of the defect, and all corners of patches shall be rounded with a radius of approximately 3 inches (75 mm).

5.8.4 Repair Verification. Each repair shall be numbered and logged. Each repair shall be nondestructively tested using the methods described in Section 5.6 as appropriate. Repairs which pass the nondestructive test shall be taken as an indication of an adequate repair. Repairs more than 150 feet long may be of sufficient extent to require destructive test sampling, at the discretion of the Geosynthetic QARE. Failed tests indicate that the repair shall be redone and retested until a passing test results. The Geosynthetic QARE shall observe all nondestructive testing of repairs and shall record the number of each repair, date, and test outcome.

5.8.5 Large Wrinkles. When seaming of the geomembrane is completed, and prior to placing overlying materials, the Geosynthetic QARE shall indicate to the Project Manager/RPR which wrinkles should be cut and reseamed by the Installer. The number of wrinkles to be repaired should be kept to an absolute minimum. Therefore, wrinkles should be located during the coldest part of the installation process, while keeping in mind the forecasted weather to which the uncovered geomembrane may be exposed. Wrinkles are considered to be large when the geomembrane can be folded over onto itself. This is generally the case for a wrinkle that extends 12 inches from the subgrade. Seams produced while repairing wrinkles shall be tested as outlined above.

When placing overlying material on the geomembrane, every effort must be made to minimize wrinkle development. If possible, cover should be placed during the coolest weather available. In addition, small wrinkles should be isolated and covered as quickly as possible to prevent their growth. The placement of cover materials shall be observed by the Geosynthetic QARE to assure that wrinkle formation is minimized.

5.9 Geomembrane Protection

The quality assurance procedures indicated in this Section are intended only to assure that the installation of adjacent materials does not damage the geomembrane.

5.9.1 Soils. A copy of the specifications prepared by the Designer for placement of soils shall be given to the Geosynthetic QARE by the Project Manager/RPR. The Geosynthetic QARE shall verify that these specifications are consistent with the state-of-practice such as:

1. Placement of soils on the geomembrane shall not proceed at an ambient temperature below 32^{o}F (0^{o}C) nor above 104^{o}F (40^{o}C) unless otherwise specified.

2. Placement of soil on the geomembrane should be done during the coolest part of the day to minimize the development of wrinkles in the geomembrane.

3. A geotextile or other cushion approved by the Designer is generally required between aggregate and the geomembrane.

4. Equipment used for placing soil shall not be driven directly on the geomembrane.

5. A minimum thickness of 1 foot (0.3 m) of soil is specified between a light dozer (ground pressure of 5 psi (35 kPa) or lighter) and the geomembrane.

6. In any areas traversed by any vehicles other than low ground pressure vehicles approved by the Project Manager/RPR, the soil layer shall have a minimum thickness of 3 feet (0.9 m). This requirement may be waived if provisions are made to protect the geomembrane through an engineered design. Drivers shall proceed with caution when on the overlying soil and prevent spinning of tires or sharp turns.

The Geosynthetic QARE shall measure soil thickness and verify that the required thicknesses are present. The Geosynthetic QARE must also verify that final thicknesses are consistent with the design and verify that placement of the soil is done in such a manner that geomembrane damage is unlikely. The Geosynthetic QARE shall inform the Project Manager/RPR if the above conditions are not fulfilled.

5.9.2 Sumps and Appurtenances. A copy of the plans and specifications prepared by the Designer for appurtenances shall be given by the Project Manager/RPR to the Geosynthetic QARE. The Geosynthetic QARE shall review these plans and verify that:

1. Installation of the geomembrane in appurtenant areas, and connection of geomembrane to appurtenances have been made according to specifications.

2. Extreme care is taken while welding around appurtenances since neither non-destructive nor destructive testing may be feasible in these areas.

3. The geomembrane has not been visibly damaged while making connections to appurtenances.

The Geosynthetic QARE shall inform the Project Manager/RPR in writing if the above conditions are not fulfilled.

5.10 Leak Location Survey:

The work shall be performed by a qualified independent testing firm that has performed surveys during the previous three years of at least 10,000,000 square feet of geomembrane covered by earth materials. This shall include at least three large scale projects consisting of at least two surveys of more than 875,000 square feet and one survey of 1,000,000 square feet. Leak Location Services, Inc. of San Antonio, Texas (Daren L. Laine, contact) is approved and is a qualified provider of these services.

5.10.1 Preparation: The following must be complete prior to the leak location service arriving on site.

- Install electrodes, if required, under the GCL prior to deployment
- Uniformly wet the leachate collection sand with water to field capacity.
- Expose or leave exposed, the geomembrane located at the top of the anchor trench or along tie-in seams with adjacent cells for the duration of the leak survey

5.10.2 Performance. The leak location equipment will be tested/calibrated to document the leak detection sensitivity. A 0.25-inch diameter hole will be used as an artificial leak to test equipment sensitivity. Once the leachate collection sand has been placed a hole shall be dug through the sand and a hole made in the drainage geocomposite. Then a drill or other suitable instrument shall be used to remove rather than displace the material (geomembrane) in the hole location. The geocomposite shall be replaced and the location marked and/or located relative to site benchmarks.

6.0 GEOTEXTILES

6.1 Quality Control Documentation

Prior to the installation of any geotextile, the Manufacturer or Installer shall provide the Project Manager/RPR with the following information:

1. The origin (resin supplier's name and resin production plant) and identification (brand name and number) of the resin used to manufacture the geotextile.

2. Copies of the quality control certificates issued by the resin supplier.

3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geotextile meets the Manufacturer's resin specifications.

4. Reports on quality control tests conducted by the Manufacturer to verify that the geotextile manufactured for the project meets the project specifications.

5. A statement indicating that the reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness.

6. A list of the materials which comprise the geotextile, expressed in the following categories as percent by weight: base polymer, carbon black, other additives.

7. A specification for the geotextile which includes all properties contained in the project specifications measured using the appropriate test methods.

8. Written certification that minimum average roll values given in the specification are guaranteed by the Manufacturer.

9. For non-woven geotextiles, written certification that the Manufacturer has continuously inspected the geotextile for the presence of needles and found the geotextile to be needle free.

10. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for those properties stated in Section 02272 Part 1.05(C) of the project specifications.

    Quality control tests shall be performed in accordance with the test methods specified in the project specifications for at least every 100,000 ft^2 of geotextile produced.

The Manufacturer shall identify all rolls of geotextiles with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
4. Roll dimensions

6.1.1 Product Review: The Project Manager/RPR shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.

2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.

4. Roll packages are appropriately labeled.

5. Certified minimum average roll properties meet the project specifications.

6.2 Conformance Testing

Upon delivery of the rolls of geotextiles, the Geosynthetic QARE shall assure that conformance test samples are obtained for the geotextile. These samples shall then be forwarded to the Geosynthetic QAL for testing to assure conformance to the project specifications.

If the Project Manager/RPR desires, the Geosynthetic QARE or his agent, can perform the conformance test sampling at the manufacturing plant. This may be advantageous in expediting the installation process for very large projects.

The conformance tests shall be performed in accordance with the test methods indicated in Section 02272 Part 2.01(B) of the project specifications. Other conformance tests may be required by the Project Manager/RPR.

6.2.1 Sampling Procedures: The rolls to be sampled shall be selected by the Geosynthetic QARE. Samples shall be taken across the entire width of the roll and shall not include the first complete revolution of fabric on the roll. Samples shall not be taken from any portion of a roll which has been subjected to excess pressure or stretching. Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QARE shall mark the machine direction on the samples with an arrow. All lots of material and the particular test sample that represents each lot should be defined before the samples are taken.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QARE based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not to exceed one conformance test per 100,000 ft^2 (10,000 m^2) of geotextile.

6.2.2 Test Results. All conformance test results shall be reviewed and accepted or rejected by the Geosynthetic QARE prior to the deployment of the geotextile.

The Geosynthetic QARE shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different approved independent laboratories at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager/RPR.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager/RPR, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

6.3 Geotextile Deployment

During shipment and storage, the geotextile shall be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions. Geotextile rolls shall be shipped and stored in relatively opaque and watertight wrappings. Wrappings shall be removed shortly before deployment.

The Geosynthetic QARE shall observe rolls upon delivery at the site and any deviation from the above requirements shall be reported to the Project Manager/RPR.

The Installer shall handle all geotextiles in such a manner as to assure they are not damaged in any way, and the following shall be complied with:

1. On slopes, the geotextiles shall be securely anchored and then rolled down the slope in such a manner as to continually keep the geotextile sheet in tension.

2. In the presence of wind, all geotextiles shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Geotextiles shall be cut using a geotextile cutter (hook blade) only. If in place, special care shall be taken to protect other materials from damage which could be caused by the cutting of the geotextiles.

4. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geotextile.

5. During placement of geotextiles, care shall be taken not to entrap, in or beneath the geotextile, stones, excessive dust, or moisture that could damage the geomembrane, cause clogging of drains or filters, or hamper subsequent seaming.

6. A visual examination of the geotextile shall be carried out over the entire surface, after installation, to assure that no potentially harmful foreign objects, such as needles, are present.

The Geosynthetic QAL shall note any noncompliance and report it to the Project Manager/RPR.

6.4 Seaming Procedures

On slopes steeper than 10 horizontal:1 vertical, all geotextiles shall be continuously sewn (i.e., spot sewing is not allowed). Geotextiles shall be overlapped a minimum of 3 inches (75 mm) prior to seaming. In general, no horizontal seams shall be allowed on sideslopes (i.e., seams shall be along, not across, the slope), except as part of a patch.

On bottoms and slopes shallower than 10 (horizontal):1 (vertical), geotextiles shall be seamed as indicated above (preferred), or continuously thermally bonded with the written approval of the Project Manager/RPR.

The Installer shall pay particular attention at seams to assure that no earth cover material could be inadvertently inserted beneath the geotextile.

Any sewing shall be done using polymeric thread with chemical and ultraviolet light resistance properties equal to or exceeding those of the geotextile. Sewing shall be done using machinery and stitch types specified in the project specifications or as approved in writing by the Project Manager/RPR.

6.5 Defects and Repairs

Any holes or tears in the geotextile shall be repaired as follows:

On slopes, a patch made from the same geotextile shall be sewn into place in accordance with the project specifications. Should any tear exceed 10 percent of the width of the roll, that roll shall be removed from the slope and replaced.

Care shall be taken to remove any soil or other material which may have penetrated the torn geotextile.

The Geosynthetic QARE shall observe any repair and report any noncompliance with the above requirements in writing to the Project Manager/RPR.

6.6 Geotextile Protection

All soil materials located on top of a geotextile shall be deployed in such a manner as to assure:

1. The geotextile and underlying lining materials are not damaged.

2. Minimal slippage of the geotextile on underlying layers occurs.

3. No excess tensile stresses occur in the geotextile.

Unless otherwise specified by the Geosynthetic QARE, all lifts of soil material shall be in conformance with the guidelines given in Section 4.9.1.

7.0 GEONETS (DRAINAGE GEOCOMPOSITE)

7.1 Quality Control Documentation

Prior to the installation of any geonet, the Manufacturer or Installer shall provide the Project Manager/RPR with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number), and production date of the resin.

2. Copies of the quality control certificates issued by the resin supplier.

3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geonet meets the specifications.

4. Reports on quality control tests conducted by the Manufacturer to verify that the geonet and drainage geocomposite manufactured for the project meets the project specifications.

5. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 2 percent by weight.

6. A list of the materials which comprise the geonet, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.

7. A specification for the geonet which includes all properties contained in the specifications measured using the appropriate test methods.

8. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.

9. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for those properties stated in Section 02272 Part 1.05 of the project specifications.

   Quality control tests shall be performed in accordance with the test methods specified in the specifications, for every 100,000 ft^2 of geonet produced.

The Manufacturer shall identify all rolls of drainage geocomposite with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
5. Roll dimensions

The Geosynthetic QARE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager/RPR. The Geosynthetic QARE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.

2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.

4. Roll packages are appropriately labeled.

5. Certified minimum properties meet the specifications.

7.2 Conformance Testing

Upon delivery of the rolls of geonet, the Geosynthetic QARE shall assure that conformance test samples are obtained for the geonet. These samples shall then be forwarded to the Geosynthetic QAL for testing to assure conformance to the specifications.

If the Project Manager/RPR desires, the Geosynthetic QARE or his agent, can perform the conformance test sampling at the manufacturing plant. This may be advantageous in expediting the installation process for very large projects.

The conformance tests shall be performed in accordance with the test methods indicated in Section 02272 Part 2.01(C)(5) of the project specifications. Other conformance tests may be required by the Project Manager/RPR.

7.2.1 Sampling Procedures: The rolls to be sampled shall be selected by the Geosynthetic QARE. Samples shall be taken across the entire width of the roll, and shall not be taken from any portion of a roll which has been subjected to excess pressure or stretching. Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QARE shall mark the machine direction on the samples with an arrow. All lots of material and the particular test sample that represents each lot should be defined before the samples are taken.

If the Project Manager/RPR desires, the Geosynthetic QARE or his agent or his agent, can perform the third-party conformance test sampling at the manufacturing plant. This may be advantageous in expediting the installation process for very large projects.

A lot consists of a group of materials which is manufactured from a specific batch of raw materials (e.g., HDPE resin, or bentonite clay). The manufacturer shall identify the consecutively numbered rolls of material, which are inclusive within a lot.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not less than one conformance test per 100,000 ft^2 (10,000 m^2) of geonet.

7.2.2 Test Results. All conformance test results shall be reviewed and accepted or rejected by the Geosynthetic QARE prior to the deployment of the geotextile.

The Geosynthetic QARE shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different approved independent laboratories at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager/RPR.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager/RPR, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

7.3 Geocomposite Deployment

During shipment and storage, the geocomposite shall be protected from inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions.

The Geosynthetic QARE shall observe rolls upon delivery at the site and any deviation from the above requirements shall be reported to the Project Manager/RPR.

The Installer shall handle all geocomposite in such a manner as to assure they are not damaged in any way, and the following shall be complied with:

1. On slopes, the geocomposite shall be securely anchored and then rolled down the slope in such a manner as to continually keep the geocomposite sheet in tension.

2. In the presence of wind, all geocomposite shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Geocomposite shall be cut using a hook blade only. If in place, special care shall be taken to protect other materials from damage which could be caused by the cutting of the geocomposite.

4. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geocomposite.

5. During placement of geocomposite, care shall be taken not to entrap, in or beneath the geocomposite, stones, excessive dust, soil, or moisture that could damage the geomembrane, cause clogging of drains or filters, or hamper subsequent seaming.

6. A visual examination of the geocomposite shall be carried out over the entire surface, after installation, to assure that no potentially harmful foreign objects are present.

The Geosynthetic QAL shall note any noncompliance and report it to the Project Manager/RPR.

<u>7.4 Seaming Procedures</u>

Geonets shall be overlapped a minimum of 4 inches (75 mm) prior to tying. In general, no horizontal seams shall be allowed on sideslopes (i.e., seams shall be along, not across, the slope), except as part of a patch.

<u>7.5 Seams and Overlaps</u>

Adjacent geonet shall be joined according to construction drawings and specifications. At a minimum, the following requirements shall be met:

1. Adjacent rolls shall be overlapped by at least 4 inches (100 mm).

2. Overlaps shall be secured by tying.

3. Tying can be achieved by plastic fasteners or polymer braid. Tying devices shall be white or yellow for easy inspection. Metallic devices are not allowed.

4. Tying shall be every 5 feet (1.5 m) along the slope, every 6 inches (0.15 m) in the anchor trench, and every 6 inches (0.15 m) along end-to-end seams on the base of the landfill.

5. In general, no horizontal seams shall be allowed on sideslopes.

6. In the corners of the sideslopes of rectangular landfills, where overlaps between perpendicular geonet strips are required, an extra layer of geonets. shall be unrolled along the slope, on top of the previously installed geonet, from top to bottom of the slope.

7. When more than one layer of geonet is installed, joints shall be staggered.

8. The geotextiles that will have direct contact with soil shall be heat-sealed at geonet overlaps.

The Geosynthetic QARE shall note any noncompliance and report it to the Project Manager/RPR.

When several layers of geonet are stacked, care shall be taken to prevent strands of one layer from penetrating the channels of the next layer, thereby significantly reducing the transmissivity. This cannot happen if stacked geonet are placed in the same direction. A stacked geonet shall never be laid in perpendicular directions to the underlying geonet (unless otherwise specified by the Designer).

<u>7.6 Defects and Repairs</u>

Any holes or tears in the geocomposite shall be repaired by placing a patch extending 1 foot (0.3 m) beyond the edges of the hole or tear. The patch shall be secured to the original geonet by tying every 6 inches (0.15 m). Tying devices shall be as indicated in Section 7.5. If the hole or tear width across the roll is more than 50 percent of the width of the roll, the damaged area shall be repaired as follows:

1. On the base of the landfill, the damaged area shall be cut out and the two portions of the geocomposite shall be joined as indicated in Section 7.5.

2. On sideslopes, the damaged geocomposite shall be removed and replaced.

7.7 Geonet Protection

Soil should never be placed in direct contact with geocomposite. Soil materials near the geocomposite shall be placed in such a manner as to assure:

1. The geocomposite and underlying lining materials are not damaged.

2. Minimal slippage of the geocomposite on underlying layers occurs.

3. No excess tensile stresses occur in the geonet.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 4.0.

Any noncompliance shall be noted by the Geosynthetic QARE and reported to the Project Manager/RPR.

8.0 GEOSYNTHETIC CLAY LINERS (GCL)

8.1 Quality Control Documentation

Prior to the installation of any GCL, the Manufacturer or Installer shall provide the Project Manager/RPR with the following information:

1. The origin (bentonite and geotextile supplier's name and bentonite and geotextile production plant) and identification (brand name and number) of the bentonite and geotextile used to manufacture the GCL.

2. Copies of the quality control certificates issued by the bentonite and geotextile supplier.

3. Reports on tests conducted by the Manufacturer to verify that the quality of the bentonite and geotextile used to manufacture the GCL meets the Manufacturer's bentonite and geotextile specifications.

4. Reports on quality control tests conducted by the Manufacturer to verify that the GCL manufactured for the project meets the project specifications.

5. A specification for the GCL which includes all properties contained in the project specifications measured using the appropriate test methods.

6. Written certification that minimum average roll values given in the specification are guaranteed by the Manufacturer.

7. For non-woven geotextiles, written certification that the Manufacturer has continuously inspected the geotextile for the presence of needles and found the geotextile to be needle free.

8. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for those properties stated in Section 02275 Part 2.01(A) of the project specifications.

   Quality control tests shall be performed in accordance with the test methods specified in the project specifications and consistent with GRI-GCL3, Standard Specification for Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs).

The Manufacturer shall identify all rolls of GCLs with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
4. Roll dimensions

8.1.1 Product Review: The Project Manager/RPR shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Roll packages are appropriately labeled.
5. Certified minimum average roll properties meet the project specifications.

8.2 Conformance Testing

Upon delivery of the rolls of GCLs, the Project Manager/RPR shall assure that conformance test samples are obtained for the GCL. Samples shall be obtained for conformance testing at a frequency consistent with GRI-GCL3 Standards, with a minimum of 1 per lot. These samples shall then be forwarded to an independent laboratory for testing to assure conformance to the project specifications.

If the Project Manager/RPR desires, the Geosynthetic QARE or his agent, can perform the conformance test sampling at the manufacturing plant. This may be advantageous in expediting the installation process for very large projects.

The conformance tests shall be performed in accordance with the test methods indicated in Section 02275 Part 1.05. Other conformance tests may be required by the Project Manager/RPR.

8.2.1 Sampling Procedures: The rolls to be sampled shall be selected by the Project Manager/RPR. Samples shall be taken across the entire width of the roll. Samples shall not be taken from any portion of a roll which has been subjected to excess pressure or stretching. Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. All lots of material and the particular test sample that represents each lot should be defined before the samples are taken.

A lot consists of a group of materials which is manufactured from a specific batch of raw materials (e.g., HDPE resin, or bentonite clay). The manufacturer shall identify the consecutively numbered rolls of material, which are inclusive within a lot.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not less than one conformance test per 50,000 ft^2 (4,645 m^2) of GCL.

8.2.2 Test Results. All conformance test results shall be reviewed and accepted or rejected by the Project Manager/RPR prior to the deployment of the GCL.

The Project Manager/RPR shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the independent laboratory incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the independent laboratory with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different approved independent laboratories at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original independent laboratory test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager/RPR.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager/RPR, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

8.3 Subgrade Preparation

8.3.1 Surface Preparation: The earthwork contractor shall be responsible for preparing the supporting soil for GCL placement.

Before the GCL installation begins, the Geosynthetic QARE shall verify that:

1. All lines and grades are verified.
2. An Owner's Representative verify that the supporting soil meets the density specified in the project specifications.
3. The surface to be lined has been rolled, compacted, or handworked so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade.
4. The surface of the supporting soil does not contain stones which may be damaging to the geosynthetics.
5. There is no area excessively softened by high water content.

The Installer shall certify in writing that the surface on which the GCL will be installed is acceptable. A certificate of acceptance shall be given by the Installer to the Geosynthetic QARE prior to commencement of GCL deployment in the area under consideration. The Project Manager/RPR shall be given a copy of this certificate by the Geosynthetic QARE.

After the supporting soil has been accepted by the Installer, it is the Installer's responsibility to indicate to the Project Manager/RPR any change in the supporting soil condition that may require repair work. The Project Manager/RPR may consult with the Geosynthetic QARE regarding the need for repairs. If the Geosynthetic QARE concurs with Installer, the Project Manager/RPR shall assure that the supporting soil is repaired.

At any time before or during the GCL installation, the Geosynthetic QARE shall indicate to the Project Manager/RPR any locations which may not be adequately prepared for the GCL.

8.4 GCL Deployment

During shipment and storage, the GCL shall be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions. GCL rolls shall be shipped and stored in relatively opaque and watertight wrappings. Wrappings shall be removed shortly before deployment.

The Geosynthetic QARE shall observe rolls upon delivery at the site and any deviation from the above requirements shall be reported to the Project Manager/RPR.

The Installer shall handle all GCLs in such a manner as to assure they are not damaged in any way, and the following shall be complied with:

1. On slopes, the GCLs shall be securely anchored and then rolled down the slope in such a manner as to continually keep the GCLs fully relaxed (but not wrinkled).

2. GCLs shall be cut using a utility knife or special (manufacturer) cutter only. If in place, special care shall be taken to protect other materials from damage which could be caused by the cutting of the GCLs.

3. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the GCL.

4. A visual examination of the GCL shall be carried out over the entire surface, after installation, to assure that no potentially harmful foreign objects, such as needles, are present.

5. The Installer shall sign and submit subgrade surface acceptance certificates for each area to be covered by the GCL.

6. The Installer shall deploy no more GCL material than can be covered with geomembrane by the end of that working day; this shall be verified by the Project Manager/RPR.

7. The Installer shall use a core pipe to lift the GCL during deployment which does not bend excessively creating unacceptable tension in the GCL, this shall be verified by the Project Manager/RPR.

8. To prevent damage, the GCL panels should not be dragged along the subgrade surface.

8.5 Seaming Procedures

GCLs shall be overlapped a minimum of 6 inches prior to seaming. In general, no horizontal seams shall be allowed on sideslopes (i.e., seams shall be along, not across, the slope), except as part of a patch. The GCL shall be seamed with a minimum of ¼-pound (115 g/lf) of bentonite. Seams at the base of the slope shall be a minimum of 5 feet away from the toe of the slope.

The Geosynthetic QARE shall pay particular attention at seams to assure that no earth cover material could be inadvertently inserted beneath the GCL.

8.6 Defects and Repairs

Any holes or tears in the GCL shall be repaired as follows:

Place a bead of granular bentonite at the minimum rate of one-quarter pound per linear foot around the damaged area, cut a batch of new GCL to fit over the damaged area and extending a minimum of 1 foot beyond it, and carefully backfill.

Care shall be taken to remove any soil or other material which may have penetrated the damaged GCL.

8.7 GCL Protection

All soil materials located on top of a GCL shall be deployed in such a manner as to assure:

1. The GCL is not damaged.
2. Minimal slippage of the GCL on underlying layers occurs.
3. No excess tensile stresses occur in the GCL.

Unless otherwise specified by the Geosynthetic QARE, all lifts of soil material shall be in conformance with the guidelines given in Section 4.0.

8.8 Installation Documentation

The Project Manager/RPR shall prepare and submit the following information as part of the project documentation plan:

1. All conformance testing results.
2. All daily reports detailing the GCL deployment.
3. Subgrade surface acceptance certifications signed by the responsible parties.
4. A compilation of all CQA checklists completed during the installation.
5. All manufacturer's certifications and accompanying test data.
6. A description of deviations, if any, made to the original CQA plan during the installation.

7. The Geosynthetic QARE will accept the GCL prior to placement.

9.0 HDPE PIPE, FITTINGS AND APPURTENANCES

9.1 Quality Control Documentation

Prior to the installation of any pipe, fittings, and appurtenances at the landfill facilities, the contractor shall provide the Engineer with material submittals on the materials to be used in construction of the landfill facilities. Submittals shall be prepared according to the project specifications. The following information shall be available and will be provided to the Engineer or CQA upon request:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number), and production date of the resin.

2. Copies of the quality control certificates issued by the resin supplier.

3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the HDPE pipe and fittings, meets the specifications.

4. Reports on quality control tests conducted by the Manufacturer to verify that the HDPE pipe and fittings manufactured for the project meets the project specifications.

5. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 2 percent by weight.

6. A list of the materials which comprise the HDPE pipe and fittings, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.

7. A specification for the pipe and fittings which includes all properties contained in the specifications measured using the appropriate test methods.

8. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.

9. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include pipe identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for:

   a. Density
   b. Melt flow index
   c. Carbon black content

   Quality control tests shall be performed in accordance with the test methods specified in the specifications, for every 1,000 ft of pipe produced.

The Manufacturer shall identify all pipe according to ASTM D 1248 and ASTM F 714.

The CQA shall review these documents, as requested, and shall report any discrepancies with the above requirements to the Project Manager/RPR. The CQA shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.

2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

3. Quality control certificates have been provided at the specified frequency for pipe produced, and that each certificate identifies the pipe related to it.

4. Pipe is appropriately labeled.

5. Certified minimum properties meet the specifications.

9.2 Conformance Testing

Upon delivery of the HDPE pipe, the CQA shall inspect the pipe and based on the pipe condition and review of the manufacturer's certification documentation, may elect to sample the pipe for conformance testing. Conformance test samples shall be identified in a manner appropriate for the ASTM standard for HDPE pipe. These samples shall then be forwarded to the QAL for testing to assure conformance to the specifications.

If elected, the following conformance tests shall be performed on the pipe:

1. Physical dimensions by ASTM D 2122
2. Density by ASTM D 1505
3. Plate bearing test by ASTM D 2412
4. Impact resistance by ASTM D 2444

These conformance tests shall be performed in accordance with the test methods specified. Other conformance tests may be required by the Project Manager/RPR.

9.2.1 Sampling Procedures: A lot shall be defined as a group of consecutively numbered pipes from the same manufacturing line. Alternatively, a lot may be designated by the CQA based on a review of all pipe information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not less than one conformance test per 1,000 ft of HDPE pipe.

9.2.2 Test Results. All conformance test results must be reviewed and accepted or rejected by the CQA prior to installation of the pipe.

The CQA shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager/RPR. The CQA shall be responsible for checking that all test results meet or exceed the minimum property values listed in project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different NEWSME Operations approved independent laboratories at the expense of the manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager/RPR.

If a test result is in nonconformance, all material from the lot represented by the failing test shall be considered out of specification and rejected. Alternatively, at the option of the Project Manager/RPR, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all pipes in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from pipes that have pipe numbers immediately adjacent to the pipe that was sampled and failed. If the two additional tests pass, the pipe that represents the initial failed test and the pipe manufactured immediately after that pipe (next larger pipe number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of pipes within the lot.

9.3 Pipe and Fitting Placement

The Installer shall handle all pipe in such a manner as to ensure it is not damaged in any way, and the following shall be complied with:

1. HDPE pipe, fittings, and appurtenances shall be placed as shown in the Contract Drawings, specifications, and/or as directed by the CQA.

2. Piping placed within a trench shall be placed according to the contract drawings. Pipe bedding and backfill shall be done according to the specifications.

3. Pipe fittings shall be installed as shown on the contract drawings and as recommended by the pipe manufacturer and CQA.

4. Solid wall HDPE transport pipe and associated fittings shall be pressure leak tested according to general industry standards. The CQA is responsible for observing and documenting these tests. The installer is responsible for locating and repairing all leaks in such a manner that is acceptable to the CQA.

9.4 Pipe Seams and Fusion Techniques

Butt fusion welding shall be used to seam pipe lengths together and install pipe fittings. Welding shall be done by qualified personnel and according to manufacturer's instructions. The installer shall provide the CQA with documentation of the pipe welder's experience. The CQA shall observe and document welding operations as necessary to assure welding techniques are highest quality.

9.5 Repairs

Any damaged pipe shall be discarded. No repairs shall be allowed.

9.6 Manholes, Valves and Other Appurtenances

Manholes, valves and other appurtenances associated with the piping systems shall be constructed according to the contract drawings and specifications. All connections to piping and/or associated equipment shall be according to the contract drawings and the manufacturer's recommendations. All manholes, valves and other pipe connections shall be leak tested according to general industry standards. The installer is responsible for repair of faulty material and repairs required to provide a leakproof installation. The CQA is responsible for observing and documenting installation and testing necessary to assure installation techniques are highest quality.

9.7 Soil Materials Placement

All soil materials located on top of a pipe shall be placed in such a manner as to ensure:

1. The pipe and underlying materials are not damaged or dislocated.

2. The pipe structural integrity is not compromised.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 4.0.

Any noncompliance shall be noted by the CQA and reported to the Project Manager/RPR.

APPENDIX C

HELP MODEL OUTPUT DATA

HELP Model Summary

Leachate Generation Evaluation		
Open Condition - 90' Waste		
Average Annual		Peak Monthly (April)
Runoff	10.763	5.29
Leachate	10.644	0.1826
Total	21.407	5.4726
Temporary Condition - 90' Waste		
Leachate	8.3483	0.0796

Pipe Spacing Evaluation		
Open Condition - 10' Waste		
Average Annual		Peak Monthly (May)
Leachate	10.53	2.343

AVERAGE ANNUAL LEACHATE FLOWS

OPEN	TEMP.	(1)FINAL	
77,624	30,304	4,429	<-- CU.FEET/AC./YR FROM HELP MODEL
1,591	621	91	<-- GAL./AC./DAY CONVERSION

AVERAGE MONTHLY LEACHATE FLOW FOR MAX. MONTH (May-Open Waste, Dec-TempCover)

OPEN	TEMP.	(1)FINAL	
19,866	289	369	<-- CU.FEET/AC./month FROM HELP MODEL
4,953	72	8	<-- GAL./AC./DAY CONVERSION

(1) Based on 1.22 inches of infiltration through final cover per acre per year

	HELP MODEL - AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1980 THROUGH 2014												
Liquids Collected	Jan	Feb	Mar	*Apr	**May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	Leachate Generation												
	Intermediate Soil Cover Condition (90' Waste)												
Leachate - Through Cover	1.2351	0.5084	0.09	0.0796	0.8142	0.768	0.6053	0.4821	0.5945	0.7291	0.9266	1.5155	8.3484
	Open Condition (90' Waste)												
Runoff	0.518	0.071	4.494	5.29	0.004	0.004	0	0	0.007	0.006	0.369	0	10.763
Leachate - Open	1.1969	0.4281	0.1791	0.1826	1.879	1.151	0.7463	0.59	0.5977	0.8538	1.1432	1.6963	10.644
Combined Open	1.7149	0.4991	4.6731	**5.4726**	1.883	1.155	0.7463	0.59	0.6047	0.8598	1.5122	1.6963	21.407
Combined Leachate and Runoff (Open + through cover)	2.95	1.0075	4.7631	5.5522	2.6972	1.923	1.3516	1.0721	1.1992	1.5889	2.4388	3.2118	
Combined Leachate	2.432	0.9365	0.2691	0.2622	2.6932	1.919	1.3516	1.0721	1.1922	1.5829	2.0698	3.2118	18.9924
Leachate 10 feet Open Waste	0.2006	0.0577	0.0396	0.3929	**2.3427**	0.7989	0.4419	0.5739	0.6518	1.2647	2.0238	1.7412	10.5297

* Peak Month for leachate generation is April based on peak month of runoff value during open condition with 90' Waste.
** Peak Month for pipe spacing is May based on peak month of infiltration value during open condition with 10' Waste.

ATTACHED : HELP MODEL RUNS

JUNIPER RIDGE LANDFILL

ESTIMATED ANNUAL LEACHATE GENERATION FROM 2019 TO 2032

		LEACHATE GENERATED (GALLONS)	
YEAR	DEVELOPED LANDFILL AREA	ANNUAL LEACHATE GENERATED (HELP)	CUMMALITIVE FLOW GENERATED (HELP)
2019	77.1	21,412,532	21,412,532
2020	77.1	17,987,213	39,399,745
2021	89.7	22,899,871	62,299,617
2022	89.7	19,299,888	81,599,505
2023	101.5	21,584,637	103,184,142
2024	101.5	18,778,199	121,962,341
2025	101.5	18,346,768	140,309,109
2026	108.2	15,772,587	156,081,696
2027	108.2	15,772,587	171,854,282
2028	108.2	14,477,636	186,331,918
2029	114.2	14,477,636	200,809,553
2030	114.2	16,299,783	217,109,336
2031	121.3	13,822,375	230,931,712
2032	121.3	13,822,375	244,754,087
	Average =	17,482,435	

JUNIPER RIDGE LANDFILL

ESTIMATED LEACHATE GENERATION FROM 2019 TO 2033

CELL DEVELOPMENT		YEAR ENDING IN OCTOBER														
CELL I.D.	CELL AREA TOTAL	2019			2020			2021			2022			2023		
		Open	Int Cover	Final	Open	Int Cover	Final	Open	Int Cover	Final	Open	Int Cover	Final	Open	Int Cover	Final
	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)
1	7.9	0	7.9	0	0	0.8	7.1	0	0.8	7.1	0	0.8	7.1	0	0.8	7.1
2	6.6	0	6.6	0	0	3.3	3.3	0	3.3	3.3	0	3.3	3.3	0	3.3	3.3
3A	4.1	0	4.1	0	0	3.9	0.2	0	3.9	0.2	0	3.9	0.2	0	3.9	0.2
3B	6.1	0	6.1	0	0	6.1	0	0.5	5.6	0	0.5	5.6	0	0	6.1	0
4	5.8	0	5.8	0	0	3.1	2.7	0	3.1	2.7	0	2.2	3.6	0	2.2	3.6
5	7.7	0	7.7	0	0	6.6	1.1	0	6.6	1.1	0	0.5	7.2	0	0.5	7.2
6	3.8	0	3.8	0	0	3.8	0	0	3.8	0	0	0.1	3.7	0	0.1	3.7
7	6.6	0.8	5.8	0	0	6.6	0	0.8	5.8	0	0.8	5.8	0	0	6.6	0
8	7.5	0	7.5	0	0	7.5	0	0	7.5	0	0	3.8	3.7	0	3.8	3.7
9	6.5	1	5.5	0	0	6.5	0	0	6.5	0	0	6.1	0.4	0	6.1	0.4
10	5.2	0	5.2	0	0	5.2	0	0	5.2	0	0	1.4	3.8	0	1.4	3.8
11	9.3	9.3	0.0	0	9.3	0	0	1.2	8.1	0	1.2	8.1	0	0	9.3	0
12	12.6	0	0	0	0	0	0	12.6	0	0	12.6	0	0	2.2	10.4	0
13	11.8	0	0	0	0	0	0	0	0	0	0	0	0	11.8	0	0
14	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	6.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	7.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	121.3	11.1	66.0	0.0	9.3	53.4	14.4	15.1	60.2	14.4	15.1	41.6	33.0	14.0	54.5	33.0

53.5

	2019 Open	2019 Int Cover	2019 Final	2020 Open	2020 Int Cover	2020 Final	2021 Open	2021 Int Cover	2021 Final	2022 Open	2022 Int Cover	2022 Final	2023 Open	2023 Int Cover	2023 Final
Leachate Average Annual (GPD)	17,676	40,988	0	14,810	33,163	1,307	24,046	37,386	1,307	24,046	25,835	2,995	22,295	33,846	2,995
		58,664			49,280			62,739			52,876			59,136	
Leachate Peak Monthly (GPD)	54,980	4,755	0	46,064	3,847	109	74,792	4,337	109	74,792	2,997	250	69,344	3,926	250
		59,735			50,020			79,238			78,039			73,520	

	2019	2020	2021	2022	2023
Average Annual (gpm)	41	34	44	37	41
Peak Monthly (gpm)	41	35	55	54	51

Average Annual = 47,897
Average Peak Monthly = 57,449

JUNIPER RIDGE LANDFILL

ESTIMATED LEACHATE GENERATION FROM 2019 TO 2033

CELL DEVELOPMENT		YEAR ENDING IN OCTOBER														
CELL I.D.	CELL AREA TOTAL	2024			2025			2026			2027			2028		
		Open	Int Cover	Final	Open	Int Cover	Final	Open	Int Cover	Final	Open	Int Cover	Final	Open	Int Cover	Final
	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)
1	7.9	0	0.8	7.1	0.4	0.4	7.1	0.4	0.4	7.1	0.4	0.4	7.1	0	0.0	7.9
2	6.6	0	3.3	3.3	0.4	2.9	3.3	0.4	2.9	3.3	0.4	2.9	3.3	0	0	6.6
3A	4.1	0	3.9	0.2	0.2	3.7	0.2	0.2	2.5	1.4	0.2	2.5	1.4	0	0.2	3.9
3B	6.1	0	6.1	0	0.2	5.9	0	0.2	3.7	2.2	0.2	3.7	2.2	0	0.8	5.3
4	5.8	0	0.6	5.2	0	0.6	5.2	0	0.0	5.8	0	0.0	5.8	0	0	5.8
5	7.7	0	0.0	7.7	0	0	7.7	0	0.0	7.7	0	0.0	7.7	0	0	7.7
6	3.8	0	0	3.8	0	0	3.8	0	0.0	3.8	0	0.0	3.8	0	0	3.8
7	6.6	0	6.6	0	0	6.6	0	0	2.4	4.2	0	2.4	4.2	0	0.5	6.1
8	7.5	0	0.4	7.1	0	0.4	7.1	0	0.0	7.5	0	0.0	7.5	0	0	7.5
9	6.5	0	0.8	5.7	0	0.8	5.7	0	0.0	6.5	0	0.0	6.5	0	0	6.5
10	5.2	0	0	5.2	0	0	5.2	0	0.0	5.2	0	0.0	5.2	0	0	5.2
11	9.3	0	7.1	2.2	0	7.1	2.2	0	3.2	6.1	0	3.2	6.1	0	1	8.3
12	12.6	2.2	10.4	0	0.6	12	0	0.6	12.0	0	0.6	12.0	0	1	11.6	0
13	11.8	11.8	0	0	0	11.8	0	0	11.8	0	0	11.8	0	0.1	11.7	0
14	6.7	0	0	0	6.7	0	0	6.7	0.0	0	6.7	0.0	0	2.1	3.4	1.2
15	6.0	0	0	0	0	0	0	0		0	0		0	6	0	0
16	7.1	0	0	0	0	0	0	0		0	0		0	0	0	0
Total	121.3	14.0	40.0	47.5	8.5	52.2	47.5	8.5	38.9	60.8	8.5	38.9	60.8	9.2	29.2	75.8
	53.5															

	2024			2025			2026			2027			2028		
Leachate Average Annual (GPD)	22,295	24,841	4,311	13,536	32,418	4,311	13,536	24,158	5,518	13,536	24,158	5,518	14,651	18,134	6,880
	51,447			50,265			43,213			43,213			39,665		
Leachate Peak Monthly (GPD)	69,344	2,882	359	42,102	3,761	359	42,102	2,803	460	42,102	2,803	460	45,569	2,104	573
	72,585			46,222			45,364			45,364			48,246		
Average Annual (gpm)	36			35			30			30			28		
Peak Monthly (gpm)	50			32			32			32			34		

JUNIPER RIDGE LANDFILL

ESTIMATED LEACHATE GENERATION FROM 2019 TO 2033

CELL DEVELOPMENT		**YEAR ENDING IN OCTOBER**														
CELL I.D.	CELL AREA TOTAL	2029			2030			2031			2032			2033		
		Open	Int Cover	Final	Open	Int Cover	Final	Open	Int Cover	Final	Open	Int Cover	Final	Open	Int Cover	Final
	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)	(Ac.)
1	7.9	0	0.0	7.9	0	0.0	7.9	0	0.0	7.9	0	0.0	7.9	0	0.0	7.9
2	6.6	0	0.0	6.6	0	0.0	6.6	0	0.0	6.6	0	0.0	6.6	0	0.0	6.6
3A	4.1	0	0.2	3.9	0	0.2	3.9	0	0.0	4.1	0	0.0	4.1	0	0.0	4.1
3B	6.1	0	0.8	5.3	0	0.8	5.3	0	0.0	6.1	0	0.0	6.1	0	0.0	6.1
4	5.8	0	0.0	5.8	0	0.0	5.8	0	0.0	5.8	0	0.0	5.8	0	0.0	5.8
5	7.7	0	0.0	7.7	0	0.0	7.7	0	0.0	7.7	0	0.0	7.7	0	0.0	7.7
6	3.8	0	0.0	3.8	0	0.0	3.8	0	0.0	3.8	0	0.0	3.8	0	0.0	3.8
7	6.6	0	0.5	6.1	0	0.5	6.1	0	0.0	6.6	0	0.0	6.6	0	0.0	6.6
8	7.5	0	0.0	7.5	0	0.0	7.5	0	0.0	7.5	0	0.0	7.5	0	0.0	7.5
9	6.5	0	0.0	6.5	0	0.0	6.5	0	0.0	6.5	0	0.0	6.5	0	0.0	6.5
10	5.2	0	0.0	5.2	0	0.0	5.2	0	0.0	5.2	0	0.0	5.2	0	0.0	5.2
11	9.3	0	1.0	8.3	0	1.0	8.3	0	0.0	9.3	0	0.0	9.3	0	0.0	9.3
12	12.6	1	11.6	0	0.1	12.5	0	0.1	7.6	4.9	0.1	7.6	4.9	0	0.0	12.6
13	11.8	0.1	11.7	0	1	10.8	0	1	10.8	0	1	10.8	0	0	0.0	11.8
14	6.7	2.1	3.4	1.2	0	5.5	1.2	0	1.6	5.1	0	1.6	5.1	0	0.0	6.7
15	6.0	6	0	0	1.6	4.4	0	1.6	2.9	1.5	1.6	2.9	1.5	0	0.0	6
16	7.1	0	0	0	7.1	0	0	7.1	0	0	7.1	0.0	0	0	0.0	7.1
Total	121.3	9.2	29.2	75.8	9.8	35.7	75.8	9.8	22.9	88.6	9.8	22.9	88.6	0.0	0.0	121.3
	53.5															
Leachate Average Annual (GPD)		14,651	18,134	6,880	15,606	22,171	6,880	15,606	14,222	8,042	15,606	14,222	8,042	0	0	11,010
		39,665			44,657			37,870			37,870			11,010		
Leachate Peak Monthly (GPD)		45,569	2,104	573	48,541	2,572	573	48,541	1,650	670	48,541	1,650	670	0	0	917
		48,246			51,686			50,861			50,861			917		
Average Annual (gpm)		28			31			26			26			8		
Peak Monthly (gpm)		34			36			35			35			1		

HELP MODEL RUNS

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\HELP3\jrl\expan\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\jrl\expan\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\jrl\expan\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\jrl\expan\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\jrl\expan\90W-FSC.D10
OUTPUT DATA FILE:           C:\HELP3\jrl\expan\90W-FSC.OUT


TIME:  10:28     DATE:  12/19/2014


******************************************************************************

     TITLE:  CASELLA - JUNIPER RIDGE EXPANSION - FINAL COVER (RUNOFF)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  12
           THICKNESS                    =    12.00   INCHES
           POROSITY                     =     0.4710 VOL/VOL
           FIELD CAPACITY               =     0.3420 VOL/VOL
           WILTING POINT                =     0.2100 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.3597 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.419999997000E-04 CM/SEC
```

```
                         LAYER  2
                         --------

               TYPE 1 - VERTICAL PERCOLATION LAYER
                   MATERIAL TEXTURE NUMBER   2
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.4370 VOL/VOL
FIELD CAPACITY              =     0.0620 VOL/VOL
WILTING POINT               =     0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.1187 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC



                         LAYER  3
                         --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                   MATERIAL TEXTURE NUMBER  20
THICKNESS                   =     0.20   INCHES
POROSITY                    =     0.8500 VOL/VOL
FIELD CAPACITY              =     0.0100 VOL/VOL
WILTING POINT               =     0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0117 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC
SLOPE                       =     5.00   PERCENT
DRAINAGE LENGTH             =   150.0    FEET



                         LAYER  4
                         --------

                 TYPE 4 - FLEXIBLE MEMBRANE LINER
                   MATERIAL TEXTURE NUMBER  35
THICKNESS                   =     0.04   INCHES
POROSITY                    =     0.0000 VOL/VOL
FIELD CAPACITY              =     0.0000 VOL/VOL
WILTING POINT               =     0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =     1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =     3.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD



                         LAYER  5
                         --------

                   TYPE 3 - BARRIER SOIL LINER
                   MATERIAL TEXTURE NUMBER  16
THICKNESS                   =    18.00   INCHES
```

```
POROSITY                    =     0.4270 VOL/VOL
FIELD CAPACITY              =     0.4180 VOL/VOL
WILTING POINT               =     0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


                       LAYER  6
                       --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   2
THICKNESS                   =     6.00   INCHES
POROSITY                    =     0.4370 VOL/VOL
FIELD CAPACITY              =     0.0620 VOL/VOL
WILTING POINT               =     0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0620 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                       LAYER  7
                       --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  18
THICKNESS                   =  1080.00   INCHES
POROSITY                    =     0.6710 VOL/VOL
FIELD CAPACITY              =     0.2920 VOL/VOL
WILTING POINT               =     0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                       LAYER  8
                       --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   1
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.4170 VOL/VOL
FIELD CAPACITY              =     0.0450 VOL/VOL
WILTING POINT               =     0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC


                       LAYER  9
                       --------
```

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 34

```
THICKNESS                    =      0.25   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   33.0000000000     CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    220.0    FEET
```

LAYER 10

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

```
THICKNESS                    =      0.08   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD
```

LAYER 11

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                    =      0.24   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC
```

LAYER 12

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4100 VOL/VOL
FIELD CAPACITY               =      0.3900 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3900 VOL/VOL
```

```
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


                    LAYER 13
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4170 VOL/VOL
FIELD CAPACITY              =      0.0450 VOL/VOL
WILTING POINT               =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC


                    LAYER 14
                    --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  20
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC
SLOPE                       =      3.00   PERCENT
DRAINAGE LENGTH             =    400.0    FEET


                    LAYER 15
                    --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                    LAYER 16
                    --------
```

```
               TYPE 1 - VERTICAL PERCOLATION LAYER
                   MATERIAL TEXTURE NUMBER   0
         THICKNESS                   =     12.00   INCHES
         POROSITY                    =      0.4100 VOL/VOL
         FIELD CAPACITY              =      0.3900 VOL/VOL
         WILTING POINT               =      0.3670 VOL/VOL
         INITIAL SOIL WATER CONTENT  =      0.3898 VOL/VOL
         EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC
```

```
             GENERAL DESIGN AND EVAPORATIVE ZONE DATA
             ----------------------------------------

       NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM A USER-
                SPECIFIED CURVE NUMBER OF 79.0, A SURFACE SLOPE
                OF  5.% AND A SLOPE LENGTH OF  200. FEET.

      SCS RUNOFF CURVE NUMBER            =     80.20
      FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
      AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
      EVAPORATIVE ZONE DEPTH             =      8.0    INCHES
      INITIAL WATER IN EVAPORATIVE ZONE  =      2.949  INCHES
      UPPER LIMIT OF EVAPORATIVE STORAGE =      3.768  INCHES
      LOWER LIMIT OF EVAPORATIVE STORAGE =      1.680  INCHES
      INITIAL SNOW WATER                 =      1.682  INCHES
      INITIAL WATER IN LAYER MATERIALS   =    339.783  INCHES
      TOTAL INITIAL WATER                =    341.465  INCHES
      TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

```
              EVAPOTRANSPIRATION AND WEATHER DATA
              -----------------------------------

       NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                BANGOR                 MAINE

           STATION LATITUDE                        =  44.80 DEGREES
           MAXIMUM LEAF AREA INDEX                 =   0.00
           START OF GROWING SEASON (JULIAN DATE)   =    134
           END OF GROWING SEASON (JULIAN DATE)     =    263
           EVAPORATIVE ZONE DEPTH                  =   8.0  INCHES
           AVERAGE ANNUAL WIND SPEED               =   8.70 MPH
           AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  70.00 %
           AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  72.00 %
           AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  77.00 %
           AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  76.00 %
```

```
       NOTE:  PRECIPITATION DATA FOR ORONO ME US ORONO ME US
                WAS ENTERED BY THE USER.
```

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BANGOR MAINE

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
23.60	16.40	27.90	43.90	53.40	57.60
66.90	72.80	55.70	37.50	31.10	8.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BANGOR MAINE
AND STATION LATITUDE = 44.80 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1980 THROUGH 2014

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.88	2.82	3.19	3.29	3.81	2.96
	3.72	3.41	3.93	3.97	4.09	2.86
STD. DEVIATIONS	1.25	1.29	1.68	1.51	1.81	1.97
	1.79	1.50	2.04	1.72	2.12	1.52
RUNOFF						
TOTALS	0.879	0.134	5.335	5.740	0.144	0.270
	0.234	0.386	0.434	0.208	0.887	0.001
STD. DEVIATIONS	1.065	0.321	3.679	5.213	0.280	0.771
	0.348	0.622	0.946	0.321	1.023	0.005
EVAPOTRANSPIRATION						
TOTALS	0.543	0.390	0.520	1.686	3.023	2.409
	2.794	2.509	2.057	1.289	0.606	0.290
STD. DEVIATIONS	0.080	0.065	0.105	0.664	0.981	1.130
	1.134	0.919	0.623	0.280	0.225	0.050
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.1057	0.0539	0.0410	0.3567	0.9113	0.5695
	0.4680	0.5947	0.8362	1.7279	1.8491	0.5237
STD. DEVIATIONS	0.0335	0.0114	0.0067	0.5192	0.6316	0.5074
	0.4388	0.5931	0.8018	1.3543	1.3987	0.5085
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 9						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 11

```
  ------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  LATERAL DRAINAGE COLLECTED FROM LAYER 14
  ----------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  PERCOLATION/LEAKAGE THROUGH LAYER 15
  ------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  PERCOLATION/LEAKAGE THROUGH LAYER 16
  ------------------------------------
    TOTALS                 0.0001   0.0001   0.0001   0.0001   0.0001   0.0001
                           0.0001   0.0001   0.0001   0.0001   0.0001   0.0001

    STD. DEVIATIONS        0.0001   0.0001   0.0001   0.0001   0.0001   0.0001
                           0.0001   0.0001   0.0001   0.0001   0.0001   0.0001


-------------------------------------------------------------------------------
             AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
    AVERAGES               0.0002   0.0001   0.0001   0.0006   0.0016   0.0010
                           0.0008   0.0010   0.0015   0.0030   0.0033   0.0009

    STD. DEVIATIONS        0.0001   0.0000   0.0000   0.0009   0.0011   0.0009
                           0.0008   0.0010   0.0014   0.0023   0.0025   0.0009

  DAILY AVERAGE HEAD ON TOP OF LAYER 10
  -------------------------------------
    AVERAGES               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  DAILY AVERAGE HEAD ON TOP OF LAYER 15
  -------------------------------------
    AVERAGES               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
```

STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1980 THROUGH 2014

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.94 (9.088)	148595.7	100.00
RUNOFF	14.653 (5.6930)	53188.82	35.794
EVAPOTRANSPIRATION	18.116 (2.7902)	65760.21	44.254
LATERAL DRAINAGE COLLECTED FROM LAYER 3	8.03750 (3.40386)	29176.137	19.63458
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00000 (0.00000)	0.014	0.00001
AVERAGE HEAD ON TOP OF LAYER 4	0.001 (0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 9	0.00000 (0.00000)	0.014	0.00001
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.00000 (0.00000)	0.001	0.00000
AVERAGE HEAD ON TOP OF LAYER 10	0.000 (0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 14	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 15	0.00000 (0.00000)	0.001	0.00000
AVERAGE HEAD ON TOP OF LAYER 15	0.000 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 16	0.00168 (0.00078)	6.095	0.00410
CHANGE IN WATER STORAGE	0.128 (4.3480)	464.41	0.313

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PEAK DAILY VALUES FOR YEARS 1980 THROUGH 2014

	(INCHES)	(CU. FT.)
PRECIPITATION	4.80	17424.000
RUNOFF	6.938	25183.8262
DRAINAGE COLLECTED FROM LAYER 3	0.90808	3296.34058
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00052
AVERAGE HEAD ON TOP OF LAYER 4	0.048	
MAXIMUM HEAD ON TOP OF LAYER 4	0.095	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	1.3 FEET	
DRAINAGE COLLECTED FROM LAYER 9	0.00000	0.00042
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.000000	0.00001
AVERAGE HEAD ON TOP OF LAYER 10	0.000	
MAXIMUM HEAD ON TOP OF LAYER 10	0.005	
LOCATION OF MAXIMUM HEAD IN LAYER 9 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 14	0.00000	0.00001
PERCOLATION/LEAKAGE THROUGH LAYER 15	0.000000	0.00001
AVERAGE HEAD ON TOP OF LAYER 15	0.000	
MAXIMUM HEAD ON TOP OF LAYER 15	0.002	
LOCATION OF MAXIMUM HEAD IN LAYER 14 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 16	0.000011	0.04033
SNOW WATER	18.00	65332.0312

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4659

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.2100

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner

by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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****

FINAL WATER STORAGE AT END OF YEAR 2014

LAYER	(INCHES)	(VOL/VOL)
1	3.9807	0.3317
2	1.1690	0.0974
3	0.0021	0.0103
4	0.0000	0.0000
5	7.6860	0.4270
6	0.3720	0.0620
7	315.3600	0.2920
8	0.5400	0.0450
9	0.0025	0.0100
10	0.0000	0.0000
11	0.1800	0.7500
12	4.6800	0.3900
13	0.5400	0.0450
14	0.0020	0.0100
15	0.0000	0.0000
16	4.6217	0.3851
SNOW WATER	6.551	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\jrl\expan\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\jrl\expan\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\jrl\expan\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\jrl\expan\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\jrl\expan\90W-TSC.D10
OUTPUT DATA FILE:           C:\HELP3\jrl\expan\90W-TSC.OUT


TIME:  10:28     DATE:  12/19/2014


******************************************************************************

     TITLE:  CASELLA - JUNIPER RIDGE EXPANSION - 18" SOIL COVER (RUNOFF)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  12
           THICKNESS                 =    18.00   INCHES
           POROSITY                  =     0.4710 VOL/VOL
           FIELD CAPACITY            =     0.3420 VOL/VOL
           WILTING POINT             =     0.2100 VOL/VOL
           INITIAL SOIL WATER CONTENT  =     0.3539 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.419999997000E-04 CM/SEC
```

```
                       LAYER  2
                       --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  18
THICKNESS                   =   1080.00   INCHES
POROSITY                    =      0.6710 VOL/VOL
FIELD CAPACITY              =      0.2920 VOL/VOL
WILTING POINT               =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2961 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                       LAYER  3
                       --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   1
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4170 VOL/VOL
FIELD CAPACITY              =      0.0450 VOL/VOL
WILTING POINT               =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1390 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC


                       LAYER  4
                       --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER  34
THICKNESS                   =      0.25   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0241 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   33.0000000000     CM/SEC
SLOPE                       =      3.00   PERCENT
DRAINAGE LENGTH             =    220.0    FEET


                       LAYER  5
                       --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.08   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  6
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.24   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC


                        LAYER  7
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4100 VOL/VOL
FIELD CAPACITY              =      0.3900 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3900 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


                        LAYER  8
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4170 VOL/VOL
FIELD CAPACITY              =      0.0450 VOL/VOL
WILTING POINT               =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC


                        LAYER  9
                        --------
```

```
              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER  20
 THICKNESS                   =      0.20   INCHES
 POROSITY                    =      0.8500 VOL/VOL
 FIELD CAPACITY              =      0.0100 VOL/VOL
 WILTING POINT               =      0.0050 VOL/VOL
 INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
 EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC
 SLOPE                       =      3.00   PERCENT
 DRAINAGE LENGTH             =    400.0    FEET


                          LAYER 10
                          --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
 THICKNESS                   =      0.06   INCHES
 POROSITY                    =      0.0000 VOL/VOL
 FIELD CAPACITY              =      0.0000 VOL/VOL
 WILTING POINT               =      0.0000 VOL/VOL
 INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
 EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
 FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
 FML INSTALLATION DEFECTS    =      3.00   HOLES/ACRE
 FML PLACEMENT QUALITY       =  3 - GOOD


                          LAYER 11
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
 THICKNESS                   =     12.00   INCHES
 POROSITY                    =      0.4100 VOL/VOL
 FIELD CAPACITY              =      0.3900 VOL/VOL
 WILTING POINT               =      0.3670 VOL/VOL
 INITIAL SOIL WATER CONTENT  =      0.3898 VOL/VOL
 EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM A USER-
         SPECIFIED CURVE NUMBER OF 79.0, A SURFACE SLOPE
         OF  5.% AND A SLOPE LENGTH OF  300. FEET.

SCS RUNOFF CURVE NUMBER             =     79.70
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
```

AREA PROJECTED ON HORIZONTAL PLANE = 1.000 ACRES
EVAPORATIVE ZONE DEPTH = 8.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 2.949 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 3.768 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.680 INCHES
INITIAL SNOW WATER = 1.682 INCHES
INITIAL WATER IN LAYER MATERIALS = 337.867 INCHES
TOTAL INITIAL WATER = 339.549 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
BANGOR MAINE

STATION LATITUDE = 44.80 DEGREES
MAXIMUM LEAF AREA INDEX = 0.00
START OF GROWING SEASON (JULIAN DATE) = 134
END OF GROWING SEASON (JULIAN DATE) = 263
EVAPORATIVE ZONE DEPTH = 8.0 INCHES
AVERAGE ANNUAL WIND SPEED = 8.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 76.00 %

NOTE: PRECIPITATION DATA FOR ORONO ME US ORONO ME US
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BANGOR MAINE

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
23.60	16.40	27.90	43.90	53.40	57.60
66.90	72.80	55.70	37.50	31.10	8.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BANGOR MAINE
AND STATION LATITUDE = 44.80 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1980 THROUGH 2014

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.88	2.82	3.19	3.29	3.81	2.96
	3.72	3.41	3.93	3.97	4.09	2.86
STD. DEVIATIONS	1.25	1.29	1.68	1.51	1.81	1.97
	1.79	1.50	2.04	1.72	2.12	1.52
RUNOFF						
TOTALS	0.779	0.126	5.352	5.798	0.139	0.266
	0.228	0.386	0.436	0.198	0.798	0.000
STD. DEVIATIONS	1.033	0.300	3.710	5.230	0.276	0.764
	0.344	0.615	0.956	0.318	0.919	0.001
EVAPOTRANSPIRATION						
TOTALS	0.543	0.390	0.520	1.681	3.018	2.414
	2.802	2.490	2.055	1.290	0.606	0.290
STD. DEVIATIONS	0.080	0.065	0.105	0.660	0.979	1.127
	1.121	0.918	0.625	0.280	0.226	0.050
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	1.2351	0.5084	0.0900	0.0796	0.8142	0.7680
	0.6053	0.4821	0.5945	0.7291	0.9266	1.5155
STD. DEVIATIONS	1.3624	0.8772	0.1112	0.1226	0.4197	0.6293
	0.6158	0.3932	0.4402	0.4904	0.5895	0.9565
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 9						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 10

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 11

TOTALS	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0016	0.0007	0.0001	0.0001	0.0010	0.0010
	0.0008	0.0006	0.0008	0.0009	0.0012	0.0019
STD. DEVIATIONS	0.0017	0.0012	0.0001	0.0002	0.0005	0.0008
	0.0008	0.0005	0.0006	0.0006	0.0008	0.0012

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1980 THROUGH 2014

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.94 (9.088)	148595.7	100.00
RUNOFF	14.508 (5.7025)	52664.98	35.442
EVAPOTRANSPIRATION	18.098 (2.7951)	65694.50	44.210
LATERAL DRAINAGE COLLECTED FROM LAYER 4	8.34838 (3.23506)	30304.613	20.39400
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000 (0.00000)	0.008	0.00001
AVERAGE HEAD ON TOP OF LAYER 5	0.001 (0.000)		

LATERAL DRAINAGE COLLECTED FROM LAYER 9	0.00000	(0.00000)	0.005	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.00000	(0.00000)	0.004	0.00000
AVERAGE HEAD ON TOP OF LAYER 10	0.000	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.00163	(0.00073)	5.909	0.00398
CHANGE IN WATER STORAGE	-0.020	(5.3236)	-74.31	-0.050

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PEAK DAILY VALUES FOR YEARS 1980 THROUGH 2014

	(INCHES)	(CU. FT.)
PRECIPITATION	4.80	17424.000
RUNOFF	6.961	25268.7363
DRAINAGE COLLECTED FROM LAYER 4	0.16193	587.80371
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 5	0.006	
MAXIMUM HEAD ON TOP OF LAYER 5	0.013	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	2.4 FEET	
DRAINAGE COLLECTED FROM LAYER 9	0.00000	0.00002
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.000000	0.00001
AVERAGE HEAD ON TOP OF LAYER 10	0.000	
MAXIMUM HEAD ON TOP OF LAYER 10	0.004	
LOCATION OF MAXIMUM HEAD IN LAYER 9 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.000011	0.04056
SNOW WATER	18.00	65332.0312

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4709
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.2100

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 2014

LAYER	(INCHES)	(VOL/VOL)
1	6.0328	0.3352
2	315.3600	0.2920
3	0.9015	0.0751
4	0.0026	0.0102
5	0.0000	0.0000
6	0.1800	0.7500
7	4.6800	0.3900
8	0.5400	0.0450
9	0.0020	0.0100
10	0.0000	0.0000
11	4.6237	0.3853
SNOW WATER	6.551	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                   **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\HELP3\jrl\expan\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\jrl\expan\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\jrl\expan\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\jrl\expan\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\jrl\expan\90W-WRO.D10
OUTPUT DATA FILE:           C:\HELP3\jrl\expan\90W-WRO.OUT


TIME:  14:48     DATE:  12/22/2014


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     TITLE:  CASELLA - JUNIPER RIDGE EXPANSION - OPEN (90' WASTE) WITH RUNOFF

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                            MATERIAL TEXTURE NUMBER  18
           THICKNESS                   =   1080.00   INCHES
           POROSITY                    =      0.6710 VOL/VOL
           FIELD CAPACITY              =      0.2920 VOL/VOL
           WILTING POINT               =      0.0770 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2950 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
```

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                    LAYER  2
                    --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1388 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC



                    LAYER  3
                    --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER  34
THICKNESS                    =      0.25   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0240 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   33.0000000000     CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    220.0    FEET



                    LAYER  4
                    --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.08   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD



                    LAYER  5
                    --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.24   INCHES
```

```
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
```

```
                        LAYER  6
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4100 VOL/VOL
FIELD CAPACITY              =      0.3900 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3900 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC
```

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                        LAYER  7
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4170 VOL/VOL
FIELD CAPACITY              =      0.0450 VOL/VOL
WILTING POINT               =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC
```

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                        LAYER  8
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  20
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC
SLOPE                       =      3.00   PERCENT
DRAINAGE LENGTH             =    400.0    FEET
```

```
                        LAYER  9
```

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

```
THICKNESS                   =     0.06   INCHES
POROSITY                    =     0.0000 VOL/VOL
FIELD CAPACITY              =     0.0000 VOL/VOL
WILTING POINT               =     0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =     1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =     3.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD
```

LAYER 10

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.4100 VOL/VOL
FIELD CAPACITY              =     0.3900 VOL/VOL
WILTING POINT               =     0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.3898 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

```
NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM A USER-
         SPECIFIED CURVE NUMBER OF 55.0, A SURFACE SLOPE
         OF  5.% AND A SLOPE LENGTH OF  300. FEET.

SCS RUNOFF CURVE NUMBER             =     57.00
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =      8.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      2.133  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      5.368  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.616  INCHES
INITIAL SNOW WATER                  =      1.682  INCHES
INITIAL WATER IN LAYER MATERIALS    =    330.338  INCHES
TOTAL INITIAL WATER                 =    332.020  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
BANGOR MAINE

STATION LATITUDE	=	44.80 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	134
END OF GROWING SEASON (JULIAN DATE)	=	263
EVAPORATIVE ZONE DEPTH	=	8.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	8.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00 %

NOTE: PRECIPITATION DATA FOR ORONO ME US ORONO ME US
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BANGOR MAINE

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
23.60	16.40	27.90	43.90	53.40	57.60
66.90	72.80	55.70	37.50	31.10	8.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BANGOR MAINE
AND STATION LATITUDE = 44.80 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1980 THROUGH 2014

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.88	2.82	3.19	3.29	3.81	2.96
	3.72	3.41	3.93	3.97	4.09	2.86
STD. DEVIATIONS	1.25	1.29	1.68	1.51	1.81	1.97
	1.79	1.50	2.04	1.72	2.12	1.52
RUNOFF						
TOTALS	0.518	0.071	4.494	5.290	0.004	0.004
	0.000	0.000	0.007	0.006	0.369	0.000
STD. DEVIATIONS	0.779	0.187	3.583	4.864	0.021	0.020
	0.000	0.003	0.043	0.033	0.626	0.000
EVAPOTRANSPIRATION						
TOTALS	0.543	0.390	0.520	1.782	3.403	2.698
	2.997	2.801	2.189	1.307	0.605	0.290
STD. DEVIATIONS	0.080	0.065	0.105	0.696	1.021	1.257
	1.216	1.037	0.663	0.277	0.225	0.050
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	1.1969	0.4281	0.1791	0.1826	1.8790	1.1510
	0.7463	0.5900	0.5977	0.8538	1.1432	1.6963
STD. DEVIATIONS	1.3740	0.7964	0.5663	0.3565	0.5135	1.0050
	0.9290	0.6513	0.5997	0.6822	0.7108	1.1343
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 8						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 10

TOTALS	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0015	0.0006	0.0002	0.0002	0.0024	0.0015
	0.0009	0.0007	0.0008	0.0011	0.0015	0.0021
STD. DEVIATIONS	0.0017	0.0011	0.0007	0.0005	0.0006	0.0013
	0.0012	0.0008	0.0008	0.0009	0.0009	0.0014

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1980 THROUGH 2014

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.94 (9.088)	148595.7	100.00
RUNOFF	10.762 (4.7361)	39067.38	26.291
EVAPOTRANSPIRATION	19.526 (3.1060)	70878.08	47.699
LATERAL DRAINAGE COLLECTED FROM LAYER 3	10.64406 (4.27971)	38637.953	26.00207
PERCOLATION/LEAKAGE THROUGH	0.00000 (0.00000)	0.009	0.00001

LAYER 5

AVERAGE HEAD ON TOP OF LAYER 4	0.001 (	0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.00000 (	0.00000)	0.005	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00000 (	0.00000)	0.004	0.00000
AVERAGE HEAD ON TOP OF LAYER 9	0.000 (	0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.00165 (	0.00075)	6.000	0.00404
CHANGE IN WATER STORAGE	0.002 (	5.9432)	6.28	0.004

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PEAK DAILY VALUES FOR YEARS 1980 THROUGH 2014

	(INCHES)	(CU. FT.)
PRECIPITATION	4.80	17424.000
RUNOFF	6.771	24580.2773
DRAINAGE COLLECTED FROM LAYER 3	0.17874	648.81573
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 4	0.007	
MAXIMUM HEAD ON TOP OF LAYER 4	0.014	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.00000	0.00002
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 9	0.000	
MAXIMUM HEAD ON TOP OF LAYER 9	0.004	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.000011	0.04059
SNOW WATER	18.00	65332.0312

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.6541

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0770

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 2014

LAYER	(INCHES)	(VOL/VOL)
1	314.5916	0.2913
2	0.9073	0.0756
3	0.0026	0.0102
4	0.0000	0.0000
5	0.1800	0.7500
6	4.6800	0.3900
7	0.5400	0.0450
8	0.0020	0.0100
9	0.0000	0.0000
10	4.6228	0.3852
SNOW WATER	6.551	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\HELP3\jrl\expan\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\jrl\expan\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\jrl\expan\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\jrl\expan\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\jrl\expan\10W-WRO.D10
OUTPUT DATA FILE:           C:\HELP3\jrl\expan\10W-WRO.OUT


TIME:  10:28     DATE:  12/19/2014


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     TITLE:  CASELLA - JUNIPER RIDGE EXPANSION - OPEN (10' WASTE)

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  18
           THICKNESS                 =    120.00   INCHES
           POROSITY                  =      0.6710 VOL/VOL
           FIELD CAPACITY            =      0.2920 VOL/VOL
           WILTING POINT             =      0.0770 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2903 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
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                    LAYER  2
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                    =    12.00   INCHES
POROSITY                     =     0.4170 VOL/VOL
FIELD CAPACITY               =     0.0450 VOL/VOL
WILTING POINT                =     0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.1082 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC



                    LAYER  3
                    --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  34
THICKNESS                    =     0.25   INCHES
POROSITY                     =     0.8500 VOL/VOL
FIELD CAPACITY               =     0.0100 VOL/VOL
WILTING POINT                =     0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.0140 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   33.0000000000     CM/SEC
SLOPE                        =     3.00   PERCENT
DRAINAGE LENGTH              =   220.0    FEET



                    LAYER  4
                    --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =     0.08   INCHES
POROSITY                     =     0.0000 VOL/VOL
FIELD CAPACITY               =     0.0000 VOL/VOL
WILTING POINT                =     0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =     1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =     3.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD



                    LAYER  5
                    --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     0.24   INCHES
```

```
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC


                        LAYER  6
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4100 VOL/VOL
FIELD CAPACITY               =      0.3900 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3900 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC


                        LAYER  7
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC


                        LAYER  8
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER  20
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   10.0000000000     CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    400.0    FEET


                        LAYER  9
```

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

```
THICKNESS                   =     0.06   INCHES
POROSITY                    =     0.0000 VOL/VOL
FIELD CAPACITY              =     0.0000 VOL/VOL
WILTING POINT               =     0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =     1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =     3.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD
```

LAYER 10

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.4100 VOL/VOL
FIELD CAPACITY              =     0.3900 VOL/VOL
WILTING POINT               =     0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.3898 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM A USER-SPECIFIED CURVE NUMBER OF 55.0, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 300. FEET.

```
SCS RUNOFF CURVE NUMBER              =     57.00
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      1.000  ACRES
EVAPORATIVE ZONE DEPTH               =      8.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      2.133  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =      5.368  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      0.616  INCHES
INITIAL SNOW WATER                   =      1.682  INCHES
INITIAL WATER IN LAYER MATERIALS     =     46.218  INCHES
TOTAL INITIAL WATER                  =     47.900  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

```
NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         BANGOR                MAINE

    STATION LATITUDE                         =  44.80 DEGREES
    MAXIMUM LEAF AREA INDEX                  =   0.00
    START OF GROWING SEASON (JULIAN DATE)    =    134
    END OF GROWING SEASON (JULIAN DATE)      =    263
    EVAPORATIVE ZONE DEPTH                   =   8.0  INCHES
    AVERAGE ANNUAL WIND SPEED                =   8.70 MPH
    AVERAGE 1ST QUARTER RELATIVE HUMIDITY    =  70.00 %
    AVERAGE 2ND QUARTER RELATIVE HUMIDITY    =  72.00 %
    AVERAGE 3RD QUARTER RELATIVE HUMIDITY    =  77.00 %
    AVERAGE 4TH QUARTER RELATIVE HUMIDITY    =  76.00 %


NOTE:  PRECIPITATION DATA FOR ORONO ME US ORONO ME US
         WAS ENTERED BY THE USER.


NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    BANGOR              MAINE

    NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)
```

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
23.60	16.40	27.90	43.90	53.40	57.60
66.90	72.80	55.70	37.50	31.10	8.90

```
NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    BANGOR              MAINE
           AND STATION LATITUDE  =  44.80 DEGREES
```

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1980 THROUGH 2014

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.88	2.82	3.19	3.29	3.81	2.96
	3.72	3.41	3.93	3.97	4.09	2.86
STD. DEVIATIONS	1.25	1.29	1.68	1.51	1.81	1.97
	1.79	1.50	2.04	1.72	2.12	1.52
RUNOFF						
TOTALS	0.518	0.071	4.494	5.290	0.004	0.004
	0.000	0.000	0.007	0.006	0.369	0.000
STD. DEVIATIONS	0.779	0.187	3.583	4.864	0.021	0.020
	0.000	0.003	0.043	0.033	0.626	0.000
EVAPOTRANSPIRATION						
TOTALS	0.543	0.390	0.520	1.782	3.403	2.698
	2.997	2.801	2.189	1.307	0.605	0.290
STD. DEVIATIONS	0.080	0.065	0.105	0.696	1.021	1.257
	1.216	1.037	0.663	0.277	0.225	0.050
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.2006	0.0577	0.0396	0.3929	2.3427	0.7989
	0.4419	0.5739	0.6518	1.2647	2.0238	1.7412
STD. DEVIATIONS	0.2170	0.0178	0.0088	0.6278	0.7247	0.9432
	0.6359	0.7059	0.8157	1.3462	1.5733	1.4444
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 8						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 9						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 10

TOTALS	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0003	0.0001	0.0001	0.0005	0.0030	0.0010
	0.0006	0.0007	0.0009	0.0016	0.0026	0.0022
STD. DEVIATIONS	0.0003	0.0000	0.0000	0.0008	0.0009	0.0012
	0.0008	0.0009	0.0011	0.0017	0.0021	0.0018

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****
****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1980 THROUGH 2014

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.94 (9.088)	148595.7	100.00
RUNOFF	10.762 (4.7361)	39067.38	26.291
EVAPOTRANSPIRATION	19.526 (3.1060)	70878.08	47.699
LATERAL DRAINAGE COLLECTED FROM LAYER 3	10.52969 (4.53332)	38222.777	25.72267
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00000 (0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 4	0.001 (0.000)		

LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.00000 (	0.00000)	0.004	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00000 (	0.00000)	0.005	0.00000
AVERAGE HEAD ON TOP OF LAYER 9	0.000 (	0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.00166 (	0.00076)	6.035	0.00406
CHANGE IN WATER STORAGE	0.116 (	4.4486)	421.42	0.284

****
****

PEAK DAILY VALUES FOR YEARS 1980 THROUGH 2014

	(INCHES)	(CU. FT.)
PRECIPITATION	4.80	17424.000
RUNOFF	6.771	24580.2773
DRAINAGE COLLECTED FROM LAYER 3	0.47826	1736.09839
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00005
AVERAGE HEAD ON TOP OF LAYER 4	0.019	
MAXIMUM HEAD ON TOP OF LAYER 4	0.038	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.00000	0.00002
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 9	0.000	
MAXIMUM HEAD ON TOP OF LAYER 9	0.004	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.000011	0.04045
SNOW WATER	18.00	65332.0312

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.6541
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0770

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****
****

FINAL WATER STORAGE AT END OF YEAR 2014

LAYER	(INCHES)	(VOL/VOL)
1	34.2717	0.2856
2	0.8815	0.0735
3	0.0025	0.0102
4	0.0000	0.0000
5	0.1800	0.7500
6	4.6800	0.3900
7	0.5400	0.0450
8	0.0020	0.0100
9	0.0000	0.0000
10	4.6224	0.3852
SNOW WATER	6.551	

****
****

APPENDIX D

DESIGN CALCULATIONS

APPENDIX D-1

PIPE STRENGTH DESIGN

Buried Pipe Design: Strength Calculations

Project : Expansion, Juniper Ridge Landfill, Old Town, Maine

Calc By: Peter Mailey **Date: April 2015**

Checked BY: KPN **Date:** 6/1/2015

Pipe Location: Along Access Road

Pipe Size/Material: 10"ϕ HDPE DR 17 Carrier Pipe

Pipe Function: Containment Pipe for force main under roadway sections

References:

1. Moser A.P.; Buried Pipe Design; Second Ed.; 2001; Chapters 2, 3 & 4

2. Chevron Phillps Chemical Company LC; Engineering Manual; 2003; Chapter 7 Buried Pipe Design.

3. Asahi/America; Engineering Design Guide for Thermoplastic Piping Systems; 2002

PIPE DATA:

Outside Diameter: $OD := 10.75 \cdot in$

Dimension Ratio $DR := 17$

Inside Diameter: $ID := OD \cdot \left[1 - \left(\frac{2.12}{DR}\right)\right]$ $ID = 9.409 \cdot in$

Wall Thickness: $t := \frac{OD}{DR}$ $t = 0.632 \cdot in$

Material Modulus of Elasticity: $E_{pipe} := 100000 \cdot \frac{lb}{in^2}$

Maximum Allowable Stress: (Hydrostatic Design Stress) $\sigma_d := 992 \cdot \frac{lb}{in^2}$

Poisson's Ratio: $\upsilon := 0.35$

BURIAL CONDITIONS:

Depth of Pipe Crown: $H := 4 \cdot ft$ Below Ground Surface

Depth of Phreatic Surface: (if above pipe crown) $H_w := 0 \cdot ft$ Below Ground Surface

Unit Weight of Overburden: $\gamma_s := 120 \cdot \frac{lb}{ft^3}$

Soil Reaction Modulus: (Iowa Formula from Table Below) $E_{soil} := 3000 \cdot \frac{lb}{in^2}$

Table 7-7 Bureau of Reclamation Average Values for E′ for Iowa Formula (Initial Deflection)

Soil type—pipe bedding material (Unified Classification)[1]	E′ for Degree of Bedding Compaction, lb/in²			
	Dumped	Slight: <85% Proctor, <40% relative density	Moderate: 85% - 95% Proctor, 40% - 70% relative density	High: >95% Proctor, >70% relative density
Fine-grained Soils (LL > 50)[2] Soils with medium to high plasticity CH, MH, CH-MH	No data available: consult a competent soils engineer, otherwise, use E′ = 0			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, CL-ML, with less than 25% coarse-grained particles	50	200	400	1000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, CL-ML, with more than 25% coarse-grained particles Coarse-grained Soils with Fines GM, GC, SM, SC[3] contains more than 12% fines	100	400	1000	2000
Coarse-grained Soils with Little or No Fines GW, GP, SW, SP[3] contains less than 12% fines	200	1000	2000	3000
Crushed Rock	1000	3000	3000	3000
Accuracy in Terms of Percentage Deflection[4]	±2%	±2%	±1%	±0.5%

1 ASTM D 2487, USBR Designation E-3
2 LL = Liquid Limit
3 Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC).
4 For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only; appropriate Deflection Lag Factor must be applied for long term deflections. If bedding falls on the borderline between two compaction categories, select lower E′ value, or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using 12,500 ft-lb/cu ft (598,000 J/m³) (ASTM D-698, AASHTO T-99, USBR Designation E-11). 1 psi = 6.9 KPa.

Unit Weigt of Water: $\gamma_w := 62.4 \cdot \frac{lb}{ft^3}$

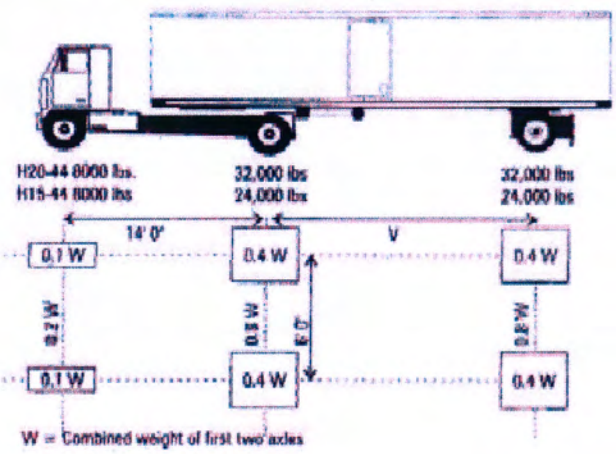
DEAD LOAD:

Soil Prism Load:

$$P_s := \gamma_s \cdot H \qquad P_s = 480 \cdot \frac{lb}{ft^2}$$

Highway Load:

Figure 7-8 AASHTO Standard HS20 Static Loading



Wheel Load: $W_l := 16000 \cdot lb$ Per Wheel (AASHTO HS20)

Impact Factor: $I_i := 1.5$

Single Wheel Load:

Halls Integration of Boussinesq Equation

Pipe Length: $L := 3 \cdot ft$
(3 ft. maximum)

Load Coefficient:

D/2H:

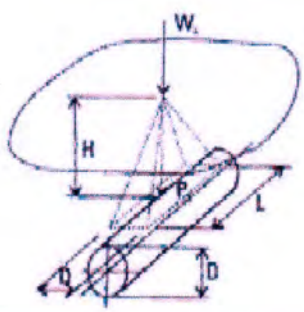
$$\frac{OD}{2 \cdot H} = 0.112$$

L/2H:

$$\frac{L}{2 \cdot H} = 0.375$$

Use the above to determine/interpolate the Load Coefficient Cs from the chart below

$$C_s := .071$$

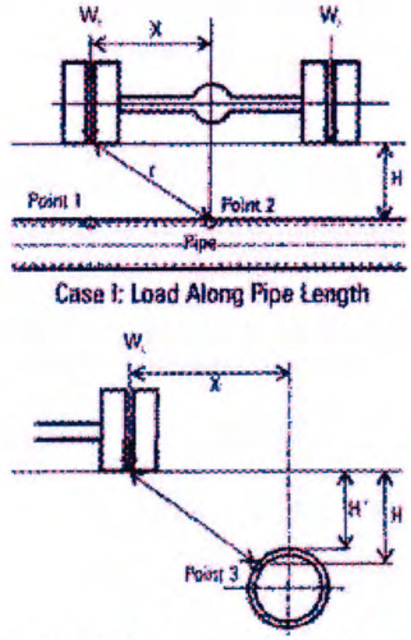


D/2H	L/2H													
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	20.0
0.1	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112	0.117	0.121	0.124	0.127
0.2	0.037	0.072	0.103	0.131	0.155	0.174	0.189	0.202	0.211	0.219	0.229	0.238	0.244	0.248
0.3	0.053	0.103	0.149	0.190	0.224	0.252	0.274	0.292	0.306	0.318	0.333	0.346	0.355	0.361
0.4	0.067	0.131	0.190	0.241	0.284	0.320	0.349	0.373	0.391	0.405	0.425	0.442	0.454	0.462
0.5	0.079	0.155	0.224	0.284	0.336	0.379	0.414	0.441	0.463	0.481	0.505	0.525	0.540	0.550
0.6	0.089	0.174	0.252	0.320	0.379	0.428	0.467	0.499	0.524	0.544	0.572	0.596	0.613	0.625
0.7	0.097	0.189	0.274	0.349	0.414	0.467	0.511	0.546	0.574	0.597	0.628	0.655	0.674	0.688
0.8	0.103	0.202	0.292	0.373	0.441	0.499	0.546	0.584	0.615	0.639	0.674	0.703	0.725	0.740
0.9	0.108	0.211	0.306	0.391	0.463	0.524	0.574	0.615	0.647	0.673	0.711	0.743	0.766	0.783
1.0	0.112	0.219	0.318	0.405	0.481	0.544	0.597	0.639	0.673	0.701	0.740	0.775	0.800	0.818
1.2	0.117	0.229	0.333	0.425	0.505	0.572	0.628	0.674	0.711	0.740	0.783	0.821	0.849	0.871
1.5	0.121	0.238	0.346	0.422	0.525	0.596	0.655	0.703	0.743	0.775	0.821	0.863	0.895	0.920
2.0	0.124	0.244	0.355	0.454	0.540	0.613	0.674	0.725	0.766	0.800	0.849	0.895	0.930	0.960
20.0	0.127	0.248	0.361	0.462	0.550	0.625	0.688	0.740	0.783	0.818	0.871	0.920	0.960	1.000

Single Wheel Highway Live Load: $P_{hl1} := \frac{C_s \cdot W_l \cdot I_i}{L \cdot OD}$

Dual Wheel Load: Multiple Wheels along Length $P_{hl1} = 634.05 \cdot \frac{lb}{ft^2}$

Figure 7-10 Concentrated Point Load



Case II: Load At Horizontal Distance From Pipe

Wheel Axle Length: $A := 6 \cdot ft$
(typ. 6 ft. for H20 Trucks)

Point Load location Mid Axle $x := \frac{A}{2}$

Distance to the Point of Load Application: $r := \sqrt{x^2 + H^2}$

Dual Wheel Highway Live Load: $P_{hl2} := 2 \cdot \left(\frac{3 \cdot I_i \cdot W_l \cdot H^3}{2 \cdot \pi \cdot r^5} \right)$

$P_{hl2} = 469.37 \frac{lb}{ft^2}$

Use the Largest Calculated Wheel Load

$$P_{HL} := \begin{vmatrix} P_{hl2} & \text{if } P_{hl2} > P_{hl1} \\ P_{hl1} & \text{otherwise} \end{vmatrix}$$

Highway Live Load $P_{HL} = 634.05 \frac{lb}{ft^2}$

TOTAL LOAD ON PIPE:

$$P_T := P_s + P_{HL}$$

$$P_T = 1.114 \cdot 10^3 \cdot \frac{lb}{ft^2}$$

PIPE STRENGTH:

WALL CRUSHING:

Wall Stress: $\sigma_{wall} := \frac{P_T \cdot OD}{2 \cdot t}$ $\sigma_{wall} = 65.76 \cdot \frac{lb}{in^2}$ < 992 psi

Factor of Safety Against Crushing:

$$FS_{crush} := \frac{\sigma_d}{\sigma_{wall}} \qquad FS_{crush} = 15.1$$

WALL BUCKLING:

Safety Factor: $N := 2$

Bouyancy Reduction Factor:

$$R_w := 1 - \left(0.33 \cdot \frac{H - H_w}{H}\right) \qquad R_w = 0.67$$

Elastic Support Factor:

$$B := \frac{4 \cdot \left(H^2 + OD \cdot H\right)}{1.5 \cdot (2 \cdot H + OD)^2} \qquad B = 0.66$$

Allowable Buckling Pressure:

$$P_{wc} := \frac{1}{N} \cdot \sqrt{32 \cdot R_w \cdot B \cdot E_{soil} \cdot \frac{E_{pipe}}{12 \cdot (DR - 1)^3}}$$

$$P_{wc} = 2.116 \cdot 10^4 \cdot \frac{lb}{ft^2}$$

Does Pipe Prevent Buckling:

$$check := \begin{cases} 1 & \text{if } P_{wc} > P_T \\ 0 & \text{otherwise} \end{cases}$$

$check = 1$

Check = 1 if pipe strength is sufficient
Check = 0 if pipe buckles under load

Factor of Safety Against Buckling:

$$FS_b := \frac{P_{wc}}{P_T}$$

$FS_b = 19$

Ring Deflection:

Bedding Factor:
(Typ 0.1)

$K := 0.1$

Deflection Lag Factor:
(Typ 1.0 for prism load)

$D_L := 1$

Deflection (Inches per Inch of Pipe Diameter):

$$\Delta := P_T \cdot \left[\frac{K \cdot D_L}{\left(\frac{2 \cdot E_{pipe}}{3}\right) \cdot \left(\frac{1}{DR - 1}\right)^3 + 0.061 \cdot E_{soil}} \right]$$

$\Delta = 3.882 \cdot 10^{-3}$

Deflection (Percentage of Pipe Diameter):

$\Delta\% := \Delta \cdot 100$

$\Delta\% = 0.388$ %

Ring Bending Strain:

Deformation Shape Factor: (Typ 6.0 for design) $f_d := 6$

Distance from Outer Fiber to Wall Centroid: $C := 0.5 \cdot (1.06 \cdot t)$

Mean Pipe Diameter: $D_m := OD - t$

Bending Strain

$$\varepsilon := f_d \cdot \Delta \cdot \frac{2 \cdot C}{D_m}$$

$$\varepsilon = 0.002$$

$$\varepsilon\% := \varepsilon \cdot 100$$

$$\varepsilon\% = 0.154 \quad \%$$

Bending Strain: < 4.2% OK for non-pressure Pipe

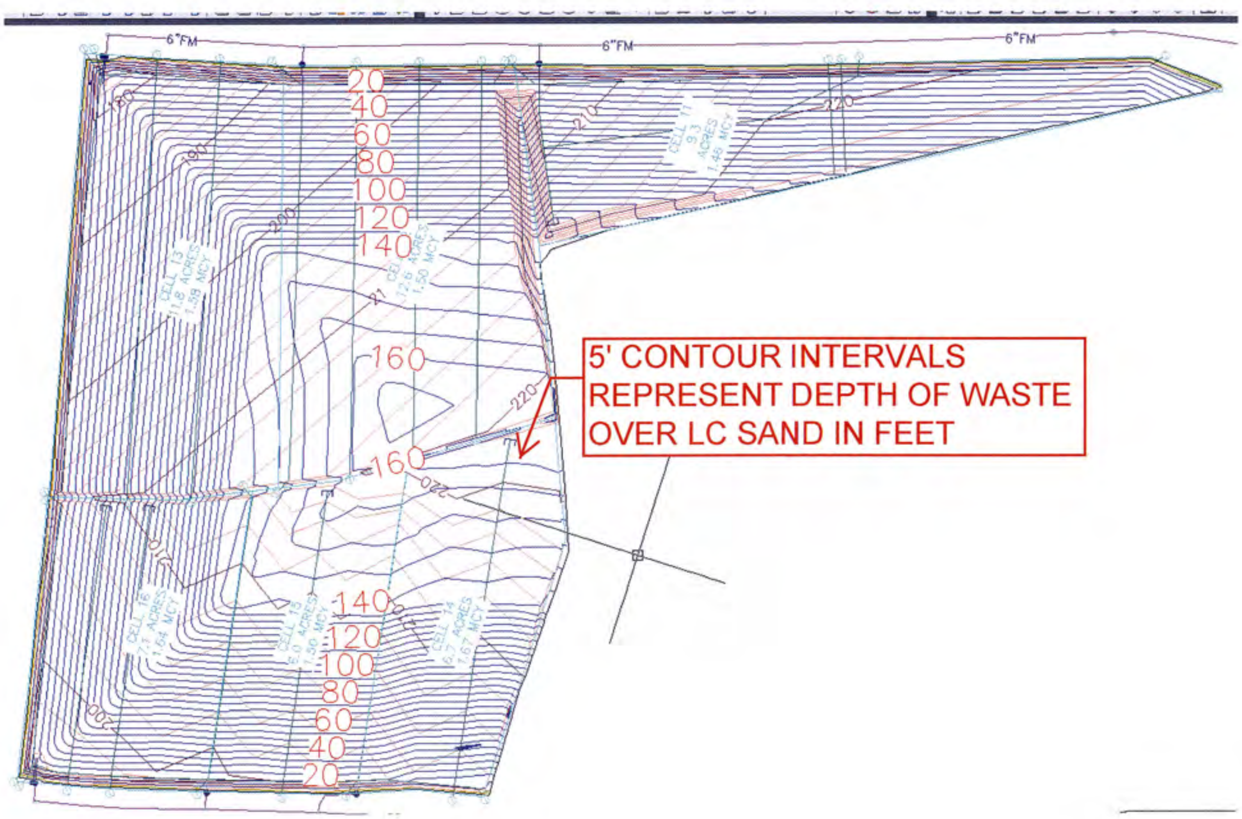
Waste Depth over LC Sand
Volumes by Triangulation (Prisms) Mon Apr 13 05:52:23 2015
Existing Surface: \\Nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Acad\Carlson\SURFACES\P-EXPANSION(9.35MCY)-TOP-LC-SAND-JAN2015.tin
Final Surface: \\Nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Acad\Carlson\SURFACES\P-EXPANSION(9.35MCY)-TOW-JAN2015.tin

Cut volume: 102.0 C.F., 3.78 C.Y.
Fill volume: 201,551,192.7 C.F., 7,464,858.99 C.Y.

Area in Cut : 178.6 S.F., 0.00 Acres
Area in Fill: 2,288,267.2 S.F., 52.53 Acres
Total inclusion area: 2,288,445.8 S.F., 52.54 Acres

Average Fill Depth: 88.08 feet
Cut to Fill ratio: 0.00
Import Volume: 7,464,855.2 C.Y.
Elevation Change To Reach Balance: -88.073
Volume Change Per .1 ft: 8,475.7 C.Y.

Cut (C.Y.) / Area (acres): 0.07
Fill (C.Y.) / Area (acres): 142091.75



PIPE CALCULATIONS
EFFECTIVE WALL THICKNESS OF PERFORATED PIPE

PROJECT: Juniper Ridge Landfill Expansion
CLIENT: NEWSME

CALC. BY: PCM **DATE: APRIL 2015**
CHECKED BY KPW **DATE** 06/01/2015

Pipe Information

$OD := 4.5 \cdot in$ **Pipe Outside Diameter (inches)**

$DR := 11$ **Pipe Dimension Ratio**

Perforations

$Dperf := 0.5 \cdot in$ **Diameter of perforations (inches)**

$Nperf := 3$ **Number of rows perforations in 12 inch wall cross section (Assumed to be cut through center of holes longitudinally through pipe)**

Calculations

$Tmin := \frac{OD}{DR}$ **Minimum wall thickness (inches)**

$Tmin = 0.409 \cdot in$

$Aperf := Dperf \cdot Tmin \cdot Nperf$ **Cross sectional area of perforations per 12" segement (sq. in.)**

$Aperf = 0.614 \cdot in^2$

$Apipe := Tmin \cdot (12 \cdot in)$ **Wall area without perforations (sq. in.)**

$Apipe = 4.909 \cdot in^2$

$Aeff := Apipe - Aperf$ **Effective area (reduced by area of perforations)**

$Aeff = 4.295 \cdot in^2$

$Teff := \frac{Aeff}{12 \cdot in}$ **Resulting effective wall thickness in the 12 inch segment**

$Teff = 0.358 \cdot in$

$DReff := \frac{OD}{Teff}$ **Effective DR due to theoretical wall area reduction**

$DReff = 12.571$

Pipe Calculations
Pipe Strength in Deep Fill

Pipe Location: Juniper Ridge Landfill Expansion Underdrain
Pipe Size & Type: 4" dia. SDR 11 HDPE Perforated Pipe

Project: Juniper Ridge Landfill Expansion
Calc. by: PCM   Date: April 2015
Date 06/01/2015 **Checked by** KPW

References:

1. Plexco, Guidelines for HDPE Pipes in Deep Fills 1998

Project Parameters

Depth of Overburden $\mathbf{H} := 160 \cdot \mathbf{ft}$

Depth of Waste Over Pipe $\mathbf{D}_{\mathbf{waste}} := 150 \cdot \mathbf{ft}$

Depth of Soil over Pipe $\mathbf{D}_{\mathbf{soil}} := 10 \cdot \mathbf{ft}$

Depth of groundwater $\mathbf{Hgw} := 0 \cdot \mathbf{ft}$

Unit weight of waste $\gamma\mathbf{w} := 85 \cdot \frac{\mathbf{lbf}}{\mathbf{ft}^3}$

Unit weight of soil $\gamma\mathbf{s} := 125 \cdot \frac{\mathbf{lbf}}{\mathbf{ft}^3}$

Hyperbolic Parameter:

Modulus Number $\mathbf{k} := 100$

Modulus Exponent $\mathbf{n} := 0.4$

(for 90% Compaction)

Pipe Parameters:

Effective DR: $\mathbf{DR} := 12.571$

Long term compressive yield strenght $\mathbf{Sc} := 1600 \cdot \mathbf{psi}$

Outside Diameter $\mathbf{OD} := 4.50 \cdot \mathbf{in}$

Short Term Modulus: $\mathbf{Estm} := 110000 \cdot \mathbf{psi}$

Long Term Modulus: $\mathbf{El} := 28200 \cdot \mathbf{psi}$

Poisson Ratio of Soil: $\mu := .35$

Temperature Design Factor: $\mathbf{f} := 1.0$

(for 100 deg. F)

Overbuden weight

Weighted soil/waste unit weight $\gamma\mathbf{wt} := \gamma\mathbf{w} \cdot \frac{\mathbf{D}_{\mathbf{waste}}}{\mathbf{H}} + \gamma\mathbf{s} \cdot \frac{\mathbf{D}_{\mathbf{soil}}}{\mathbf{H}}$

$\gamma\mathbf{wt} = 87.5 \cdot \frac{\mathbf{lbf}}{\mathbf{ft}^3}$

Pipe Dimensional Parameters

Pipe Wall Thickness $\mathbf{t} := \frac{\mathbf{OD}}{\mathbf{DR}}$ $\quad \mathbf{t} = 0.358 \cdot \mathbf{in}$

Mean Radius $\mathbf{r} := \frac{\mathbf{OD} - \mathbf{t}}{2}$ $\quad \mathbf{r} = 2.071 \cdot \mathbf{in}$

Long Term Compressive Yeild Strength due to Temperture

$\mathbf{Sct} := \mathbf{Sc} \cdot \mathbf{f}$ $\quad \mathbf{Sct} = 1.6 \cdot 10^3 \cdot \mathbf{psi}$

Constrained Modulus

$\mathbf{Ms} := \mathbf{k} \cdot 14.7 \cdot \mathbf{psi} \cdot \left(\gamma\mathbf{wt} \cdot \frac{\mathbf{H}}{14.7 \cdot \mathbf{psi}}\right)^{\mathbf{n}}$ $\quad \mathbf{Ms} = 3.13 \cdot 10^3 \cdot \mathbf{psi}$

Hoop Thrust Stiffness

$$\mathbf{Sa} := \frac{1.43}{\mathbf{El}\cdot\mathbf{t}}\cdot\mathbf{Ms}\cdot\mathbf{r} \qquad \mathbf{Sa} = 0.918$$

Vertical Arching Factor, (Eq. 1 of "Guidelines for HDPE Pipes in Deep Fills")

$$\mathbf{VAF} := .88 - .71\cdot\left(\frac{\mathbf{Sa} - 1}{\mathbf{Sa} + 2.5}\right) \qquad \mathbf{VAF} = 0.897$$

Radial Direct Earth Pressure, Eq. 3a for Deep Fills

$$\mathbf{Prd} := \mathbf{VAF}\cdot\gamma\mathbf{wt}\cdot\mathbf{H} \qquad \mathbf{Prd} = 1.256\cdot10^{4}\,\frac{\mathbf{lbf}}{\mathbf{ft}^2}$$

Ring Compressive Stress, Eq. 4 for Deep Fills

$$\mathbf{S} := \frac{\mathbf{Prd}\cdot\mathbf{DR}}{\left[\frac{288\cdot(\mathbf{in})^2}{\mathbf{ft}^2}\right]} \qquad \mathbf{S} = 548.145\,\mathbf{psi} \qquad \mathbf{N} := \frac{\mathbf{Sct}}{\mathbf{S}} \qquad \mathbf{N} = 2.9$$

Safety Factor

Watkins - Gaube Deflection

Secant Modulus, Eq. 6

$$\mathbf{Es} := \frac{\mathbf{Ms}\cdot(1+\mu)\cdot(1-2\cdot\mu)}{1-\mu} \qquad \mathbf{Es} = 1.95\cdot10^{3}\,\mathbf{psi}$$

Rigity, Eq. 5

$$\mathbf{Rf} := \frac{12\cdot\mathbf{Es}\cdot(\mathbf{DR}-1)^3}{\mathbf{El}} \qquad \mathbf{Rf} = 1.286\cdot10^{3}$$

****Input Df factor from Figure 1 Guidlines for HDPE Pipe in Deep Fills****Plexco

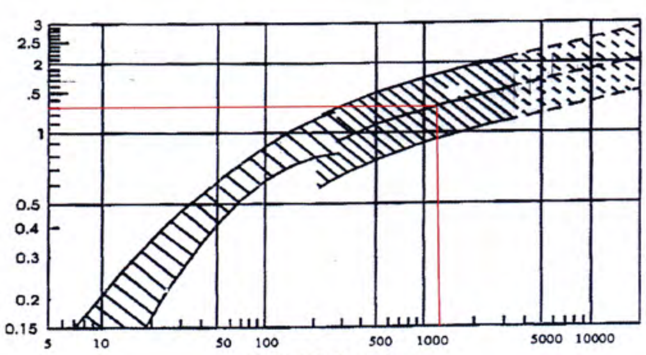


Figure 1. Rigidity Factor vs Deformation Factor
If D_f is less than one on graph, use D_f =1.

$\mathbf{Df} := 1.30$

Soil Strain (Settlement of Fill Layer at pipe), Eq. 7

$$\varepsilon s := \frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right) \cdot Es} \qquad \varepsilon s = 5 \circ \%$$

Pipe Deflection

$\mathbf{DEFL} := \mathbf{Df} \cdot \varepsilon s \qquad \mathbf{DEFL} = 6.5 \circ \%$ **Not to exceed 7.5% for design.**

Allowable Deflection, Eq. 9

$\mathbf{e} := .05$

$\mathbf{fD} := 4.28$ **Deformaton factor for shape**

Allowable Deflection=$\Delta Y / D$

$$\mathbf{Dallow} := \frac{e}{fD} \cdot (DR - 1) \qquad \mathbf{Dallow} = 13.5 \circ \%$$

Constrained Buckling (Use Prism Load with VAF=1),Eq. 11

$\mathbf{Rh} := 1$ **Geometry Factor**

$\mathbf{Cf} := .8$ **Construction Factor**

$\phi := .55$ **Calibration Factor**

Pcr **Pressure Critical - psi**

$$\mathbf{Pcr} := \frac{Cf \cdot \phi \cdot Rh \cdot EI^{\frac{1}{3}} \cdot \left(\frac{Es}{1 - \mu}\right)^{\frac{2}{3}}}{DR - 1} \qquad \mathbf{Pcr} = 240.758 \circ psi$$

$$\mathbf{SF} := \frac{Pcr}{\left[\frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right)}\right]} \qquad \mathbf{SF} = 2.5$$

Safety Factor against Buckling

$2 \le SF \le 4$ **Guidlines for HDPE Pipe in Deep Fills****Plexco**

PIPE CALCULATIONS
EFFECTIVE WALL THICKNESS OF PERFORATED PIPE

PROJECT: Juniper Ridge Landfill Expansion
CLIENT: NEWSME

CALC. BY: PCM **DATE: APRIL 2015**
CHECKED BY KPN **DATE** 06/01/2015

Pipe Information

$OD := 6.625 \cdot in$ **Pipe Outside Diameter (inches)**

$DR := 11$ **Pipe Dimension Ratio**

Perforations

$Dperf := 0.5 \cdot in$ **Diameter of perforations (inches)**

$Nperf := 3$ **Number of rows perforations in 12 inch wall cross section (Assumed to be cut through center of holes longitudinally through pipe)**

Calculations

$Tmin := \frac{OD}{DR}$ **Minimum wall thickness (inches)**

$Tmin = 0.602 \cdot in$

$Aperf := Dperf \cdot Tmin \cdot Nperf$ **Cross sectional area of perforations per 12" segement (sq. in.)**

$Aperf = 0.903 \cdot in^2$

$Apipe := Tmin \cdot (12 \cdot in)$ **Wall area without perforations (sq. in.)**

$Apipe = 7.227 \cdot in^2$

$Aeff := Apipe - Aperf$ **Effective area (reduced by area of perforations)**

$Aeff = 6.324 \cdot in^2$

$Teff := \frac{Aeff}{12 \cdot in}$ **Resulting effective wall thickness in the 12 inch segment**

$Teff = 0.527 \cdot in$

$DReff := \frac{OD}{Teff}$ **Effective DR due to theoretical wall area reduction**

$DReff = 12.571$

Pipe Calculations
Pipe Strength in Deep Fill

Pipe Location: Leachate Collection Laterals
Pipe Size & Type: 6" dia. SDR 11 HDPE Perforated Pipe

Project: Juniper Ridge Landfill Expansion
Calc. by: PCM Date: April 2015
Date KPN **Checked by** 06/01/2015

References:

1. Plexco, Guidelines for HDPE Pipes in Deep Fills 1998

Project Parameters

Depth of Overburden $H := 170 \cdot ft$

Depth of Waste Over Pipe $D_{waste} := 165 \cdot ft$

Depth of Soil over Pipe $D_{soil} := 5.0 \cdot ft$

Depth of groundwater $Hgw := 0 \cdot ft$

Unit weight of waste $\gamma w := 85 \cdot \frac{lbf}{ft^3}$

Unit weight of soil $\gamma s := 125 \cdot \frac{lbf}{ft^3}$

Hyperbolic Parameter:

Modulus Number $k := 100$

Modulus Exponent $n := 0.4$

(for 90% Compaction)

Pipe Parameters:

Effective DR: $DR := 12.571$

Long term compressive yield strenght $Sc := 1600 \cdot psi$

Outside Diameter $OD := 6.625 \cdot in$

Short Term Modulus: $Estm := 110000 \cdot psi$

Long Term Modulus: $El := 28200 \cdot psi$

Poisson Ratio of Soil: $\mu := .35$

Temperature Design Factor: $f := 1.0$

(for 100 deg. F)

Overbuden weight

Weighted soil/waste unit weight

$$\gamma wt := \gamma w \cdot \frac{D_{waste}}{H} + \gamma s \cdot \frac{D_{soil}}{H}$$

$$\gamma wt = 86.176 \cdot \frac{lbf}{ft^3}$$

Pipe Dimensional Parameters

Pipe Wall Thickness $t := \frac{OD}{DR}$ $\quad t = 0.527 \cdot in$

Mean Radius $r := \frac{OD - t}{2}$ $\quad r = 3.049 \cdot in$

Long Term Compressive Yeild Strength due to Temperture

$Sct := Sc \cdot f$ $\quad Sct = 1.6 \cdot 10^3 \cdot psi$

Constrained Modulus

$$Ms := k \cdot 14.7 \cdot psi \cdot \left(\gamma wt \cdot \frac{H}{14.7 \cdot psi} \right)^n \qquad Ms = 3.187 \cdot 10^3 \cdot psi$$

Hoop Thrust Stiffness

$$\mathbf{Sa} := \frac{1.43}{\mathbf{El} \cdot \mathbf{t}} \cdot \mathbf{Ms} \cdot \mathbf{r} \qquad \mathbf{Sa} = 0.935$$

Vertical Arching Factor, (Eq. 1 of "Guidelines for HDPE Pipes in Deep Fills")

$$\mathbf{VAF} := .88 - .71 \cdot \left(\frac{\mathbf{Sa} - 1}{\mathbf{Sa} + 2.5} \right) \qquad \mathbf{VAF} = 0.893$$

Radial Direct Earth Pressure, Eq. 3a for Deep Fills

$$\mathbf{Prd} := \mathbf{VAF} \cdot \gamma \mathbf{wt} \cdot \mathbf{H} \qquad \mathbf{Prd} = 1.309 \cdot 10^{4} \circ \frac{\mathbf{lbf}}{\mathbf{ft}^2}$$

Ring Compressive Stress, Eq. 4 for Deep Fills

$$\mathbf{S} := \frac{\mathbf{Prd} \cdot \mathbf{DR}}{\left[\frac{288 \cdot (\mathbf{in})^2}{\mathbf{ft}^2} \right]} \qquad \mathbf{S} = 571.318 \circ \mathbf{psi} \qquad \mathbf{N} := \frac{\mathbf{Sct}}{\mathbf{S}} \qquad \mathbf{N} = 2.8$$

Safety Factor

Watkins - Gaube Deflection

Secant Modulus, Eq. 6

$$\mathbf{Es} := \frac{\mathbf{Ms} \cdot (1 + \mu) \cdot (1 - 2 \cdot \mu)}{1 - \mu} \qquad \mathbf{Es} = 1.986 \cdot 10^{3} \circ \mathbf{psi}$$

Rigity, Eq. 5

$$\mathbf{Rf} := \frac{12 \cdot \mathbf{Es} \cdot (\mathbf{DR} - 1)^3}{\mathbf{El}} \qquad \mathbf{Rf} = 1.309 \cdot 10^{3}$$

****Input Df factor from Figure 1 Guidlines for HDPE Pipe in Deep Fills****

Plexco

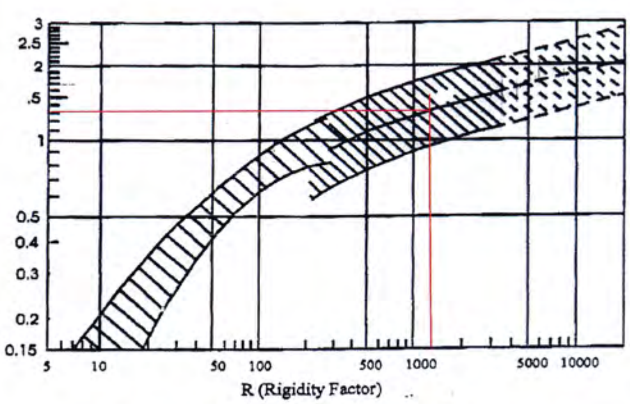


Figure 1. Rigidity Factor vs Deformation Factor
If D_f is less than one on graph, use D_f =1.

$$Df := 1.32$$

Soil Strain (Settlement of Fill Layer at pipe), Eq. 7

$$\varepsilon s := \frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right) \cdot Es} \qquad \varepsilon s = 5.1 \cdot \%$$

Pipe Deflection

$$DEFL := Df \cdot \varepsilon s \qquad DEFL = 6.8 \cdot \%$$

Not to exceed 7.5% for design.

Allowable Deflection, Eq. 9

$$e := .05$$

$fD := 4.28$ **Deformaton factor for shape**

Allowable Deflection=$\Delta Y / Dm$

$$Dallow := \frac{e}{fD} \cdot (DR - 1) \qquad Dallow = 13.5 \cdot \%$$

Constrained Buckling (Use Prism Load with VAF=1),Eq. 11

$Rh := 1$ **Geometry Factor**

$Cf := .8$ **Construction Factor**

$\phi := .55$ **Calibration Factor**

Pcr **Pressure Critical - psi**

$$Pcr := \frac{Cf \cdot \phi \cdot Rh \cdot EI^{\frac{1}{3}} \cdot \left(\frac{Es}{1 - \mu}\right)^{\frac{2}{3}}}{DR - 1} \qquad Pcr = 243.69 \cdot psi$$

$$SF := \frac{Pcr}{\left[\frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right)}\right]} \qquad SF = 2.4$$

Safety Factor against Buckling

$2 \le SF \le 4$ **Guidlines for HDPE Pipe in Deep Fills****Plexco**

Pipe Calculations
Pipe Strength in Deep Fill

Pipe Location: Juniper Ridge Landfill Expansion LD PIPE
Pipe Size & Type: 6" dia. SDR 11 HDPE Perforated Pipe

Project: Juniper Ridge Landfill Expansion
Calc. by: PCM **Date: April 2015**
Date 06/01/2015 **Checked by** KPW

Project Parameters

Depth of Overburden $\mathbf{H} := 170 \cdot \mathbf{ft}$

Depth of Waste Over Pipe $\mathbf{D}_{\mathbf{waste}} := 163 \cdot \mathbf{ft}$

Depth of Soil over Pipe $\mathbf{D}_{\mathbf{soil}} := 7.0 \cdot \mathbf{ft}$

Depth of groundwater $\mathbf{Hgw} := 0 \cdot \mathbf{ft}$

Unit weight of waste $\gamma\mathbf{w} := 85 \cdot \frac{\mathbf{lbf}}{\mathbf{ft}^3}$

Unit weight of soil $\gamma\mathbf{s} := 125 \cdot \frac{\mathbf{lbf}}{\mathbf{ft}^3}$

Hyperbolic Parameter:

Modulus Number $\mathbf{k} := 100$

Modulus Exponent $\mathbf{n} := 0.4$

(for 90% Compaction)

References:

1. Plexco, Guidelines for HDPE Pipes in Deep Fills 1998

Pipe Parameters:

Effective DR: $\mathbf{DR} := 12.571$

Long term compressive yield strenght $\mathbf{Sc} := 1600 \cdot \mathbf{psi}$

Outside Diameter $\mathbf{OD} := 6.625 \cdot \mathbf{in}$

Short Term Modulus: $\mathbf{Estm} := 110000 \cdot \mathbf{psi}$

Long Term Modulus: $\mathbf{El} := 28200 \cdot \mathbf{psi}$

Poisson Ratio of Soil: $\mu := .35$

Temperature Design Factor: $\mathbf{f} := 1.0$

(for 100 deg. F)

Overbuden weight

Weighted soil/waste unit weight

$$\gamma\mathbf{wt} := \gamma\mathbf{w} \cdot \frac{\mathbf{D}_{\mathbf{waste}}}{\mathbf{H}} + \gamma\mathbf{s} \cdot \frac{\mathbf{D}_{\mathbf{soil}}}{\mathbf{H}}$$

$$\gamma\mathbf{wt} = 86.647 \cdot \frac{\mathbf{lbf}}{\mathbf{ft}^3}$$

Pipe Dimensional Parameters

Pipe Wall Thickness $\mathbf{t} := \frac{\mathbf{OD}}{\mathbf{DR}}$ $\mathbf{t} = 0.527 \cdot \mathbf{in}$

Mean Radius $\mathbf{r} := \frac{\mathbf{OD} - \mathbf{t}}{2}$ $\mathbf{r} = 3.049 \cdot \mathbf{in}$

Long Term Compressive Yeild Strength due to Temperture

$\mathbf{Sct} := \mathbf{Sc} \cdot \mathbf{f}$ $\mathbf{Sct} = 1.6 \cdot 10^3 \cdot \mathbf{psi}$

Constrained Modulus

$\mathbf{Ms} := \mathbf{k} \cdot 14.7 \cdot \mathbf{psi} \cdot \left(\gamma\mathbf{wt} \cdot \frac{\mathbf{H}}{14.7 \cdot \mathbf{psi}}\right)^{\mathbf{n}}$ $\mathbf{Ms} = 3.194 \cdot 10^3 \cdot \mathbf{psi}$

Hoop Thrust Stiffness

$$\mathbf{Sa} := \frac{1.43}{\mathbf{El \cdot t}} \cdot \mathbf{Ms \cdot r} \qquad \mathbf{Sa} = 0.937$$

Vertical Arching Factor, (Eq. 1 of "Guidelines for HDPE Pipes in Deep Fills")

$$\mathbf{VAF} := .88 - .71 \cdot \left(\frac{\mathbf{Sa} - 1}{\mathbf{Sa} + 2.5} \right) \qquad \mathbf{VAF} = 0.893$$

Radial Direct Earth Pressure, Eq. 3a for Deep Fills

$$\mathbf{Prd} := \mathbf{VAF \cdot \gamma wt \cdot H} \qquad \mathbf{Prd} = 1.315 \cdot 10^4 \cdot \frac{\mathbf{lbf}}{\mathbf{ft}^2}$$

Ring Compressive Stress, Eq. 4 for Deep Fills

$$\mathbf{S} := \frac{\mathbf{Prd \cdot DR}}{\left[\frac{288 \cdot (\mathbf{in})^2}{\mathbf{ft}^2} \right]} \qquad \mathbf{S} = 574.162 \cdot \mathbf{psi} \qquad \mathbf{N} := \frac{\mathbf{Sct}}{\mathbf{S}} \qquad \mathbf{N} = 2.8$$

Safety Factor

Watkins - Gaube Deflection

Secant Modulus, Eq. 6

$$\mathbf{Es} := \frac{\mathbf{Ms} \cdot (1 + \mu) \cdot (1 - 2 \cdot \mu)}{1 - \mu} \qquad \mathbf{Es} = 1.99 \cdot 10^3 \cdot \mathbf{psi}$$

Rigity, Eq. 5

$$\mathbf{Rf} := \frac{12 \cdot \mathbf{Es} \cdot (\mathbf{DR} - 1)^3}{\mathbf{El}} \qquad \mathbf{Rf} = 1.312 \cdot 10^3$$

****Input Df factor from Figure 1 Guidlines for HDPE Pipe in Deep Fills**** Plexco

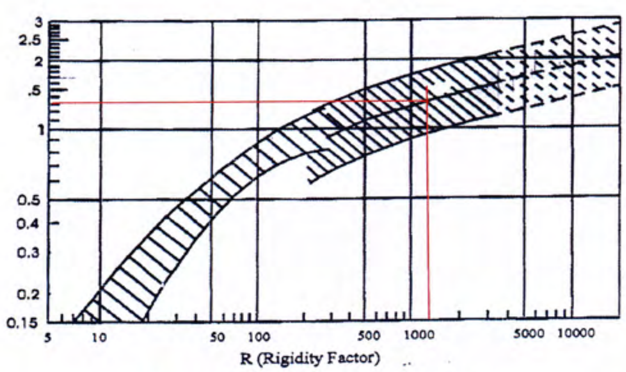


Figure 1. Rigidity Factor vs Deformation Factor
If D_f is less than one on graph, use D_f =1.

$$Df := 1.32$$

Soil Strain (Settlement of Fill Layer at pipe), Eq. 7

$$\varepsilon s := \frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right) \cdot Es} \qquad \varepsilon s = 5.1 \circ \%$$

Pipe Deflection

$$DEFL := Df \cdot \varepsilon s \qquad DEFL = 6.8 \circ \%$$

Not to exceed 7.5% for design.

Allowable Deflection, Eq. 9

$$e := .05$$

$fD := 4.28$ **Deformaton factor for shape**

Allowable Deflection=$\Delta Y / Dr$

$$Dallow := \frac{e}{fD} \cdot (DR - 1) \qquad Dallow = 13.5 \circ \%$$

Constrained Buckling (Use Prism Load with VAF=1),Eq. 11

$Rh := 1$ **Geometry Factor**

$Cf := .8$ **Construction Factor**

$\phi := .55$ **Calibration Factor**

Pcr **Pressure Critical - psi**

$$Pcr := \frac{Cf \cdot \phi \cdot Rh \cdot EI^{\frac{1}{3}} \cdot \left(\frac{Es}{1 - \mu}\right)^{\frac{2}{3}}}{DR - 1} \qquad Pcr = 244.044 \circ psi$$

$$SF := \frac{Pcr}{\left[\frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right)}\right]} \qquad SF = 2.4$$

Safety Factor against Buckling

$2 \le SF \le 4$ **Guidlines for HDPE Pipe in Deep Fills****Plexco**

PIPE CALCULATIONS
EFFECTIVE WALL THICKNESS OF PERFORATED PIPE

PROJECT: Juniper Ridge Landfill Expansion
CLIENT: NEWSME

CALC. BY: PCM **DATE: April 2015**
CHECKED BY KPN **DATE** 06/01/2015

Pipe Information

OD := 12·in **Pipe Outside Diameter (inches)**

DR := 17 **Pipe Dimension Ratio**

Perforations

Dperf := 0.625·in **Diameter of perforations (inches)**

Nperf := 12 **Number of rows perforations in 12 inch wall cross section (Assumed to be cut through center of holes longitudinally through pipe)**

Calculations

$Tmin := \frac{OD}{DR}$ **Minimum wall thickness (inches)**

Tmin = 0.706·in

Aperf := Dperf·Tmin·Nperf **Cross sectional area of perforations per 12" segement (sq. in.)**

$Aperf = 5.294 \cdot in^2$

Apipe := Tmin·(12·in) **Wall area without perforations (sq. in.)**

$Apipe = 8.471 \cdot in^2$

Aeff := Apipe − Aperf **Effective area (reduced by area of perforations)**

$Aeff = 3.176 \cdot in^2$

$Teff := \frac{Aeff}{12 \cdot in}$ **Resulting effective wall thickness in the 12 inch segment**

Teff = 0.265·in

$DReff := \frac{OD}{Teff}$ **Effective DR due to theoretical wall area reduction**

DReff = 45.333

Pipe Calculations
Pipe Strength in Deep Fill

Pipe Location: Leachate Collection Header Pipe
Pipe Size & Type: 8" dia. SDR 11, HDPE, Perforated

Project: Juniper Ridge Landfill Expansion
Calc. by: PCM Date: April 2015
Date 06/01/2015 **Checked by** KPW

Project Parameters

References:
1. Plexco, Guidelines for HDPE Pipes in Deep Fills 1998

Depth of Overburden $H := 170 \cdot ft$

Depth of Waste Over Pipe $D_{waste} := 165\ ft$

Depth of Soil over Pipe $D_{soil} := 5 \cdot ft$

Depth of groundwater $Hgw := 0 \cdot ft$

Unit weight of waste $\gamma w := 85 \cdot \frac{lbf}{ft^3}$

Unit weight of soil $\gamma s := 125 \cdot \frac{lbf}{ft^3}$

Hyperbolic Parameter:

Modulus Number $k := 100$

Modulus Exponent $n := 0.4$

(for 90% Compaction)

Pipe Parameters:

Effective DR: $DR := 12.57$

Long term compressive yield strenght $Sc := 1600 \cdot psi$

Outside Diameter $OD := 8.625 \cdot in$

Short Term Modulus: $Estm := 110000 \cdot psi$

Long Term Modulus: $El := 28200 \cdot psi$

Poisson Ratio of Soil: $\mu := .35$

Temperature Design Factor: $f := 1.0$

(for 100 deg. F)

Overbuden weight

Weighted soil/waste unit weight

$$\gamma wt := \gamma w \cdot \frac{D_{waste}}{H} + \gamma s \cdot \frac{D_{soil}}{H}$$

$$\gamma wt = 86.176 \cdot \frac{lbf}{ft^3}$$

Pipe Dimensional Parameters

Pipe Wall Thickness $t := \frac{OD}{DR}$ $\quad t = 0.686 \cdot in$

Mean Radius $r := \frac{OD - t}{2}$ $\quad r = 3.969 \cdot in$

Long Term Compressive Yeild Strength due to Temperture

$Sct := Sc \cdot f$ $\quad Sct = 1.6 \cdot 10^3 \cdot psi$

Constrained Modulus

$$Ms := k \cdot 14.7 \cdot psi \cdot \left(\gamma wt \cdot \frac{H}{14.7 \cdot psi}\right)^n \qquad Ms = 3.187 \cdot 10^3 \cdot psi$$

Hoop Thrust Stiffness

$$Sa := \frac{1.43}{El \cdot t} \cdot Ms \cdot r \qquad Sa = 0.935$$

Vertical Arching Factor, (Eq. 1 of "Guidelines for HDPE Pipes in Deep Fills")

$$VAF := .88 - .71 \cdot \left(\frac{Sa - 1}{Sa + 2.5}\right) \qquad VAF = 0.893$$

Radial Direct Earth Pressure, Eq. 3a for Deep Fills

$$Prd := VAF \cdot \gamma wt \cdot H \qquad Prd = 1.309 \cdot 10^4 \cdot \frac{lbf}{ft^2}$$

Ring Compressive Stress, Eq. 4 for Deep Fills

$$S := \frac{Prd \cdot DR}{\left[\frac{288 \cdot (in)^2}{ft^2}\right]} \qquad S = 571.284 \cdot psi \qquad N := \frac{Sct}{S} \qquad N = 2.8$$

Safety Factor

Watkins - Gaube Deflection

Secant Modulus, Eq. 6

$$Es := \frac{Ms \cdot (1 + \mu) \cdot (1 - 2 \cdot \mu)}{1 - \mu} \qquad Es = 1.986 \cdot 10^3 \cdot psi$$

Rigity, Eq. 5

$$Rf := \frac{12 \cdot Es \cdot (DR - 1)^3}{El} \qquad Rf = 1.309 \cdot 10^3$$

******Input Df factor from Figure 1** **Guidlines for HDPE Pipe in Deep Fills * Plexco**

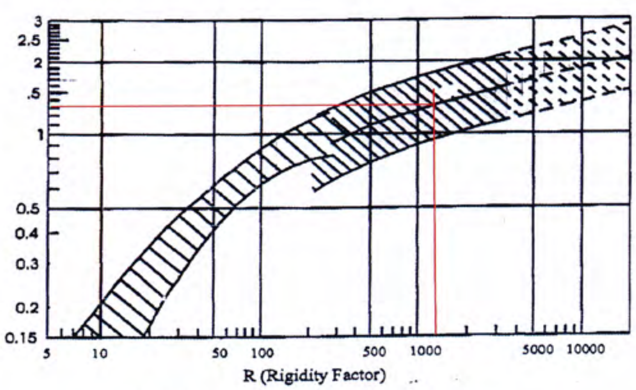


Figure 1. Rigidity Factor vs Deformation Factor
If D_f is less than one on graph, use D_f =1.

$$Df := 1.32$$

Soil Strain (Settlement of Fill Layer at pipe), Eq. 7

$$\varepsilon s := \frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right) \cdot Es} \qquad \varepsilon s = 5.1 \cdot \%$$

Pipe Deflection

$DEFL := Df \cdot \varepsilon s$ $\qquad DEFL = 6.8 \cdot \%$ **Not to exceed 7.5% for design.**

Allowable Deflection, Eq. 9

$$e := .05$$

$fD := 4.28$ **Deformaton factor for shape**

Allowable Deflection=ΔY/ r

$$Dallow := \frac{e}{fD} \cdot (DR - 1) \qquad Dallow = 13.5 \cdot \%$$

Constrained Buckling (Use Prism Load with VAF=1),Eq. 11

$Rh := 1$ **Geometry Factor**

$Cf := .8$ **Construction Factor**

$\phi := .55$ **Calibration Factor**

Pcr **Pressure Critical - psi**

$$Pcr := \frac{Cf \cdot \phi \cdot Rh \cdot El^{\frac{1}{3}} \cdot \left(\frac{Es}{1 - \mu}\right)^{\frac{2}{3}}}{DR - 1} \qquad Pcr = 243.711 \cdot psi$$

$$SF := \frac{Pcr}{\left[\frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right)}\right]} \qquad SF = 2.4$$

Safety Factor against Buckling

$2 \le SF \le 4$ **Guidlines for HDPE Pipe in Deep Fills****Plexco**

PIPE CALCULATIONS
EFFECTIVE WALL THICKNESS OF PERFORATED PIPE

PROJECT: Juniper Ridge Landfill Expansion
CLIENT: NEWSME

CALC. BY: PCM **DATE:** APRIL 2015
CHECKED BY KPN **DATE** 06/01/2015

Pipe Information

$OD := 8.625 \cdot in$ **Pipe Outside Diameter (inches)**

$DR := 11$ **Pipe Dimension Ratio**

Perforations

$Dperf := 0.5 \cdot in$ **Diameter of perforations (inches)**

$Nperf := 3$ **Number of rows perforations in 12 inch wall cross section (Assumed to be cut through center of holes longitudinally through pipe)**

Calculations

$Tmin := \frac{OD}{DR}$ **Minimum wall thickness (inches)**

$Tmin = 0.784 \cdot in$

$Aperf := Dperf \cdot Tmin \cdot Nperf$ **Cross sectional area of perforations per 12" segement (sq. in.)**

$Aperf = 1.176 \cdot in^2$

$Apipe := Tmin \cdot (12 \cdot in)$ **Wall area without perforations (sq. in.)**

$Apipe = 9.409 \cdot in^2$

$Aeff := Apipe - Aperf$ **Effective area (reduced by area of perforations)**

$Aeff = 8.233 \cdot in^2$

$Teff := \frac{Aeff}{12 \cdot in}$ **Resulting effective wall thickness in the 12 inch segment**

$Teff = 0.686 \cdot in$

$DReff := \frac{OD}{Teff}$ **Effective DR due to theoretical wall area reduction**

$DReff = 12.571$

Pipe Calculations
Pipe Strength in Shallow Fill

Pipe Location: Along Perimeter Berms (worst case)
Pipe Size & Type: 8"ϕ HDPE SDR 11 Perforated

Project: JRL Expansion
Calc. by: PCM **Date: April 2015**
Date 06/21/2015 **Checked by** KPW

References:

1. Chevron Phillps Chemical Company LC; Plexco Engineering Manual; 2003; Chapter 7 Buried Pipe Design.

Project Parameters

Depth of Overburden $H := 40 \cdot ft$

Depth of groundwater $Hgw := 0 \cdot ft$

Unit weight of waste $\gamma w := 85 \cdot \frac{lbf}{ft^3}$

Unit weight of soil $\gamma s := 125 \cdot \frac{lbf}{ft^3}$

Backfill Soil Modulus $Es := 3000 \cdot psi$

(for 90% Compaction in crushed stone)

Bedding Factor $K := .1$

Pipe Parameters:

Effective DR: $DR := 12.571$

Outside Diameter $OD := 8.625 \cdot in$

Short Term Modulus: $Estm := 100000 \cdot psi$

Long Term Modulus: $El := 23000 \cdot psi$

Pipe thickness $t := 0.507 \cdot in$

Base natural log (2.71828) $e := 2.71828$

Deflection Lag Factor $D := 1.5$

Calculations

Overbuden weight

Weighted soil/waste unit weight

$$\gamma wt := \gamma w \cdot \frac{30 \cdot ft}{H} + \gamma s \cdot \frac{10 \cdot ft}{H}$$

$$\gamma wt = 95 \cdot \frac{lbf}{ft^3}$$

Constrained Buckling ,(from Plexco design manual, Eq. 29)

Bouyancy Reduction Factor

$R := 1$

Moment of Inertia

$$I := \frac{t^3}{12} \qquad I = 0.011 \cdot in^3$$

$$B := \frac{1}{1 + 4 \cdot e^{(-.065 \cdot 16)}} \qquad B = 0.414$$

$Dm := OD - 1.06 \cdot t$ $\quad Dm = 8.088 \cdot in$ **Mean Pipe Diameter**

$N := 1$ **Safety Factor**

$Pwc := \left(\sqrt{R \cdot B \cdot Es \cdot El \cdot \frac{I}{Dm^3}}\right) \cdot \left(\frac{5.65}{N}\right)$ $\quad Pwc = 136.872 \cdot psi$ **Critical Wall Pressure**

$SF := \frac{Pwc}{\left[\frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right)}\right]}$ $\quad SF = 5.187$ **Safety Factor against Buckling**

Pipe Deflection, (from Plexco Application Note No. 1)

$Rm := \frac{OD - t}{2}$ $\quad Rm = 4.059 \cdot in$ **Mean Pipe Radius**

$PS := \frac{Estm \cdot I}{.149 \cdot Rm^3}$ $\quad PS = 108.993 \cdot psi$ **Pipe Stiffness**

$W := \frac{H \cdot OD \cdot \gamma wt}{144 \cdot \frac{in^2}{ft^2}}$ $\quad W = 227.604 \cdot \frac{lbf}{in}$ **Load on Pipe**

$x := \frac{K \cdot D \cdot W}{.149 \cdot PS + .061 \cdot Es}$ $\quad x = 0.171 \cdot in$ **Deflection**

$\%Deflection := \frac{x}{OD} \cdot 100$ $\quad \%Deflection = 1.987$

PIPE CALCULATIONS
EFFECTIVE WALL THICKNESS OF PERFORATED PIPE

PROJECT: Juniper Ridge Landfill Expansion
CLIENT: NEWSME

CALC. BY: PCM **DATE: April 2015**
CHECKED BY KPM **DATE** 06/01/2015

Pipe Information

$OD := 12 \cdot in$ **Pipe Outside Diameter (inches)**

$DR := 17$ **Pipe Dimension Ratio**

Perforations

$Dperf := 0.625 \cdot in$ **Diameter of perforations (inches)**

$Nperf := 12$ **Number of rows perforations in 12 inch wall cross section (Assumed to be cut through center of holes longitudinally through pipe)**

Calculations

$Tmin := \frac{OD}{DR}$ **Minimum wall thickness (inches)**

$Tmin = 0.706 \cdot in$

$Aperf := Dperf \cdot Tmin \cdot Nperf$ **Cross sectional area of perforations per 12" segement (sq. in.)**

$Aperf = 5.294 \cdot in^2$

$Apipe := Tmin \cdot (12 \cdot in)$ **Wall area without perforations (sq. in.)**

$Apipe = 8.471 \cdot in^2$

$Aeff := Apipe - Aperf$ **Effective area (reduced by area of perforations)**

$Aeff = 3.176 \cdot in^2$

$Teff := \frac{Aeff}{12 \cdot in}$ **Resulting effective wall thickness in the 12 inch segment**

$Teff = 0.265 \cdot in$

$DReff := \frac{OD}{Teff}$ **Effective DR due to theoretical wall area reduction**

$DReff = 45.333$

Pipe Calculations **Pipe Location: Temp. & Permanent Sumps (Leak Detection)**

Pipe Strength in Shallow Fill **Pipe Size & Type: 12"ϕ HDPE SDR 17 Perforated**

Project: Juniper Ridge Landfill Expansion
Calc. by: PCM **Date: April 2015**
Date 06/01/2015 **Checked by** KPN

References:

1. Chevron Phillps Chemical Company LC; Plexco Engineering Manual; 2003; Chapter 7 Buried Pipe Design.

Project Parameters

Depth of Overburden $H := 42 \cdot ft$

Depth of groundwater $Hgw := 0 \cdot ft$

Unit weight of waste $\gamma w := 85 \cdot \frac{lbf}{ft^3}$

Unit weight of soil $\gamma s := 125 \cdot \frac{lbf}{ft^3}$

Backfill Soil Modulus $Es := 3000 \cdot psi$

(for 90% Compaction in crushed stone)

Bedding Factor $K := .1$

Pipe Parameters:

Effective DR: $DR := 45.3$

Outside Diameter $OD := 12.0 \cdot in$

Short Term Modulus: $Estm := 100000 \cdot psi$

Long Term Modulus: $El := 23000 \cdot psi$

Pipe thickness $t := 0.75 \cdot in$

Base natural log (2.71828) $e := 2.71828$

Deflection Lag Factor $D := 1.5$

Calculations

Overbuden weight

Weighted soil/waste unit weight $\gamma wt := \gamma w \cdot \frac{30 \cdot ft}{H} + \gamma s \cdot \frac{12 \cdot ft}{H}$

$$\gamma wt = 96.429 \cdot \frac{lbf}{ft^3}$$

Constrained Buckling ,(from Plexco design manual, Eq. 29)

Bouyancy Reduction Factor

$R := 1$

Moment of Inertia

$I := \frac{t^3}{12}$ $I = 0.035 \cdot in^3$

$B := \frac{1}{1 + 4 \cdot e^{(-.065 \cdot 16)}}$ $B = 0.414$

$Dm := OD - 1.06 \cdot t$ $\qquad Dm = 11.205 \cdot in$ **Mean Pipe Diameter**

$N := 1$ **Safety Factor**

$$Pwc := \left(\sqrt{R \cdot B \cdot Es \cdot El \cdot \frac{I}{Dm^3}}\right) \cdot \left(\frac{5.65}{N}\right)$$ $Pwc = 151.009 \cdot psi$ **Critical Wall Pressure**

$$SF := \frac{Pwc}{\left[\frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right)}\right]}$$ $SF = 5.369$ **Safety Factor against Buckling**

Pipe Deflection, (from Plexco Application Note No. 1)

$Rm := \frac{OD - t}{2}$ $\qquad Rm = 5.625 \cdot in$ **Mean Pipe Radius**

$PS := \frac{Estm \cdot I}{.149 \cdot Rm^3}$ $\qquad PS = 132.571 \cdot psi$ **Pipe Stiffness**

$W := \frac{H \cdot OD \cdot \gamma wt}{144 \cdot \frac{in^2}{ft^2}}$ $\qquad W = 337.5 \cdot \frac{lbf}{in}$ **Load on Pipe**

$x := \frac{K \cdot D \cdot W}{.149 \cdot PS + .061 \cdot Es}$ $\qquad x = 0.25 \cdot in$ **Deflection**

$\%Deflection := \frac{x}{OD} \cdot 100$ $\qquad \%Deflection = 2.081$

PIPE CALCULATIONS
EFFECTIVE WALL THICKNESS OF 24" ϕ SDR 17 PERFORATED PIPE

PROJECT: 9.35 Million CY Expansion JRL
CALC. BY: PCM **DATE: APRIL 2015**
DATE 6/01/2015 **CHECKED BY** KPN

Pipe Information

$OD := 24 \cdot in$	**Pipe Outside Diameter (inches)**
$DR := 17$	**Pipe Dimension Ratio**

Perforations

$Dperf := 0.625 \cdot in$	**Diameter of perforations (inches)**
$Nperf := 12$	**Number of perforations per foot**

Calculations

$Tmin := \frac{OD}{DR}$	**Minimum wall thickness (inches)**
$Tmin = 1.412 \cdot in$	
$Aperf := Dperf \cdot Tmin \cdot Nperf$	**Cross sectional area of perforations per 12" segement (sq. in.)**
$Aperf = 10.588 \cdot in^2$	
$Apipe := Tmin \cdot (12 \cdot in)$	**Wall area without perforations (sq. in.)**
$Apipe = 16.941 \cdot in^2$	
$Aeff := Apipe - Aperf$	**Effective area (reduced by area of perforations)**
$Aeff = 6.353 \cdot in^2$	
$Teff := \frac{Aeff}{12 \cdot in}$	**Resulting effective wall thickness per 12" segment (in.)**
$Teff = 0.529 \cdot in$	
$DReff := \frac{OD}{Teff}$ $\quad DReff = 45.333$	**Effective DR due to theoretical wall area reduction**

Pipe Calculations
Pipe Strength in Shallow Fill

Pipe Location: Temp. Sumps
Pipe Size & Type: 24"ϕ HDPE SDR 17 Perforated

Project: JRL Expansion
Calc. by: PCM **Date: April 2015**
Date 06/01/2015 **Checked by** KPN

References:

1. Chevron Phillps Chemical Company LC; Plexco Engineering Manual; 2003; Chapter 7 Buried Pipe Design.

Project Parameters

Depth of Overburden $H := 40 \cdot ft$

Depth of groundwater $Hgw := 0 \cdot ft$

Unit weight of waste $\gamma w := 85 \cdot \frac{lbf}{ft^3}$

Unit weight of soil $\gamma s := 125 \cdot \frac{lbf}{ft^3}$

Backfill Soil Modulus $Es := 3000 \cdot psi$

(for 90% Compaction in crushed stone)

Bedding Factor $K := .1$

Pipe Parameters:

Effective DR: $DR := 45.3$

Outside Diameter $OD := 24.0 \cdot in$

Short Term Modulus: $Estm := 100000 \cdot psi$

Long Term Modulus: $El := 23000 \cdot psi$

Pipe thickness $t := 1.412 \cdot in$

Base natural log (2.71828) $e := 2.71828$

Deflection Lag Factor $D := 1.5$

Calculations

Overbuden weight

Weighted soil/waste unit weight

$$\gamma wt := \gamma w \cdot \frac{30 \cdot ft}{H} + \gamma s \cdot \frac{10 \cdot ft}{H}$$

$$\gamma wt = 95 \cdot \frac{lbf}{ft^3}$$

Constrained Buckling ,(from Plexco design manual, Eq. 29)

Bouyancy Reduction Factor

$R := 1$

Moment of Inertia

$$I := \frac{t^3}{12} \qquad I = 0.235 \cdot in^3$$

$$B := \frac{1}{1 + 4 \cdot e^{(-.065 \cdot 16)}} \qquad B = 0.414$$

$Dm := OD - 1.06 \cdot t$ $\quad Dm = 22.503 \cdot in$ **Mean Pipe Diameter**

$N := 1$ **Safety Factor**

$$Pwc := \left(\sqrt{R \cdot B \cdot Es \cdot El \cdot \frac{I}{Dm^3}}\right) \cdot \left(\frac{5.65}{N}\right) \qquad Pwc = 137.061 \cdot psi$$ **Critical Wall Pressure**

$$SF := \frac{Pwc}{\left[\frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right)}\right]} \qquad SF = 5.194$$ **Safety Factor against Buckling**

Pipe Deflection, (from Plexco Application Note No. 1)

$$Rm := \frac{OD - t}{2} \qquad Rm = 11.294 \cdot in$$ **Mean Pipe Radius**

$$PS := \frac{Estm \cdot I}{.149 \cdot Rm^3} \qquad PS = 109.293 \cdot psi$$ **Pipe Stiffness**

$$W := \frac{H \cdot OD \cdot \gamma wt}{144 \cdot \frac{in^2}{ft^2}} \qquad W = 633.333 \cdot \frac{lbf}{in}$$ **Load on Pipe**

$$x := \frac{K \cdot D \cdot W}{.149 \cdot PS + .061 \cdot Es} \qquad x = 0.477 \cdot in$$ **Deflection**

$$\%Deflection := \frac{x}{OD} \cdot 100 \qquad \%Deflection = 1.986$$

PIPE CALCULATIONS
EFFECTIVE WALL THICKNESS OF PERFORATED PIPE

PROJECT: Landfill Expansion, Juniper Ridge Landfill
CLIENT: NEWSME

CALC. BY: PCM **DATE: April 2015**
CHECKED BY KPW **DATE** 06/01/2015

Pipe Information

$OD := 36 \cdot in$ **Pipe Outside Diameter (inches)**

$DR := 17$ **Pipe Dimension Ratio**

Perforations

$Dperf := 0.625 \cdot in$ **Diameter of perforations (inches)**

$Nperf := 12$ **Number of rows perforations in 12 inch wall cross section (Assumed to be cut through center of holes longitudinally through pipe)**

Calculations

$Tmin := \frac{OD}{DR}$ **Minimum wall thickness (inches)**

$Tmin = 2.118 \cdot in$

$Aperf := Dperf \cdot Tmin \cdot Nperf$ **Cross sectional area of perforations per 12" segement (sq. in.)**

$Aperf = 15.882 \cdot in^2$

$Apipe := Tmin \cdot (12 \cdot in)$ **Wall area without perforations (sq. in.)**

$Apipe = 25.412 \cdot in^2$

$Aeff := Apipe - Aperf$ **Effective area (reduced by area of perforations)**

$Aeff = 9.529 \cdot in^2$

$Teff := \frac{Aeff}{12 \cdot in}$ **Resulting effective wall thickness in the 12 inch segment**

$Teff = 0.794 \cdot in$

$DReff := \frac{OD}{Teff}$ **Effective DR due to theoretical wall area reduction**

$DReff = 45.333$

Pipe Calculations
Pipe Strength in Shallow Fill

Pipe Location: Permanent Sumps
Pipe Size & Type: 36"ϕ HDPE SDR 17 Perforated

Project: JRL Expansion
Calc. by: PCM **Date: April 2015**
Date 6/01/2015 **Checked by** KPW

References:

1. Chevron Phillps Chemical Company LC; Plexco Engineering Manual; 2003; Chapter 7 Buried Pipe Design.

Project Parameters

Depth of Overburden $H := 40 \cdot ft$

Depth of groundwater $Hgw := 0 \cdot ft$

Unit weight of waste $\gamma w := 85 \cdot \frac{lbf}{ft^3}$

Unit weight of soil $\gamma s := 125 \cdot \frac{lbf}{ft^3}$

Backfill Soil Modulus $Es := 3000 \cdot psi$

(for 90% Compaction in crushed stone)

Bedding Factor $K := .1$

Pipe Parameters:

Effective DR: $DR := 45.3$

Outside Diameter $OD := 36.0 \cdot in$

Short Term Modulus: $Estm := 100000 \cdot psi$

Long Term Modulus: $El := 23000 \cdot psi$

Pipe thickness $t := 2.118 \cdot in$

Base natural log (2.71828) $e := 2.71828$

Deflection Lag Factor $D := 1.5$

Calculations

Overbuden weight

Weighted soil/waste unit weight

$$\gamma wt := \gamma w \cdot \frac{30 \cdot ft}{H} + \gamma s \cdot \frac{10 \cdot ft}{H}$$

$$\gamma wt = 95 \cdot \frac{lbf}{ft^3}$$

Constrained Buckling ,(from Plexco design manual, Eq. 29)

Bouyancy Reduction Factor

$R := 1$

Moment of Inertia

$$I := \frac{t^3}{12} \qquad I = 0.792 \cdot in^3$$

$$B := \frac{1}{1 + 4 \cdot e^{(-.065 \cdot 16)}} \qquad B = 0.414$$

$Dm := OD - 1.06 \cdot t$ $\quad Dm = 33.755 \cdot in$ **Mean Pipe Diameter**

$N := 1$ **Safety Factor**

$$Pwc := \left(\sqrt{R \cdot B \cdot Es \cdot El \cdot \frac{I}{Dm^3}}\right) \cdot \left(\frac{5.65}{N}\right)$$ $Pwc = 137.061 \cdot psi$ **Critical Wall Pressure**

$$SF := \frac{Pwc}{\left[\frac{\gamma wt \cdot H}{\left(\frac{144 \cdot in^2}{ft^2}\right)}\right]}$$ $SF = 5.194$ **Safety Factor against Buckling**

Pipe Deflection, (from Plexco Application Note No. 1)

$$Rm := \frac{OD - t}{2}$$ $Rm = 16.941 \cdot in$ **Mean Pipe Radius**

$$PS := \frac{Estm \cdot I}{.149 \cdot Rm^3}$$ $PS = 109.293 \cdot psi$ **Pipe Stiffness**

$$W := \frac{H \cdot OD \cdot \gamma wt}{144 \cdot \frac{in^2}{ft^2}}$$ $W = 950 \cdot \frac{lbf}{in}$ **Load on Pipe**

$$x := \frac{K \cdot D \cdot W}{.149 \cdot PS + .061 \cdot Es}$$ $x = 0.715 \cdot in$ **Deflection**

$$\%Deflection := \frac{x}{OD} \cdot 100$$ $\%Deflection = 1.986$

APPENDIX D-2

SOIL/FILTER DESIGN

Soil Filter Design

Project Name: Juniper Ridge Landfill Expansion
Project Location: Old Town, Maine
Project No: 14101
Comp By: PCM
Date: 4/1/2015
Chk. By: KPM 6/1/2015

OBJECTIVE: Evaluate Filter Properites of Specified Soils

REFERENCES:

1. Cedergen, Drainage of Highway and Airfield Pavements, 1974

DESIGN PROCEDURE:

Use the following design criteria to determine suitablility of soil filter material:

1. D_{15}(filter)/5 < D_{85} (soil) (to prevent intrusion of fines)
2. D_{50}(filter)/25 < D_{50} (soil) (to assure uniformity of grading and prevent gap-graded materials)

ANALYSIS

Drainage Sand (as soil) to Filter Stone (as filter)

Soil Material= Drainage Sand
Soil Gradation= See Attached Gradation Curve

D_{85}(soil)=	2	to	10	mm
D_{50}(soil)=	0.35	to	2	mm

Filter Material= Filter Stone
Filter Gradation= See Attached Gradation Curve

D_{15}(filter)=	0.75	to	2.75	mm
D_{50}(filter)=	2.1	to	8.5	mm

Criteria 1:	0.55	<	2.00	**PASS**
Criteria 2:	0.34	<	0.35	**PASS**

Filter Stone (as soil) to Drainage Stone (as filter)

Soil Material= Filter Stone
Soil Gradation= See Attached Gradation Curve

D_{85}(soil)=	4	to	18	mm
D_{50}(soil)=	2.1	to	8.5	mm

Filter Material= Drainage Stone
Filter Gradation= See Attached Gradation Curve

D_{15}(filter)=	5	to	17	mm
D_{50}(filter)=	13	to	27	mm

Criteria 1:	3.40	<	4.00	**PASS**
Criteria 2:	1.08	<	2.10	**PASS**

Soil Filter Design

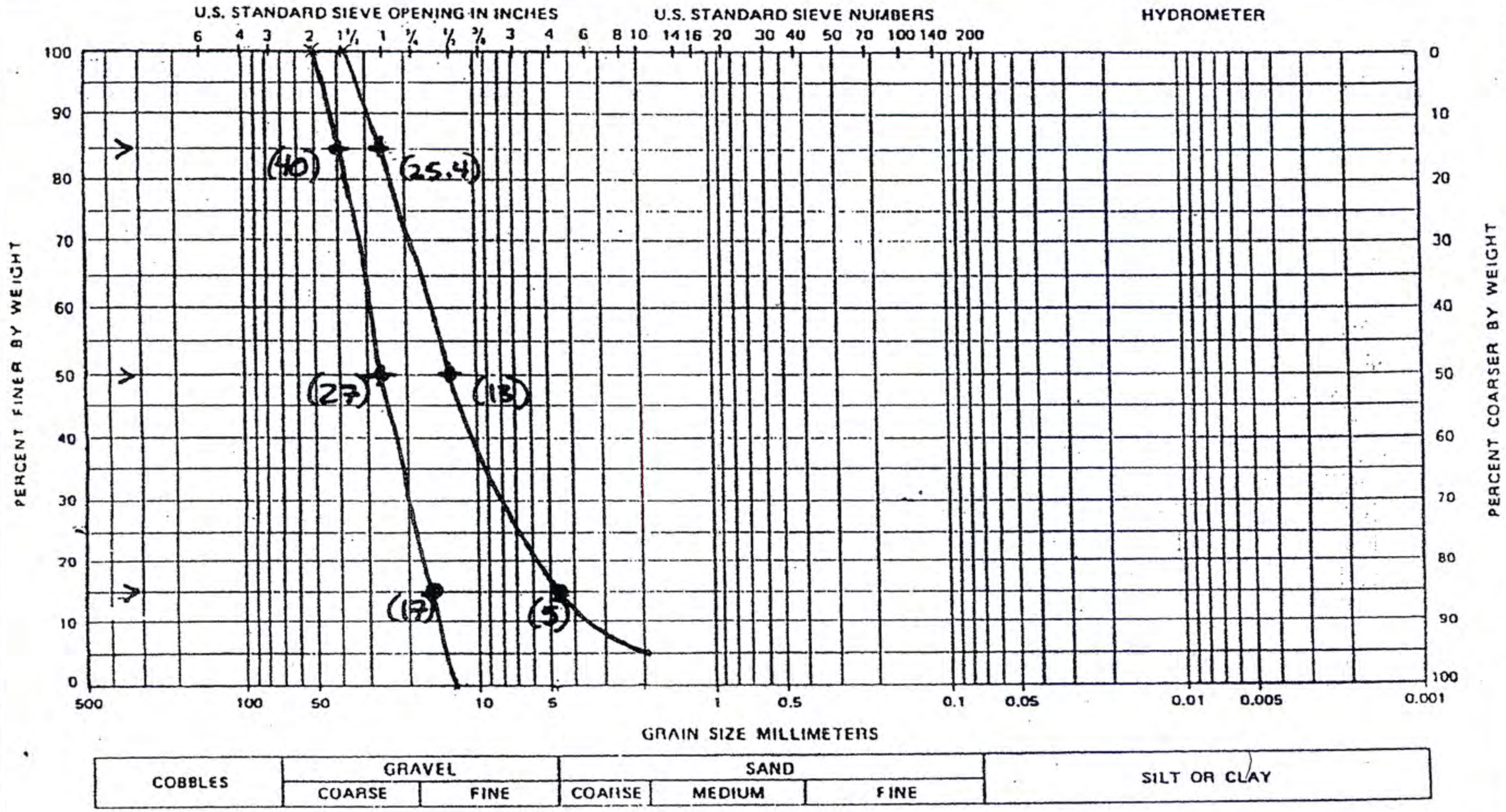
Project Name:	Juniper Ridge Landfill Expansion
Project Location:	Old Town, Maine
Project No:	14101
Comp By:	PCM
Date:	4/1/2015
Chk. By:	KPW 06/01/2015

(Continued)

Drainage Stone (as soil) to Sump Stone (as filter)

Soil Material=	Drainage Stone			
Soil Gradation=	See Attached Gradation Curve			
D_{85}(soil)=	25.4	to	40	mm
D_{50}(soil)=	13	to	27	mm
Filter Material=	Drainage Stone			
Filter Gradation=	See Attached Gradation Curve			
D_{15}(filter)=			80	mm
D_{50}(filter)=			90	mm
Criteria 1:	16.00	<	25.40	**PASS**
Criteria 2:	3.6	<	13.00	**PASS**

GRADATION C VES

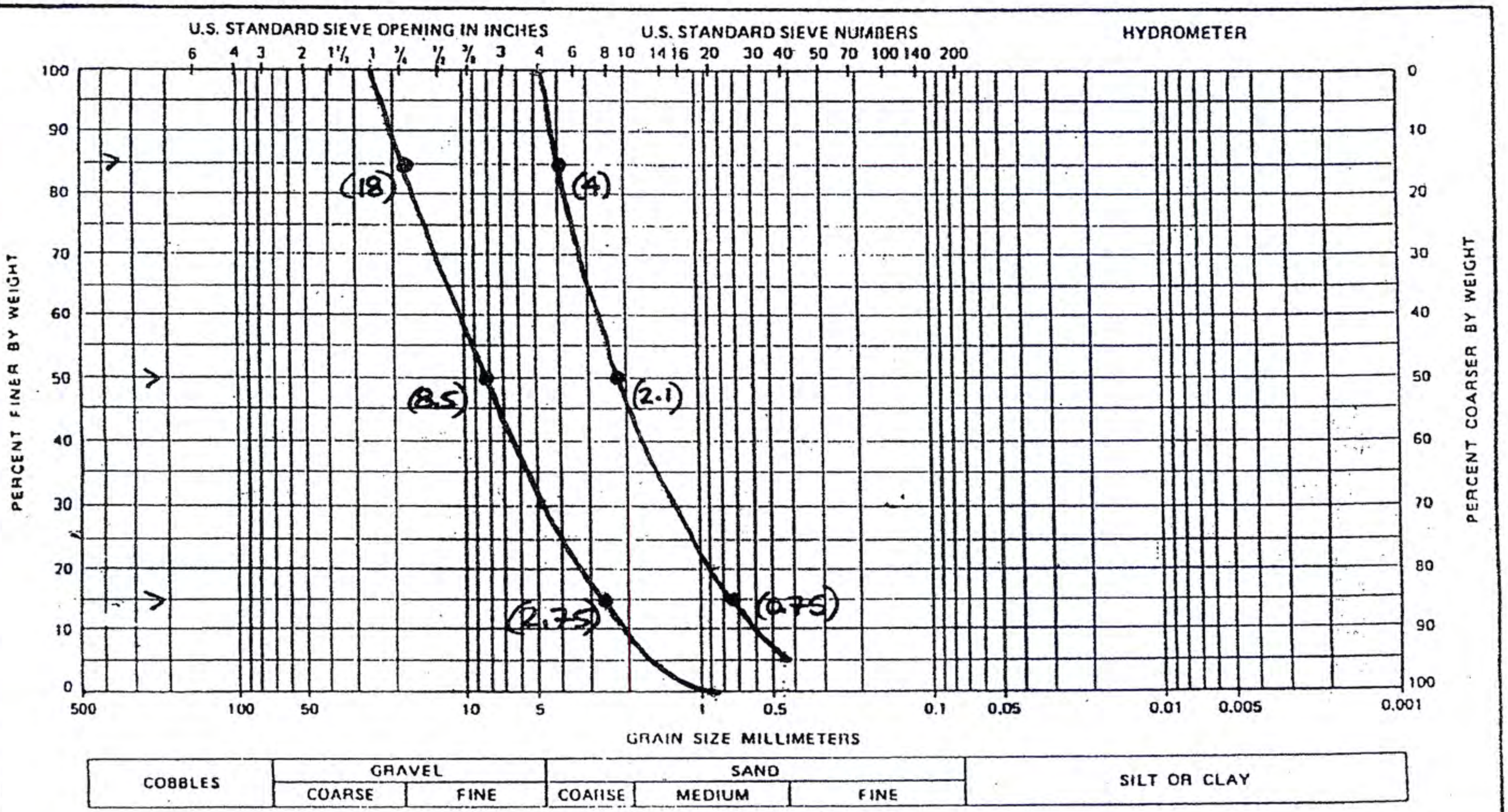


SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI	PROJECT
							DATE
							DRAINAGE STONE

02-4/86

SEVEE & MAHER ENGINEERS

GRADATION C ,ES



SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT

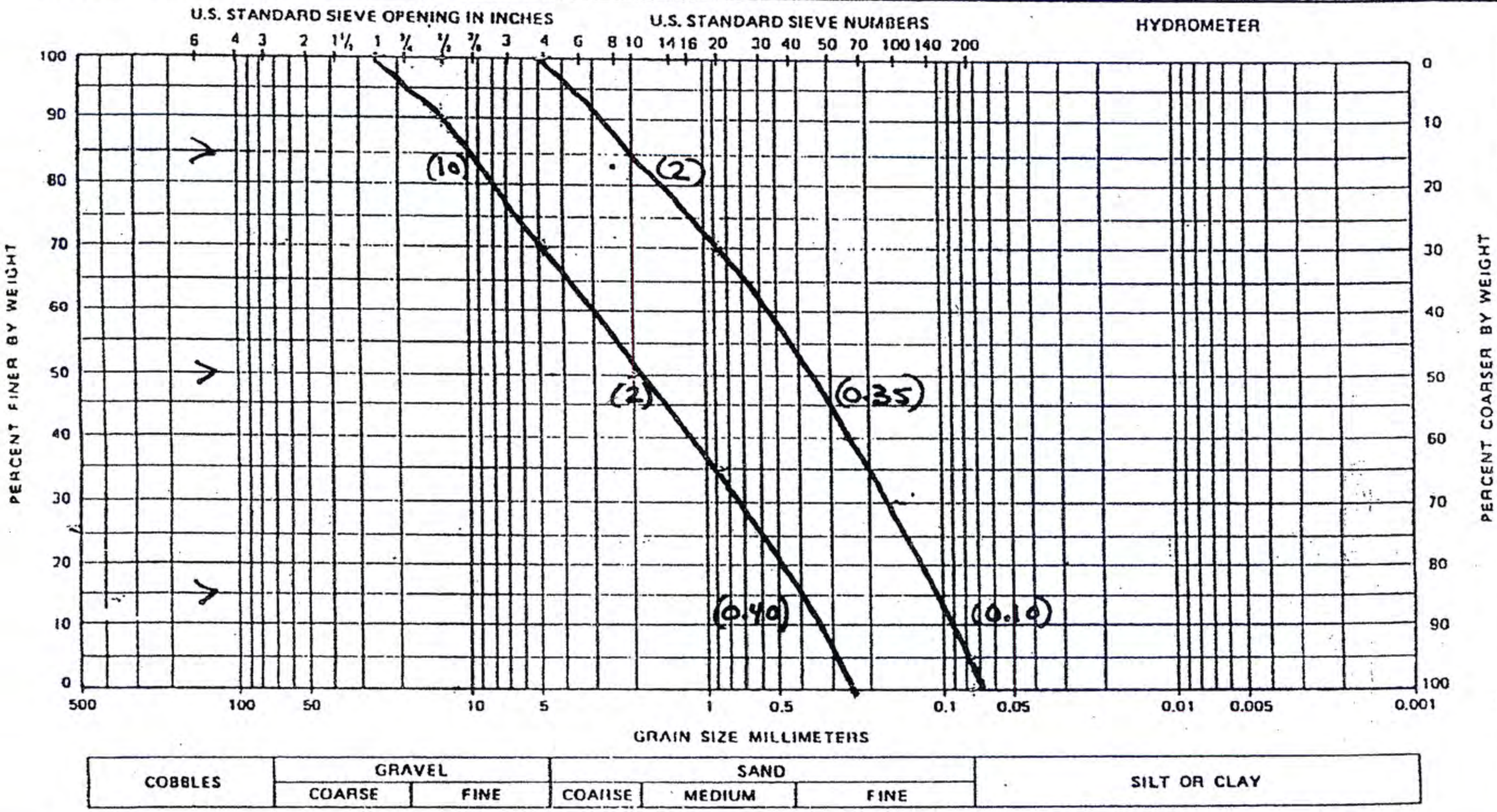
DATE

FILTER STONE

02-4/86

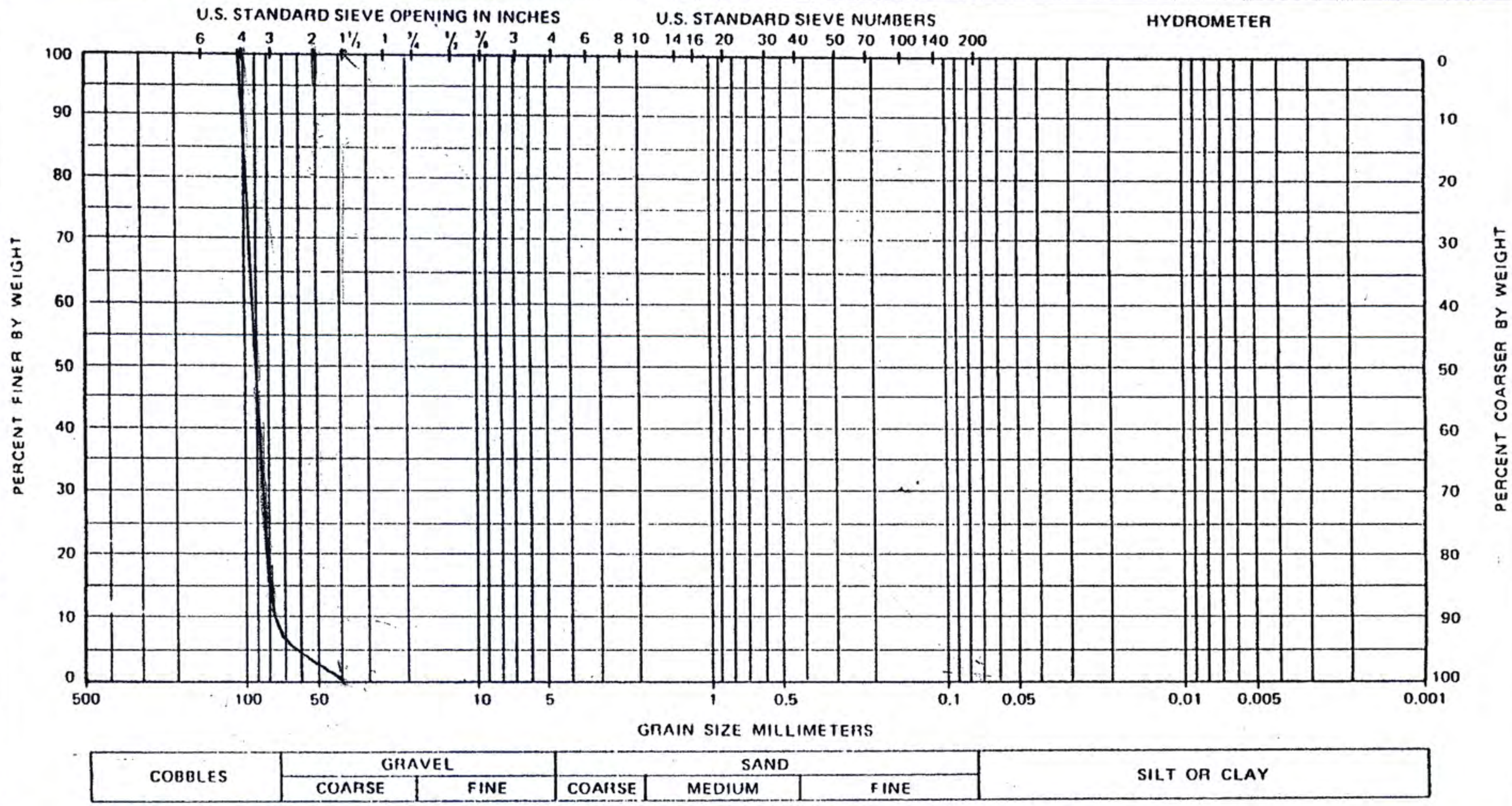
SEVEE & MAHER ENGINEERS

GRADATION C /ES



SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI	PROJECT
							DATE
							DRAINAGE SAND

GRADATION CURVES



SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI	PROJECT
							DATE
							LEACHATE SUMP STONE
							2" TO 4" ROUNDED STONE

02 - 4/86

SEVEE & MAHER ENGINEERS

2. Drainage Stone: Shall be screened and washed stone free of organic matter, silt, or clay lumps, and deleterious material. The stone shall contain no more that 15% calcium carbonate as determined by ASTM D 4373 or equivalent method approved by Engineer (i.e., whole rock geochemistry methods). The material shall meet the following gradation requirements:

a) Pipe Drainage Stone: $D_{50}\geq 3/4"$

Sieve Designation	percent by Weight Passing Square Mesh Sieve
2"	100
1-1/2"	80-100
1"	50- 85
1/2"	0- 50
#4	0- 15
#10	0- 5

b) Leachate Sump Stone: will consist of rounded durable screened and washed stone or washed tailings meeting the calcium carbonate requirements above.

Sieve Designation	percent by Weight Passing Square Mesh Sieve
4"	100
2"	0

3. Filter Stone: Shall be screened and washed stone free of organic matter, silt, or clay lumps, and deleterious material. The stone shall contain no more that 15% calcium carbonate as determined by ASTM D 4373 or equivalent method approved by Engineer (i.e., whole rock geochemistry methods). The material shall meet the following gradation requirements:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
1"	100
No. 4	30-100
No. 20	0-20
No. 40	0-5

4. Underdrain Sand: Clean sand, free from organic matter, graded to meet the following criteria for the appropriate designation. Underdrain sand will have a hydraulic conductivity not less than $1x10^{-3}$ cm/sec and average of $1x10^{-2}$ cm/sec as determined by ASTM D 2434. The sand shall contain no more that 15% calcium carbonate as determined by ASTM D 4373 or equivalent method approved by Engineer (i.e., whole rock geochemistry methods).

Gradation Requirements:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
1"	100
1/2"	90-100
#4	70 – 100
#10	50 - 85
#20	35 – 70
#60	0- 40
#200	0- 5[1]

1.Based on the portion passing the U.S. Standard Size No. 4.

5. Drainage Sand: Must meet the underdrain sand gradation stated above and have a remolded hydraulic conductivity average $1x10^{-2}$ cm/sec, minimum $5x10^{-3}$ cm/sec. as determined by ASTM D2434. The sand shall contain no more that 15% calcium carbonate as determined by ASTM D 4373 or equivalent method approved by Engineer (i.e., whole rock geochemistry methods).

6. Tire Chips: Type B shredded tire chips graded to meet the following criteria for the appropriate designation. Shall be free of contaminants such as oil, grease, gasoline, diesel fuel, etc. that could create a fire hazard. No remains of tires that have been subjected to a fire. Tire chips shall be from fragments of wood, wood chips and other fibrous organic matter. Tire chips shall have less than 1% (by weight) of metal fragments that are not at least partially encased in rubber. Metal fragments that are partially encased in rubber shall protrude no more than 1 inch from the cut edge of the tire shred on 75% of the pieces (by weight) and no more than 2 inches on 90% of the pieces (by weight)

Gradation Requirements:

Sieve Designation	percent by Weight Passing Square Mesh Sieve
18"	100
12"	90
8"	75
3"	50
1-1/2"	25
#4	1

Drainage of Highway and Airfield Pavements

HARRY R. CEDERGREN

A Wiley-Interscience Publication

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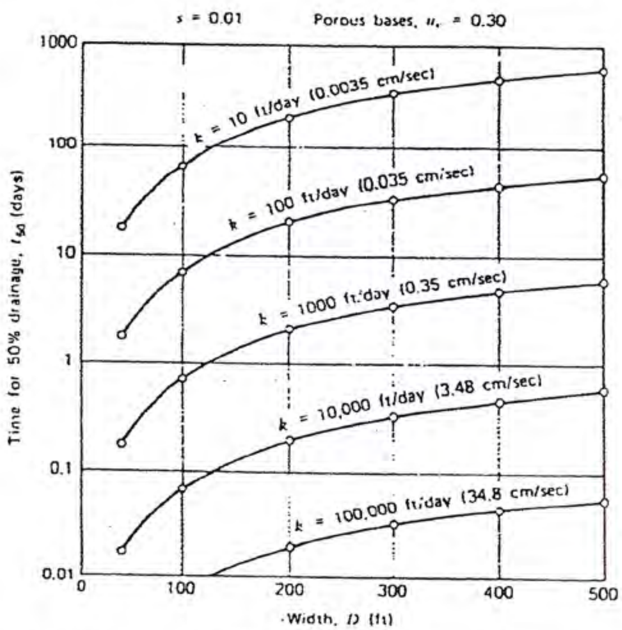


FIG. 5.8 Permeability versus time for 50% drainage of bases with edge drains. (Courtesy CERL.)

expressed in ft/day, Eq. 5.5 becomes:

$$t = \frac{n_e D^2}{2\,kH_o} \tag{5.6}$$

Figure 5.8 was prepared from Eq. 5.6 to relate the amount of time needed for 50 percent drainage of pavements having bases 12 in. thick on slopes of 1 percent ($s = 0.01$) and an effective porosity of 30 percent ($n_e = 0.3$). By examining Fig 5.8, it is seen that if a criterion of 50 percent base drainage in 0.1 day (2.4 hours) is assumed, the permeability would need to be approximately 2000 ft/day for taxiways with half-widths of 40 feet. For the wider dimensions of most airfield pavements, a criterion of 0.1 day for 50 percent drainage would require that k values of 10,000 to 80,000 ft/day be obtained.

5.5 FILTER PROTECTION OF OPEN-GRADED DRAINAGE MATERIALS

Where coarse, open-graded macadam types of bases are used for pavement drainage on erodible subgrades, these layers must be

protected from the intrusion of fine material that can clog pore spaces and reduce permeability. The "inverted filter" invented by K. Terzaghi for the prevention of heave and piping failures of dams, sheet pile walls, and so forth (Terzaghi, 1922, 1929), utilizes a coarse water-removing layer placed over an appropriate "filter" that keeps fine-grained soils from working up through the coarse material. This principle has been widely used in the design of earth dams and other water-retaining structures for the past 30 or 40 years. Experimental work by Bertram (1940), the U.S. Bureau of Reclamation (Karpoff, 1955), the U.S. Corps of Engineers (1941), and others has produced practical criteria for the design of filters for dams, pavements, and other structures.

The work of Bertram and the corps of engineers led to the following criterion for filter design:

$$\frac{D_{15}\ (\text{of filter})}{5} \leqq D_{85}\ (\text{of soil}) \tag{5.7}$$

In Eq. 5.7, D_{15} is the 15 percent size (15% is finer than this size) of the filter layer that is protecting a soil with an 85 percent size of D_{85}.

To assure reasonable uniformity of grading and to prevent the use of gap-graded materials, the following additional criterion has also been used:

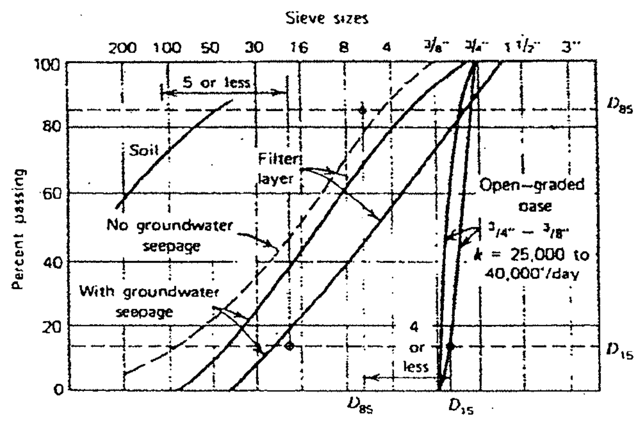
$$\frac{D_{50}\ (\text{of filter})}{25} \leqq D_{50}\ (\text{of soil}) \tag{5.8}$$

Use of these criteria assures a high level of filter protection, because it is virtually impossible for soil fines to work into or through uniformly mixed filter materials conforming to Eqs. 5.7 and 5.8. A coarse, open-graded drainage layer should never be placed in direct contact with nonstabilized sand, silt, clay, or any other erodible subgrade soil that can be washed into the bottom or sides of the layer by seepage or be forced into it under the pressures or impacts of traffic. Nor should any aggregate or paving material be in direct contact with the top of an open-graded layer if it can penetrate into the layer. When open-graded drainage aggregates are placed over or under many of the normally used bases or subbases, the foregoing filter criteria (Eqs. 5.7 and 5.8) will often be satisfied. Nevertheless, a check of the compatibility of adjacent materials should always be made, and their gradations should be modified or a thin choker or filter layer placed between them and the open-graded material whenever necessary to ensure that no migration or intrusion of any fines or foreign matter can take place *from any direction.*

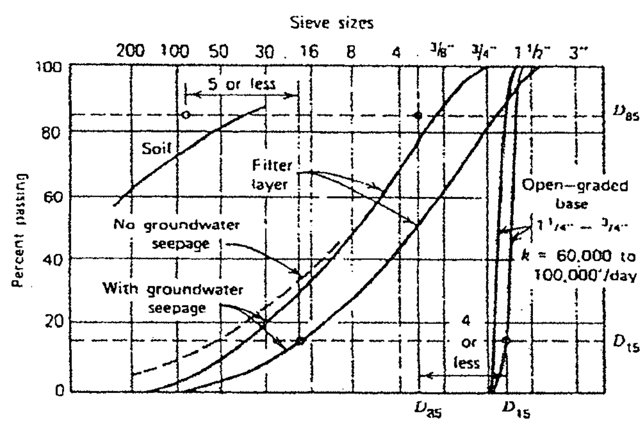
Figure 5.9 gives examples of gradations of bases or subbases that are compatible with two sizes of open-graded drainage materials.

Figure 5.9*a* has an open-graded drainage layer with a size range of 3/4 to 3/8 in., and a compatible filter layer that could range in sizes from a maxium of around 1 1/4 in. down to about the no. 50 sieve, or from a maximum size of about 3/4 in. down to the no. 100 sieve. If no groundwater seepage can occur, larger amounts of fines could be permitted in the base or subbase (filter layer) as indicated.

In Fig. 5.9*b* the open-graded base drainage layer ranges from 1 1/4 to 3/4 in. in size. Slightly coarser base or subbase materials (filter ma-



(*a*) Open–graded base constructed with 3/4" – 3/8" aggregate.



(*b*) Open–graded base constructed with 1 1/4" – 3/4" aggregate.

FIG. 5.9 Examples of gradations of open-graded bases and their protective filters.

terials) could be used with an open-graded base of this coarseness than with the finer open-graded base material.

If large groundwater flows can be expected, the capabilities of the base or filter layer to accept flows of water should be verified by calculations with Darcy's law *for flow through the thin dimensions of such a layer*. In estimating the capabilities of bases and subbases (or filter layers) to accept groundwater, flows from springs, and so forth, the flow per square foot can be estimated from the expression,

$$q = ki \tag{5.9}$$

For flow through the thin dimensions of these layers it is usually reasonable to allow a hydraulic gradient of about 0.5. Then the amount of water that can enter each square foot of open-graded drainage layer is about equal to $0.5k$, where k is the in-place coefficient of permeability of the filter or subbase separating the open-graded layer from the water source.

If negligible or zero groundwater flow can occur, it is not necessary to verify the inflow capability across a base, subbase, or filter by the method just described, and the gradations of these layers need verification only with respect to their capabilities to serve as filters to protect open-graded layers from clogging.

Various types of plastic filter cloths can be used as filters to protect open-graded drainage layers and drain trench backfill. Extensive testing of such materials has been done by the Waterways Experiment Station, U.S. Corps of Engineers (Calhoun, et al., 1971; Calhoun, 1972). At any location where a filter cloth is proposed, the suitability of any proposed material should have the approval of a recognized testing laboratory. The choice between aggregates or plastic cloths for filter protection is largely a matter of construction feasibility and economics.

When perforated or slotted pipes are placed in drainage systems for the collection or removal of water, there should be no unplugged ends, and the drainage materials in contact with the pipes must be coarse enough so that no appreciable amount of this material can enter into the pipes. The criteria used by the U.S. Army Corps of Engineers (1965) for pipes with slots and circular holes are as follows:

For slots:

$$\frac{85\%\ \text{size of filter material}}{\text{slot width}} > 1.2 \tag{5.10}$$

For circular holes:

$$\frac{85\%\ \text{size of filter material}}{\text{hole diameter}} > 1.0 \tag{5.11}$$

Other agencies use these criteria or some that may vary slightly from these standards. For example, the U.S. Bureau of Reclamation (1965) specifies that the 85 percent size (D_{85}) of the aggregate nearest the pipe should be 2 or more times the size of the maximum opening in a drain pipe.

5.6 PROTECTION OF SENSITIVE SUBGRADES

In areas where highway or airfield pavements are constructed over highly expansive soils, expansive shales, or other similar geological formations, noncohesive, uniformly graded materials such as loess or other sensitive materials, it may be necessary to provide an impermeable seal under the structural section (see Fig. 4.1) to prevent surface water from soaking downward into these materials. A number of types of seals such as catalytically blown asphalt and plastic sheeting can be used to keep water out of sensitive subgrades. In some instances lime or cement has been successfuly used to stabilize such materials.

The soils investigation for important pavements should include sufficient tests to identify any soil or rock formations that would be susceptible either to swelling, collapsing, or other detrimental changes caused by water infiltration; the soils report should include recommendations for any special treatments required (impermeable membranes, stabilization, etc.). Unless adequate measures are taken, uneven swelling can cause warping of concrete slabs, cracking, or uneven humps that can be both hazardous and discomforting to the users of the pavements.

5.7 TRENCH BACKFILL PERMEABILITY REQUIREMENTS

In designing subsurface drainage systems it is important that any water that enters any part of a system be unrestricted in its flow toward a discharge exit. A basic concept, called a "condition of continuity" is described in Chapter 3. Equation 3.8 is an expression of that concept. In essence it says that in progressing along possible paths of flow in drainage systems, the water removing capabilities should get greater, never smaller, in the direction of flow. This is particularly important with respect to pipe drains and the backfill surrounding them. If low permeability backfill is used, or dirt or other matter is allowed to contaminate the top of the backfill, the flows to the pipes can be greatly restricted, if not virtually cut off.

In cases where drain pipes can be placed in shallow "V" trenches under the outer edges of open-graded base drainage layers (see Fig.

6.7*a*, *b*, and *c*), excellent flow to the pipes is assured. High water tables, other groundwater conditions, or deep freezing, however, will often require the use of deeper trench drains. If other kinds of materials are selected for backfilling the trench (for economic or other reasons) it is necessary to determine that the backfill material is permeable enough to assure free flow of water to the pipes. Wherever sufficiently permeable backfill material is too coarse to be placed next to erodible soils, suitable plastic filter cloths will be needed on the sides and bottom of the trenches (see Sec. 5.5, "Filter Protection of Open-Graded Drainage Materials").

Wherever collector pipes are placed in trenches (see Fig. 6.7*d* and *e*), a check of backfill permeability requirements can be made with Darcy's law, using appropriate dimensions and hydraulic gradients together with the estimated discharge rates, to determine the minimum required permeability of the trench backfill. In Darcy's law, k is represented by k_t (the permeability of the trench backfill), A is equal to the trench width in feet B times 1.0 ft, and the inflow rate in cubic feet per day per linear foot is Q. Since flow is essentially vertically downward, the hydraulic gradient is unity or nearly unity. In such calculations a liberal factor of safety should be used to allow for possible imperfections in entrance conditions into the trench.

Figure 5.10 is a chart that can be used for directly reading the required combinations of B and k_t that will assure sufficient capability for downward flow in collector trenches. This figure is from the FHWA *Guidelines* (FHWA, 1973) redrawn to a different scale and modified slightly.

To use Fig. 5.10 enter the chart along the abscissa to the length of pavement strip contributing flow to a drain, extend vertically to the line corresponding to the design infiltration rate (total combined inflows from surface and groundwater etc., expressed in equivalent infiltration rates) and project horizontally to the left side of the chart to read Bk_t, the product of trench width B and trench backfill permeability k_t. Assume, for example, that a 40-ft width of pavement is contributing flow to a drain, and the design infiltration rate is $I = 2$ in./hour; then a value of Bk_t of approximately 3200 ft²/day is read from the chart. If the trench width is 1.5 ft, the required value of k_t is $3200/1.5 = 2100$ ft/day. This would require the use of clean, washed pea gravel, stone chips, or equivalent. If the soil in which the trench is to be excavated is an erodible type, it will be necessary to line the sides and bottom with an approved, satisfactory type of filter cloth (see Fig. 6.8) because pea gravel, stone chips, or coarser material cannot be placed against such soils without filter protection and it is generally not practical to line such trenches with fine-filter aggregate.

Pipe Perforation / Stone Size Design

Project Name:	Juniper Ridge Landfill Expansion
Project Location:	Old Town, Maine
Project No:	14101
Comp By:	PCM
Date:	4/1/2015
Chk. By:	KPW 06/01/2015

OBJECTIVE: Evaluate suitability of materials in contact with perforated piping.

REFERENCES:

1. Cedergen, Drainage of Highway and Airfield Pavements, 1974

DESIGN PROCEDURE:

Use the following design criteria to determine suitablility of perforation size/stone size suitability:

1. D_{85} (pipe stone)/ Hole Dia. > 1.0
   (to prevent intrusion of soil particles into the piping)

ANALYSIS

Drainage Stone to Perforated Pipe

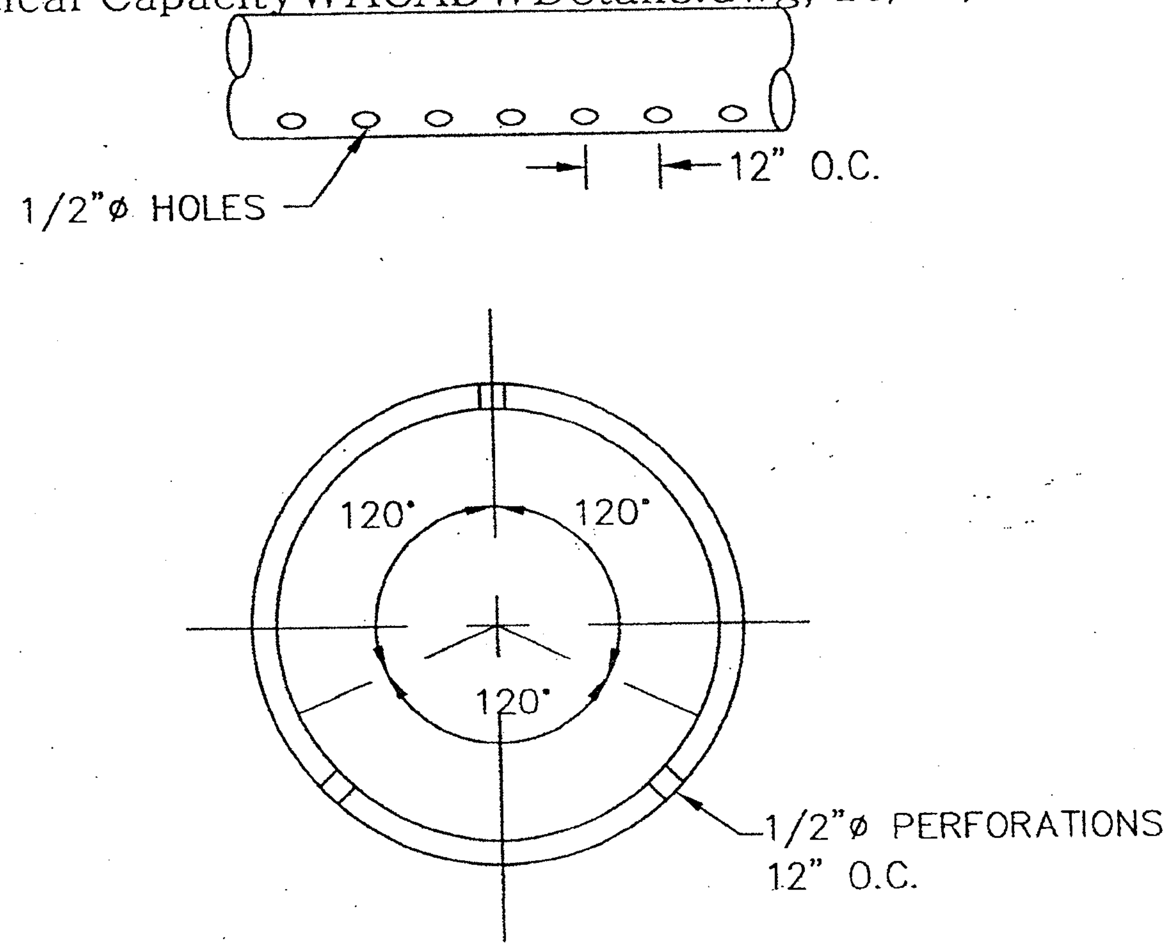
Soil Material= Drainage Stone
Soil Gradation= See Attached Gradation Curve

D_{85}(stone)=	25.4	to	40	mm
Hole Dia.=	0.375	in. =	9.525	mm
Criteria 1:	2.67	>	1.00	**PASS**

Sump Stone to Pump Conduit Pipe

Soil Material= Drainage Stone
Soil Gradation= See Attached Gradation Curve

D_{85}(stone)=	48	mm		
Hole Dia.=	0.625	in. =	15.875	mm
Criteria 1:	3.02	>	1.00	**PASS**

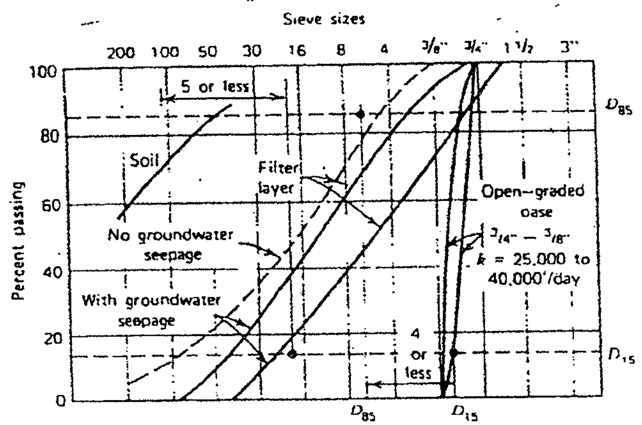


PERFORATED PIPE

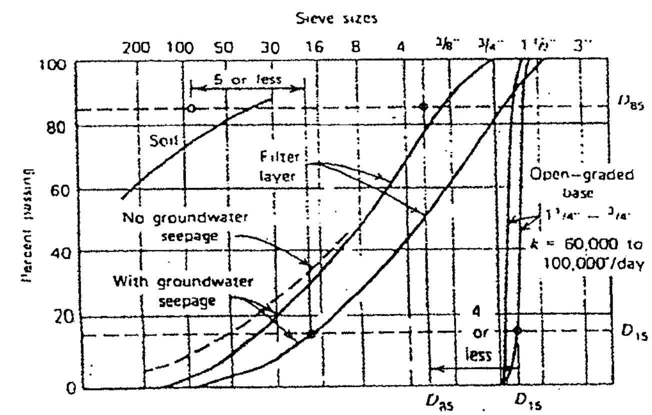
N.T.S.

Figure 5.9*a* has an open-graded drainage layer with a size range of ¾ to ⅜ in., and a compatible filter layer that could range in sizes from a maxium of around 1¼ in. down to about the no. 50 sieve, or from a maximum size of about ¾ in. down to the no. 100 sieve. If no groundwater seepage can occur, larger amounts of fines could be permitted in the base or subbase (filter layer) as indicated.

In Fig. 5.9*b* the open-graded base drainage layer ranges from 1¼ to ¾ in. in size. Slightly coarser base or subbase materials (filter materials) could be used with an open-graded base of this coarseness than with the finer open-graded base material.



(*a*) Open-graded base constructed with 3/4" – 3/8" aggregate.



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In cases where drain pipes can be placed in shallow "V" trenches under the outer edges of open-graded base drainage layers (see Fig. 6.7*a*, *b*, and c), excellent flow to the pipes is assured. High water tables other groundwater conditions, or deep freezing, however, will often re quire the use of deeper trench drains. If other kinds of materials ar selected for backfilling the trench (for economic or other reasons) it i necessary to determine that the backfill material is permeable enoug to assure free flow of water to the pipes. Wherever sufficientl permeable backfill material is too coarse to be placed next to erodibl soils, suitable plastic filter cloths will be needed on the sides and bot tom of the trenches (see Sec. 5.5, "Filter Protection of Open-Grade Drainage Materials").

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APPENDIX D-3

GEOCOMPOSITE DRAINAGE NET DESIGN

CLIENT: Juniper Ridge Landfill Expansion
PROJECT:Cell 11 Leachate Collection Design
Initial Condition

Completed By: Peter Mailey   Date: 5/20/15

Checkd By: KPW   Date: 06/01/2015

Geocomposite Drainage Design

Ref. Giroud ET Al., 1993

Design Objective: To maintain maximum head on the liner to the thickness of the drainage net (geonet).

Design Parameters

K	Permeability of Drainage Geocomposite
$L := 42.7 \cdot m$	Length between pipe laterals (140 ft. measured along slope)
$t := .3048 \cdot m$	Leachate Collection Sand Thickness (12 inches)
$e := 2.3029 \cdot 10^{-8} \cdot \frac{m}{sec}$	Impingement Rate = 2.35-inches per month (Max Average Monthly Impingement Rate(10 ft. of Waste 100% Area Allowed Runoff)) from HELP Model Output. See Appendix C.
$\beta := 1.1458 \cdot deg$	Slope of the Landfill Base Between Pipes (2 percent)
$T_{max} := .0064 \cdot m$	Geonet Thickness = 0.25 inches

$$T_{max} = L \cdot \frac{\left[\sqrt{\left(4 \cdot \frac{e}{K}\right) + \tan(\beta)^2} - \tan(\beta)\right]}{2 \cdot \cos(\beta)}$$

Solve for K:

$$K := \frac{(4 \cdot e)}{\left(T_{max} \, 2 \cdot \frac{\cos(\beta)}{L} + \tan(\beta)\right)^2 - \tan(\beta)^2}$$

$K = 7.626 \cdot 10^{-3} \, m \cdot s^{-1}$

Solve for Design Transmisivity:

$\psi Design := K \cdot T_{max}$ $\psi Design = 4.881 \cdot 10^{-5} \, m^2 \cdot s^{-1}$

Solve for Required Transmisivity (Required Specified Value):

Apply Reduction Factor: Design of Lateral Drainage Systems, Richardson 1999

$RFtotal := 6.5$ RFtotal = Design Drainage Factor (3) x Intrusion (1.0) x Creep (1.1), Biological Clogging (1.4) x Chemical Clogging (1.4) = 6.5

$\psi Spec := RFtotal \cdot \psi Design$ $\psi Spec = 3.173 \cdot 10^{-4} \, m^2 \cdot s^{-1}$

CLIENT: Juniper Ridge Landfill Expansion
PROJECT:Cell 11 Leachate Collection Design
Intermediate Condition - Check

Completed By: Peter Mailey — Date: 5/20/15

Checkd By: KPN — Date: 06/01/2015

Geocomposite Drainage Design

Ref. Giroud ET Al., 1993

Design Objective: To maintain maximum head on the liner to the thickness of the drainage net (geonet).

Design Parameters

K	Permeability of Drainage Geocomposite
$L := 42.7 \cdot m$	Length between pipe laterals (140 ft. measured along slope)
$t := .3048 \cdot m$	Leachate Collection Sand Thickness (12 inches)
$e := 1.4851 \cdot 10^{-8} \cdot \frac{m}{sec}$	Impingement Rate = 1.52-inches per month (Max Average Monthly Impingement Rate (90 ft. of Waste w/ 18" Intermediate Cover)) from HELP Model Output. See Appendix C.
$\beta := 1.1458 \cdot deg$	Slope of the Landfill Base Between Pipes (2 percent)
$T_{max} := .0064 \cdot m$	Geonet Thickness = 0.25 inches

$$T_{max} = L \cdot \frac{\left[\sqrt{\left(4 \cdot \frac{e}{K}\right) + \tan(\beta)^2} - \tan(\beta)\right]}{2 \cdot \cos(\beta)}$$

Solve for K:

$$K := \frac{(4 \cdot e)}{\left(T_{max} \, 2 \cdot \frac{\cos(\beta)}{L} + \tan(\beta)\right)^2 - \tan(\beta)^2} \qquad K = 4.918 \cdot 10^{-3} \, m \cdot s^{-1}$$

Solve for Design Transmisivity:

$$\psi Design := K \cdot T_{max} \qquad \psi Design = 3.148 \cdot 10^{-5} \, m^2 \cdot s^{-1}$$

Solve for Required Transmisivity and Compare to Specified Value:

Apply Reduction Factor: Design of Lateral Drainage Systems, Richardson 1999

$RFtotal := 6.1$ — RFtotal = Design Drainage Factor (2) x Intrusion (1.0) x Creep (1.2), Biological Clogging (1.6) x Chemical Clogging (1.6) = 6.1

$\psi Req := RFtotal \cdot \psi Design$ — $\psi Req = 1.92 \cdot 10^{-4} \, m^2 \cdot s^{-1}$

Value is less than Specified Value of $\Psi Spec = 3.17 \times 10^{-3} \, m^2/sec$ ***Okay***

CLIENT: Juniper Ridge Landfill Expansion
PROJECT:Cell 12 Leak Detection Design

Completed By: Peter Mailey   Date: 5/20/15

Checkd By: KPN   Date: 06/01/2015

Geocomposite Drainage Design

Ref. Giroud ET Al., 1993

Design Objective: To maintain maximum head on the liner to the thickness of the drainage net (geonet).

Design Parameters

K	Permeability of Drainage Geocomposite
$L := 500.406 \cdot m$	Maximum Length between pipe laterals (1642 ft. measured along slope) Maximum Planned Travel Length in Geocomposite is 400 ft.
$t := .3048 \cdot m$	Leak Detection Sand Thickness (12 inches)
$e := 3.84 \cdot 10^{-9} \cdot \frac{m}{sec}$	Impingement Rate based on 0.236-gallons per acre per day from three 1 cm^3 holes per acre. Calculated leakage through 3 holes per acre with a GCL barrier layer below holes. See Leak Detection Design in Appendix D-!
$\beta := 1.4894 \cdot deg$	Slope of the Landfill Base Between Pipes (2.6 percent)
$T_{max} := .0064 \cdot m$	Geonet Thickness = 0.25 inches

$$T_{max} = L \cdot \frac{\left[\sqrt{\left(4 \cdot \frac{e}{K}\right) + \tan(\beta)^2} - \tan(\beta)\right]}{2 \cdot \cos(\beta)}$$

Solve for K:

$$K := \frac{(4 \cdot e)}{\left(T_{max} \, 2 \cdot \frac{\cos(\beta)}{L} + \tan(\beta)\right)^2 - \tan(\beta)^2} \qquad K = 0.012 \; m \cdot s^{-1}$$

Solve for Design Transmisivity:

$$\psi Design := K \cdot T_{max} \qquad \psi Design = 7.389 \cdot 10^{-5} \; m^2 \cdot s^{-1}$$

Solve for Required Transmisivity (Required Specified Value):

Apply Reduction Factor: Design of Lateral Drainage Systems, Richardson 1999

$RFtotal := 4.29$ RFtotal = Design Drainage Factor (2) x Intrusion (1.0) x Creep (1.1), Biological Clogging (1.3) x Chemical Clogging (1.5) = 6.5

$$\psi Spec := RFtotal \cdot \psi Design \qquad \psi Spec = 3.17 \cdot 10^{-4} \; m^2 \cdot s^{-1}$$

APPENDIX D-4

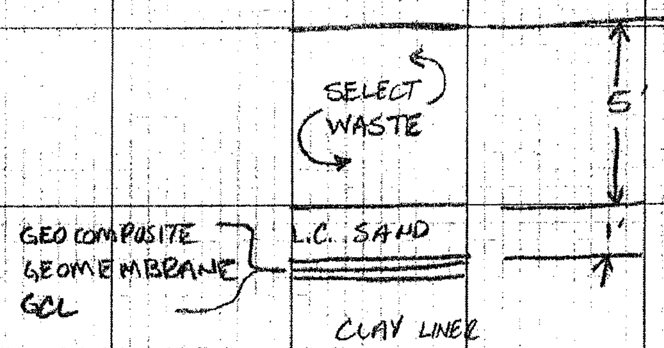
FROST PROTECTION DESIGN

PROJECT FROST PROTECTION JUNIPER RIDGE LANDFILL EXPANSION OLD TOWN, MAINE	COMP. BY BDP	JOB NO.
	CHK. BY PCM 7/2015	DATE 12/29/2008

EVALUATE FROST PENETRATION DEPTH FOR JUNIPER RIDGE LANDFILL EXPANSION.

ASSUMPTIONS:

① CONDITION EVALUATED IS AFTER INITIAL 5-FOOT THICK LAYER OF SELECT WASTE IS PLACED



② USE MODIFIED BERGGREN EQUATION TO SOLVE FOR ANTICIPATED FROST DEPTH. Mod Berg (Version 99.2) COMPUTER PROGRAM USED TO PERFORM THIS CALCULATION. PRINTOUT OF RESULTS IS ATTACHED.

③ SELECT WASTE
- N-FACTOR = 0.9 (ASSUMED)
- DENSITY = 80 pcf
- MOISTURE CONTENT = 32%
- WEATHER DATA = ORONO, MAINE

RESULTS: FROST PENETRATION = 6.1" < 60" WASTE THICKNESS

∴ OK

SEVEE & MAHER ENGINEERS

--- ModBerg Results ---

Project Location: Orono, Maine

Air Design Freezing Index = 1588 F-days
N-Factor = 0.90
Surface Design Freezing Index = 1429 F-days
Mean Annual Temperature = 43.5 deg F
Design Length of Freezing Season = 132 days

Layer #:Type	t	w%	d	Cf	Cu	Kf	Ku	L
1-Insulating	6.1	32.0	80.0	26	39	.0	.0	3,686

t = Layer thickness, in inches.
w% = Moisture content, in percentage of dry density.
d = Dry density, in lbs/cubic ft.
Cf = Heat Capacity of frozen phase, in BTU/(cubic ft degree F).
Cu = Heat Capacity of thawed phase, in BTU/(cubic ft degree F).
Kf = Thermal conductivity in frozen phase, in BTU/(ft hr degree).
Ku = Thermal conductivity in thawed phase, in BTU/(ft hr degree).
L = Latent heat of fusion, in BTU / cubic ft.

Total Depth of Frost Penetration = .51 ft = 6.1 in.

APPENDIX D-5

LEAK DETECTION DESIGN

LEAK DETECTION SYSTEM DESIGN

Project Name:	Juniper Ridge Landfill Expansion
Project Location:	Old Town, Maine
Project No:	14101
Comp By:	PCM
Chk. By:	KPW 06/01/2015

PURPOSE

Evaluate the length of time required for a leak to be detected under the worst case design conditions.

ASSUMPTIONS

1. Longest Leak Detection travel path as shown on sketch below (Cell 12).
2. Liner System is as shown below:
   - 80-mil HDPE Geomembrane
   - GCL
   - 12-inch Compacted Clay
   - 12-inches Drainage Sand with 6-inch diameter HDPE piping
   - Drainage Geocomposite
   - 60-mil HDPE Geomembrane
3. Gradient along geocomposite is 2.6% (minimum)
4. Compressive load strength is 10,000 lbs/ft^2

ANALYSIS

Giroud et. al., 1992,

Determine Geocomposite Flow Properties:

Geocomposite Transmissivity (T) at 15,000 lbs/ft2 based on past Cell 4 thru Cell 8 test data.

T_{270} = 0.000317 m^2/sec

Geocomposite Reduction Factors

RF_{IN} =	1.0	Reduction Factor for Intrusion
RF_{CR} =	1.1	Reduction Factor for Creep
RF_{CC} =	1.3	Reduction Factor for Chemical Clogging
RF_{BC} =	1.5	Reduction Factor for Biological Clogging
RF_{DE} =	2.0	Reduciton Factor for Design

Reduced Geocomposite Transmissivity (T_{250RED}) = T_{270} / (RF_{IN} x RF_{CR} x RF_{CC} x RF_{BC} x RF_{DE})

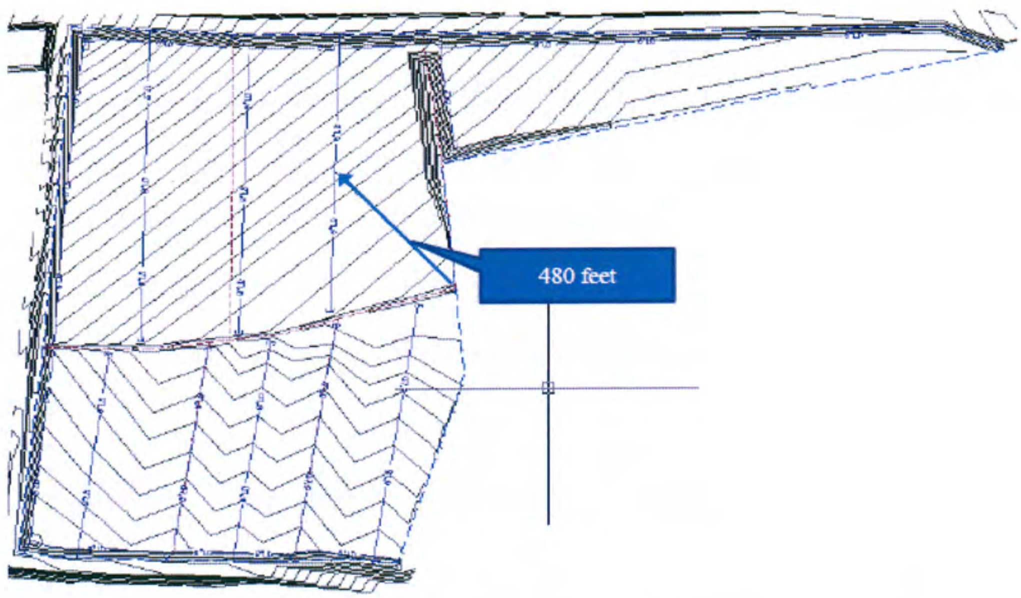
T_{270RED} = 7.389E-05 m^2/sec

System Design: 270 ml Geonet / Drainage Geocomposite

T_{270RED} = Design Value

Cell 12 LD Conditions:

I =	0.026 ft/ft	LF Gradient
L =	480 ft	Longest Flow Length to Cell 12 LD Pipe
L =	146.3414634 m	Flow Path Length in meters
t_g =	0.0063 m	thickness of LD drain
n =	0.6	porosity of drain



SOLVE FOR TRAVEL TIME (LEAK DETECTION TIME) IN DRAINAGE GEOCOMPOSITE TO NEAREST PIPE

Leak Detection Time:

T_{spec} =	$T_{270}/(RF_{CR}*RF_{CC}*RF_{BC}*]$	m^2/sec	
T_{spec} =	7.39E-05	m^2/sec	Design value (Reduced Specified Value) .
$k_{req} = T_{req}/t_g$	m/sec		permeability of drain
k_{spec} =	1.17E-02	m/sec	
$t_L = (n*L)/k_{spec}*i$			
t_L =	287928.0	sec	Travel time in geocomposite only. Pipe travel time is insignificant.
	4798.8	min	
	80.0	hrs	
	3.3	days	

SUMMARY DESIGN LEAKAGE RATE THROUGH GEOMEMBRANE	
JUNIPER RIDGE LANDFILL EXPANSION	
Size of Design Holes 1 cm^2 = 11mm diameter actual 2mm (1)	Leakage Rate based on 3 Design Holes per acre (GPAD)
11 mm hole (design conditions leakage through primary liner) (2) (3) (4)	0.26
Geomembrane with underlying Clay, with 1ft of head and with 11 mm hole (design conditions leakage through secondary liner) (3) (5)	0.46

See Attached Calculations (Landfill Design.com)

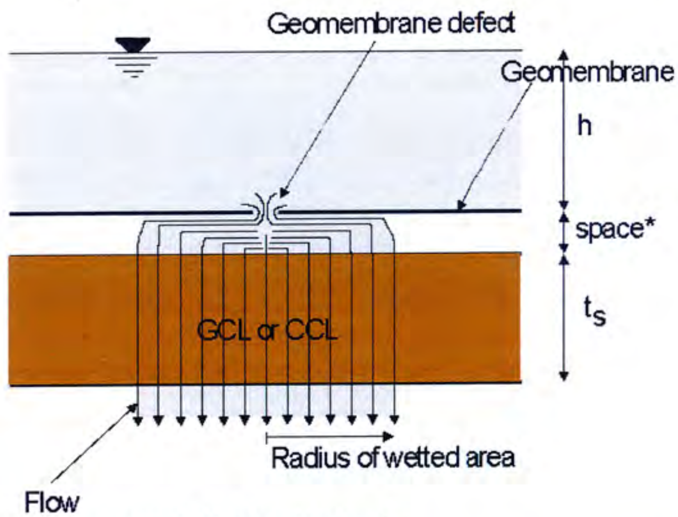
1. Giroud et al., 1994
2. Hydraulic Conductivity of GCL $5*10^{-9}$ cm/sec
3. 12" head over Holes in primary and secondary geomembrane
4. Thickness of GCL 6.35 mm
5. Hydraulic Conductivity of 12" Clay Layer below GCL is $1*10^{-7}$ cm/sec

landfilldesign.com
Design Calculator
Leakage Rate Through a Composite Liner

Problem Statement

This calculator computes the rate of leakage through defects in a composite liner, i.e. geomembrane/CCL or geomembrane/GCL. The thickness of a CCL is between 0.3 to 1.5 m whereas the thickness of a hydrated GCL depends on the compressive stress applied during hydration. Typical values are between 5 and 10 mm; or in the order of 100 times less than the thickness of a CCL. Field evaluation, sponsered by USEPA, of leakage rate for double-lined landfills indicates that GM/GCL composite liners outperform GM/CCL liners (Othman et al.,1998.)

The rate of leakage through a geomembrane liner due to geomembrane permeability is negligible compared to the rate of leakage through defects in the geomembrane (Giroud and Bonaparte 1989.) Hence, only leakage through defects will be considered. If there is a defect in the geomembrane, the liquid first passes through the defect, then it flows laterally some distance between the geomembrane and the low-permeability soil, and, finally it infiltrates in the low permeability soil.



* Space exaggerated to show interface flow

Flow between geomembrane and low-permeability soil is called interface flow, and is highly dependent upon the quality of contact between the two components (Bonaparte et al. 1989.) Contact conditions are defined as follows:

- **Good contact conditions** correspond to a geomembrane installed, with as few wrinkles as possible, on top of a low-permeability soil layer that has been adequately compacted and has a smooth surface.
- **Poor contact conditions** correspond to a geomembrane that has been installed with a certain number of wrinkles, and/or placed on a low-permeability soil that has not been well compacted and does not appear smooth.

Table 1

	Contact quality factor (C_{qo}) (circular, square, rectangular)	Contact quality factor ($C_{q\infty}$) (infinite length)
Good contact	0.21	0.52
Poor contact	1.15	1.22

The Help model provides guidance for estimating the defect densities (Schroeder et al., 1994). Some useful information on the Help model is given in the Technical Note on Using HELP Model (ver 3.07). There are mainly two types of defects, manufacturing defects and installation defects. Typical geomembranes may have about 0.5 to 1 (1 to 2 pe hectare) pinholes per acre from manufacturing defects (Pinholes are defects with a diameter equal or smaller than the geomembrane thickness. The density of installation defects is a function of the quality of installation, testing, materials, surface preparation, equipment, and QA/QC program. Representative installation defect densities as a function of the quality of installation are given in Table 2 for landfills being built today with the state of the art in materials, equipment and QA/QC.

Table 2

Installation quality	Defect density (number per acre)	Frequency (percent)
Excellent	Up to 1	10
Good	1 to 4	40
Fair	4 to 10	40
Poor	10 to 20*	10

*Higher defect densities have been reported for older landfills with poor installation operations and materials; however, these high densities are not characteristic of modern practice.

Studies by Giroud and Bonaparte (1989) have shown that for geomembrane liners installed, with strict construction quality assurance, could have one to two defects per acre (4000 m^2) with a typical defect diameter of 2 mm (i.e., a defect area of $3.14 * 10^{-6}$ m^2).

Typical for liner performance evaluation one defect per acre (4000 m^2) is considered with a defect area of 0.1 cm^2 (equivalent to defect diameter of 3.5 mm), for a conservative design a defect area of 1 cm^2 (equivalent defect diameter of 11 mm) can be considered (Giroud et al., 1994)

Problem Solution

Different geomembrane defect shapes will be considered:

Circular defect with diameter of d

$$\frac{Q}{A} = n \cdot 0.976 C_{qo} \cdot [1 + 0.1 \cdot (h/t_s)^{0.95}] \cdot d^{0.2} \cdot h^{0.9} \cdot k_s^{0.74}$$

Square defect with side length b

$$\frac{Q}{A} = n \cdot C_{qo} \cdot [1 + 0.1 \cdot (h/t_s)^{0.95}] \cdot b^{0.2} \cdot h^{0.9} \cdot k_s^{0.74}$$

Infinitely long defect with width of b

$$\frac{Q^*}{A} = n \cdot C_{q\infty} \cdot [1 + 0.2 \cdot (h/t_s)^{0.95}] \cdot b^{0.1} \cdot h^{0.45} \cdot k_s^{0.87}$$

Rectangular defect with width of b and length of B

$$\frac{Q}{A} = n \cdot C_{qo} \cdot [1 + 0.1 \cdot (h/t_s)^{0.95}] \cdot b^{0.2} \cdot h^{0.9} \cdot k_s^{0.74}$$
$$+ n \cdot C_{q\infty} \cdot [1 + 0.2 \cdot (h/t_s)^{0.95}] \cdot (B - b) \cdot b^{0.1} \cdot h^{0.45} \cdot k_s^{0.87}$$

Q	Leakage rate through the considered geomembrane defect (m^3/s)
Q*	Leakage rate per unit length of geomembrane defect ($m^3/s.m$)
A	Considered geomembrane area (m^2)
n	Number of defects per considered geomembrane area (A)
Co or $C_{q\infty}$	Contact quality factor (see above table 1)
h	Hydraulic head on top of the geomembrane (m)
t_s	Thickness of the low-permeability soil component of the composite liner (m)
d	Diameter of circular defect (m)
b	Width of defect (m)
B	Length of rectangular defect (m)

Limitation of the equations presented (Giroud et al. 1997):

- If the effect is circular, the defect diameter should be no less than 0.5 mm and not greater than 25 mm. In the case of the defects that are not circular, it is proposed to use these limitations for the defect width.
- The liquid head on top of the geomembrane should be equal to or less than 3 m.

Input Values

Geometry of circular defect

Considered geomembrane area (A)	4000	m^2
Hydraulic head on top of the geomembrane (m)	.33	m
Thickness of the low-permeability soil (m)	.00635 >	m
Permeability of the low-permeability soil (m/s)	5.00E-11	m/s

12" HEAD

GCL (5X10-9CM/ SEC)

Properties of circular defect

Contact (good or poor)	Good ▼	
Number of defects (n)	3	
Diameter of defect (d)	.011	m

3 - 1 CM SQ. HOLES

Geometry of square defect

Considered geomembrane area (A)	4000	m^2
Hydraulic head on top of the geomembrane (m)	0.3	m
Thickness of the low-permeability		m

soil (m)	2	
Permeability of the low-permeability soil (m/s)	1.00E-7	m/s

Properties of square defect

Contact (good or poor)	Good	
Number of defects (n)	0	
Side length of defect (d)	0.0002	m

Geometry of Infinitely Long Defect

Considered geomembrane area (A)	4000	m^2
Hydraulic head on top of the geomembrane (m)	0.3	m
Thickness of the low-permeability soil (m)	2	m
Permeability of the low-permeability soil (m/s)	1.00E-7	m/s

Properties of Infinitely Long Defect

Contact (good or poor)	Good	
Number of defects (n)	0	
Width of defect (b)	0.0002	m

Geometry of Rectangular Defect

Considered geomembrane area (A)	4000	m^2
Hydraulic head on top of the geomembrane (m)	0.3	m
Thickness of the low-permeability soil (m)	2	m
Permeability of the low-permeability soil (m/s)	1.00E-7	m/s

Properties of Rectangular Defect

Contact (good or poor)	Good	
Number of defects (n)	0	
Width of defect (b)	0.002	m
Length of defect (B)	0.01	m

Calculate

Solution

Circular Defect

Leakage Rate	2.886E-012	$(m^3/s)/m^2$
	2.5920	lphd (liter per hectare per day)
		1 $(m^3/s)/m^2 = 8.64 \cdot 10^{11}$ lphd
	0.26334	gpad (gallons per acre per day)
		1 lphd =0.1056 gpad

Square Defect

Leakage Rate	0.000E+000	$(m^3/s)/m^2$
	0.0000	lphd (liter per hectare per day)
		1 $(m^3/s)/m^2 = 8.64 \cdot 10^{11}$ lphd
	0.00000	
		1 lphd =0.1056 gpad

Infinitely Long Defect

Leakage Rate per unit length	0.000E+000	$(m^3/s)/m^2.m$
	0.0000	lphd/m (liter per hectare per day per meter)
		1 $(m^3/s)/m^2 = 8.64 \cdot 10^{11}$ lphd
	0.00000	gpad/ft (gallons per acre per day per feet)
		1 lphd =0.1056 gpad

Rectangular Defect

Leakage Rate	0.000E+000	$(m^3/s)/m^2.m$
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Assistance

References

R. Bonaparte, J.P.Giroud, and B.A. Gross,"Rates of Leakage through Landfill Liners", Proceedings of Geosynthetics '89, Vol. 1, IFAI, San Diego, California, USA, February 1989, pp. 18-29, 1989.

J.P. Giroud and R. Bonaparte, "Leakage Through Liners Constructed with Geomembranes, Part I", Geomembrane Liners, Geotextiles and Geomembranes, 8, 1: 27-67, 1989.

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landfilldesign.com
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This calculator computes the rate of leakage through defects in a composite liner, i.e. geomembrane/CCL or geomembrane/GCL. The thickness of a CCL is between 0.3 to 1.5 m whereas the thickness of a hydrated GCL depends on the compressive stress applied during hydration. Typical values are between 5 and 10 mm; or in the order of 100 times less than the thickness of a CCL. Field evaluation, sponsered by USEPA, of leakage rate for double-lined landfills indicates that GM/GCL composite liners outperform GM/CCL liners (Othman et al.,1998.)

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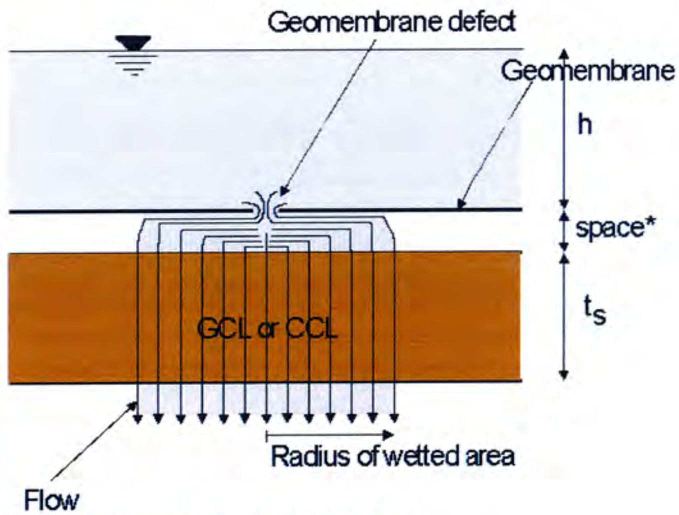

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*Higher defect densities have been reported for older landfills with poor installation operations and materials; however, these high densities are not characteristic of modern practice.

Studies by Giroud and Bonaparte (1989) have shown that for geomembrane liners installed, with strict construction quality assurance, could have one to two defects per acre (4000 m^2) with a typical defect diameter of 2 mm (i.e., a defect area of $3.14 * 10^{-6}$ m^2).

Typical for liner performance evaluation one defect per acre (4000 m^2) is considered with a defect area of 0.1 cm^2 (equivalent to defect diameter of 3.5 mm), for a conservative design a defect area of 1 cm^2 (equivalent defect diameter of 11 mm) can be considered (Giroud et al., 1994)

Problem Solution

Different geomembrane defect shapes will be considered:

Circular defect with diameter of d

$$\frac{Q}{A} = n \cdot 0.976\, C_{qo} \cdot [1 + 0.1 \cdot (h/t_s)^{0.95}] \cdot d^{0.2} \cdot h^{0.9} \cdot k_s^{0.74}$$

Square defect with side length b

$$\frac{Q}{A} = n \cdot C_{qo} \cdot [1 + 0.1 \cdot (h/t_s)^{0.95}] \cdot b^{0.2} \cdot h^{0.9} \cdot k_s^{0.74}$$

Infinitely long defect with width of b

$$\frac{Q^*}{A} = n \cdot C_{q\infty} \cdot [1 + 0.2 \cdot (h/t_s)^{0.95}] \cdot b^{0.1} \cdot h^{0.45} \cdot k_s^{0.87}$$

Rectangular defect with width of b and length of B

$$\frac{Q}{A} = n \cdot C_{qo} \cdot [1 + 0.1 \cdot (h/t_s)^{0.95}] \cdot b^{0.2} \cdot h^{0.9} \cdot k_s^{0.74}$$
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Q	Leakage rate through the considered geomembrane defect (m^3/s)
Q*	Leakage rate per unit length of geomembrane defect ($m^3/s.m$)
A	Considered geomembrane area (m^2)
n	Number of defects per considered geomembrane area (A)
Co or $C_{q\,\infty}$	Contact quality factor (see above table 1)
h	Hydraulic head on top of the geomembrane (m)
t_s	Thickness of the low-permeability soil component of the composite liner (m)
d	Diameter of circular defect (m)
b	Width of defect (m)
B	Length of rectangular defect (m)

Limitation of the equations presented (Giroud et al. 1997):

- If the effect is circular, the defect diameter should be no less than 0.5 mm and not greater than 25 mm. In the case of the defects that are not circular, it is proposed to use these limitations for the defect width.
- The liquid head on top of the geomembrane should be equal to or less than 3 m.

Input Values

Geometry of circular defect

Considered geomembrane area (A) 4000 m^2

Hydraulic head on top of the geomembrane (m) 0.3 m

Thickness of the low-permeability soil (m) 0.33 > m

Permeability of the low-permeability soil (m/s) 1.00E-9 m/s

Properties of circular defect

Contact (good or poor) Good

Number of defects (n) 3

Diameter of defect (d) .011 m

12" HEAD

CLAY (1X10-7CM/SEC)

3 - 1 CM SQ. HOLES

Geometry of square defect

Considered geomembrane area (A) 4000 m^2

Hydraulic head on top of the geomembrane (m) 0.3 m

Thickness of the low-permeability m

soil (m)	2	
Permeability of the low-permeability soil (m/s)	1.00E-7	m/s

Properties of square defect

Contact (good or poor)	Good	
Number of defects (n)	0	
Side length of defect (d)	0.0002	m

Geometry of Infinitely Long Defect

Considered geomembrane area (A)	4000	m^2
Hydraulic head on top of the geomembrane (m)	0.3	m
Thickness of the low-permeability soil (m)	2	m
Permeability of the low-permeability soil (m/s)	1.00E-7	m/s

Properties of Infinitely Long Defect

Contact (good or poor)	Good	
Number of defects (n)	0	
Width of defect (b)	0.0002	m

Geometry of Rectangular Defect

Considered geomembrane area (A)	4000	m^2
Hydraulic head on top of the geomembrane (m)	0.3	m
Thickness of the low-permeability soil (m)	2	m
Permeability of the low-permeability soil (m/s)	1.00E-7	m/s

Properties of Rectangular Defect

Contact (good or poor)	Good	
Number of defects (n)	0	
Width of defect (b)	0.002	m
Length of defect (B)	0.01	m

Calculate

Solution

Circular Defect

Leakage Rate	5.039E-012	$(m^3/s)/m^2$
	25.9200	lphd (liter per hectare per day)
		1 $(m^3/s)/m^2 = 8.64 \cdot 10^{11}$ lphd
	0.45979	gpad (gallons per acre per day)
		1 lphd =0.1056 gpad

Square Defect

Leakage Rate	0.000E+000	$(m^3/s)/m^2$
	0.0000	lphd (liter per hectare per day)
		1 $(m^3/s)/m^2 = 8.64 \cdot 10^{11}$ lphd
	0.00000	
		1 lphd =0.1056 gpad

Infinitely Long Defect

Leakage Rate per unit length	0.000E+000	$(m^3/s)/m^2.m$
	0.0000	lphd/m (liter per hectare per day per meter)
		1 $(m^3/s)/m^2 = 8.64 \cdot 10^{11}$ lphd
	0.00000	gpad/ft (gallons per acre per day per feet)
		1 lphd =0.1056 gpad

Rectangular Defect

Leakage Rate	0.000E+000	$(m^3/s)/m^2.m$
	0.0000	lphd (liter per hectare per day)
		1 $(m^3/s)/m^2 = 8.64 \cdot 10^{11}$ lphd
	0.00000	gpad (gallons per acre per day)
		1 lphd =0.1056 gpad

Assistance

References

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LEAK DETECTION PIPE AND SUMP EVALUATION

Project Name: Juniper Ridge Landfill Expansion
Project Location: Old Town, Maine
Project No: 14101.00
Comp By: PCM
Chk. By: KPW 06/01/2015

OBJECTIVE: Evaluate sizing of leachate collection piping.

DESIGN CRITERIA

1. Size pipes appropriately to allow the flow deveolped by a leak using the ALR2 for the site. See Liner Action Plan.
2. Minimum pipe size is 6" (OD) to allow for proper cleaning.

DESIGN ASSUMPTIONS

1. For the leak detection piping assume largest ALR2 contributing to a leak detection system and minimum pipe slope (1%) as design condition. Cell 12 has the largest ALR of 1159 gallons per day.
2. Assume pipe flow using Mannings Equation with HDPE pipe n= 0.012.

ANALYSIS

LEAK DETECTION PIPE SIZING ANALYSIS
Determine maximum amount of leakage flow to any one pipe based on maximum ALR.
Convert Gallons/day to ft^3/sec.

$$1159 \frac{\text{gals}}{\text{day}} \times 7.48 \frac{1\,\text{ft}^3}{\text{gal}} \times 24 \frac{\text{day}}{\text{hr}} \times 60 \frac{\text{hr}}{\text{min}} \times 60 \frac{\text{min}}{\text{sec}}$$

= 0.002 ft^3/sec

Determine maximum flow in 6-inch diameter and 8-inch diameter HDPE pipes using mannings equation.

OD =	6 inches (EJP Refrence Manual)
SDR =	11 unitless
ID =	5.349 inches (EJP Refrence Manual)
	0.45 feet
Slope =	0.01 ft/ft (minimum design slope)
n =	0.012 unitless
Qmax =	0.42 ft^3/sec (See attached Printout)

Qmax of pipe is greater than maximum Q anticipated therefore pipe sizing on drawings is appropriate.

LEAK DETECTION SUMP SIZING ANALYSIS
Determine maximum amount of leakage flow to any one sump based on maximum ALR.

SUMP SIZE

	AREA(FT^2)	AVERAGE AREA(FT^2)	INTERVAL (FT)	CUMM.VOL UME (FT^3)	CUMM.VOL UME (GAL)	
BOTTOM	40	0	0	0		
1' DEPTH	113	76.5	1	76.5	572.22	
2' DEPTH	220	166.5	1	243	1817.64	SUMP CAPACITY > ALR OKAY

LEAK DETECTION PUMP CAPACITY = 30 GPM

TIME TO PUMP FULL SUMP = 60.588 MINUTES (1 HOUR TO PUMP OUT THE SUMP)

Free Online Manning Pipe Flow Calculator

List of Calculators Hydraulics Language

Manning Formula Uniform Pipe Flow at Given Slope and Depth

Can you help me translate this calculator to your language or host this calculator at your web site?

Juniper Ridge Landfill

Leak Detection Pipe Sizing

Set units: m mm ft inches

Pipe diameter, d_0	5.35 inches
Manning roughness, n ?	0.012
Pressure slope (possibly ? equal to pipe slope), S_0	.01 rise/run
Percent of (or ratio to) full depth (100% or 1 if flowing full)	100 %

Results:

Flow, q	0.4477	cfs
Velocity, v	2.8678	ft/sec
Velocity head, h_v	1.5339	inches
Flow area	22.4801	sq. in.
Wetted perimeter	16.8075	inches
Hydraulic radius	1.3375	inches
Top width, T	0.0000	inches
Froude number, F	0.00	
Shear stress (tractive force), tau	13.3254	N/m^2

Please give us your valued words of suggestion or praise. Did this free calculator exceed your expectations in every way?

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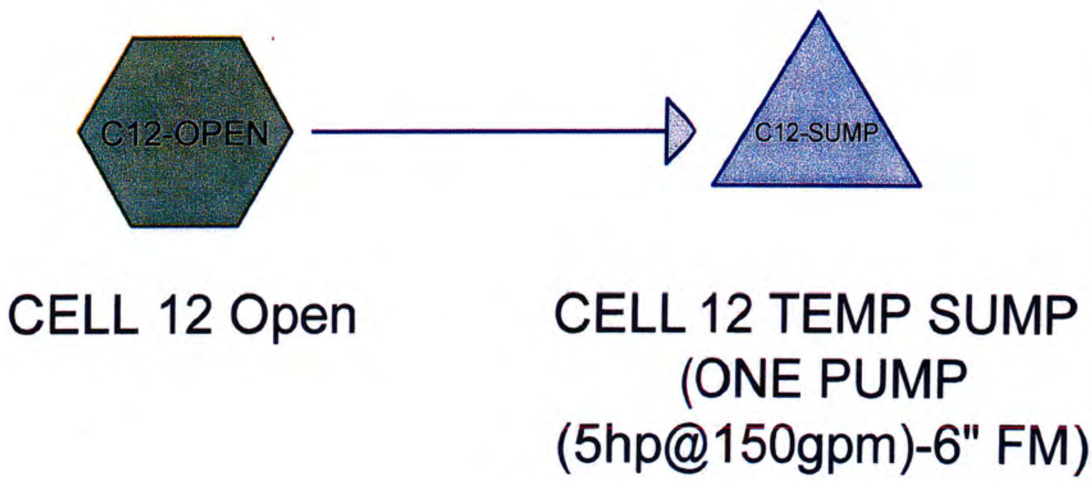
Last Modified 05/22/2015 07:58:02

APPENDIX D-6

STORAGE VOLUME FOR LEACHATE COLLECTION SUMPS

CELL 12 SUMP & PUMP DESIGN



Routing Diagram for Sump-Design-Temporary
Prepared by Microsoft, Printed 5/5/2015
HydroCAD® 10.00 s/n 01260 © 2012 HydroCAD Software Solutions LLC

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
2.500	65	OPEN WASTE AT 38 PERCENT (C12-OPEN)
12.600	55	OPEN WASTE AT 5 PERCENT GRADE (C12-OPEN)
15.100	**57**	**TOTAL AREA**

Time span=0.00-60.00 hrs, dt=0.01 hrs, 6001 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

SubcatchmentC12-OPEN: CELL 12 Open Runoff Area=15.100 ac 0.00% Impervious Runoff Depth=1.00"
Tc=15.0 min CN=57 Runoff=10.88 cfs 1.258 af

Pond C12-SUMP: CELL 12 TEMP SUMP Peak Elev=199.85' Storage=40,114 cf Inflow=10.88 cfs 1.258 af
Outflow=0.33 cfs 1.258 af

Total Runoff Area = 15.100 ac Runoff Volume = 1.258 af Average Runoff Depth = 1.00"
100.00% Pervious = 15.100 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment C12-OPEN: CELL 12 Open

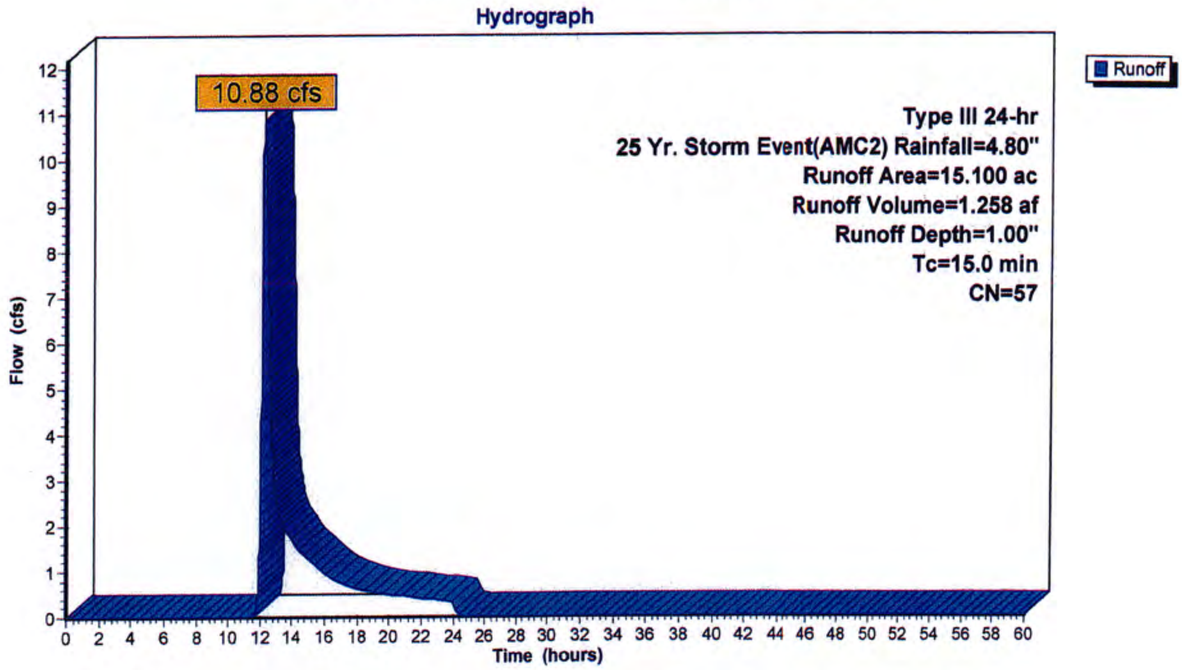
Runoff = 10.88 cfs @ 12.25 hrs, Volume= 1.258 af, Depth= 1.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs
Type III 24-hr 25 Yr. Storm Event(AMC2) Rainfall=4.80"

	Area (ac)	CN	Description
*	12.600	55	OPEN WASTE AT 5 PERCENT GRADE
*	2.500	65	OPEN WASTE AT 38 PERCENT
	15.100	57	Weighted Average
	15.100		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry, Time of Conc. (Conservative)**

Subcatchment C12-OPEN: CELL 12 Open



Summary for Pond C12-SUMP: CELL 12 TEMP SUMP (ONE PUMP (5hp@150gpm)-6" FM)

Inflow Area = 15.100 ac, 0.00% Impervious, Inflow Depth = 1.00" for 25 Yr. Storm Event(AMC2) event
Inflow = 10.88 cfs @ 12.25 hrs, Volume= 1.258 af
Outflow = 0.33 cfs @ 11.98 hrs, Volume= 1.258 af, Atten= 97%, Lag= 0.0 min
Primary = 0.33 cfs @ 11.98 hrs, Volume= 1.258 af

Routing by Stor-Ind method, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs
Peak Elev= 199.85' @ 23.99 hrs Surf.Area= 53,095 sf Storage= 40,114 cf
Flood Elev= 204.00' Surf.Area= 135,600 sf Storage= 154,250 cf

Plug-Flow detention time= 1,198.7 min calculated for 1.258 af (100% of inflow)
Center-of-Mass det. time= 1,198.9 min (2,096.1 - 897.3)

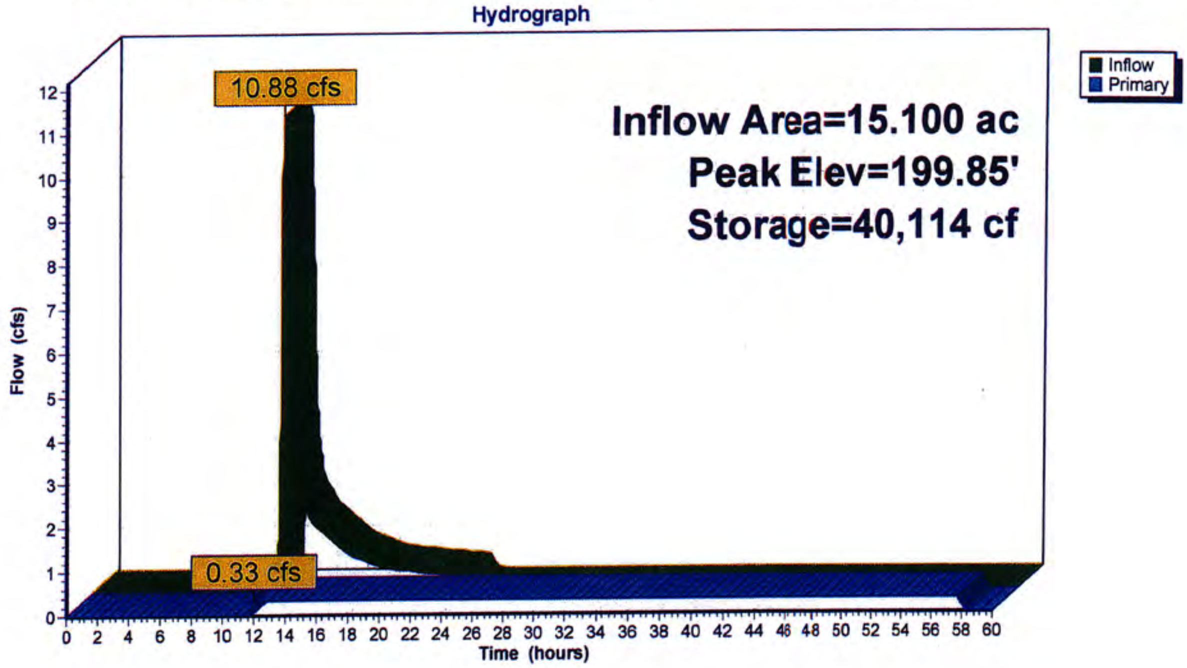
Volume	Invert	Avail.Storage	Storage Description
#1	193.00'	154,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Voids (%)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
193.00	0	0.0	0	0
194.00	1,700	40.0	340	340
196.00	11,300	40.0	5,200	5,540
198.00	28,500	30.0	11,940	17,480
200.00	55,100	30.0	25,080	42,560
202.00	90,800	30.0	43,770	86,330
204.00	135,600	30.0	67,920	154,250

Device	Routing	Invert	Outlet Devices
#1	Primary	193.00'	**PUMP SYSTEM** Head (feet) 0.00 1.00 2.00 3.00 4.00 5.00 6.00 8.00 10.00 Disch. (cfs) 0.000 0.330 0.330 0.330 0.330 0.330 0.330 0.330 0.330

Primary OutFlow Max=0.33 cfs @ 11.98 hrs HW=194.04' (Free Discharge)
↑—**1=PUMP SYSTEM** (Custom Controls 0.33 cfs)

Pond C12-SUMP: CELL 12 TEMP SUMP (ONE PUMP (5hp@150gpm)-6" FM)



Hydrograph for Pond C12-SUMP: CELL 12 TEMP SUMP (ONE PUMP (5hp@150gpm)-6" FM)

Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Primary (cfs)
0.00	0.00	0	193.00	0.00
0.20	0.00	0	193.00	0.00
0.40	0.00	0	193.00	0.00
0.60	0.00	0	193.00	0.00
0.80	0.00	0	193.00	0.00
1.00	0.00	0	193.00	0.00
1.20	0.00	0	193.00	0.00
1.40	0.00	0	193.00	0.00
1.60	0.00	0	193.00	0.00
1.80	0.00	0	193.00	0.00
2.00	0.00	0	193.00	0.00
2.20	0.00	0	193.00	0.00
2.40	0.00	0	193.00	0.00
2.60	0.00	0	193.00	0.00
2.80	0.00	0	193.00	0.00
3.00	0.00	0	193.00	0.00
3.20	0.00	0	193.00	0.00
3.40	0.00	0	193.00	0.00
3.60	0.00	0	193.00	0.00
3.80	0.00	0	193.00	0.00
4.00	0.00	0	193.00	0.00
4.20	0.00	0	193.00	0.00
4.40	0.00	0	193.00	0.00
4.60	0.00	0	193.00	0.00
4.80	0.00	0	193.00	0.00
5.00	0.00	0	193.00	0.00
5.20	0.00	0	193.00	0.00
5.40	0.00	0	193.00	0.00
5.60	0.00	0	193.00	0.00
5.80	0.00	0	193.00	0.00
6.00	0.00	0	193.00	0.00
6.20	0.00	0	193.00	0.00
6.40	0.00	0	193.00	0.00
6.60	0.00	0	193.00	0.00
6.80	0.00	0	193.00	0.00
7.00	0.00	0	193.00	0.00
7.20	0.00	0	193.00	0.00
7.40	0.00	0	193.00	0.00
7.60	0.00	0	193.00	0.00
7.80	0.00	0	193.00	0.00
8.00	0.00	0	193.00	0.00
8.20	0.00	0	193.00	0.00
8.40	0.00	0	193.00	0.00
8.60	0.00	0	193.00	0.00
8.80	0.00	0	193.00	0.00
9.00	0.00	0	193.00	0.00
9.20	0.00	0	193.00	0.00
9.40	0.00	0	193.00	0.00
9.60	0.00	0	193.00	0.00
9.80	0.00	0	193.00	0.00
10.00	0.00	0	193.00	0.00
10.20	0.00	0	193.00	0.00
10.40	0.00	0	193.00	0.00

Hydrograph for Pond C12-SUMP: CELL 12 TEMP SUMP (ONE PUMP (5hp@150gpm)-6" FM) (continued)

Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Primary (cfs)
10.60	0.00	0	193.00	0.00
10.80	0.00	0	193.00	0.00
11.00	0.00	0	193.00	0.00
11.20	0.00	0	193.00	0.00
11.40	0.00	0	193.00	0.00
11.60	0.00	0	193.00	0.00
11.80	0.16	12	193.18	**0.06**
12.00	2.02	477	194.16	**0.33**
12.20	**10.41**	4,575	195.78	0.33
12.40	**8.95**	11,671	197.23	0.33
12.60	5.72	16,772	197.92	0.33
12.80	3.37	19,652	198.24	0.33
13.00	2.62	21,535	198.43	0.33
13.20	2.18	23,016	198.57	0.33
13.40	2.00	24,275	198.68	0.33
13.60	1.88	25,435	198.79	0.33
13.80	1.77	26,516	198.88	0.33
14.00	1.66	27,514	198.96	0.33
14.20	1.54	28,427	199.03	0.33
14.40	1.47	29,272	199.10	0.33
14.60	1.41	30,073	199.16	0.33
14.80	1.35	30,833	199.22	0.33
15.00	1.29	31,549	199.27	0.33
15.20	1.23	32,222	199.32	0.33
15.40	1.17	32,848	199.36	0.33
15.60	1.10	33,427	199.40	0.33
15.80	1.03	33,957	199.44	0.33
16.00	0.96	34,437	199.48	0.33
16.20	0.89	34,867	199.50	0.33
16.40	0.86	35,259	199.53	0.33
16.60	0.82	35,626	199.56	0.33
16.80	0.79	35,971	199.58	0.33
17.00	0.76	36,294	199.60	0.33
17.20	0.73	36,595	199.62	0.33
17.40	0.70	36,873	199.64	0.33
17.60	0.67	37,129	199.66	0.33
17.80	0.64	37,361	199.67	0.33
18.00	0.60	37,569	199.69	0.33
18.20	0.57	37,754	199.70	0.33
18.40	0.56	37,923	199.71	0.33
18.60	0.55	38,084	199.72	0.33
18.80	0.54	38,238	199.73	0.33
19.00	0.53	38,385	199.74	0.33
19.20	0.52	38,525	199.75	0.33
19.40	0.51	38,659	199.76	0.33
19.60	0.50	38,787	199.76	0.33
19.80	0.49	38,907	199.77	0.33
20.00	0.48	39,020	199.78	0.33
20.20	0.47	39,127	199.79	0.33
20.40	0.47	39,227	199.79	0.33
20.60	0.46	39,322	199.80	0.33
20.80	0.45	39,412	199.80	0.33
21.00	0.44	39,497	199.81	0.33

Hydrograph for Pond C12-SUMP: CELL 12 TEMP SUMP (ONE PUMP (5hp@150gpm)-6" FM) (continued)

Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Primary (cfs)
21.20	0.44	39,576	199.82	0.33
21.40	0.43	39,650	199.82	0.33
21.60	0.42	39,719	199.82	0.33
21.80	0.41	39,783	199.83	0.33
22.00	0.41	39,841	199.83	0.33
22.20	0.40	39,894	199.84	0.33
22.40	0.39	39,941	199.84	0.33
22.60	0.38	39,983	199.84	0.33
22.80	0.38	40,019	199.84	0.33
23.00	0.37	40,049	199.84	0.33
23.20	0.36	40,075	199.85	0.33
23.40	0.35	40,094	199.85	0.33
23.60	0.35	40,108	199.85	0.33
23.80	0.34	**40,116**	**199.85**	0.33
24.00	0.33	**40,118**	**199.85**	0.33
24.20	0.18	40,086	199.85	0.33
24.40	0.03	39,906	199.84	0.33
24.60	0.00	39,677	199.82	0.33
24.80	0.00	39,440	199.81	0.33
25.00	0.00	39,202	199.79	0.33
25.20	0.00	38,965	199.78	0.33
25.40	0.00	38,727	199.76	0.33
25.60	0.00	38,489	199.75	0.33
25.80	0.00	38,252	199.73	0.33
26.00	0.00	38,014	199.72	0.33
26.20	0.00	37,777	199.70	0.33
26.40	0.00	37,539	199.68	0.33
26.60	0.00	37,301	199.67	0.33
26.80	0.00	37,064	199.65	0.33
27.00	0.00	36,826	199.64	0.33
27.20	0.00	36,589	199.62	0.33
27.40	0.00	36,351	199.61	0.33
27.60	0.00	36,113	199.59	0.33
27.80	0.00	35,876	199.57	0.33
28.00	0.00	35,638	199.56	0.33
28.20	0.00	35,401	199.54	0.33
28.40	0.00	35,163	199.52	0.33
28.60	0.00	34,925	199.51	0.33
28.80	0.00	34,688	199.49	0.33
29.00	0.00	34,450	199.48	0.33
29.20	0.00	34,213	199.46	0.33
29.40	0.00	33,975	199.44	0.33
29.60	0.00	33,737	199.43	0.33
29.80	0.00	33,500	199.41	0.33
30.00	0.00	33,262	199.39	0.33
30.20	0.00	33,025	199.38	0.33
30.40	0.00	32,787	199.36	0.33
30.60	0.00	32,549	199.34	0.33
30.80	0.00	32,312	199.32	0.33
31.00	0.00	32,074	199.31	0.33
31.20	0.00	31,837	199.29	0.33
31.40	0.00	31,599	199.27	0.33
31.60	0.00	31,361	199.26	0.33

Hydrograph for Pond C12-SUMP: CELL 12 TEMP SUMP (ONE PUMP (5hp@150gpm)-6" FM) (continued)

Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Primary (cfs)
31.80	0.00	31,124	199.24	0.33
32.00	0.00	30,886	199.22	0.33
32.20	0.00	30,649	199.20	0.33
32.40	0.00	30,411	199.18	0.33
32.60	0.00	30,173	199.17	0.33
32.80	0.00	29,936	199.15	0.33
33.00	0.00	29,698	199.13	0.33
33.20	0.00	29,461	199.11	0.33
33.40	0.00	29,223	199.09	0.33
33.60	0.00	28,985	199.08	0.33
33.80	0.00	28,748	199.06	0.33
34.00	0.00	28,510	199.04	0.33
34.20	0.00	28,273	199.02	0.33
34.40	0.00	28,035	199.00	0.33
34.60	0.00	27,797	198.98	0.33
34.80	0.00	27,560	198.96	0.33
35.00	0.00	27,322	198.94	0.33
35.20	0.00	27,085	198.92	0.33
35.40	0.00	26,847	198.90	0.33
35.60	0.00	26,609	198.88	0.33
35.80	0.00	26,372	198.86	0.33
36.00	0.00	26,134	198.85	0.33
36.20	0.00	25,897	198.83	0.33
36.40	0.00	25,659	198.80	0.33
36.60	0.00	25,421	198.78	0.33
36.80	0.00	25,184	198.76	0.33
37.00	0.00	24,946	198.74	0.33
37.20	0.00	24,709	198.72	0.33
37.40	0.00	24,471	198.70	0.33
37.60	0.00	24,233	198.68	0.33
37.80	0.00	23,996	198.66	0.33
38.00	0.00	23,758	198.64	0.33
38.20	0.00	23,521	198.62	0.33
38.40	0.00	23,283	198.60	0.33
38.60	0.00	23,045	198.57	0.33
38.80	0.00	22,808	198.55	0.33
39.00	0.00	22,570	198.53	0.33
39.20	0.00	22,333	198.51	0.33
39.40	0.00	22,095	198.48	0.33
39.60	0.00	21,857	198.46	0.33
39.80	0.00	21,620	198.44	0.33
40.00	0.00	21,382	198.42	0.33
40.20	0.00	21,145	198.39	0.33
40.40	0.00	20,907	198.37	0.33
40.60	0.00	20,669	198.34	0.33
40.80	0.00	20,432	198.32	0.33
41.00	0.00	20,194	198.30	0.33
41.20	0.00	19,957	198.27	0.33
41.40	0.00	19,719	198.25	0.33
41.60	0.00	19,481	198.22	0.33
41.80	0.00	19,244	198.20	0.33
42.00	0.00	19,006	198.17	0.33
42.20	0.00	18,769	198.15	0.33

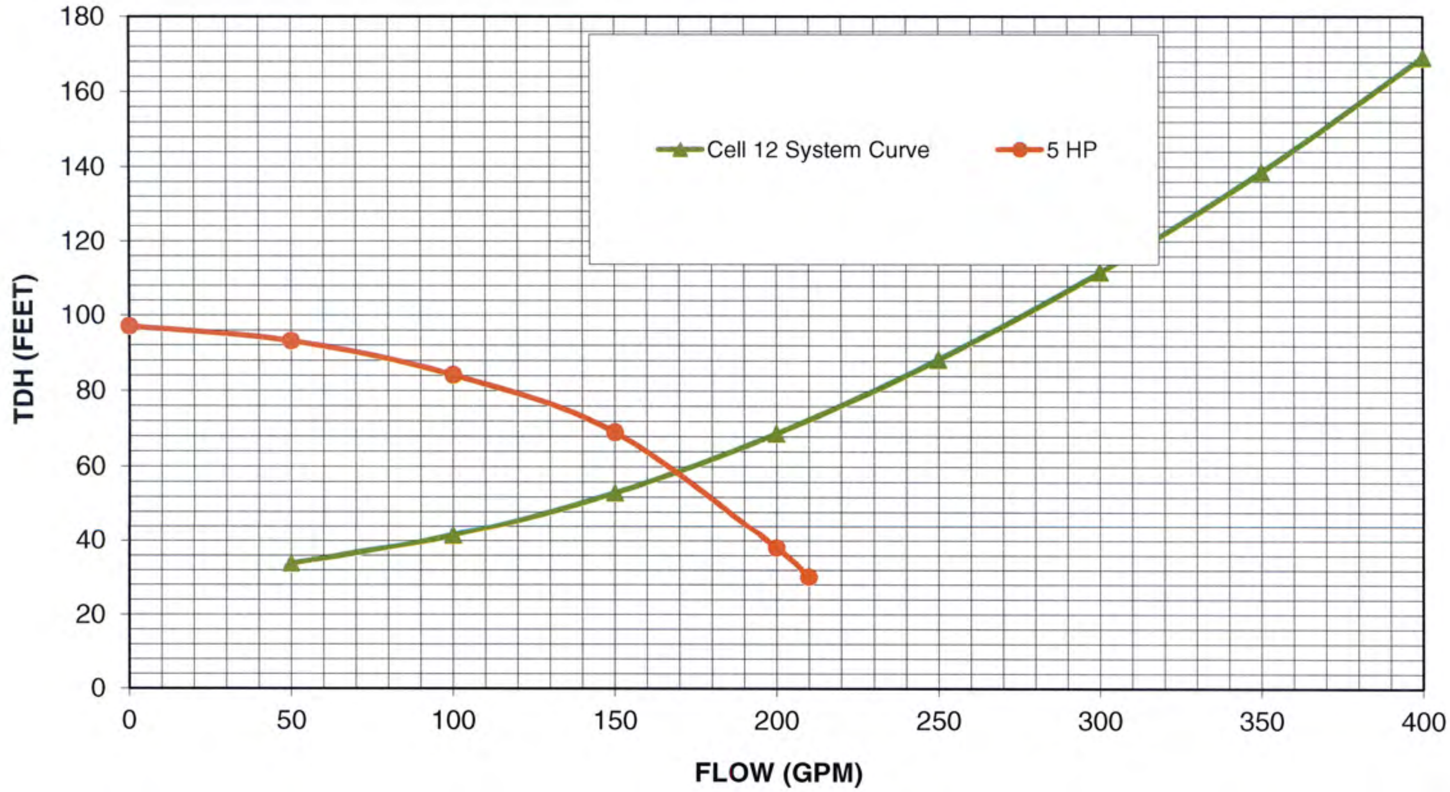
Hydrograph for Pond C12-SUMP: CELL 12 TEMP SUMP (ONE PUMP (5hp@150gpm)-6" FM) (continued)

Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Primary (cfs)
42.40	0.00	18,531	198.12	0.33
42.60	0.00	18,293	198.09	0.33
42.80	0.00	18,056	198.07	0.33
43.00	0.00	17,818	198.04	0.33
43.20	0.00	17,581	198.01	0.33
43.40	0.00	17,343	197.98	0.33
43.60	0.00	17,105	197.96	0.33
43.80	0.00	16,868	197.93	0.33
44.00	0.00	16,630	197.90	0.33
44.20	0.00	16,393	197.87	0.33
44.40	0.00	16,155	197.84	0.33
44.60	0.00	15,917	197.81	0.33
44.80	0.00	15,680	197.78	0.33
45.00	0.00	15,442	197.75	0.33
45.20	0.00	15,205	197.72	0.33
45.40	0.00	14,967	197.69	0.33
45.60	0.00	14,729	197.66	0.33
45.80	0.00	14,492	197.63	0.33
46.00	0.00	14,254	197.60	0.33
46.20	0.00	14,017	197.57	0.33
46.40	0.00	13,779	197.53	0.33
46.60	0.00	13,541	197.50	0.33
46.80	0.00	13,304	197.47	0.33
47.00	0.00	13,066	197.44	0.33
47.20	0.00	12,829	197.40	0.33
47.40	0.00	12,591	197.37	0.33
47.60	0.00	12,353	197.33	0.33
47.80	0.00	12,116	197.30	0.33
48.00	0.00	11,878	197.26	0.33
48.20	0.00	11,641	197.23	0.33
48.40	0.00	11,403	197.19	0.33
48.60	0.00	11,165	197.15	0.33
48.80	0.00	10,928	197.12	0.33
49.00	0.00	10,690	197.08	0.33
49.20	0.00	10,453	197.04	0.33
49.40	0.00	10,215	197.00	0.33
49.60	0.00	9,977	196.96	0.33
49.80	0.00	9,740	196.92	0.33
50.00	0.00	9,502	196.88	0.33
50.20	0.00	9,265	196.83	0.33
50.40	0.00	9,027	196.79	0.33
50.60	0.00	8,789	196.75	0.33
50.80	0.00	8,552	196.70	0.33
51.00	0.00	8,314	196.65	0.33
51.20	0.00	8,077	196.61	0.33
51.40	0.00	7,839	196.56	0.33
51.60	0.00	7,601	196.51	0.33
51.80	0.00	7,364	196.46	0.33
52.00	0.00	7,126	196.41	0.33
52.20	0.00	6,889	196.35	0.33
52.40	0.00	6,651	196.29	0.33
52.60	0.00	6,413	196.24	0.33
52.80	0.00	6,176	196.18	0.33

Hydrograph for Pond C12-SUMP: CELL 12 TEMP SUMP (ONE PUMP (5hp@150gpm)-6" FM) (continued)

Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Primary (cfs)
53.00	0.00	5,938	196.11	0.33
53.20	0.00	5,701	196.05	0.33
53.40	0.00	5,463	195.98	0.33
53.60	0.00	5,225	195.93	0.33
53.80	0.00	4,988	195.87	0.33
54.00	0.00	4,750	195.82	0.33
54.20	0.00	4,513	195.76	0.33
54.40	0.00	4,275	195.70	0.33
54.60	0.00	4,037	195.64	0.33
54.80	0.00	3,800	195.58	0.33
55.00	0.00	3,562	195.51	0.33
55.20	0.00	3,325	195.44	0.33
55.40	0.00	3,087	195.37	0.33
55.60	0.00	2,849	195.30	0.33
55.80	0.00	2,612	195.22	0.33
56.00	0.00	2,374	195.14	0.33
56.20	0.00	2,137	195.06	0.33
56.40	0.00	1,899	194.97	0.33
56.60	0.00	1,661	194.87	0.33
56.80	0.00	1,424	194.77	0.33
57.00	0.00	1,186	194.65	0.33
57.20	0.00	949	194.52	0.33
57.40	0.00	711	194.36	0.33
57.60	0.00	473	194.16	0.33
57.80	0.00	244	193.85	0.28
58.00	0.00	84	193.50	0.16
58.20	0.00	8	193.15	0.05
58.40	0.00	0	193.00	0.00
58.60	0.00	0	193.00	0.00
58.80	0.00	0	193.00	0.00
59.00	0.00	0	193.00	0.00
59.20	0.00	0	193.00	0.00
59.40	0.00	0	193.00	0.00
59.60	0.00	0	193.00	0.00
59.80	0.00	0	193.00	0.00
60.00	0.00	0	193.00	0.00

JUNIPER RIDGE LANDFILL CELL 12 PUMP STATION W/ 6-INCH TRANSPORT PIPING



JUNIPER RIDGE LANDFILL EXPANSION
CELL 12 FORCE ANALYSIS
PRESSURE PIPE HEAD LOSS CALCULATIONS

DESCRIPTION	ELEVATION HEAD LOSS			FRICTIONAL HEAD LOSS							FITTING HEAD LOSSES														
	Pump Elev. (feet)	Highest Elev. (feet)	Elevation Head Loss (feet)	Total Length (feet)	Pipe Flow (gpm)	HW Frict. Factor[1] C	Pipe SDR	Pipe O.D. Nominal (inches)	Pipe ID Average[2] (inches)	Friction Head Loss[3] (feet)	KL Ck Valve (swing)	Quantity	Elbow 90	Quantity	Elbow 45	Quantity	Tee (in-line)	Quantity	Butterfly valve	Quantity	Contraction Enlargement	Quantity	Ball Valve	Quantity	velocity
C12- Pump Station to Storage Tank																									
(Q=50gpm)				200	50	100	17.0	12	11.160	0.00	1.3		0.4	2	0.2	0	0.8	0		0			0.04		0.2
	194.0	225.0	31.0	3150	50	100	17.0	6	5.798	1.8	1.5		0.5	2	0.2	1	0.9	6		2	0.02	1	0.05	2	0.6
				50	50	100		3	3.000	0.7	1.8		0.5	1	0.3	0	1.1	0	0.8		0.02	0	0.05	1	2.3
				5	50	100		4	4.000	0.0	1.7		0.5	1	0.3	0	1.0	0		1.0	0.02	1	0.05	1	1.3
						100																			
(Q=100gpm)				200	100	100	17.0	12	11.160	0.02	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	0.3
	194.0	225.0	31.0	3150	100	100	17.0	6	5.798	6.4	1.5		0.5	1	0.2	1	1.8	6			0.02	1	0.05	2	1.2
				50	100	100		3	3.000	2.5	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	4.5
					100	100			4.000	0.0	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	0.0
						100																			
(Q=150gpm)				200	150	100	17.0	12	11.160	0.04	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	0.5
	194.0	225.0	31.0	3150	150	100	17.0	6	5.798	13.5	1.5		0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	1.8
				50	150	100		3	3.000	5.3	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	6.8
					150	100			4.000	0.0	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	3.8
						100																			
(Q=200gpm)				200	200	100	17.0	12	11.160	0.06	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	0.7
	194.0	225.0	31.0	3150	200	100	17.0	6	5.798	22.9	1.5		0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	2.4
				50	200	100		3	3.000	9.0	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	9.1
					200	100			4.000	0.0	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	5.1
						100																			
(Q=250gpm)				200	250	100	17.0	12	11.160	0.09	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	0.8
	194.0	225.0	31.0	3150	250	100	17.0	6	5.798	34.6	1.5		0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	3.0
				50	250	100		3	3.000	13.6	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	11.4
					250	100			4.000	0.0	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	6.4
						100																			
(Q=300gpm)				200	300	100	17.0	12	11.160	0.13	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	1.0
	194.0	225.0	31.0	3150	300	100	17.0	6	5.798	48.5	1.5		0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	3.6
				50	300	100		3	3.000	19.0	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	13.6
					300	100			4.000	0.0	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	7.7
						100																			
(Q=350gpm)				200	350	100	17.0	12	11.160	0.17	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	1.1
	194.0	225.0	31.0	3150	350	100	17.0	6	5.798	64.5	1.5		0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	4.3
				50	350	100		3	3.000	25.3	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	15.9
					350	100			4.000	0.0	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	8.9
						100																			
(Q=400gpm)				200	400	100	17.0	12	11.160	0.22	1.3	0	0.4	2	0.2	0	1.8	0		0			0.04	1	1.3
	194.0	225.0	31.0	3150	400	100	17.0	6	5.798	82.6	1.5	0	0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	4.9
				50	400	100		3	3.000	32.4	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	18.2
					400	100			4.000	0.0	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	10.2

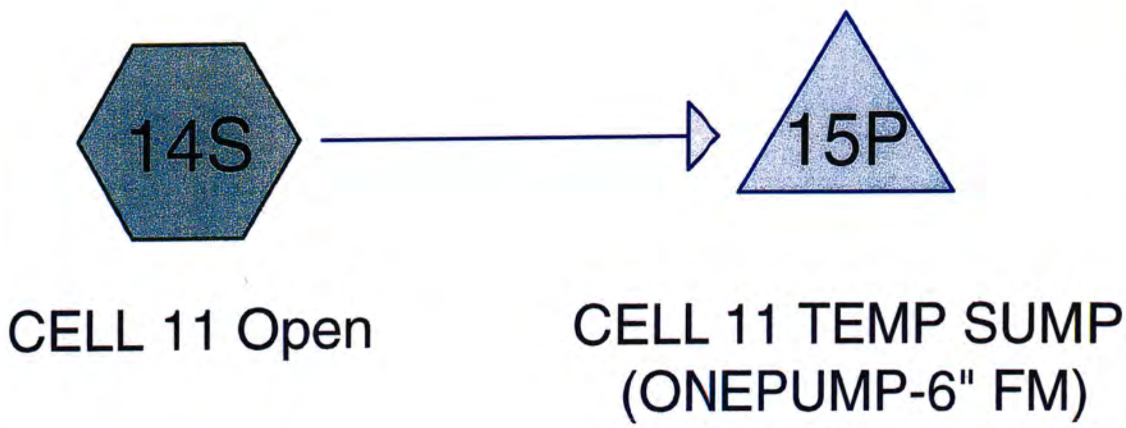
Notes:
1. Friction Factor Assumes scaling in pipe system.
2. Nominal ID from Rinker Pipe Design Guidance Table A-2 Page A-4.
3. Frictional Headloss Determined from Hazen Williams Equation.
4. Minor Headloss = $K(V^2/2g)$
5. Reference: Cameron Hydraulic Data 19th edition

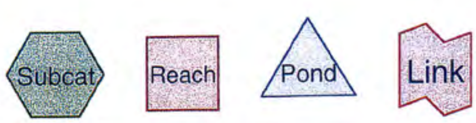
JUNIPER RIDGE LANDFILL EXPANSION
CELL 12 FORCE ANALYSIS
PRESSURE PIPE HEAD LOSS CALCULATIONS

DESCRIPTION	ELEVATION HEAD LOSS			FRICTIONAL HEAD LOSS									DISCHARGE LOSS		SYSTEM HEAD	MAX PIPE PRESSURE	Flow VELOCITY
	Pump Elev. (feet)	Highest Elev. (feet)	Elevation Head Loss (feet)	Total Length (feet)	Pipe Flow (gpm)	HW Frict. Factor[1] C	Pipe SDR	Pipe O.D. Nominal (inches)	Pipe ID Average[2] (inches)	Friction Head Loss[3] (feet)	K_{Ltotal}	Fitting Head Loss[4]	Outlet Factor	Discharge Head Loss (ft)	(feet)	(psi)	(ft/sec)
C12- Pump Station to Storage Tank																	
(Q=50gpm)				200	50	100	17.0	12	11.160	0.00	0.8	0.0	1.0	0	0.0		0.2
	194.0	225.0	31.0	3150	50	100	17.0	6	5.798	1.8	6.7	0.0	1.0	0	33		0.6
				50	50	100		3	3.000	0.7	0.6	0.0	1.0	0	1		2.3
				5	50	100		4	4.000	0.0	0.6	0.0	1.0	0	0		1.3
						100								Total:	34	15	
(Q=100gpm)				200	100	100	17.0	12	11.160	0.02	0.8	0.0	1.0	0	0.0		0.3
	194.0	225.0	31.0	3150	100	100	17.0	6	5.798	6.4	11.6	0.3	1.0	0	38		1.2
				50	100	100		3	3.000	2.5	2.2	0.7	1.0	0	4		4.5
					100	100			4.000	0.0	0.1	0.0	1.0	0	0		2.6
						100								Total:	41	18	
(Q=150gpm)				200	150	100	17.0	12	11.160	0.04	0.8	0.0	1.0	0	0.0		0.5
	194.0	225.0	31.0	3150	150	100	17.0	6	5.798	13.5	11.6	0.6	1.0	0	45		1.8
				50	150	100		3	3.000	5.3	2.2	1.6	1.0	1	8		6.8
					150	100			4.000	0.0	0.1	0.0	1.0	0	0		3.8
						100								Total:	53	23	
(Q=200gpm)				200	200	100	17.0	12	11.160	0.06	0.8	0.0	1.0	0	0.1		0.7
	194.0	225.0	31.0	3150	200	100	17.0	6	5.798	22.9	11.6	1.1	1.0	0	55		2.4
				50	200	100		3	3.000	9.0	2.2	2.8	1.0	1	13		9.1
					200	100			4.000	0.0	0.1	0.0	1.0	0	0		5.1
						100								Total:	69	30	
(Q=250gpm)				200	250	100	17.0	12	11.160	0.09	0.8	0.0	1.0	0	0.1		0.8
	194.0	225.0	31.0	3150	250	100	17.0	6	5.798	34.6	11.6	1.7	1.0	0	67		3.0
				50	250	100		3	3.000	13.6	2.2	4.4	1.0	2	20		11.4
					250	100			4.000	0.0	0.1	0.0	1.0	1	1		6.4
						100								Total:	88	38	
(Q=300gpm)				200	300	100	17.0	12	11.160	0.13	0.8	0.0	1.0	0	0.2		1.0
	194.0	225.0	31.0	3150	300	100	17.0	6	5.798	48.5	11.6	2.4	1.0	0	82		3.6
				50	300	100		3	3.000	19.0	2.2	6.4	1.0	3	28		13.6
					300	100			4.000	0.0	0.1	0.0	1.0	1	1		7.7
						100								Total:	111	48	
(Q=350gpm)				200	350	100	17.0	12	11.160	0.17	0.8	0.0	1.0	0	0.2		1.1
	194.0	225.0	31.0	3150	350	100	17.0	6	5.798	64.5	11.6	3.3	1.0	0	99		4.3
				50	350	100		3	3.000	25.3	2.2	8.7	1.0	4	38		15.9
					350	100			4.000	0.0	0.1	0.1	1.0	1	1		8.9
						100								Total:	138	60	
(Q=400gpm)				200	400	100	17.0	12	11.160	0.22	0.8	0.0	1.0	0	0.3		1.3
	194.0	225.0	31.0	3150	400	100	17.0	6	5.798	82.6	11.6	4.3	1.0	0	118		4.9
				50	400	100		3	3.000	32.4	2.2	11.3	1.0	5	49		18.2
					400	100			4.000	0.0	0.1	0.1	1.0	2	2		10.2
														Total:	169	73	

Notes:
1. Friction Factor Assumes scaling in pipe system.
2. Nominal ID from Rinker Pipe Design Guidance Table A-2 Page A-4.
3. Frictional Headloss Determined from Hazen Williams Equation.
4. Minor Headloss = $K(V^2/2g)$
5. Reference: Cameron Hydraulic Data 19th edition

CELL 11 SUMP
& PUMP DESIGN





Routing Diagram for Sump-Design-Temporary
Prepared by Microsoft, Printed 5/28/2015
HydroCAD® 10.00 s/n 01260 © 2012 HydroCAD Software Solutions LLC

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
2.800	65	OPEN WASTE AT 38 PERCENT (14S)
8.500	55	OPEN WASTE AT 5 PERCENT GRADE (14S)
11.300	**57**	**TOTAL AREA**

Summary for Subcatchment 14S: CELL 11 Open

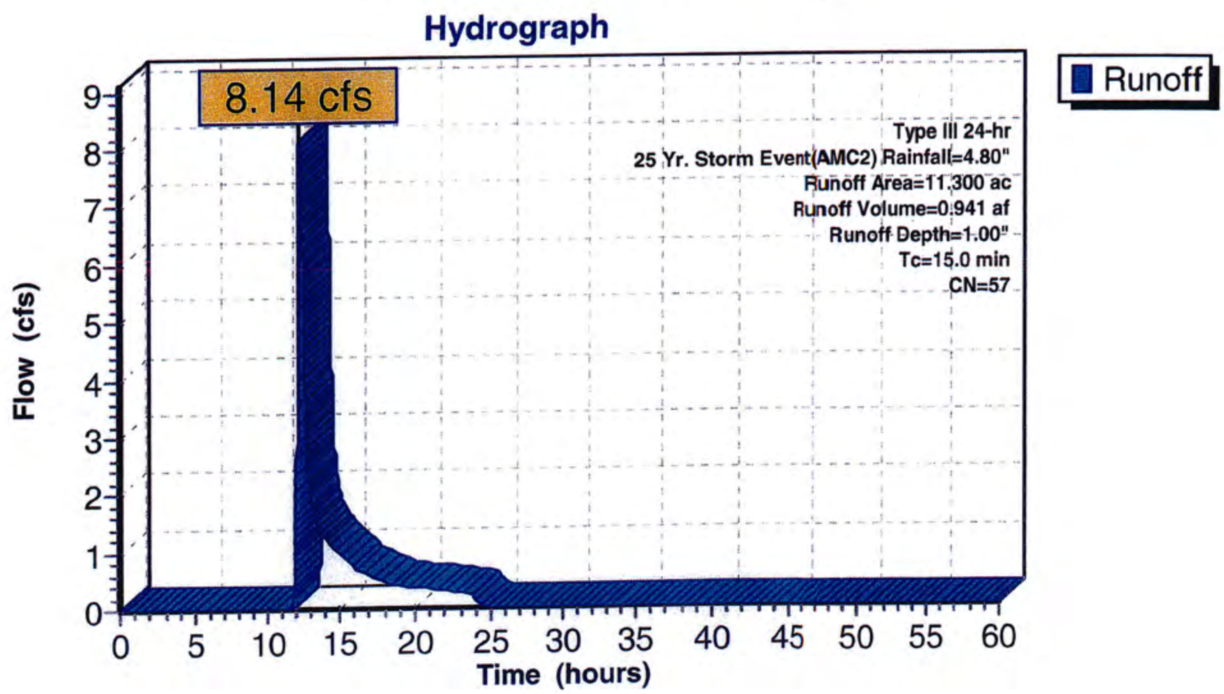
Runoff = 8.14 cfs @ 12.25 hrs, Volume= 0.941 af, Depth= 1.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs
Type III 24-hr 25 Yr. Storm Event(AMC2) Rainfall=4.80"

	Area (ac)	CN	Description
*	8.500	55	OPEN WASTE AT 5 PERCENT GRADE
*	2.800	65	OPEN WASTE AT 38 PERCENT
	11.300	57	Weighted Average
	11.300		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry, Time of Conc. (Direct Entry)**

Subcatchment 14S: CELL 11 Open



Time span=0.00-60.00 hrs, dt=0.01 hrs, 6001 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 14S: CELL 11 Open Runoff Area=11.300 ac 0.00% Impervious Runoff Depth=1.00"
Tc=15.0 min CN=57 Runoff=8.14 cfs 0.941 af

Total Runoff Area = 11.300 ac Runoff Volume = 0.941 af Average Runoff Depth = 1.00"
100.00% Pervious = 11.300 ac 0.00% Impervious = 0.000 ac

Summary for Pond 15P: CELL 11 TEMP SUMP (ONEPUMP-6" FM)

Inflow Area =	11.300 ac,	0.00% Impervious,	Inflow Depth > 1.16"	for 25 Yr. Storm Event(AMC2) event
Inflow =	8.17 cfs @	12.25 hrs, Volume=	1.090 af,	Incl. 0.03 cfs Base Flow
Outflow =	0.33 cfs @	12.09 hrs, Volume=	1.083 af,	Atten= 96%, Lag= 0.0 min
Primary =	0.33 cfs @	12.09 hrs, Volume=	1.083 af	

Routing by Stor-Ind method, Time Span= 0.00-60.00 hrs, dt= 0.01 hrs
Peak Elev= 211.10' @ 22.16 hrs Surf.Area= 32,797 sf Storage= 28,326 cf
Flood Elev= 214.00' Surf.Area= 72,000 sf Storage= 87,200 cf

Plug-Flow detention time= 860.1 min calculated for 1.082 af (99% of inflow)
Center-of-Mass det. time= 842.4 min (1,862.9 - 1,020.5)

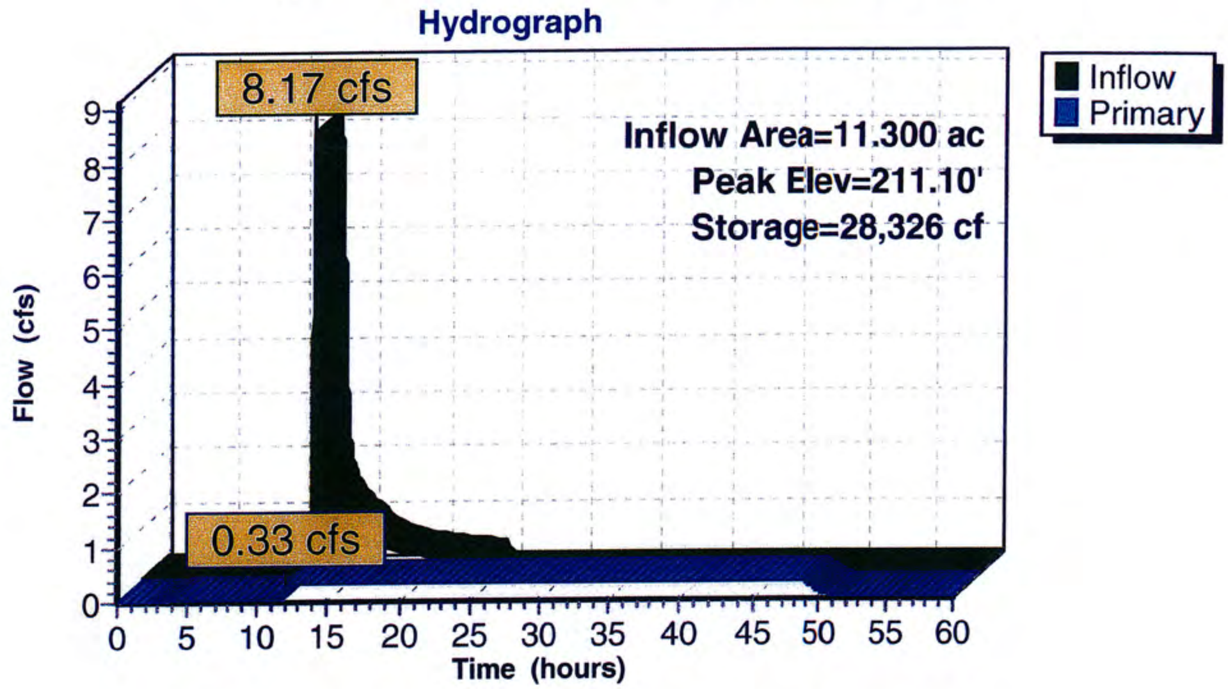
Volume	Invert	Avail.Storage	Storage Description
#1	205.00'	160,840 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Voids (%)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
205.00	100	0.0	0	0
206.00	1,300	40.0	280	280
207.00	4,400	40.0	1,140	1,420
208.00	9,200	40.0	2,720	4,140
209.00	14,700	40.0	4,780	8,920
210.00	22,100	40.0	7,360	16,280
212.00	41,600	40.0	25,480	41,760
214.00	72,000	40.0	45,440	87,200
216.00	112,100	40.0	73,640	160,840

Device	Routing	Invert	Outlet Devices
#1	Primary	206.00'	**PUMP SYSTEM** Head (feet) 0.00 1.00 2.00 3.00 4.00 5.00 6.00 8.00 10.00 Disch. (cfs) 0.000 0.330 0.330 0.330 0.330 0.330 0.330 0.330 0.330

Primary OutFlow Max=0.33 cfs @ 12.09 hrs HW=207.05' (Free Discharge)
↑**1=PUMP SYSTEM** (Custom Controls 0.33 cfs)

Pond 15P: CELL 11 TEMP SUMP (ONEPUMP-6" FM)



CELL 11 LEACHATE SUMP DESIGN

Project: 9.35 Million Expansion
Juniper Ridge Landfill, West Old Town, Maine
Calc by: PCM
date :May 2015

assume:

leachate base flow	20
pump rate(GPM)	150

sump volume(from HydroCad)

Elevation	Cumm. Vol. (ft^3)	Cumm. Vol. (Gal)		
205	0			
206	280	2094		pump on at 206
207	1420	10622		
208	4140	30967		
209	8920	66722		pump off at 209
210	16720	125066	**64627**	subtotal (gallons)
212	42200	315656		
214	87640	655547		
216	161280	1206374		

calculate pump cycle time

cycle time =storage volume/(pump rate-leachate flow) +storage volume/leachate flow

storage(gal)	cycle time(min)	cycles per day
64627	3728	**0.4**
run time(min)	497	
run time(hrs)	8	

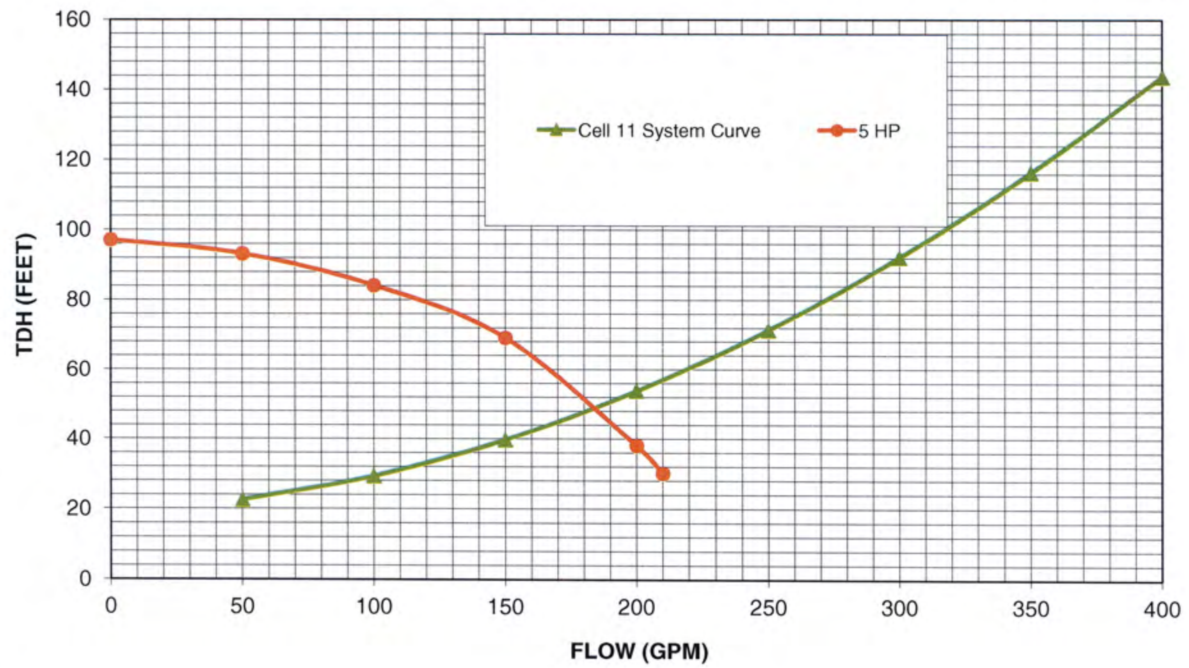
Calculate number of holes required to pump 150 GPM

Flow through pipe orifice			
Bernoulii Equation	$Q=CA(2g\Delta h)^{.5}$		
Q= flow (CFS)			
C=discharge coefficient .62			
A= area of hole SF			
g=gravitational constant			
Δh= change in head			
hole diameter/area	0.5 inches	area(ft^2)	0.001363
Δh(FT)	0.5ft		
Q(CFS)	0.005		
Q(gpm)	2.1		
Number of holes required	71.4		
use SF of 3(clogging)	214.3		

Check design perforations

	holes per foot	length	# holes	
24 -inch pipe	12	10	120	
8 inch pipe(Elv 205 -206.5)	3	95	285	
		total	**405**	okay

JUNIPER RIDGE LANDFILL CELL 11 PUMP STATION W/ 6-INCH TRANSPORT PIPING



JUNIPER RIDGE LANDFILL EXPANSION
CELL 11 FORCE ANALYSIS
PRESSURE PIPE HEAD LOSS CALCULATIONS

DESCRIPTION	ELEVATION HEAD LOSS			FRICTIONAL HEAD LOSS						
	Pump Elev. (feet)	Highest Elev. (feet)	Elevation Head Loss (feet)	Total Length (feet)	Pipe Flow (gpm)	HW Frict. Factor[1] C	Pipe SDR	Pipe O.D. Nominal (inches)	Pipe ID Average[2] (inches)	Friction Head Loss[3] (feet)
C11- Pump Station to Storage Tank										
(Q=50gpm)				200	50	100	17.0	12	11.160	0.00
	205.0	225.0	20.0	2600	50	100	17.0	6	5.798	1.5
				50	50	100		3	3.000	0.7
				5	50	100		4	4.000	0.0
						100				
(Q=100gpm)				200	100	100	17.0	12	11.160	0.02
	205.0	225.0	20.0	2600	100	100	17.0	6	5.798	5.2
				50	100	100		3	3.000	2.5
					100	100			4.000	0.0
						100				
(Q=150gpm)				200	150	100	17.0	12	11.160	0.04
	205.0	225.0	20.0	2600	150	100	17.0	6	5.798	11.1
				50	150	100		3	3.000	5.3
					150	100			4.000	0.0
						100				
(Q=200gpm)				200	200	100	17.0	12	11.160	0.06
	205.0	225.0	20.0	2600	200	100	17.0	6	5.798	18.9
				50	200	100		3	3.000	9.0
					200	100			4.000	0.0
						100				
(Q=250gpm)				200	250	100	17.0	12	11.160	0.09
	205.0	225.0	20.0	2600	250	100	17.0	6	5.798	28.6
				50	250	100		3	3.000	13.6
					250	100			4.000	0.0
						100				
(Q=300gpm)				200	300	100	17.0	12	11.160	0.13
	205.0	225.0	20.0	2600	300	100	17.0	6	5.798	40.0
				50	300	100		3	3.000	19.0
					300	100			4.000	0.0
						100				
(Q=350gpm)				200	350	100	17.0	12	11.160	0.17
	205.0	225.0	20.0	2600	350	100	17.0	6	5.798	53.3
				50	350	100		3	3.000	25.3
					350	100			4.000	0.0
						100				
(Q=400gpm)				200	400	100	17.0	12	11.160	0.22
	205.0	225.0	20.0	2600	400	100	17.0	6	5.798	68.2
				50	400	100		3	3.000	32.4
					400	100			4.000	0.0

DESCRIPTION	FITTING HEAD LOSSES														
	KL Ck Valve (swing)	Quantity	Elbow 90	Quantity	Elbow 45	Quantity	Tee (in-line)	Quantity	Butterfly valve	Quantity	Contraction Enlargement	Quantity	Ball Valve	Quantity	velocity
C11- Pump Station to Storage Tank															
(Q=50gpm)	1.3		0.4	2	0.2	0	0.8	0		0			0.04		0.2
	1.5		0.5	2	0.2	1	0.9	6		2	0.02	1	0.05	2	0.6
	1.8		0.5	1	0.3	0	1.1	0	0.8		0.02	0	0.05	1	2.3
	1.7		0.5	1	0.3	0	1.0	0		1.0	0.02	1	0.05	1	1.3
(Q=100gpm)	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	0.3
	1.5		0.5	1	0.2	1	1.8	6			0.02	1	0.05	2	1.2
	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	4.5
	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	0.0
(Q=150gpm)	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	0.5
	1.5		0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	1.8
	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	6.8
	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	3.8
(Q=200gpm)	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	0.7
	1.5		0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	2.4
	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	9.1
	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	5.1
(Q=250gpm)	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	0.8
	1.5		0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	3.0
	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	11.4
	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	6.4
(Q=300gpm)	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	1.0
	1.5		0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	3.6
	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	13.6
	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	7.7
(Q=350gpm)	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1	1.1
	1.5		0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	4.3
	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	15.9
	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	8.9
(Q=400gpm)	1.3	0	0.4	2	0.2	0	1.8	0		0			0.04	1	1.3
	1.5	0	0.5	1	0.2	1	1.8	6		0	0.02	1	0.05	2	4.9
	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1	18.2
	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1	10.2

Notes:
1. Friction Factor Assumes scaling in pipe system.
2. Nominal ID from Rinker Pipe Design Guidance Table A-2 Page A-4.
3. Frictional Headloss Determined from Hazen Williams Equation.
4. Minor Headloss = $K(V^2/2g)$
5. Reference: Cameron Hydraulic Data 19th edition

JUNIPER RIDGE LANDFILL EXPANSION
CELL 11 FORCE ANALYSIS
PRESSURE PIPE HEAD LOSS CALCULATIONS

DESCRIPTION	ELEVATION HEAD LOSS			FRICTIONAL HEAD LOSS									DISCHARGE LOSS		SYSTEM HEAD	MAX PIPE PRESSURE	Flow VELOCITY
	Pump Elev. (feet)	Highest Elev. (feet)	Elevation Head Loss (feet)	Total Length (feet)	Pipe Flow (gpm)	HW Frict. Factor[1] C	Pipe SDR	Pipe O.D. Nominal (inches)	Pipe ID Average[2] (inches)	Friction Head Loss[3] (feet)	K_{Ltotal}	Fitting Head Loss[4]	Outlet Factor	Discharge Head Loss (ft)	(feet)	(psi)	(ft/sec)
C11- Pump Station to Storage Tank																	
(Q=50gpm)				200	50	100	17.0	12	11.160	0.00	0.8	0.0	1.0	0	0.0		0.2
	205.0	225.0	20.0	2600	50	100	17.0	6	5.798	1.5	6.7	0.0	1.0	0	21		0.6
				50	50	100		3	3.000	0.7	0.6	0.0	1.0	0	1		2.3
				5	50	100		4	4.000	0.0	0.6	0.0	1.0	0	0		1.3
						100								Total:	22	10	
(Q=100gpm)				200	100	100	17.0	12	11.160	0.02	0.8	0.0	1.0	0	0.0		0.3
	205.0	225.0	20.0	2600	100	100	17.0	6	5.798	5.2	11.6	0.3	1.0	0	26		1.2
				50	100	100		3	3.000	2.5	2.2	0.7	1.0	0	4		4.5
					100	100			4.000	0.0	0.1	0.0	1.0	0	0		2.6
						100								Total:	29	13	
(Q=150gpm)				200	150	100	17.0	12	11.160	0.04	0.8	0.0	1.0	0	0.0		0.5
	205.0	225.0	20.0	2600	150	100	17.0	6	5.798	11.1	11.6	0.6	1.0	0	32		1.8
				50	150	100		3	3.000	5.3	2.2	1.6	1.0	1	8		6.8
					150	100			4.000	0.0	0.1	0.0	1.0	0	0		3.8
						100								Total:	40	17	
(Q=200gpm)				200	200	100	17.0	12	11.160	0.06	0.8	0.0	1.0	0	0.1		0.7
	205.0	225.0	20.0	2600	200	100	17.0	6	5.798	18.9	11.6	1.1	1.0	0	40		2.4
				50	200	100		3	3.000	9.0	2.2	2.8	1.0	1	13		9.1
					200	100			4.000	0.0	0.1	0.0	1.0	0	0		5.1
						100								Total:	54	23	
(Q=250gpm)				200	250	100	17.0	12	11.160	0.09	0.8	0.0	1.0	0	0.1		0.8
	205.0	225.0	20.0	2600	250	100	17.0	6	5.798	28.6	11.6	1.7	1.0	0	50		3.0
				50	250	100		3	3.000	13.6	2.2	4.4	1.0	2	20		11.4
					250	100			4.000	0.0	0.1	0.0	1.0	1	1		6.4
						100								Total:	71	31	
(Q=300gpm)				200	300	100	17.0	12	11.160	0.13	0.8	0.0	1.0	0	0.2		1.0
	205.0	225.0	20.0	2600	300	100	17.0	6	5.798	40.0	11.6	2.4	1.0	0	63		3.6
				50	300	100		3	3.000	19.0	2.2	6.4	1.0	3	28		13.6
					300	100			4.000	0.0	0.1	0.0	1.0	1	1		7.7
						100								Total:	92	40	
(Q=350gpm)				200	350	100	17.0	12	11.160	0.17	0.8	0.0	1.0	0	0.2		1.1
	205.0	225.0	20.0	2600	350	100	17.0	6	5.798	53.3	11.6	3.3	1.0	0	77		4.3
				50	350	100		3	3.000	25.3	2.2	8.7	1.0	4	38		15.9
					350	100			4.000	0.0	0.1	0.1	1.0	1	1		8.9
						100								Total:	116	50	
(Q=400gpm)				200	400	100	17.0	12	11.160	0.22	0.8	0.0	1.0	0	0.3		1.3
	205.0	225.0	20.0	2600	400	100	17.0	6	5.798	68.2	11.6	4.3	1.0	0	93		4.9
				50	400	100		3	3.000	32.4	2.2	11.3	1.0	5	49		18.2
					400	100			4.000	0.0	0.1	0.1	1.0	2	2		10.2
														Total:	144	62	

Notes:
1. Friction Factor Assumes scaling in pipe system.
2. Nominal ID from Rinker Pipe Design Guidance Table A-2 Page A-4.
3. Frictional Headloss Determined from Hazen Williams Equation.
4. Minor Headloss = $K(V^2/2g)$
5. Reference: Cameron Hydraulic Data 19th edition

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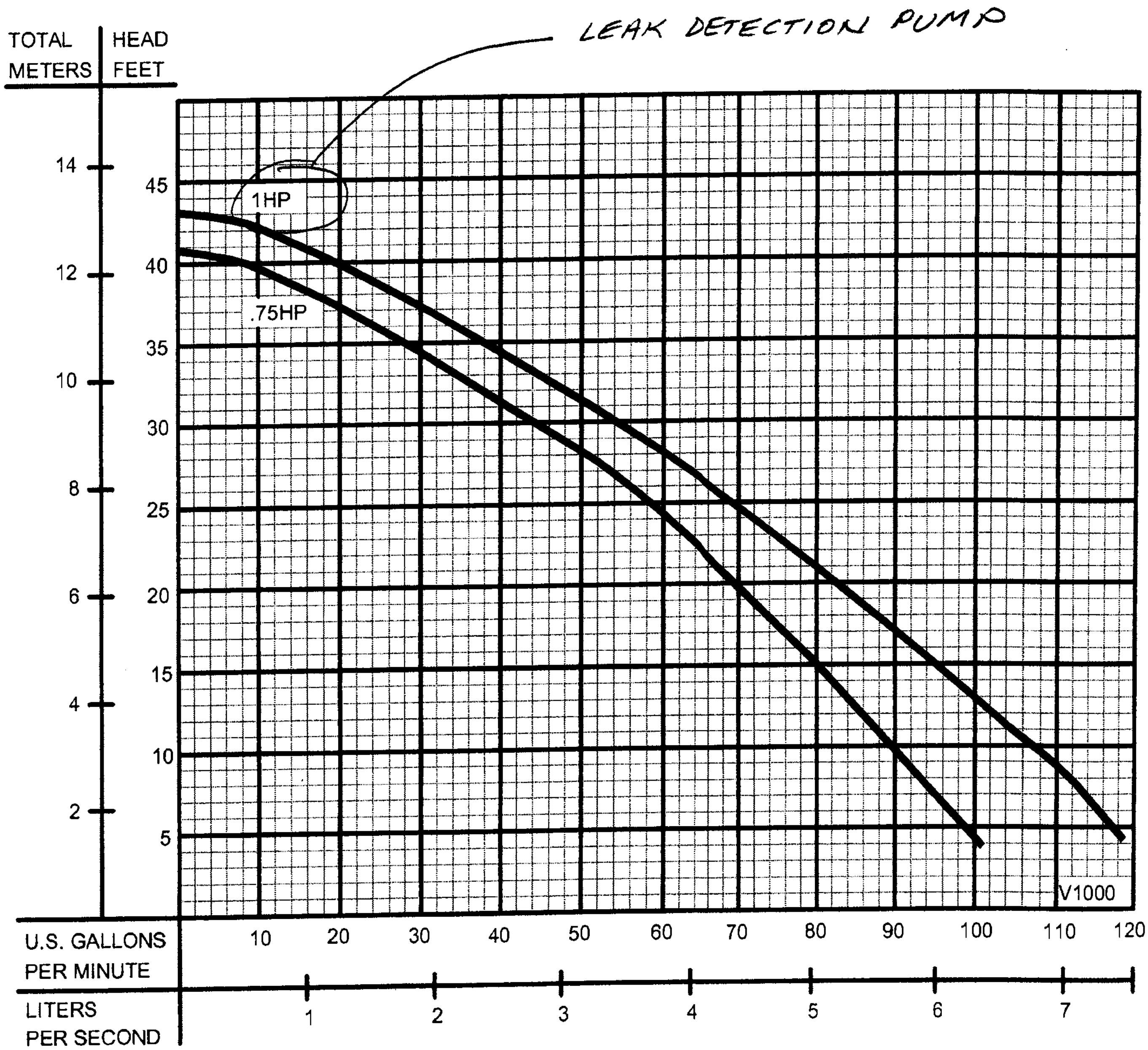
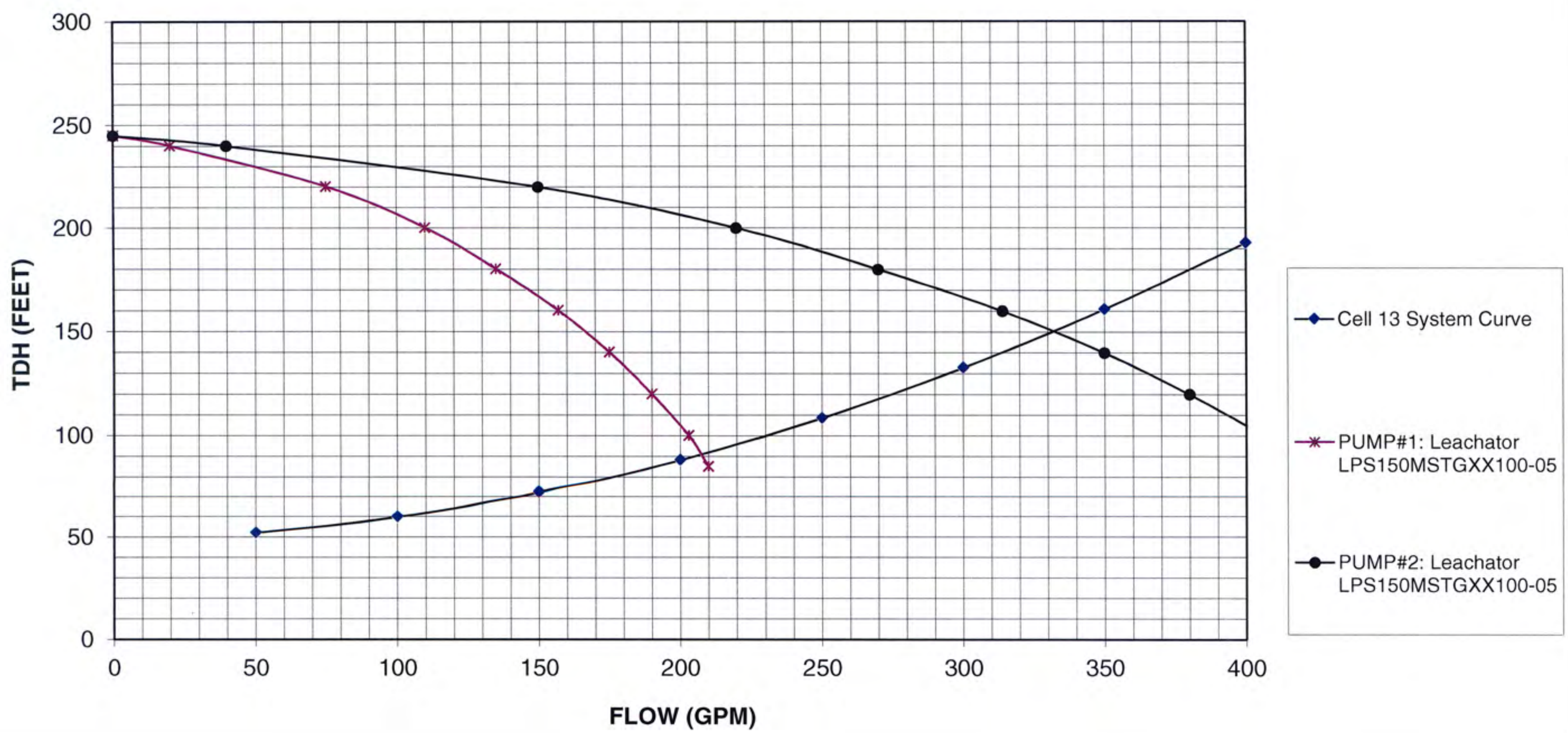


Testing is performed with water, specific gravity 1.0 @ 68° F @ (20ºC), **other fluids may vary perfor - mance**

JUNIPER RIDGE LANDFILL CELL 13 PUMP STATION W/ 6-INCH TRANSPORT PIPING



DESCRIPTION	ELEVATION HEAD LOSS			FRICTIONAL HEAD LOSS							FITTING HEAD LOSSES													
	Pump Elev. (feet)	Highest Elev. (feet)	Elevation Head Loss (feet)	Total Length (feet)	Pipe Flow (gpm)	HW Frict. Factor[1] C	Pipe SDR	Pipe O.D. Nominal (inches)	Pipe ID Average[2] (inches)	Friction Head Loss[3] (feet)	KL Ck Valve	Quantity	Elbow 90	Quantity	Elbow 45	Quantity	Tee (in-line)	Quantity	Flow Meter	Quantity	Contraction 5 to 1	Quantity	Ball Valve	Quantity
Pump Station 13 to Storage Tank																								
(Q=50gpm)				200	50	120	17.0	12	11.160	0.00	1.3		0.4	2	0.2	0	0.8	0		0			0.04	
	176.0	225.0	49.0	3570	50	100	17.0	6	5.798	2.0	1.5		0.5	2	0.2	1	0.9	6			0.02	1	0.05	2
				40	50	100		3	3.000	0.6	1.8		0.5	1	0.3	0	1.1	0	0.8	2	0.02	0	0.05	1
				6	50	100		4	4.000	0.0	1.7		0.5	0	0.3	0	1.0	0				1	0.05	1
(Q=100gpm)				200	100	100	17.0	12	11.160	0.02	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1
	176.0	225.0	49.0	3570	100	100	17.0	6	5.798	7.2	1.5		0.5	2	0.2	1	1.8	6			0.02	1	0.05	2
				20	100	100		3	3.000	1.0	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1
				6	100	100		4	4.000	0.1	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1
(Q=150gpm)				200	150	100	17.0	12	11.160	0.04	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1
	176.0	225.0	49.0	3570	150	100	17.0	6	5.798	15.3	1.5		0.5	2	0.2	1	1.8	6		0	0.02	1	0.05	2
				40	150	100		3	3.000	4.2	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1
				6	150	100		4	4.000	0.2	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1
(Q=200gpm)				200	200	100	17.0	12	11.160	0.06	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1
	176.0	225.0	49.0	3570	200	100	17.0	6	5.798	26.0	1.5		0.5	2	0.2	1	1.8	6		0	0.02	1	0.05	2
				40	200	100		3	3.000	7.2	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1
				6	200	100		4	4.000	0.3	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1
(Q=250gpm)				200	250	100	17.0	12	11.160	0.09	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1
	176.0	225.0	49.0	3570	250	100	17.0	6	5.798	39.2	1.5		0.5	2	0.2	1	1.8	6		0	0.02	1	0.05	2
				40	250	100		3	3.000	10.9	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1
				6	250	100		4	4.000	0.4	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1
(Q=300gpm)				200	300	100	17.0	12	11.160	0.13	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1
	176.0	225.0	49.0	3570	300	100	17.0	6	5.798	55.0	1.5		0.5	2	0.2	1	1.8	6		0	0.02	1	0.05	2
				40	300	100		3	3.000	15.2	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1
				6	300	100		4	4.000	0.6	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1
(Q=350gpm)				200	350	100	17.0	12	11.160	0.17	1.3		0.4	2	0.2	0	1.8	0		0			0.04	1
	176.0	225.0	49.0	3570	350	100	17.0	6	5.798	73.1	1.5		0.5	2	0.2	1	1.8	6		0	0.02	1	0.05	2
				40	350	100		3	3.000	20.2	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1
				6	350	100		4	4.000	0.7	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1
(Q=400gpm)				200	400	100	17.0	12	11.160	0.22	1.3	0	0.4	2	0.2	0	1.8	0		0			0.04	1
	176.0	225.0	49.0	3570	400	100	17.0	6	5.798	93.6	1.5	0	0.5	2	0.2	1	1.8	6		0	0.02	1	0.05	2
				40	400	100		3	3.000	25.9	1.8		0.5	1	0.3	0	1.8	0	0.8	2	0.02	0	0.05	1
				6	400	100		4	4.000	1.0	1.7		0.5	0	0.3	0	1.8	0		0		1	0.05	1

Notes:
1. Friction Factor Assumes scaling in pipe system.
2. Nominal ID from Rinker Pipe Design Guidance Table A-2 Page A-4.
3. Frictional Headloss Determined from Hazen Williams Equation.
4. Minor Headloss = $K(V^2/2g)$

JUNIPER RIDGE LANDFILL EXPANSION
CELL 13 FORCE ANALYSIS
PRESSURE PIPE HEAD LOSS CALCULATIONS

DESCRIPTION	ELEVATION HEAD LOSS Pump Elev. (feet)	Highest Elev. (feet)	Elevation Head Loss (feet)	FRICTIONAL HEAD LOSS Total Length (feet)	Pipe Flow (gpm)	HW Frict. Factor[1] C	Pipe SDR	Pipe O.D. Nominal (inches)	Pipe ID Average[2] (inches)	Friction Head Loss[3] (feet)	velocity	K_{Local}	Fitting Head Loss[4]	DISCHARGE LOSS Outlet Factor	Discharge Head Loss (ft)	SYSTEM HEAD (feet)	MAX PIPE PRESSURE (psi)	Flow VELOCITY (ft/sec)
Pump Station 13 to Storage Tank																		
(Q=50gpm)				200	50	120	17.0	12	11.160	0.00	0.2	0.8	0.0	1.0	0	0.0		0.2
	176.0	225.0	49.0	3570	50	100	17.0	6	5.798	2.0	0.6	6.7	0.0	1.0	0	51		0.6
				40	50	100		3	3.000	0.6	2.3	2.2	0.2	1.0	0	1		2.3
				6	50	100		4	4.000	0.0	1.3	0.1	0.0	1.0	0	0		1.3
															Total:	52	22	
(Q=100gpm)				200	100	100	17.0	12	11.160	0.02	0.3	0.8	0.0	1.0	0	0.0		0.3
	176.0	225.0	49.0	3570	100	100	17.0	6	5.798	7.2	1.2	12.1	0.3	1.0	1	57		1.2
				20	100	100		3	3.000	1.0	4.5	2.2	0.7	1.0	0	2		4.5
				6	100	100		4	4.000	0.1	0.0	0.1	0.0	1.0	0	0		2.6
															Total:	60	26	
(Q=150gpm)				200	150	100	17.0	12	11.160	0.04	0.5	0.8	0.0	1.0	0	0.0		0.5
	176.0	225.0	49.0	3570	150	100	17.0	6	5.798	15.3	1.8	12.1	0.6	1.0	0	65		1.8
				40	150	100		3	3.000	4.2	6.8	2.2	1.6	1.0	1	7		6.8
				6	150	100		4	4.000	0.2	3.8	0.1	0.0	1.0	0	0		3.8
															Total:	72	31	
(Q=200gpm)				200	200	100	17.0	12	11.160	0.06	0.7	0.8	0.0	1.0	0	0.1		0.7
	176.0	225.0	49.0	3570	200	100	17.0	6	5.798	26.0	2.4	12.1	1.1	1.0	0	76		2.4
				40	200	100		3	3.000	7.2	9.1	2.2	2.8	1.0	1	11		9.1
				6	200	100		4	4.000	0.3	5.1	0.1	0.0	1.0	0	1		5.1
															Total:	88	38	
(Q=250gpm)				200	250	100	17.0	12	11.160	0.09	0.8	0.8	0.0	1.0	0	0.1		0.8
	176.0	225.0	49.0	3570	250	100	17.0	6	5.798	39.2	3.0	12.1	1.7	1.0	0	90		3.0
				40	250	100		3	3.000	10.9	11.4	2.2	4.4	1.0	2	17		11.4
				6	250	100		4	4.000	0.4	6.4	0.1	0.0	1.0	1	1		6.4
															Total:	109	47	
(Q=300gpm)				200	300	100	17.0	12	11.160	0.13	1.0	0.8	0.0	1.0	0	0.2		1.0
	176.0	225.0	49.0	3570	300	100	17.0	6	5.798	55.0	3.6	12.1	2.5	1.0	0	107		3.6
				40	300	100		3	3.000	15.2	13.6	2.2	6.4	1.0	3	24		13.6
				6	300	100		4	4.000	0.6	7.7	0.1	0.0	1.0	1	2		7.7
															Total:	133	57	
(Q=350gpm)				200	350	100	17.0	12	11.160	0.17	1.1	0.8	0.0	1.0	0	0.2		1.1
	176.0	225.0	49.0	3570	350	100	17.0	6	5.798	73.1	4.3	12.1	3.4	1.0	0	126		4.3
				40	350	100		3	3.000	20.2	15.9	2.2	8.7	1.0	4	33		15.9
				6	350	100		4	4.000	0.7	8.9	0.1	0.1	1.0	1	2		8.9
															Total:	161	70	
(Q=400gpm)				200	400	100	17.0	12	11.160	0.22	1.3	0.8	0.0	1.0	0	0.3		1.3
	176.0	225.0	49.0	3570	400	100	17.0	6	5.798	93.6	4.9	12.1	4.4	1.0	0	147		4.9
				40	400	100		3	3.000	25.9	18.2	2.2	11.3	1.0	5	42		18.2
				6	400	100		4	4.000	1.0	10.2	0.1	0.1	1.0	2	3		10.2
															Total:	193	83	

Notes:
1. Friction Factor Assumes scaling in pipe system.
2. Nominal ID from Rinker Pipe Design Guidance Table A-2 Page A-4.
3. Frictional Headloss Determined from Hazen Williams Equation.
4. Minor Headloss = $K(V^2/2g)$

APPENDIX D-7

LEACHATE COLLECTION AND UNDERDRAIN PIPE SIZING AND SPACING DESIGN

LEACHATE COLLECTION PIPE SIZING	Project Name: Juniper Ridge Landfill Expansion Project Location: Old Town, Maine Project No: 14101 Comp By: PCM Chk. By: KPN 06/01/2015

OBJECTIVE: Evaluate sizing of leachate collection piping.

DESIGN CRITERIA

1. Size pipes appropriately to allow peak daily infiltration into waste and runoff over waste assuming 10-feet of waste to collection pipe. See HELP Model output Appendix C.
   Infiltration = 0.4783
   Runoff = 6.771 (over 179,000 ft^2)
2. Minimum pipe size is 6" (OD) to allow for proper cleaning.

DESIGN ASSUMPTIONS

1. For leachate collection laterals assume largest area contributing to a single leachate lateral (173, 000 ft^2 in Cell 13 on south side) and minimum pipe slope (5.4%) as design condition.
2. For leachate header pipes assume largest area contributing to a leachate header (397,000 ft^2 in Cell 12) and minimum pipe slope (2%) as design condition.
3. Assume pipe flow using Mannings Equation with HDPE pipe n= 0.012.

ANALYSIS

LEACHATE COLLECTION LATERAL AND HEADER ANALYSIS
Determine maximum amount of leachate to a lateral

Q = KA

Q= Flow to Pipe (ft^3/sec)
K= Infiltration through Waste (ft/sec)
A = Area contributing to flow (ft^2)

Convert Help Model Infiltration (in/day) to ft/sec.
Flow to Lateral = Infiltration

$$0.4783\,\frac{in}{day} \times \frac{ft}{12\,in} \times \frac{day}{24\,hr} \times \frac{hr}{60\,min} \times \frac{min}{60\,sec}$$

= 4.61E-07 ft/sec

Flow to Header = Infiltration + Runoff

$$6.771\,\frac{in}{day} \times \frac{ft}{12\,in} \times \frac{day}{24\,hr} \times \frac{hr}{60\,min} \times \frac{min}{60\,sec}$$

= 6.53E-06 ft/sec

Multiply Infiltration rate above times the contributing area to determine Q.

$A_{laterals}$ = 173,000 ft^2
$A_{headers}$ = 373,000 ft^2
$A_{runoff\ to\ Header}$ = 179,000 ft^2

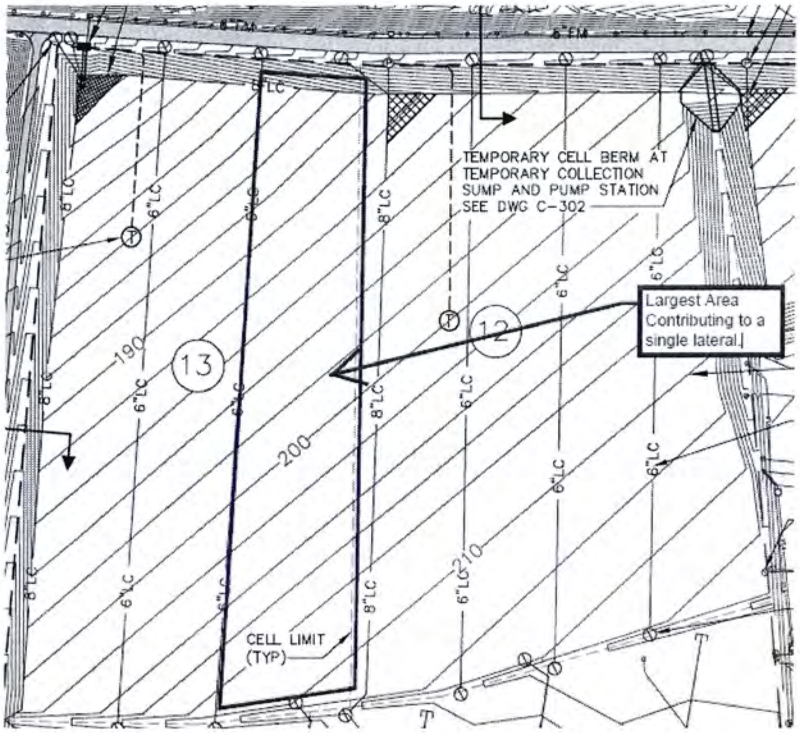
$Q_{laterals}$ =	173,000 ft^2	x	4.61E-07 ft/sec	=	0.08 ft^3/sec
$Q_{Infilt\ to\ Header}$ =	373,000 ft^2	x	4.61E-07 ft/sec	=	0.17 ft^3/sec
$Q_{runoff\ to\ Header}$ =	179,000 ft^2	x	6.53E-06 ft/sec	=	1.17 ft^3/sec
$Q_{total\ to\ header}$ =					1.3 ft^3/sec

Determine maximum flow in 6-inch diameter and 8-inch diameter HDPE pipes using mannings equation.

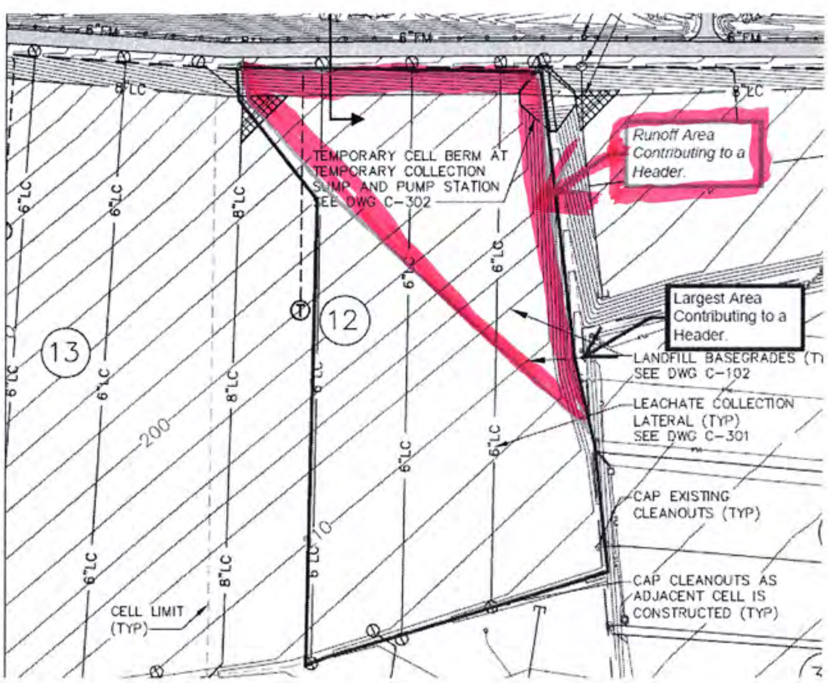
OD =	6 inches (EJP Refrence Manual)
SDR =	11 unitless
ID =	5.349 inches (EJP Refrence Manual)
	0.45 feet
Slope =	0.054 ft/ft (minimum design slope)
n =	0.012 unitless
Qmax =	1 ft^3/sec (See attached printout)

OD =	8 inches (EJP Refrence Manual)
SDR =	11 unitless
ID =	6.963 inches (EJP Refrence Manual)
	0.58 feet
Slope =	0.021 ft/ft (minimum design slope)
n =	0.012 unitless
Qmax =	1.3 ft^3/sec (See attached Flowmaster Printouts)

In both cases Qmax of pipe is greater than or equal to maximum Q anticipated therefore pipe sizing on drawings is appropriate.



TEMPORARY CELL BERM AT
TEMPORARY COLLECTION
SUMP AND PUMP STATION
SEE DWG C-302
Largest Area
Contributing to a
single lateral.
CELL LIMIT
(TYP)



TEMPORARY CELL BERM AT
TEMPORARY COLLECTION
SUMP AND PUMP STATION
SEE DWG C-302
Runoff Area
Contributing to a
Header.
Largest Area
Contributing to a
Header.
LANDFILL BASEGRADES
SEE DWG C-102
LEACHATE COLLECTION
LATERAL (TYP)
SEE DWG C-301
CAP EXISTING
CLEANOUTS (TYP)
CAP CLEANOUTS AS
ADJACENT CELL IS
CONSTRUCTED (TYP)
CELL LIMIT
(TYP)

Free Online Manning Pipe Flow Calculator

List of Calculators   Hydraulics   Language

Manning Formula Uniform Pipe Flow at Given Slope and Depth

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Juniper Ridge Landfill

Header Sizing

Set units: m | mm | ft | inches

Pipe diameter, d_0	6.96	inches
Manning roughness, n ?	0.012	
Pressure slope (possibly ? equal to pipe slope), S_0	.021	rise/run
Percent of (or ratio to) full depth (100% or 1 if flowing full)	100	%

Results:

Flow, q	1.3085	cfs
Velocity, v	4.9526	ft/sec
Velocity head, h_v	4.5745	inches
Flow area	38.0460	sq. in.
Wetted perimeter	21.8655	inches
Hydraulic radius	1.7400	inches
Top width, T	0.0000	inches
Froude number, F	0.00	
Shear stress (tractive force), tau	36.4045	N/m^2

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Free Online Manning Pipe Flow Calculator

List of Calculators Hydraulics Language

Manning Formula Uniform Pipe Flow at Given Slope and Depth

Can you help me translate this calculator to your language or host this calculator at your web site?

Juniper Ridge Landfill

Lateral Sizing

Set units: m mm ft inches

Pipe diameter, d_0	5.35	inches ▼
Manning roughness, n ?	0.012	
Pressure slope (possibly ? equal to pipe slope), S_0	.054	rise/run ▼
Percent of (or ratio to) full depth (100% or 1 if flowing full)	100	% ▼

Results:

Flow, q	1.0403	cfs ▼
Velocity, v	6.6642	ft/sec ▼
Velocity head, h_v	8.2828	inches ▼
Flow area	22.4801	sq. in. ▼
Wetted perimeter	16.8075	inches ▼
Hydraulic radius	1.3375	inches ▼
Top width, T	0.0000	inches ▼
Froude number, F	0.00	
Shear stress (tractive force), tau	71.9572	N/m^2 ▼

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CLIENT: Juniper Ridge Landfill Expansion
PROJECT:Cells 14-15-16 Leachate Collection Design
Initial Condition at 1.5 Percent Slope

Completed By: Peter Mailey Date: 2/19/15

Checkd By: 6/01/2015 Date: KFN

Pipe Spacing Calculation

Design Objective: To determine necessay pipe spacing while maintaining maximum head on the liner to the thickness of the drainage net (geonet).

Design Parameters

$\psi Spec := 3.17 \cdot 10^{-4} \cdot m^2 \, s^{-1}$	Transmisivity Required Specified of Drainage Geocomposite
K	Permeability of Drainage Geocomposite
L	Spacing between pipe laterals (measured along slope)
$t \equiv 12$ inches	Leachate Collection Sand Thickness (12 inches)
$e := 2.3029 \cdot 10^{-8} \cdot \frac{m}{sec}$	Impingement Rate = 2.35-inches per month (Max Average Monthly Impingement Rate(10 ft. of Waste 100% Area Allowed Runoff)) from Attached HELP Model Output
$\beta := 0.8594 \cdot deg$	Average Slope of the Landfill Base Between Pipes (1.5 percent)
$T_{max} := .00635 \cdot m$	Geonet Thickness = 0.25 inches

Solve for Design Transmisivity:

Design of Lateral Drainage Systems, Richardson 1999

Apply Reduction Factor:

RFtotal = Design Drainage Factor (3) x Intrusion (1.0) x Creep (1.1), Biological Clogging (1.4) x Chemical Clogging (1.4) = 6.5

$RFtotal := 6.5$

$$\psi Design := \frac{\psi Spec}{RFtotal}$$

$\psi Design = 4.877 \cdot 10^{-5} \, m^2 \cdot s^{-1}$

Solve for K: $K := \frac{\psi Design}{T_{max}}$ $K = 7.68 \cdot 10^{-3} \, m \cdot s^{-1}$

Solve Pipe Spacing L:

$$L := \frac{T_{max} \cdot (2 \cdot \cos(\beta))}{\left[\sqrt{\left(4 \cdot \frac{e}{K}\right) + \tan(\beta)^2} - \tan(\beta)\right]}$$

$L = 105.581 \, ft$

Equation
Ref. Giroud ET Al., 1993

CLIENT: Juniper Ridge Landfill Expansion
PROJECT:Cells 11 Leachate Collection Design
Initial Condition at 2.0 Percent Slope

Completed By: Peter Mailey Date: 2/19/15

Checkd By: KPW Date: 06/1/2015

Pipe Spacing Calculation

Design Objective: To determine necessay pipe spacing while maintaining maximum head on the liner to the thickness of the drainage net (geonet).

Design Parameters

$\psi Spec := 3.17 \cdot 10^{-4} \cdot m^2\ s^{-1}$	Transmisivity Required Specified of Drainage Geocomposite
K	Permeability of Drainage Geocomposite
L	Spacing between pipe laterals (measured along slope)
$t = 12$ inches	Leachate Collection Sand Thickness (12 inches)
$e := 2.3029 \cdot 10^{-8} \cdot \frac{m}{sec}$	Impingement Rate = 2.35-inches per month (Max Average Monthly Impingement Rate(10 ft. of Waste 100% Area Allowed Runoff)) from Attached HELP Model Output
$\beta := 1.1458 \cdot deg$	Average Slope of the Landfill Base Between Pipes (2.0 percent)
$T_{max} := .00635 \cdot m$	Geonet Thickness = 0.25 inches

Solve for Design Transmisivity:

Design of Lateral Drainage Systems, Richardson 1999

Apply Reduction Factor:

RFtotal = Design Drainage Factor (3) x Intrusion (1.0) x Creep (1.1), Biological Clogging (1.4) x Chemical Clogging (1.4) = 6.5

$RFtotal := 6.5$

$$\psi Design := \frac{\psi Spec}{RFtotal}$$

$$\psi Design = 4.877 \cdot 10^{-5}\ m^2 \cdot s^{-1}$$

Solve for K: $K := \frac{\psi Design}{T_{max}}$ $K = 7.68 \cdot 10^{-3}\ m \cdot s^{-1}$

Solve Pipe Spacing L:

$$L := \frac{T_{max} \cdot (2 \cdot \cos(\beta))}{\left[\sqrt{\left(4 \cdot \frac{e}{K}\right) + \tan(\beta)^2} - \tan(\beta)\right]}$$

$L = 139.969 \cdot ft$

Equation
Ref. Giroud ET Al., 1993

CLIENT: Juniper Ridge Landfill Expansion Completed By: Peter Mailey Date: 2/19/15
PROJECT:Cells 14-15-16 Leachate Collection Design
Initial Condition at 2.5 Percent Slope Checkd By: KPW Date: 06/01/2015

Pipe Spacing Calculation

Design Objective: To determine necessay pipe spacing while maintaining maximum head on the liner to the thickness of the drainage net (geonet).

Design Parameters

$\psi Spec := 3.17 \cdot 10^{-4} \cdot m^2 \, s^{-1}$	Transmisivity Required Specified of Drainage Geocomposite
K	Permeability of Drainage Geocomposite
L	Spacing between pipe laterals (measured along slope)
$t = 12$ inches	Leachate Collection Sand Thickness (12 inches)
$e := 2.3029 \cdot 10^{-8} \cdot \frac{m}{sec}$	Impingement Rate = 2.35-inches per month (Max Average Monthly Impingement Rate(10 ft. of Waste 100% Area Allowed Runoff)) from Attached HELP Model Output
$\beta := 1.4321 \cdot deg$	Average Slope of the Landfill Base Between Pipes (2.5 percent)
$T_{max} := .00635 \cdot m$	Geonet Thickness = 0.25 inches

Solve for Design Transmisivity:

Design of Lateral Drainage Systems, Richardson 1999

Apply Reduction Factor:

RFtotal = Design Drainage Factor (3) x Intrusion (1.0) x Creep (1.1), Biological Clogging (1.4) x Chemical Clogging (1.4) = 6.5

$RFtotal := 6.5$

$$\psi Design := \frac{\psi Spec}{RFtotal}$$

$\psi Design = 4.877 \cdot 10^{-5} \, m^2 \cdot s^{-1}$

Solve for K: $K := \frac{\psi Design}{T_{max}}$ $K = 7.68 \cdot 10^{-3} \, m \cdot s^{-1}$

Solve Pipe Spacing L:

$$L := \frac{T_{max} \cdot (2 \cdot \cos(\beta))}{\left[\sqrt{\left(4 \cdot \frac{e}{K}\right) + \tan(\beta)^2} - \tan(\beta)\right]}$$

$L = 174.474 \cdot ft$

Equation
Ref. Giroud ET Al., 1993

CLIENT: Juniper Ridge Landfill Expansion
PROJECT:Cells 14-15-16 Leachate Collection Design
Initial Condition at 2.7 Percent Slope

Completed By: Peter Mailey — Date: 2/19/15

Checkd By: KPW — Date: 06/01/2015

Pipe Spacing Calculation

Design Objective: To determine necessay pipe spacing while maintaining maximum head on the liner to the thickness of the drainage net (geonet).

Design Parameters

$\psi Spec := 3.17 \cdot 10^{-4} \cdot m^2\ s^{-1}$	Transmisivity Required Specified of Drainage Geocomposite
K	Permeability of Drainage Geocomposite
L	Spacing between pipe laterals (measured along slope)
$t = 12$ inches	Leachate Collection Sand Thickness (12 inches)
$e := 2.3029 \cdot 10^{-8} \cdot \frac{m}{sec}$	Impingement Rate = 2.35-inches per month (Max Average Monthly Impingement Rate(10 ft. of Waste 100% Area Allowed Runoff)) from Attached HELP Model Output
$\beta := 1.5466 \cdot deg$	Average Slope of the Landfill Base Between Pipes (2.7 percent)
$T_{max} := .00635 \cdot m$	Geonet Thickness = 0.25 inches

Solve for Design Transmisivity:

Design of Lateral Drainage Systems, Richardson 1999

Apply Reduction Factor:

RFtotal = Design Drainage Factor (3) x Intrusion (1.0) x Creep (1.1), Biological Clogging (1.4) x Chemical Clogging (1.4) = 6.5

$RFtotal := 6.5$

$$\psi Design := \frac{\psi Spec}{RFtotal}$$

$$\psi Design = 4.877 \cdot 10^{-5}\ m^2 \cdot s^{-1}$$

Solve for K: $K := \frac{\psi Design}{T_{max}}$ $K = 7.68 \cdot 10^{-3}\ m \cdot s^{-1}$

Solve Pipe Spacing L:

$$L := \frac{T_{max} \cdot (2 \cdot \cos(\beta))}{\left[\sqrt{\left(4 \cdot \frac{e}{K}\right) + \tan(\beta)^2} - \tan(\beta)\right]}$$

$L = 188.293 \cdot ft$

Equation
Ref. Giroud ET Al., 1993

CLIENT: Juniper Ridge Landfill Expansion
PROJECT:Cells 12 Leachate Collection Design
Initial Condition at 3.0 Percent Slope

Completed By: Peter Mailey Date: 2/19/15

Checkd By: KPW Date: 06/01/2015

Pipe Spacing Calculation

Design Objective: To determine necessay pipe spacing while maintaining maximum head on the liner to the thickness of the drainage net (geonet).

Design Parameters

$\psi Spec := 3.17 \cdot 10^{-4} \cdot m^2\ s^{-1}$	Transmisivity Required Specified of Drainage Geocomposite
K	Permeability of Drainage Geocomposite
L	Spacing between pipe laterals (measured along slope)
$t = 12$ inches	Leachate Collection Sand Thickness (12 inches)
$e := 2.3029 \cdot 10^{-8} \cdot \frac{m}{sec}$	Impingement Rate = 2.35-inches per month (Max Average Monthly Impingement Rate(10 ft. of Waste 100% Area Allowed Runoff)) from Attached HELP Model Output
$\beta := 1.7184 \cdot deg$	Average Slope of the Landfill Base Between Pipes (3.0 percent)
$T_{max} := .00635 \cdot m$	Geonet Thickness = 0.25 inches

Solve for Design Transmisivity:

Design of Lateral Drainage Systems, Richardson 1999

Apply Reduction Factor:

RFtotal = Design Drainage Factor (3) x Intrusion (1.0) x Creep (1.1), Biological Clogging (1.4) x Chemical Clogging (1.4) = 6.5

$RFtotal := 6.5$

$$\psi Design := \frac{\psi Spec}{RFtotal}$$

$$\psi Design = 4.877 \cdot 10^{-5}\ m^2 \cdot s^{-1}$$

Solve for K: $K := \frac{\psi Design}{T_{max}}$ $K = 7.68 \cdot 10^{-3}\ m \cdot s^{-1}$

Solve Pipe Spacing L:

$$L := \frac{T_{max} \cdot (2 \cdot \cos(\beta))}{\left[\sqrt{\left(4 \cdot \frac{e}{K}\right) + \tan(\beta)^2} - \tan(\beta)\right]}$$

$L = 209.041 \cdot ft$

Equation
Ref. Giroud ET Al., 1993

CLIENT: Juniper Ridge Landfill Expansion
PROJECT:Cells 13 Leachate Collection Design
Initial Condition at 4.0 Percent Slope

Completed By: Peter Mailey   Date: 2/19/15

Checkd By: KPN   Date: 06/01/2015

Pipe Spacing Calculation

Design Objective: To determine necessay pipe spacing while maintaining maximum head on the liner to the thickness of the drainage net (geonet).

Design Parameters

$\psi Spec := 3.17 \cdot 10^{-4} \cdot m^2\ s^{-1}$	Transmisivity Required Specified of Drainage Geocomposite
K	Permeability of Drainage Geocomposite
L	Spacing between pipe laterals (measured along slope)
$t = 12$ inches	Leachate Collection Sand Thickness (12 inches)
$e := 2.3029 \cdot 10^{-8} \cdot \frac{m}{sec}$	Impingement Rate = 2.35-inches per month (Max Average Monthly Impingement Rate(10 ft. of Waste 100% Area Allowed Runoff)) from Attached HELP Model Output
$\beta := 2.2906 \cdot deg$	Average Slope of the Landfill Base Between Pipes (4.0 percent)
$T_{max} := .00635 \cdot m$	Geonet Thickness = 0.25 inches

Solve for Design Transmisivity:

Design of Lateral Drainage Systems, Richardson 1999

Apply Reduction Factor:

RFtotal = Design Drainage Factor (3) x Intrusion (1.0) x Creep (1.1), Biological Clogging (1.4) x Chemical Clogging (1.4) = 6.5

$RFtotal := 6.5$

$$\psi Design := \frac{\psi Spec}{RFtotal}$$

$$\psi Design = 4.877 \cdot 10^{-5}\ m^2 \cdot s^{-1}$$

Solve for K: $K := \frac{\psi Design}{T_{max}}$ $K = 7.68 \cdot 10^{-3}\ m \cdot s^{-1}$

Solve Pipe Spacing L:

$$L := \frac{T_{max} \cdot (2 \cdot \cos(\beta))}{\left[\sqrt{\left(4 \cdot \frac{e}{K}\right) + \tan(\beta)^2} - \tan(\beta)\right]}$$

$L = 278.214 \cdot ft$

Equation
Ref. Giroud ET Al., 1993

CLIENT: Juniper Ridge Landfill Expansion
PROJECT:Cells 12 Leachate Collection Design
Initial Condition at 5.0 Percent Slope

Completed By: Peter Mailey Date: 2/19/15

Checkd By: KPN Date: 06/01/2015

Pipe Spacing Calculation

Design Objective: To determine necessay pipe spacing while maintaining maximum head on the liner to the thickness of the drainage net (geonet).

Design Parameters

$\psi Spec := 3.17 \cdot 10^{-4} \cdot m^2\ s^{-1}$	Transmisivity Required Specified of Drainage Geocomposite
K	Permeability of Drainage Geocomposite
L	Spacing between pipe laterals (measured along slope)
$t = 12$ inches	Leachate Collection Sand Thickness (12 inches)
$e := 2.3029 \cdot 10^{-8} \cdot \frac{m}{sec}$	Impingement Rate = 2.35-inches per month (Max Average Monthly Impingement Rate(10 ft. of Waste 100% Area Allowed Runoff)) from Attached HELP Model Output
$\beta := 2.8624 \cdot deg$	Average Slope of the Landfill Base Between Pipes (5.0 percent)
$T_{max} := .00635 \cdot m$	Geonet Thickness = 0.25 inches

Solve for Design Transmisivity:

Design of Lateral Drainage Systems, Richardson 1999

Apply Reduction Factor:

RFtotal = Design Drainage Factor (3) x Intrusion (1.0) x Creep (1.1), Biological Clogging (1.4) x Chemical Clogging (1.4) = 6.5

$RFtotal := 6.5$

$$\psi Design := \frac{\psi Spec}{RFtotal}$$

$$\psi Design = 4.877 \cdot 10^{-5}\ m^2 \cdot s^{-1}$$

Solve for K: $K := \frac{\psi Design}{T_{max}}$ $K = 7.68 \cdot 10^{-3}\ m \cdot s^{-1}$

Solve Pipe Spacing L:

$$L := \frac{T_{max} \cdot (2 \cdot \cos(\beta))}{\left[\sqrt{\left(4 \cdot \frac{e}{K}\right) + \tan(\beta)^2} - \tan(\beta)\right]}$$

$L = 347.378 \cdot ft$

Equation
Ref. Giroud ET Al., 1993

UNDERDRAIN PIPE SPACING
CELLS 12 & 13

Project Name:	JUNIPER RIDGE LANDFILL EXPANSION
Project Location:	OLD TOWN, MAINE
Project No:	14101
Comp By:	PCM
Date:	3/3/2015
Chk. By:	KRW 26/03/2015

OBJECTIVE: Determine spacing of underdrain piping in underdrain system.

DESIGN CRITERIA

1. Space underdrain piping so that underdrain sand flow capacity is not exceeded.

ANALYSIS:

Determine when flow from till will exceed the capacity of the proposed underdrain sand.

Q=KiA

1. Determine the Capacity of the Underdrain Sand per unit width of collection pipe

K_{sand} = Horizontal Hydraulic Conductivity of underdrain sand =	1.00E-02	cm/sec
	1.97E-02	ft/min
i_{sand}= Hydraulic Gradient of underdrain sand =	0.035	ft/ft (min Base grade Slope)
A_{sand} =Width x Thickness of UD Sand =	1	ft^2
(Assuming Saturation)		
Q_{sand} = calculated flow capacity of underdrain sand =	6.89E-04	ft^3/min

To find quantity of groundwater expressed from exisitng till :

Per unit width of collection pipe (w = 1ft)

Q=Ki(LxW)

K_{till} = Horizontal Hydraulic Conductivity of existing till =	1.00E-05	cm/sec
	1.97E-05	ft/min
i_{till}= Hydraulic Gradient of overburden soil =	0.058	ft/ft (typical high pre-construction overburden phreatic slope
W = Till Width	1	ft
Q_{till} =Q_{sand} =	6.89E-04	ft3/min
Solve for L		
$L=(Q_{sand})/(K_{till}*i_{till}*L)$		
L=	603	ft

UNDERDRAIN PIPE SPACING
CELLS 12 & 13
AT CELLS 12 & 13

Project Name: JUNIPER RIDGE LANDFILL EXPANSION
Project Location: OLD TOWN, MAINE
Project No: 14101
Comp By: PCM
Date: 3/3/2015
Chk. By: KPN 06/01/2015

OBJECTIVE: Determine anticapated uderdrain flows from Cells 12 and 13

DESIGN CRITERIA

1. Evaluate pipe sizing necessary to carry anticitpated flows.

ANALYSIS:

Determine flow from till into proposed underdrain sand.

Q=KiA

1. Determine the Capacity of the Underdrain Sand per unit width of collection pipe

K_{till} = Horizontal Hydraulic Conductivity of existing till = 1.00E-05 cm/sec
1.97E-05 ft/min

i_{till}= Hydraulic Gradient of overburden soil = 0.058 ft/ft (typical high pre-construction overburden phreatic slope)

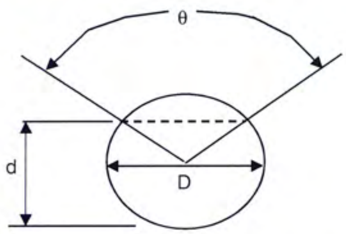
	AREA (sf)	K-till (ft/min)	*i* -till	Q (cfs)	Q (gpm)	
CELL 12	147,461	1.97E-05	0.058	0.00	1.3	
CELL 13	363,140	1.97E-05	0.058	0.01	3.1	
				Total =	4.4	Capacity of discharge pipe.

*UNDERDRAIN DISCHARGE PIPE CAPACITY > COMBINED CELL 12 + CELL 13 ESTIMATED UNDERDRAIN FLOW

SEVEE && MAHER ENGINEERS, INC.

UNDERDRAIN DISCHARGE PIPE CAPACITY

CELLS 12 & 13 Location: OLD TOWN, MAINE
By: PCM Date: 3/3/2015
Chk. By: KPN 06/01/2015 Date: mdo version 12.8.00



INPUT

D=	3.63	inches
d=	1.82	inches
n=	0.015	mannings coeff
θ=	179.7	degrees
S=	0.02	slope in/in

Mannings Formula

$Q=(1.486/n)AR_h^{2/3}S^{1/2}$

R=A/P
A=cross sectional area
P=wetted perimeter
S=slope of channel
n=Manning's roughness coefficient

$V=(1.49/n)R_h^{2/3}S^{1/2}$
$Q=V \times A$

			Solution to Mannings Equation		
Area,ft^2	Wetted Perimeter, ft	Hydraulic Radius, ft	velocity ft/s	flow, cfs	flow, GPM
0.04	0.48	0.08	2.51	0.09	41

Manning's n-values	
PVC	0.01
PE (<9"dia)	0.015
PE (>12"dia)	0.02
PE(9-12"dia)	0.017
CMP	0.025
ADS N12	0.012
HCMP	0.023
Conc	0.013

APPENDIX D-8

LEACHATE TANK STORAGE CAPACITY

JUNIPER RIDGE LANDFILL
EXPANSION APPLICATION
LEACHATE STORAGE TANK EVALUATION

Tank Diameter =	81	ft
Tank Height=	23.8	ft
Total Tank Capacity=	921,000	gallons
Capacity per foot	38,667	gallons

Depth (ft)	Capacity	Cumulative Capacity	Remaining Capacity at Water Depth	
1	38,667	38,667	882,333	
2	38,667	77,334	843,666	
3	38,667	116,001	804,999	
4	38,667	154,668	766,332	
5	38,667	193,335	727,665	Average 5.2 feet Leachate Level (May 2013)
6	38,667	232,002	688,998	
7	38,667	270,669	650,331	
8	38,667	309,336	611,664	
9	38,667	348,003	572,997	
10	38,667	386,670	534,330	
11	38,667	425,337	495,663	
12	38,667	464,004	456,996	
13	38,667	502,671	418,329	
14	38,667	541,338	379,662	
15	38,667	580,005	340,995	
16	38,667	618,672	302,328	
17	38,667	657,339	263,661	
18	38,667	696,006	224,994	
19	38,667	734,673	186,327	
20	38,667	773,340	147,660	
21	38,667	812,007	108,993	
22	38,667	850,674	70,326	
23	38,667	889,341	31,659	
23.84	32,480	921,000	0	

Storage Capacity Consumed by the 25% requirement 230,250

- Assume leachate level in is 5.2 feet (Average Leachate Level in Tank in May 2013) there fore the leachate utilizes 201,068 gallons of the total tank capacity of 921,000 gallons leaving **719,932 gallons** of capacity available at start of analysis.
- Account for capacity required to store the base leachate flow (Based on average annual infiltration determined by Help Model) for the entire site of the Expansion Life is 48,000 gallons/day or 2,000 gallon/hr. It will take 46 hours (from Hydrocad time to pump storage in sump) which 92,000 gallons of base flow leaving **627,932 gallons** of capacity available in the tank.
- Account for the capacity required to store a 25 year 24 hour storm event (4.8 inches) in active operating area of 12.6 acres with extra 2.5 acres of sideslope open (Cell 12 sump calcs). Total runoff volume 1.258 acre-ft or 410,000 gallons from HydroCad model. The resulting capacity remaining in the tank is **217,932 gallons.**
- Account for leachate removed from the tank and hauled to treatment plant during the pumping of leachate from Cell 12. During this peak leachate generation event leachate can be removed from the tank and hauled to the treatment plant at a rate of 48,000 gpd. Therefore approximately 96,000 gallons will be removed during the Cell pumping period of 46 hours. **The final resulting capacity remaining in the tank is 313,932 gallons which is about 34% of the total tank capacity.**

AQUASTORE® TANK CAPACITY CHART
WATER TANKS WITH CONCRETE FLOORS (x 1000 US Gallons)

Actual Sidewall Height (feet) - Number of Rings - Courses

Model Diameter	# Sheets	Exact Diameter (feet)	Capacity Per Foot (gallons)	Max Water Depth (Ft) AISC Design A 375" max	B 5" max	5.51 1	10.09 2	14.68 3	19.26 4	23.84 5	28.43 6	33.01 7	37.59 8	42.17 9	46.76 10	51.34 11	55.92 12	60.51 13	65.09 14	69.67 15	74.26 16
11	4	11.19	735	65.1	65.1	4	7	10	14	17	20	24	27	30	34	37	41	44	47	47 68.79	-
14	5	13.98	1,149	138.4	138.4	6	11	16	22	27	32	37	43	48	53	58	64	69	74	80	85
17	6	16.78	1,655	138.4	138.4	9	16	24	31	39	47	54	62	69	77	84	92	100	107	115	122
20	7	19.58	2,252	138.4	138.4	12	22	33	43	53	64	74	84	94	105	115	125	136	146	156	167
22	8	22.37	2,942	138.4	138.4	16	29	43	56	70	83	97	110	124	137	151	164	178	191	204	218
25	9	25.17	3,724	138.4	138.4	20	37	54	71	88	105	122	139	157	174	191	208	225	242	259	276
28	10	27.97	4,597	126.8	138.4	25	46	67	88	109	130	151	172	193	214	236	257	278	299	320	341
31	11	30.77	5,563	115.2	138.4	30	56	81	107	132	158	183	209	234	260	285	311	336	362	387	413
34	12	33.56	6,620	105.7	138.4	36	66	97	127	157	188	218	248	279	309	339	370	400	430	461	491
36	13	36.36	7,770	97.5	133.2	42	78	114	149	185	220	256	292	327	363	398	434	470	505	541	576
39	14	39.16	9,011	90.6	123.9	49	90	132	173	214	256	297	338	380	421	462	503	545	586	627	669
42	15	41.96	10,345	84.5	115.6	57	104	151	199	246	294	341	388	436	483	531	578	625	673	720	768
45	16	44.75	11,770	79.2	108.4	64	118	172	226	280	334	388	442	496	550	604	658	712	766	820	873
48	17	47.55	13,287	74.6	102.0	73	134	195	255	316	377	438	499	560	621	682	743	803	864	925	986
50	18	50.35	14,896	70.4	96.4	82	150	218	286	355	423	491	559	628	696	764	833	901	969	1,037	1,092 73.37
53	19	53.15	16,598	66.7	91.3	91	167	243	319	395	471	547	623	700	776	852	928	1,004	1,080	1,141 68.79	1,203 72.49
56	20	55.95	18,391	63.4	86.7	101	185	269	354	438	522	607	691	775	859	944	1,028	1,112	1,180 64.21	1,248 67.91	1,316 71.61
59	21	58.74	20,276	60.4	82.6	111	204	297	390	483	576	669	762	855	948	1,040	1,133	1,208 59.62	1,283 63.33	1,359 67.03	1,434 70.73
62	22	61.54	22,253	57.6	78.8	122	224	326	428	530	632	734	836	938	1,040	1,142	1,244	1,326 59.62	1,409 63.33	1,491 67.03	1,573 70.73
64	23	64.34	24,322	55.1	75.4	134	245	356	468	579	691	802	914	1,025	1,137	1,248	1,338 55.04	1,428 58.74	1,518 62.44	1,608 66.15	1,698 69.85
67	24	67.13	26,483	52.8	72.3	145	267	388	510	631	752	874	995	1,116	1,238	1,359	1,457 55.04	1,555 58.74	1,653 62.44	1,751 66.15	1,849 69.85
70	25	69.93	28,736	50.7	69.4	158	290	421	553	685	816	948	1,080	1,211	1,343	1,449 50.46	1,566 54.16	1,662 57.86	1,769 61.56	1,875 65.26	1,981 68.96
73	26	72.73	31,081	48.8	66.7	171	313	456	598	741	883	1,025	1,168	1,310	1,453	1,568 50.46	1,683 54.16	1,798 57.86	1,913 61.56	2,028 65.26	2,073 68.96
76	27	75.53	33,518	46.9	64.2	184	338	491	645	799	952	1,106	1,259	1,413	1,567	1,691 50.46	1,815 54.16	1,939 57.86	2,063 61.56	2,151 65.26	
78	28	78.32	36,046	45.3	61.9	198	363	529	694	859	1,024	1,189	1,355	1,520	1,653 45.88	1,787 49.58	1,920 53.28	2,053 56.98	2,187 60.68	2,231 64.38	
81	29	81.12	38,667	43.7	59.8	213	390	567	744	921	1,099	1,276	1,453	1,630	1,773 45.88	1,916 49.58	2,060 53.28	2,203 56.98	2,312 60.68		
84	30	83.92	41,380	42.3	57.8	228	417	607	796	986	1,176	1,365	1,555	1,745	1,898 45.88	2,051 49.58	2,204 53.28	2,357 56.98	2,391 60.68		
87	31	86.72	44,184	40.9	55.9	243	445	648	850	1,053	1,255	1,458	1,660	1,824 41.29	1,987 44.99	2,151 48.69	2,315 52.40	2,469 56.10			
90	32	89.51	47,081	39.6	54.2	259	475	690	906	1,122	1,338	1,554	1,769	1,944 41.29	2,118 44.99	2,292 48.69	2,466 52.40	2,551 56.10			
92	33	92.31	50,070	38.4	52.5	275	505	734	964	1,193	1,423	1,652	1,882	2,067 41.29	2,252 44.99	2,438 48.69	2,623 52.40	2,628 56.10			
95	34	95.11	53,150	37.3	51.0	292	536	780	1,023	1,267	1,510	1,754	1,951 36.71	2,147 40.41	2,344 44.11	2,541 47.81	2,710 51.51				
98	35	97.91	56,323	36.2	49.5	310	568	826	1,084	1,342	1,600	1,859	2,067 36.71	2,276 40.41	2,484 44.11	2,692 47.81	2,787 51.51				
101	36	100.70	59,587	35.2	48.2	328	601	874	1,147	1,420	1,693	1,966	2,187 36.71	2,407 40.41	2,628 44.11	2,849 47.81	2,872 51.51				
104	37	103.50	62,944	34.3	46.9	346	635	923	1,212	1,500	1,789	2,077	2,310 36.71	2,543 40.41	2,776 44.11	2,952 47.81					

Actual Sidewall Height (feet) - Number of Rings - Courses

Model Diameter	78.84 17	83.42 18	88.00 19	92.59 20	97.17 21	101.75 22	106.34 23	110.92 24	115.50 25	120.09 26	124.67 27	129.25 28	133.83 29	138.42 30	31	32
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	90	95	101	106	111	116	122	127	132	137	143	148	153	158 138	159 141.24	-
17	130	138	145	153	160	168	175	183	191	198	206	213	221	227 138	229 141.24	-
20	177	187	198	208	218	229	239	249	260	270	280	291	301	309 138	311 141.24	-
22	231	245	258	272	285	299	312	326	339	353	366	380	393	404 137.54	407 141.24	-
25	293	310	327	344	361	378	395	413	430	447	464	481	498	512 138	515 141.24	-
28	362	383	404	425	446	467	488	509	530	552	573	590 128.37	607 132.07	624 135.77	636 139.47	-
31	438	464	489	515	540	566	591	617	637 114.62	658 118.32	678 122.02	699 125.72	719 129.43	740 133.13	761 136.83	770 140.5
34	521	552	582	612	643	673	698 105.45	722 109.16	747 112.86	771 116.56	796 120.26	820 123.96	845 127.66	869 131.36	894 135.06	916 138.7
36	612	648	683	719	755	783 100.87	812 104.57	841 108.27	870 111.98	898 115.68	927 119.38	956 123.08	985 126.78	1,013 130.48	1,034 134.18	
39	710	751	793	826 91.71	859 95.41	893 99.11	926 102.81	959 106.51	993 110.21	1,026 113.91	1,059 117.61	1,093 121.32	1,116 125.02			
42	815	862	901 87.12	939 90.82	977 94.52	1,016 98.23	1,054 101.93	1,092 105.63	1,131 109.33	1,169 113.03	1,195 116.73					
45	927	971 82.54	1,015 86.24	1,058 89.94	1,102 93.64	1,145 97.34	1,189 101.05	1,232 104.75	1,275 108.45							
48	1,035 77.96	1,084 81.66	1,134 85.36	1,183 89.06	1,232 92.76	1,281 96.46	1,330 100.16	1,355 103.87								
50	1,148 77.07	1,203 80.78	1,258 84.48	1,313 88.18	1,368 91.88	1,423 95.58	1,435 99.28									
53	1,264 76.19	1,326 79.89	1,387 83.60	1,448 87.30	1,510 91.00	1,515 94.70										
56	1,385 75.31	1,453 79.01	1,521 82.71	1,589 86.41	1,594 90.12											
59	1,509 74.43	1,584 78.13	1,659 81.83	1,674 85.53												
62	1,656 74.43	1,738 78.13	1,753 81.83													
64	1,788 73.55	1,833 77.25														
67	1,914 73.55															
70	1,994 72.67															

Glass Tanks with a Heart of Steel™

SPLIT-CELL CHART KEY:

1,836 56.09

1. Top number is tank volume (x 1000) in US Gallons
2. Bottom number is actual sidewall height with 44" high shell sheets

Notes:
1. 100 mph wind speed
2. 25 psf live snow load
3. Seismic Zone 0,1
4. Importance Factor, I = 1.25
5. Site Amplification Factor, S = 1.5
6. Specific gravity 1.0 @ STP
7. Structure height limitations dependent upon local soil conditions and construction techniques
8. AISC designates American Institute of Steel Construction Inc
9. Model Designation => Model Diameter & Model Sidewall Height
   Example: Model Designation 4228 => 42' diameter & 28' height
10. For steel floor option: Add .678' X Capacity Per Foot (gallons) to listed capacities
11. No freeboard allowance except in the darker gray shaded areas at the far right end of the rows, where the freeboard is variable

Part#: 274483-000
ECN#: 07387

ENGINEERED STORAGE PRODUCTS COMPANY

AISC - Seismic 0,1 - English

AQUASTORE Tanks & Domes

AQUASTORE® TANK CAPACITY CHART
WATER TANKS WITH CONCRETE FLOORS (x 1000 US Gallons)

AQUASTORE Tanks & Domes

Model Diameter	# Sheets	Exact Diameter (feet)	Capacity Per Foot (gallons)	Max Water Depth (Ft) AISC Design A 375" max	B .5" max	5.51 1	10.09 2	14.68 3	19.26 4	23.84 5	28.43 6	33.01 7	37.59 8	42.17 9	46.76 10	51.34 11
						Actual Sidewall Height (feet) - Number of Rings - Courses										
106	38	106.30	66,392	33.4	**45.6**	365	670	974	1,278	1,582	1,887	2,191	2,437 36.71	2,682 40.41	2,928 44.11	3,027 47.81
109	39	109.10	69,932	32.5	**44.4**	385	705	1,026	1,346	1,667	1,987	2,246 32.13	2,505 35.83	2,764 39.53	3,023 43.23	3,104 46.93
112	40	111.90	73,565	31.7	**43.3**	405	742	1,079	1,416	1,753	2,091	2,363 32.13	2,635 35.83	2,907 39.53	3,180 43.23	3,185 46.93
115	41	114.69	77,289	30.9	**42.3**	425	780	1,134	1,488	1,842	2,196	2,483 32.13	2,769 35.83	3,055 39.53	3,269 43.23	
117	42	117.49	81,105	30.2	**41.3**	446	818	1,190	1,562	1,933	2,305	2,605 32.13	2,905 35.83	3,205 39.53	3,349 43.23	
120	43	120.29	85,013	29.5	**40.3**	468	858	1,247	1,637	2,026	2,416	2,731 32.13	3,045 35.83	3,360 39.53	3,426 43.23	
123	44	123.09	89,013	28.8	**39.4**	490	898	1,306	1,714	2,122	2,530	2,859 32.13	3,189 35.83	3,507 39.53		
126	45	125.89	93,105	28.2	**38.5**	513	939	1,366	1,793	2,219	2,564 27.54	2,909 31.24	3,253 34.95	3,584 38.65		
129	46	128.68	97,289	27.6	**37.7**	536	981	1,427	1,873	2,319	2,679 27.54	3,039 31.24	3,399 34.95	3,667 38.65		
131	47	131.48	101,565	27.0	**36.9**	559	1,025	1,490	1,956	2,421	2,797 27.54	3,173 31.24	3,549 34.95	3,747 38.65		
134	48	134.27	105,933	26.4	**36.1**	583	1,069	1,554	2,040	2,525	2,917 27.54	3,309 31.24	3,701 34.95	3,824 38.65		
137	49	137.07	110,393	25.9	**35.4**	608	1,114	1,620	2,126	2,631	3,040 27.54	3,449 31.24	3,857 34.95	3,907 38.65		
140	50	139.87	114,945	25.4	**34.7**	633	1,160	1,686	2,213	2,740	3,165 27.54	3,591 31.24	3,988 34.95			
143	51	142.67	119,589	24.9	**34.0**	658	1,207	1,755	2,303	2,851	3,293 27.54	3,736 31.24	4,066 34.95			
145	52	145.46	124,324	24.4	**33.3**	685	1,254	1,824	2,394	2,964	3,424 27.54	3,884 31.24	4,139 34.95			
148	53	148.26	129,152	23.9	**32.7**	711	1,303	1,895	2,487	3,079	3,557 27.54	4,035 31.24	4,223 34.95			
151	54	151.06	134,072	23.5	**32.1**	738	1,353	1,967	2,582	3,078 22.96	3,574 26.66	4,070 30.36	4,303 34.06			
154	55	153.86	139,083	23.0	**31.5**	766	1,403	2,041	2,678	3,193 22.96	3,708 26.66	4,222 30.36	4,381 34.06			
157	56	156.66	144,187	22.6	**30.9**	794	1,455	2,116	2,776	3,310 22.96	3,844 26.66	4,377 30.36	4,455 34.06			
159	57	159.46	149,382	22.2	**30.4**	823	1,507	2,192	2,876	3,429 22.96	3,982 26.66	4,535 30.36	4,541 34.06			
162	58	162.26	154,670	21.9	**29.9**	852	1,561	2,269	2,978	3,551 22.96	4,123 26.66	4,624 30.36				
171	61	170.65	171,082	20.8	**28.4**	942	1,726	2,510	3,294	3,928 22.96	4,561 26.66	4,858 30.36				
179	64	179.04	188,318	19.8	**27.1**	1,037	1,900	2,763	3,626	4,323 22.96	5,020 26.66	5,103 30.36				
187	67	187.43	206,381	18.9	**25.9**	1,137	2,083	3,028	3,792 18.38	4,556 22.08	5,320 25.78	5,345 29.48				
193	69	193.03	218,898	18.4	**25.1**	1,206	2,209	3,212	4,022 18.38	4,832 22.08	5,494 25.78					
201	72	201.42	238,340	17.6	**24.1**	1,313	2,405	3,497	4,380 18.38	5,262 22.08	5,743 25.78					
210	75	209.81	258,609	16.9	**23.1**	1,424	2,610	3,795	4,752 18.38	5,709 22.08	5,973 25.78					
218	78	218.20	279,712	16.3	**22.2**	1,541	2,823	4,105	5,140 18.38	6,175 22.08	6,209 25.78					
227	81	226.59	301,642	15.6	**21.4**	1,662	3,044	4,426	5,543 18.38	6,455 22.08						
235	84	234.99	324,399	15.1	**20.6**	1,787	3,274	4,760	5,961 18.38	6,682 22.08						
243	87	243.38	347,984	14.6	**19.9**	1,917	3,512	4,800 13.79	6,088 17.50	6,924 21.20						

Actual Sidewall Height (feet) - Number of Rings - Courses (continued)

55.92	60.51	65.09	69.67	74.26	78.84	83.42	88.00	92.59	97.17	101.75	106.34	110.92	115.50	120.09	124.67	129.25	133.83	138.42		
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

AQUASTORE Tanks & Domes
Glass Tanks with a Heart of Steel™

SPLIT-CELL CHART KEY:

1,836
56.09

1. Top number is tank volume (x 1000) in US Gallons
2. Bottom number is actual sidewall height with 44" high shell sheets

Notes:
1. 100 mph wind speed
2. 25 psf live snow load
3. Seismic Zone 0,1
4. Importance Factor, I = 1.25
5. Site Amplification Factor, S = 1.5
6. Specific gravity 1.0 @ STP
7. Structure height limitations dependent upon local soil conditions and construction techniques
8. AISC designates American Institute of Steel Construction Inc
9. Model Designation => Model Diameter & Model Sidewall Height
   Example: Model Designation 4228 => 42' diameter & 28' height
10. For steel floor option: Add .678' X Capacity Per Foot (gallons) to listed capacities
11. No freeboard allowance except in the darker gray shaded areas at the far right end of the rows, where the freeboard is variable

Part#: 274483-000
ECN#: 07387

ENGINEERED STORAGE PRODUCTS COMPANY
AQUASTORE Tanks & Domes

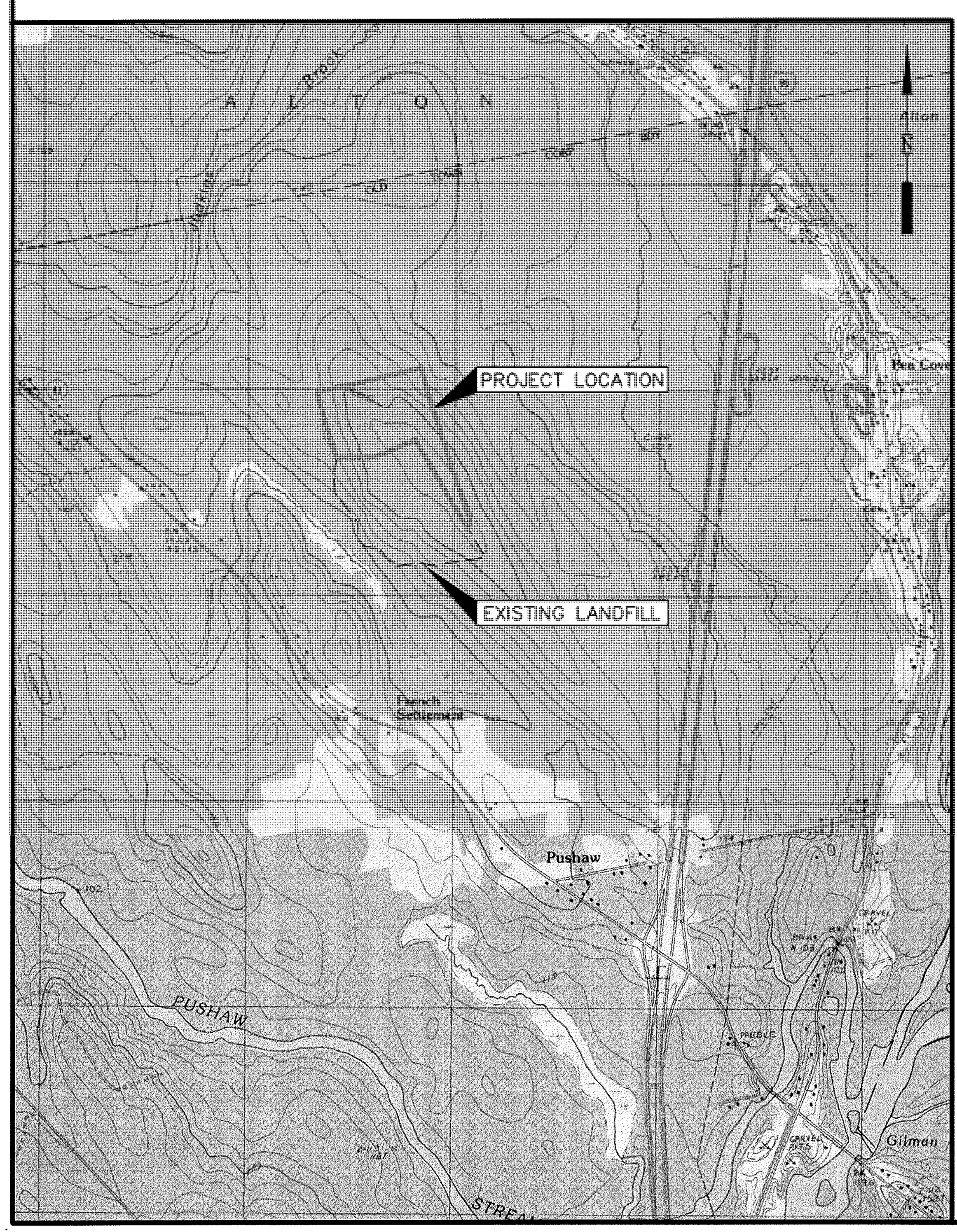
AISC - Seismic 0,1 - English Units

APPENDIX E

DESIGN DRAWINGS

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

LOCATION MAP



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SYMBOLS

EXISTING	PROPOSED	
		NORTH ARROW (TRUE)
DATE		NORTH ARROW (MAGNETIC)
N		NORTH ARROW (PLAN NORTH)
25	25	CONTOUR LINES
	INV 25.56	SPOT ELEVATION (INVERT ELEVATION)
		EXISTING GROUND
		SURVEY BASELINE WITH TRIANGULATION OR INTERSECTION PT.
		PROPERTY LINE OR R.O.W.
N35°-10'-10"W 251.17'	N35°-10'-10"W 251.17'	PROPERTY LINE W/ BEARING AND DISTANCE
7		CELL DESIGNATION
		BOUNDARY LINE (State, County, Municipality)
		SURVEY MONUMENT
		SURVEY CONTROL
		PROPERTY PIN, DRILL HOLE, PK, OR STAKE
		WOODS OR BRUSH LINE
		INDIVIDUAL TREE
		WETLAND DELINEATED
		WETLAND PHOTO INTERPRETED
		WETLAND TO BE IMPACTED
		GAS VENT
		GAS VENT (CAPPED)
		CLEAN OUT STRUCTURE
		SAMPLE SUMP
		CULVERT
		SLOPE INCLINOMETER
		VIBRATING WIRE SETTLEMENT CELL
		VERTICAL/HORIZONTAL DISPLACEMENT MONUMENT
		VERTICAL DISPLACEMENT MONUMENT

EXISTING	PROPOSED	
		DRAINAGE COURSE (WITH DIRECTION)
		EDGE OF WATER
		WATER ELEVATION (GROUND OR SURFACE)
		FENCE LINE (WOOD)
x x	x x	FENCE LINE (WIRE)
		STONE WALL
		RETAINING WALL
		GUARD RAIL
		BUILDING AND STRUCTURES
	1 2 OR 2:1	SLOPE RATIO (HORIZONTAL TO VERTICAL)
TOP OF SLOPE 2:1	TOP OF SLOPE 2:1	SLOPES (WITH SLOPE RATIO)
		EDGE OF ROAD
		CUT OR FILL LINE
		BITUMINOUS PAVEMENT
		CONCRETE
B-12 MW-12 P-12	B-12 MW-12 P-12	TEST BORING, MONITORING WELL, OR PIEZOMETER AND NUMBER
TP-12	TP-12	TEST PIT AND NUMBER
SW-12	SW-12	SURFACE WATER SAMPLE LOCATION
		GAS EXTRACTION WELL
		GAS CONDENSATE TRAP
		MANHOLE
		CATCH BASIN
		WATER OR GAS VALVE
		HYDRANT
		AIR RELEASE VALVE
		SURGE RELEASE VALVE
		UTILITY POLE
		LIGHT POLE

EXISTING	PROPOSED	
G	UG	UNDERGROUND GAS MAIN
T	UT	UNDERGROUND TELEPHONE LINE
E	UE	UNDERGROUND ELECTRICAL LINE
OE	OE	OVERHEAD ELECTRICAL LINE
OT	OT	OVERHEAD TELEPHONE LINE
12" SS	12" SS	SANITARY SEWER
8" FM	8" FM	FORCE MAIN
8" W	8" W	WATER MAIN
12" SD	12" SD	STORM DRAIN
8" UD	8" UD	UNDERDRAIN
6" PD	6" PD	PERIMETER DRAIN
6" LT	6" LT	LEACHATE TRANSPORT
6" LC	6" LC	LEACHATE COLLECTION
LD	6" LD	LEAK DETECTION
GC	6" GC	GAS COLLECTION
GT	6" GT	GAS TRANSPORT
		REDUCER
		MECHANICAL CAP OR PLUG
		COUPLING
		BEND
		TEE
		PIPE TO BE ABANDONED
		RISER PIPE & INLET GRATE
		STORM GRATE
		DRAINAGE INLET STRUCTURE
		UNDERDRAIN SUMP
	SF	SILTATION FENCE
	CLL	CLEARING OR CONSTRUCTION LIMIT LINE

ACCMP	ASPHALT COATED CMP
ACP	ASBESTOS CEMENT PIPE
AC	ACRE
AGG	AGGREGATE
ALUM	ALUMINUM
APPD	APPROVED
APPROX	APPROXIMATE
ARMH	AIR RELEASE MANHOLE
ASB	ASBESTOS
ASP	ASPHALT
AUTO	AUTOMATIC
AUX	AUXILIARY
AVE	AVENUE
AZ	AZIMUTH
BCCMP	BITUMINOUS COATED CMP
BM	BENCH MARK
BIT	BITUMINOUS
BLDG	BUILDING
BOT	BOTTOM
BRG	BEARING
BV	BALL VALVE
CB	CATCH BASIN
CEN	CENTER
CEM LIN	CEMENT LINED
CMP	CORRUGATED METAL PIPE
CO	CLEAN OUT
CF	CUBIC FEET
CFS	CUBIC FEET PER SECOND
CI	CAST IRON
CL	CLASS
CONC	CONCRETE
CONST	CONSTRUCTION
CONTR	CONTRACTOR
CS	CURB STOP
CTR	CENTER
CU	COPPER
CY	CUBIC YARD
D	DEGREE OF CURVE
DBL	DOUBLE
DEG OR °	DEGREE
DEPT	DEPARTMENT
DI	DUCTILE IRON
DIA OR ø	DIAMETER
DIM	DIMENSION
DIST	DISTANCE
DN	DOWN
DR	DRAIN
DWG	DRAWING
EA	EACH
EG	EXISTING GROUND OR GRADE
ELEC	ELECTRIC
EL	ELEVATION
ELB	ELBOW
EOP	EDGE OF PAVEMENT
EQUIP	EQUIPMENT
EST	ESTIMATED
EXC	EXCAVATE
EXIST	EXISTING
FG	FINISH GRADE
FBRGL	FIBERGLASS
FDN	FOUNDATION
FLEX	FLEXIBLE
FLG	FLANGE
FLR	FLOOR
FPS	FEET PER SECOND
FT OR '	FEET
FTG	FOOTING
GA	GAUGE
GAL	GALLON
GALV	GALVANIZED
GPD	GALLONS PER DAY
GPM	GALLONS PER MINUTE
HDPE	HIGH DENSITY POLYETHYLENE
HORIZ	HORIZONTAL
HP	HORSEPOWER
HYD	HYDRANT
ID	INSIDE DIAMETER
IN OR "	INCHES
INV	INVERT
INV EL	INVERT ELEVATION
LB	POUND
LC	LEACHATE COLLECTION
LD	LEAK DETECTION
LF	LINEAR FEET
LOC	LOCATION
LT	LEACHATE TRANSPORT
MH	MANHOLE
MJ	MECHANICAL JOINT
MATL	MATERIAL
MAX	MAXIMUM
MFR	MANUFACTURE
MIN	MINIMUM
MISC	MISCELLANEOUS
MON	MONUMENT
NITC	NOT IN THIS CONTRACT
NTS	NOT TO SCALE
N/F	NOW OR FORMERLY
NO OR #	NUMBER
OC	ON CENTER
OD	OUTSIDE DIAMETER
PC	POINT OF CURVE
PD	PERIMETER DRAIN
PI	POINT OF INTERSECTION
PIV	POST INDICATOR VALVE
PT	POINT OF TANGENT
PERF	PERFORATED
PP	POWER POLE
PSI	POUNDS PER SQUARE INCH
PVC	POLYVINYL CHLORIDE
PVMT	PAVEMENT
QTY	QUANTITY
RCP	REINFORCED CONCRETE PIPE
ROW	RIGHT OF WAY
RAD	RADIUS
REQD	REQUIRED
RT	RIGHT
RTE	ROUTE
S	SLOPE
SCH	SCHEDULE
SF	SQUARE FEET
SHT	SHEET
SMH	SANITARY MANHOLE
ST	STREET
STA	STATION
SY	SQUARE YARD
TAN	TANGENT
TDH	TOTAL DYNAMIC HEAD
TEMP	TEMPORARY
TYP	TYPICAL
UD	UNDERDRAIN
V	VOLTS
VA TEE	VALVE ANCHORING TEE
VERT	VERTICAL
WG	WATER GATE
W/	WITH
W/O	WITHOUT
YD	YARD

VIEW MARKERS & IDENTIFICATION

SECTION TITLE & NO.
ACCESS ROAD 3
C-100
DRAWING WHERE SECTION APPEARS

DETAIL TITLE
MANHOLE
SEE DWG C-300
DRAWING WHERE DETAIL APPEARS

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. COTE, JR. No. 5144 — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SYMBOLS & ABBREVIATIONS

SME
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DESIGN BY: PCM
DRAWN BY: SJM
DATE: 3/4/2015
CHECKED BY:
LMN: NONE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE SYMSHT

C-000

LEGEND

- (7) CELL IDENTIFICATION
- WETLAND DELINEATED
- WETLAND PHOTO INTERPRETED

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

2. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.
3. BORINGS & TEST PIT LOCATIONS ARE BASED ON FIELD SURVEY BY SEVEE & MAHER ENGINEERS, INC., CUMBERLAND, MAINE.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

EXISTING SITE CONDITIONS PLAN

STATE OF MAINE · SUWAH. COTE, JR. No. 5148 · LICENSED · PROFESSIONAL ENGINEER

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LMN:	EXCON
CTB:	SME-STD

JOB NO. 14101.00 DWG FILE BASE

C-100

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

2. EXISTING PERMITTED LANDFILL BASE GRADES REPRESENT THE TOP OF THE 12-INCH UNDERDRAIN LAYER.
3. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE THE SUBBASE ROAD GRADES.
4. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.
5. BORINGS & TEST PIT LOCATIONS ARE APPROXIMATE AND BASED ON FIELD SURVEY BY SEVEE & MAHER ENGINEERS, INC., CUMBERLAND, MAINE.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SITE DEVELOPMENT PLAN

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LMN: SITEDEV
CTB: SME-STD
JOB NO. 14101.00 DWG FILE BASE
C-101

LEGEND

(7)	CELL IDENTIFICATION
	WETLAND DELINEATED
	WETLAND PHOTO INTERPRETED

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

2. EXISTING PERMITTED LANDFILL BASE GRADES REPRESENT THE TOP OF THE 12-INCH UNDERDRAIN LAYER.
3. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.
4. AREA IDENTIFIED TO RECEIVE UNDERDRAIN SHALL BE UNDERCUT TO 1-FOOT BELOW BASE GRADE. THE UNDERDRAIN SHALL BE CONSTRUCTED ON THE RESULTING GRADE.
5. AREA IDENTIFIED SHALL BE UNDERCUT 1-FOOT BELOW BASEGRADE. THE SECONDARY LINER SHALL BE AUGMENTED IN THIS AREA AS DETAILED ON DRAWING C-300.
6. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.
7. BORINGS & TEST PIT LOCATIONS ARE APPROXIMATE AND BASED ON FIELD SURVEY BY SEVEE & MAHER ENGINEERS, INC., CUMBERLAND, MAINE.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. COTE, JR. — No. 5144 — LICENSED — PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SITE BASE GRADING PLAN

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DATE:	3/4/2015
CHECKED BY:	
LMN:	BASEGRADE
CTB:	SME-STD

JOB NO. 14101.00 DWG FILE BASE

C-102

LEGEND

(7)	CELL IDENTIFICATION
[hatch]	WETLAND DELINEATED
[crosshatch]	WETLAND PHOTO INTERPRETED

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93
2. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.
3. AREA IDENTIFIED TO RECEIVE UNDERDRAIN SHALL BE UNDERCUT TO 1-FOOT BELOW BASE GRADE. THE UNDERDRAIN SHALL BE CONSTRUCTED ON THE RESULTING GRADE.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. COTE, JR. No. 5146 — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

UNDERDRAIN PIPING PLAN

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DRAWN BY:	SJM
DATE:	3/4/2015
CHECKED BY:	[signature]
LMN:	UD-PIPE
CTB:	SME-STD

JOB NO. 14101.00 DWG FILE BASE

C-103

LEGEND

(7) CELL IDENTIFICATION

WETLAND DELINEATED

WETLAND PHOTO INTERPRETED

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

2. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.

3. AREA IDENTIFIED TO RECEIVE UNDERDRAIN SHALL BE UNDERCUT TO 1-FOOT BELOW BASE GRADE. THE UNDERDRAIN SHALL BE CONSTRUCTED ON THE RESULTING GRADE.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — BUY H. COTE, JR. — No. 5144 — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

LEAK DETECTION PIPING PLAN

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DESIGN BY: PCM
DRAWN BY: SJM
DATE: 3/4/2015
CHECKED BY:
LMN: LD-PIPE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE BASE

C-104

LEGEND

(7) CELL IDENTIFICATION

WETLAND DELINEATED

WETLAND PHOTO INTERPRETED

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

2. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.

3. EXTENSIONS SHALL BE INSTALLED IN THE SOFT WASTE LAYER. PIPE SHALL BE HDPE SOLID WALL PIPE SLOPED 2 PERCENT MINIMUM DOWN TO CELL 7 AND CELL 9.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. COTE, JR. No. 5144 — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

LEACHATE COLLECTION PIPING PLAN

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DESIGN BY:	PCM
DRAWN BY:	SJM
DATE:	3/4/2015
CHECKED BY:	
LMN:	LC-PIPE
CTB:	SME-STD

JOB NO. 14101.00 DWG FILE BASE

C-105

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

2. LANDFILL GAS INFRASTRUCTURE FROM PLANS ENTITLED "LFG SYSTEM EXPANSION MASTER PLAN" BY SANBORN HEAD, DATED JUNE 2015.
3. PROPOSED FINAL WASTE GRADES REPRESENT GRADES PRIOR TO CONSTRUCTION OF FINAL COVER SYSTEM.
4. PERMITTED LANDFILL FINAL WASTE GRADES REPRESENT GRADES PRIOR TO CONSTRUCTION OF FINAL COVER SYSTEM.
5. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.

LFG INFRASTRUCTURE LEGEND

EXISTING		PROPOSED
GW-11	VERTICAL LFG WELL	GW-152
12"GC	LFG CONVEYANCE PIPE	12"GC
T	CONDENSATE TRAP	T
	CONTROL VALVE	
KO-2	CONDENSATE KNOCKOUT	KO-4
	LEACHATE COLLECTION CLEANOUT	
	VERTICAL RISER	
	HIGH POINT	HP
	TEMPORARY PIPE TERMINATION	

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE
GUY R. COTE, JR.
No. 5144
LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

GAS COLLECTION SYSTEM PLAN

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DESIGN BY: PCM
DRAWN BY: SJM
DATE: 3/4/2015
CHECKED BY:
LMN: GC-PIPE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE BASE

C-106

LEGEND

- WETLAND DELINEATED
- WETLAND PHOTO INTERPRETED

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

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2. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.
3. PERMITTED LANDFILL FINAL WASTE GRADES REPRESENT GRADES PRIOR TO CONSTRUCTION OF FINAL COVER SYSTEM.
4. PROPOSED FINAL WASTE GRADES REPRESENT GRADES PRIOR TO CONSTRUCTION OF FINAL COVER SYSTEM.
5. CULVERT SCHEDULE IS SHOWN ON DRAWING C-306. CULVERT SCHEDULE INCLUDES CULVERTS FOR DETENTION BASIN OUTLET STRUCTURES.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. COTE, JR. — No. 5144 — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

FINAL SITE DRAINAGE PLAN

SME Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE
4 Blanchard Road, PO Box 85A, Cumberland Center, Maine 04021
Phone 207.829.5016 • Fax 207.829.5692 • www.smemaine.com

DESIGN BY:	PCM
DRAWN BY:	SJM
DATE:	3/4/2015
CHECKED BY:	
LMN:	FINAL-DRAIN
CTB:	SME-STD

JOB NO. 14101.00 DWG FILE BASE

C-107

LEGEND

WETLAND DELINEATED

WETLAND PHOTO INTERPRETED

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

2. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.
3. PERMITTED LANDFILL FINAL WASTE GRADES REPRESENT GRADES PRIOR TO CONSTRUCTION OF FINAL COVER SYSTEM.
4. PROPOSED FINAL WASTE GRADES REPRESENT GRADES PRIOR TO CONSTRUCTION OF FINAL COVER SYSTEM.
5. CULVERT SCHEDULE IS SHOWN ON DRAWING C-306. CULVERT SCHEDULE INCLUDES CULVERTS FOR DETENTION BASIN OUTLET STRUCTURES.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

FINAL DEVELOPMENT PLAN

SME
Sevee & Maher Engineers, Inc.
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4 Blanchard Road, PO Box 85A, Cumberland Center, Maine 04021
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DESIGN BY: PCM	
DRAWN BY: SJM	
DATE: 3/4/2015	
CHECKED BY:	
LMN: FINAL-DEV	
CTB: SME-STD	

JOB NO. 14101.00 DWG FILE BASE

C-108

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

2. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.
3. PERMITTED LANDFILL FINAL WASTE GRADES REPRESENT GRADES PRIOR TO CONSTRUCTION OF FINAL COVER SYSTEM.
4. PROPOSED FINAL WASTE GRADES REPRESENT GRADES PRIOR TO CONSTRUCTION OF FINAL COVER SYSTEM.
5. CULVERT SCHEDULE IS SHOWN ON DRAWING C-306. CULVERT SCHEDULE INCLUDES CULVERTS FOR DETENTION BASIN OUTLET STRUCTURES.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY R. COTE, JR. No. 514 — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SECTIONS LOCATION PLAN

SME
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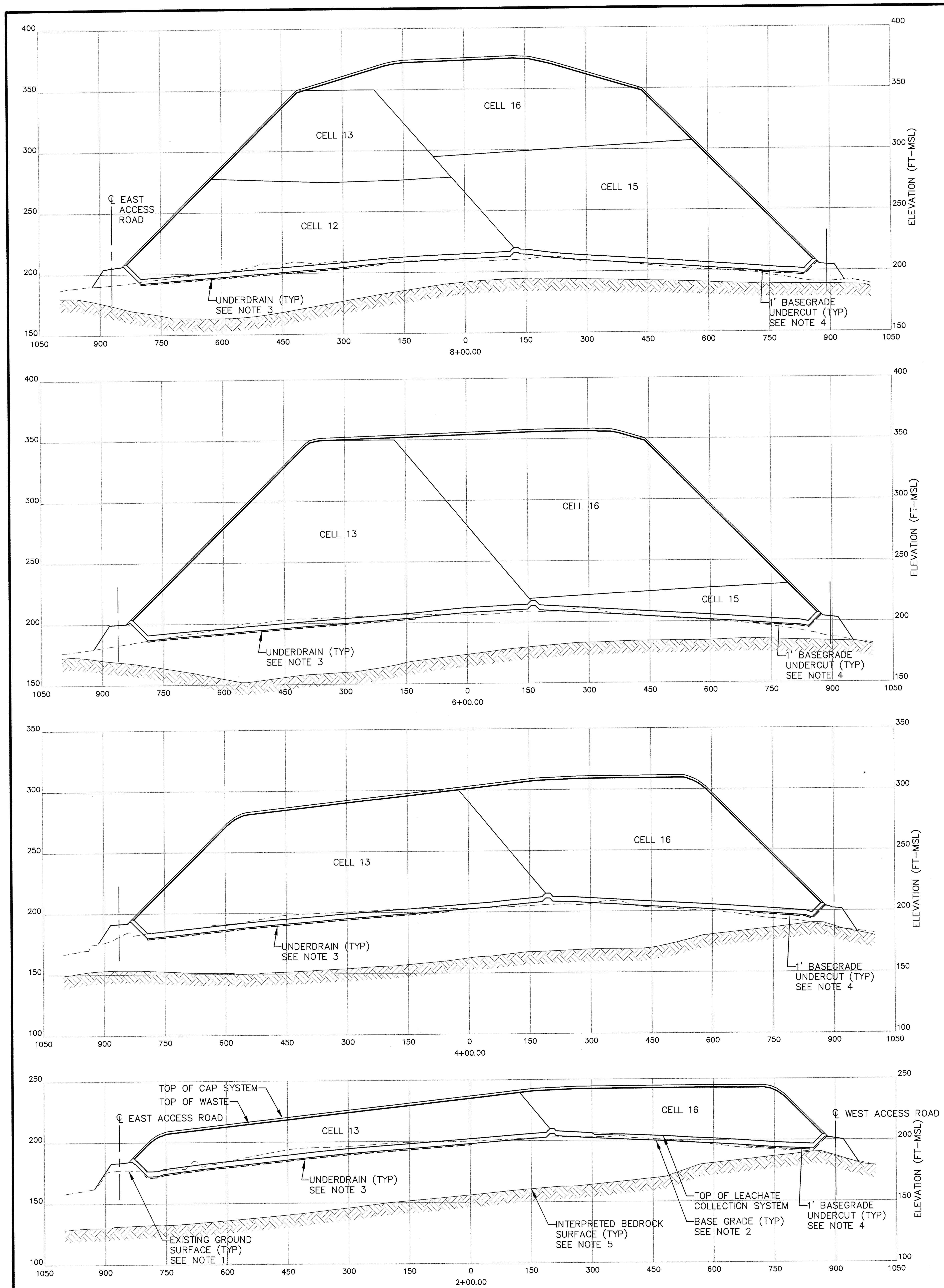
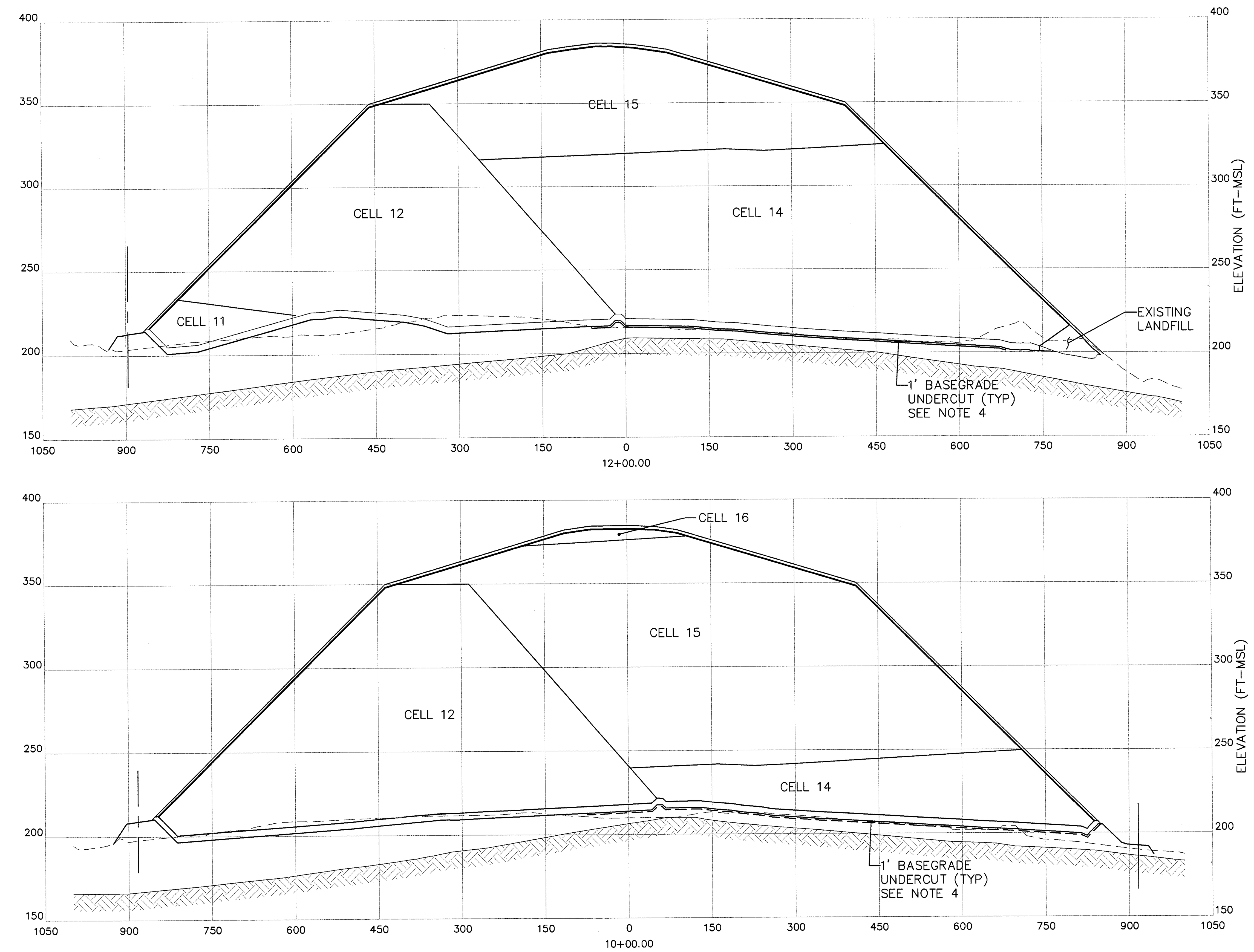
DESIGN BY: PCM
DRAWN BY: SJM
DATE: 3/4/2015
CHECKED BY:
LMN: XSEC-LOCATION
CTB: SME-STD

JOB NO. 14101.00 DWG FILE BASE

C-109





NOTES:

1. EXISTING GROUND SURFACE INTERPRETED FROM TOPOGRAPHIC BASE MAP PREPARED BY AERIAL SURVEY AND PHOTO, NORRIDGEWOCK, MAINE. PHOTO DATED 12/31/2014.
2. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.
3. AREA IDENTIFIED TO RECEIVE UNDERDRAIN SHALL BE UNDERCUT TO 1-FOOT BELOW BASE GRADE. THE UNDERDRAIN SHALL BE CONSTRUCTED ON THE RESULTING GRADE.
4. AREA IDENTIFIED SHALL BE UNDERCUT 1-FOOT BELOW BASEGRADE. THE SECONDARY LINER SHALL BE AUGMENTED IN THIS AREA AS DETAILED ON DRAWING C-300.
5. BEDROCK SURFACE INTERPRETATION FROM SECTION 4.2 VOLUME II SITE ASSESSMENT REPORT FOR JUNIPER RIDGE LANDFILL EXPANSION APPLICATION, DATED JULY, 2014.

75 0 150 300 FEET (HORZ)
25 0 50 100 FEET (VERT)

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. COTE, JR. No. 5144 — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

TRANSVERSE CROSS SECTIONS
STA 2+00 TO STA 12+00

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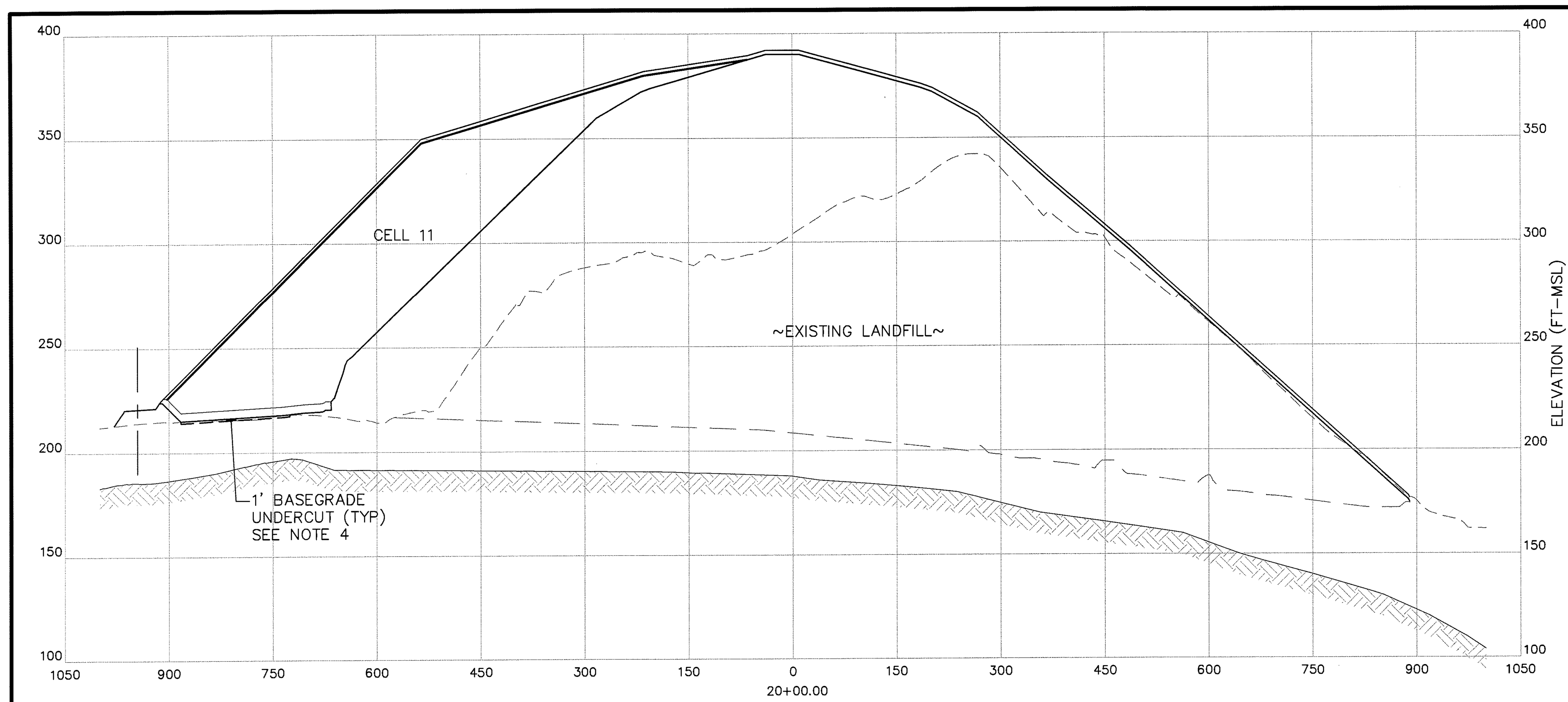
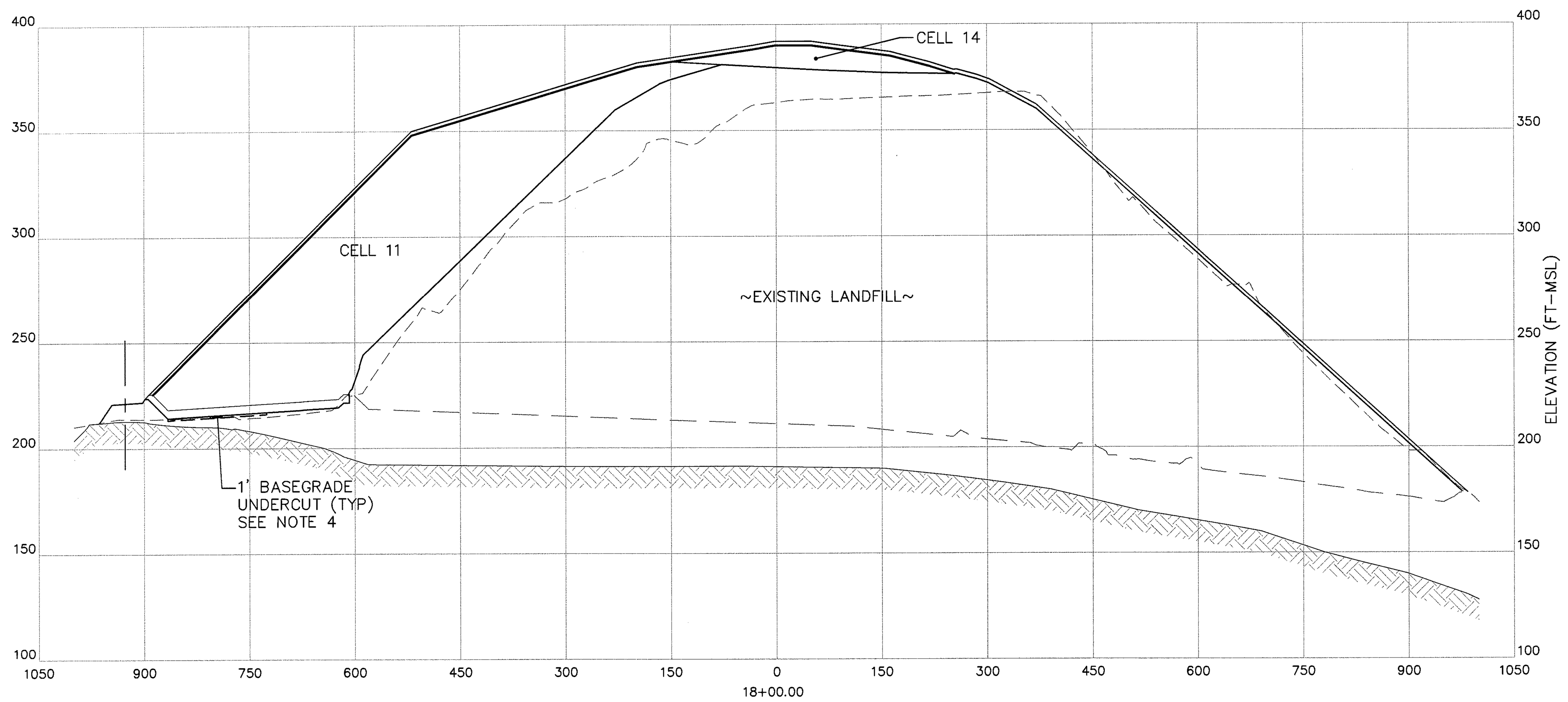
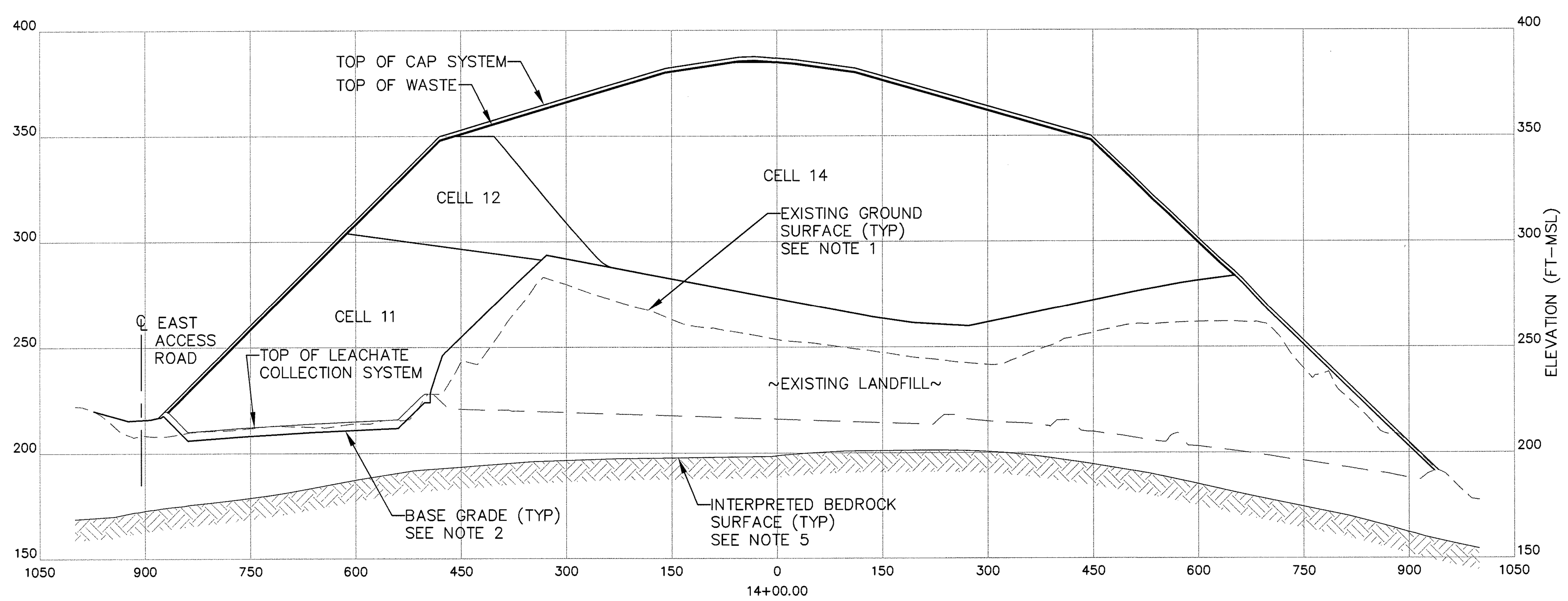
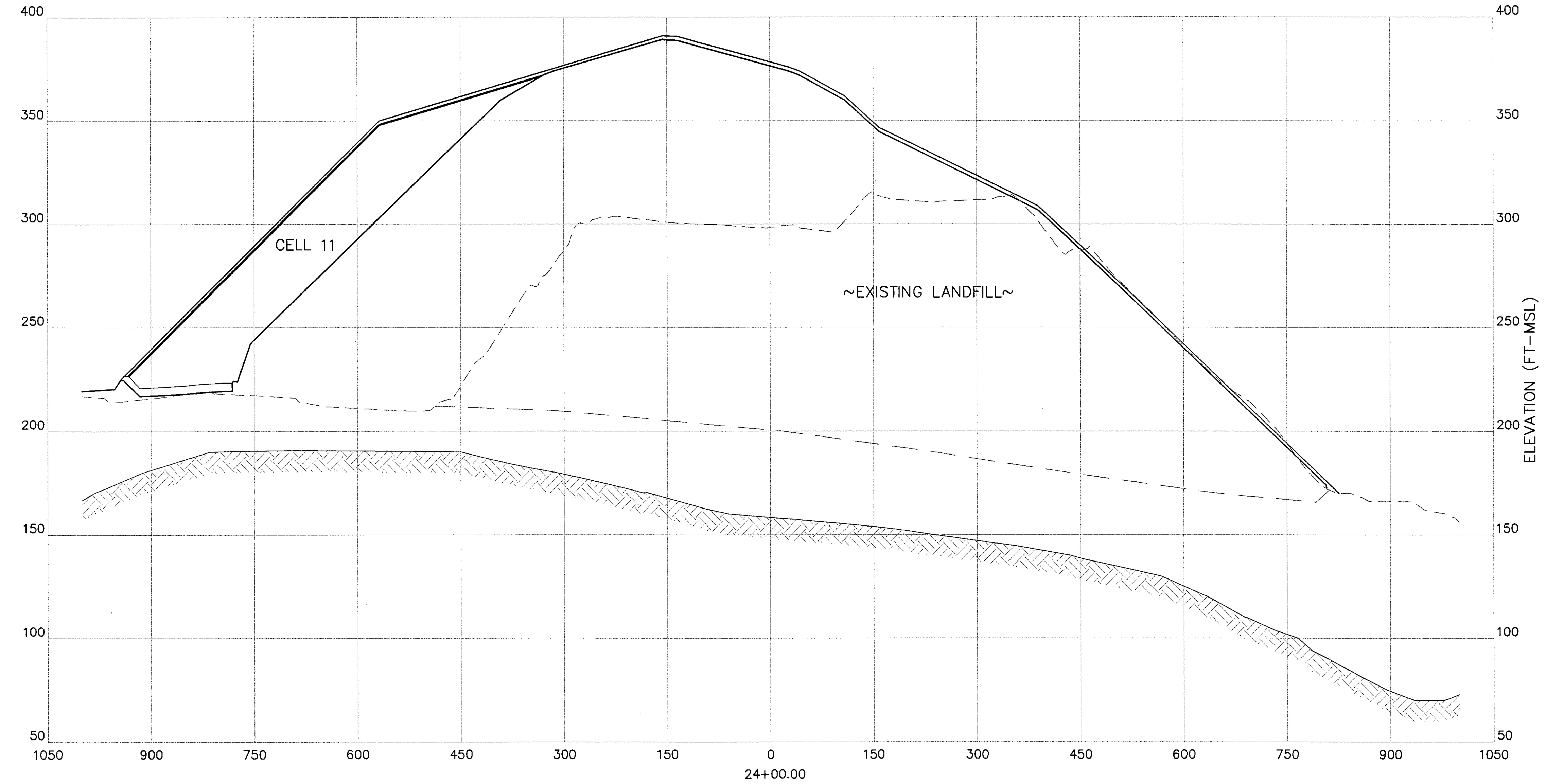
DESIGN BY: PCM
DRAWN BY: SJM
DATE: 5/2015
CHECKED BY:
LMN:
CTB: SME-STD

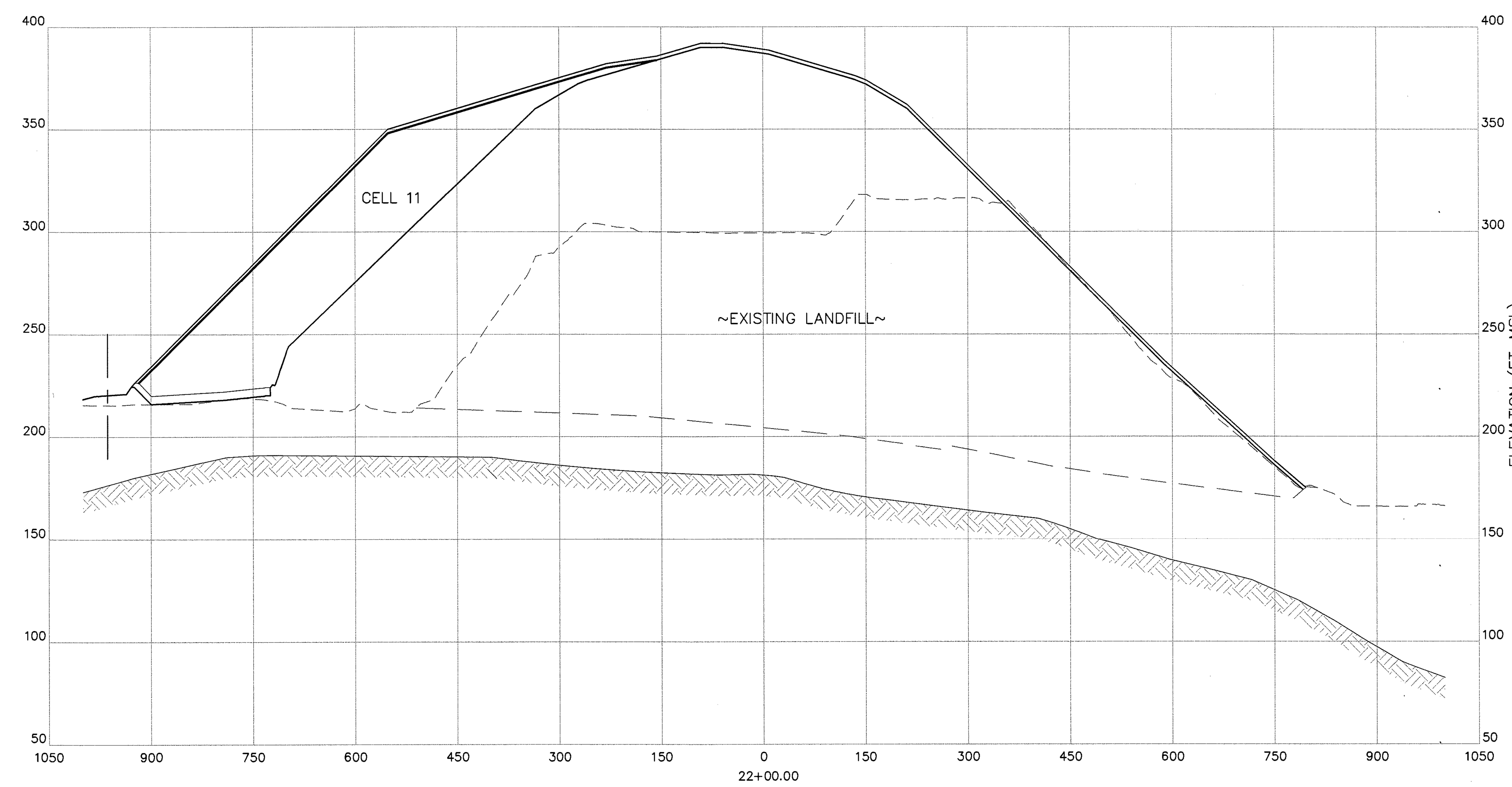
JOB NO. 14101 DWG FILE SECTIONS
C-200











NOTES:

1. EXISTING GROUND SURFACE INTERPRETED FROM TOPOGRAPHIC BASE MAP PREPARED BY AERIAL SURVEY AND PHOTO, NORRIDGEWOCK, MAINE. PHOTO DATED 12/31/2014.
2. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.
3. AREA IDENTIFIED TO RECEIVE UNDERDRAIN SHALL BE UNDERCUT TO 1-FOOT BELOW BASE GRADE. THE UNDERDRAIN SHALL BE CONSTRUCTED ON THE RESULTING GRADE.
4. AREA IDENTIFIED SHALL BE UNDERCUT 1-FOOT BELOW BASEGRADE. THE SECONDARY LINER SHALL BE AUGMENTED IN THIS AREA AS DETAILED ON DRAWING C-300.
5. BEDROCK SURFACE INTERPRETATION FROM SECTION 4.2 VOLUME II SITE ASSESSMENT REPORT FOR JUNIPER RIDGE LANDFILL EXPANSION APPLICATION, DATED JULY, 2014.

75 0 150 300 FEET (HORZ)
25 0 50 100 FEET (VERT)

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. COTE JR. — No. 5144 — LICENSED — PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

TRANSVERSE CROSS SECTIONS
STA 14+00 TO STA 24+00

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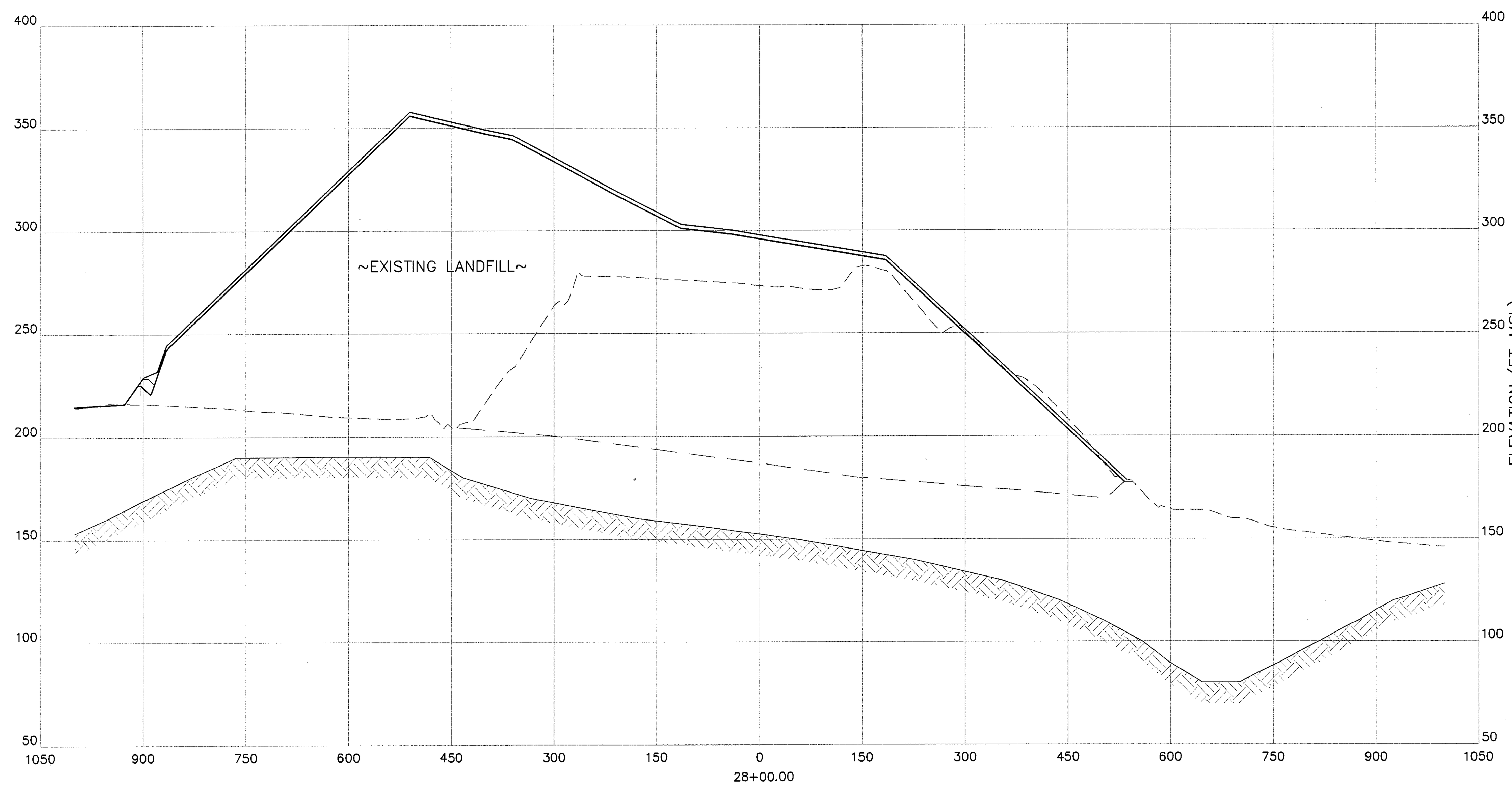
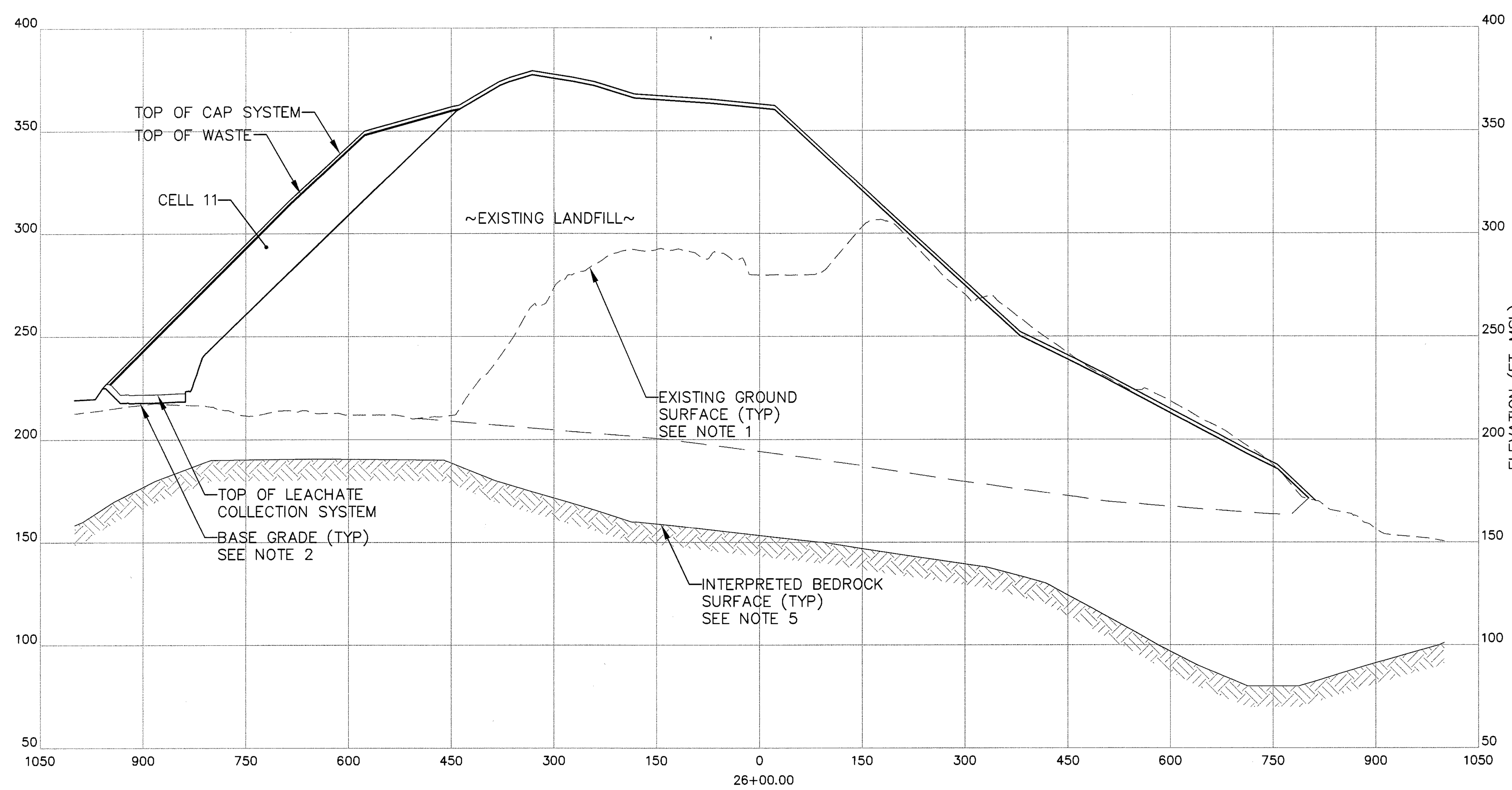
DESIGN BY:	PCM
DRAWN BY:	SJM
DATE:	5/2015
CHECKED BY:	
LMN:	
CTB:	SME-STD

JOB NO. 14101 DWG FILE SECTIONS

C-201





NOTES:

1. EXISTING GROUND SURFACE INTERPRETED FROM TOPOGRAPHIC BASE MAP PREPARED BY AERIAL SURVEY AND PHOTO, NORRIDGEWOCK, MAINE. PHOTO DATED 12/31/2014.
2. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.
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4. AREA IDENTIFIED SHALL BE UNDERCUT 1-FOOT BELOW BASEGRADE. THE SECONDARY LINER SHALL BE AUGMENTED IN THIS AREA AS DETAILED ON DRAWING C-300.
5. BEDROCK SURFACE INTERPRETATION FROM SECTION 4.2 VOLUME II SITE ASSESSMENT REPORT FOR JUNIPER RIDGE LANDFILL EXPANSION APPLICATION, DATED JULY, 2014.

75 0 150 300 FEET (HORZ)
25 0 50 100 FEET (VERT)

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

TRANSVERSE CROSS SECTIONS STA. 26+00 TO STA. 28+00

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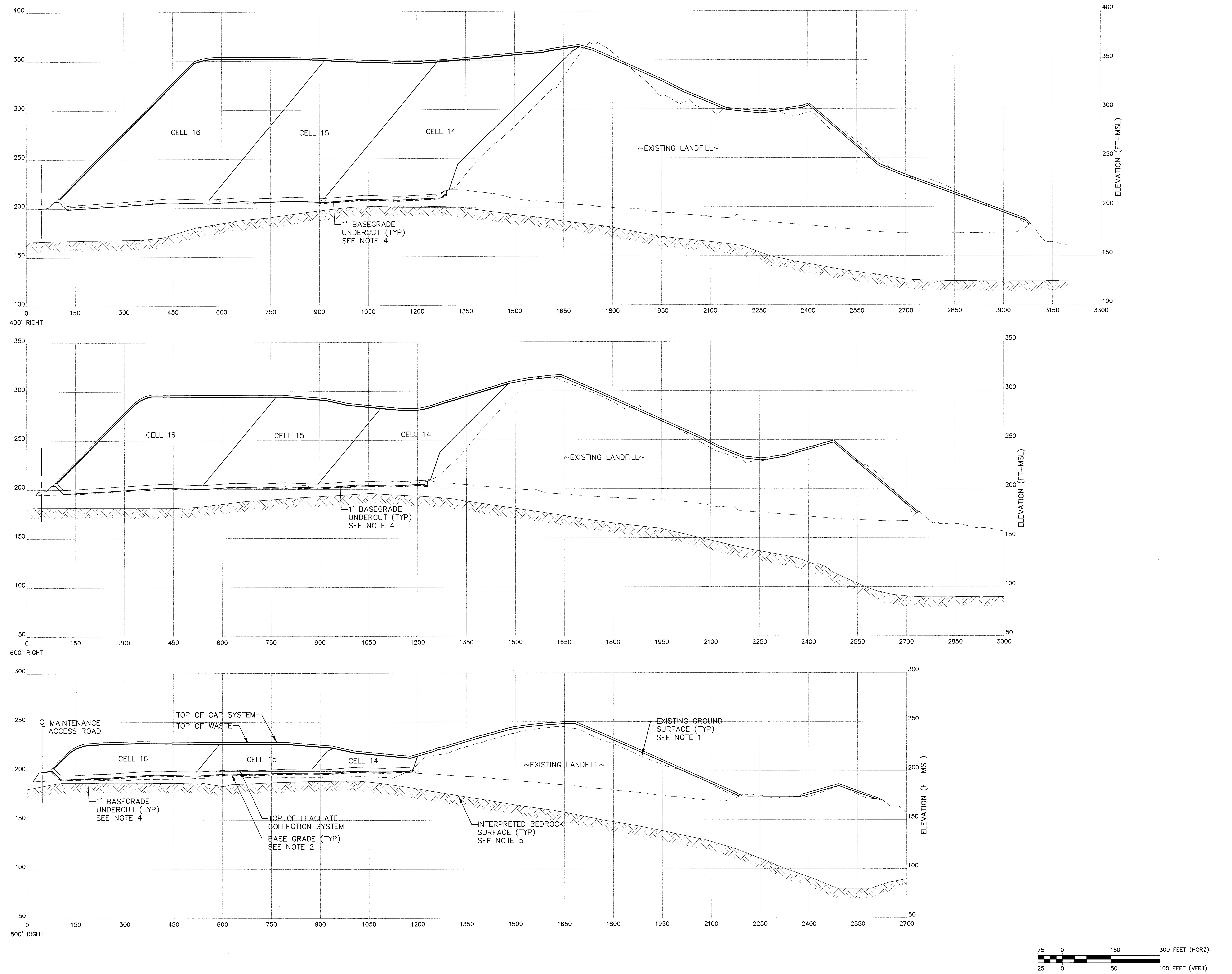
DESIGN BY:	PCM
DRAWN BY:	SJM
DATE:	5/2015
CHECKED BY:	
LMN:	
CTB:	SME-STD

JOB NO. 14101 DWG FILE SECTIONS C-202



NOTES:

1. EXISTING GROUND SURFACE INTERPRETED FROM TOPOGRAPHIC BASE MAP PREPARED BY AERIAL SURVEY AND PHOTO, NORRIDGEWOCK, MAINE. PHOTO DATED 12/31/2014.
2. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.
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4. AREA IDENTIFIED SHALL BE UNDERCUT 1-FOOT BELOW BASEGRADE. THE SECONDARY LINER SHALL BE AUGMENTED IN THIS AREA AS DETAILED ON DRAWING C-300.
5. BEDROCK SURFACE INTERPRETATION FROM SECTION 4.2 VOLUME II SITE ASSESSMENT REPORT FOR JUNIPER RIDGE LANDFILL EXPANSION APPLICATION, DATED JULY, 2014.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE GUY H. COTE, JR. No. 514 LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

LONGITUDINAL CROSS SECTIONS 800' RIGHT TO 400' RIGHT

SME
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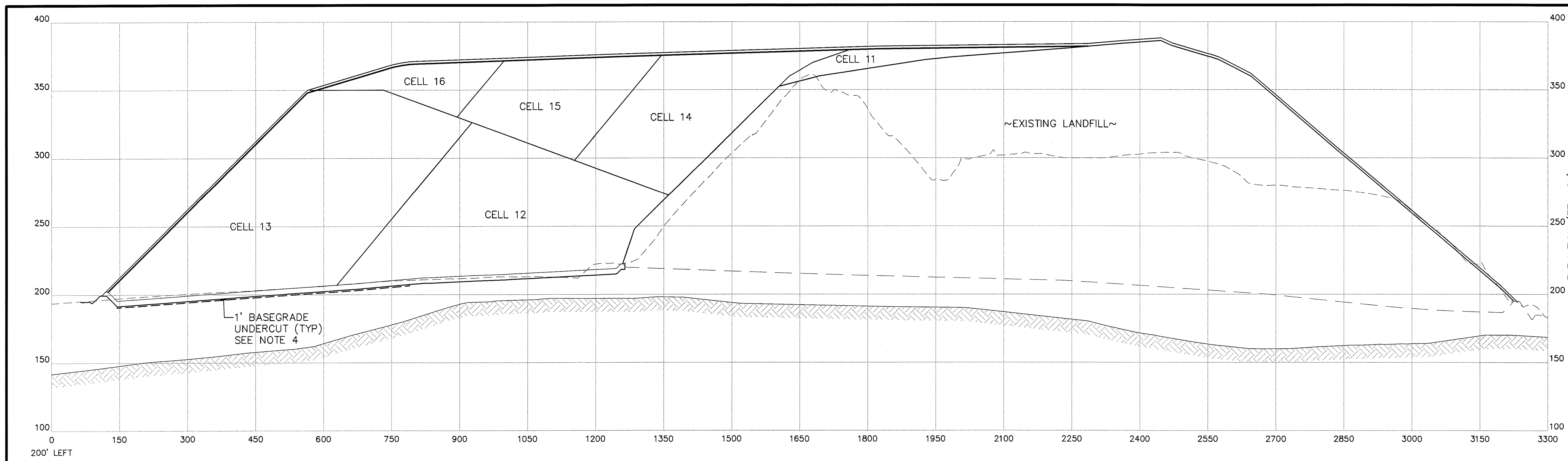
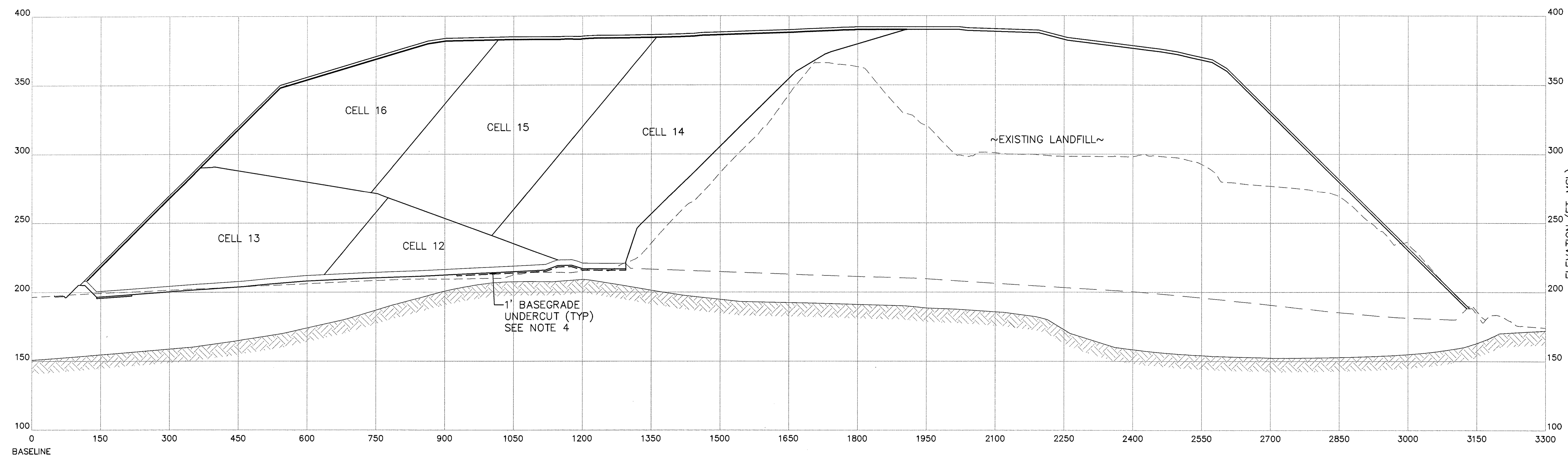
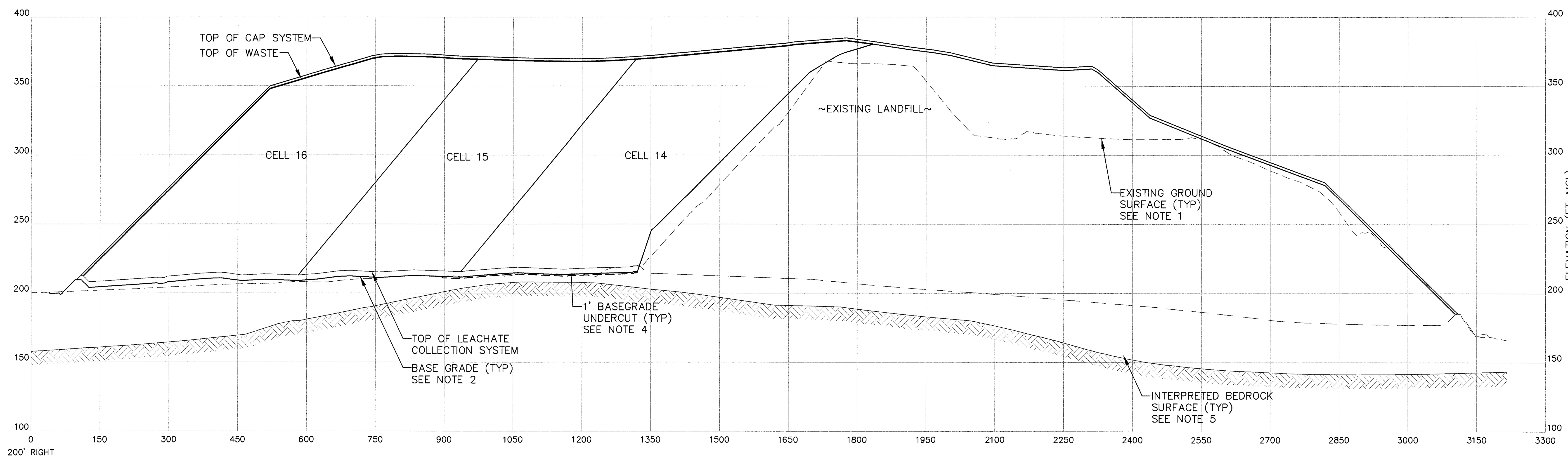
DESIGN BY:	PCM
DRAWN BY:	SJM
DATE:	5/2015
CHECKED BY:	
LMN:	
CTB:	SME-STD

JOB NO. 14101 DWG FILE SECTIONS C-203







NOTES:

1. EXISTING GROUND SURFACE INTERPRETED FROM TOPOGRAPHIC BASE MAP PREPARED BY AERIAL SURVEY AND PHOTO, NORRIDGEWOCK, MAINE. PHOTO DATED 12/31/2014.
2. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.
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4. AREA IDENTIFIED SHALL BE UNDERCUT 1-FOOT BELOW BASEGRADE. THE SECONDARY LINER SHALL BE AUGMENTED IN THIS AREA AS DETAILED ON DRAWING C-300.
5. BEDROCK SURFACE INTERPRETATION FROM SECTION 4.2 VOLUME II SITE ASSESSMENT REPORT FOR JUNIPER RIDGE LANDFILL EXPANSION APPLICATION, DATED JULY, 2014.

75 0 150 300 FEET (HORZ)
25 0 50 100 FEET (VERT)

REV.	BY	DATE	STATUS
		7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. COTE, JR. No. 5144 — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

LONGITUDINAL CROSS SECTIONS 400' RIGHT TO BASELINE

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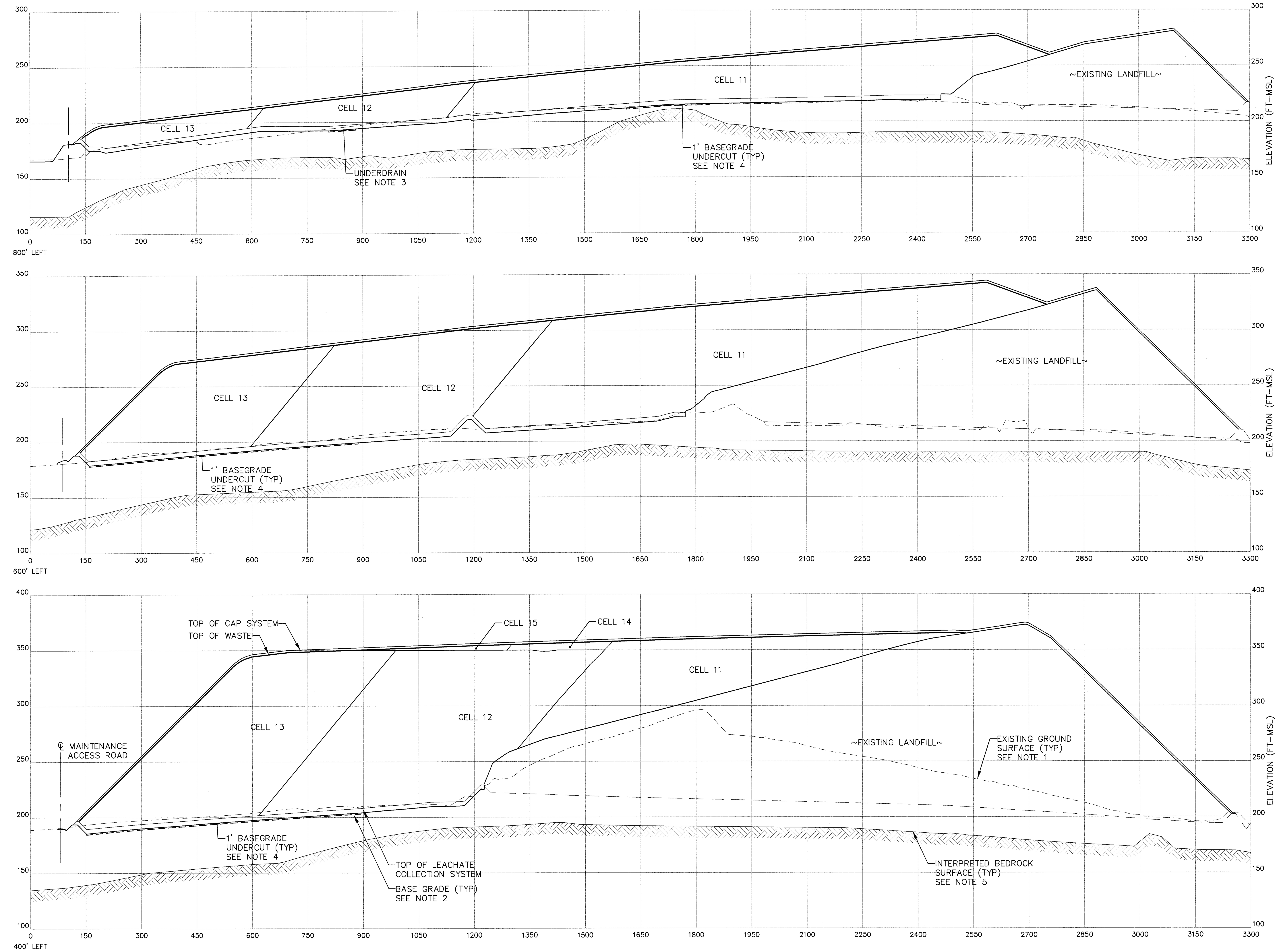
DESIGN BY: PCM
DRAWN BY: SJM
DATE: 5/2015
CHECKED BY:
LMN:
CTB: SME-STD

JOB NO. 14101 DWG FILE SECTIONS C-204



75 0 150 300 FEET (HORZ)
25 0 50 100 FEET (VERT)

NOTES:

1. EXISTING GROUND SURFACE INTERPRETED FROM TOPOGRAPHIC BASE MAP PREPARED BY AERIAL SURVEY AND PHOTO, NORRIDGEWOCK, MAINE. PHOTO DATED 12/31/2014.

2. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.

3. AREA IDENTIFIED TO RECEIVE UNDERDRAIN SHALL BE UNDERCUT TO 1-FOOT BELOW BASE GRADE. THE UNDERDRAIN SHALL BE CONSTRUCTED ON THE RESULTING GRADE.

4. AREA IDENTIFIED SHALL BE UNDERCUT 1-FOOT BELOW BASEGRADE. THE SECONDARY LINER SHALL BE AUGMENTED IN THIS AREA AS DETAILED ON DRAWING C-300.

5. BEDROCK SURFACE INTERPRETATION FROM SECTION 4.2 VOLUME II SITE ASSESSMENT REPORT FOR JUNIPER RIDGE LANDFILL EXPANSION APPLICATION, DATED JULY, 2014.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — LICENSED PROFESSIONAL ENGINEER — No. 5144

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

LONGITUDINAL CROSS SECTIONS 200' LEFT TO 600' LEFT

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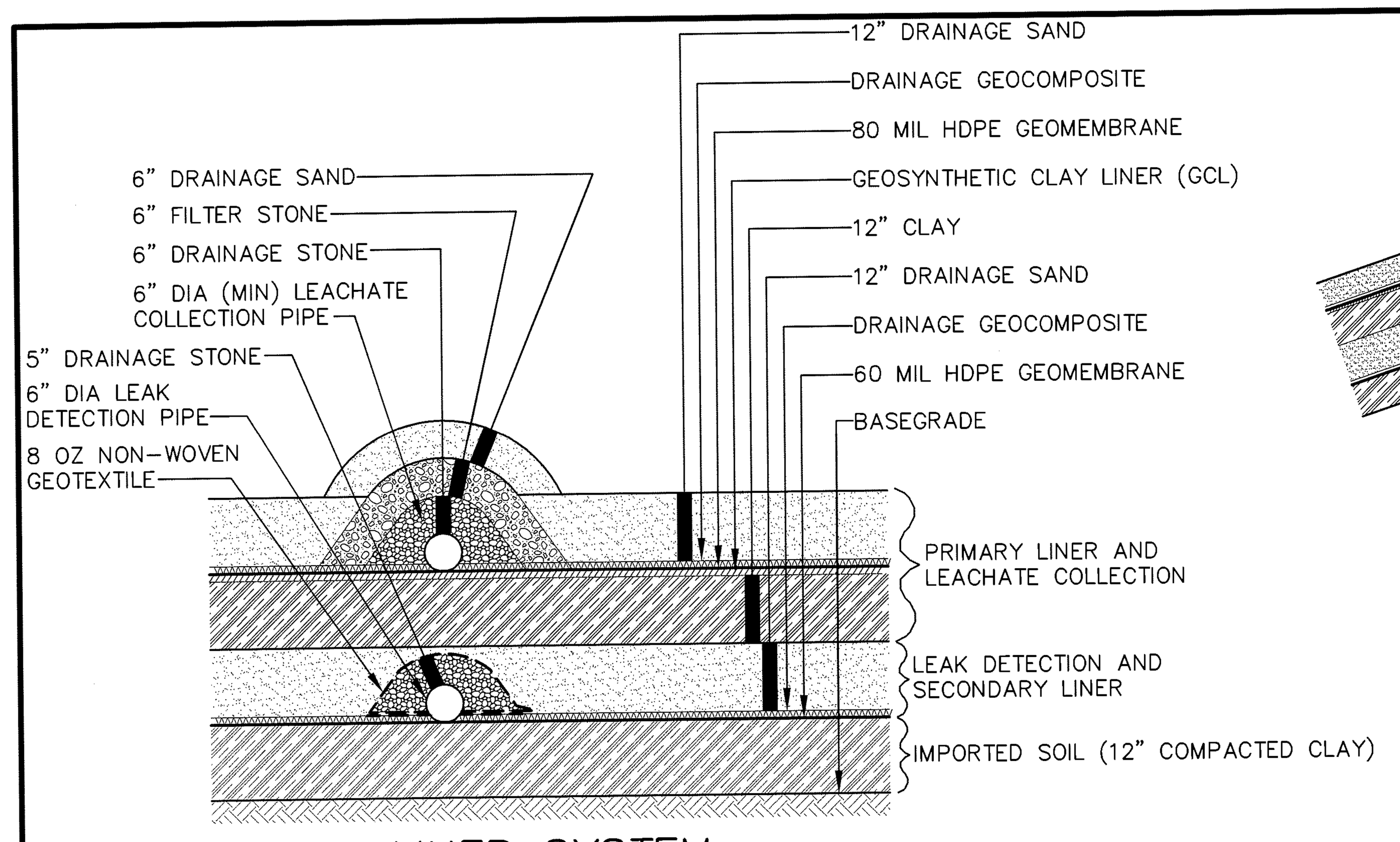
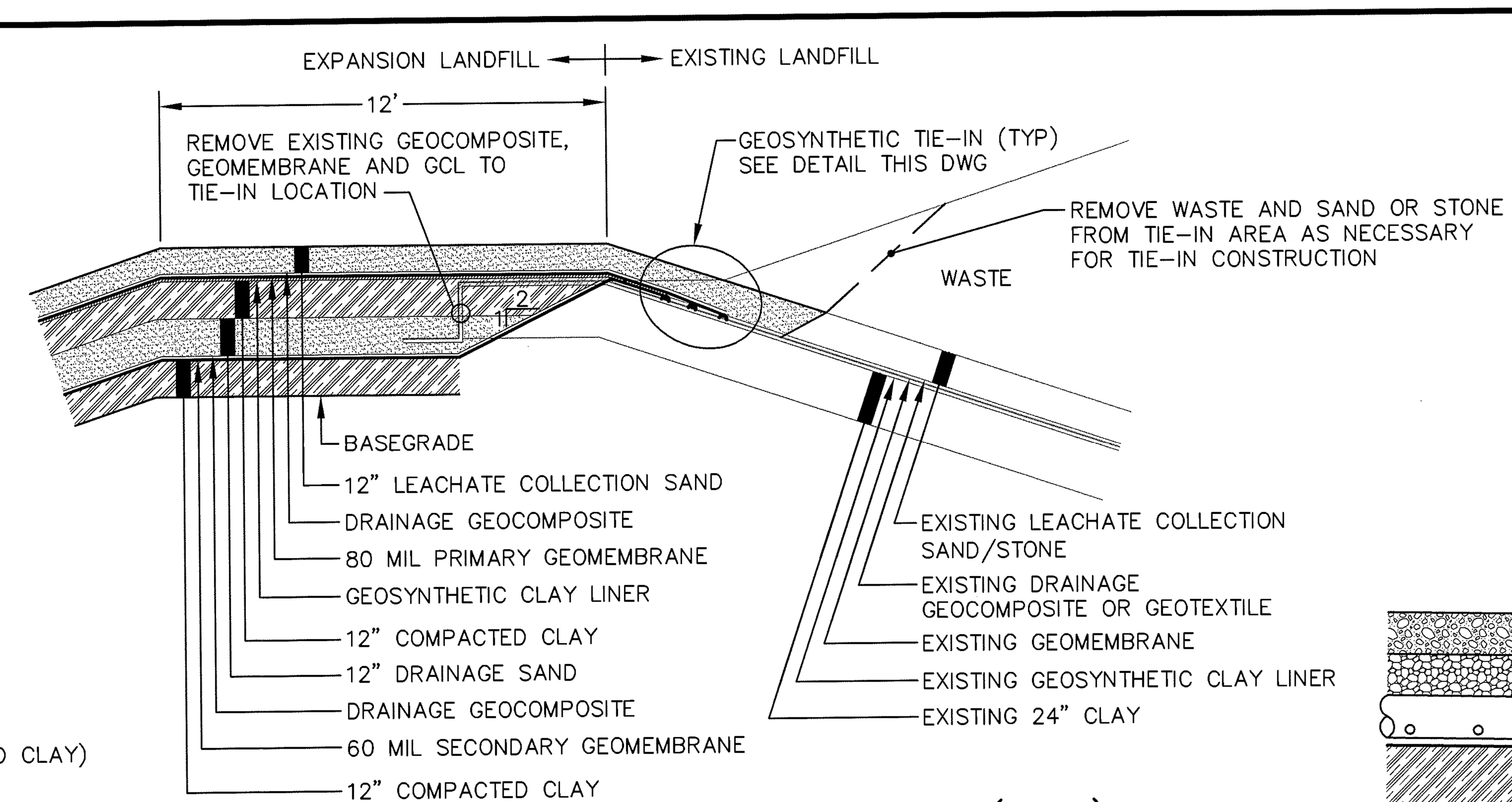
DESIGN BY:	PCM
DRAWN BY:	SJM
DATE:	5/2015
CHECKED BY:	
LMN:	
CTB:	SME-STD

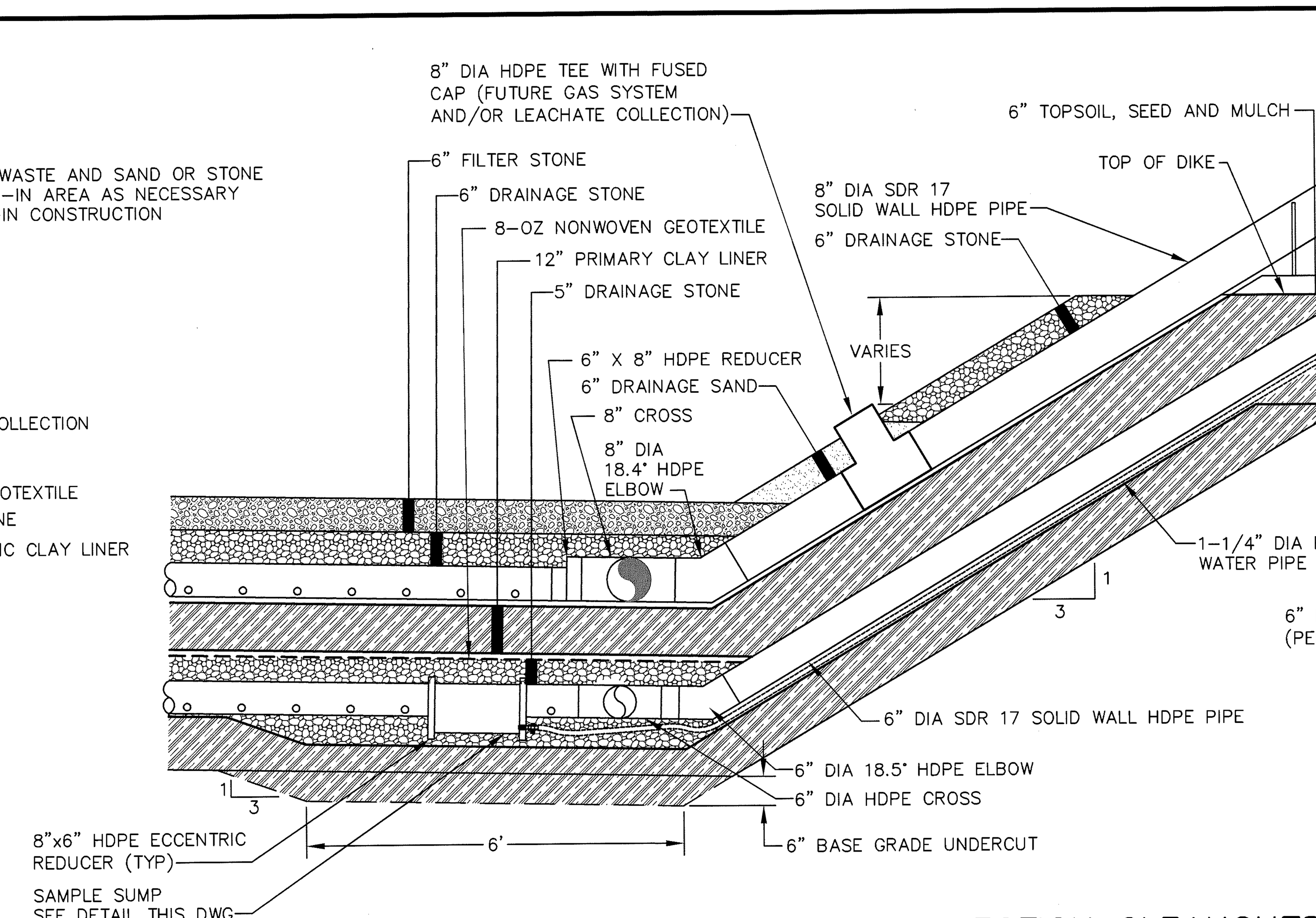
JOB NO. 14101 DWG FILE SECTIONS C-205



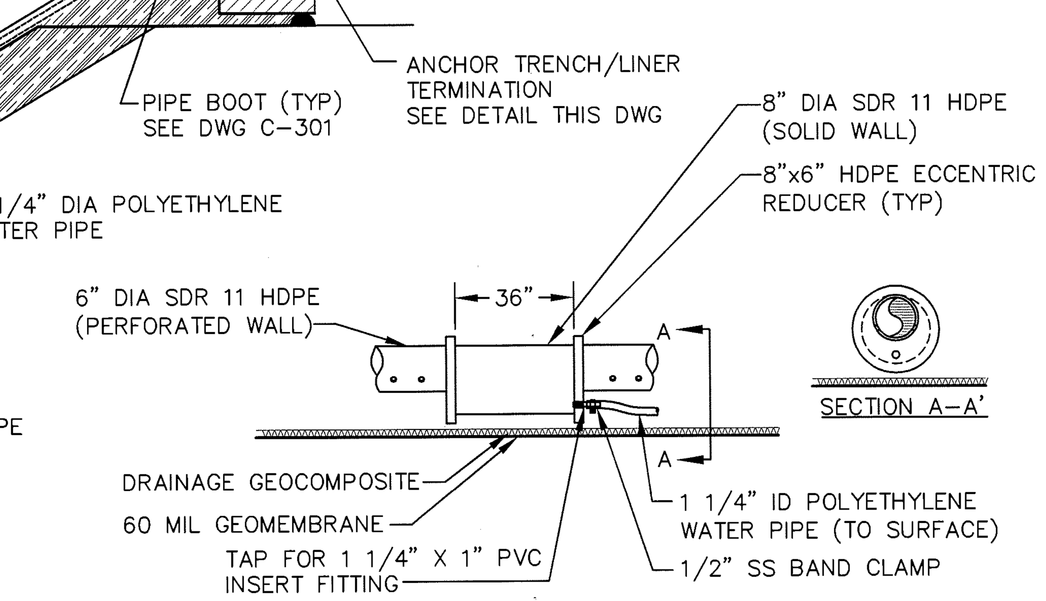
LINER SYSTEM
NTS



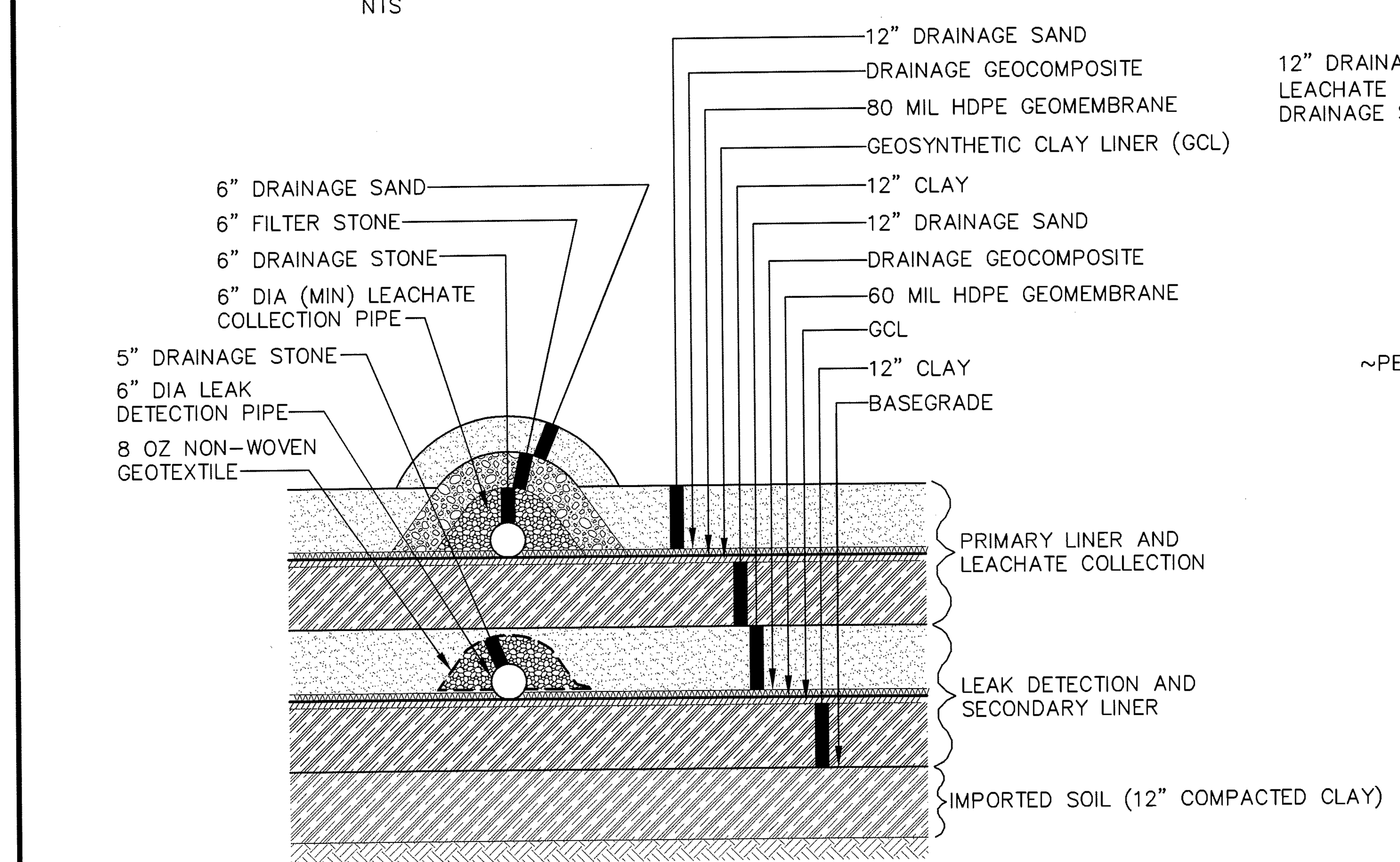
LANDFILL LINER SYSTEM TIE-IN (TYP)
NTS



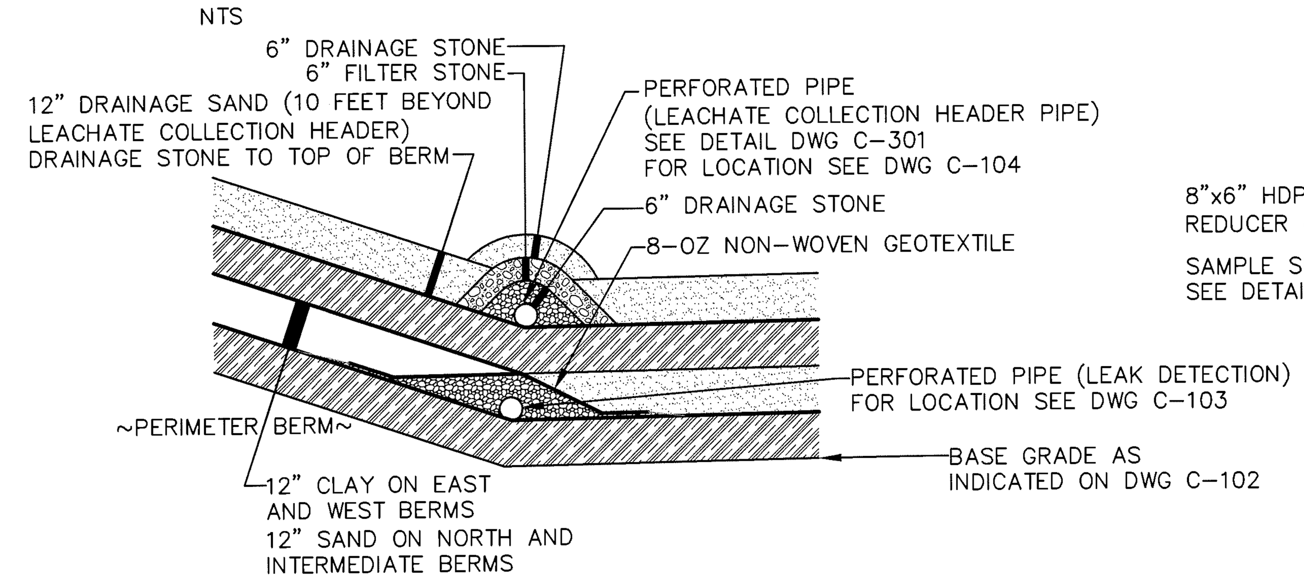
LEACHATE COLLECTION & LEAK DETECTION CLEANOUTS
NTS



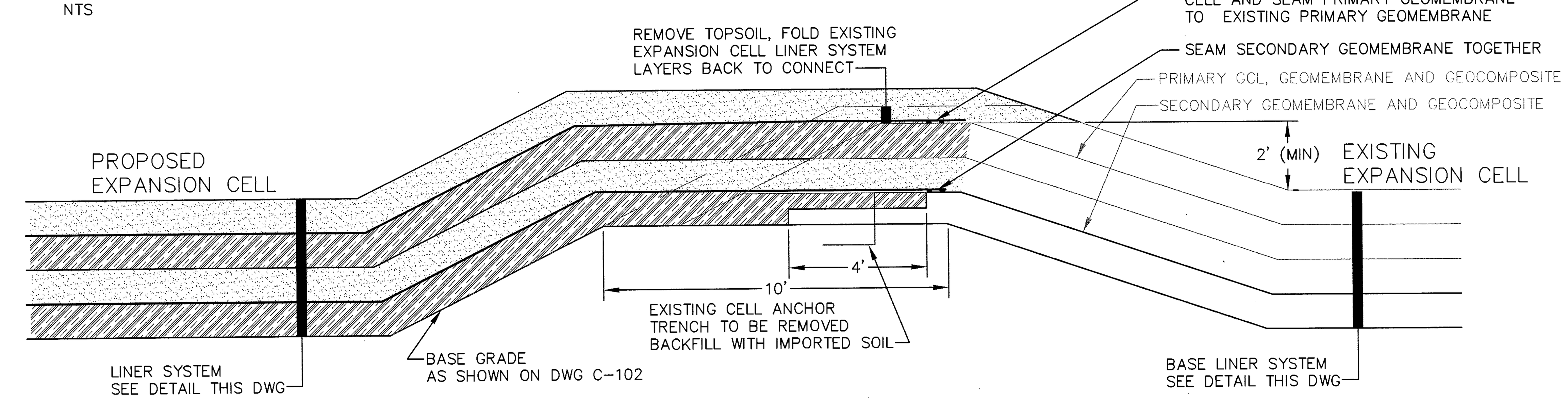
SAMPLE SUMP
NTS



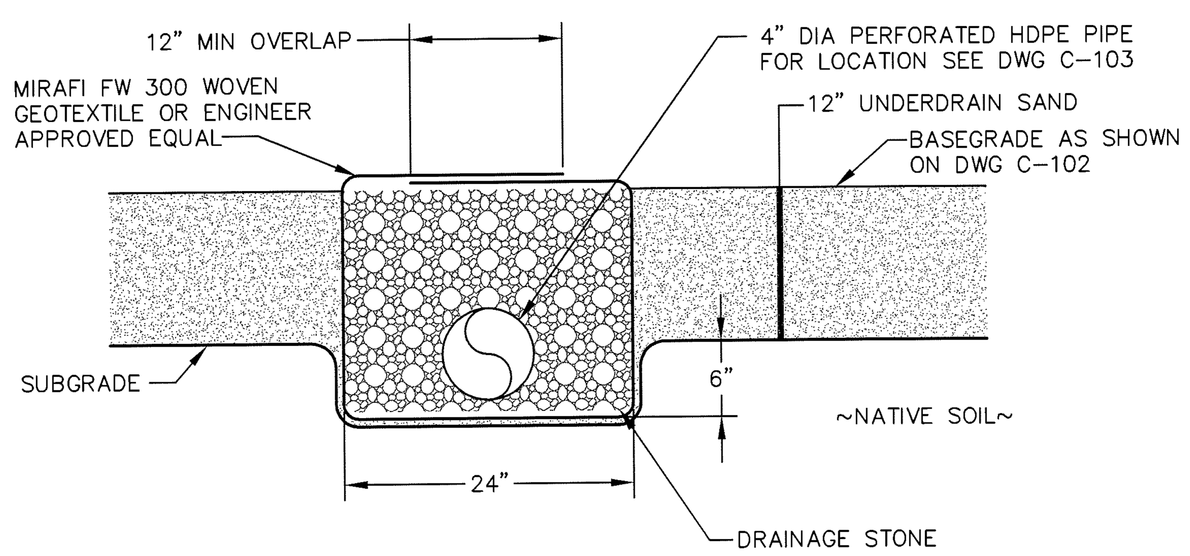
LINER SYSTEM WITH AUGMENTED SECONDARY LINER
NTS



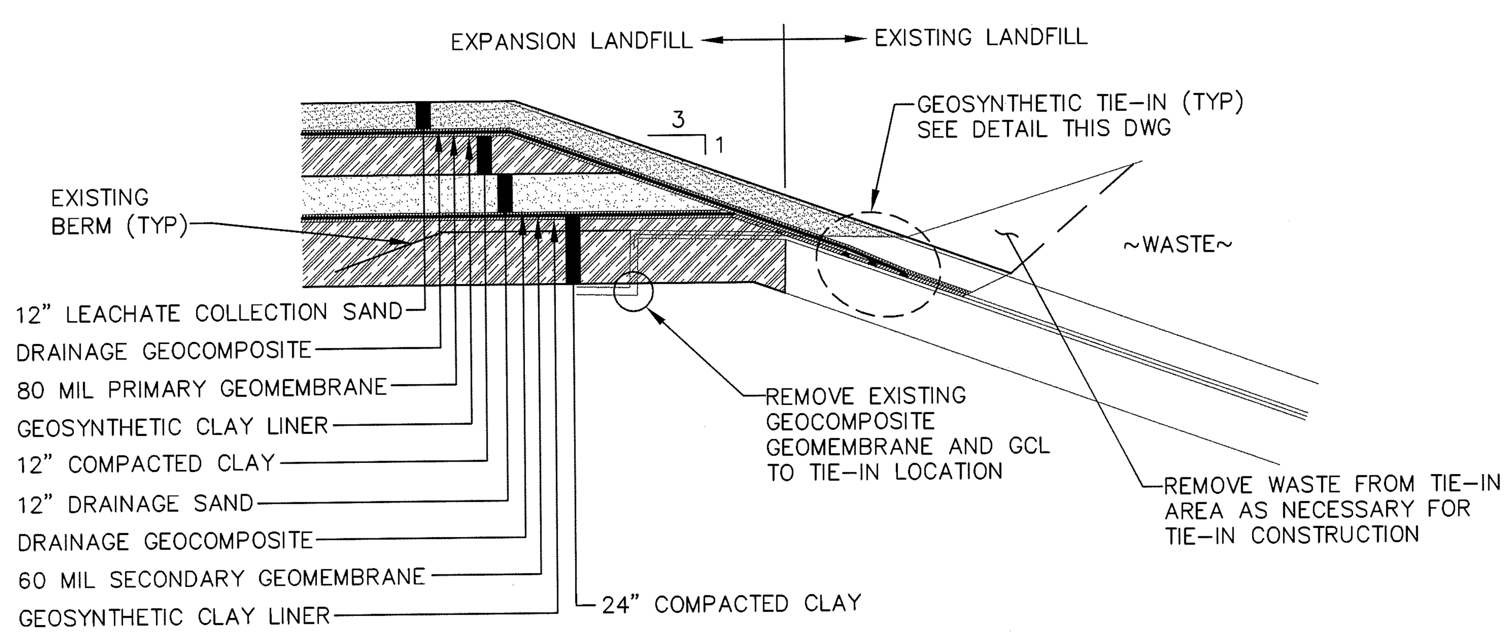
PIPING AT PERIMETER BERM
NTS



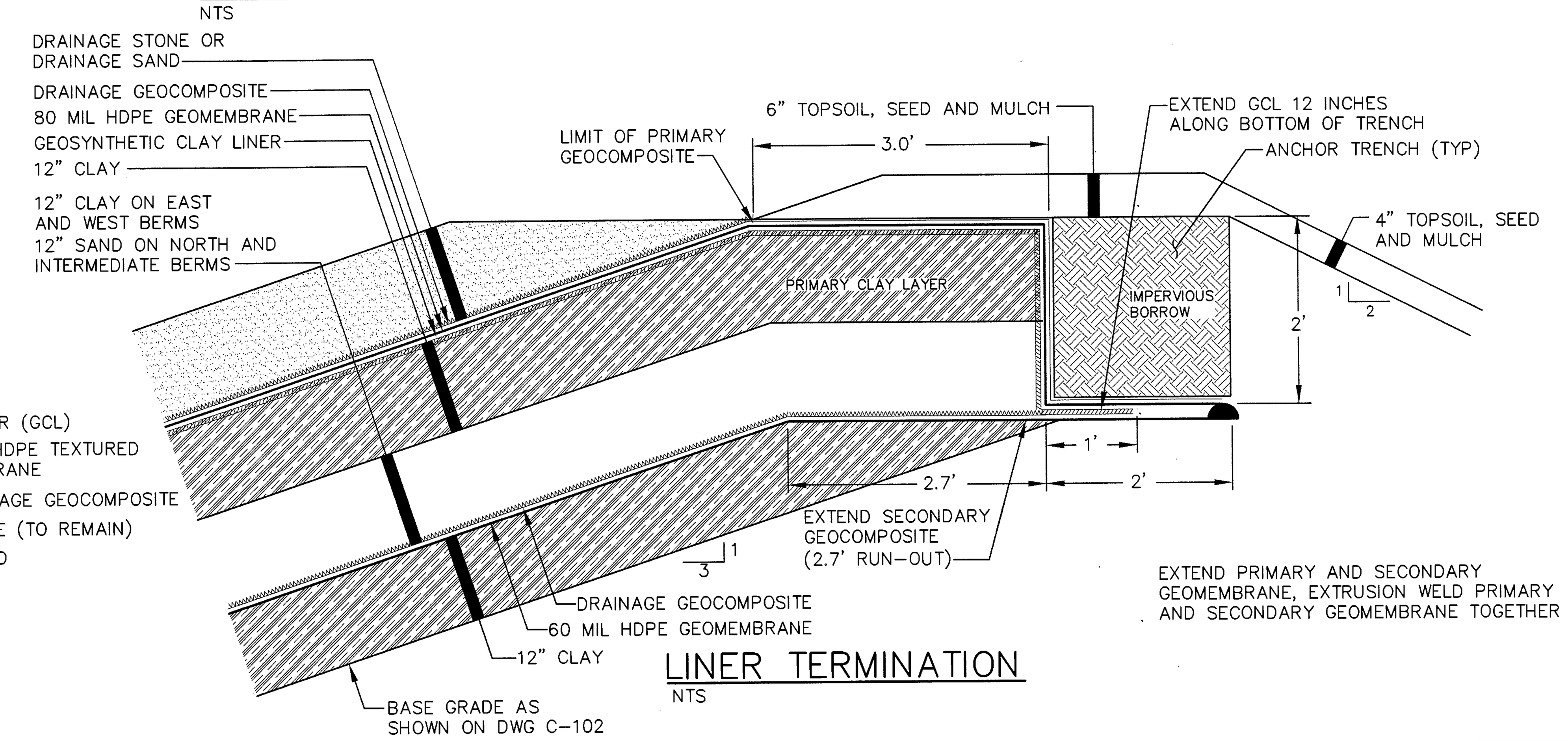
INTERMEDIATE BERM BASE LINER CONNECTION
NTS



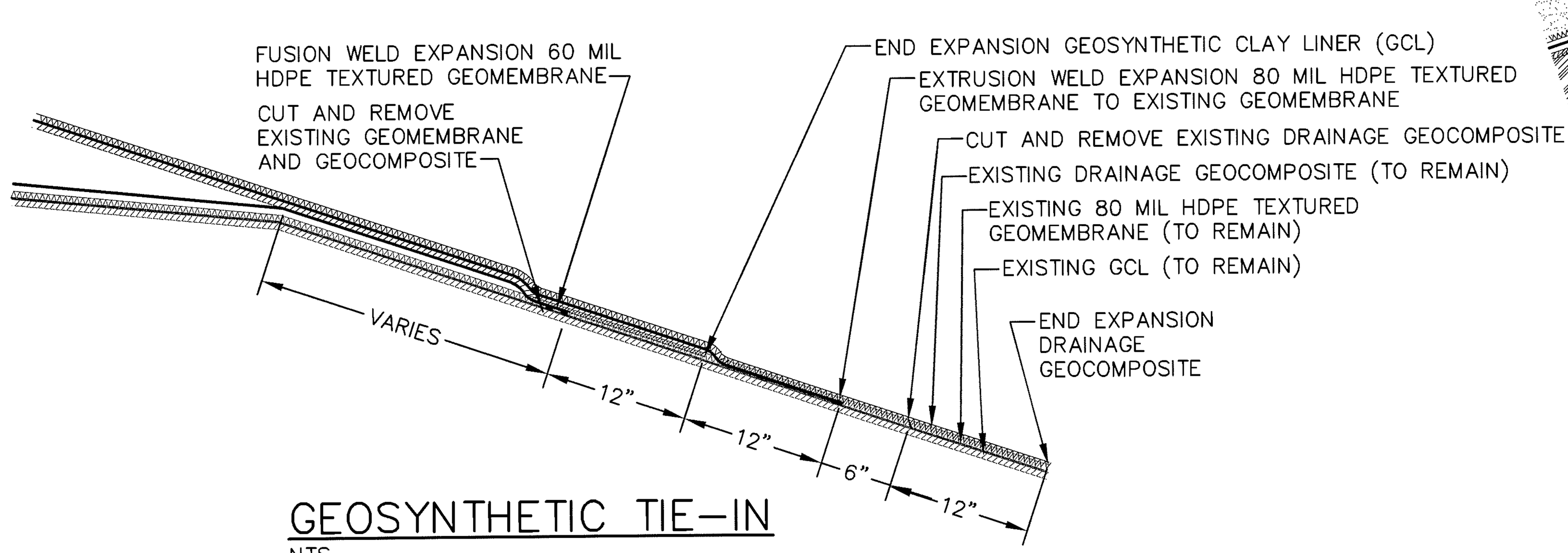
UNDERDRAIN PIPE
NTS



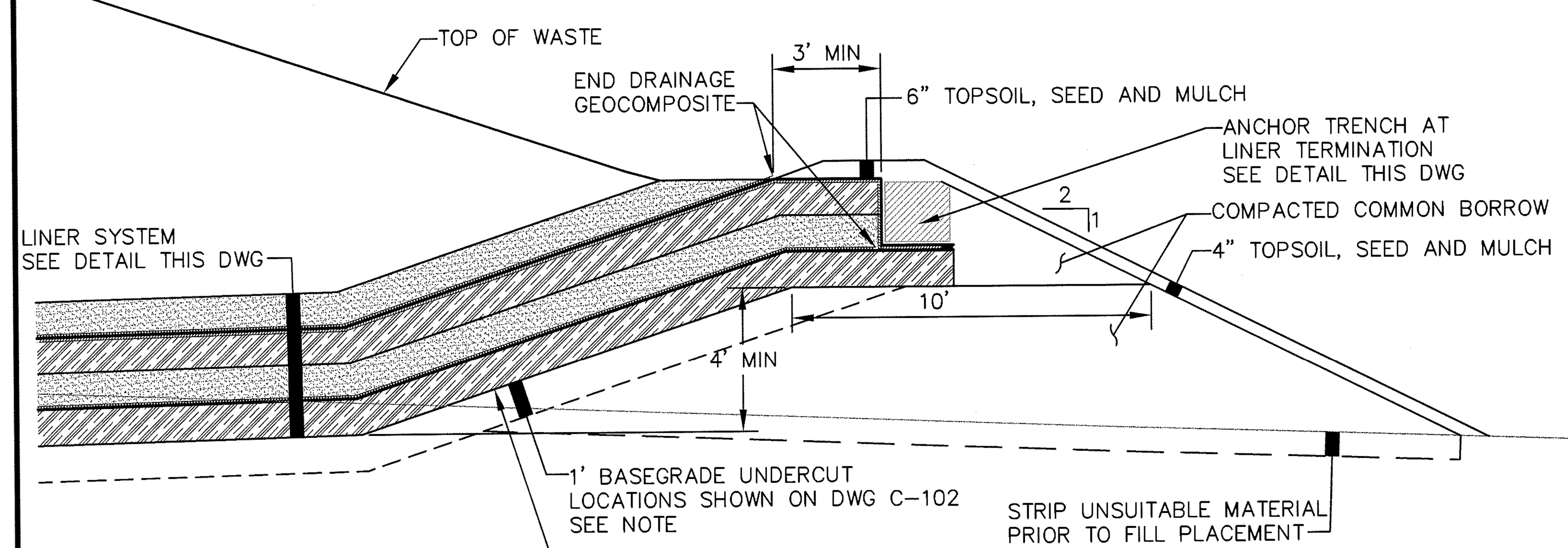
LANDFILL LINER SYSTEM TIE-IN SOUTH END OF CELL 14
NTS



LINER TERMINATION
NTS



GEOSYNTHETIC TIE-IN
NTS



NOTE: AT LOCATION WHERE BASE GRADE UNDERCUT IS REQUIRED THE LINER SYSTEM WITH AUGMENTED SECONDARY LINER SHALL BE CONSTRUCTED.

INTERMEDIATE CELL BERM
NTS

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. WHITE, JR. — No. 5144 — LICENSED — PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

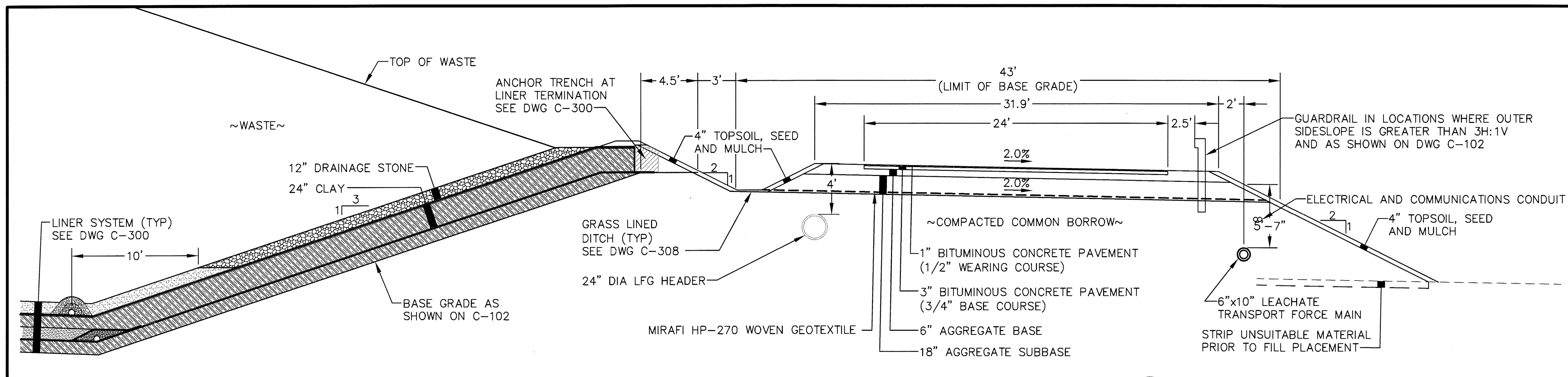
SECTIONS AND DETAILS

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE
4 Blanchard Road, PO Box 85A, Cumberland Center, Maine 04021
Phone 207.829.5016 • Fax 207.829.5692 • www.smemaine.com

DESIGN BY: PCM
DRAWN BY: SJM
DATE: 12/5/2014
CHECKED BY:
LMN: NONE
CTB: SME-STD

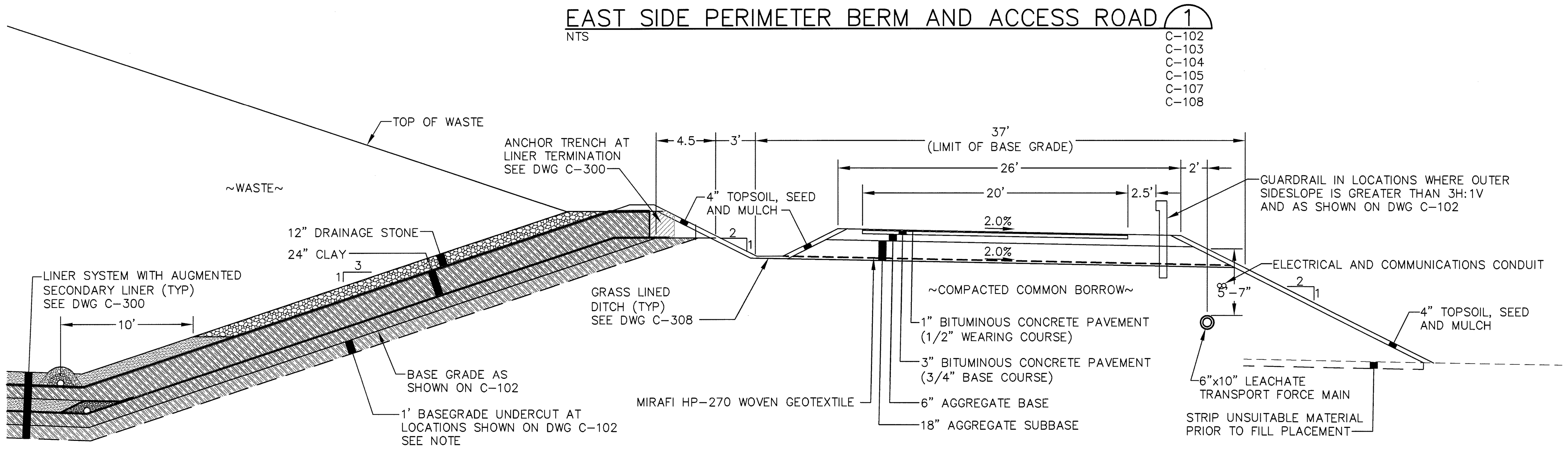
JOB NO. 14101.00 DWG FILE DETAILS

C-300



EAST SIDE PERIMETER BERM AND ACCESS ROAD (1)
NTS

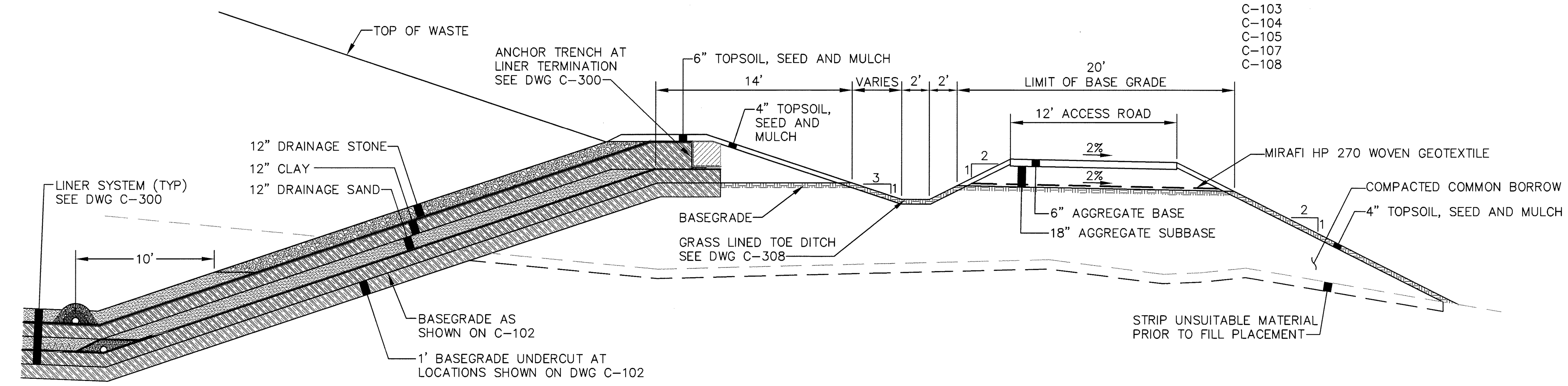
C-102
C-103
C-104
C-105
C-107
C-108



NOTE: AT LOCATION WHERE BASE GRADE UNDERCUT IS REQUIRED THE LINER SYSTEM WITH AUGMENTED SECONDARY LINER SHALL BE CONSTRUCTED.

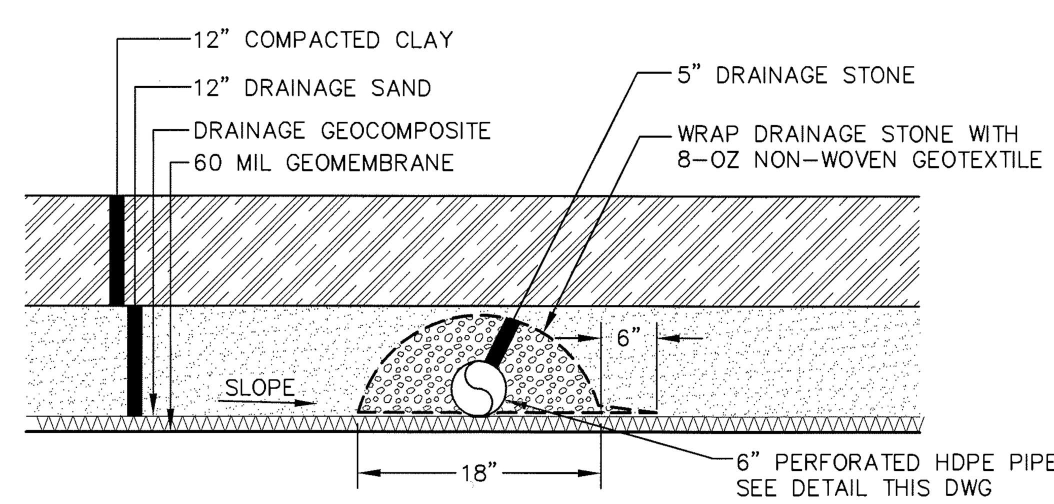
WEST SIDE PERIMETER BERM AND ACCESS ROAD (2)
NTS

C-102
C-103
C-104
C-105
C-107
C-108

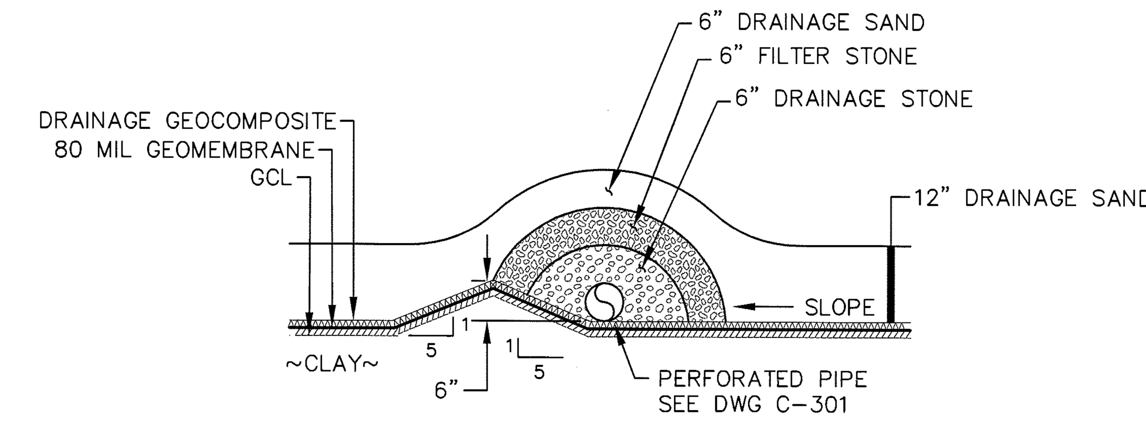


NORTH BERM (3)
NTS

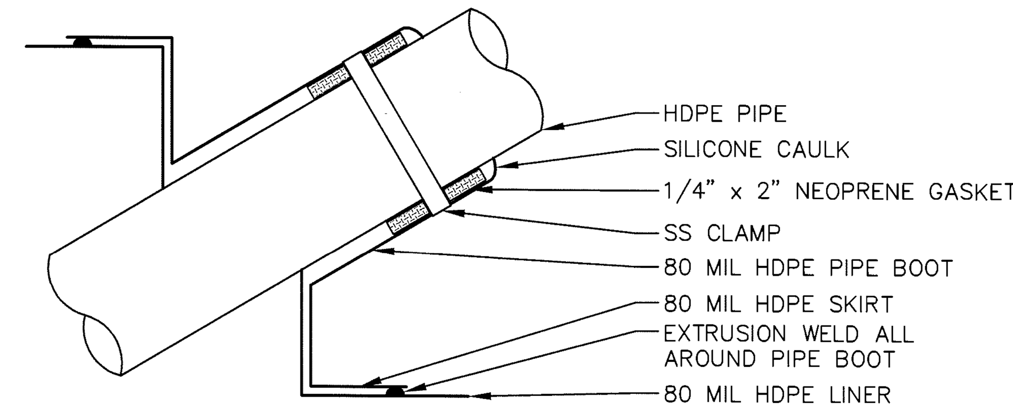
C-102
C-103
C-104
C-105
C-107
C-108



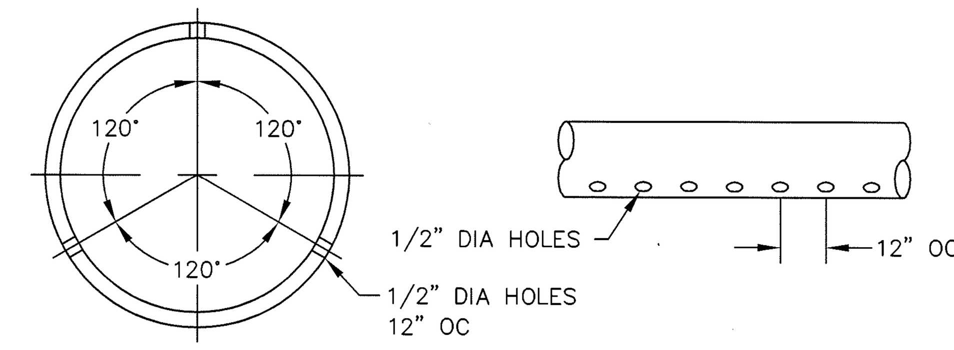
LEAK DETECTION LATERAL (TYP)
NTS



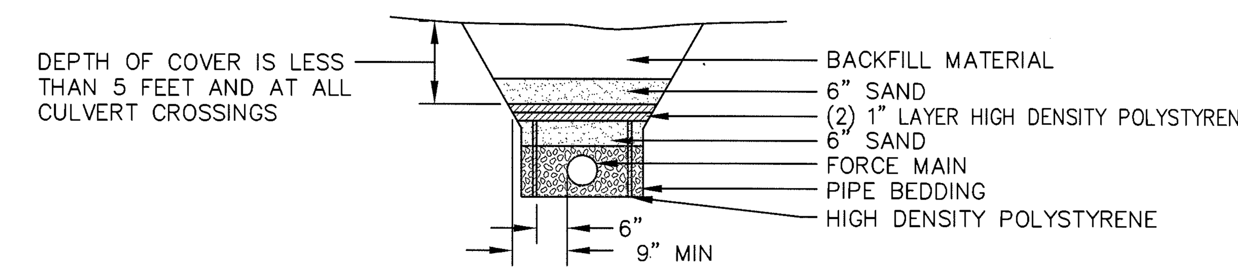
LEACHATE COLLECTION LATERAL (TYP)
NTS



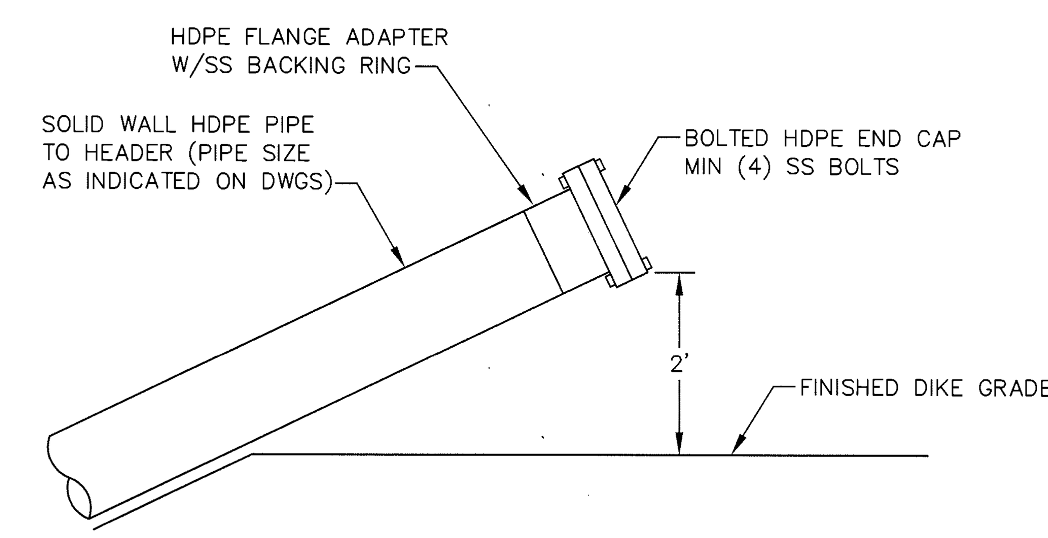
PIPE BOOT
NTS



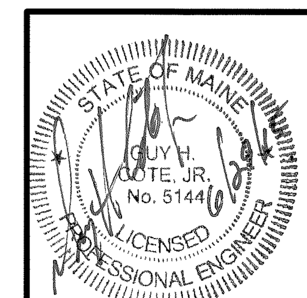
PERFORATED PIPE
NTS



PIPE INSULATION
NTS



FLANGED END CAP
NTS



JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SECTIONS AND DETAILS

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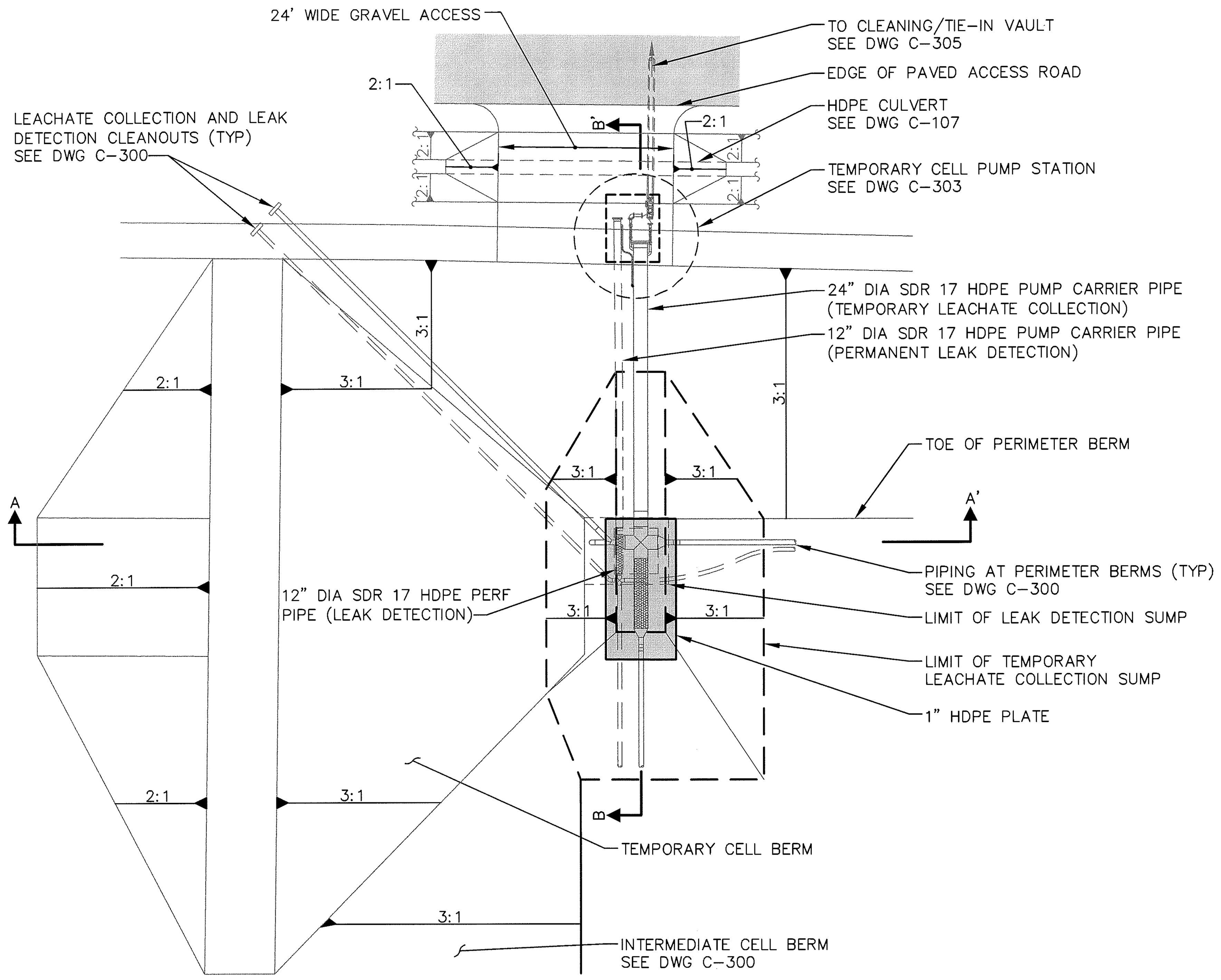
DATE: 12/5/2014	
CHECKED BY:	
LMN: NONE	
CTB: SME-STD	
JOB NO. 14101.00 DWG FILE DETAILS	C-301

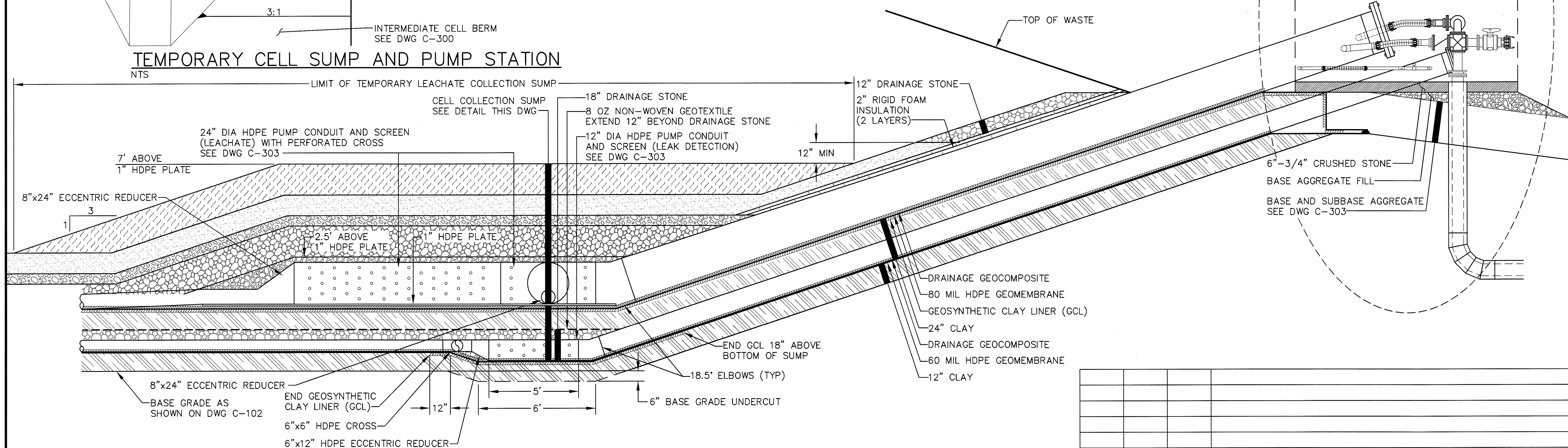
REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

SECTION A-A'
NTS

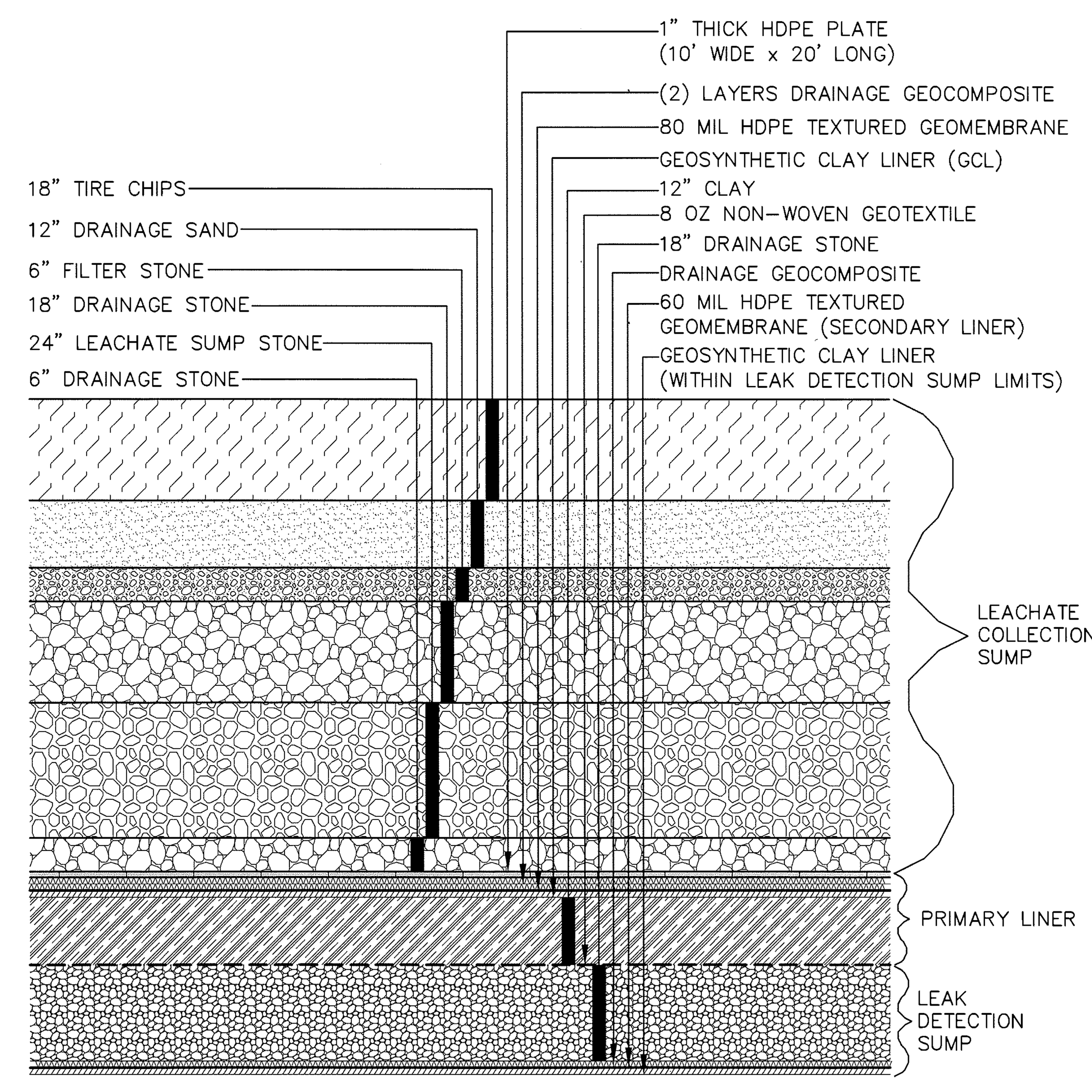
NOTES:
1. UNDERDRAIN AND AUGMENTED SECONDARY LINER ARE NOT SHOWN IN DETAIL. BASE GRADE SHALL BE UNDERCUT AN ADDITIONAL 1-FOOT IN THOSE LOCATIONS
2. LIMIT OF LEACHATE COLLECTION SUMP IS DEFINED BY THE LIMIT OF THE 18" TIRE CHIPS LAYER



TEMPORARY CELL SUMP AND PUMP STATION
NTS



SECTION B-B'
NTS



CELL COLLECTION SUMP
NTS

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. COTE — No. 5[illegible] — LICENSED — PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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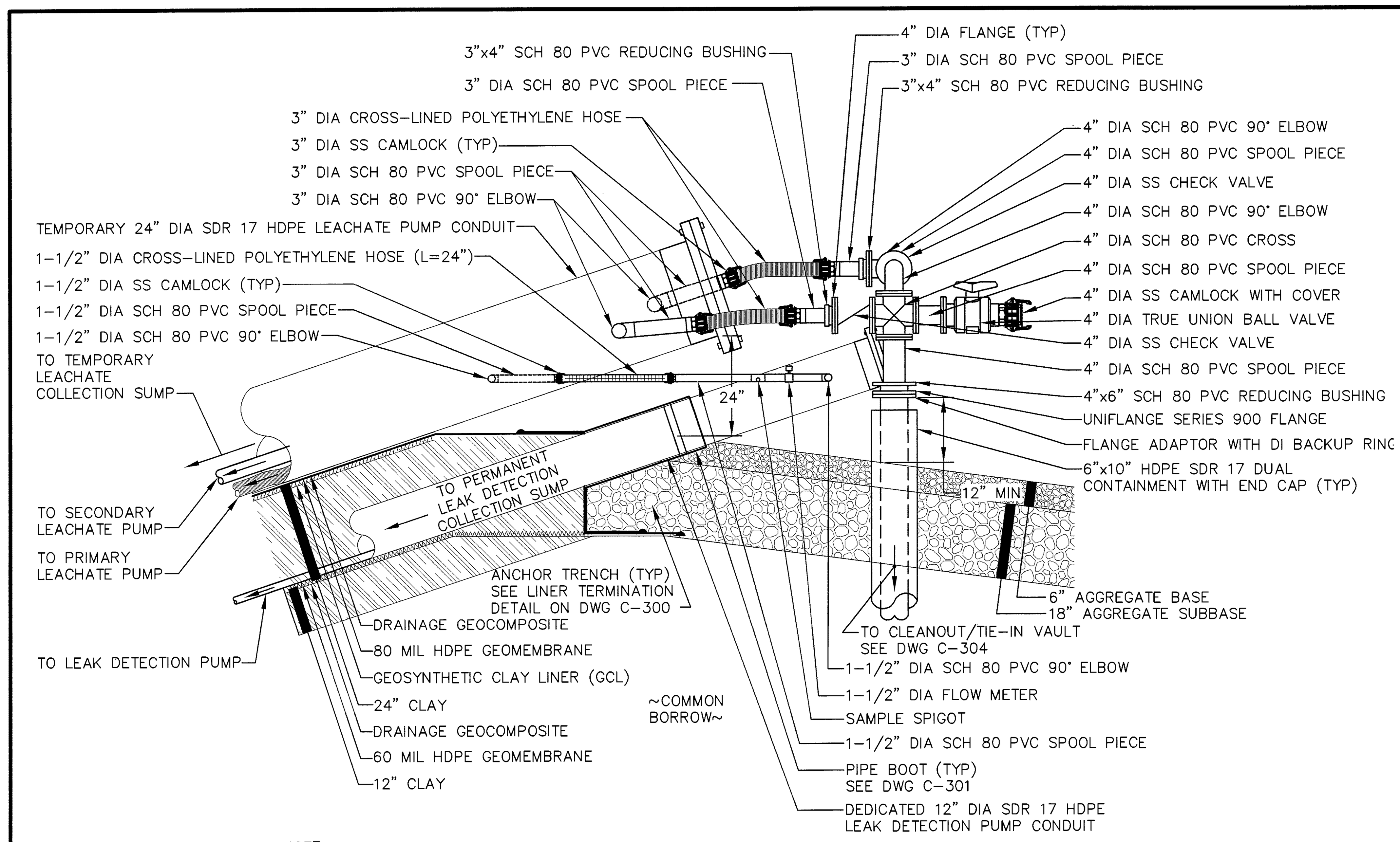
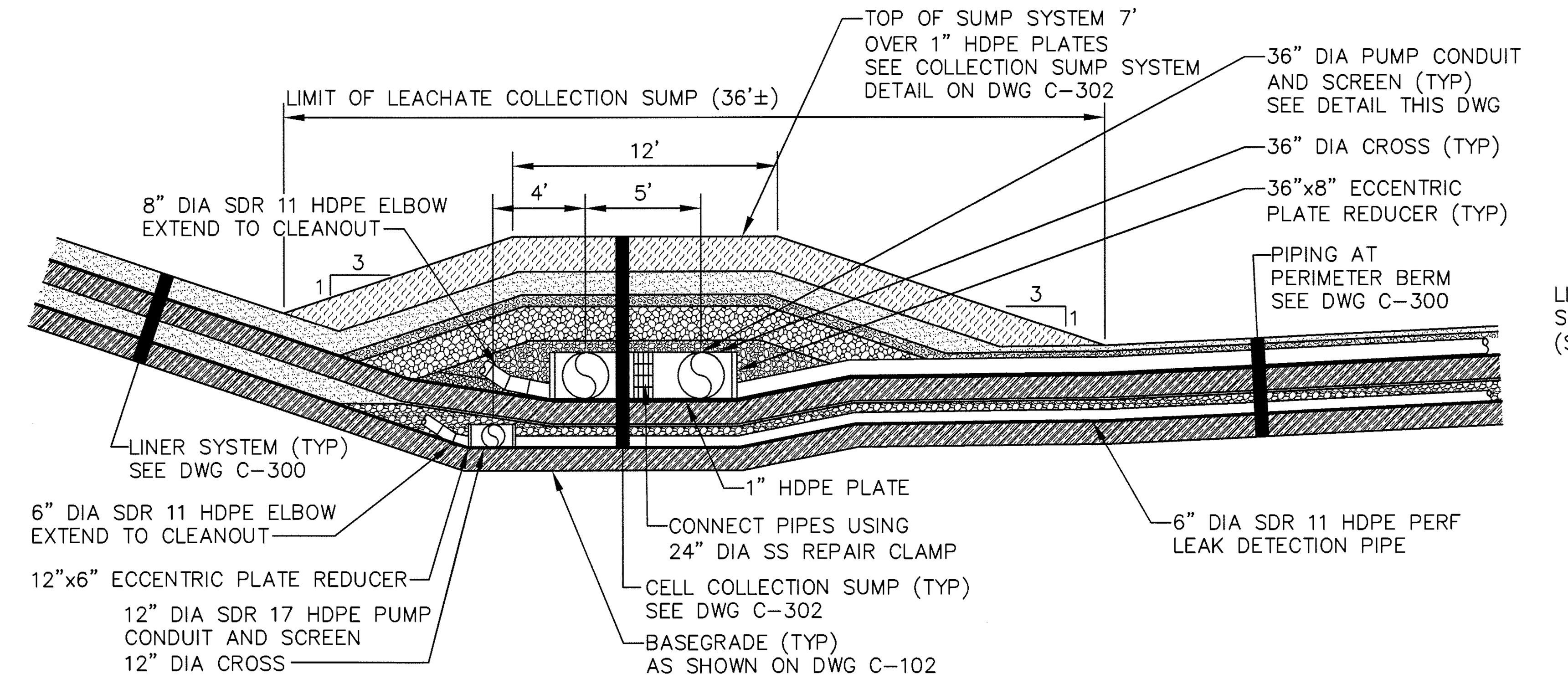
JOB NO. 14101.00 DWG FILE DETAILS
C-302

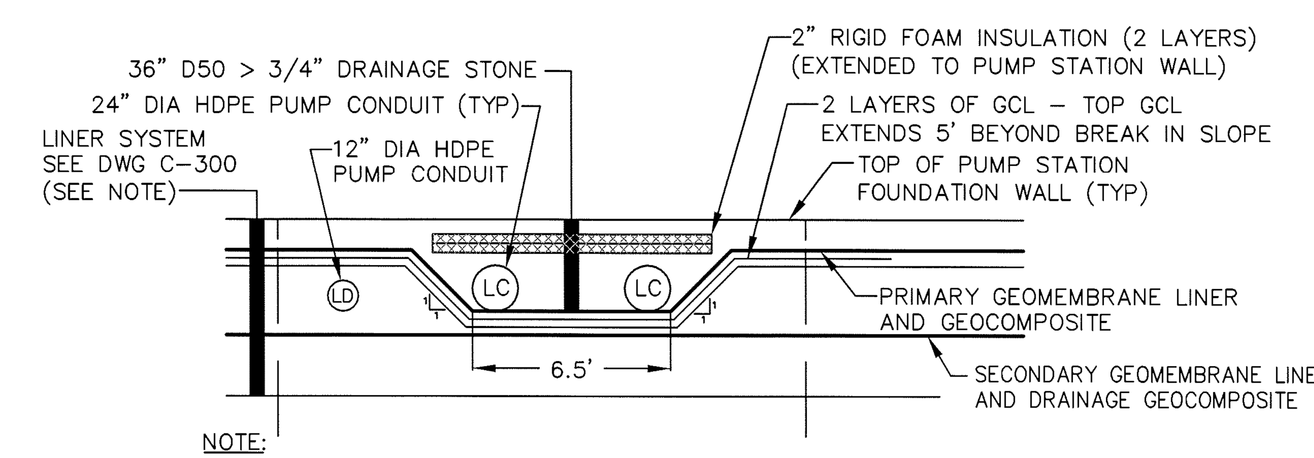


NOTE:
ALL LEACHATE COLLECTION PUMPS AND TRANSPORT PIPING SHOWN ARE TEMPORARY AND SHALL BE REMOVED OR ABANDONED AS SUBSEQUENT DOWNSTREAM CELL IS CONSTRUCTED. THE 24" PUMP CARRIER PIPE SHALL REMAIN IN PLACE AS A CLEANOUT. THE LEAK DETECTION PUMP AND PIPING IS PERMANENT AND SHALL REMAIN IN PLACE.

SECTION A-A'

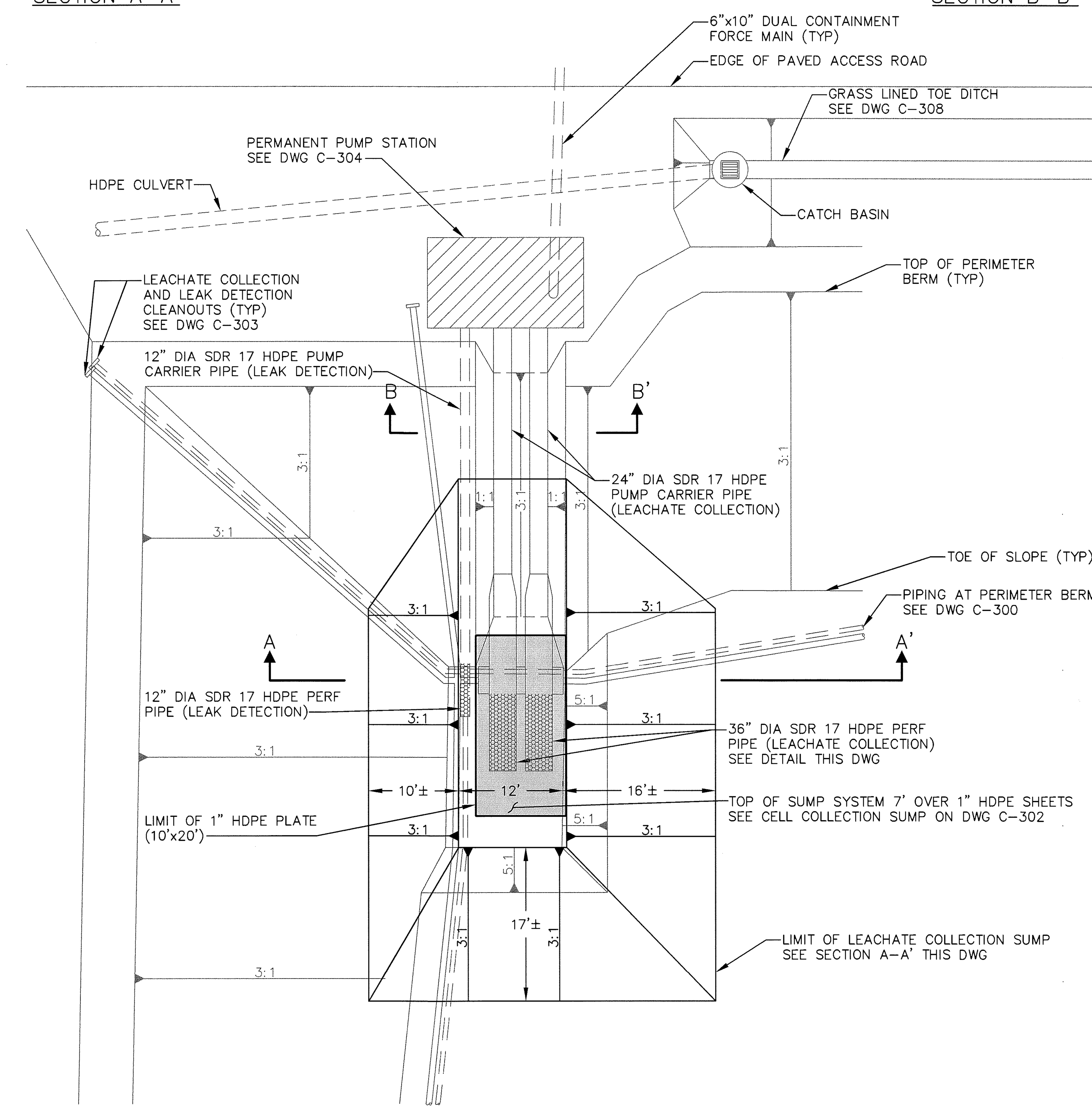


SECTION A-A'

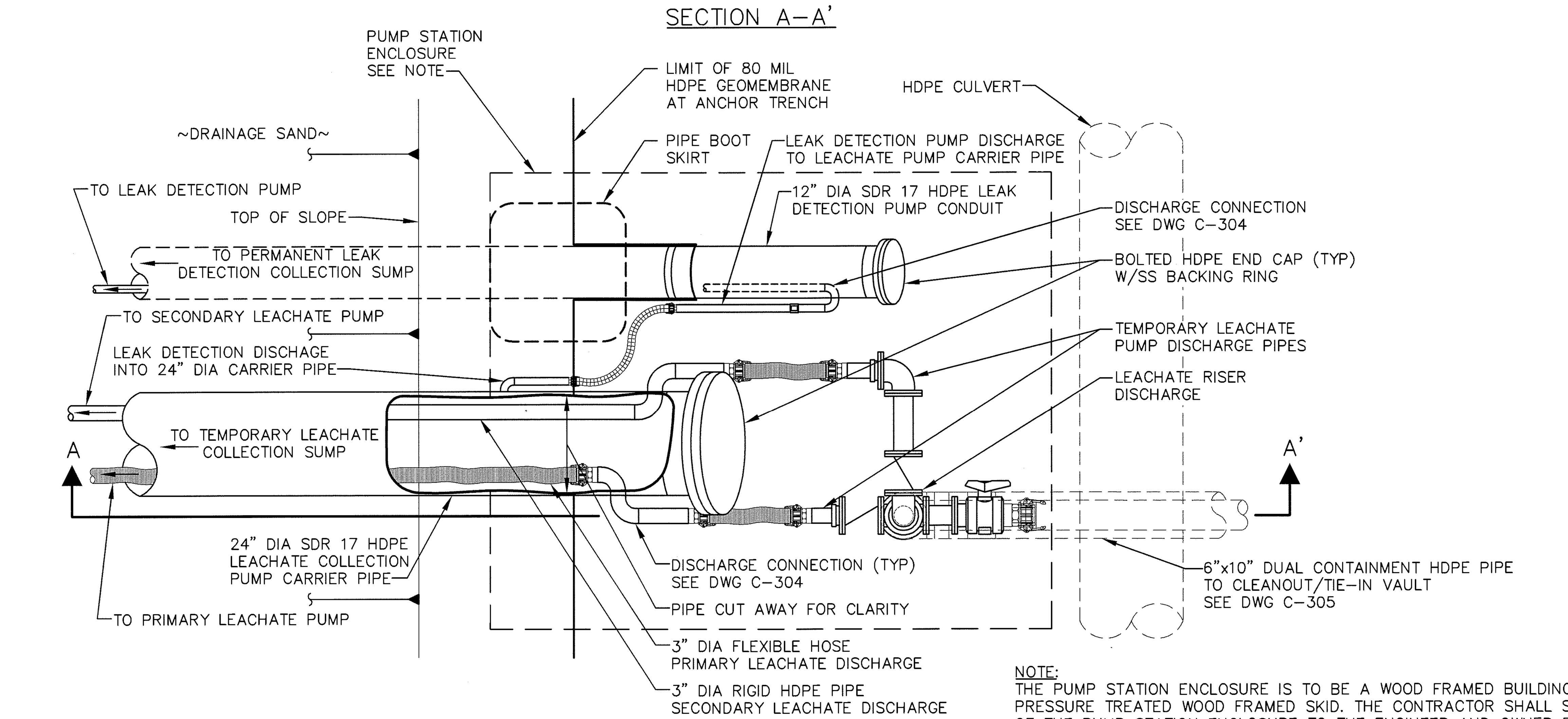


NOTE:
ON THE EAST AND WEST PERIMETER BERM SIDESLOPES THE LEACHATE COLLECTION DRAINAGE SAND IS REPLACED WITH DRAINAGE STONE AND THE LEAK DETECTION DRAINAGE SAND REPLACED WITH 12" OF CLAY.

SECTION B-B'

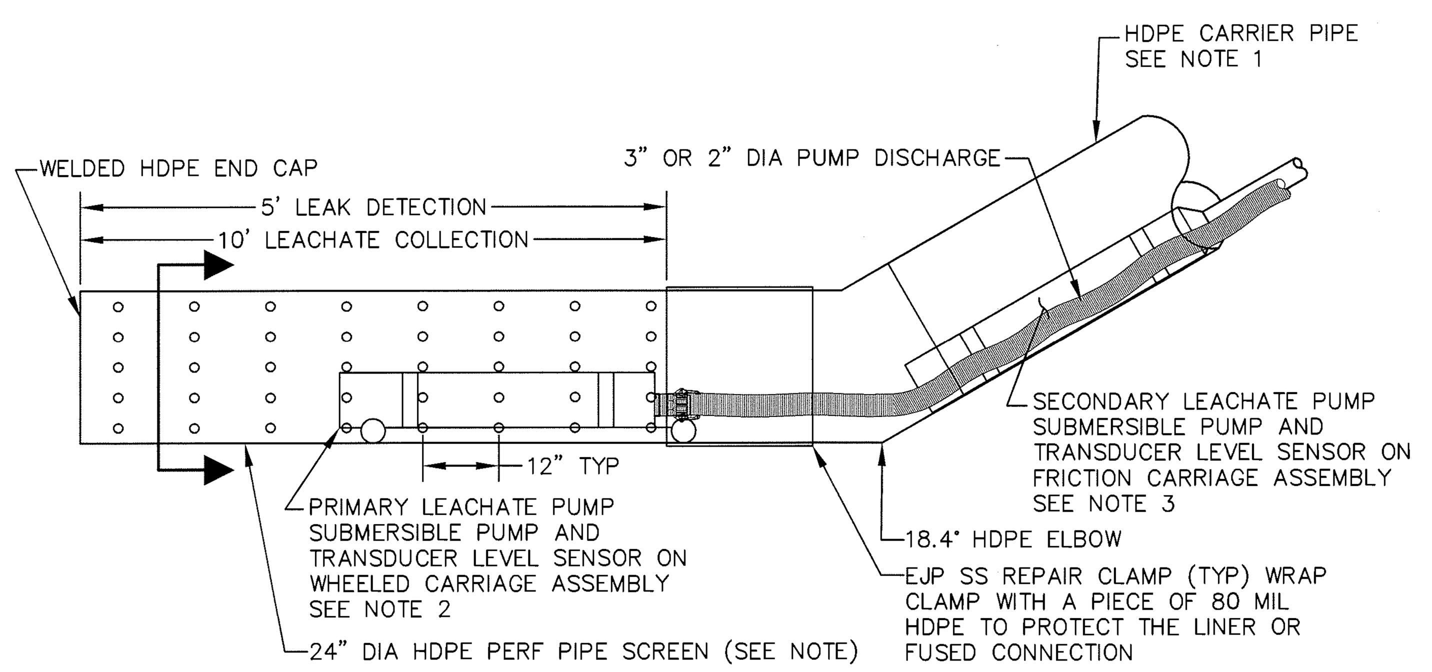


PERMANENT COLLECTION SUMP AND PUMP STATION
NTS

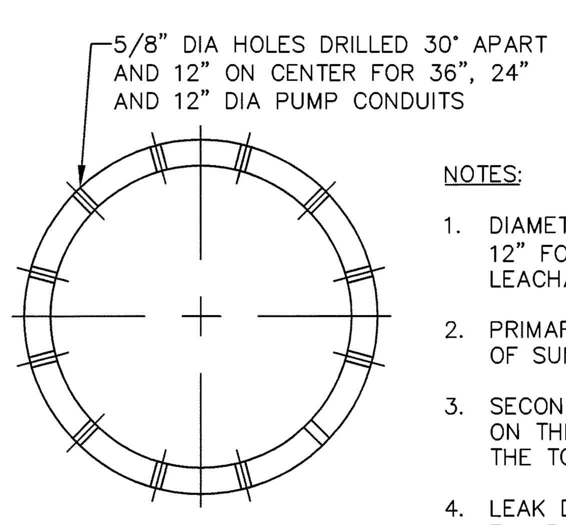


NOTE:
THE PUMP STATION ENCLOSURE IS TO BE A WOOD FRAMED BUILDING MOUNTED TO A PRESSURE TREATED WOOD FRAMED SKID. THE CONTRACTOR SHALL SUBMIT SHOP DRAWINGS OF THE PUMP STATION ENCLOSURE TO THE ENGINEER AND OWNER FOR APPROVAL. THE PUMP STATION SHALL INCLUDE BUT NOT BE LIMITED TO, 2"x6" WOOD FRAMING, INSULATION, METAL ROOF, T-111 SIDING, ELECTRICAL LIGHTING, GFIC RECEPTACLE, INSULATED DOUBLE STEEL DOORS, PASSIVE VENTILATION AND GAS MONITORING SYSTEM.

TEMPORARY CELL PUMP STATION
NTS



HDPE PUMP CONDUIT AND SCREEN
NTS



SECTION

NOTES:

1. DIAMETER OF PUMP CONDUIT AND SCREEN IS EITHER 12" FOR LEAK DETECTION SYSTEM OR 24" FOR LEACHATE COLLECTION SYSTEM.
2. PRIMARY LEACHATE PUMP SHALL BE AT THE BOTTOM OF SUMP AND SIT HORIZONTALLY ON SUMP FLOOR.
3. SECONDARY LEACHATE PUMP SHALL BE POSITIONED ON THE INCLINED SIDESLOPE AND BE LOWERED TO THE TOW OF SLOPE.
4. LEAK DETECTION PUMP SHALL BE POSITIONED AT THE BOTTOM OF THE LEAK DETECTION SUMP AND SIT HORIZONTALLY ON SUMP FLOOR. LEAK DETECTION DISCHARGE HOSE IS 2-INCH DIAMETER.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SECTIONS AND DETAILS

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JOB NO. 14101.00 DWG FILE DETAILS

C-303

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE · LICENSED PROFESSIONAL ENGINEER · No. 5144

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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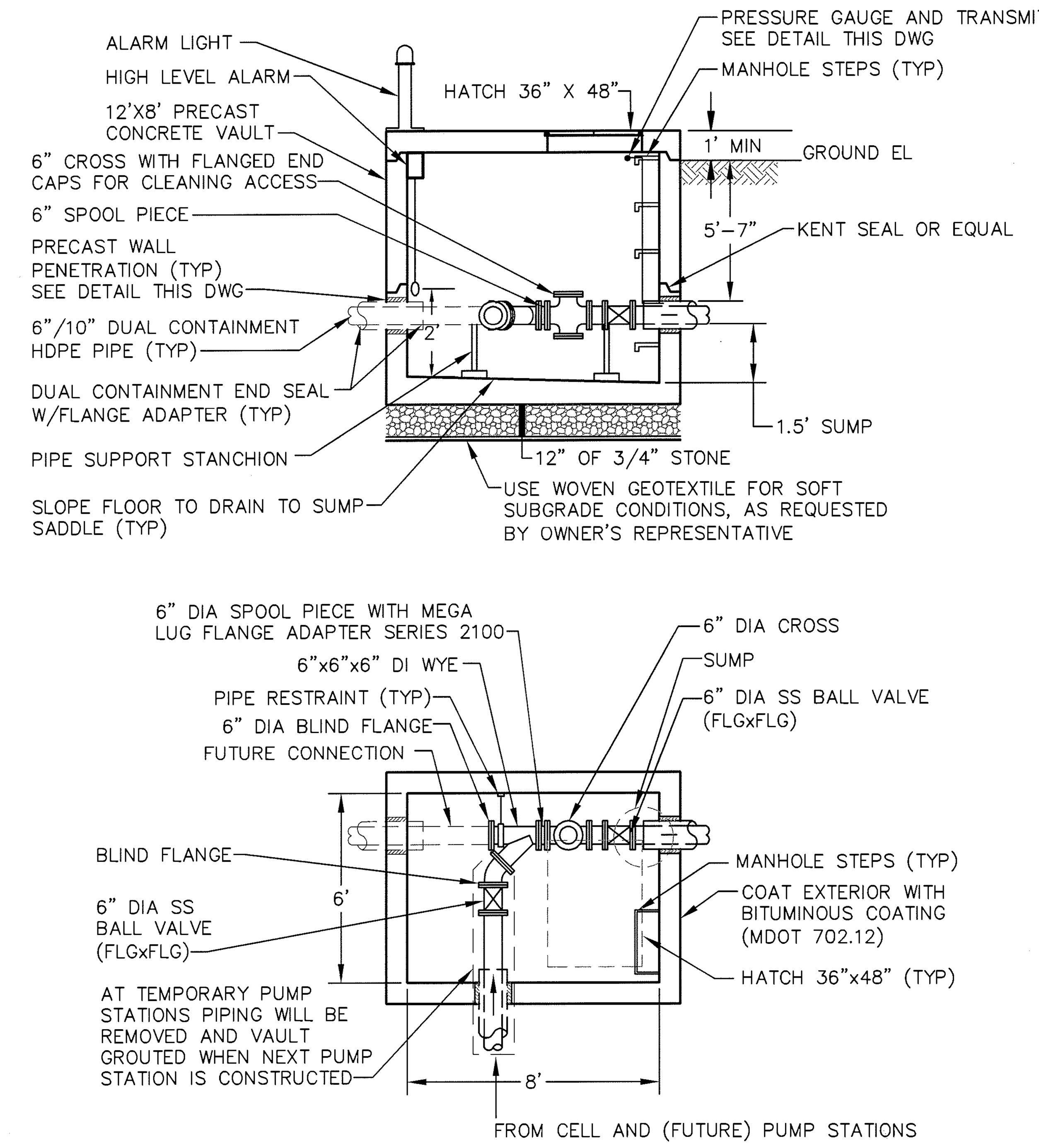
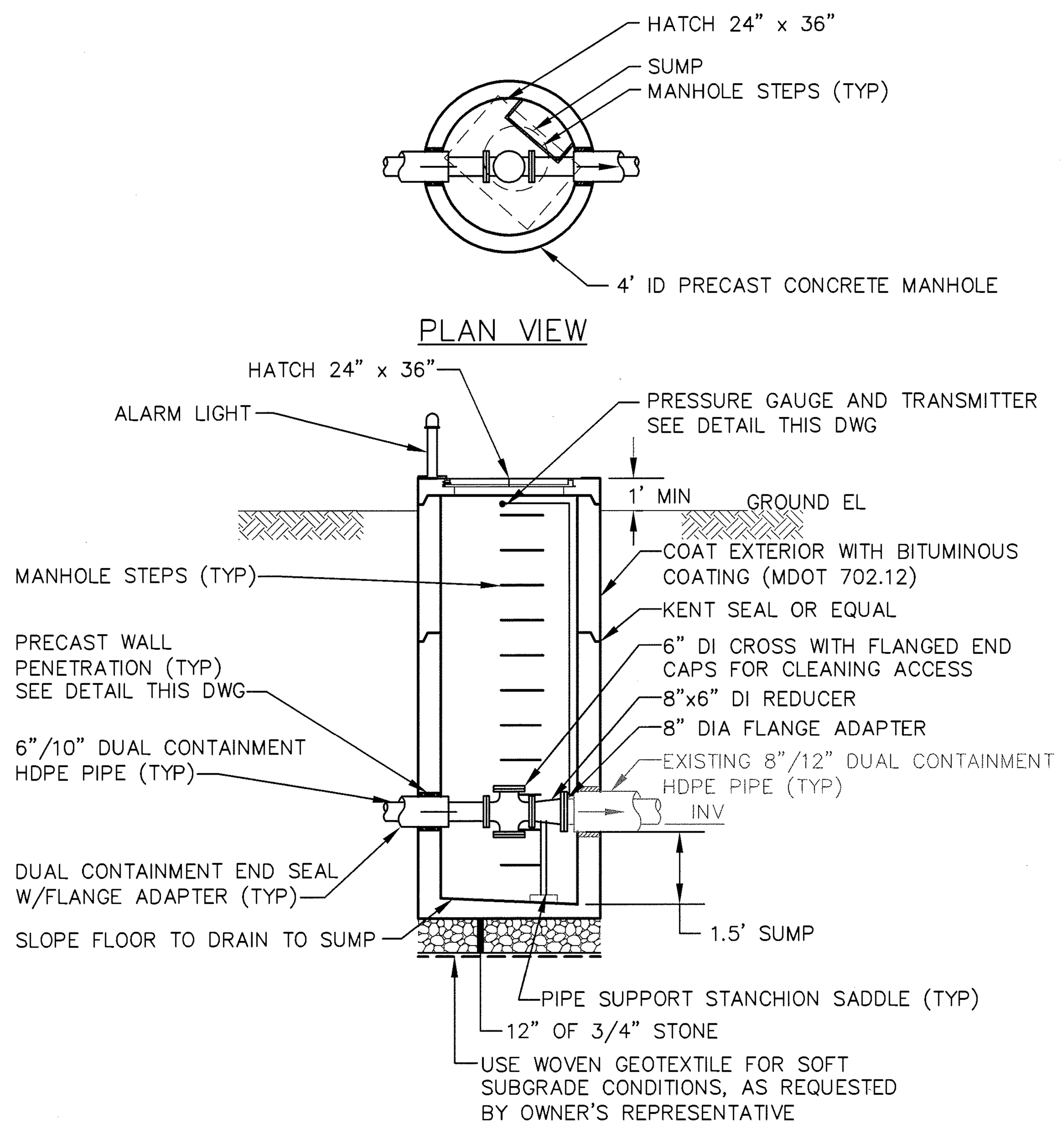
JOB NO. 14101.00 DWG FILE DETAILS

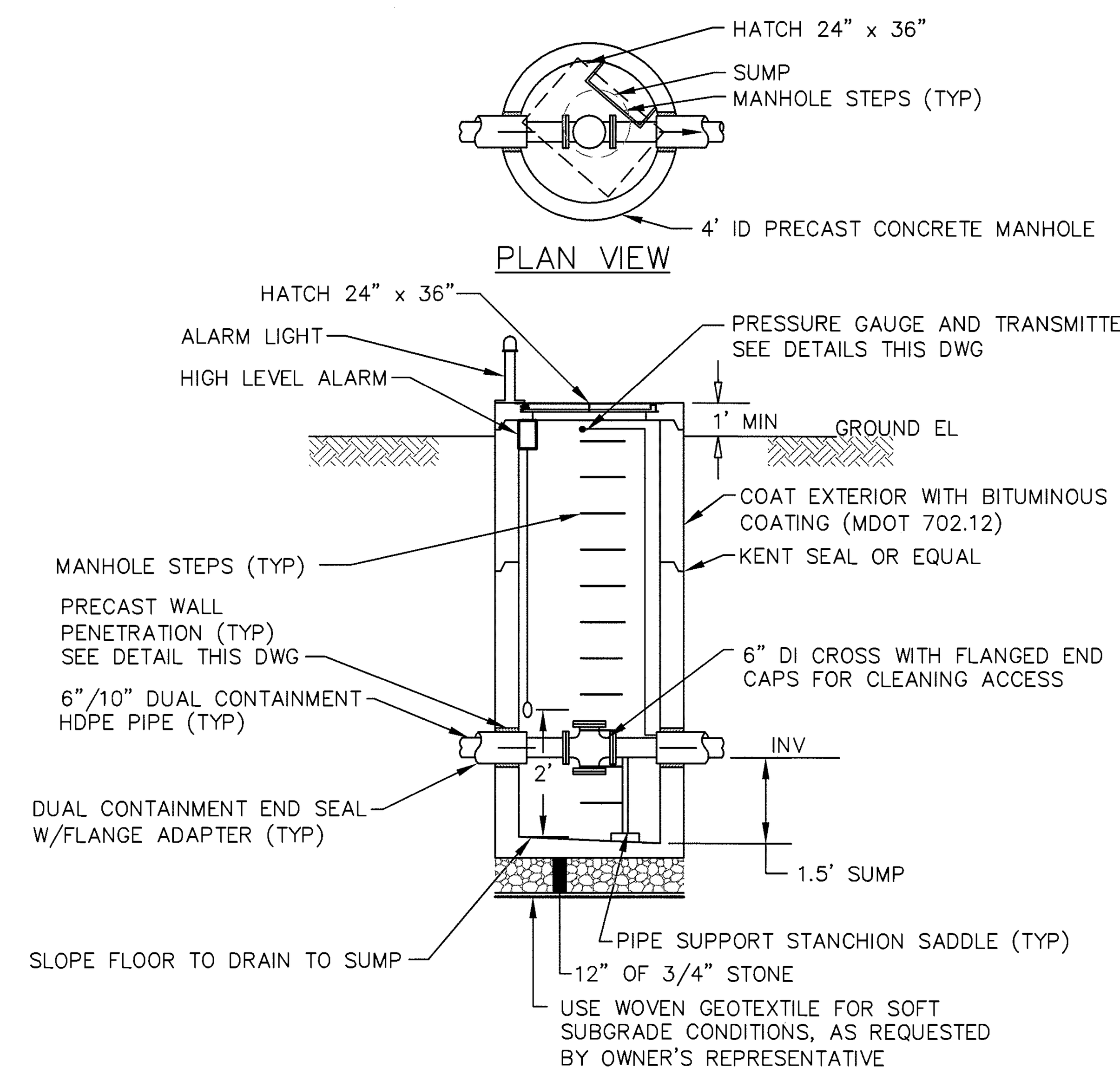
C-304



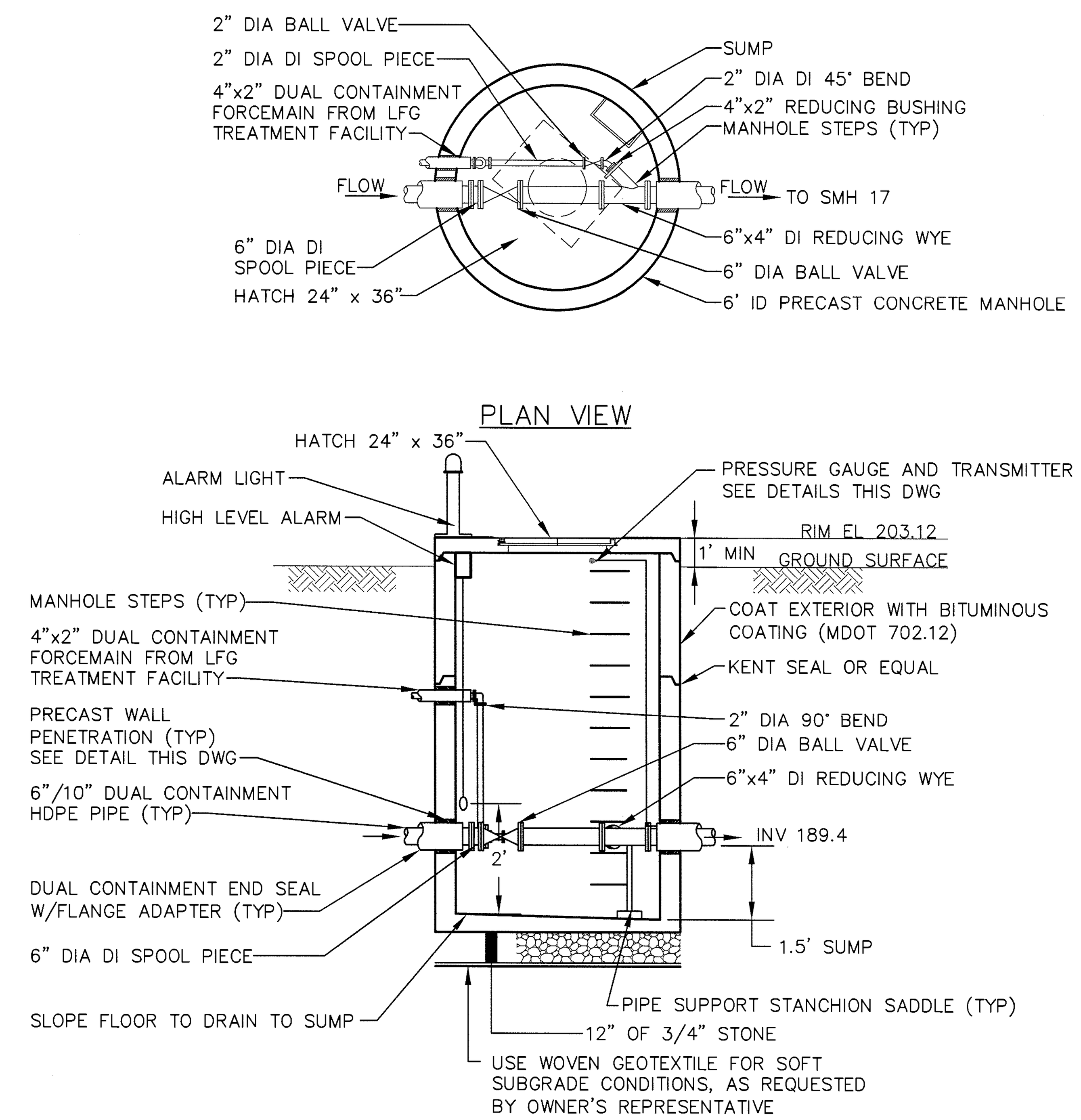
CLEANING/TIE-IN VAULT
NTS



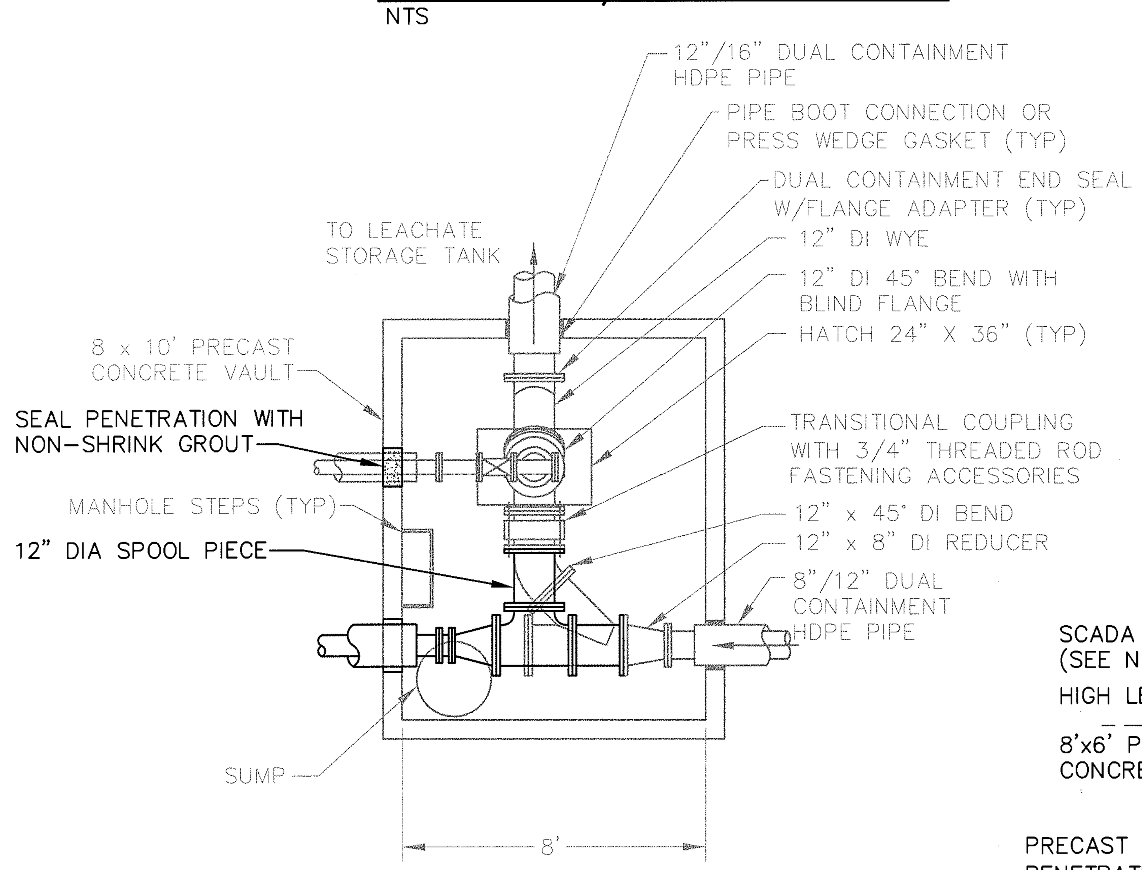
FORCEMAIN TIE-IN CONNECTION AT FORMER LEACHATE POND PUMP STATION
NTS

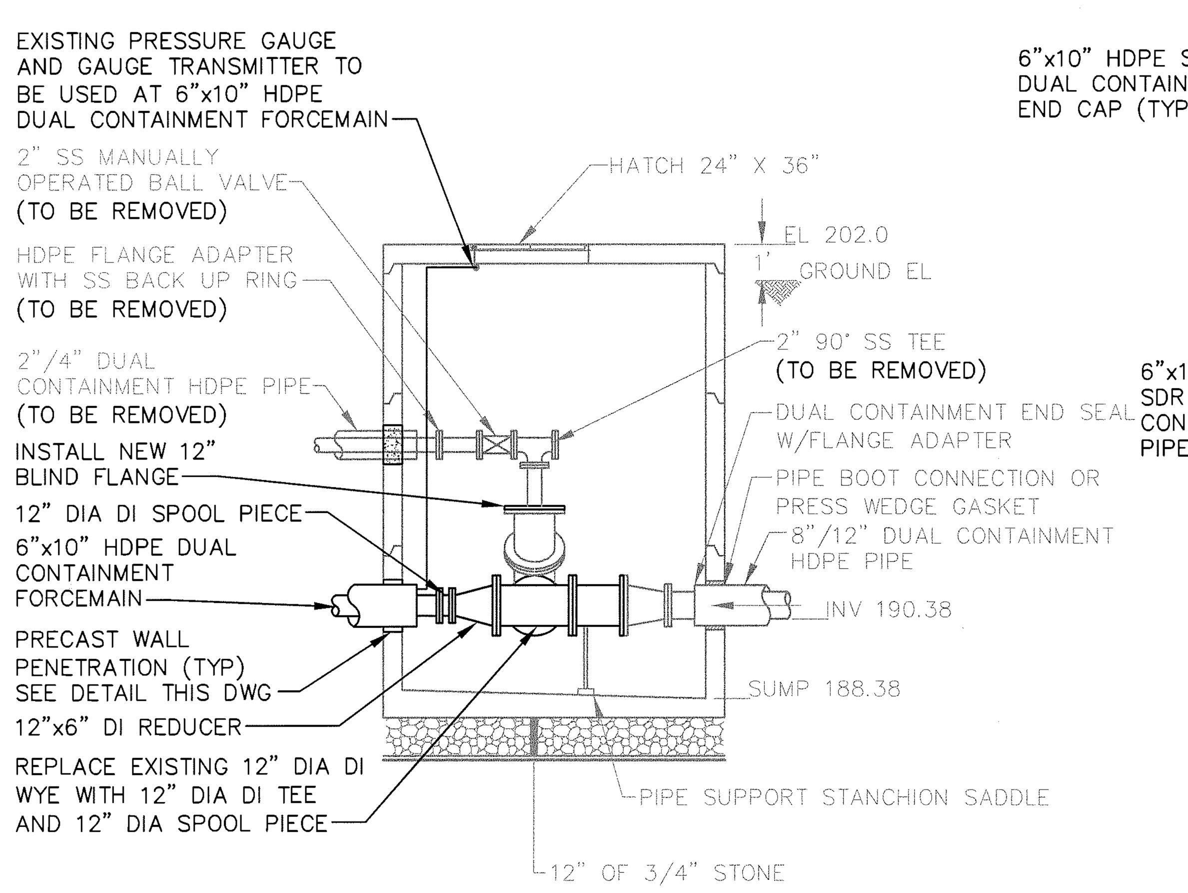


CLEANING MANHOLE
NTS

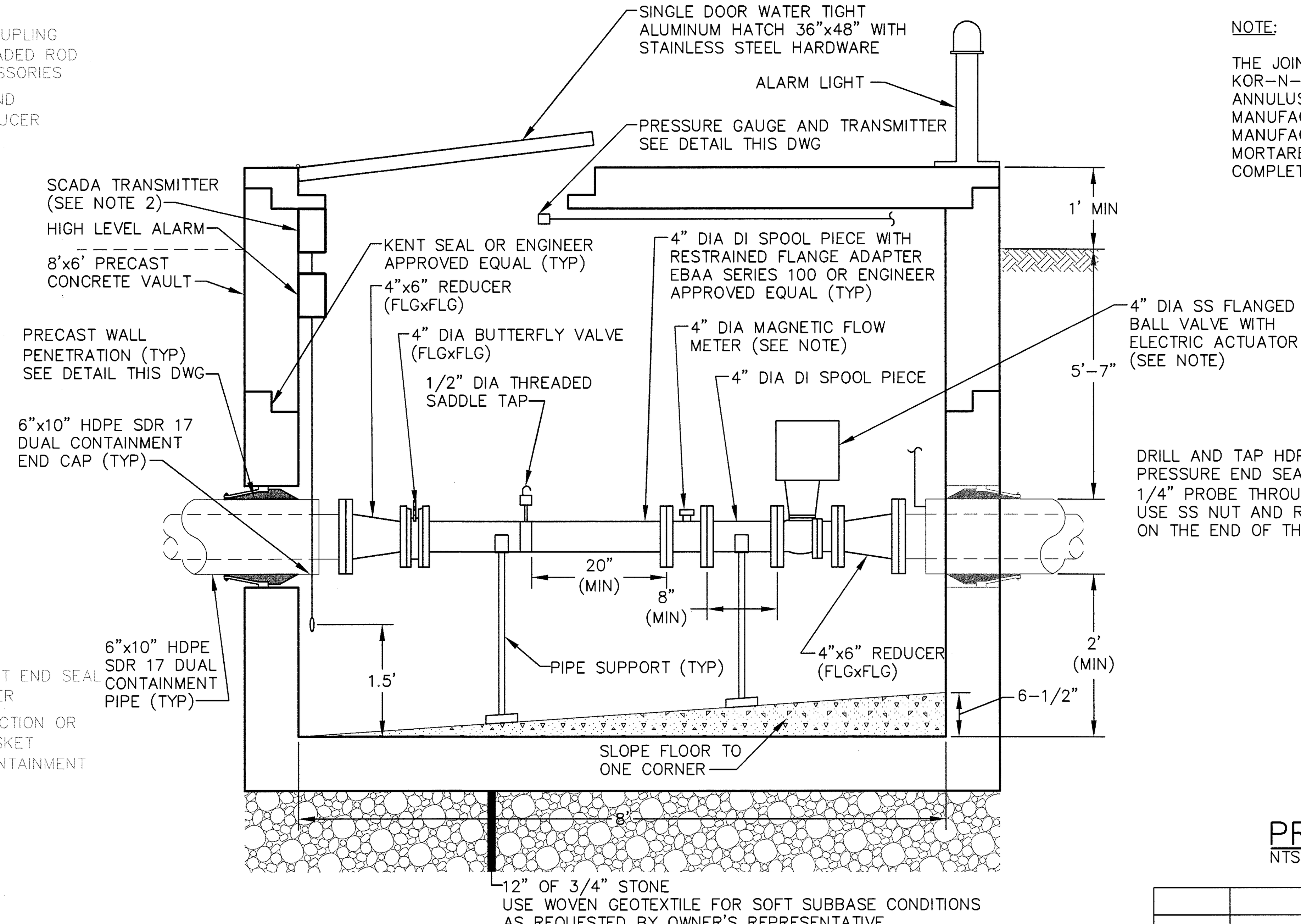


FORCEMAIN TIE-IN AT LEACHATE STORAGE TANK
NTS





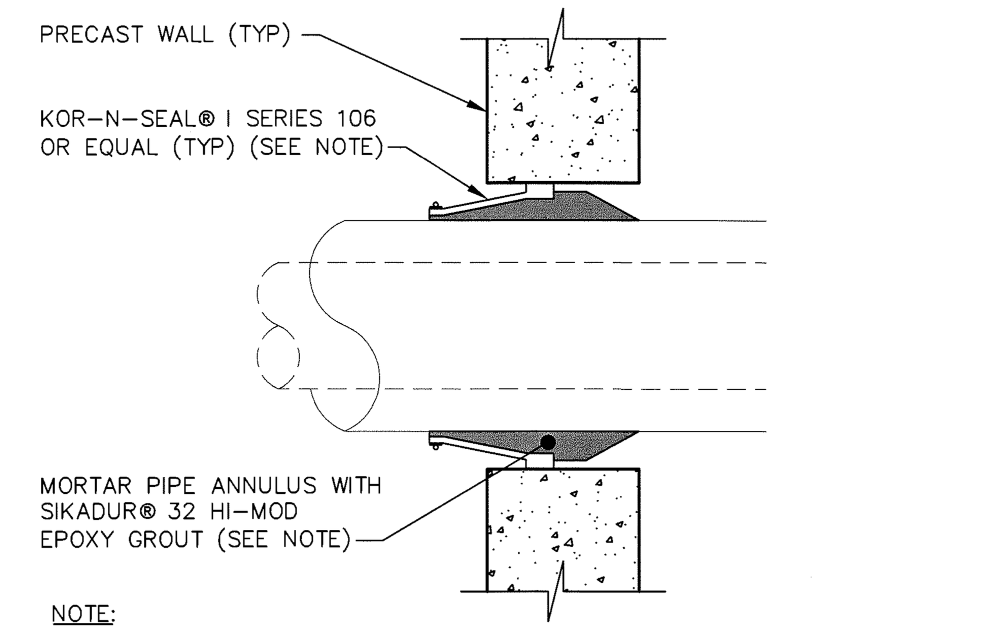
SMH-17 TIE-IN
NTS



NOTE:

FLOW METER AND BALL VALVE WITH ELECTRIC ACTUATOR SHALL BE CONNECTED TO SCADA TRANSMITTER.

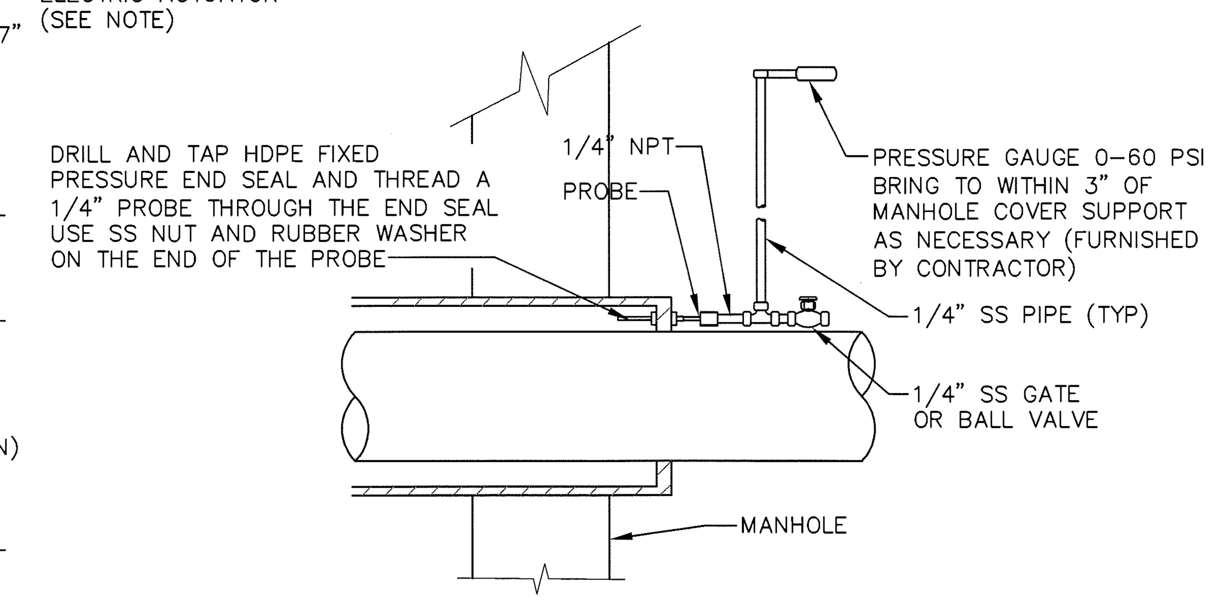
FORCE MAIN METER AND VALVE PIT
NTS



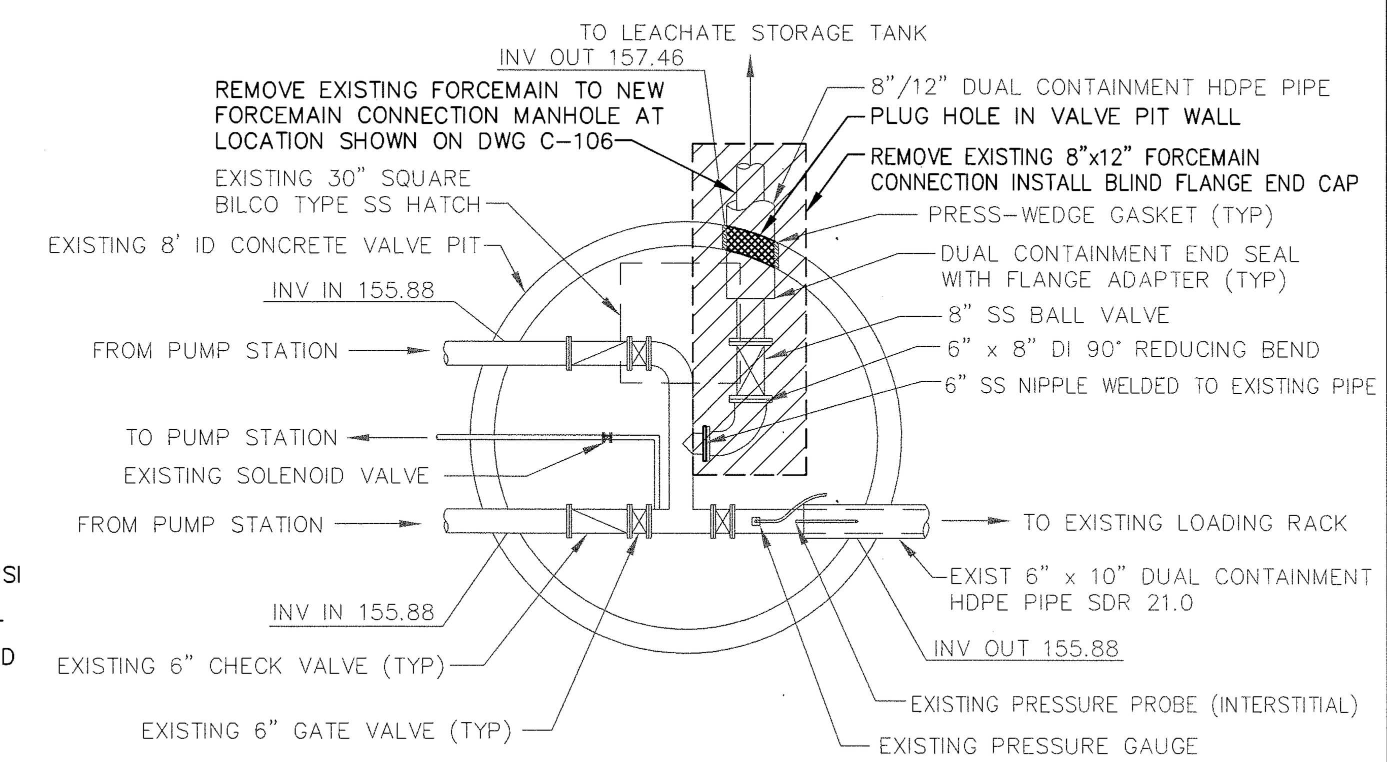
NOTE:

THE JOINTS FOR THE PIPES THROUGH PRECAST WALLS SHALL BE WEDGE STYLE KOR-N-SEAL®I SERIES 106 AS MANUFACTURED BY TRELLEBORG OR EQUAL. THE ANNULUS SHALL BE MORTARED WITH SIKADUR®32 HI-MOD GROUT AS MANUFACTURED BY SIKA CORPORATION. THE CONTRACTOR SHALL FOLLOW THE MANUFACTURERS INSTRUCTIONS TO MIX AND APPLY THE EPOXY GROUT. THE FINAL MORTARED PLUG SHALL YIELD A STRONG AND RIGID SEAL AROUND THE PIPE. COMPLETE VACUUM TESTING PRIOR TO THE INSTALLATION OF GROUT.

PRECAST WALL PENETRATION
NTS



PRESSURE PROBE AND GAUGE
NTS



EXISTING VALVE PIT MODIFICATION
NTS

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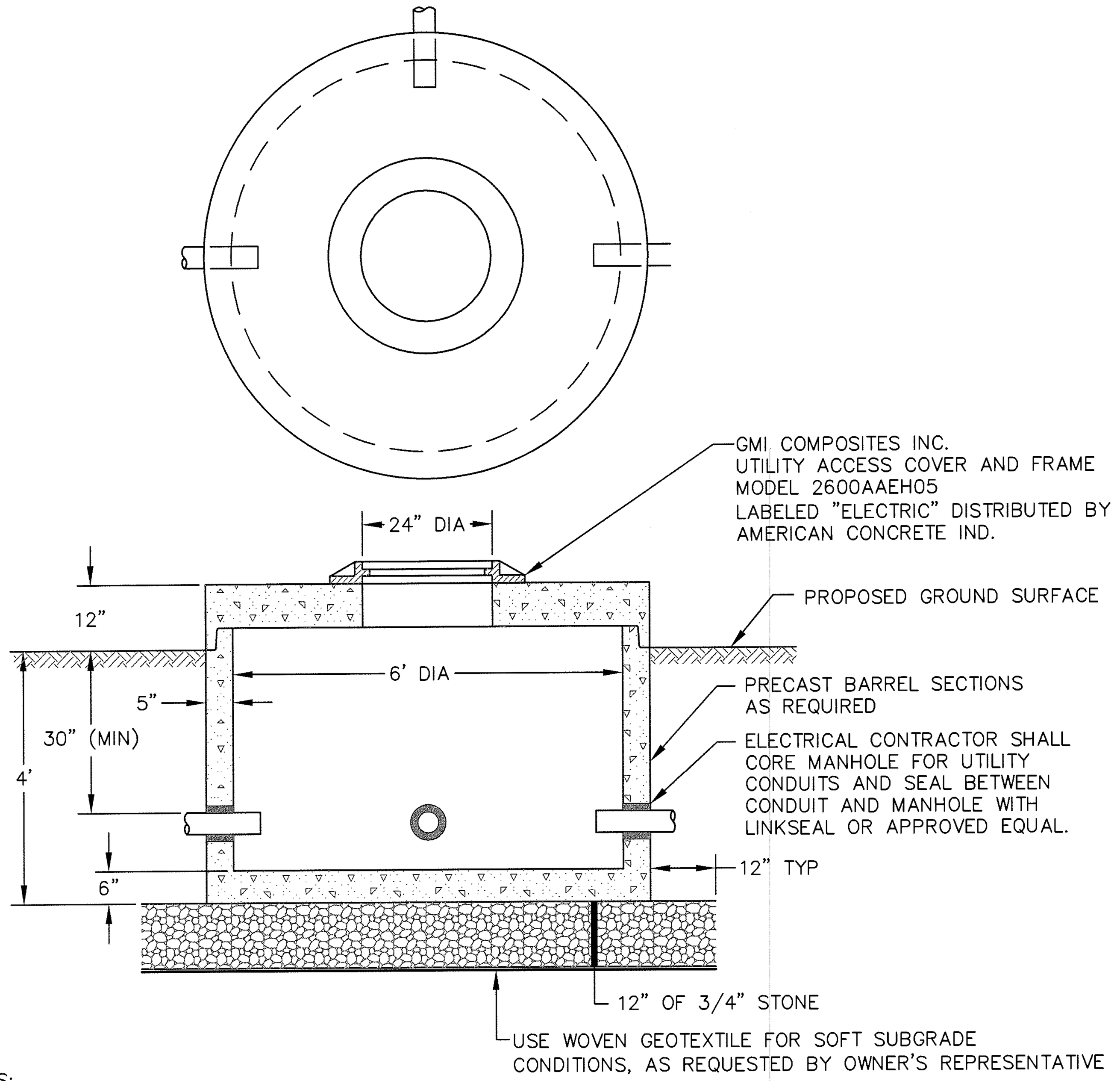
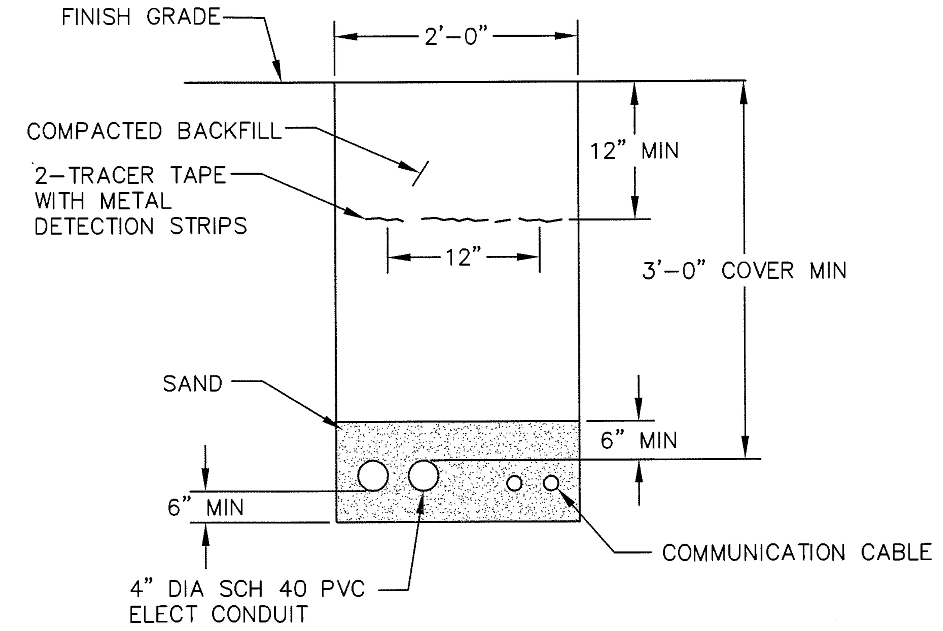
C-305



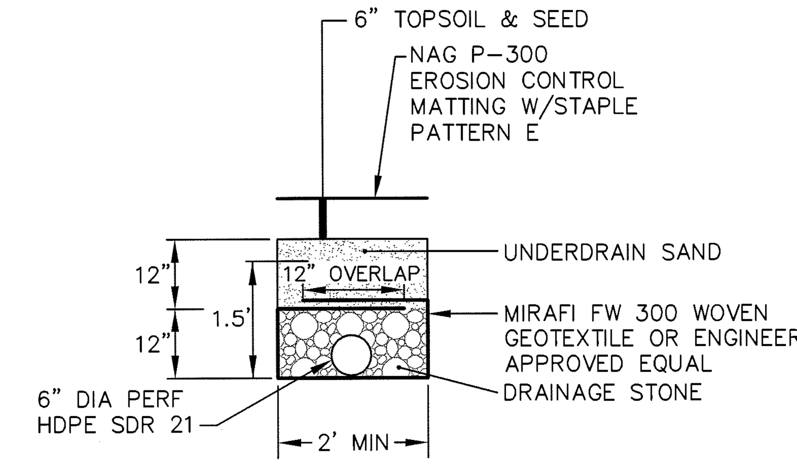
NOTES:

1. 6' DIA MANHOLE AS MANUFACTURED BY AMERICAN CONCRETE INDUSTRIES OR ENGINEER APPROVED EQUAL.
2. 4000 PSI CONCRETE AT 28 DAYS.
3. DESIGNED FOR H-20 WHEEL LOADING.
4. CONFORMS TO ASTM C-478 SPECIFICATIONS.
5. REINFORCED TO 0.12 IN SQ/LF.
6. SHIPLAP JOINTS SEALED WITH BUTYL RUBBER.
7. EXTERIOR COATED WITH ASPHALTIC PROTECTIVE DAMPPROOFING.
8. BOTTOM MIN 5'-0" BELOW FINISH GRADE.
9. PRECAST CONCRETE VAULT MANUFACTURER TO PROVIDE ANTI-FLOATATION EXTENDED BASE SLAB AS NECESSARY. ANTI-FLOATATION DESIGN AND SHOP DRAWINGS SHALL BE PREPARED BY THE MANUFACTURER AND SUBMITTED TO THE ENGINEER FOR APPROVAL.

ELECTRIC UTILITY MANHOLE
NTS

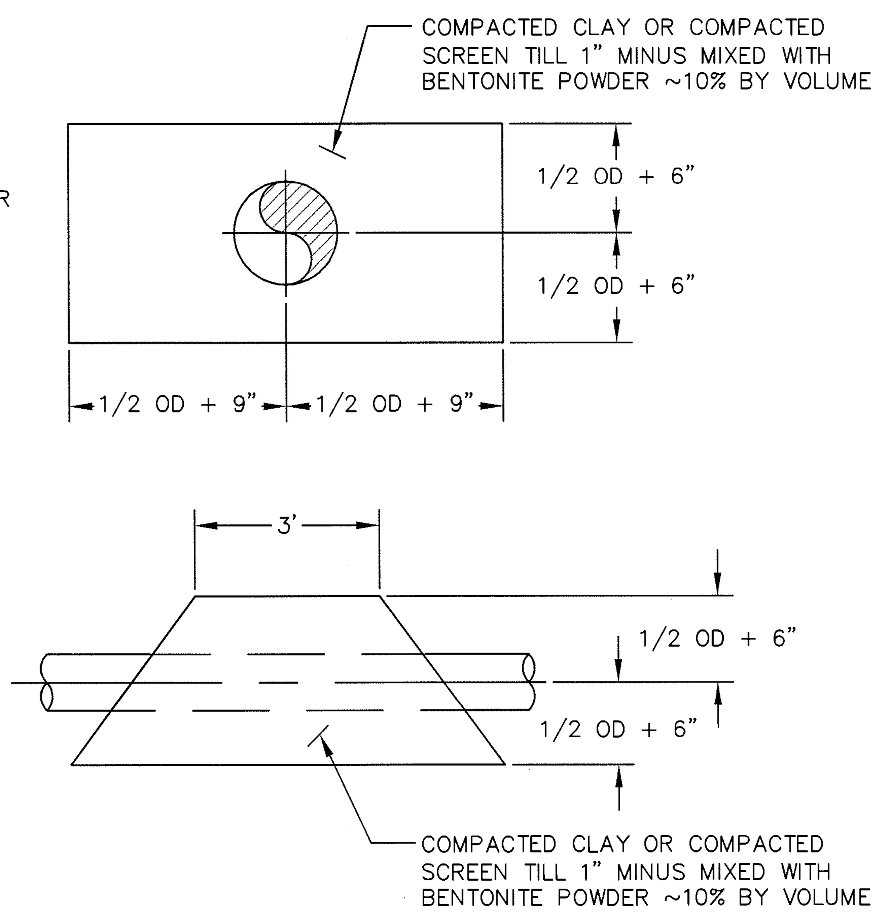


UNDERGROUND ELECTRIC AND COMMUNICATION TRENCH
NTS



POND UNDERDRAIN
NTS

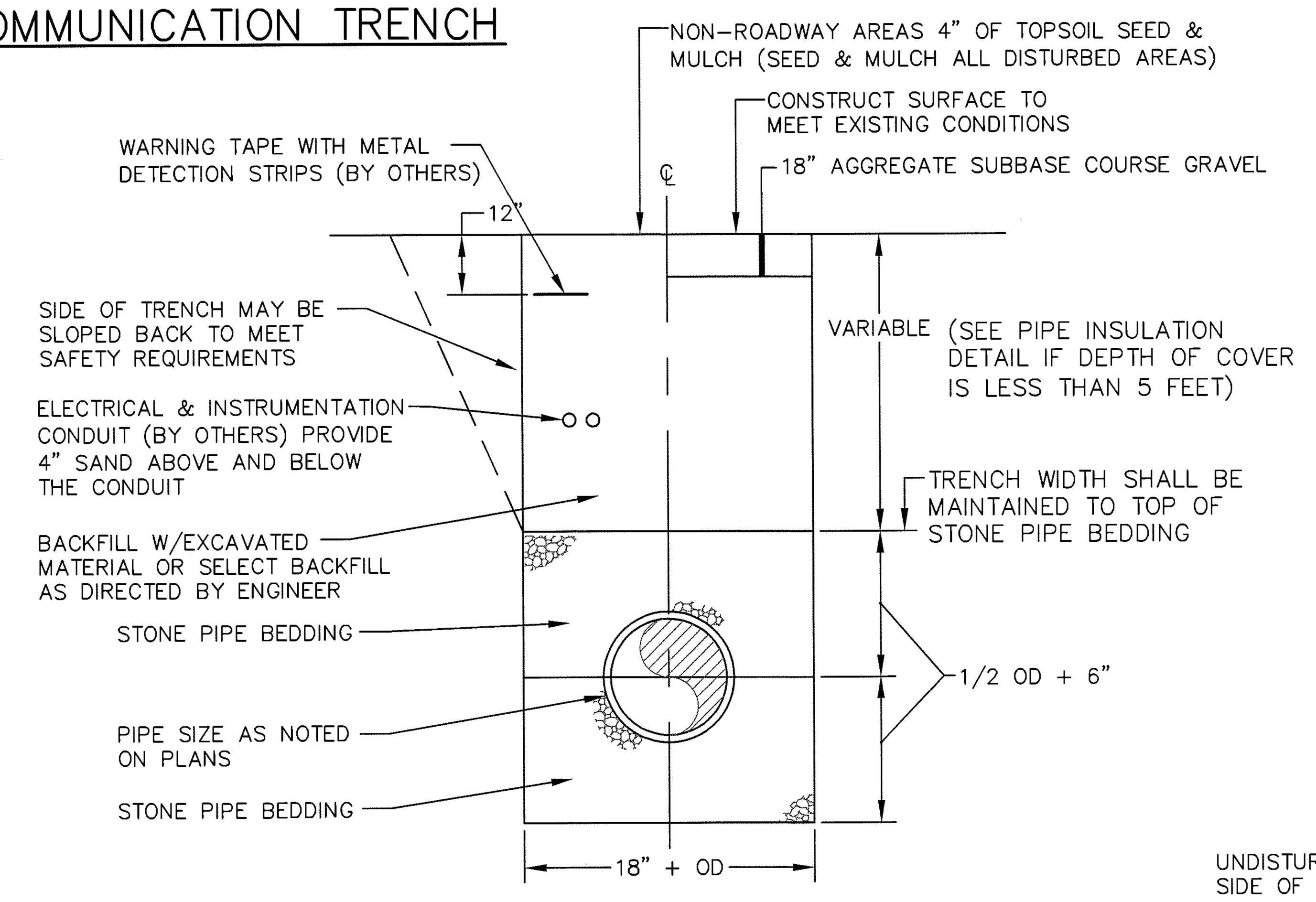
NOTE: DAMS SPACED AT 150' ALONG FORCE MAIN AND AT LOCATION SHOWN ON PLAN DRAWINGS



PIPE DAM
NTS

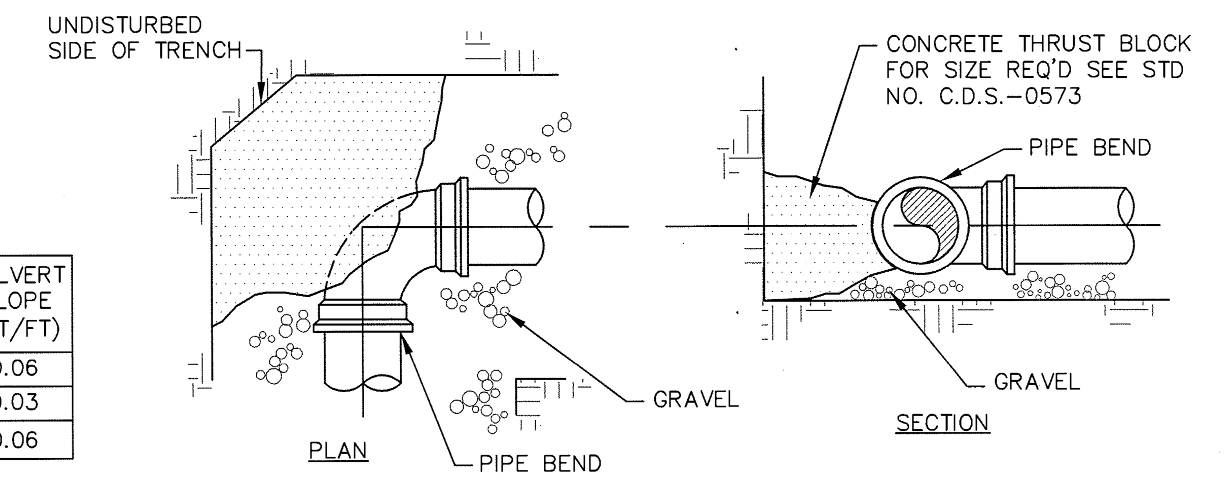
CULVERTS	DIAMETER (IN)	LENGTH (FT)	SLOPE (FT/FT)	INV IN (FT)	INV OUT (FT)
C-2BA	36	40	0.02	202.2	202.9
C-2BB	24	96	0.01	195.0	194.0
C-4BA	24	78	0.01	204.4	203.7
C-4BB	24	78	0.01	204.4	203.7
C-4F	18	78	0.04	165.0	162.0
C-4G	24	36	0.03	175.0	174.0
C-4HA	18	40	0.03	201.9	200.9
C-4HB	18	101	0.03	178.5	176.0
C-4I	18	80	0.13	202.5	192.0
C-4IA	18	40	0.02	212.9	212.2
C-4JA	18	60	0.03	214.0	212.3
C-4JB	24	73	0.02	211.5	210.0
C-4JC	24	73	0.02	211.5	210.0
C-4K	24	51	0.04	216.5	214.3
C-4L	18	121	0.02	213.0	211.0
C-4N	18	33	0.03	184.0	183.0

CULVERT SCHEDULE
NTS

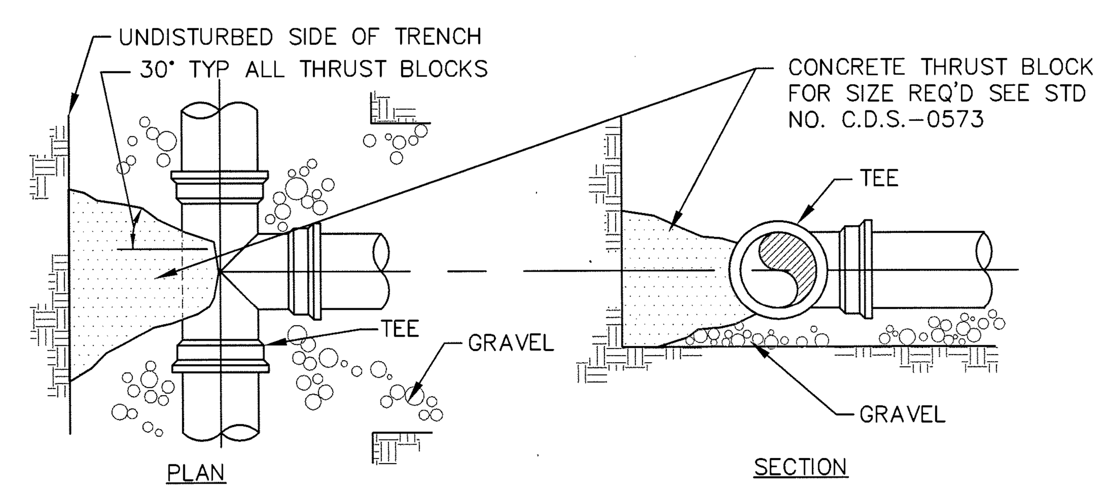


PIPE TRENCH
NTS

SIZE REQUIREMENTS FOR CONCRETE THRUST BLOCKS					
		BEARING ON UNDISTURBED SOIL (SQ FT)			
FITTINGS		90° BENDS	45° BENDS	TEES & PLUGS	HYDRANTS
PIPE SIZE	4"	2.0	1.0	1.0	N/A
	6"	3.0	2.0	2.0	6.0
	8"	5.0	3.0	4.0	N/A
	10"	7.0	4.0	5.0	N/A
	12"	10.0	6.0	7.0	N/A
	14"	13.0	7.0	10.0	N/A
	16"	17.0	9.0	12.0	N/A



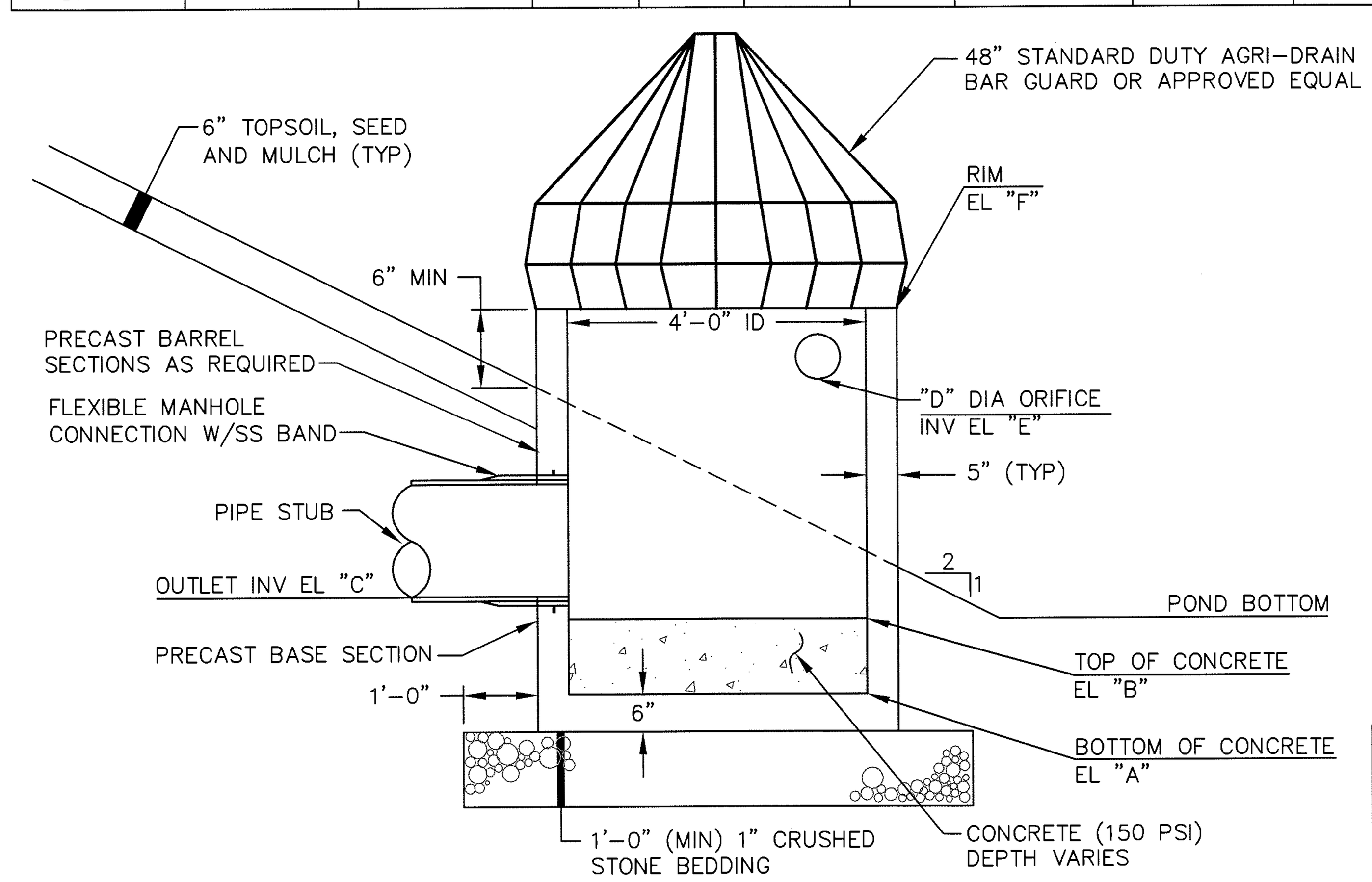
TYPICAL THRUST BLOCK PLACEMENT ON BENDS
NTS



TYPICAL THRUST BLOCK PLACEMENT ON TEES
NTS

OUTLET CONTROL STRUCTURE SCHEDULE

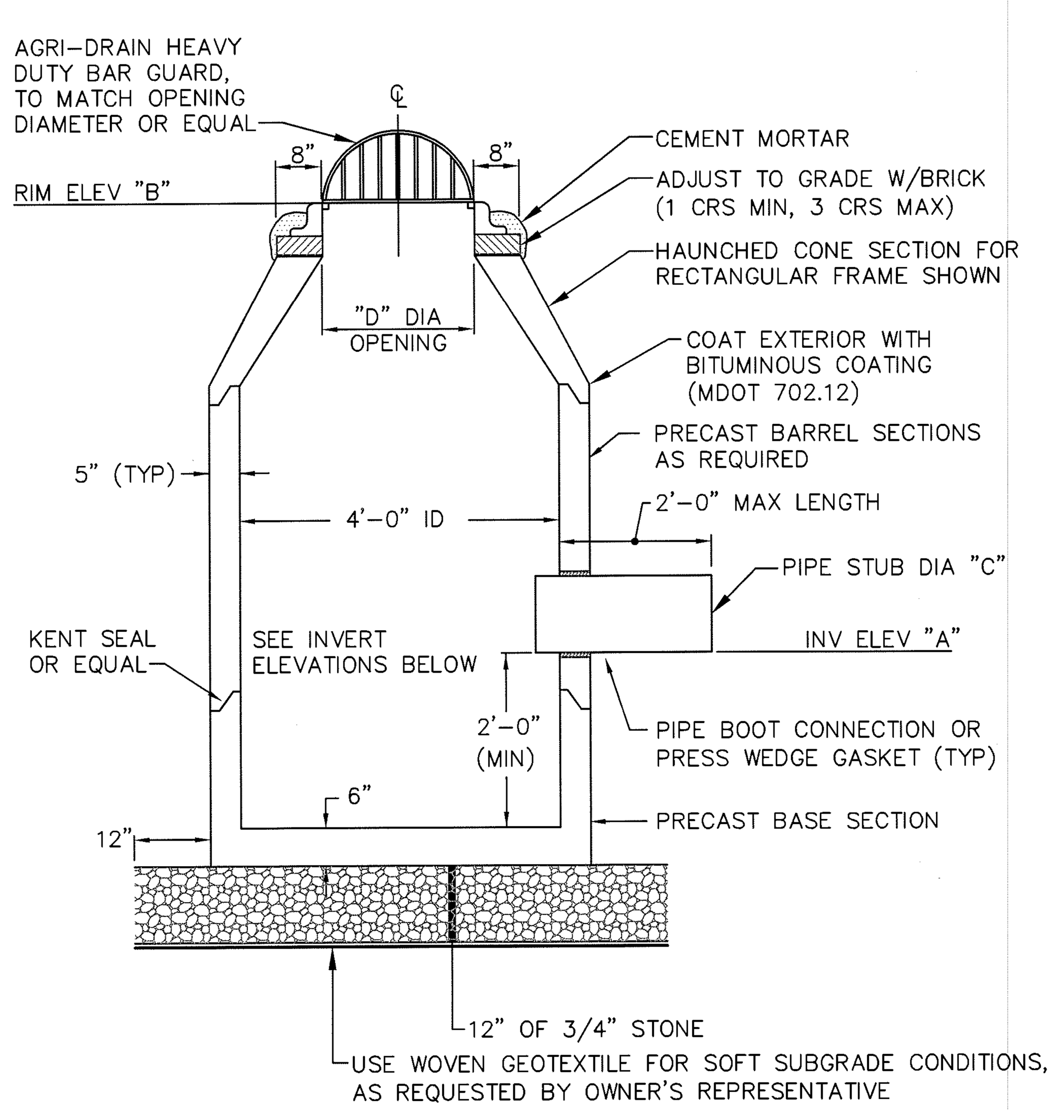
STRUCTURE DESIGNATION	BOTTOM OF CONCRETE EL "A" (FT)	TOP OF CONCRETE EL "B" (FT)	OUTLET INV EL "C" (FT)	ORIFICE DIA "D" (IN)	ORIFICE INV EL "E" (FT)	RIM EL "F" (FT)	OUTLET (C) CULVERT DIAMETER (IN)	CULVERT LENGTH (FT)	CULVERT SLOPE (FT/FT)
DP-10	174.2	174.7	175.2	6	178.3	179.0	18 HDPE	52	0.06
DP-11	163.5	164.0	164.3	6	167.5	168.4	18 HDPE	92	0.03
DP-12	183.5	184.0	184.5	8	186.8	188.0	18 HDPE	80	0.06



OUTLET CONTROL STRUCTURE
NTS

CATCH BASIN SCHEDULE A

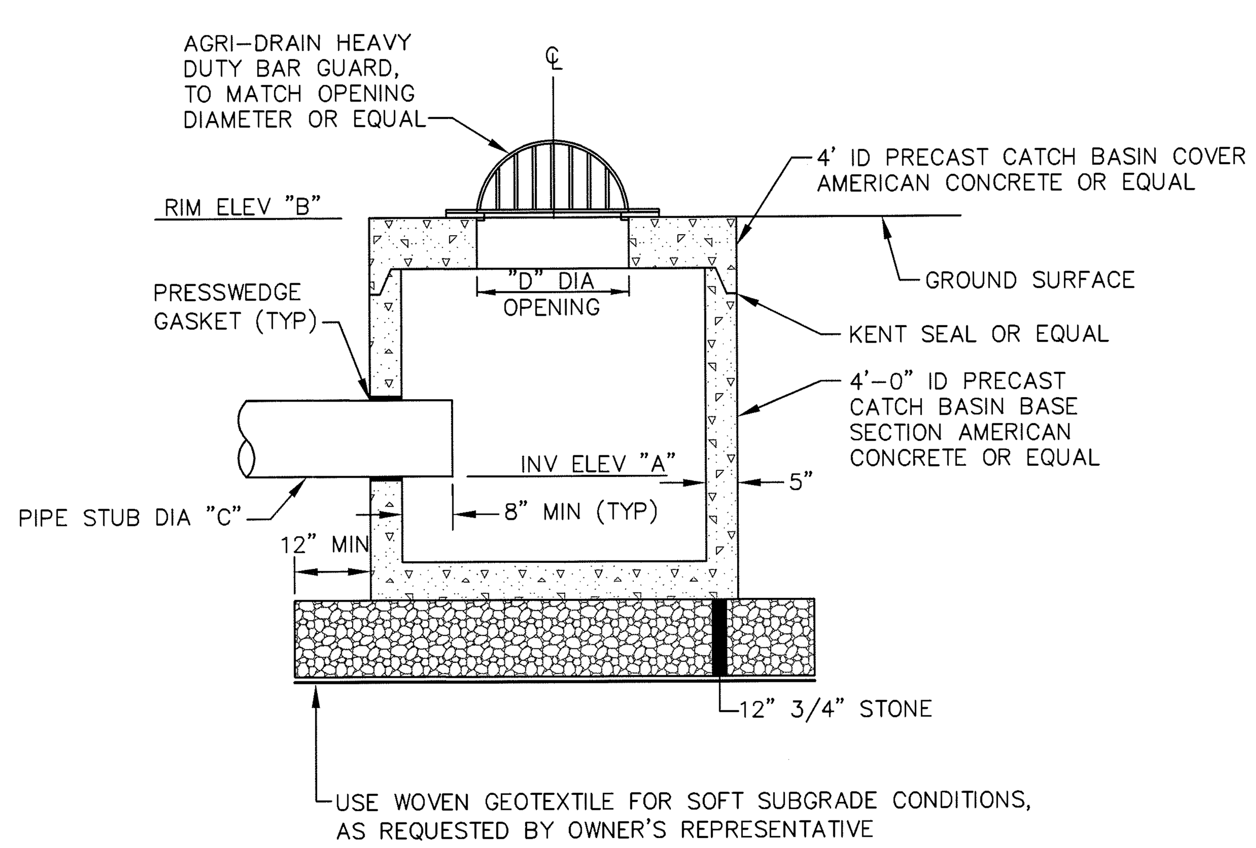
CATCH BASIN DESIGNATION	PIPE INV EL "A" (FT)	RIM EL "B" (FT)	PIPE DIA "C" (IN)	TOP OPENING DIA "D" (IN)
CB-2BB	195.0	200.2	24"	30"
CB-4G	175.0	181.0	24"	24"
CB-4HB	178.5	183.4	18"	24"
CB-4I	202.5	207.6	18"	24"
CB-4JA	214.0	218.7	18"	24"



CATCH BASINS 2BB, 4G, 4HB, 4I, & 4JA
NTS

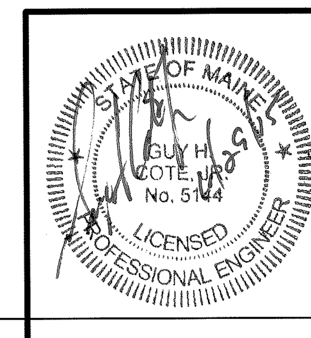
CATCH BASIN SCHEDULE B

CATCH BASIN DESIGNATION	PIPE INV EL "A" (FT)	RIM EL "B" (FT)	PIPE DIA "C" (IN)	TOP OPENING DIA "D" (IN)
CB-4K	216.5	220.0	24"	30"
CB-4L	213.0	215.0	18"	24"



CATCH BASINS 4K & 4L
NTS

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION



JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SECTIONS AND DETAILS

SME
Sevee & Maher Engineers, Inc.
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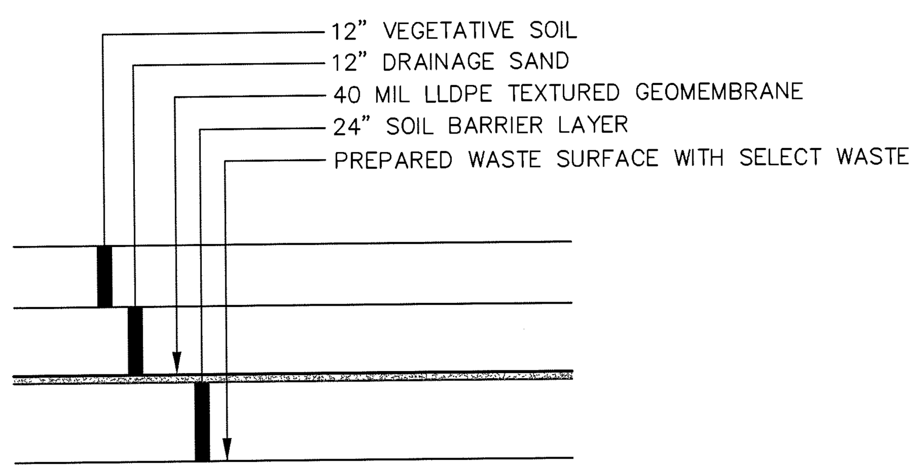
Phone 207.829.5016 • Fax 207.829.5692 • www.smemaine.com

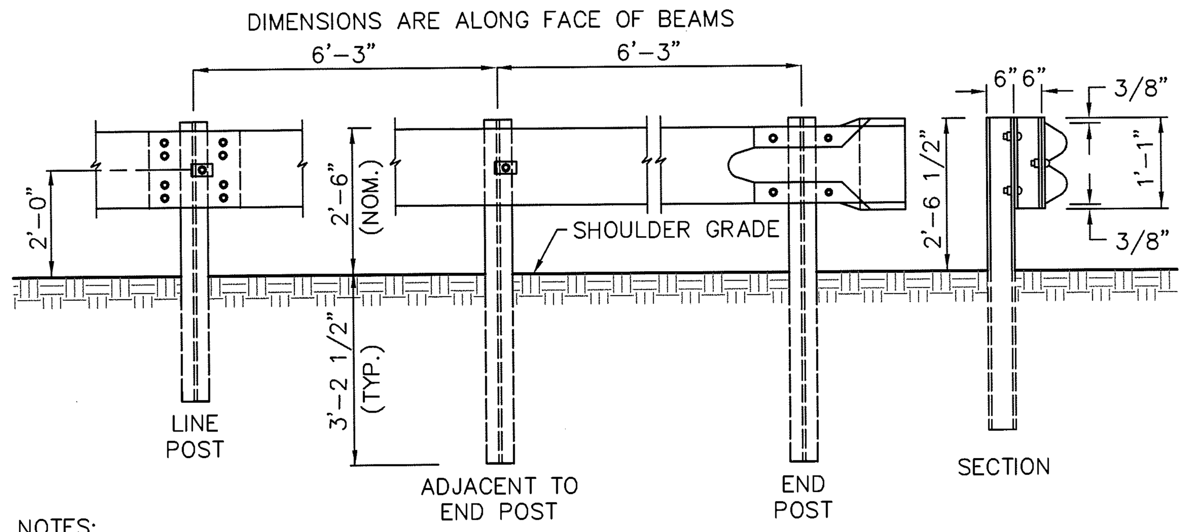
DESIGN BY: PCM
DRAWN BY: SJM
DATE: 12/5/2014
CHECKED BY:
LMN: NONE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE DETAILS

C-306

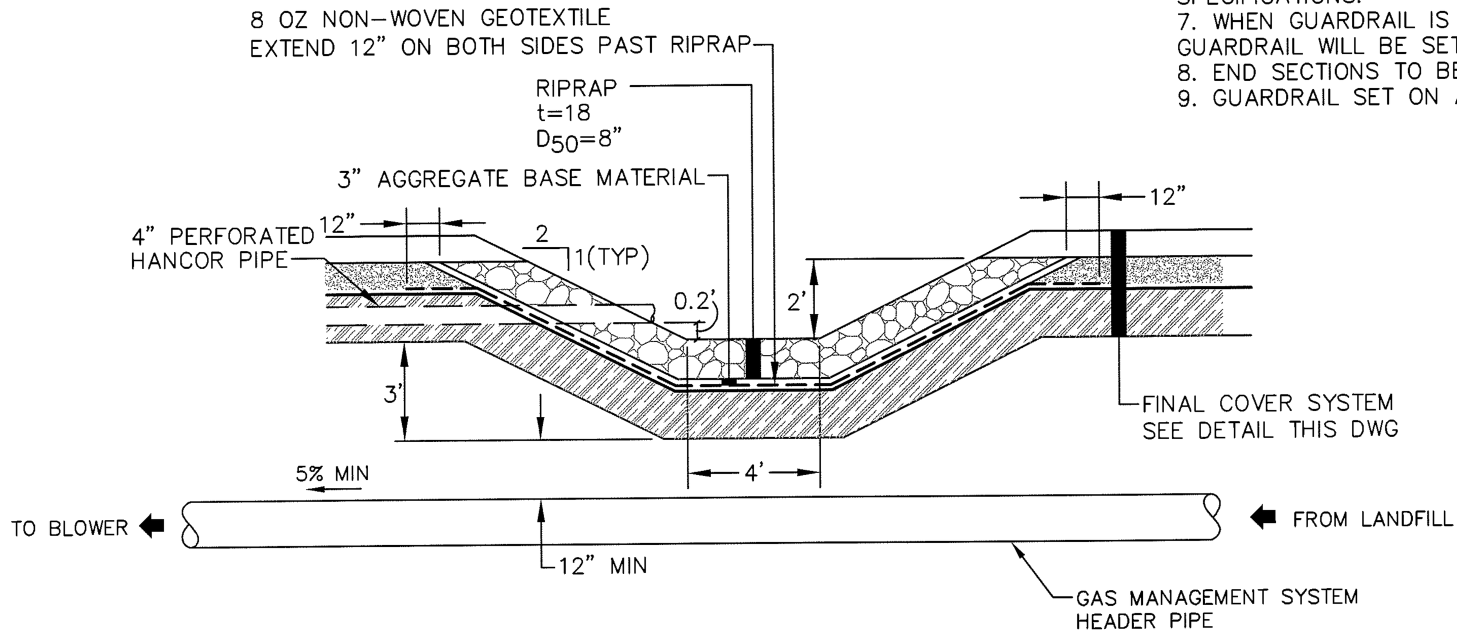


FINAL COVER SYSTEM
NTS

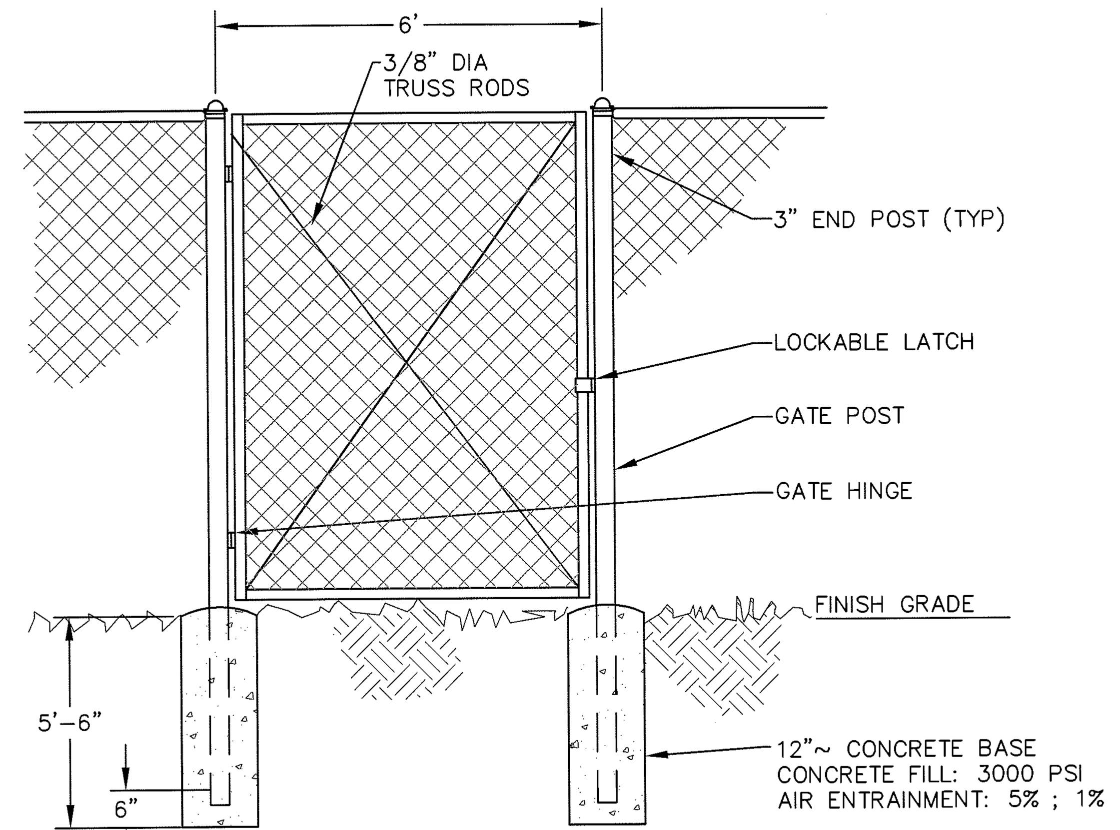


NOTES:
1. INTERMEDIATE POST SPACING SHALL BE 6'-3" UNLESS OTHERWISE SHOWN.
2. POST AND OFFSET BRACKETS SHALL BE 4"x 6" I-BEAM 8.5 OR 9.0 LBS/FT. LENGTH OF 5'-9" ATTACHED WITH 5/8" DIA BOLTS WITH HEX NUTS.
3. ALL HOLES IN BEAM TO BE SHOP-PUNCHED PRIOR TO GALVANIZING.
4. RAIL PANELS AND END SECTIONS TO BE 12 GAUGE STEEL.
5. BACK-UP PLATE TO BE PLACED BEHIND RAIL ELEMENTS AT INTERMEDIATE STEEL POSTS (NON-SPLICE POSTS).
6. ALL PARTS SHALL CONFORM TO CURRENT MAINE DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS.
7. WHEN GUARDRAIL IS CONSTRUCTED AT UP TO FOUR FEET FROM THE EDGE OF PAVEMENT, THE GUARDRAIL WILL BE SET FROM THE GRADE AT THE FACE OF RAIL.
8. END SECTIONS TO BE IN ACCORDANCE WITH MAINE DEPARTMENT OF TRANSPORTATION STANDARDS.
9. GUARDRAIL SET ON A RADIUS OF 150 FEET OR LESS TO BE CIRCULAR.

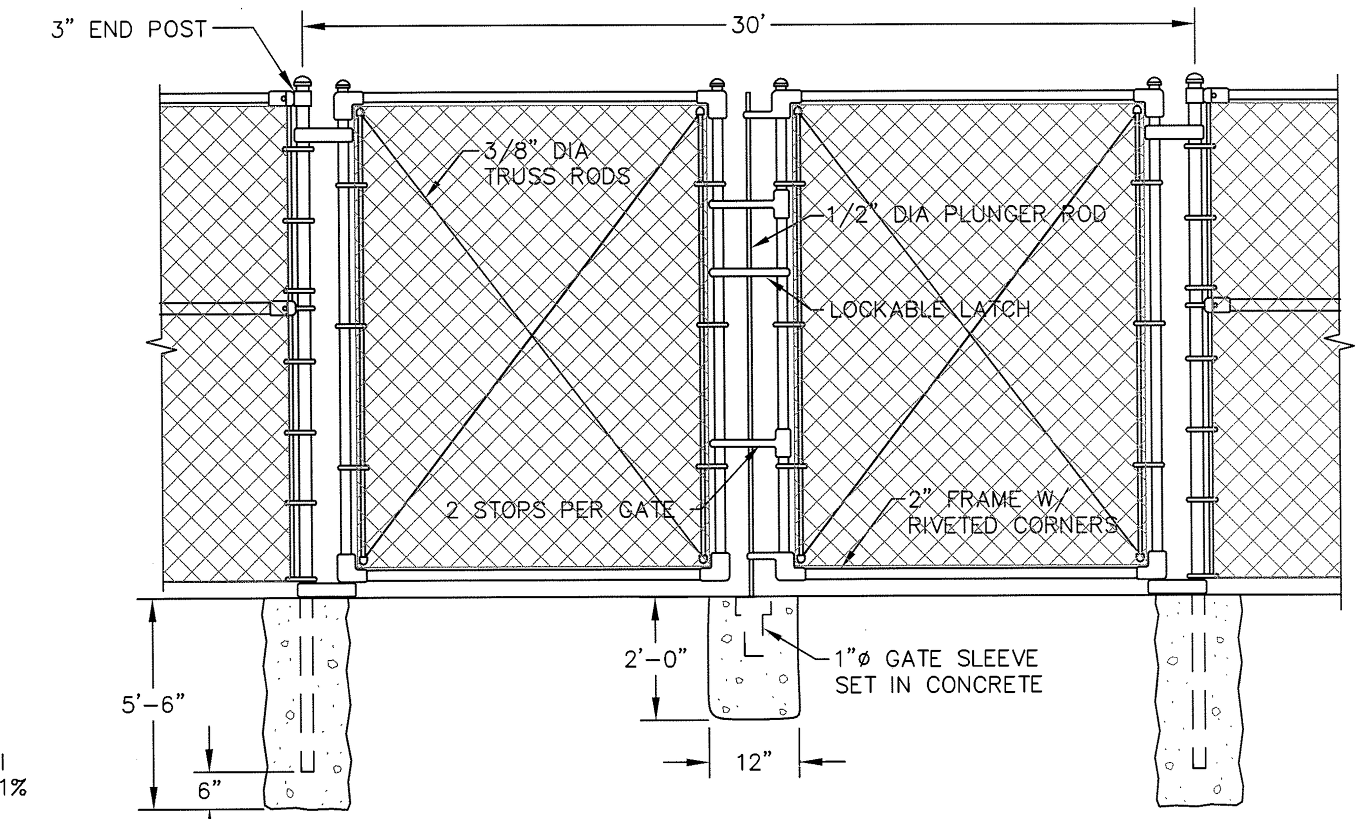
GUARDRAIL
NTS



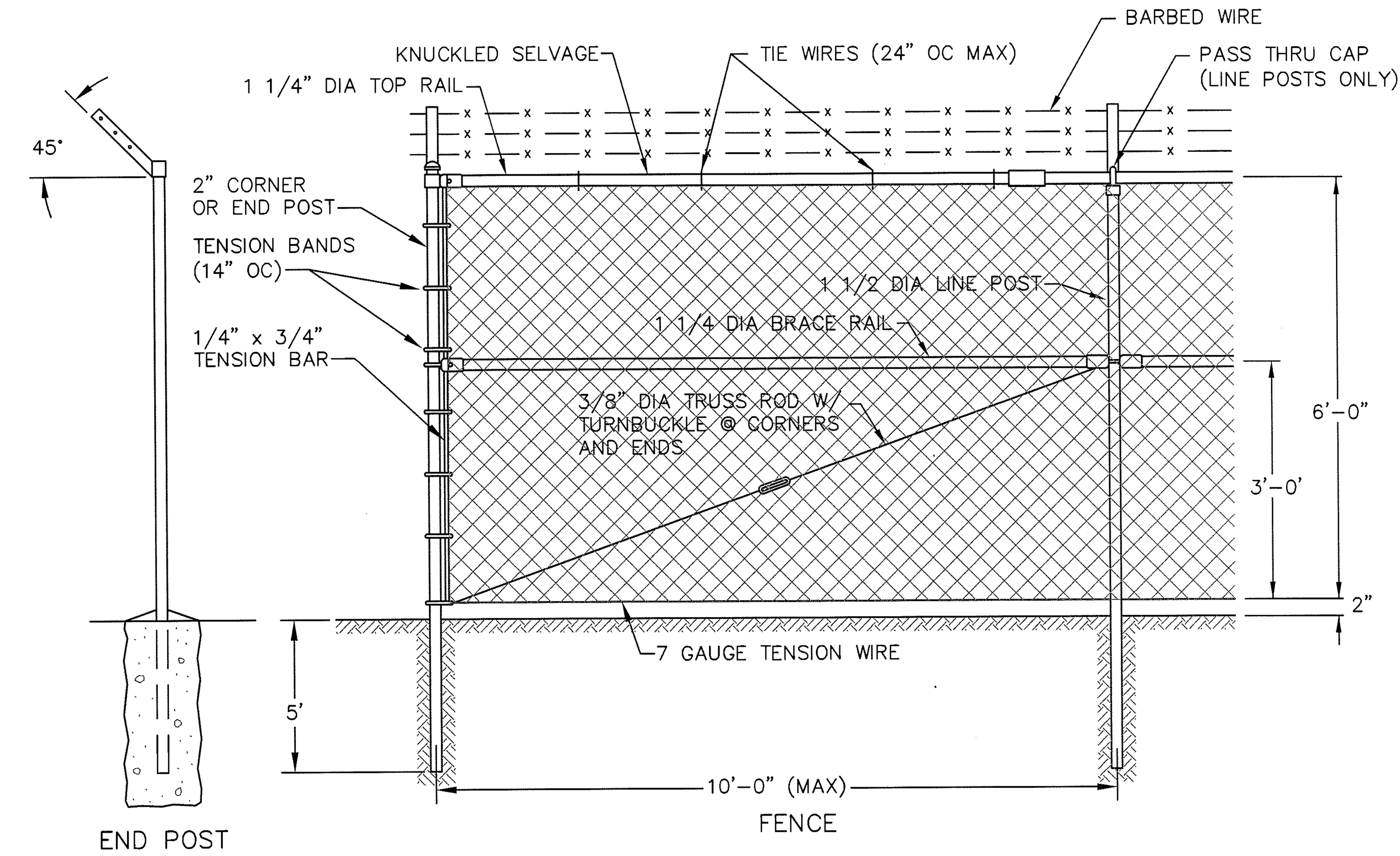
RIPRAP DOWN SPOUT
NTS



CHAIN LINK FENCE PEDESTRIAN GATE
NTS

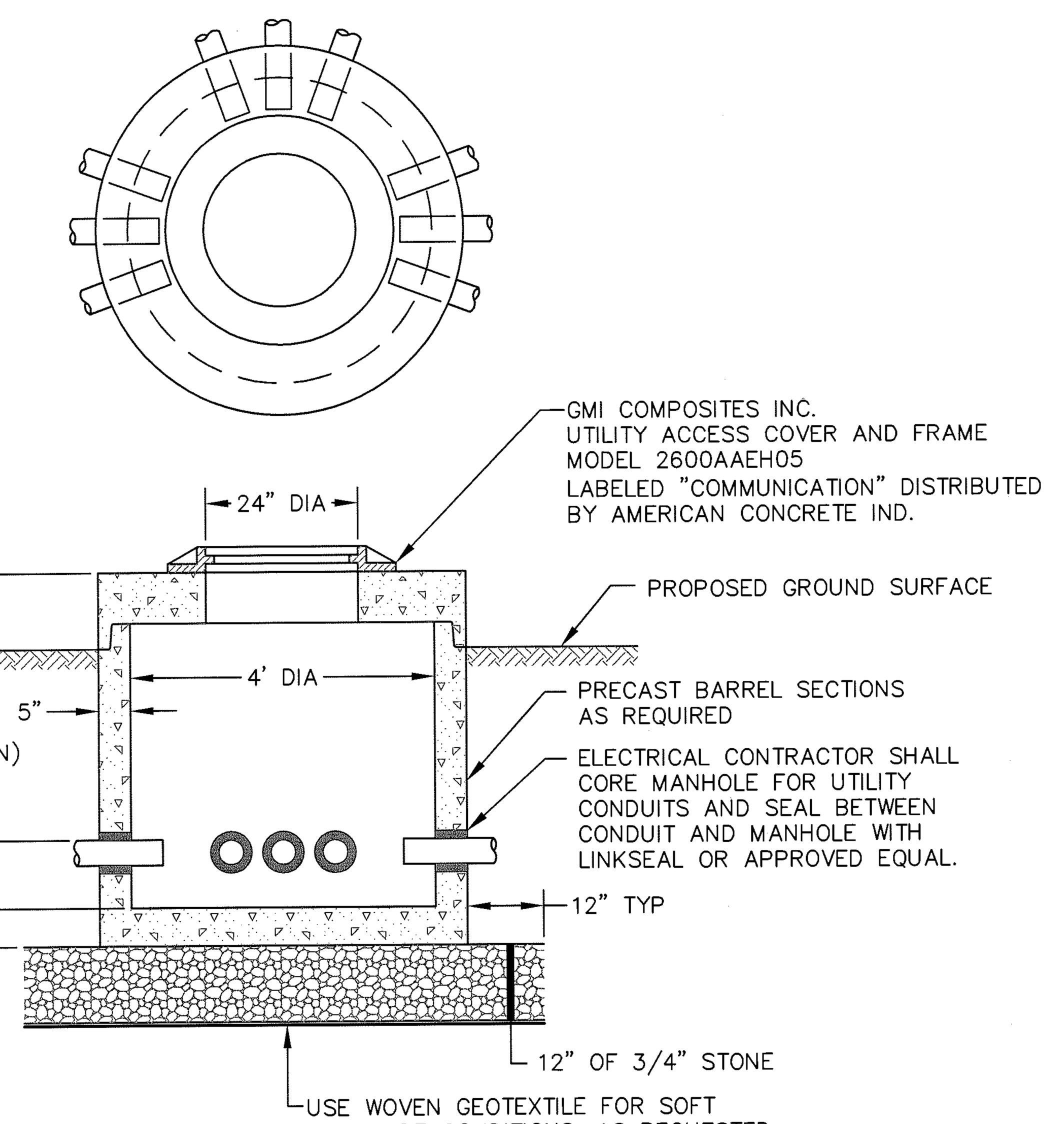


DOUBLE SWING GATE
NTS



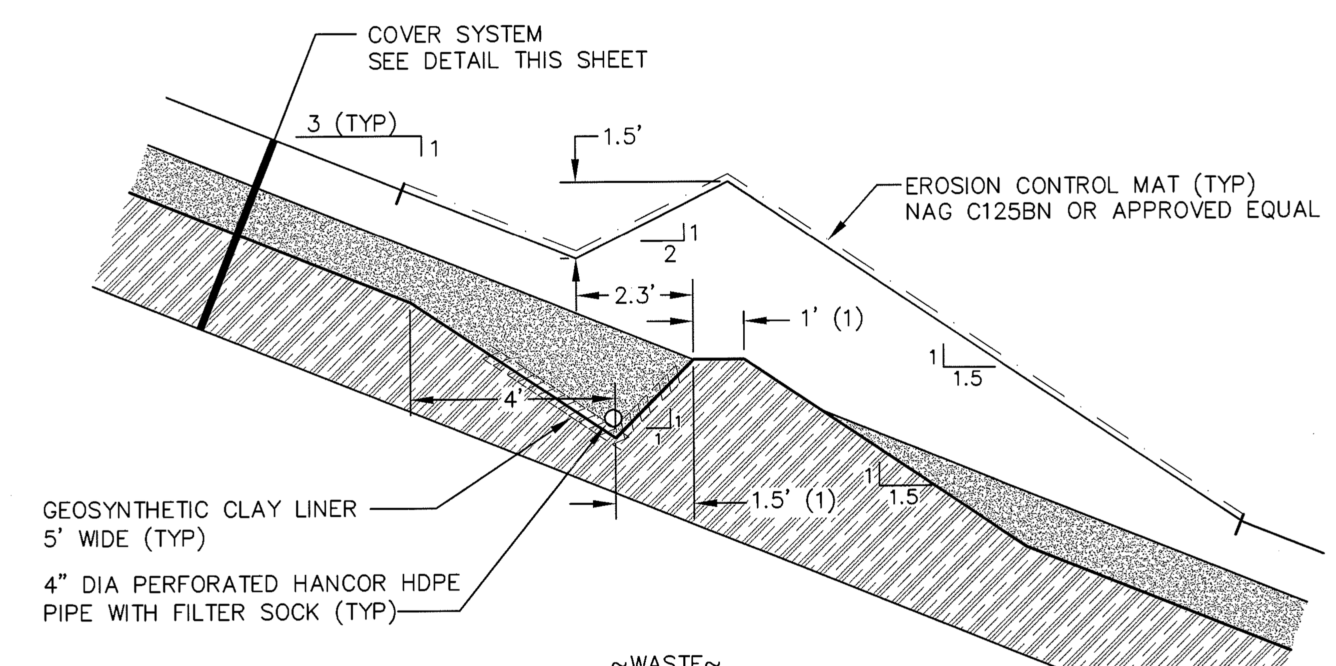
NOTES:
1. END OR CORNER POSTS: NOM 2" DIA GALV STL PIPE, MIN 3.65 LB/LF OR 2 1/4" x 2" "H" SECTION, 4.10 LB/LF, OR 3 1/2" x 3 1/2" "L" SECTION WITH INTEGRAL FABRIC LOOPS 5.14 LB/LF.
2. LINE POSTS: NOM 1 1/2" DIA GALV STL PIPE, MIN 2.72 LB/LF OR 1 7/8" x 1 5/8" "H" SECTION, 2.70 LB/LF, OR 1 7/8" x 1 5/8" "C" SECTION, 2.28 LB/LF.
3. TOP & BRACE RAILS: NOM 1 1/4" DIA GALV STL PIPE, MIN 2.27 LB/LF OR 1 5/8" x 1 1/4" "⊓" SHAPED, ROLLED FORMED SECTION.
4. STRETCHER BARS: LENGTH TO BE 1" LESS THAN FULL HEIGHT OF FABRIC. ONE STRETCHER BAR FOR EACH GATE AND END POST, AND TWO STRETCHER BARS FOR CORNER AND BRACING.
5. CLEARING LIMIT 10 FEET EACH SIDE OF FENCE.

CHAIN LINK FENCE
NTS



NOTES:
1. 4' DIA MANHOLE AS MANUFACTURED BY AMERICAN CONCRETE INDUSTRIES OR ENGINEER APPROVED EQUAL.
2. 4000 PSI CONCRETE AT 28 DAYS.
3. DESIGNED FOR H-20 WHEEL LOADING.
4. CONFORMS TO ASTM C-478 SPECIFICATIONS.
5. REINFORCED TO 0.12 IN SQ/LF.
6. SHIPLAP JOINTS SEALED WITH BUTYL RUBBER.
7. EXTERIOR COATED WITH ASPHALTIC PROTECTIVE DAMPROOFING.
8. BOTTOM MIN 5'-0" BELOW FINISH GRADE.
9. PRECAST CONCRETE VAULT MANUFACTURER TO PROVIDE ANTI-FLOATATION EXTENDED BASE SLAB AS NECESSARY. ANTI-FLOATATION DESIGN AND SHOP DRAWINGS SHALL BE PREPARED BY THE MANUFACTURER AND SUBMITTED TO THE ENGINEER FOR APPROVAL.

COMMUNICATION UTILITY MANHOLE
NTS



TERRACE DRAINAGE SWALE
NTS

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE — GUY H. COTE, JR. — No. 5140 — LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SECTIONS AND DETAILS

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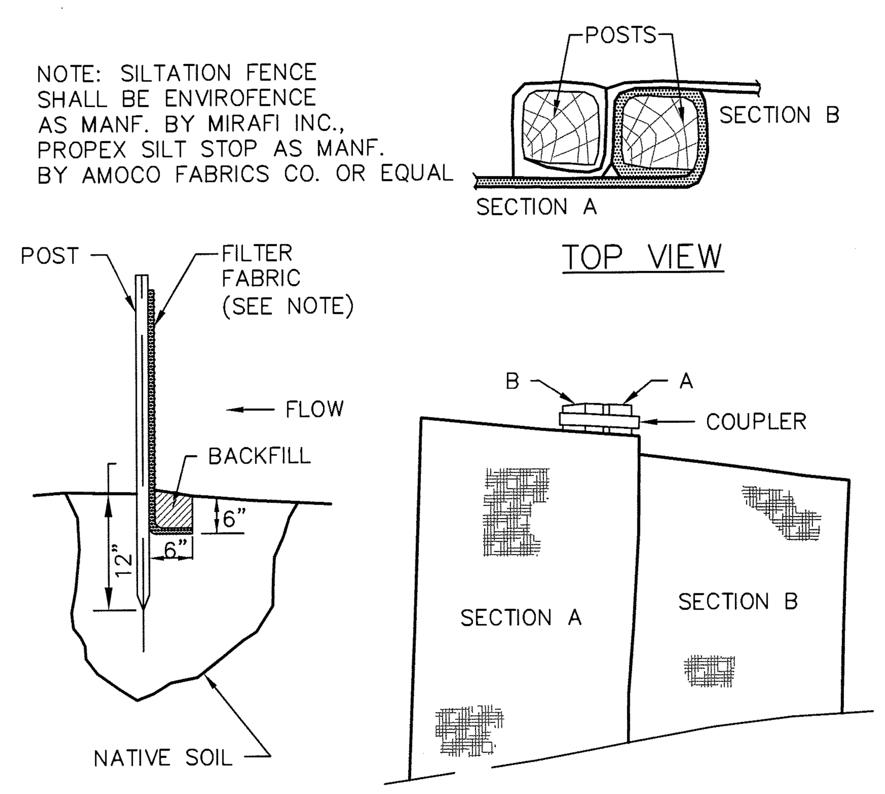
CHECKED BY:
LMN: NONE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE DETAILS

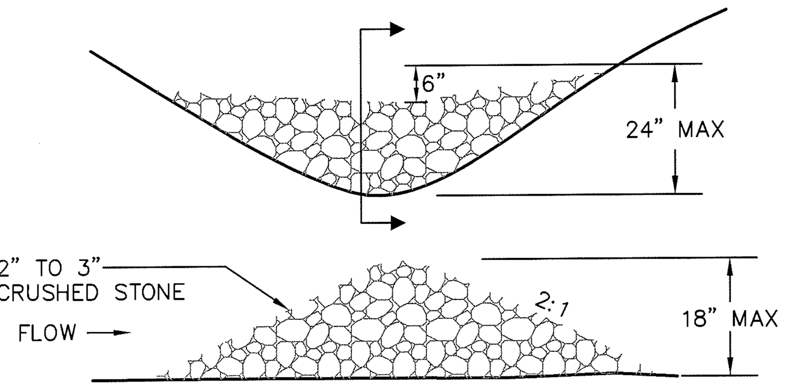
C-307

NOTE: SILTATION FENCE SHALL BE ENVIROFENCE AS MANF. BY MIRAFI INC., PROPEX SILT STOP AS MANF. BY AMOCO FABRICS CO. OR EQUAL

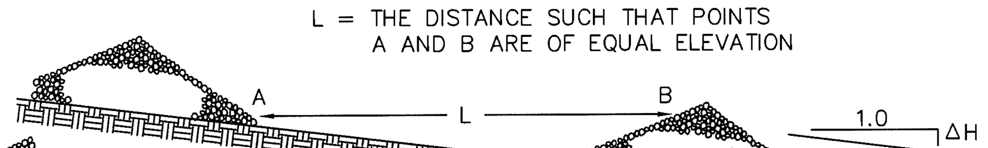


SILTATION FENCE

NTS



L = THE DISTANCE SUCH THAT POINTS A AND B ARE OF EQUAL ELEVATION

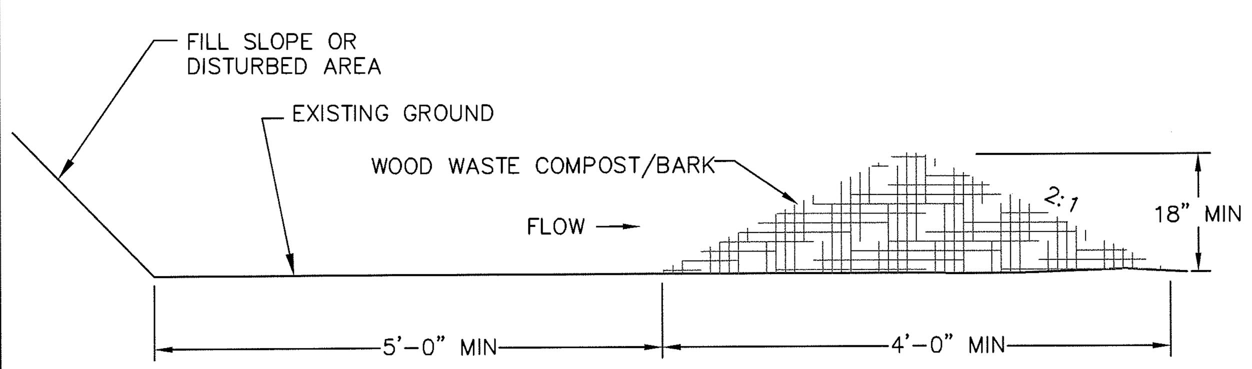


SPACING BETWEEN CHECK DAMS

S_o (FT/FT)	L (FT)
0.020	75
0.030	50
0.040	40
0.050	30
0.080	20
0.100	10

STONE CHECK DAM

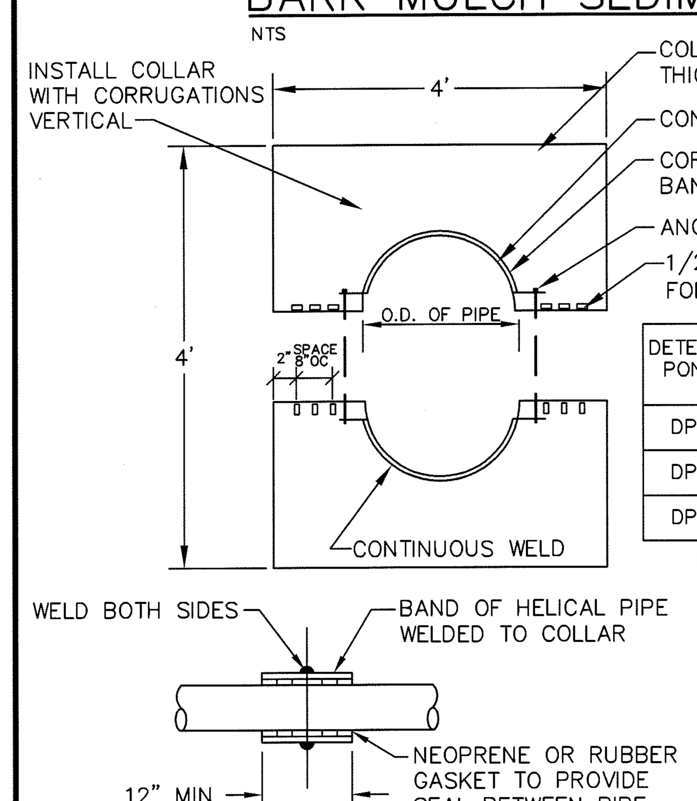
NTS



NOTE:
BARK MULCH SEDIMENT BARRIERS MAY BE USED AS AN ALTERNATE TO SILT FENCE WHEN APPROVED BY THE ENGINEER.

BARK MULCH SEDIMENT BARRIER

NTS

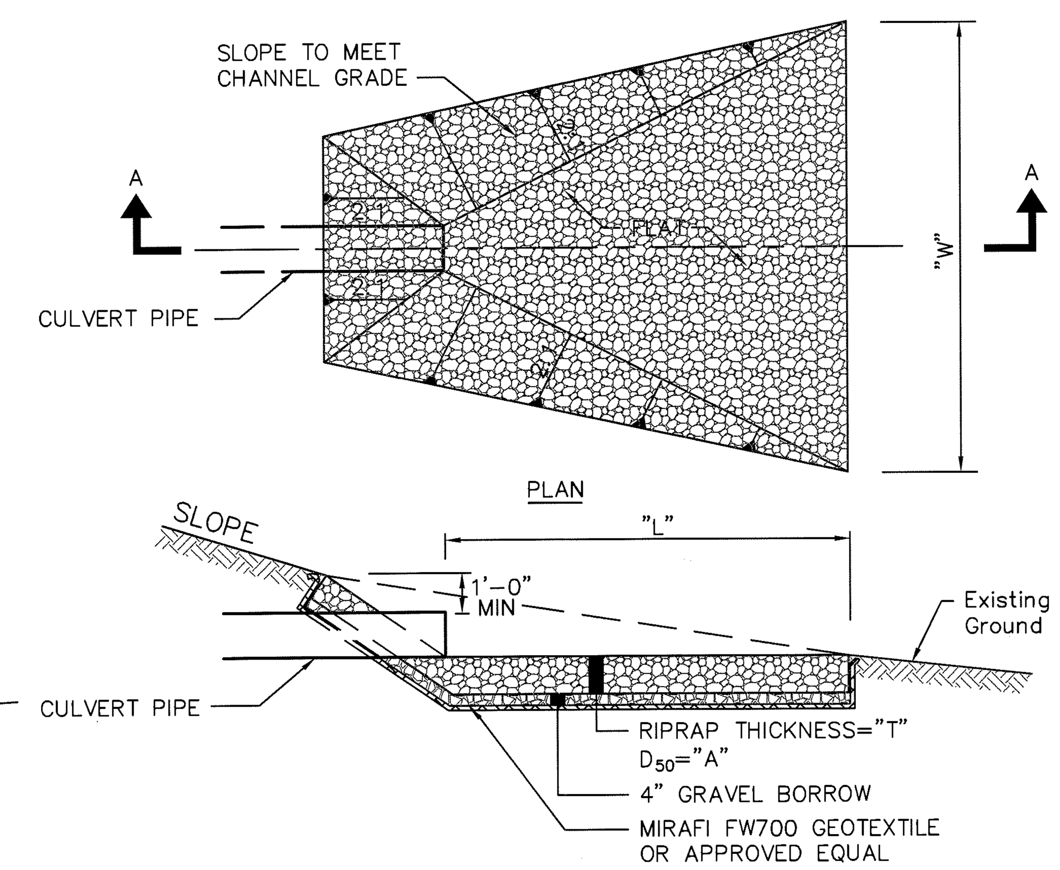


DETENTION POND #	OUTLET PIPE DIA (IN)	PIPE LENGTH (FT)	SATURATED LENGTH (FT)	# OF COLLARS	SPACING (FT)
DP-10	18	70	32	2	11
DP-11	18	92	30	2	10
DP-12	18	80	31	2	10

NOTES:
1. UNASSEMBLED COLLAR SHALL BE MARKED BY PAINTING OR TAGGING TO IDENTIFY MATCHING PARTS.
2. THE LAP BETWEEN THE TWO HALF SECTIONS AND BETWEEN THE PIPE AND CONNECTING BAND SHALL BE CAULKED WITH ASPHALT MASTIC AT TIME OF INSTALLATION.
3. RIPLEY'S DAM BY MCRIP MANUFACTURING MAY BE USED WITH ENGINEERS APPROVAL PROVIDING THAT LENGTH AND WIDTH OF COLLAR IS EQUAL TO OR GREATER THAN THAT SPECIFIED IN THE DETAIL.

ANTI-SEEP COLLAR

NTS

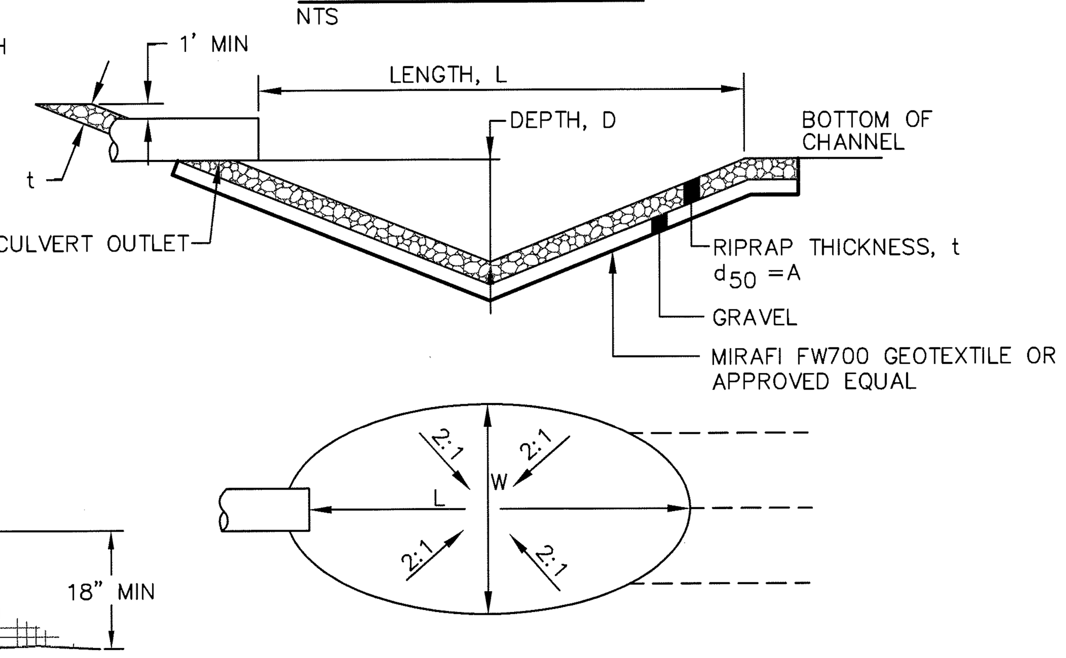


SECTION A–A

CULVERT OUTLET	L (FT)	W (FT)	A (d_{50}) IN.	t (IN)
2BA	18	20	8	18
2BB	18	20	6	14
4BA	12	14	5	12
4BB	12	14	5	12
4F	10	12	4	9
4G	12	14	5	12
4HA	10	12	4	9
4HB	10	12	4	9
4I	18	20	10	23
4IA	10	12	4	9
4JA	18	20	10	23
4JB	12	14	5	12
4JC	12	14	5	12
4K	12	14	5	12
4L	14	16	8	18
4N	10	12	4	9

RIPRAP APRON

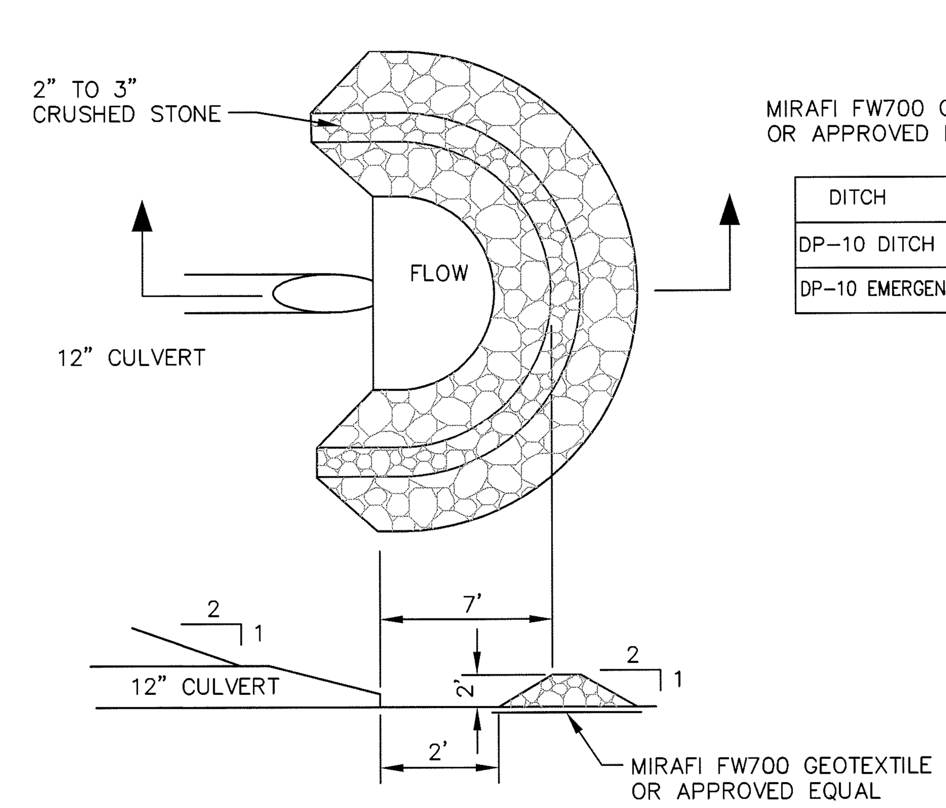
NTS



CULVERT OUTLET	L (FT)	W (FT)	A (d_{50}) IN.	t (IN)	D (FT)
DP-10	6	6	8	18	1.5
DP-11	6	6	4	9	1.5
DP-12	6	6	4	9	1.5

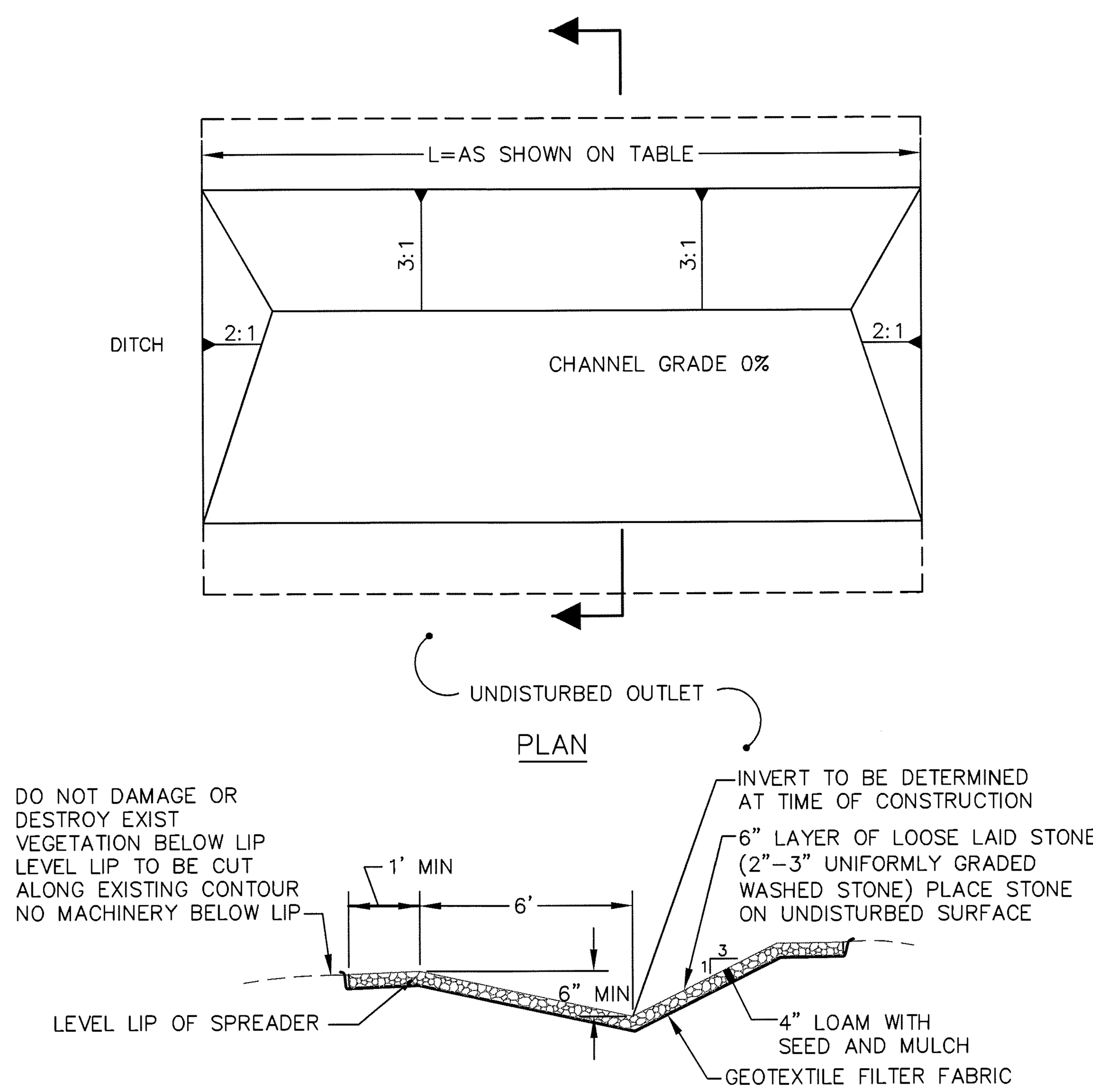
RIPRAP PLUNGE POOL

NTS



RIPRAP CULVERT INLET PROTECTION (TEMPORARY)

NTS

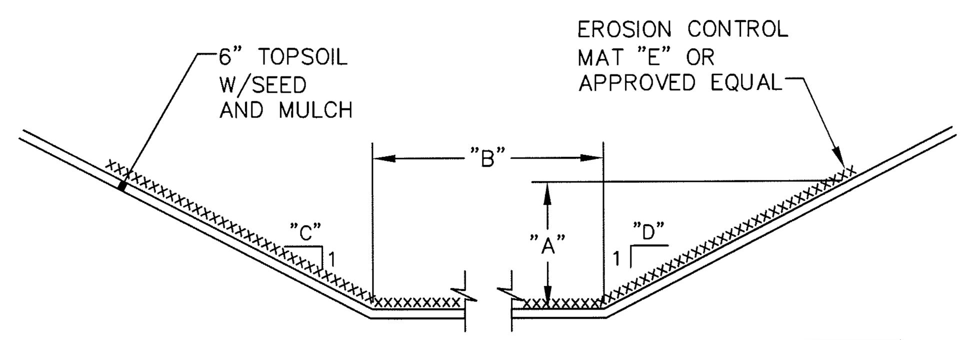


NOTES:
1. CONSTRUCT LEVEL LIP ON ZERO PERCENT GRADE TO INSURE UNIFORM SPREADING OF SEDIMENT – FREE RUNOFF (CONVERTING CHANNEL FLOW TO SHEET FLOW).
2. LAST 20 FT OF DRAINAGE DITCH NOT TO EXCEED 1% GRADE

LEVEL SPREADER	LENGTH, L (FT)
DP-10	20
DP-11	15
DP-12	15

LEVEL SPREADER

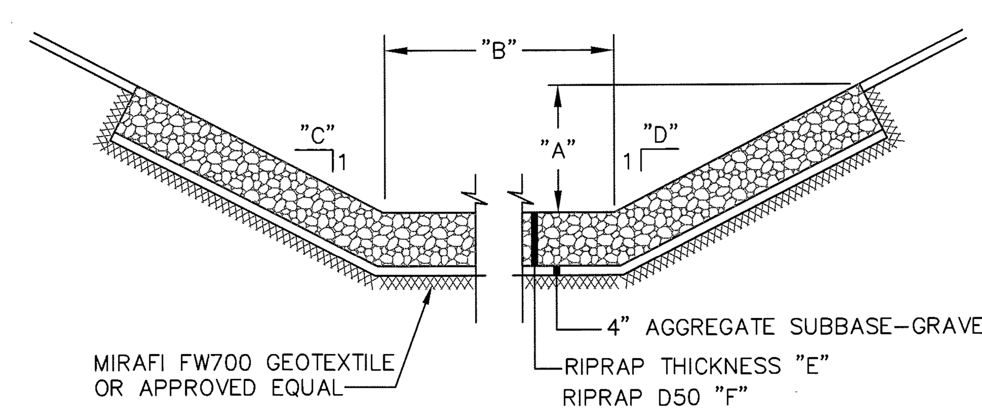
NTS



DITCH	"A"	"B"	"C"	"D"	"E"
TOE DITCH	2'	2'	2'	2'	NAG S75
DP-10 DITCH SEGMENTS 1 & 2	2'	2'	2'	2'	NAG S75
DITCH 4B-1	2'	2'	2'	2'	NAG S75
MAINTENANCE ROAD DITCH	3'	2'	2'	2'	NAG S75

GRASS DITCH

NTS



DITCH	"A"	"B"	"C"	"D"	"E"	"F"
DP-10 DITCH SEGMENT 3	2'	2'	2'	2'	9"	4"
DP-10 EMERGENCY SPILLWAY	2'	10'	2'	2'	9"	4"

RIPRAP DITCH

NTS

EROSION AND SEDIMENTATION CONTROL
TEMPORARY AND PERMANENT

A. GENERAL

1. Soil erosion and sediment control will be done in accordance with the Maine Erosion and Sediment Control: Best Management Practices, Maine Department of Environmental Protection, March 2003.

2. The contractor will be responsible for the repair/replacement/maintenance of all erosion control measures until all disturbed areas are stabilized.

3. Disturbed areas will be permanently stabilized within 7 days of final grading. Disturbed areas not to be worked upon within 14 days of disturbance, shall be temporarily stabilized within 7 days of the disturbance.

4. Removal of trees, bushes and other vegetation, as well as disturbance of topsoil will be kept to a minimum while allowing proper site operations.

5. Suitable topsoil will be stripped and stockpiled for reuse in final grading. Topsoil will be stockpiled in a manner such that natural drainage is not obstructed and no off-site sediment damage will result. If a stockpile is necessary, the side slopes of the topsoil stockpile will not exceed 2:1. Silt fence will be installed around the perimeter of all topsoil stockpiles. Topsoil stockpiles will be temporarily seeded with Aroostook rye, annual or perennial ryegrass, within 7 days of formation, or temporarily mulched if seeding cannot be done within the recommended seeding dates. Recommended seeding dates and application rates are as follows:

* Aroostook Rye: Recommended Seeding Dates: 9/15 – 11/1
  Application Rate: 112 lbs/acre

* Annual Ryegrass: Recommended Seeding Dates: 4/1 – 7/1
  Application Rate: 40 lbs/acre

* Perennial Ryegrass: Recommended Seeding Dates: 8/15 – 9/15
  Application Rate: 40 lbs/acre

Mulch:

o Hay or Straw: Application Rate: 1.5 – 2.0 tons/acre. Anchor with mulch netting (installed per manufacturer's recommendations)

o Wood Fiber Cellulose: Application Rate: 4,000 lbs/acre. Anchoring nat required

B. TEMPORARY MEASURES

1. Silt Fence

(a) Silt fence will be installed prior to and downgradient of all construction activity where soil disturbance may result in erosion.

(b) The height of a silt fence will not exceed 36 inches.

(c) Unless a prefabricated system is utilized, the filter fabric will be purchased in a continuous roll cut to the length of the barrier to avoid the use of joints. When joints are necessary, filter cloth will be spliced together only at a support post, with a minimum 6-inch overlap, and securely sealed.

(d) Posts will be spaced a maximum of 10 feet apart at the barrier location and driven securely into the ground (minimum of 12 inches). When extra strength fabric is used without the wire support fence, post spacing will not exceed 6 feet.

(e) A trench will be excavated approximately 6 inches wide and 6 inches deep along the line of posts and upgradient from the barrier.

(f) The fabric will not extend more than 36 inches above the original ground surface. Filter fabric will not be stapled to existing trees.

(g) When extra strength filter fabric and closer post spacing are used, the wire mesh support fence may be eliminated. In such a case, the filter fabric will be stapled or wired directly to the posts with all other provisions of item (f) applying.

(h) The trench will be backfilled and the soil compacted over the filter fabric.

(i) Silt fences will be removed when they have served their useful purpose, but not before the upgradient areas have been permanently stabilized.

(j) Silt fences will be inspected immediately after each rainfall, which exceeds 1 inch in a 24-hour period, and at least daily during prolonged rainfall. If there are any signs of erosion or sedimentation below them, appropriate repairs will be made. If there are signs of undercutting at the center or the edges, or impounding of large volumes of water behind them, they will be replaced with a temporary crushed stone check dam.

(k) Should the fabric on a silt fence decompose or become ineffective prior to the end of the expected usable life, and the barrier still be necessary, the fabric will be replaced promptly.

(l) Sediment deposits should be removed after each storm event if significant buildup has occurred or if deposits exceed 15 inches in depth.

(m) In lieu of providing the 4" x 4" trench for conditions of frozen ground, severe rocky soil or hummucky conditions with large roots, or other prohibitive conditions. A wood waste compost/bark mulch filler berm may be used in such situations.

2. Stone Check Dams

(a) Stone check dams should be constructed of 2 to 3 inch stone. The stone should be placed according to the configuration shown on the detail. Hand or mechanical placement will be necessary to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges.

(b) Check dams should be installed as the swale is being constructed.

(c) Sediment will be removed from behind the check dams when it has accumulated to one half of the original height of the dam.

(d) Check dams will be removed when the grass has matured sufficiently to protect the ditch or swale. The area beneath the check dams will be seeded and mulched immediately after the check dams are removed.

(e) Regular inspections will be made to ensure that the center of the dam is lower than the edges. Erosion caused by high flows around the edges of the dam will be corrected. If evidence of siltation in the water is apparent downstream from the check dam, the check dam will be inspected and adjusted. Check dams will be checked for sediment accumulation after each significant rainfall.

CONSTRUCTION SEQUENCE

1. Construct temporary sediment and erosion control facilities. Erosion and sediment measures shall be installed prior to any earth moving operation in the area of work.
2. All permanent ditches are to be stabilized with vegetation or stone check dams prior to directing runoff to them.
3. Inspect and maintain all erosion and sediment control measures.
4. Complete permanent erosion control measures which may include seeding, mulching, and landscaping.
5. Remove all temporary erosion control measures.
6. Each stage will be stabilized prior to initiating the next stage.
7. Any exposed areas will be hay mulched prior to winter shutdown, if necessary.

EROSION CONTROL MEASURES

1. The smallest practical area of land shall be exposed to construction at any one time.
2. The temporary erosion control measures shall be maintained until permanent erosion control measures are present.
3. All areas disturbed by construction shall have available loam placed before seeding (or an acceptable alternative).
4. After construction is terminated, all temporary erosion control measures shall be removed and accumulated sediment disposed of in a secure location.
5. Mulch shall be mowings of acceptable herbaceous growth, free from noxious weeds or woody stems, and shall be dry.

3. Wood Waste Compost/Bark Mulch Filter Berms

(a) The filter berm shall consist of an approved wood waste compost/bark mulch mix or recycled composted bark flume grit and fragmented wood generated from water-flume log handling systems or small shredding of stumpage (6 inches long x 1/2" dia.). The mixture needs to be a well-graded blend of organic and mineral substance. The composition is usually manufactured on or off site and by blending it with a well graded sand and gravel. The objective is a tight, heavy, non-erodible mixture that is not composed of one uniform material, i.e. just bark mulch will not suffice. Comparable composted mixes can be used upon approval of the Department of Environmental Protection, Bureau of Land and Water Quality.

(b) The mix shall conform to the following standards:

* Moisture Content 30 – 60%
* PH-5.0-8.0
* Screen Size – 100% less than 3" max.; 70% less than one inch.
* No less than 40% organic material (dry weight) by loss of ignition.
* No stones larger than 2 inch diameter.
* Silts, clays or sugar sands are not acceptable in the mix.

(c) Installation and Size of Berm:

The dimensions of the berm are more a function of the strength of the material than the flows (forces) it will encounter. At a minimum the berm shall be 4 feet wide and 18 inches high. The berm shall be placed, uncompacted along a relatively level contour. Wherever possible the existing surface must be scoured and the mixture keyed in like any other sediment control measure.

(d) Maintenance:

All deficiencies shall be immediately corrected with additional material place on top of the berm to reach the desired height. When the berm is decomposed, clogged with sediment, eroded, or becomes ineffective, it shall be replaced.

(e) Clean up and Retrieval:

At the end of the job, an erosion control berm shall be removed or spread out so that the native earth can be seen below.

(f) Rock Filter Berms

To provide more filtering capacity or to act as a velocity check dam, a berm's center can be composed of clean crushed rock ranging in size from the French drain stone to riprap. The rocks shall be laid on geotextile to facilitate removal and the geotextile shall be wrapped over the core layer of stone and then covered with another layer of erosion control mix. The center core of stone shall be approx. 12 inches high or two-thirds the height of the filter berm. Rock filter berms shall be a minimum of 18 inches high by 4 feet wide.

4. Stabilized Construction Entrance

(a) Aggregate size: Use 2 inch stone, or reclaimed or recycled concrete equivalent.

(b) Aggregate thickness: Not less than eight inches.

(c) Width: 16 foot minimum, but not less than the full width of where ingress or egress occurs.

(d) Length: as required, but not less than 50 feet.

(e) Geotextile: To be placed over the entire area to be covered with aggregate. Piping of surface water under entrance shall be provided as required. All piping is impossible, a mountable berm with 5:1 slopes will be permitted.

(f) Criteria for Geotextile: The filter cloth shall be woven or NON-WOVEN fabric consisting only of continuous chain polymeric filaments or yards of polyester. The fabric shall be inert to commonly encountered chemicals, hydrocarbons, mildew and rot resistant.

(1) Acceptable materials are Trivira Spunbound 1135, Mirafi 600X, or equivalent.
(2) Fabrics not meeting these specifications may be used only when design procedure and supporting documentation are supplied to determine aggregate depth and fabric strength.

(g) Maintenance: The entrance shall be maintained in a condition which will prevent tracking of sediment onto public rights-of-way. When washing is required, it shall be done in on an area stabilized with aggregate which drains into an approved sediment trapping device. All sediment shall be prevented from entering storm drains, ditches, or waterways.

5. Erosion Control Mats

(a) During the growing season (April 15 to September 15) use mats specified in the drawings or, if not specifically identified, use North American Green S75 or equal or mulch with netting on:

* The base of grassed waterways and steep slopes (>15 percent)
* Any disturbed soil within 100 feet of streams and wetlands.

During the late fall and winter (September 15 to April 15) use heavy grade mats specified in the drawings or, if not specifically specified, use North American Green SC150 or equal on all areas noted above, plus use lighter grade mats or mulch with netting on:

* Sideslopes of grassed waterways
* Moderate slopes (>8 percent)

(2) Install mats in accordance with manufacturers' recommendations.

C. PERMANENT MEASURES

1. Riprapped Aprons and Plunge Pools

(a) Construct riprapped aprons in accordance with the details shown on the drawings.

(b) Stone for riprap will consist of sub-angular field stone or rough unhewn quarry stone. The stone will be hard and of such quality that it will not disintegrate on exposure to water or weathering, be chemically stable and suitable in all other respects for the purpose intended. The bulk specific gravity (saturated surface-dry basis) of the individual stones will be at least 2.5.

(c) The riprap should be placed so that it produces a dense well-graded mass of stone with a minimum of voids. The desired distribution of stones throughout the mass may be obtained by selective loading at the quarry, controlled clumping of successive loads during final placing, or by combination of these methods. The riprap should be placed to its full thickness on one operation. The riprap should not be placed in layers. The riprap should not be placed by dumping into chutes or similar methods which are likely to cause segregation of the various stone sizes. Care should be taken not to dislodge the underlying material when placing the stones.

The finished slope should be free of pockets of small stone or clusters of large stones. Hand placing may be necessary to achieve the required grades and a good distribution of stone sizes. Final thickness of the riprap blanket should be within plus or minus 1/4 of the specified thickness.

(d) Riprap will be inspected periodically to determine if high flows have caused scour beneath the riprap or dislodged any of the stone. If repairs are needed, they should be accomplished immediately.

2. Topsoil, Seed, Mulch

(a) Topsoil: Use stockpiled materials spread to the depths shown on the plans, if available. Approved topsoil substitutes may be used (refer to Section C-2 of Erosion and Sediment Control BMP, see Note 2).

(b) Seeding should be completed by August 15 of each year. Late season seeding may be done between August 15 and September 15. Areas not seeded or which do not obtain satisfactory growth by October 1, will be seeded with Aroostook Rye or mulched at rates previously specified herein. After November 1, or the first killing frost, disturbed areas should be treated as specified in (c) below.

SEEDING SPECIFICATIONS

Permanent Seeding (120 lbs/acre)		Temporary Seeding (120 lbs/acre)
Tall Fescue	54 lbs/acre	(Aroostook Rye 100%)
Red Fescue	25 lbs/acres	
Red Top	5 lbs/acres	
Ladino Clover	13 lbs/acre	
Annual Ryegrass	8 lbs/acre	
Birdsfoot Trefoil	5 lbs/acre	
Timothy	10 lbs/acre	

(2) Fertilizer: Apply 1300 pounds per acre of 10-10-10 fertilizer or equivalent per acre (29.8 lbs/1,000 sq. ft.).

(3) Lime: Apply ground limestone at a rate of 3 tons per acre (138 lbs/1,000 sq. ft.).

(4) Mulch: Mulch with hay or straw at 2.0 – 3.0 tons per acre, or 2-3 bales per 1,000 sq. ft.

Anchor mulch with mulch netting installed per manufacturer's recommendations.

(c) If permanent vegetated stabilization cannot be established due to the season of the year, all exposed and disturbed areas not to undergo further disturbance are to have dormant seeding applied and be temporarily mulched to protect the site. The following methods may be used to perform a dormant seeding:

(1) Prepare the seedbed, add the required amounts of lime and fertilizer, then mulch and anchor. After the first killing frost and before snow fall, broadcast or hydroseed the selected seed mixture. Double the regular seeding rates for this type seeding.

(2) When soil conditions permit, between the first killing frost and before snow fall, prepare the seedbed, lime and fertilize, apply the selected seed mixture, and mulch and anchor. Double the regular seeding rates for this type of seeding.

Dormant seedings need to be anchored extremely well on slopes, ditch bases and areas of concentrated flows.

Dormant seeding requires inspection and reseeding as needed in the spring. All areas where cover is inadequate must be immediately reseeded and mulched as soon as possible.

(3) Erosion Control Mats

(a) During the growing season (April 15–Sept 15) use mats indicated on drawings or, if not specified use North American Green S75 or equal or mulch with netting on:

* The base of grassed waterways
* Steep slopes (>15%)
* Any disturbed soil within 100 feet of lakes, streams and wetlands

During the late fall and winter (Sept 15–April 15) use heavy grade mats indicated on drawings or, if not specified use North American Green SC150 or equal on all areas noted above plus use lighter grade mats or mulch with netting on:

* Side slopes of grassed waterways
* Moderate slopes (>8%)

(b) Install mats in accordance with manufacturers' recommendations.

3. Lined Ditches

On designated ditches, use reinforced mats (North American Green as specified or approved equal) as permanent stabilization. Install mats in accordance with manufacturers' recommendations.

D. CONSTRUCTION SEQUENCE

It is anticipated that construction will commence upon receipt of all necessary permits and approvals. The following outlines the preliminary construction sequence:

a. Install silt fence and other temporary erosion control measures for the construction of Cell and accessory facilities such as detention ponds, berms, and service roads;

b. Construct upslope stormwater diversion berms, ditches, culvert outlets, and control structures:

c. Clear and grub Cell areas;

d. Construct service road;

e.. Construct Cell base grade and underdrain system;

f. Construct Cell liner system, and leachate collection system;

g. Operate Cell;

h. As permanent erosion control measures become stabilized, remove temporary measures (e.g., silt fence, stone check dams); and

i. Install intermediate and final cover on cells filled to capacity in areas shown in the Cell Development Plans – Appendix C of this application.

E. CONSTRUCTION INSPECTIONS

Inspections will be undertaken by qualified personnel to ensure that temporary and permanent erosion and sedimentation controls are properly installed and correctly functioning, and that additional erosion control measures are installed if needed. Such inspections will occur bi-weekly and after each significant rainfall event (1 inch or more within a 24 hour period) during construction until permanent erosion control measures have been properly installed and the site is stabilized.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE – GUY H. COTE, JR. – No. 5146 – LICENSED PROFESSIONAL ENGINEER

JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

SECTIONS AND DETAILS

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE
4 Blanchard Road, PO Box 85A, Cumberland Center, Maine 04021
Phone 207.829.5016 • Fax 207.829.5692 • www.smemaine.com

DESIGN BY: PCM
DRAWN BY: SJM
DATE: 12/5/2014
CHECKED BY:
LMN: NONE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE DETAILS

C-308

APPENDIX F

GEOTECHNICAL DATA

APPENDIX F-1

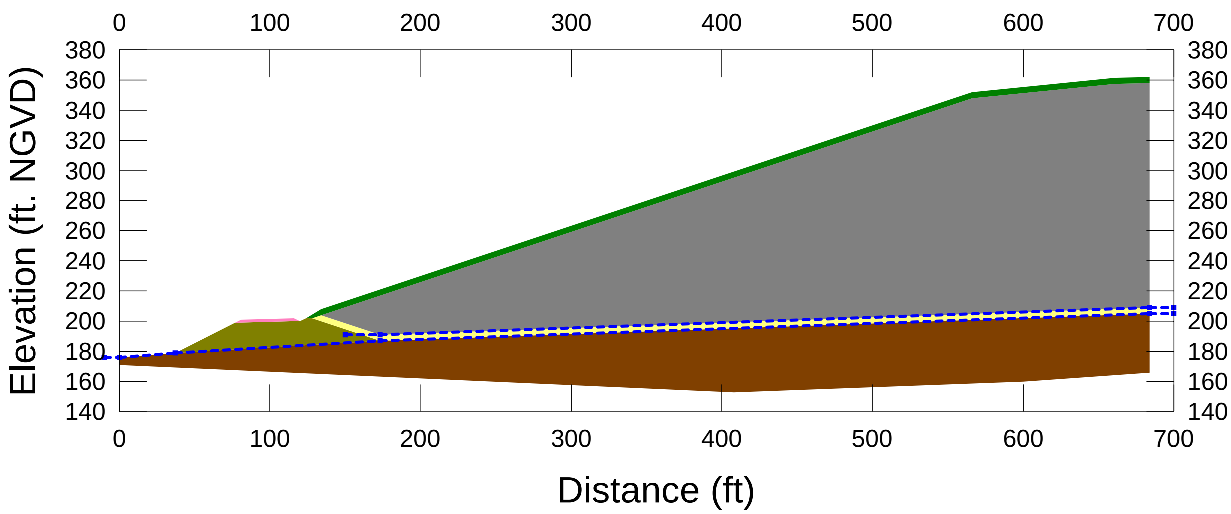
STABILITY CROSS-SECTIONS

Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section A-A'.gsz
Description: For Appendix F-1
Analysis Name: 0 Cross-Section A-A'
Date: 2/19/2015

Name: Cover System   Model: Mohr-Coulomb   Unit Weight: 125   Cohesion: 0   Phi: 30   Phi-B: 0
Name: Solid Waste   Model: Mohr-Coulomb   Unit Weight: 74   Cohesion: 0   Phi: 32   Phi-B: 0   Piezometric Line: 1
Name: Liner Peak Spec   Model: Shear/Normal Fn.   Unit Weight: 120   Strength Function: Liner Peak Spec   Phi-B: 0   Piezometric Line: 1
Name: Gravel Roads   Model: Mohr-Coulomb   Unit Weight: 128   Cohesion: 0   Phi: 34   Phi-B: 0   Piezometric Line: 2
Name: Foundation Soils (Glacial Till)   Model: Mohr-Coulomb   Unit Weight: 132   Cohesion: 1000   Phi: 38   Phi-B: 0   Piezometric Line: 2
Name: Till Road Base   Model: Mohr-Coulomb   Unit Weight: 128   Cohesion: 250   Phi: 34   Phi-B: 0   Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 0 Cross-Section A-A'
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555

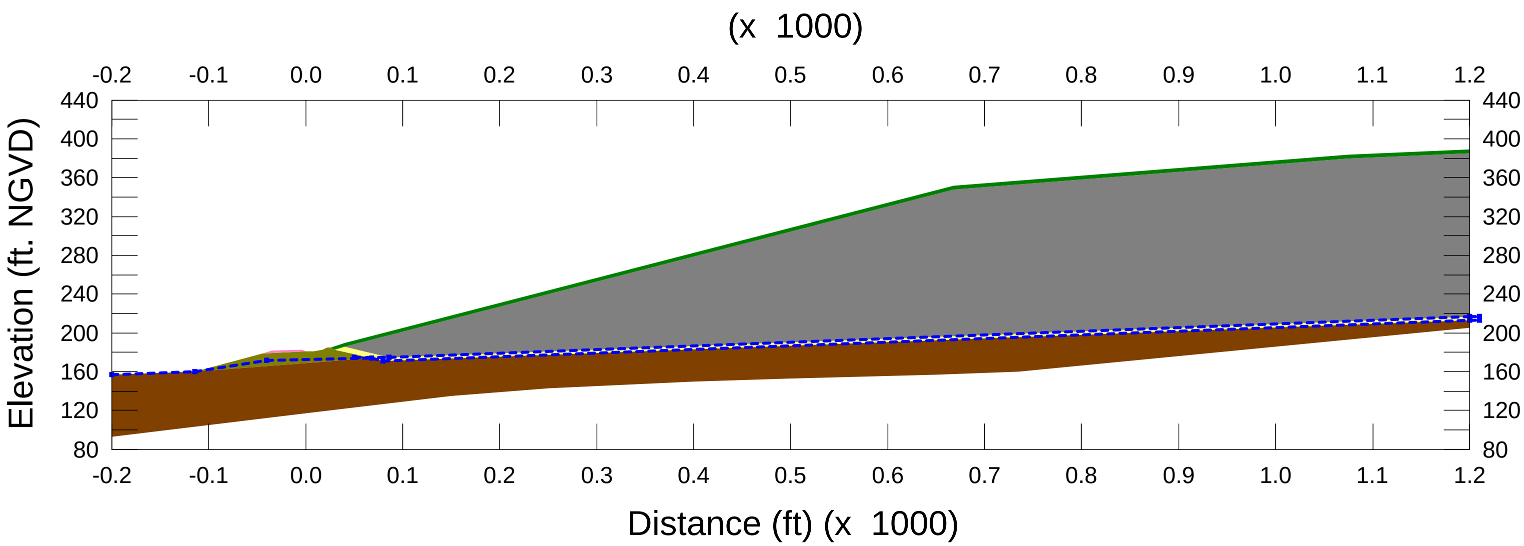


Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section B-B'.gsz
Description: For Appendix F-1
Analysis Name: 0 Cross-Section B-B'
Date: 2/19/2015

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 0 Cross-Section B-B'
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section C-C'.gsz
Description: For Appendix F-1
Analysis Name: 0 Cross-Section C-C'
Date: 2/19/2015

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 0 Cross-Section C-C'
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
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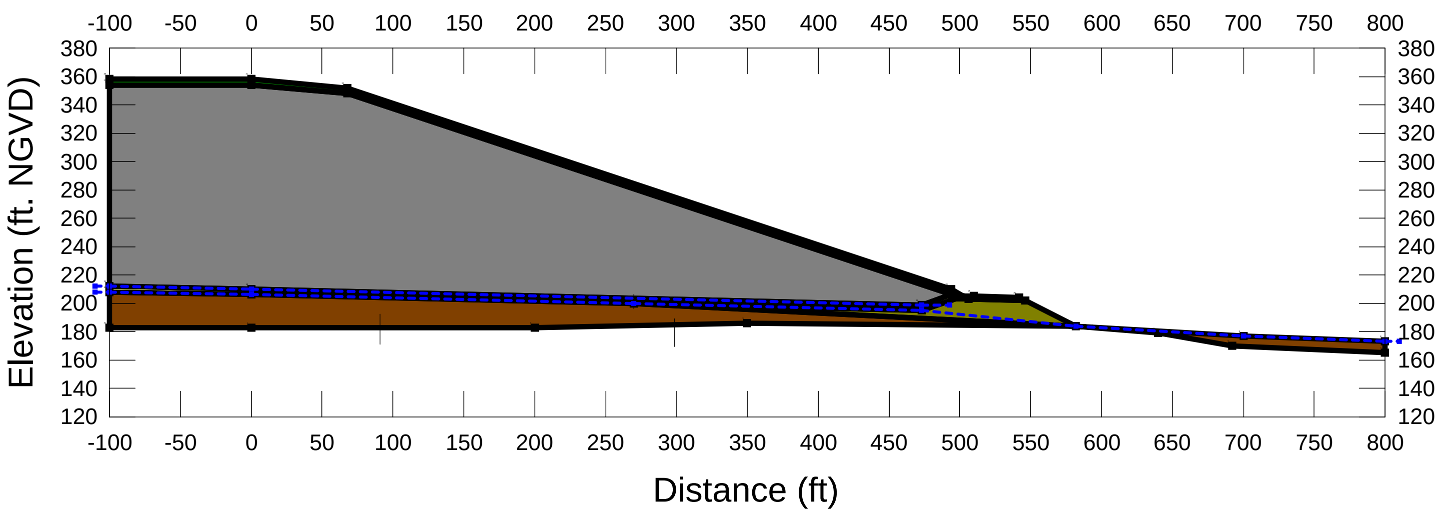
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555

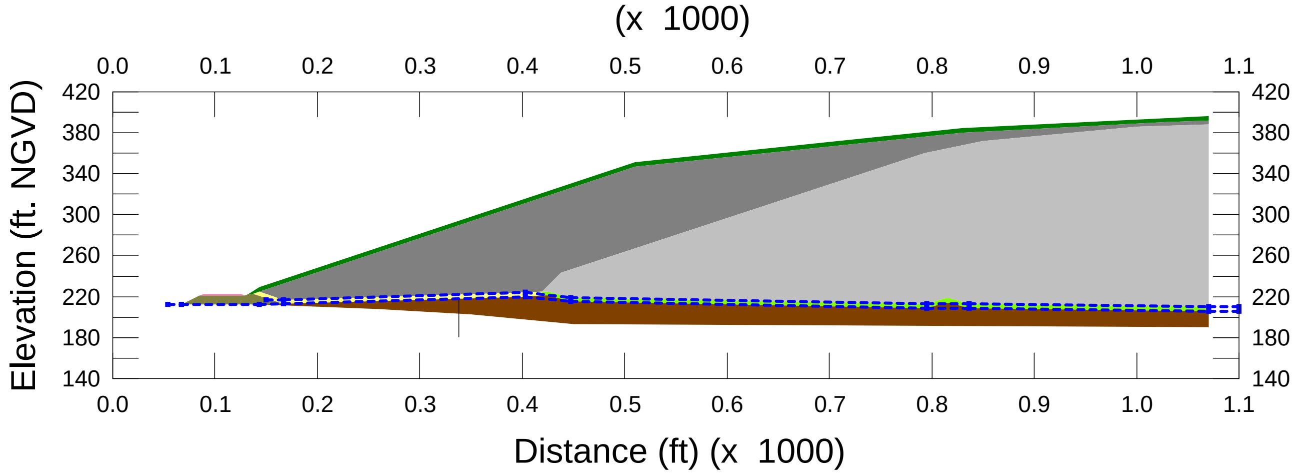


Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section D-D''.gsz
Description: For Appendix F-1
Analysis Name: 0 Cross-Section D-D'
Date: 2/19/2015

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak - Cells 7&3A Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 0 Cross-Section D-D'
Seismic Coefficient (ks): 0

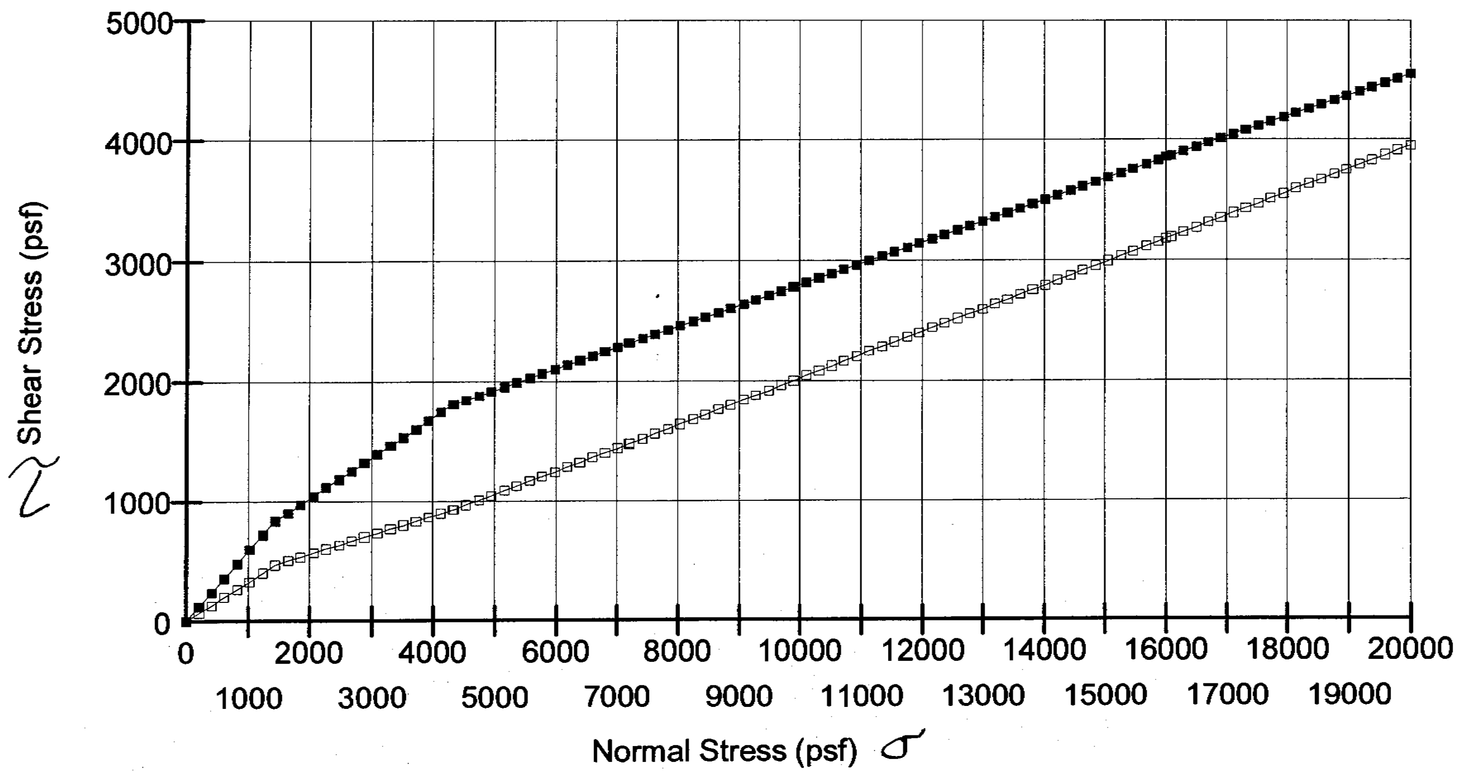
Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



APPENDIX F-2

INTERFACE SHEAR STRENGTHS

Liner Interface Shear Strengths, 9.35 Mcy Expansion at JRL



Values Used:

■ Liner Peak Spec

σ	τ
0	0
1440	830
4320	1811
7200	2315
16000	3855
20000	4555

□ Liner LD Spec

σ	τ
0	0
1440	463
4320	924
7200	1480
16000	3179
20000	3951

source, see next page.

From: Updated Geotechnical Stability Analysis (REW, 2005c)

Table 3-2
Specifications for Liner Interfacial Strengths
Updated Geotechnical Stability Analysis
State of Maine/NEWSME Landfill Operations LLC
West Old Town, Maine

	critical stresses (psf)			
	peak		large displacement	
interface	σ_n	τ	σ_n	τ
lowest peak	0	0	0	0
(HDPE/GDN)	1,440	830	1,440	463
	4,320	1,811	4,320	924
	7,200	2,315	7,200	1,480
	16,000	*3,855*	*16,000*	*3,179*
	20,000	*4,555*	*20,000*	*3,951*
lowest LD	-	-	0	0
(GCL Internal)	-	-	1,440	430
	-	-	3,600	760
	-	-	5,760	940
	-	-	*16,000*	*1,793*
	-	-	*20,000*	*2,127*

Used to Create Peak-Strength Envelope

Used to create Large-Displacement Strength Envelope

Notes:
1. New Liner (top down) - 12" leachate collection sand, GC, 80-mil HDPE(tx), GCL, 24" compacted clay

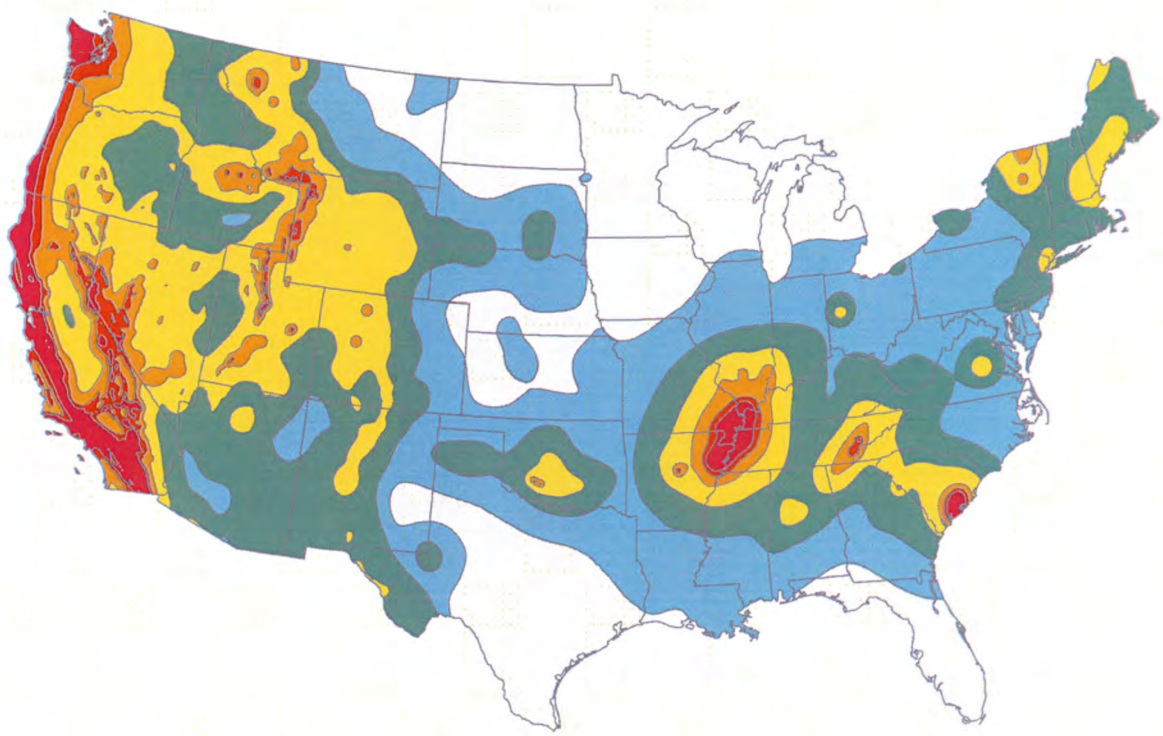
APPENDIX F-3

SEISMIC HAZARD MAP

science for a changing world

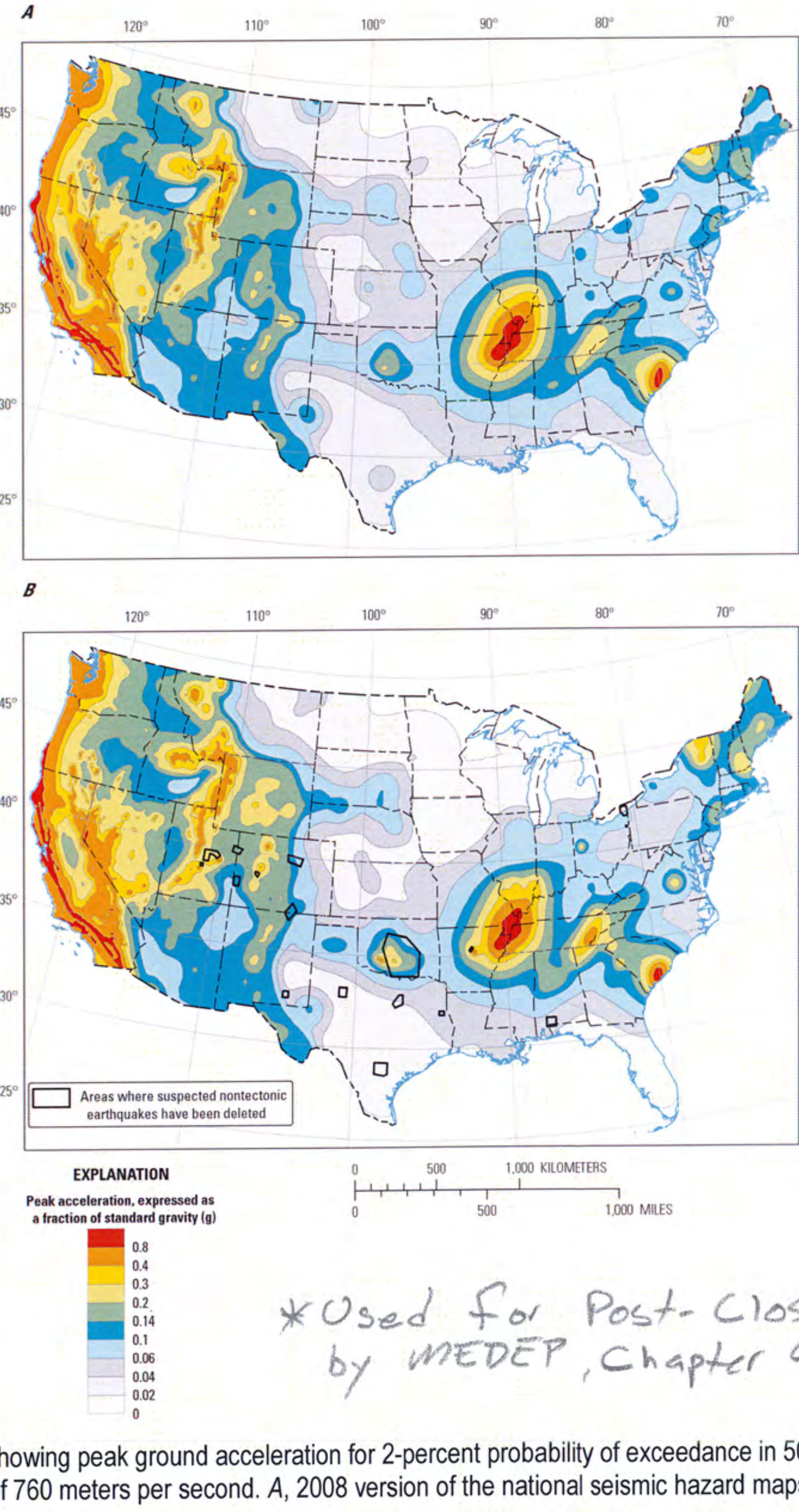
Documentation for the 2014 Update of the United States National Seismic Hazard Maps

Mark D. Petersen, Morgan P. Moschetti, Peter M. Powers, Charles S. Mueller, Kathleen M. Haller, Arthur D. Frankel, Yuehua Zeng, Sanaz Rezaeian, Stephen C. Harmsen, Oliver S. Boyd, Ned Field, Rui Chen, Kenneth S. Rukstales, Nico Luco, Russell L. Wheeler, Robert A. Williams, and Anna H. Olsen



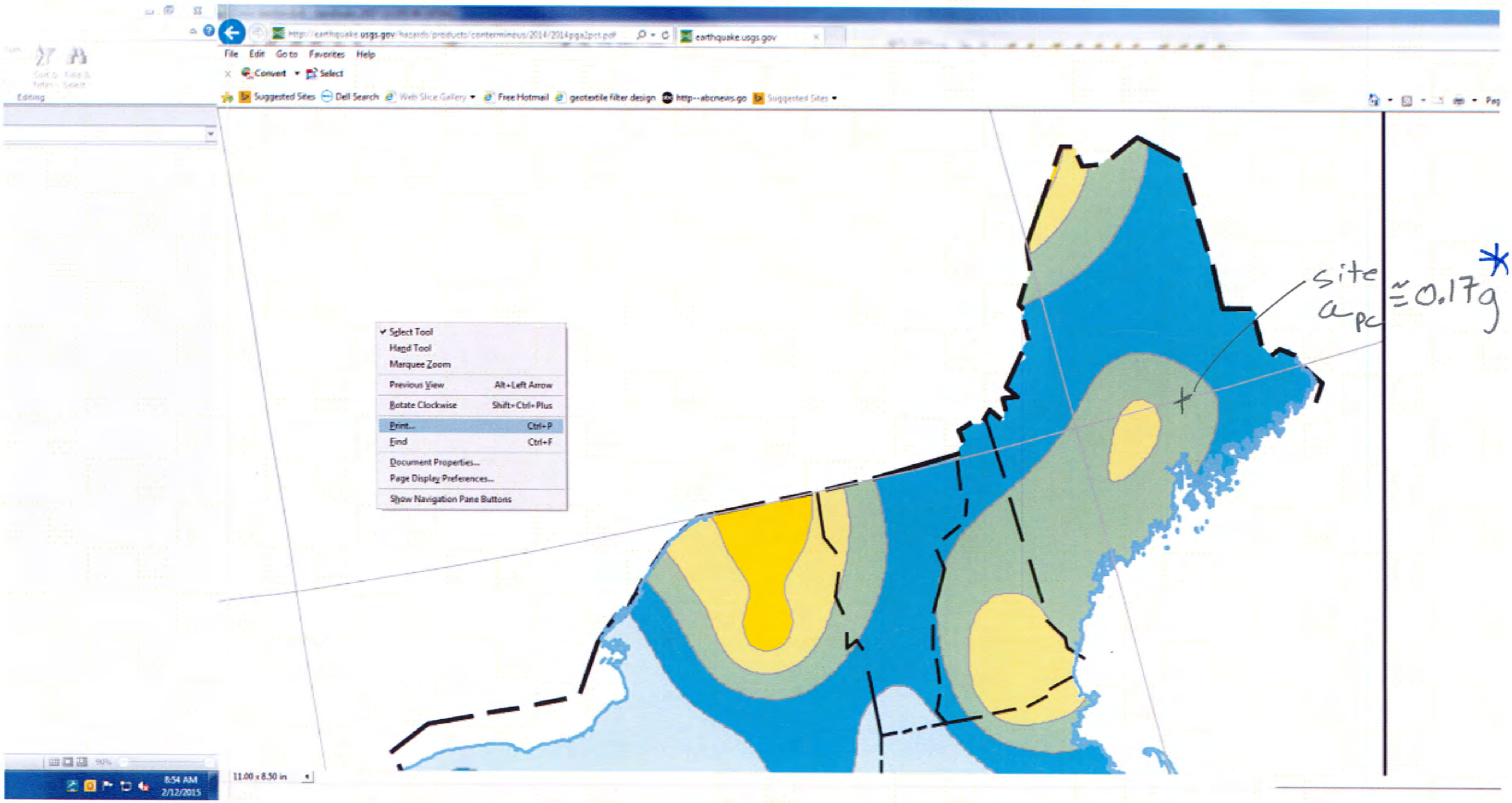
Open-File Report 2014–1091

U.S. Department of the Interior
U.S. Geological Survey



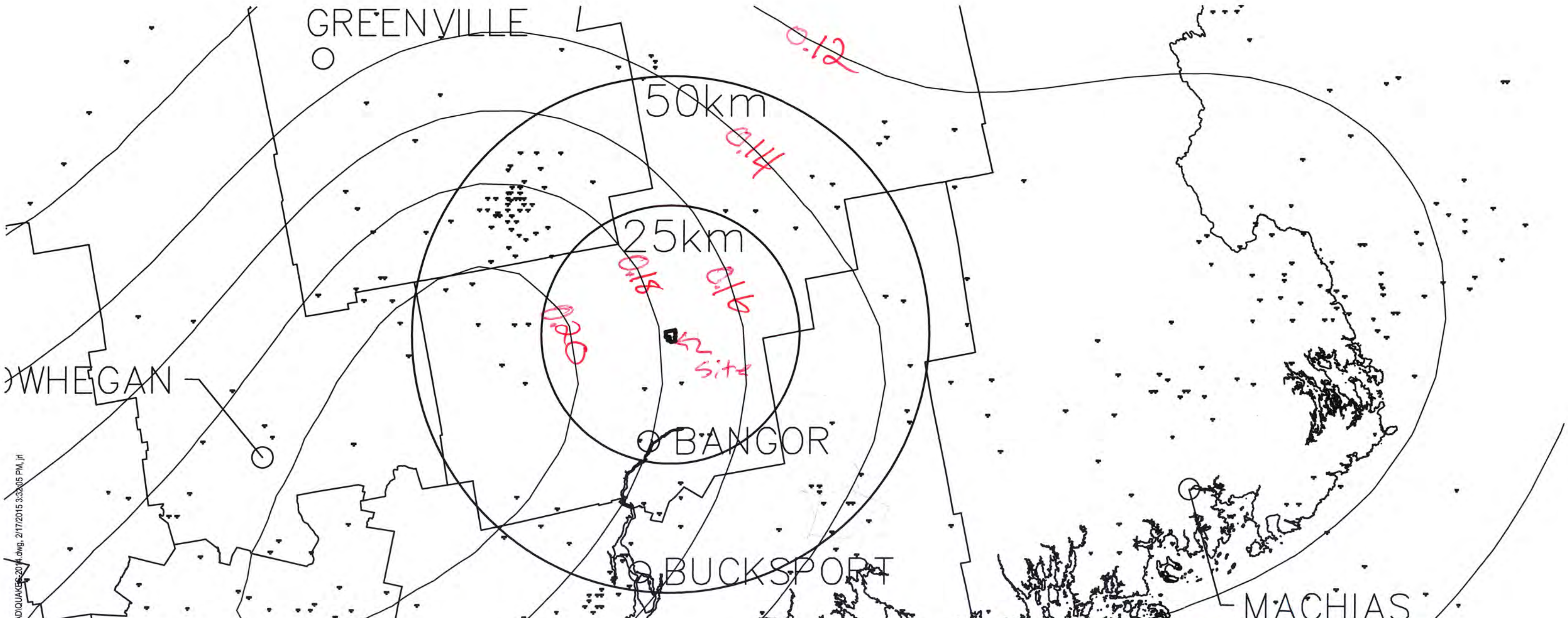
*Used for Post-Closure by MEDEP, Chapter 401.

Figure 1. Maps showing peak ground acceleration for 2-percent probability of exceedance in 50 years and V_{S30} site condition of 760 meters per second. *A*, 2008 version of the national seismic hazard maps and *B*, 2014 version.



PGA 2% in 50 yrs
= 10% in 250 yrs
* Post-Closure

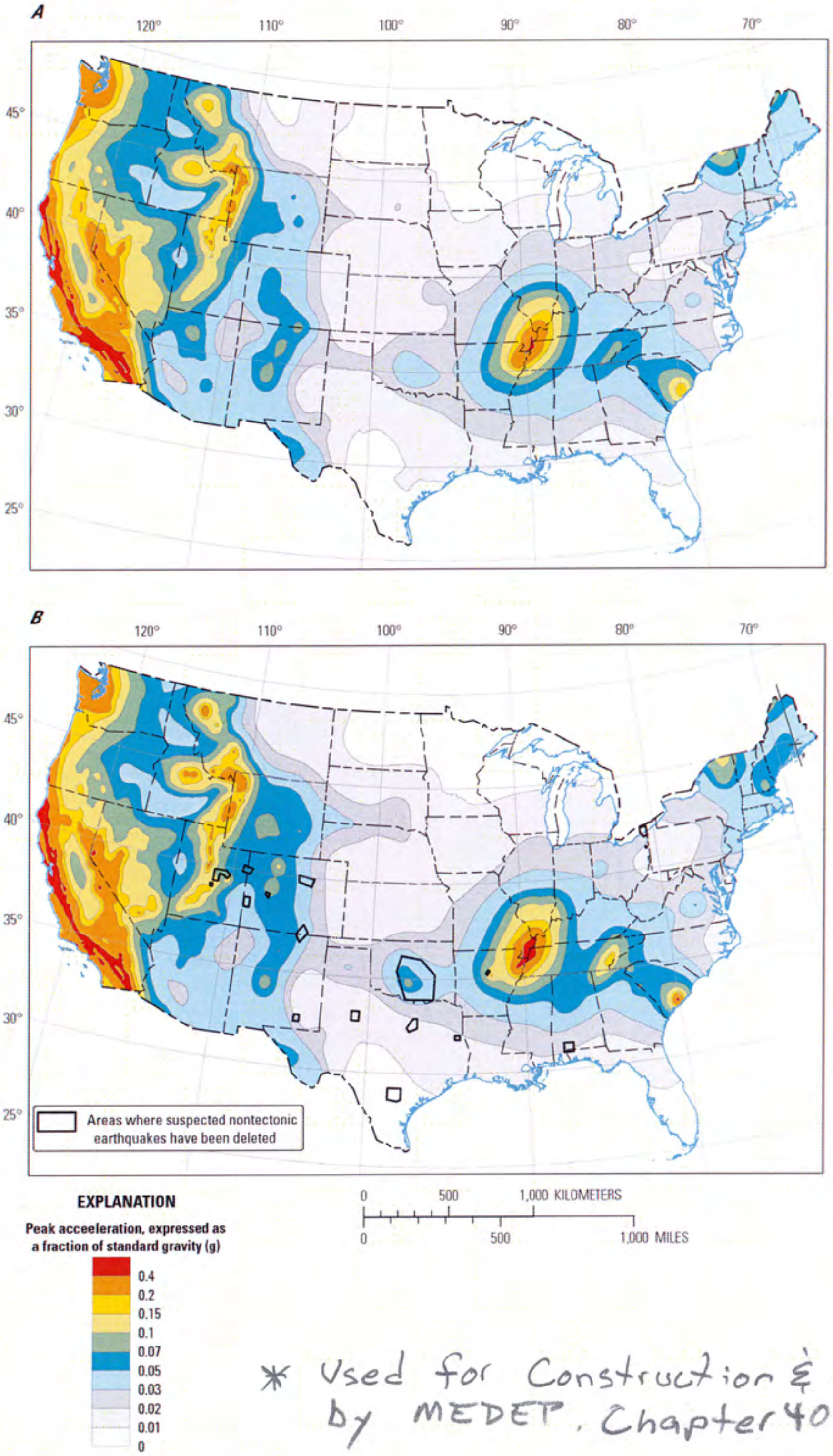
*See next page



Produced from Shape file
from USGS, 2014

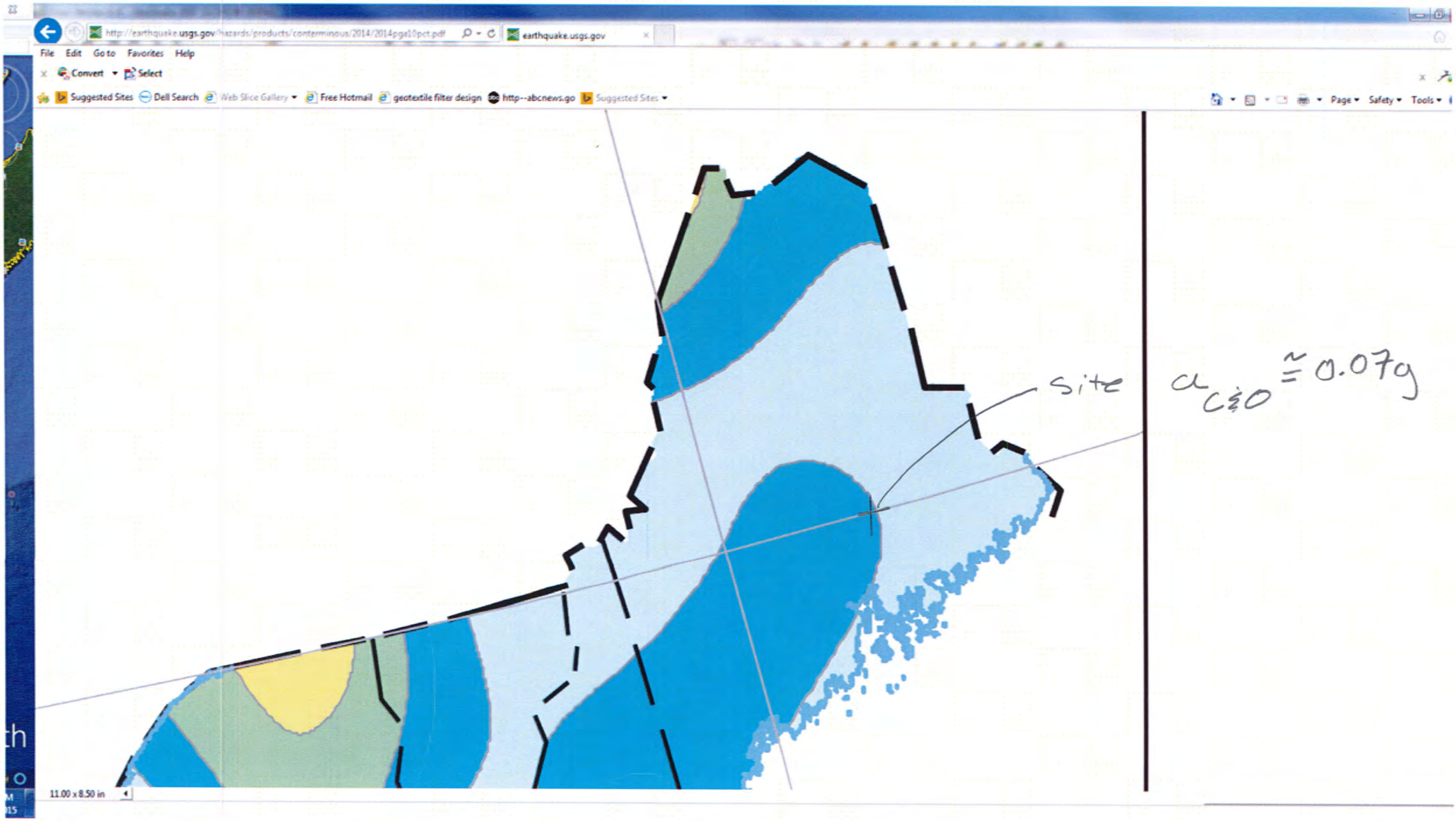
PGA @ 10% in 250 yrs @ JRL PGA ≤ 0.18
A.K.A → 2% in 50 yrs

\\Nserver\cfs\SME\Professional\Engineering\QUAKE\ACAD\QUAKES-2014.dwg, 2/17/2015 3:32:05 PM, jrl



* Used for Construction & Operations by MEDEP. Chapter 401.

Figure 4. Maps showing peak ground acceleration for 10-percent probability of exceedance in 50 years and V_{S30} site condition of 760 meters per second. *A*, 2008 version of the national seismic hazard maps and *B*, 2014 version.



PGA 10% in 50.

* Construction & Operations (maine)

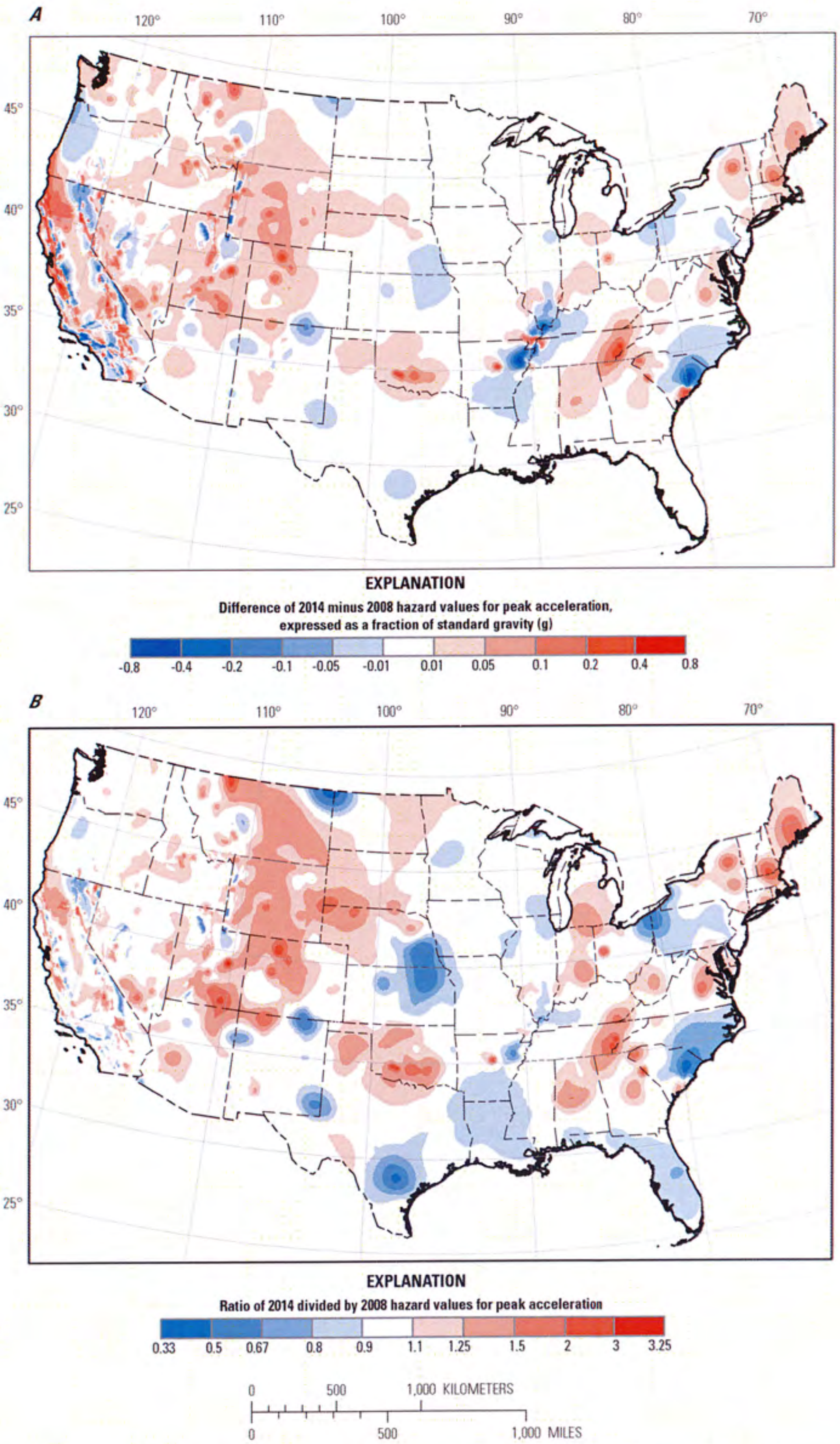


Figure 7. Maps comparing change in peak ground acceleration for 2-percent probability of exceedance in 50 years and V_{S30} site condition of 760 meters per second. *A*, Difference between the 2014 and 2008 versions of the national seismic hazard maps and *B*, ratio between the 2014 and 2008 versions.

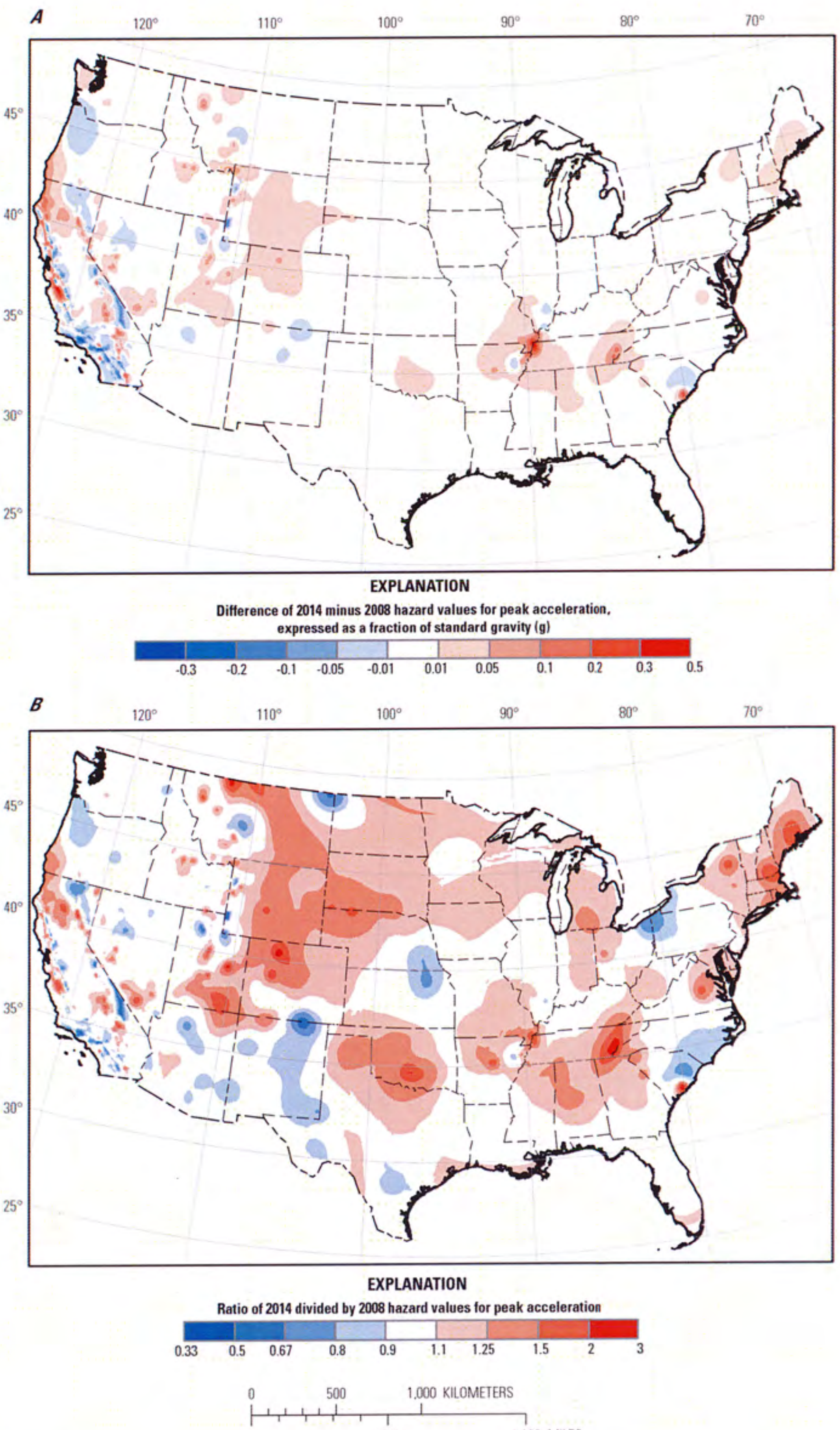


Figure 10. Maps comparing change in peak ground acceleration for 10-percent probability of exceedance in 50 years and V_{S30} site condition of 760 meters per second. *A*, Difference between the 2014 and 2008 versions of the national seismic hazard maps and *B*, ratio between the 2014 and 2008 versions.

APPENDIX F-4

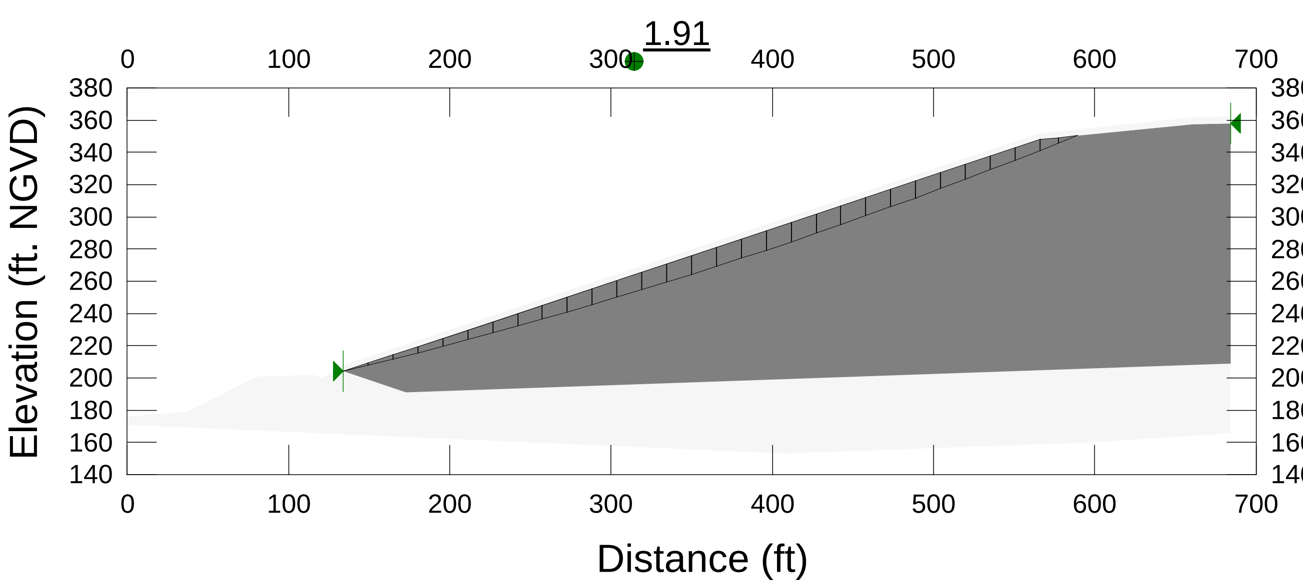
STABILITY ASSESSMENT RESULTS

Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section A-A'.gsz
Description: Waste Operational
Analysis Name: 6 Waste Ops
Date: 2/19/2015

Minimum Factor of Safety = 1.91

Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 6 Waste Ops
Seismic Coefficient (ks): 0



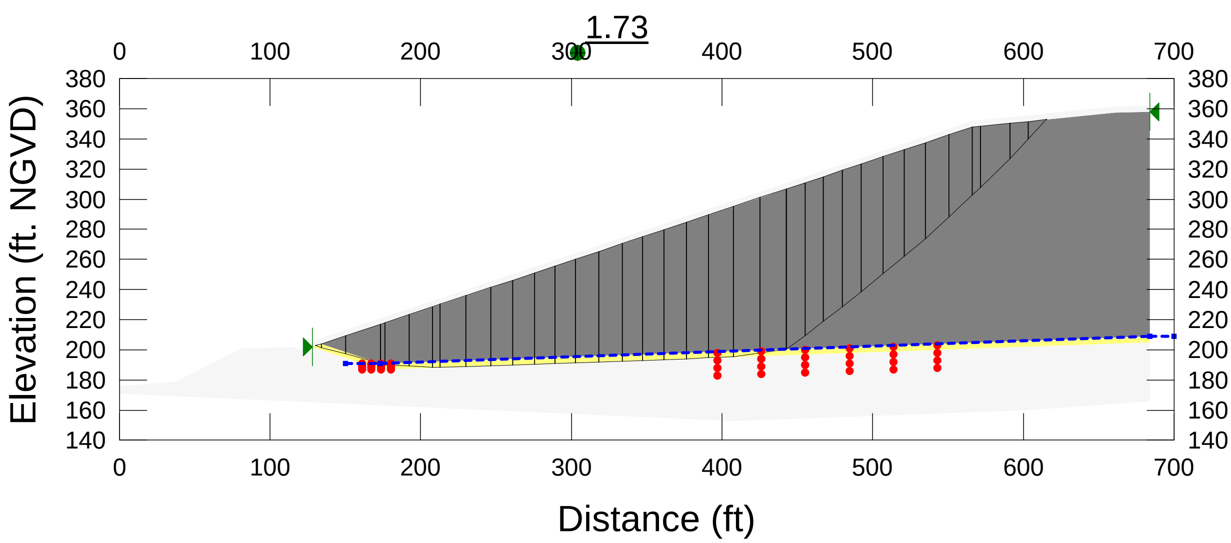
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section A-A'.gsz
Description: Liner Operational
Analysis Name: 4 Liner Ops
Date: 2/19/2015

Minimum Factor of Safety = 1.73

Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 4 Liner Ops
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



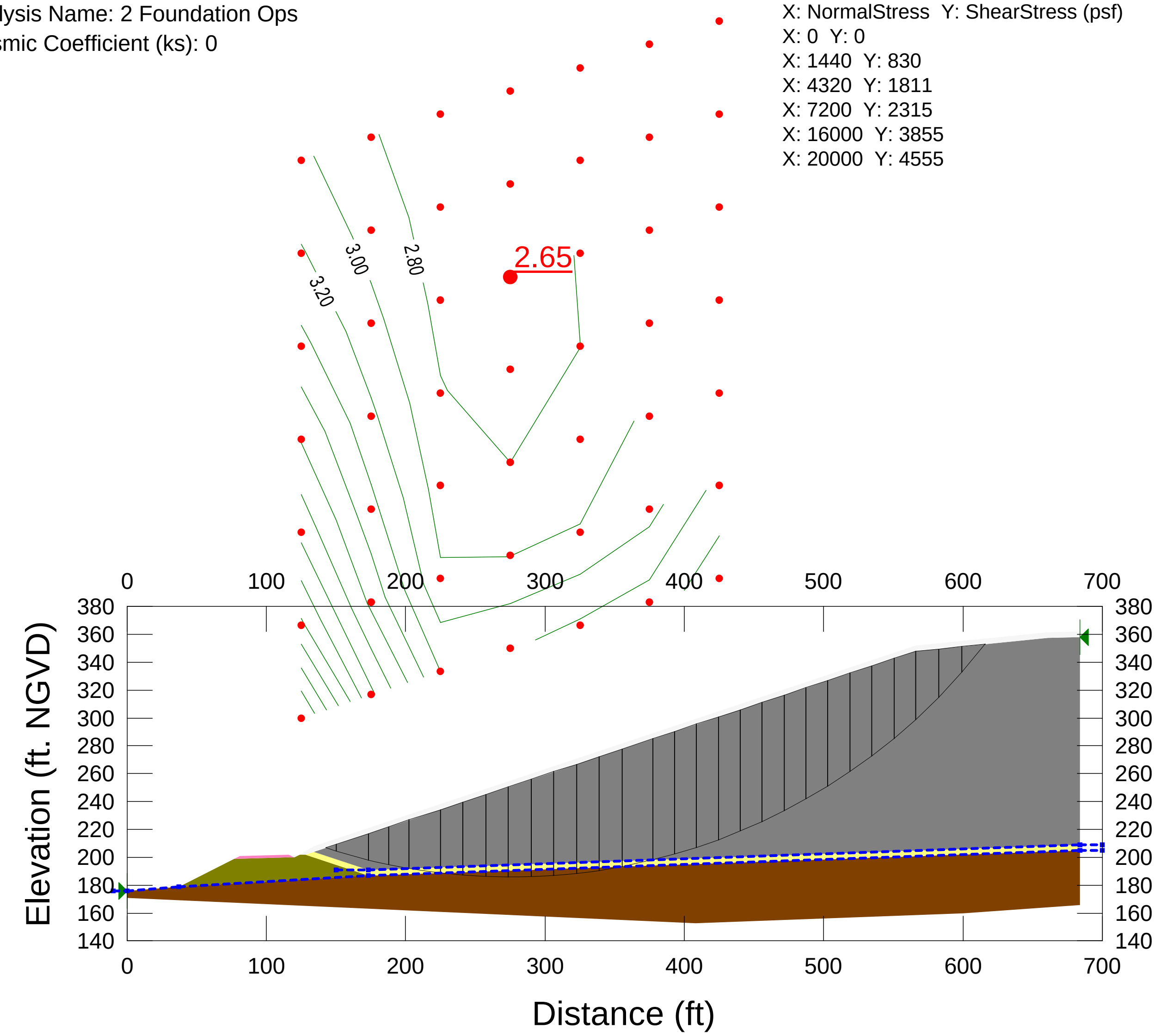
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section A-A'.gsz
Description: Foundation Operational
Analysis Name: 2 Foundation Ops
Date: 2/19/2015

Minimum Factor of Safety = 2.65

Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 2 Foundation Ops
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555

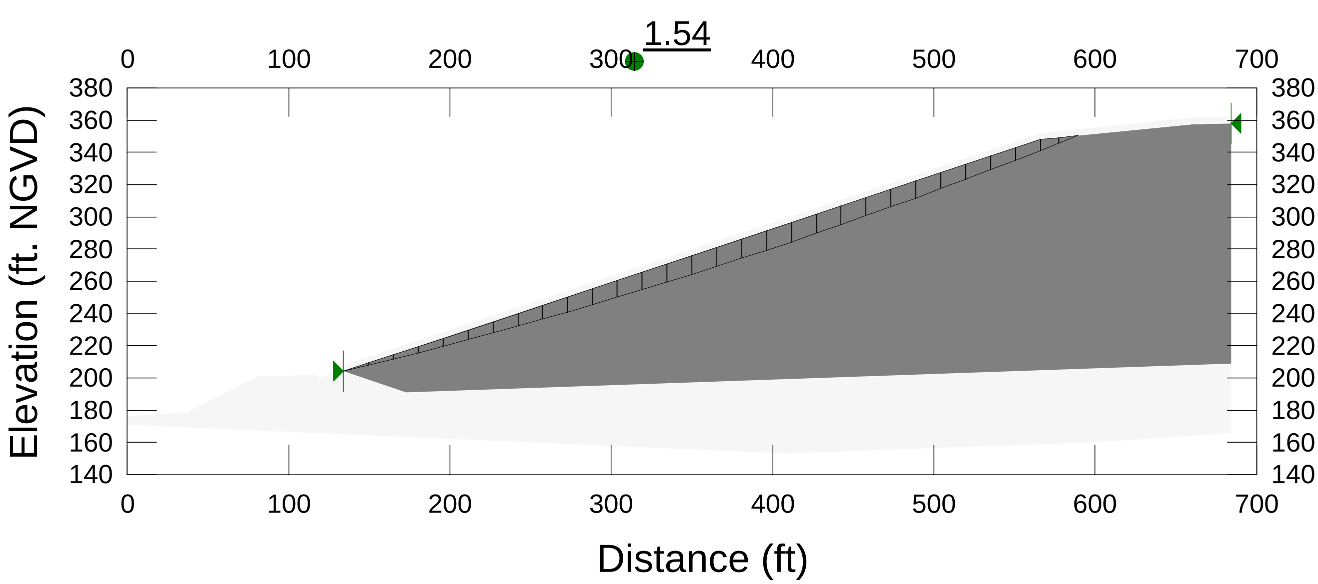


Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section A-A'.gsz
Description: Waste Operational; Seismic
Analysis Name: 6s Waste Ops s
Date: 2/19/2015

Minimum Factor of Safety = 1.54

Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 6s Waste Ops s
Seismic Coefficient (ks): 0.07



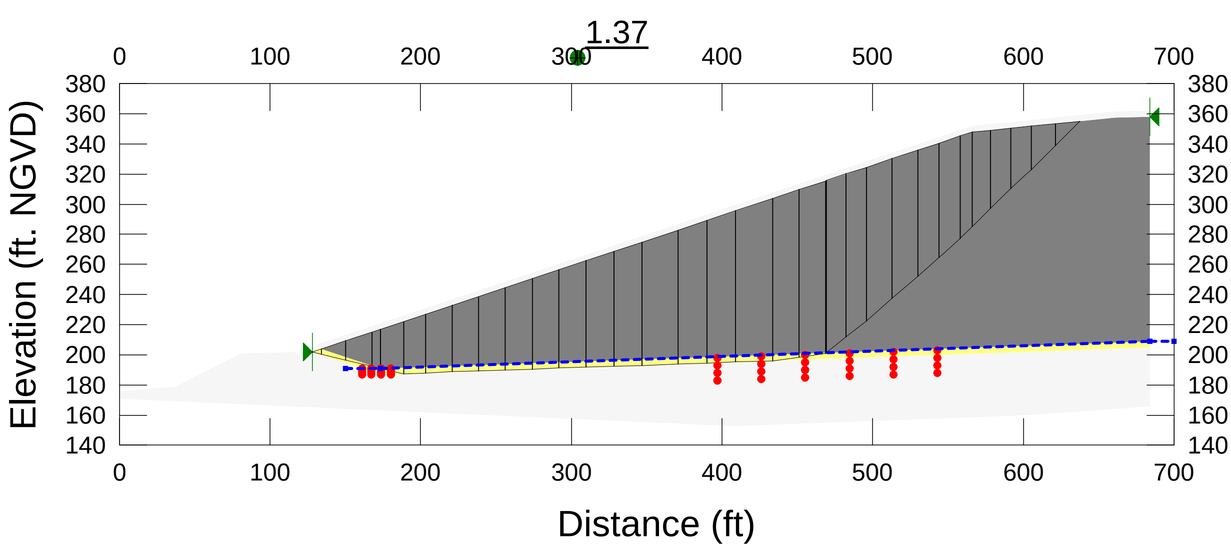
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section A-A'.gsz
Description: Liner Operational; Seismic
Analysis Name: 4s Liner Ops s
Date: 2/19/2015

Minimum Factor of Safety = 1.37

Name: Solid Waste   Model: Mohr-Coulomb   Unit Weight: 74   Cohesion: 0   Phi: 32   Phi-B: 0   Piezometric Line: 1
Name: Liner Peak Spec   Model: Shear/Normal Fn.   Unit Weight: 120   Strength Function: Liner Peak Spec   Phi-B: 0   Piezometric Line: 1

Method: Spencer
Analysis Name: 4s Liner Ops s
Seismic Coefficient (ks): 0.07

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



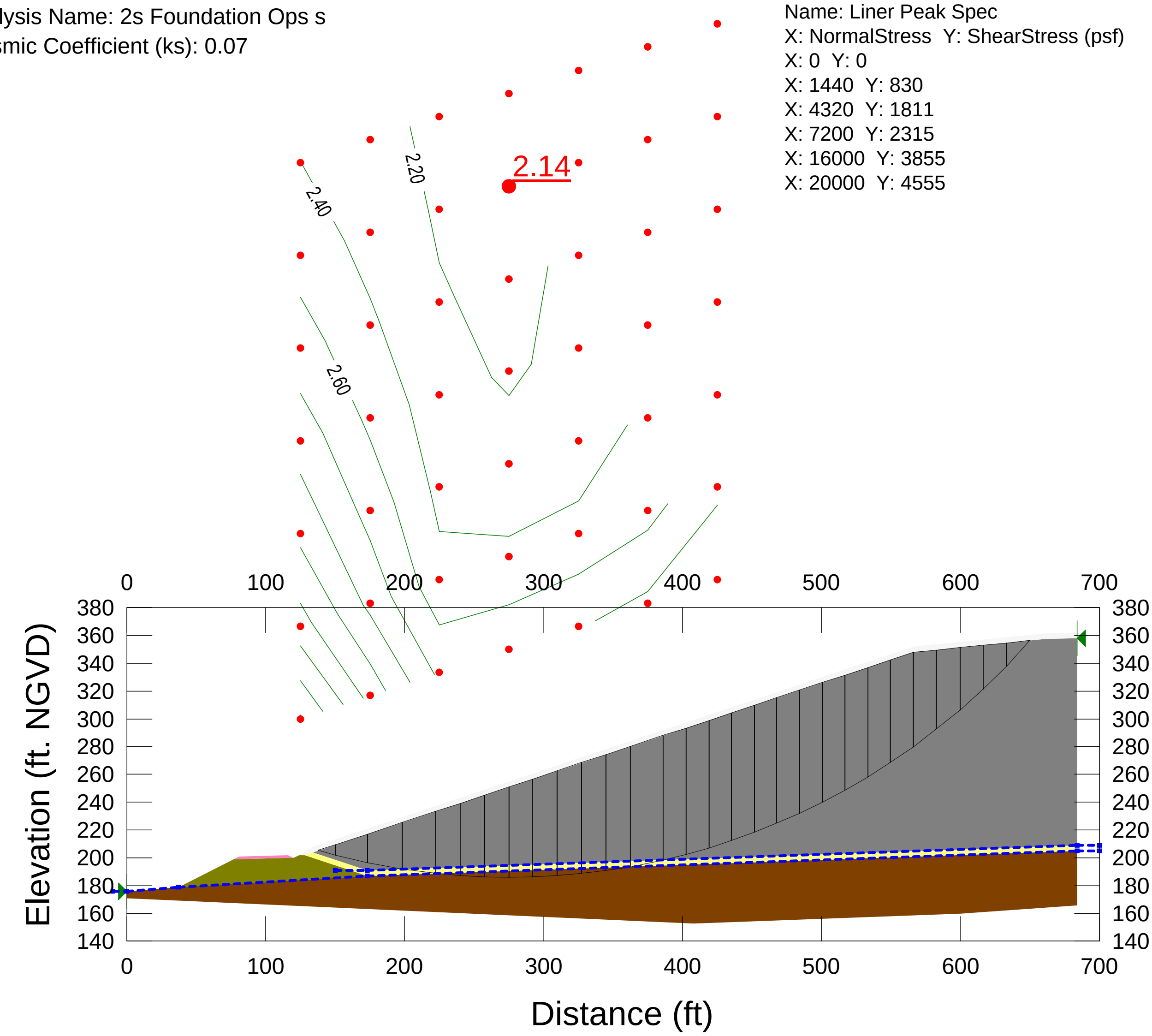
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section A-A'.gsz
Description: Foundation Operational; Seismic
Analysis Name: 2s Foundation Ops s
Date: 2/19/2015

Minimum Factor of Safety = 2.14

Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 2s Foundation Ops s
Seismic Coefficient (ks): 0.07

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555

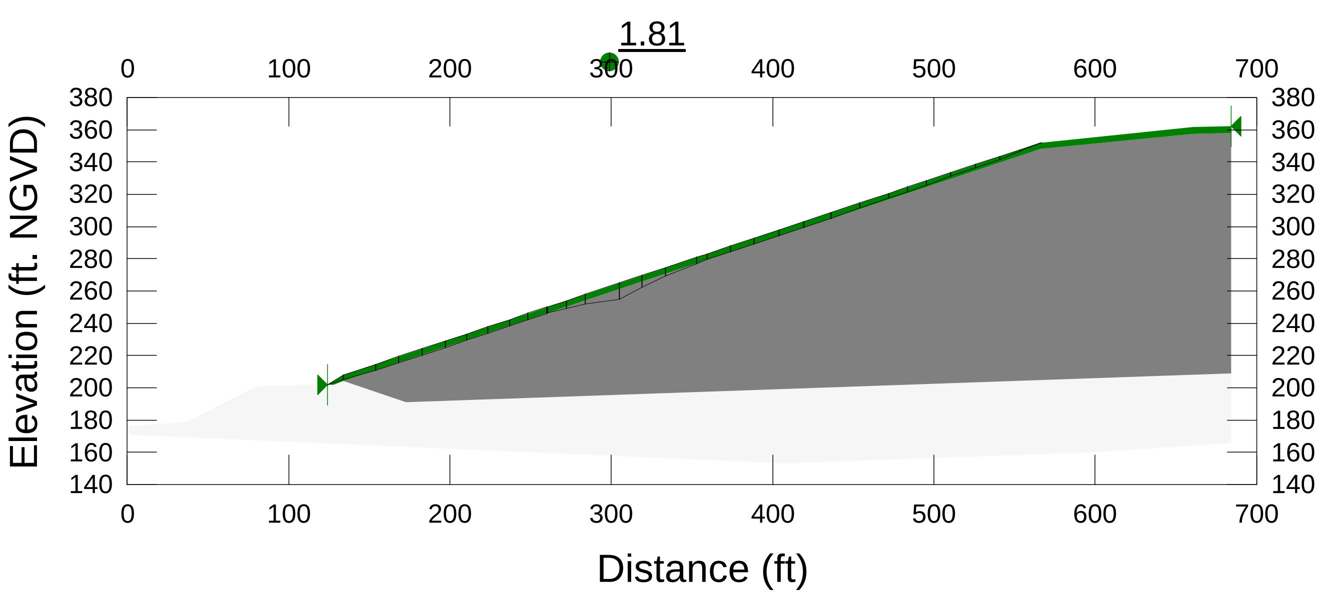


Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section A-A'.gsz
Description: Waste Closed
Analysis Name: 5 Waste Closed
Date: 2/19/2015

Minimum Factor of Safety = 1.81

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 5 Waste Closed
Seismic Coefficient (ks): 0



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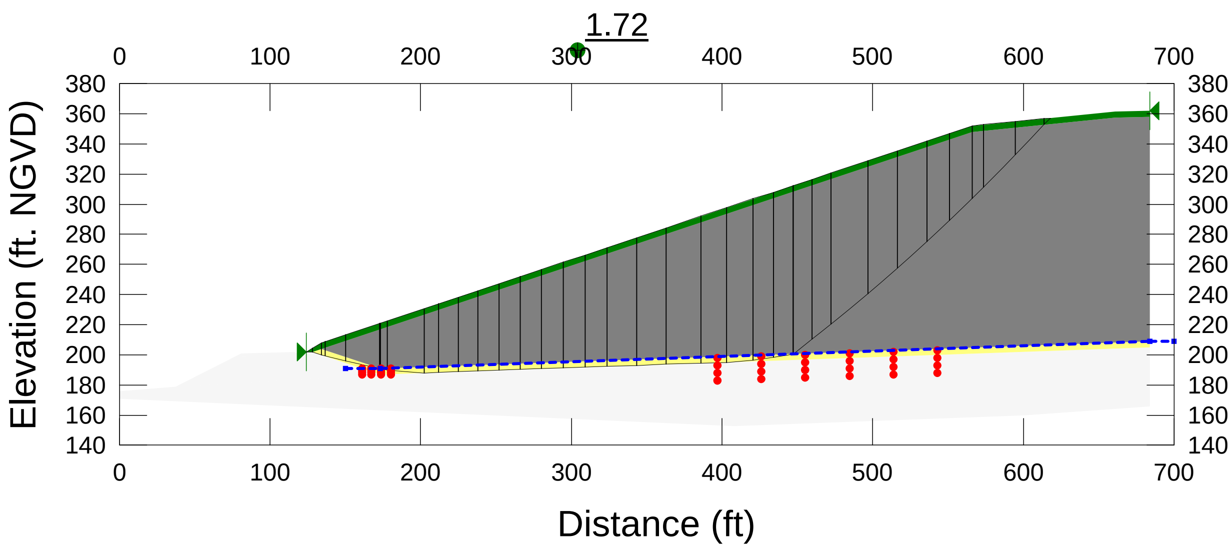
File Name: Cross-Section A-A'.gsz
Description: Liner Closed
Analysis Name: 3 Liner Closed
Date: 2/19/2015

Minimum Factor of Safety = 1.72

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 3 Liner Closed
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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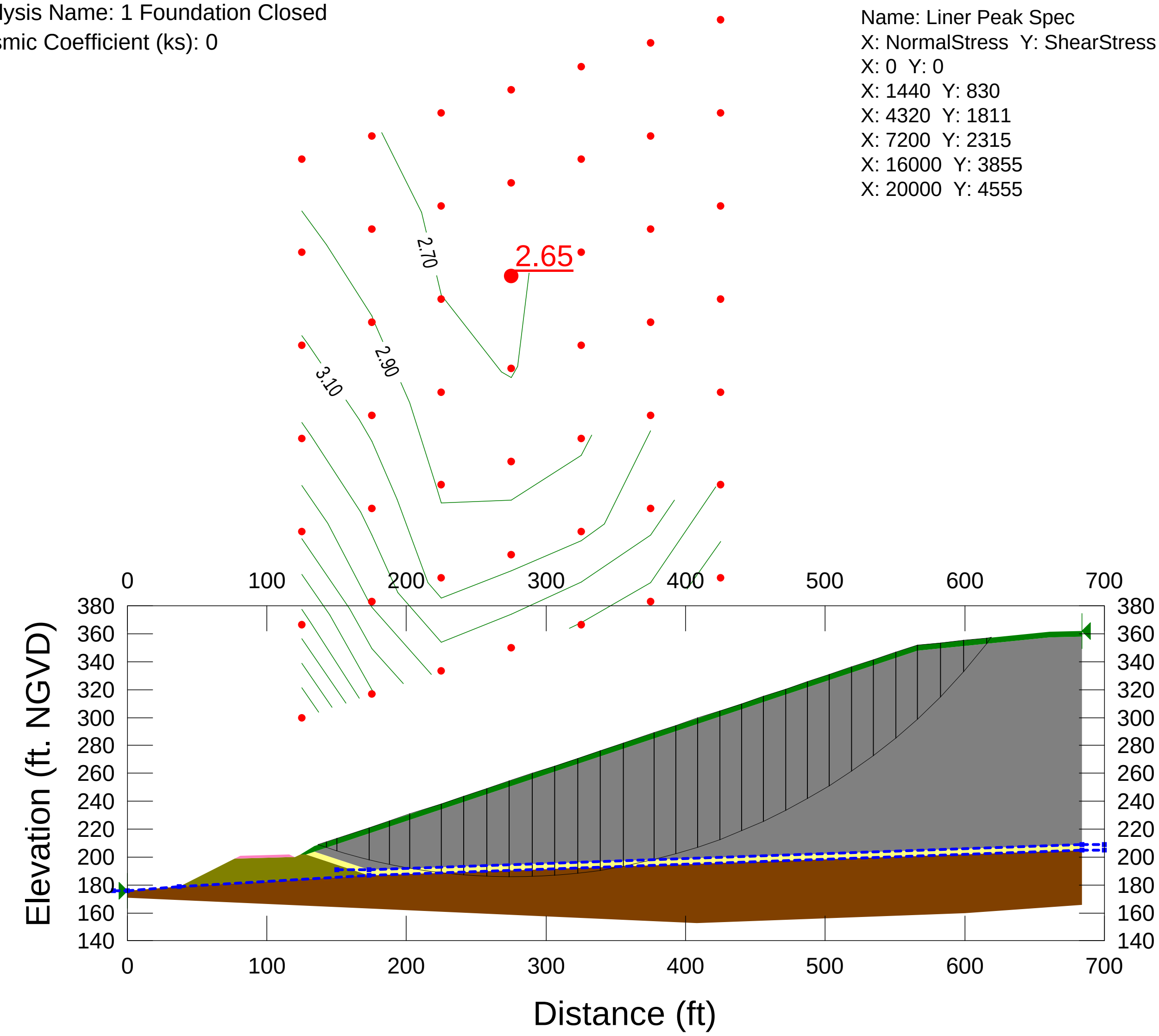
File Name: Cross-Section A-A'.gsz
Description: Foundation Closed
Analysis Name: 1 Foundation Closed
Date: 2/19/2015

Minimum Factor of Safety = 2.65

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 1 Foundation Closed
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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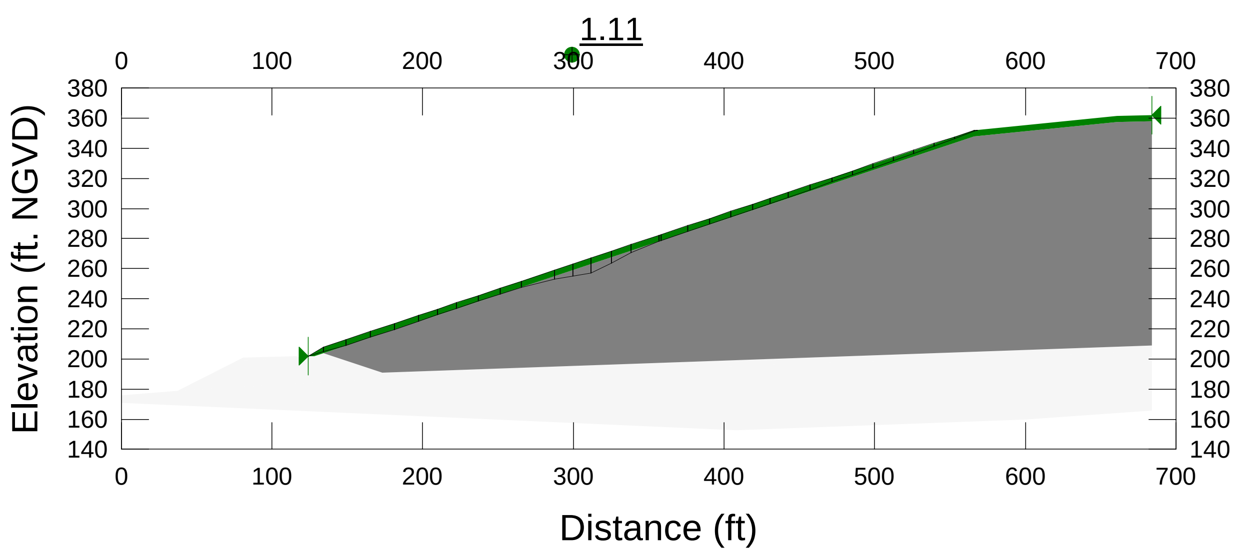
File Name: Cross-Section A-A'.gsz
Description: Waste Closed; Seismic
Analysis Name: 5s Waste Closed s
Date: 2/19/2015

Minimum Factor of Safety = 1.11

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 5s Waste Closed s
Seismic Coefficient (ks): 0.18



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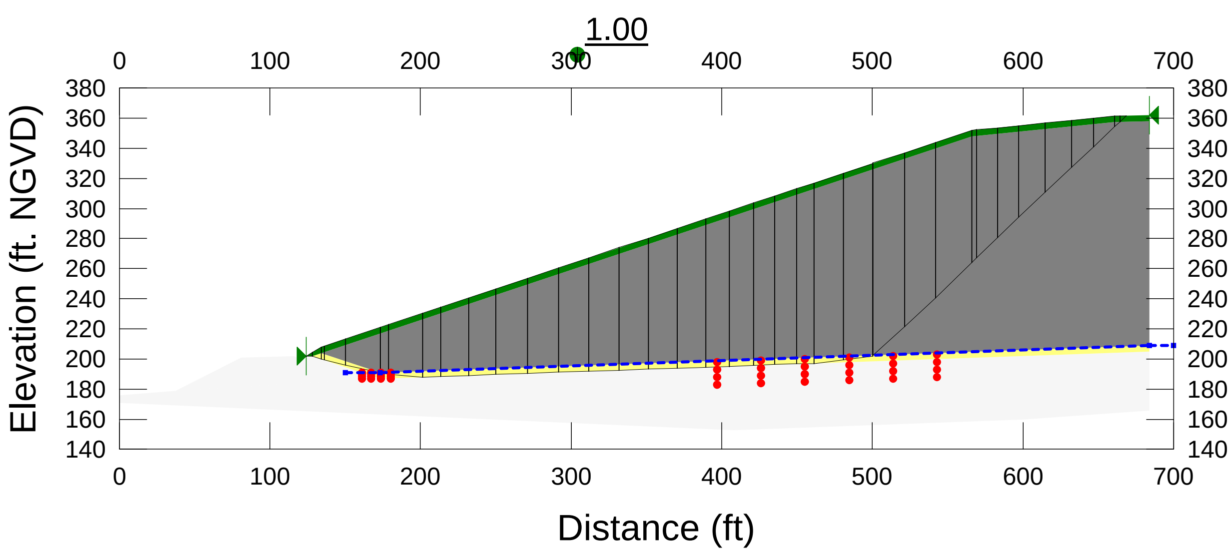
File Name: Cross-Section A-A'.gsz
Description: Liner Closed; Seismic
Analysis Name: 3s Liner Closed a=0.18g
Date: 2/19/2015

Minimum Factor of Safety = 1.00

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 3s Liner Closed a=0.18g
Seismic Coefficient (ks): 0.18

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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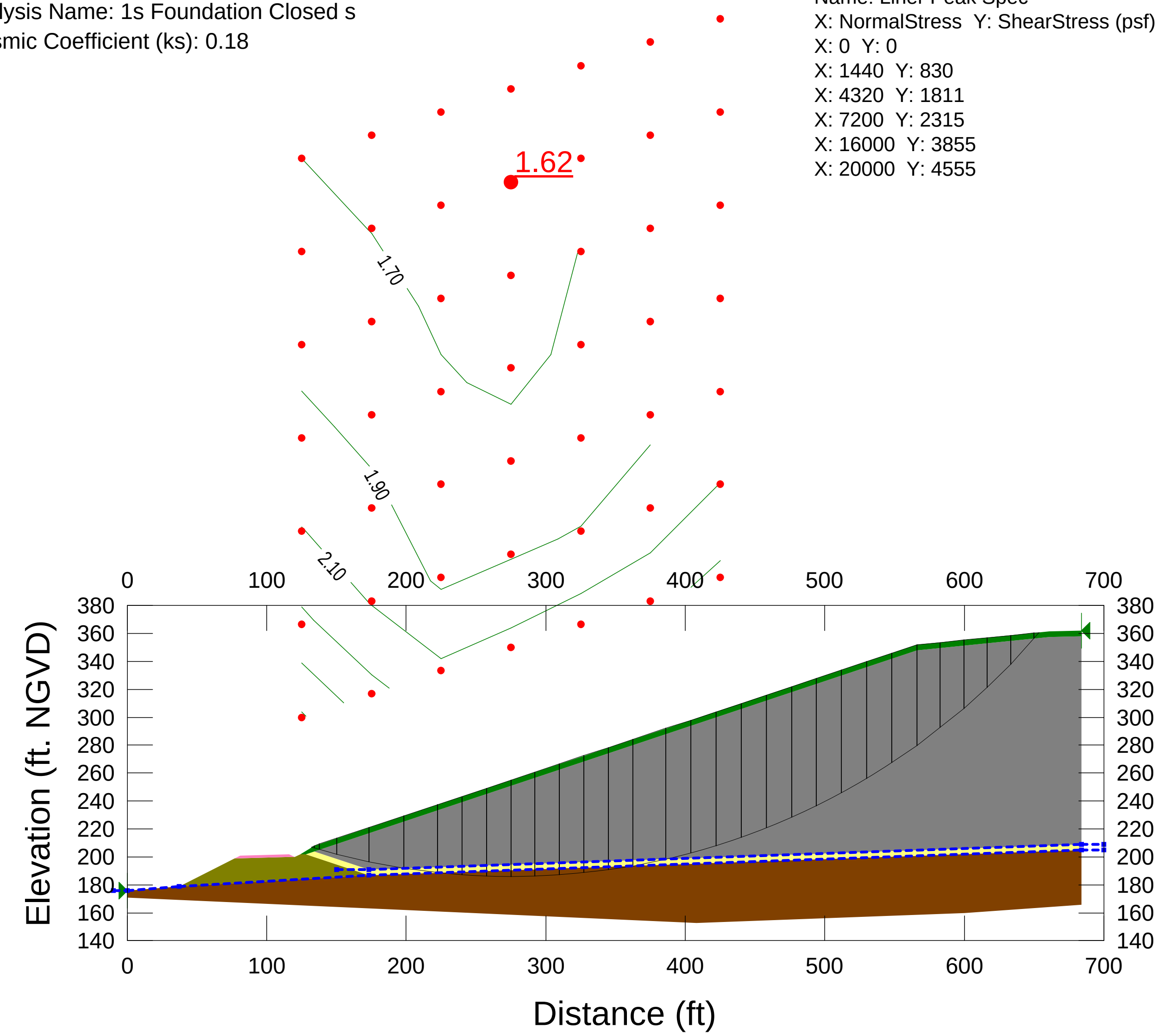
File Name: Cross-Section A-A'.gsz
Description: Foundation Closed; Seismic
Analysis Name: 1s Foundation Closed s
Date: 2/19/2015

Minimum Factor of Safety = 1.62

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 1s Foundation Closed s
Seismic Coefficient (ks): 0.18

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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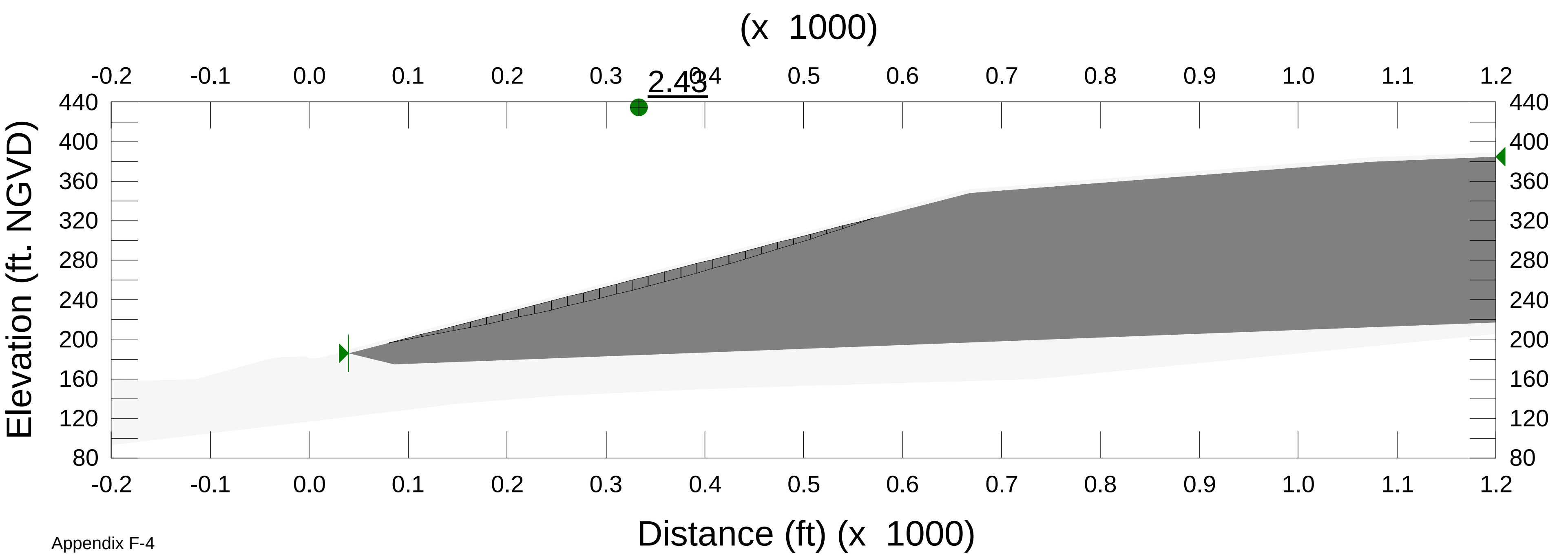
File Name: Cross-Section B-B'.gsz
Description: Waste Operational
Analysis Name: 6 Waste Ops
Date: 2/19/2015

Minimum Factor of Safety = 2.43

Name: Solid Waste - Expansion   Model: Mohr-Coulomb   Unit Weight: 74   Cohesion: 0   Phi: 32   Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 6 Waste Ops
Seismic Coefficient (ks): 0



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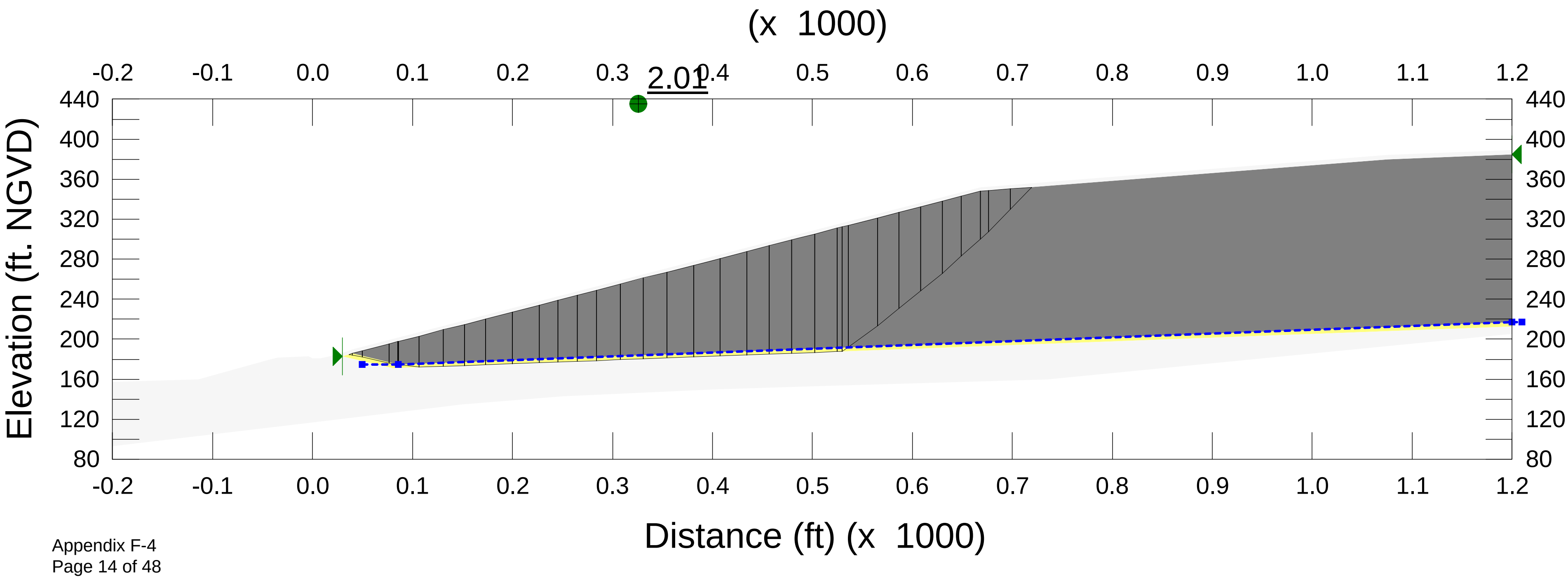
File Name: Cross-Section B-B'.gsz
Description: Liner Operational
Analysis Name: 4 Liner Ops
Date: 2/19/2015

Minimum Factor of Safety = 2.01

Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 4 Liner Ops
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



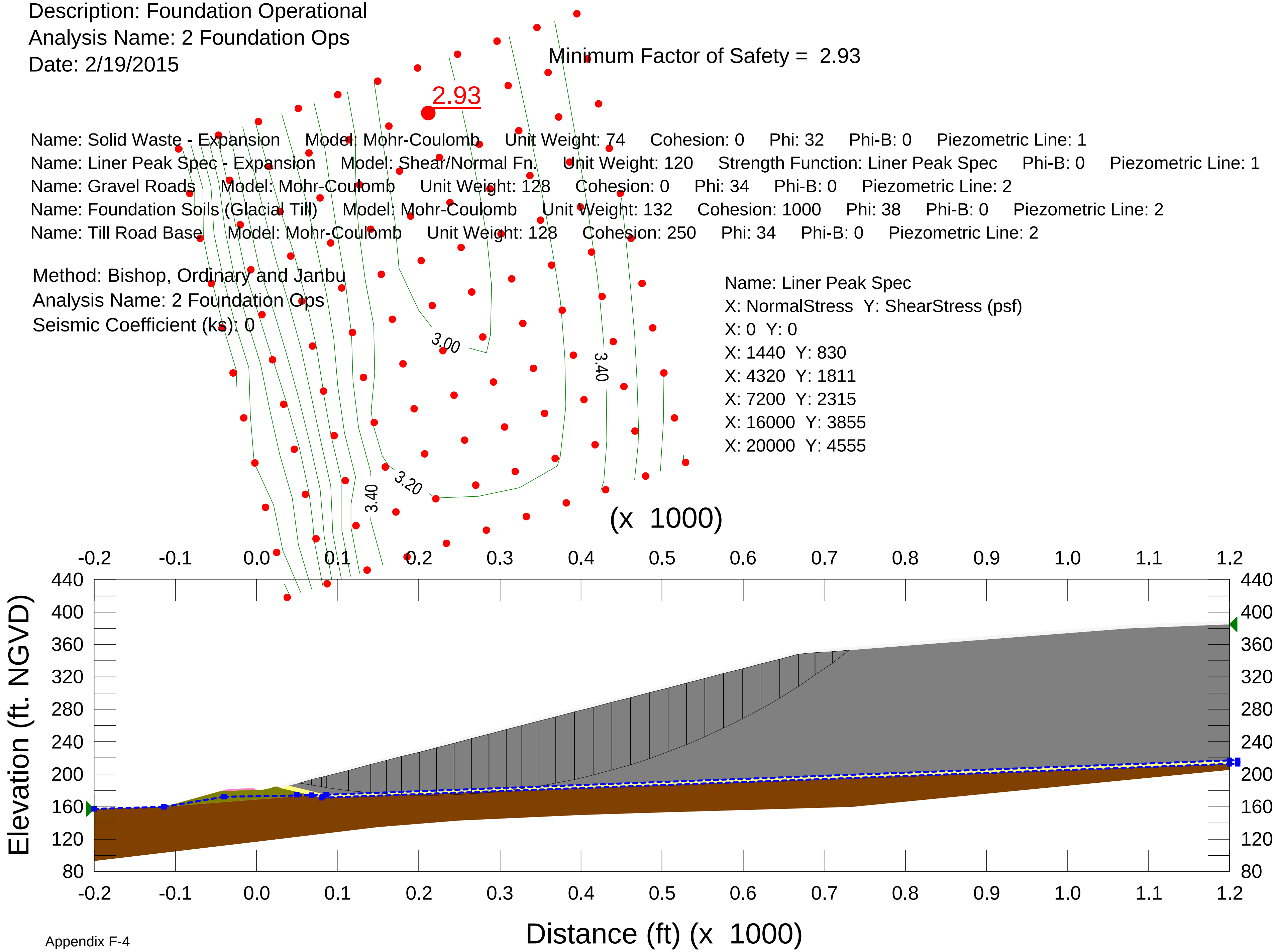
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section B-B'.gsz
Description: Foundation Operational
Analysis Name: 2 Foundation Ops
Date: 2/19/2015

Minimum Factor of Safety = 2.93

Name: Solid Waste - Expansion   Model: Mohr-Coulomb   Unit Weight: 74   Cohesion: 0   Phi: 32   Phi-B: 0   Piezometric Line: 1
Name: Liner Peak Spec - Expansion   Model: Shear/Normal Fn.   Unit Weight: 120   Strength Function: Liner Peak Spec   Phi-B: 0   Piezometric Line: 1
Name: Gravel Roads   Model: Mohr-Coulomb   Unit Weight: 128   Cohesion: 0   Phi: 34   Phi-B: 0   Piezometric Line: 2
Name: Foundation Soils (Glacial Till)   Model: Mohr-Coulomb   Unit Weight: 132   Cohesion: 1000   Phi: 38   Phi-B: 0   Piezometric Line: 2
Name: Till Road Base   Model: Mohr-Coulomb   Unit Weight: 128   Cohesion: 250   Phi: 34   Phi-B: 0   Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 2 Foundation Ops
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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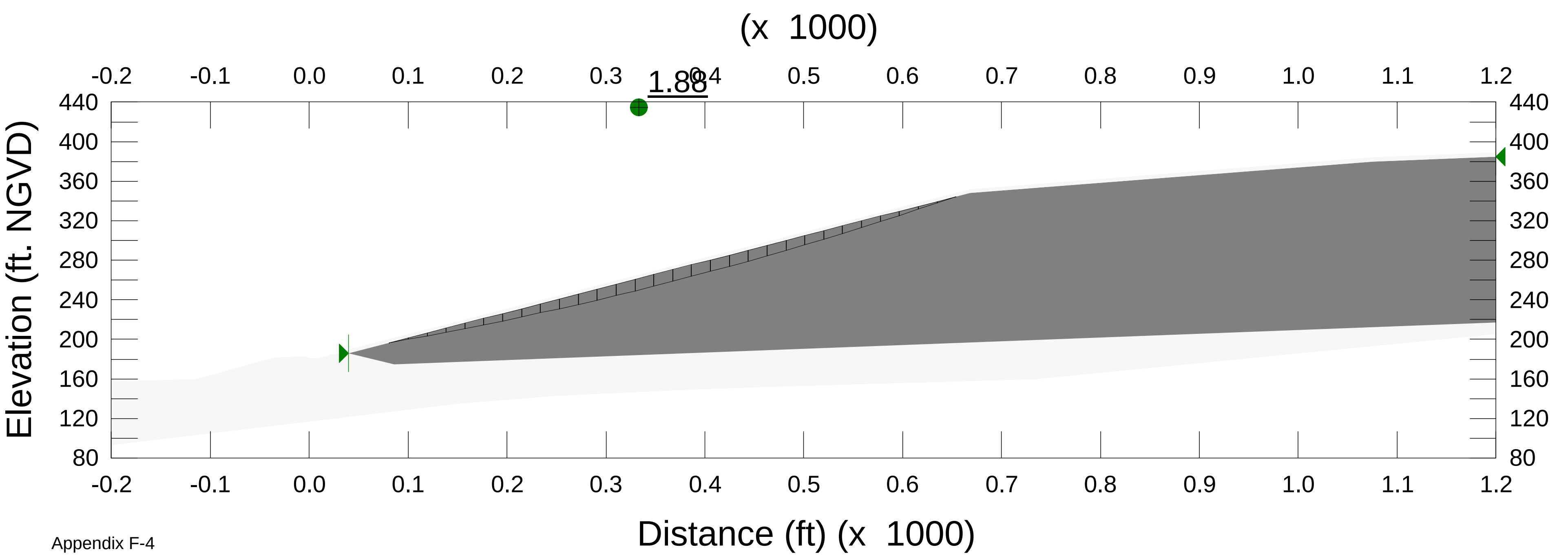
File Name: Cross-Section B-B'.gsz
Description: Waste Operational; Seismic
Analysis Name: 6s Waste Ops s
Date: 2/19/2015

Minimum Factor of Safety = 1.88

Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 6s Waste Ops s
Seismic Coefficient (ks): 0.07



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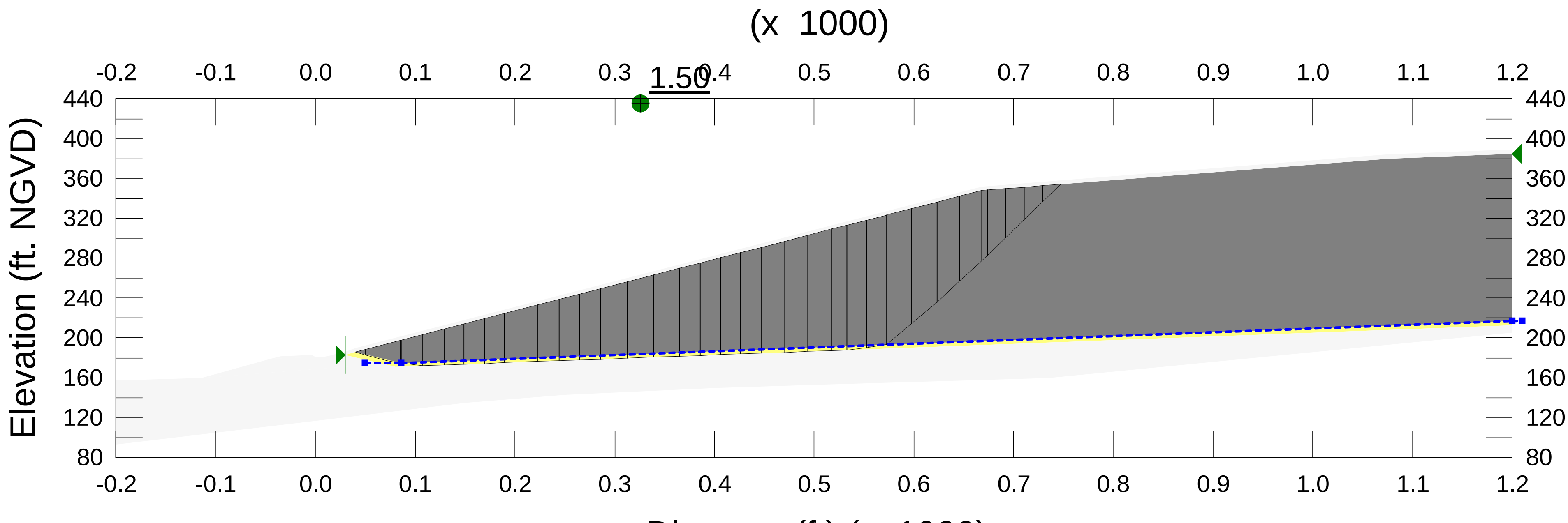
File Name: Cross-Section B-B'.gsz
Description: Liner Operational; Seismic
Analysis Name: 4s Liner Ops s
Date: 2/19/2015

Minimum Factor of Safety = 1.50

Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 4s Liner Ops s
Seismic Coefficient (ks): 0.07

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



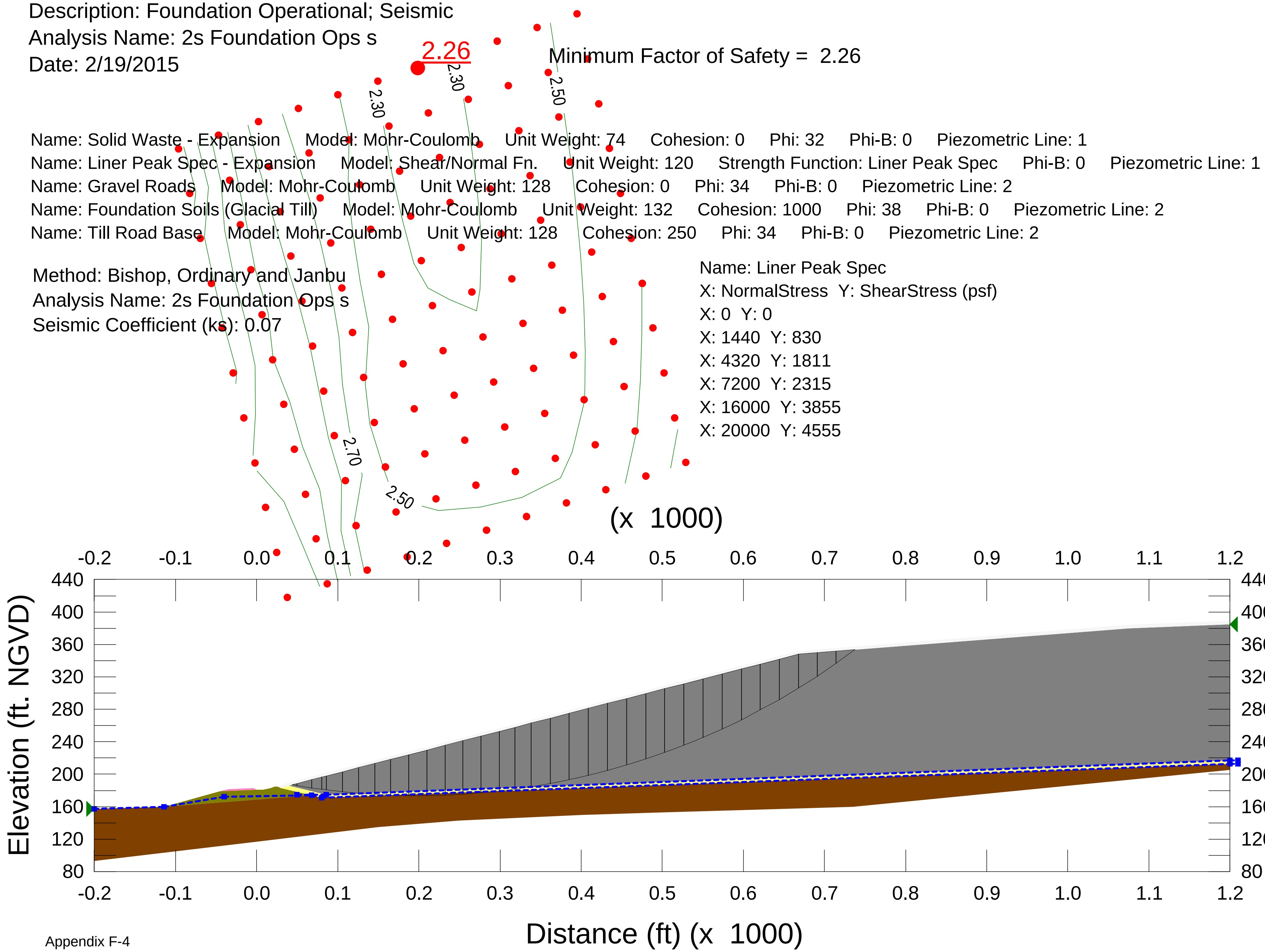
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section B-B'.gsz
Description: Foundation Operational; Seismic
Analysis Name: 2s Foundation Ops s
Date: 2/19/2015

Minimum Factor of Safety = 2.26

Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 2s Foundation Ops s
Seismic Coefficient (ks): 0.07

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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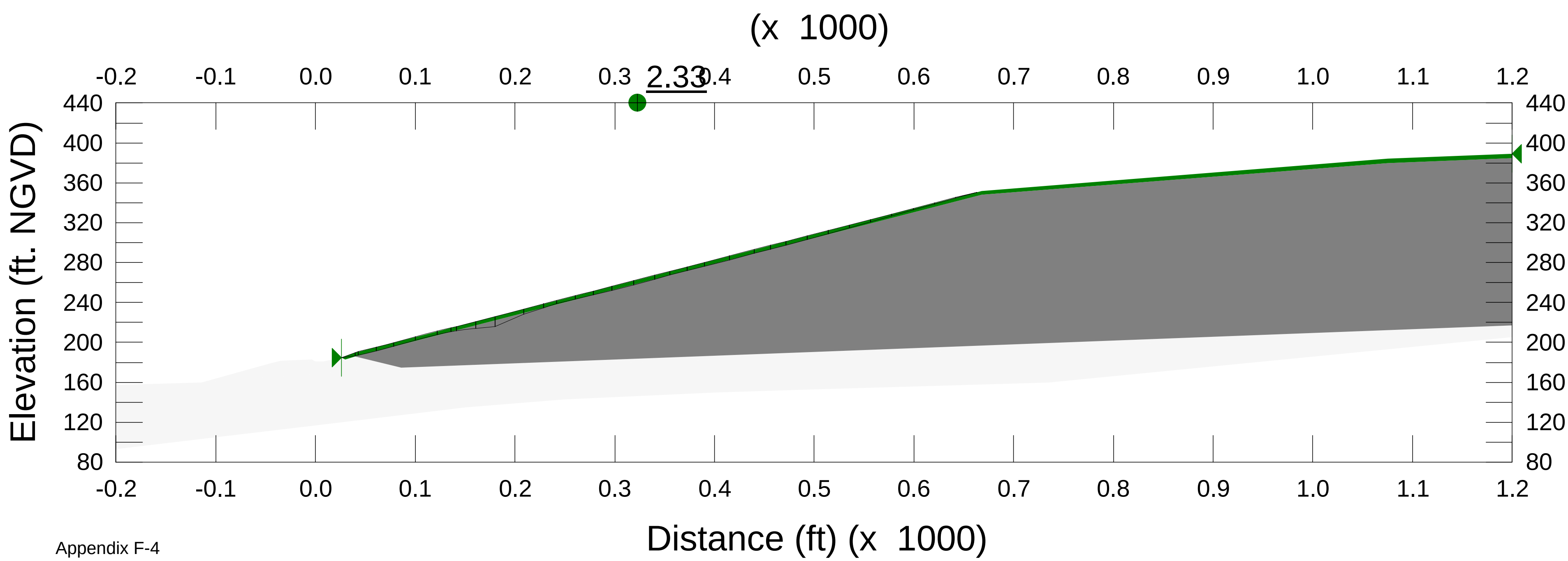
File Name: Cross-Section B-B'.gsz
Description: Waste Closed
Analysis Name: 5 Waste Closed
Date: 2/19/2015

Minimum Factor of Safety = 2.33

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 5 Waste Closed
Seismic Coefficient (ks): 0



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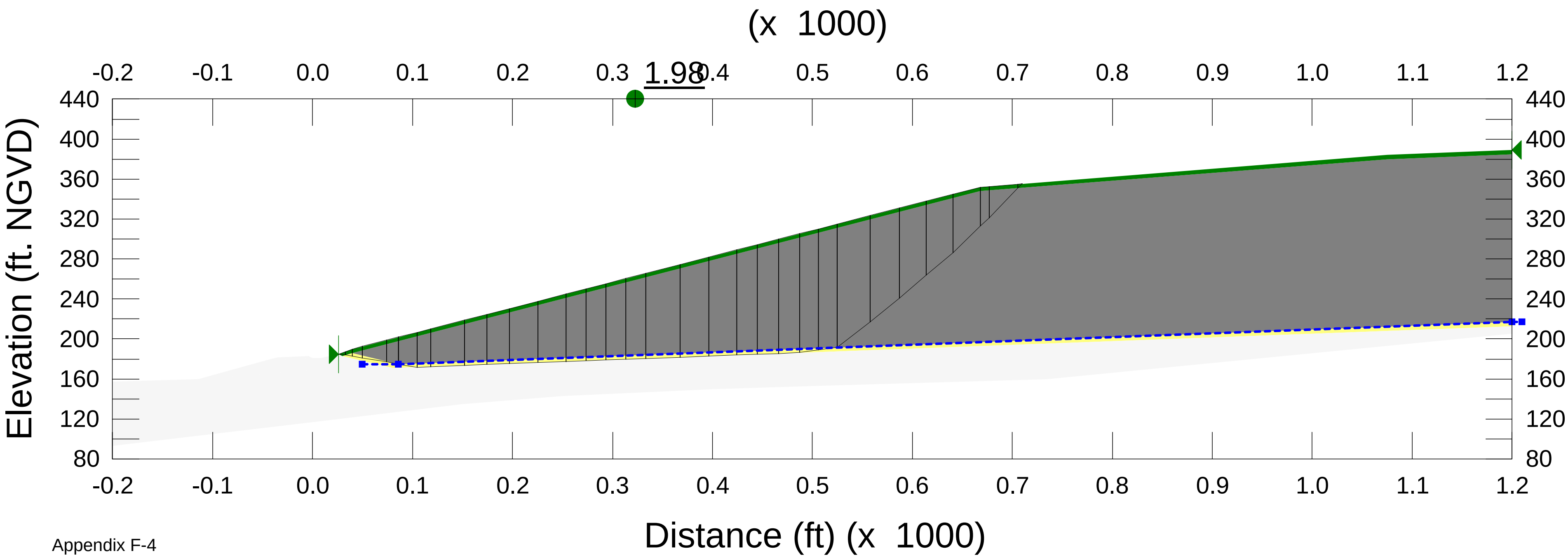
File Name: Cross-Section B-B'.gsz
Description: Liner Closed
Analysis Name: 3 Liner Closed
Date: 2/19/2015

Minimum Factor of Safety = 1.98

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 3 Liner Closed
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



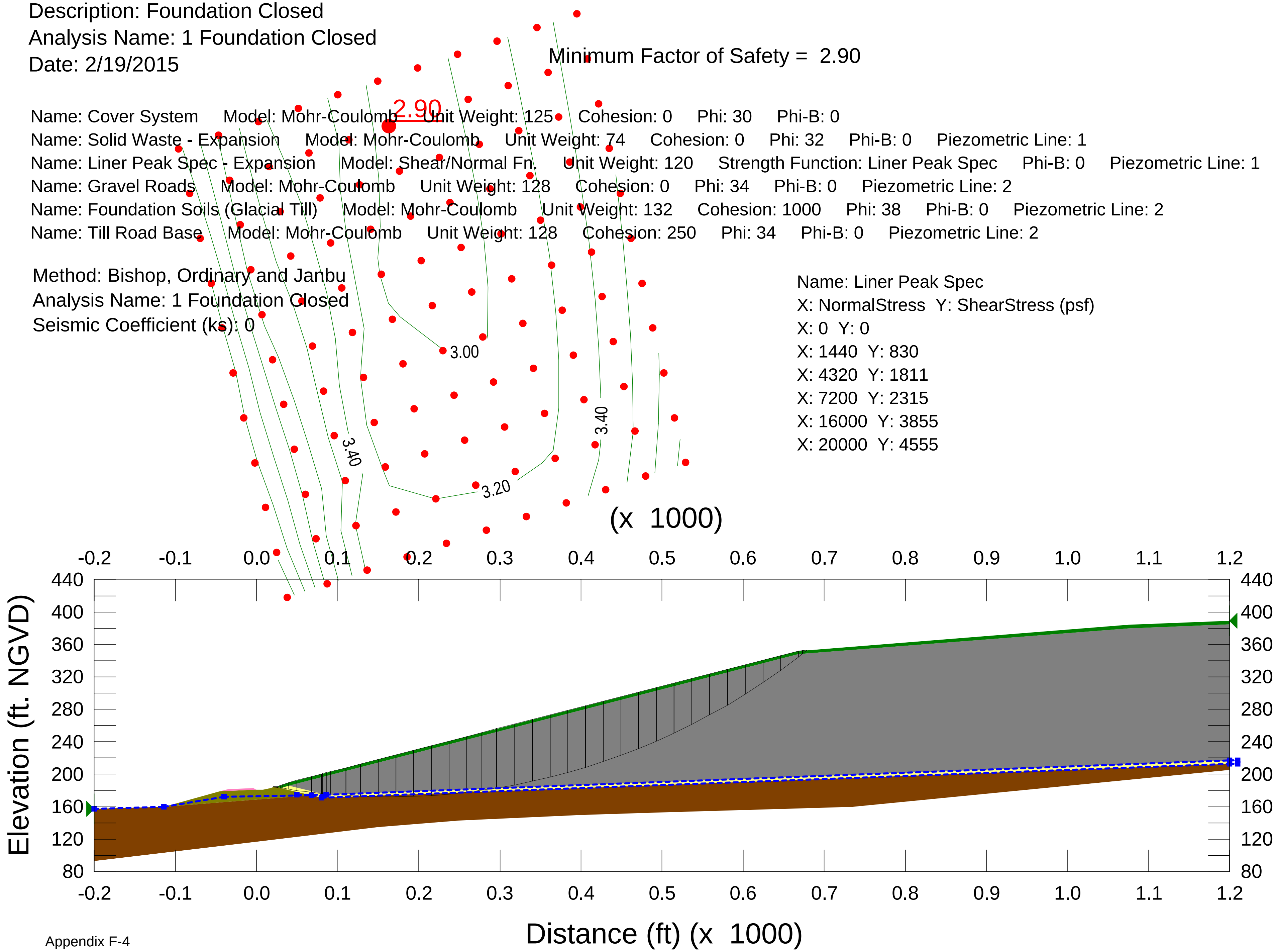
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section B-B'.gsz
Description: Foundation Closed
Analysis Name: 1 Foundation Closed
Date: 2/19/2015

Minimum Factor of Safety = 2.90

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 1 Foundation Closed
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



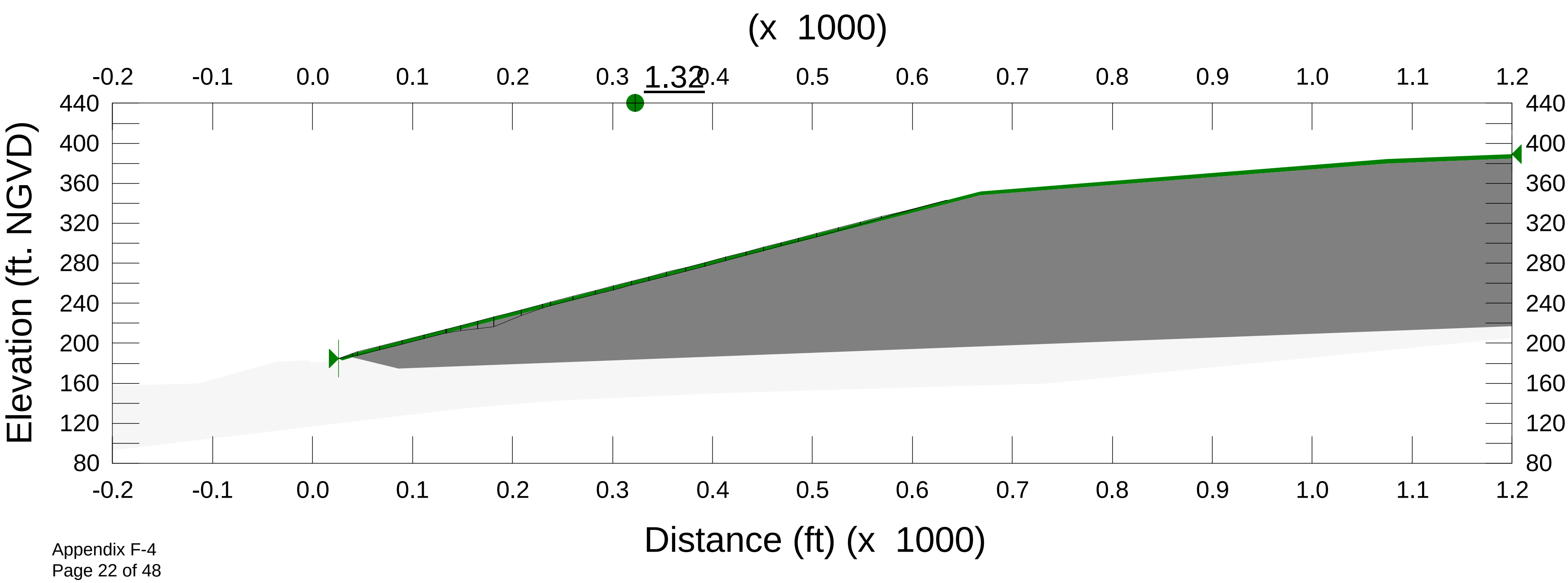
Appendix F-4
Page 21 of 48
02/19/2015

Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section B-B'.gsz
Description: Waste Closed; Seismic
Analysis Name: 5s Waste Closed s
Date: 2/19/2015

Minimum Factor of Safety = 1.32

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 5s Waste Closed s
Seismic Coefficient (ks): 0.18



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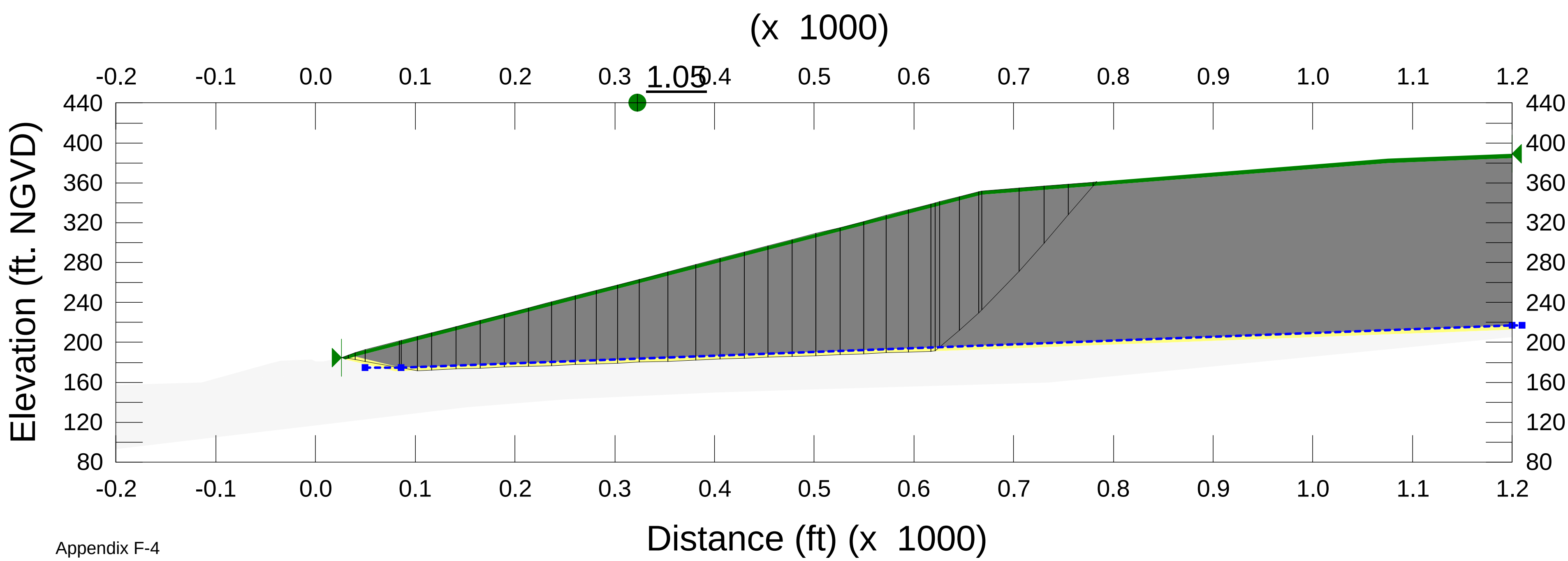
File Name: Cross-Section B-B'.gsz
Description: Liner Closed; Seismic
Analysis Name: 3s Liner Closed s
Date: 2/19/2015

Minimum Factor of Safety = 1.05

Name: Cover System   Model: Mohr-Coulomb   Unit Weight: 125   Cohesion: 0   Phi: 30   Phi-B: 0
Name: Solid Waste - Expansion   Model: Mohr-Coulomb   Unit Weight: 74   Cohesion: 0   Phi: 32   Phi-B: 0   Piezometric Line: 1
Name: Liner Peak Spec - Expansion   Model: Shear/Normal Fn.   Unit Weight: 120   Strength Function: Liner Peak Spec   Phi-B: 0   Piezometric Line: 1

Method: Spencer
Analysis Name: 3s Liner Closed s
Seismic Coefficient (ks): 0.18

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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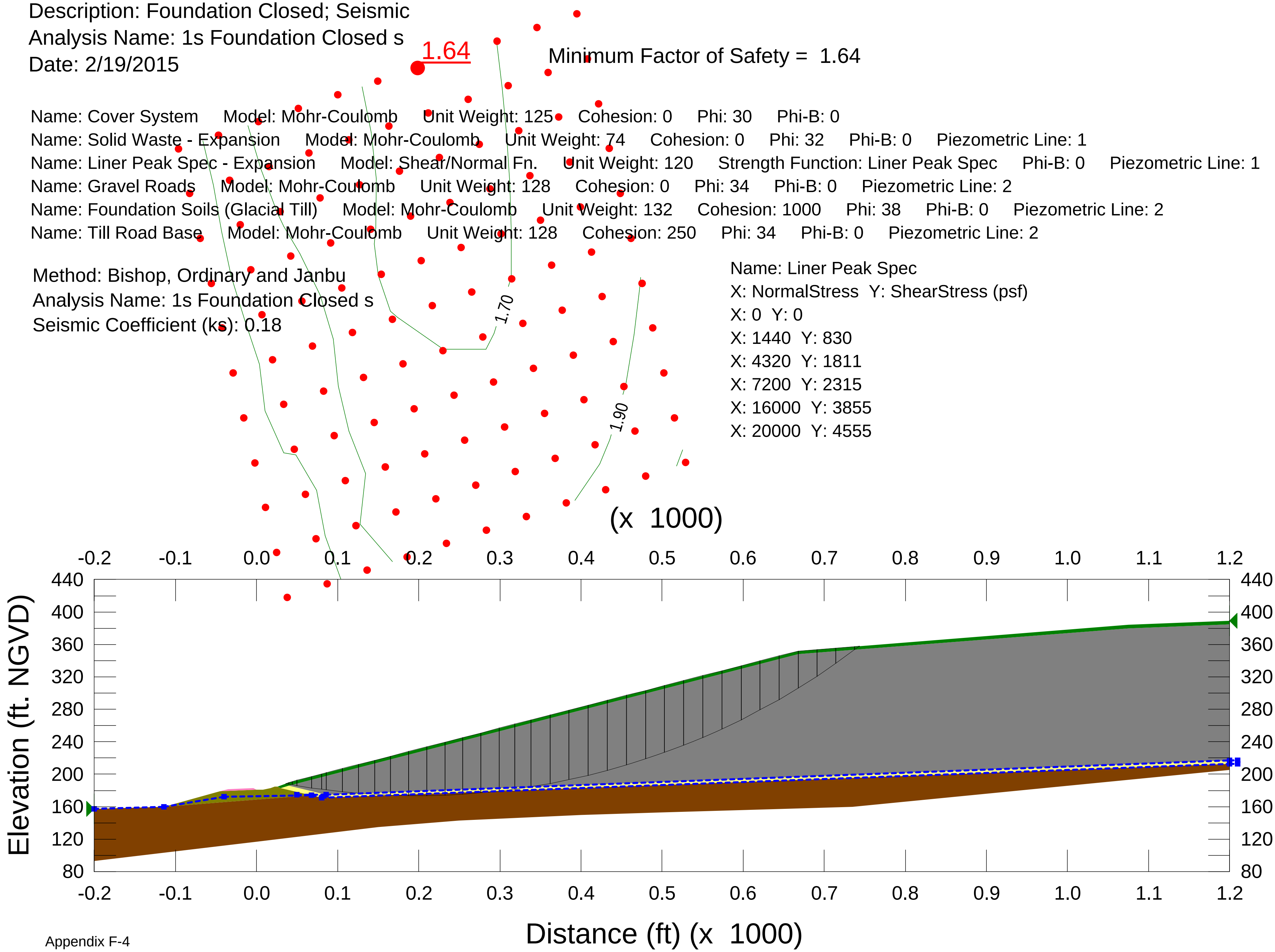
File Name: Cross-Section B-B'.gsz
Description: Foundation Closed; Seismic
Analysis Name: 1s Foundation Closed s
Date: 2/19/2015

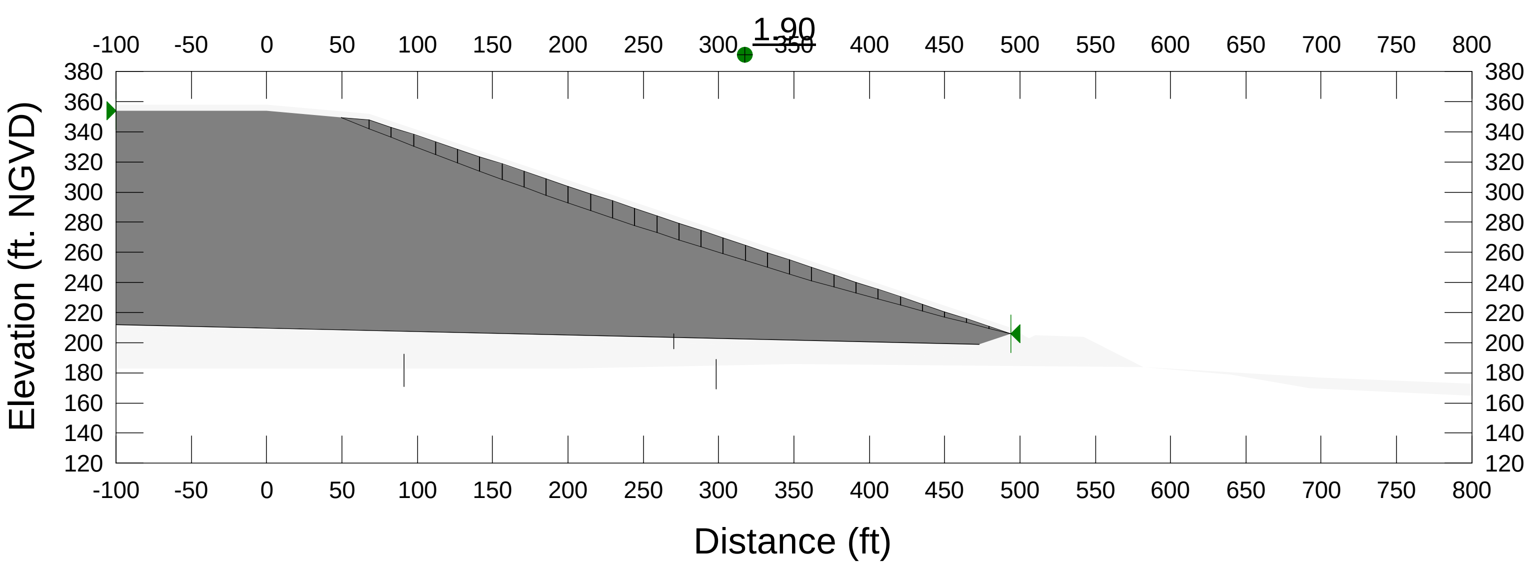


Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section C-C'.gsz
Description: Waste Operational
Analysis Name: 6 Waste Ops
Date: 2/19/2015

Minimum Factor of Safety = 1.90

Name: Solid Waste   Model: Mohr-Coulomb   Unit Weight: 74   Cohesion: 0   Phi: 32   Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 6 Waste Ops
Seismic Coefficient (ks): 0



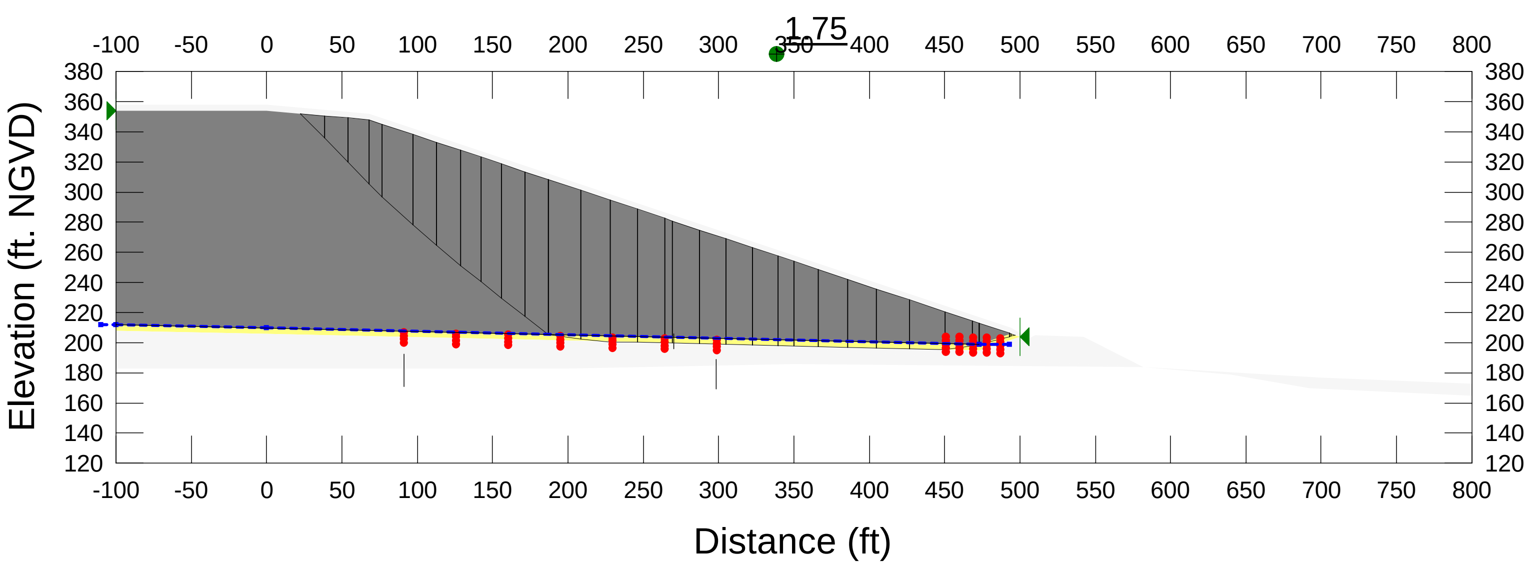
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section C-C'.gsz
Description: Liner Operational
Analysis Name: 4 Liner Ops
Date: 2/19/2015

Minimum Factor of Safety = 1.75

Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 4 Liner Ops
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



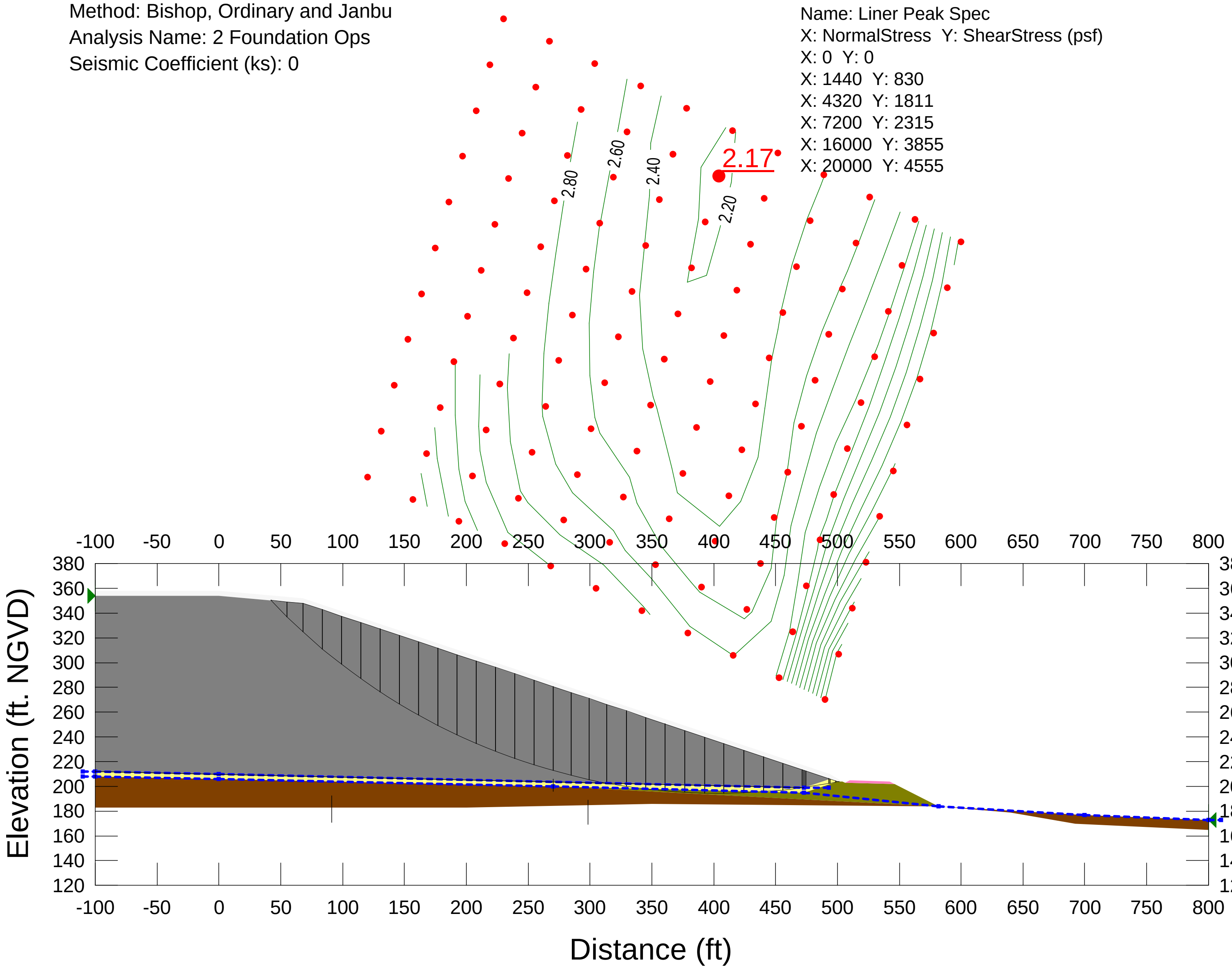
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section C-C'.gsz
Description: Foundation Operational
Analysis Name: 2 Foundation Ops
Date: 2/19/2015

Minimum Factor of Safety = 2.17

Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 2 Foundation Ops
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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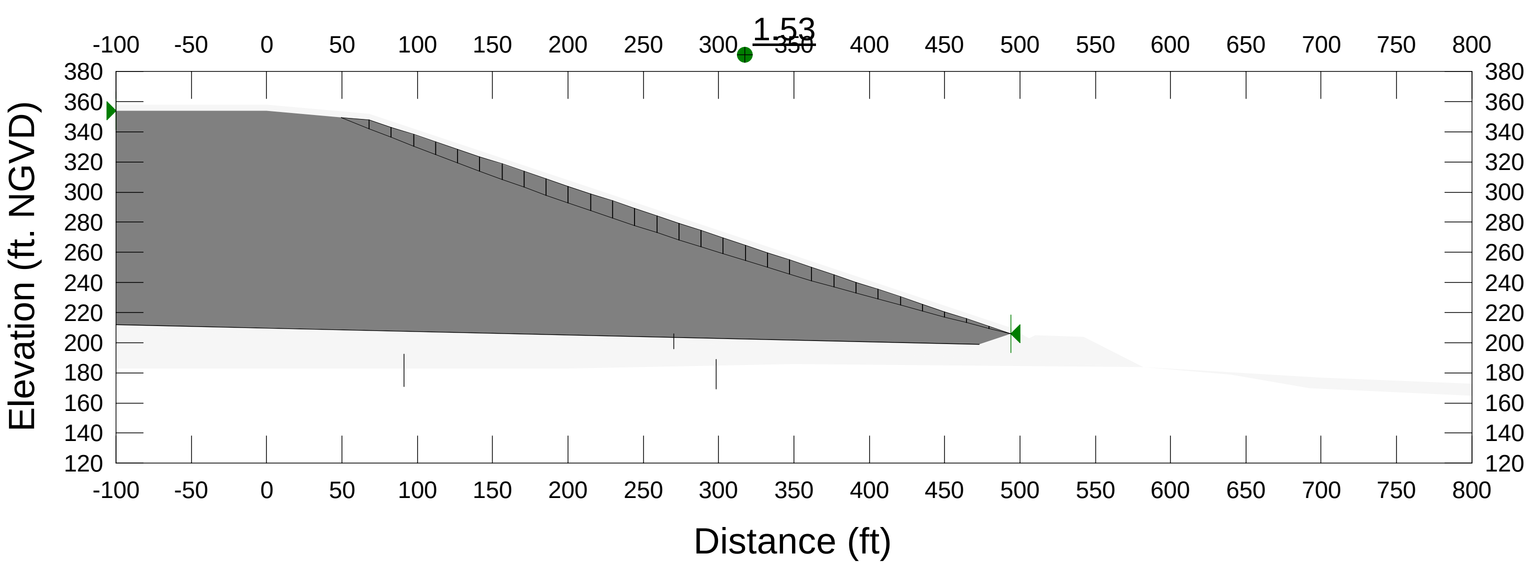
File Name: Cross-Section C-C'.gsz
Description: Waste Operational; Seismic
Analysis Name: 6s Waste Ops s
Date: 2/19/2015

Minimum Factor of Safety = 1.53

Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 6s Waste Ops s
Seismic Coefficient (ks): 0.07



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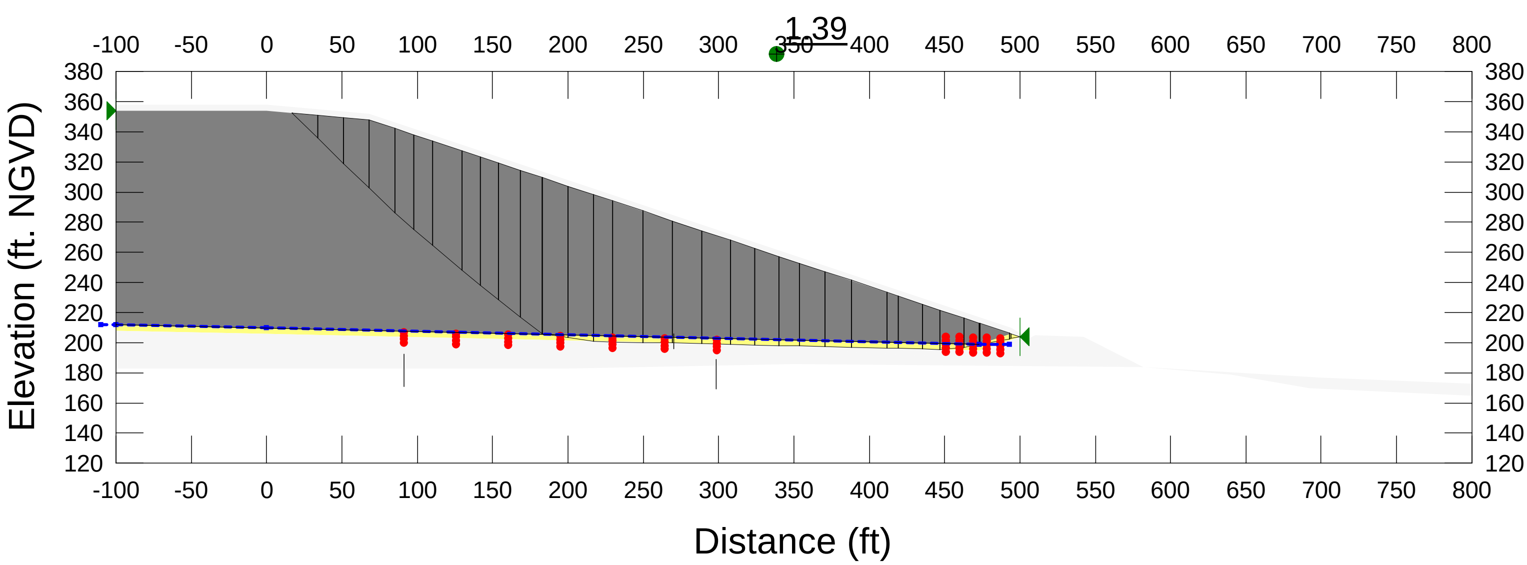
File Name: Cross-Section C-C'.gsz
Description: Liner Operational; Seismic
Analysis Name: 4s Liner Ops s
Date: 2/19/2015

Minimum Factor of Safety = 1.39

Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 4s Liner Ops s
Seismic Coefficient (ks): 0.07

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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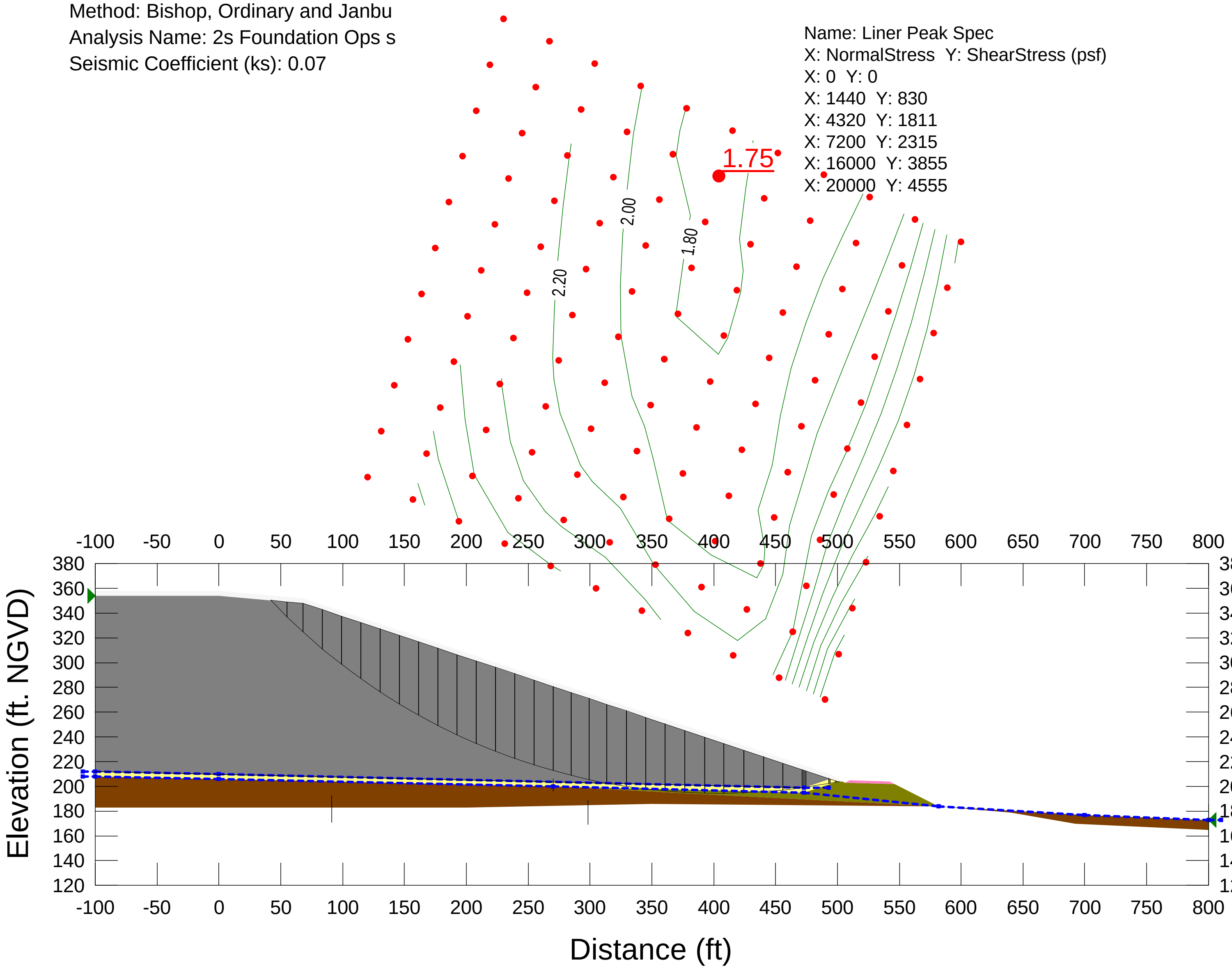
File Name: Cross-Section C-C'.gsz
Description: Foundation Operational; Seismic
Analysis Name: 2s Foundation Ops s
Date: 2/19/2015

Minimum Factor of Safety = 1.75

Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 2s Foundation Ops s
Seismic Coefficient (ks): 0.07

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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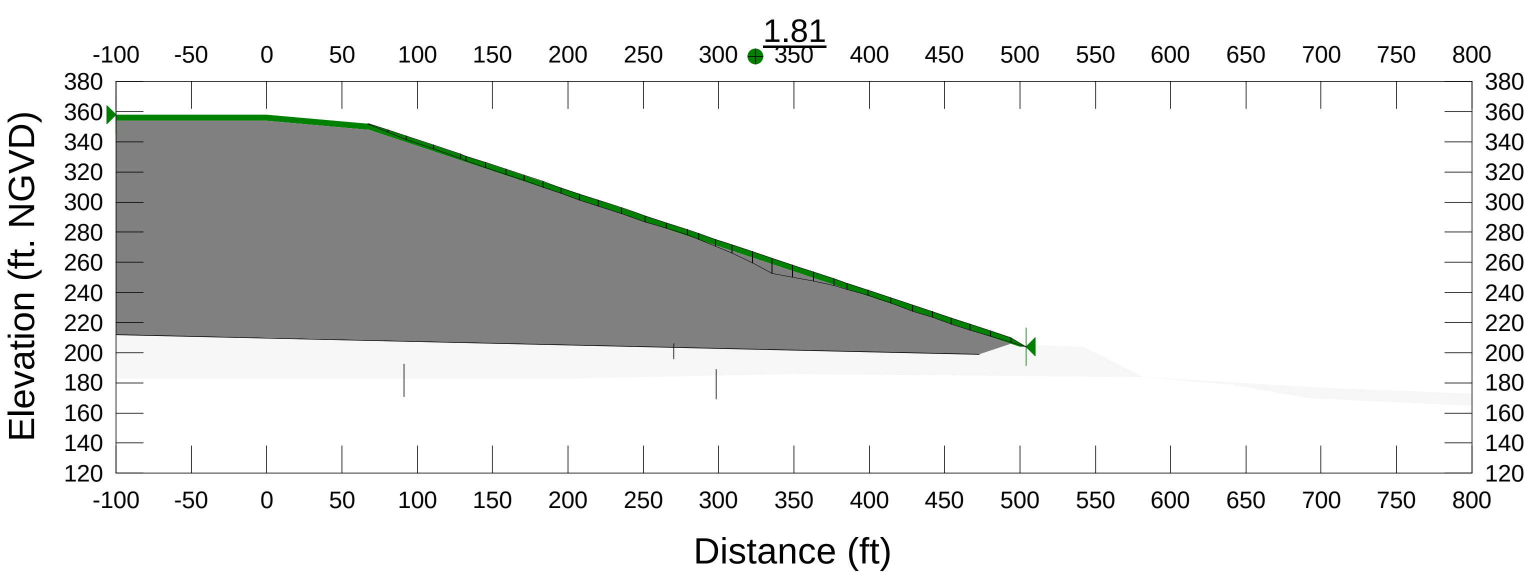
File Name: Cross-Section C-C'.gsz
Description: Waste Closed
Analysis Name: 5 Waste Closed
Date: 2/19/2015

Minimum Factor of Safety = 1.81

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 5 Waste Closed
Seismic Coefficient (ks): 0



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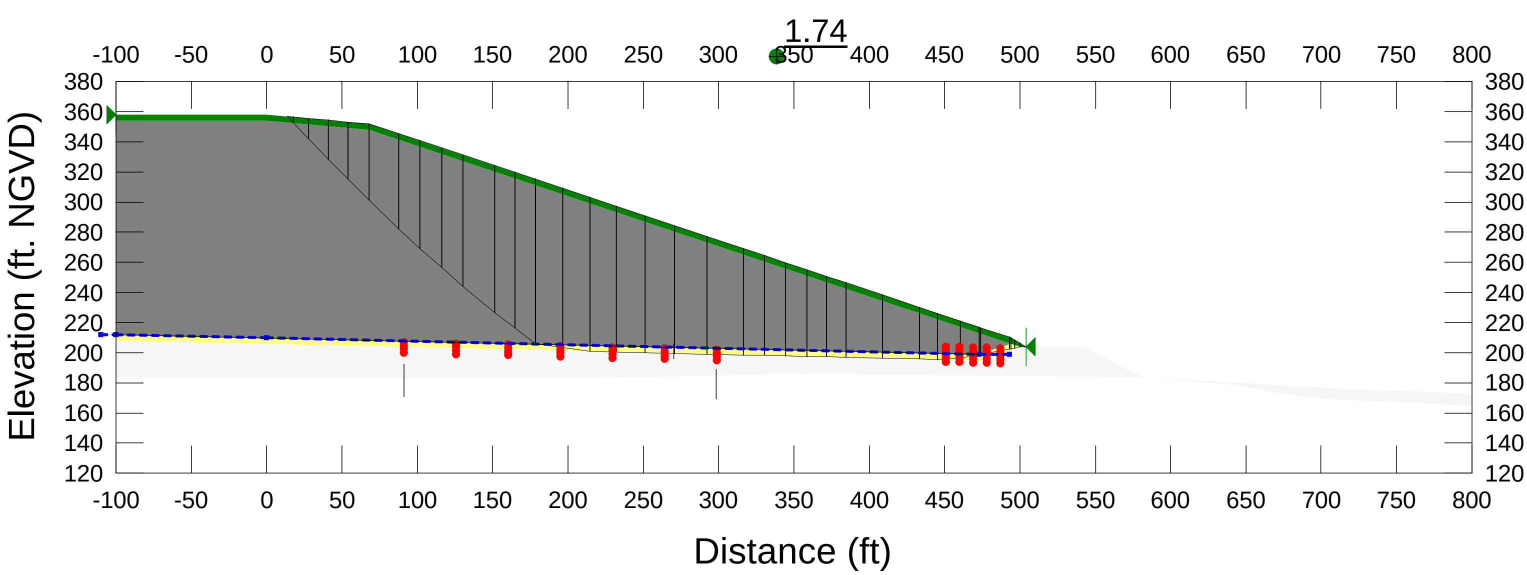
File Name: Cross-Section C-C'.gsz
Description: Liner Closed
Analysis Name: 3 Liner Closed
Date: 2/19/2015

Minimum Factor of Safety = 1.74

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 3 Liner Closed
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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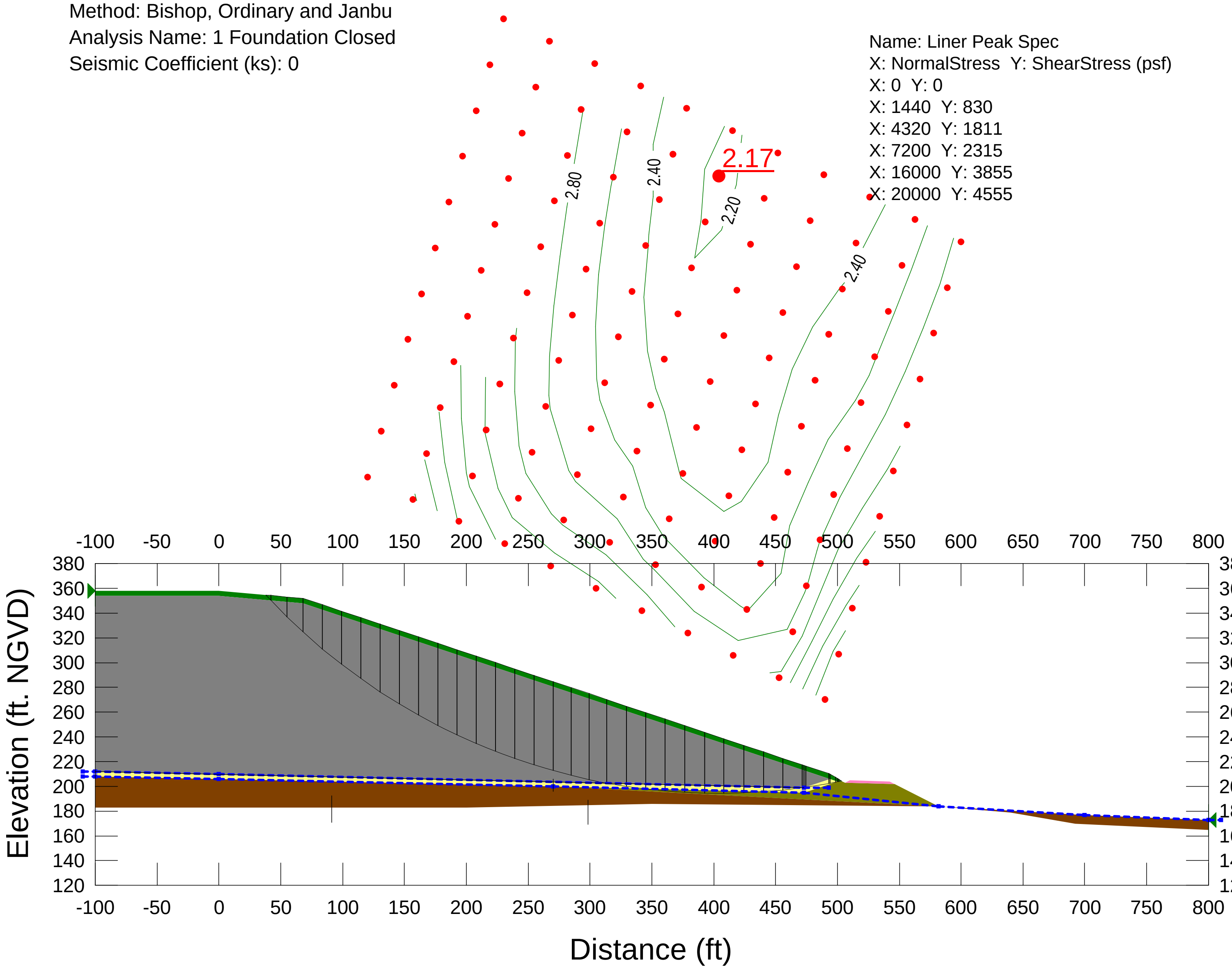
File Name: Cross-Section C-C'.gsz
Description: Foundation Closed
Analysis Name: 1 Foundation Closed
Date: 2/19/2015

Minimum Factor of Safety = 2.17

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 1 Foundation Closed
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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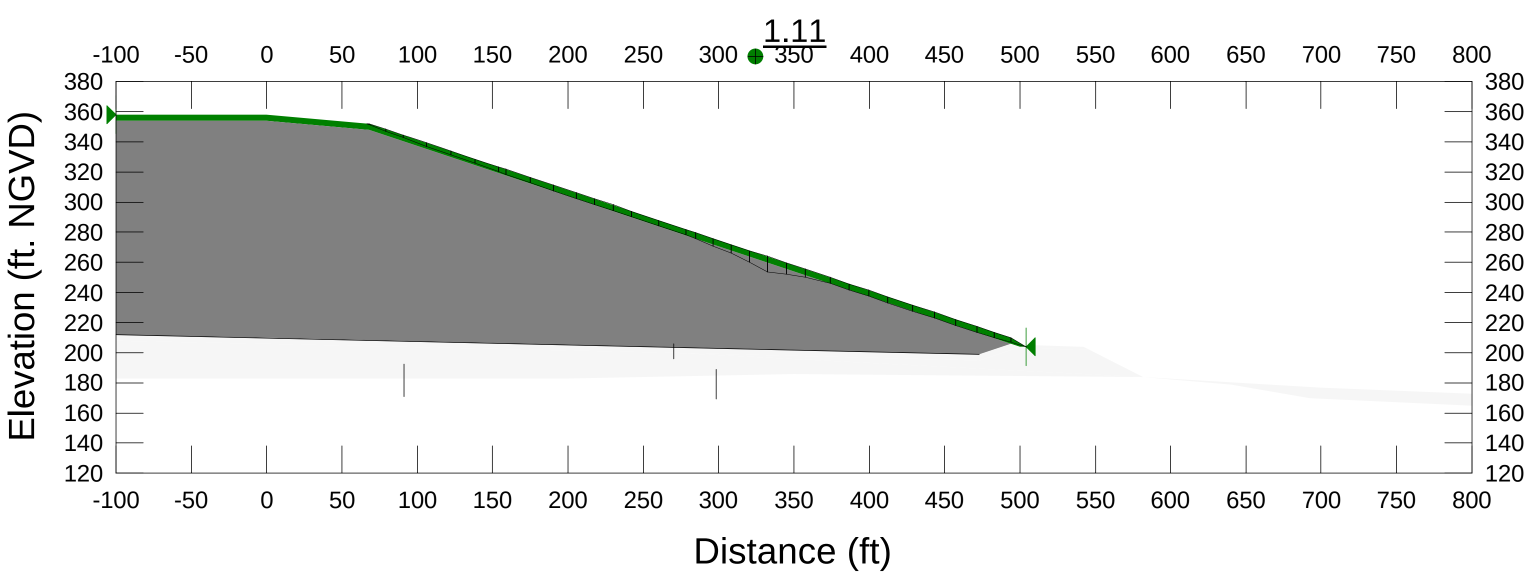
File Name: Cross-Section C-C'.gsz
Description: Waste Closed; Seismic
Analysis Name: 5s Waste Closed s
Date: 2/19/2015

Minimum Factor of Safety = 1.11

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 5s Waste Closed s
Seismic Coefficient (ks): 0.18



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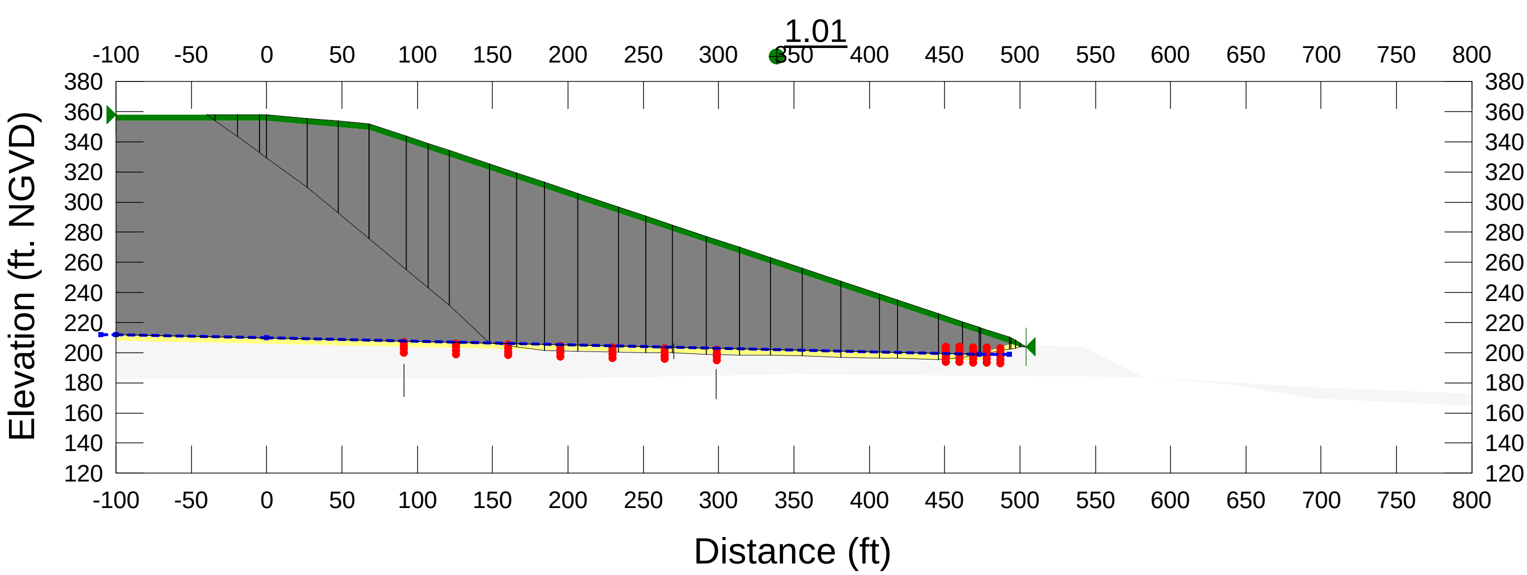
File Name: Cross-Section C-C'.gsz
Description: Liner Closed; Seismic
Analysis Name: 3s Liner Closed s
Date: 2/19/2015

Minimum Factor of Safety = 1.01

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 3s Liner Closed s
Seismic Coefficient (ks): 0.18

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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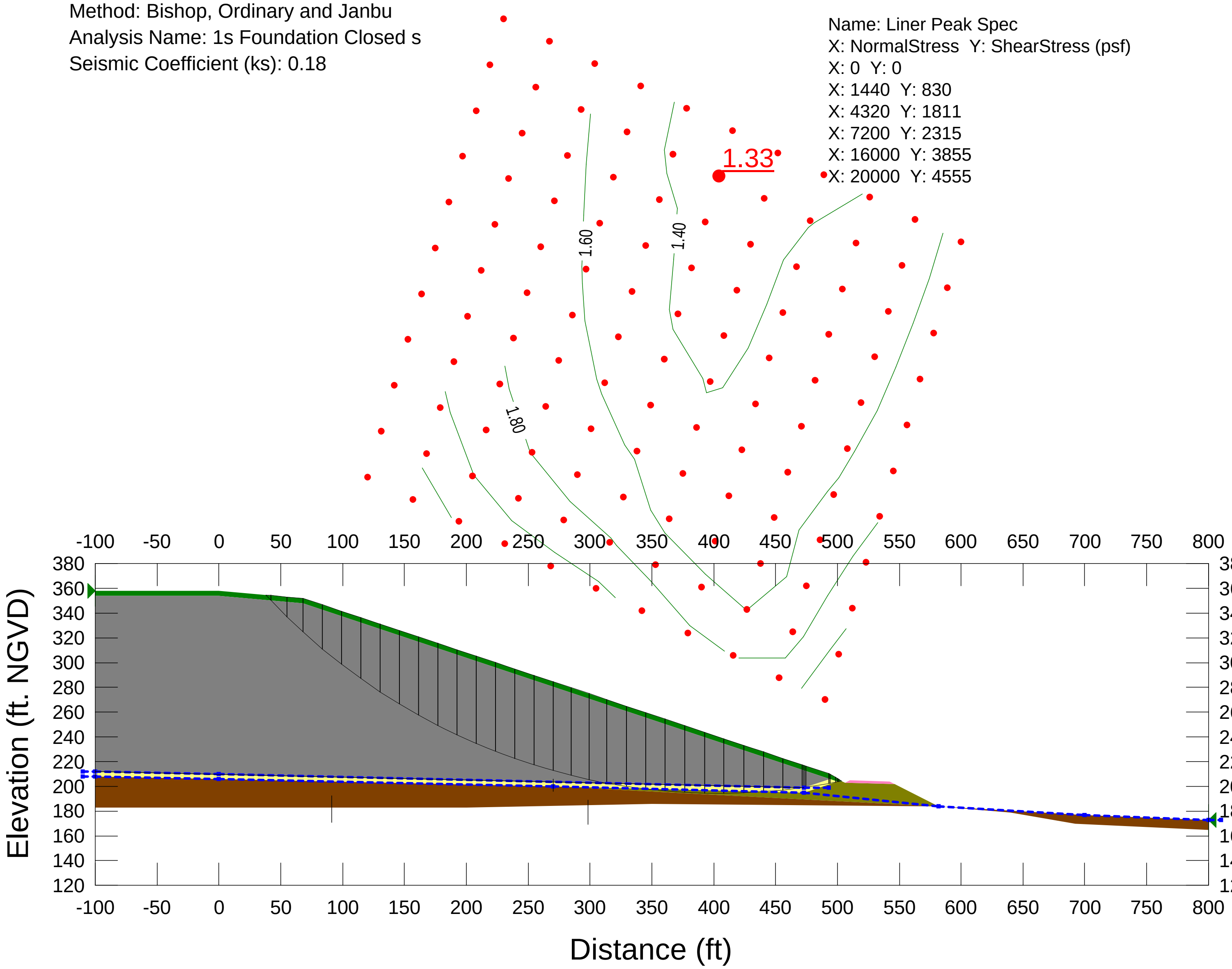
File Name: Cross-Section C-C'.gsz
Description: Foundation Closed; Seismic
Analysis Name: 1s Foundation Closed s
Date: 2/19/2015

Minimum Factor of Safety = 1.33

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 1s Foundation Closed s
Seismic Coefficient (ks): 0.18

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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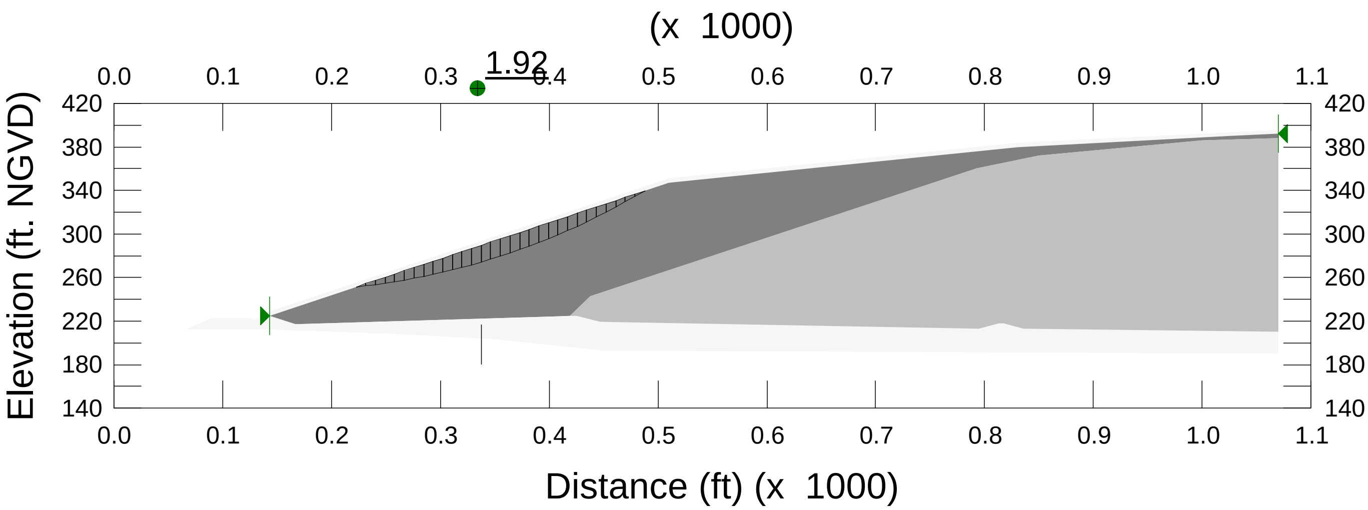
File Name: Cross-Section D-D''.gsz
Description: Waste Operational
Analysis Name: 6 Waste Ops
Date: 2/19/2015

Minimum Factor of Safety = 1.92

Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 6 Waste Ops
Seismic Coefficient (ks): 0



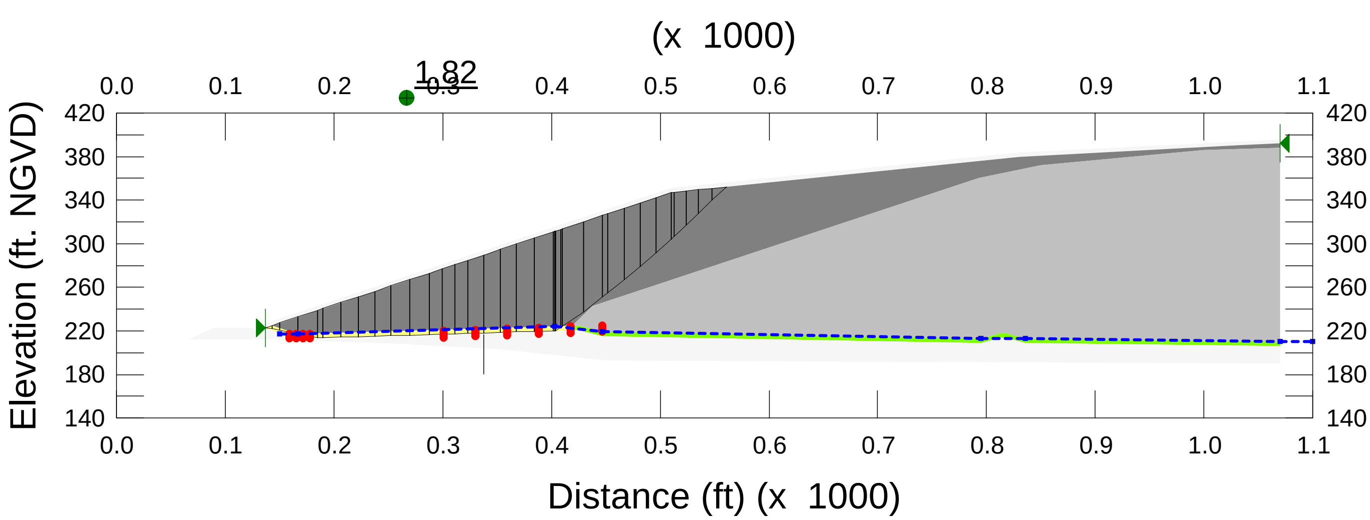
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section D-D''.gsz
Description: Liner Operational
Analysis Name: 4 Liner Ops
Date: 2/19/2015

Minimum Factor of Safety = 1.82

Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak - Cells 7&3A Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 4 Liner Ops
Seismic Coefficient (ks): 0

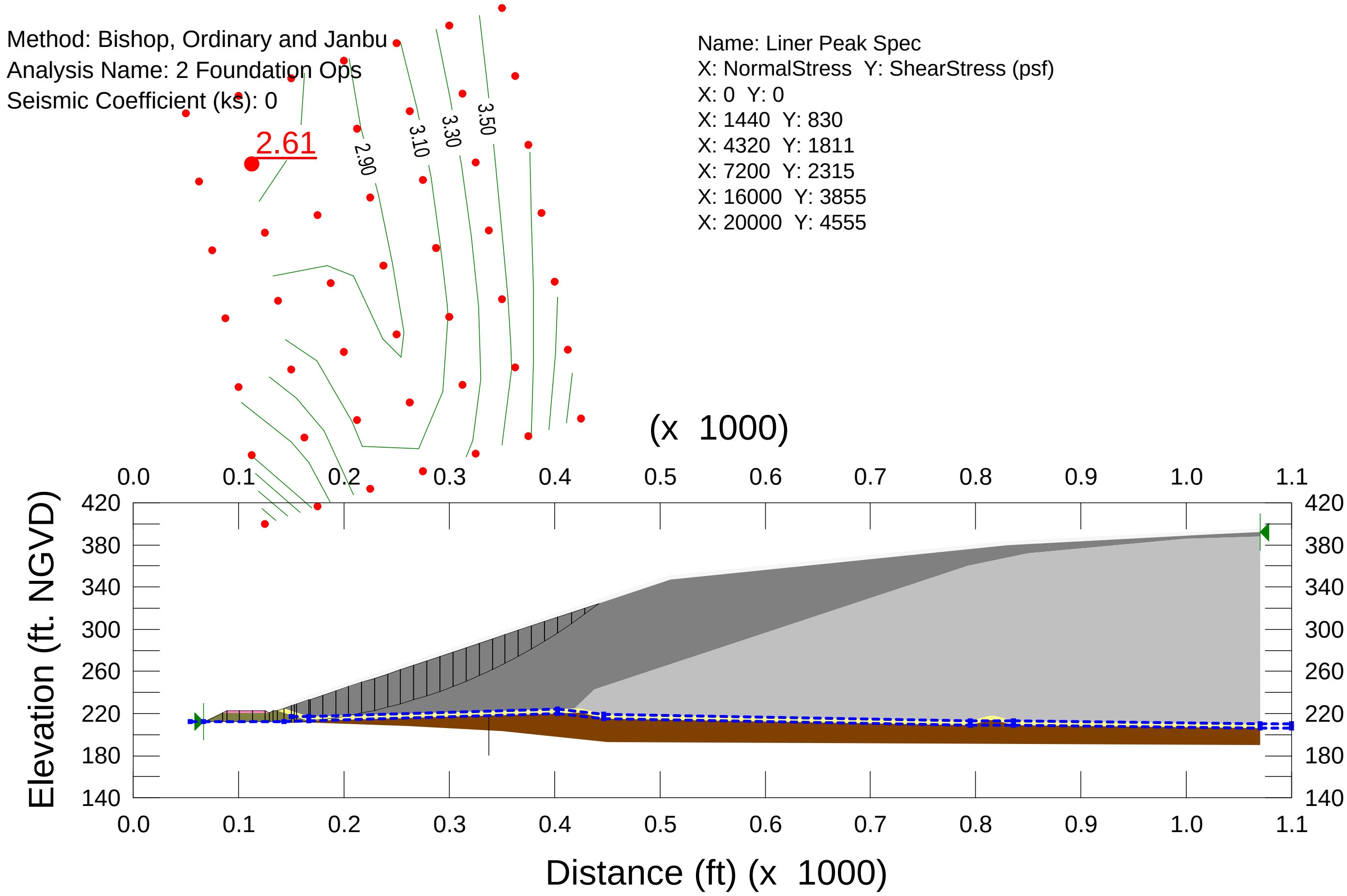
Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section D-D".gsz
Description: Foundation Operational
Analysis Name: 2 Foundation Ops
Date: 2/19/2015

Minimum Factor of Safety = 2.61

Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

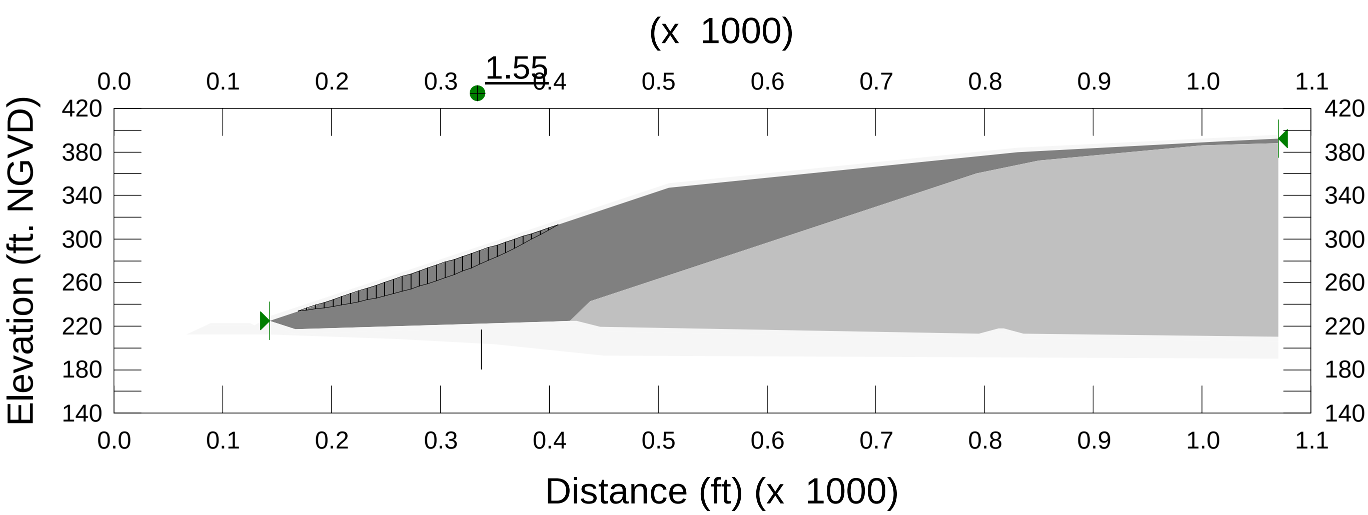


Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section D-D".gsz
Description: Waste Operational; Seismic
Analysis Name: 6s Waste Ops s
Date: 2/19/2015

Minimum Factor of Safety = 1.55

Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 6s Waste Ops s
Seismic Coefficient (ks): 0.07



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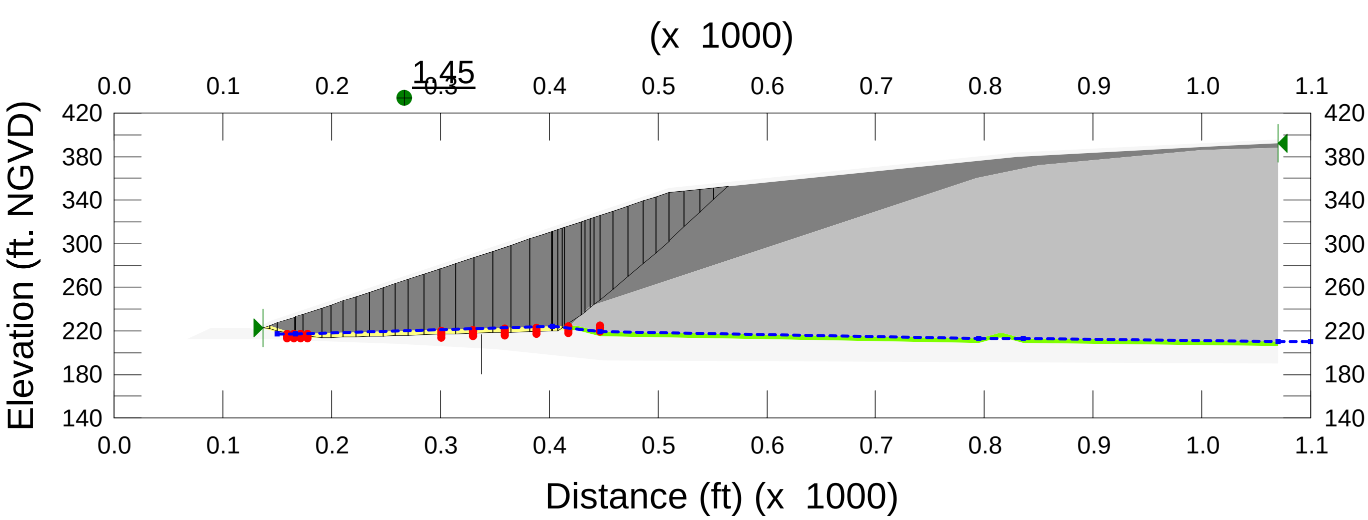
File Name: Cross-Section D-D''.gsz
Description: Liner Operational; Seismic
Analysis Name: 4s Liner Ops s
Date: 2/19/2015

Minimum Factor of Safety = 1.45

Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak - Cells 7&3A Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 4s Liner Ops s
Seismic Coefficient (ks): 0.07

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



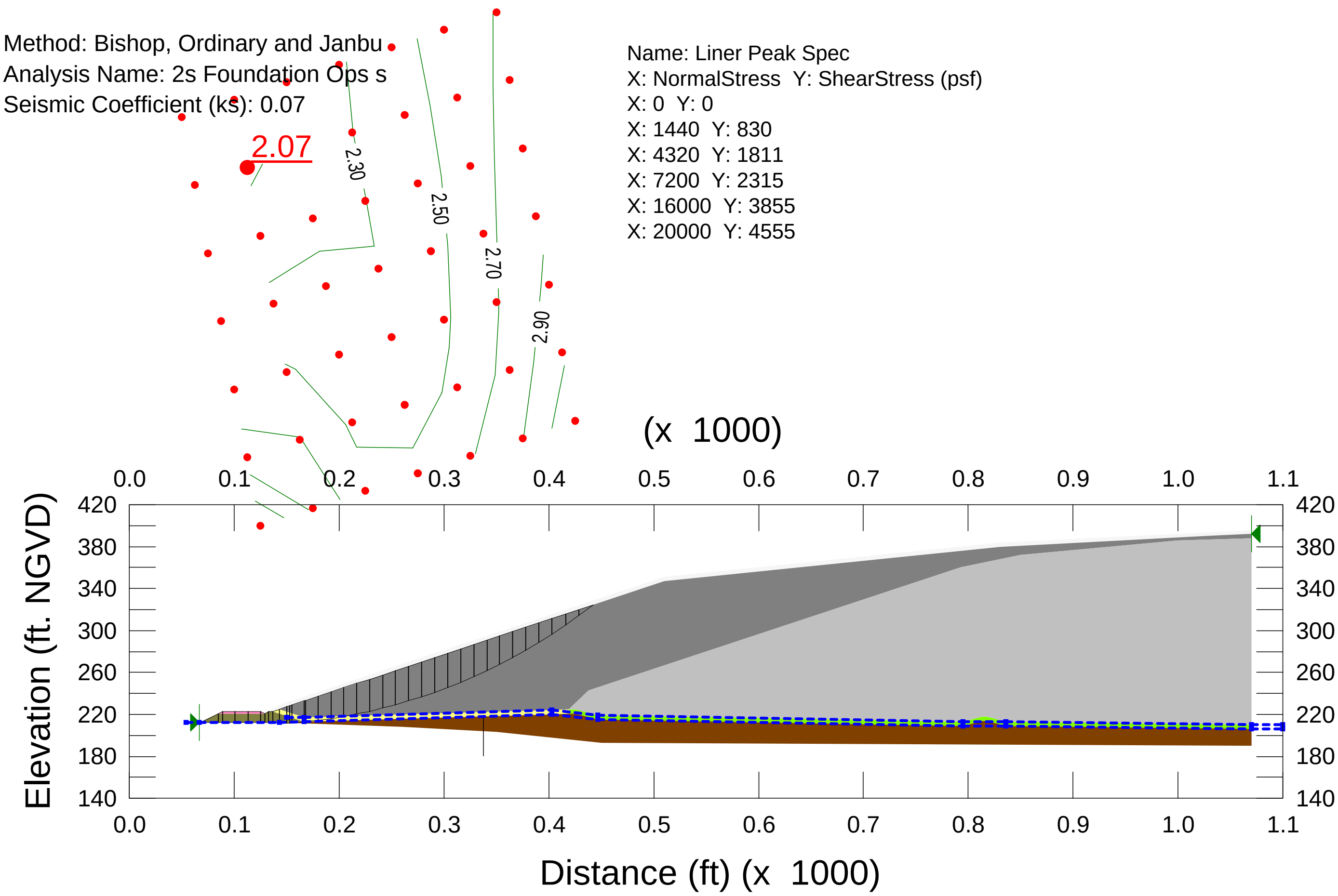
Directory: \\rnserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section D-D".gsz
Description: Foundation Operational; Seismic
Analysis Name: 2s Foundation Ops s
Date: 2/19/2015

Minimum Factor of Safety = 2.07

Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Gravel Roads Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 0 Phi: 34 Phi-B: 0 Piezometric Line: 2
Name: Foundation Soils (Glacial Till) Model: Mohr-Coulomb Unit Weight: 132 Cohesion: 1000 Phi: 38 Phi-B: 0 Piezometric Line: 2
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak - Cells 7&3A Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Till Road Base Model: Mohr-Coulomb Unit Weight: 128 Cohesion: 250 Phi: 34 Phi-B: 0 Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 2s Foundation Ops s
Seismic Coefficient (ks): 0.07

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555

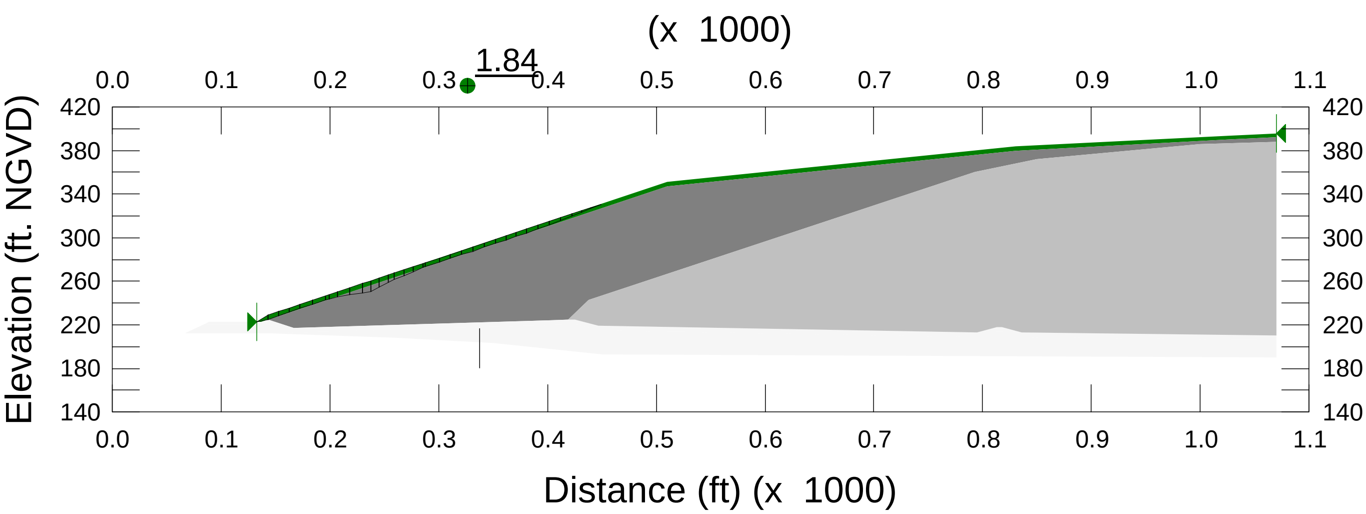


Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section D-D".gsz
Description: Waste Closed
Analysis Name: 5 Waste Closed
Date: 2/19/2015

Minimum Factor of Safety = 1.84

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 5 Waste Closed
Seismic Coefficient (ks): 0



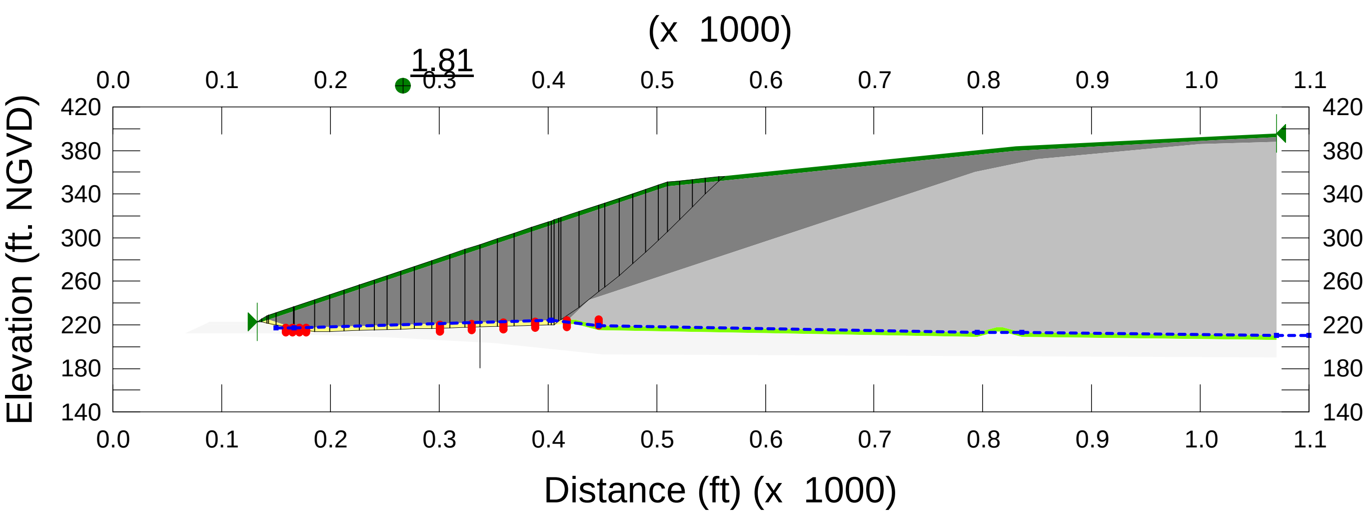
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section D-D''.gsz
Description: Liner Closed
Analysis Name: 3 Liner Closed
Date: 2/19/2015

Minimum Factor of Safety = 1.81

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak - Cells 7&3A Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 3 Liner Closed
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



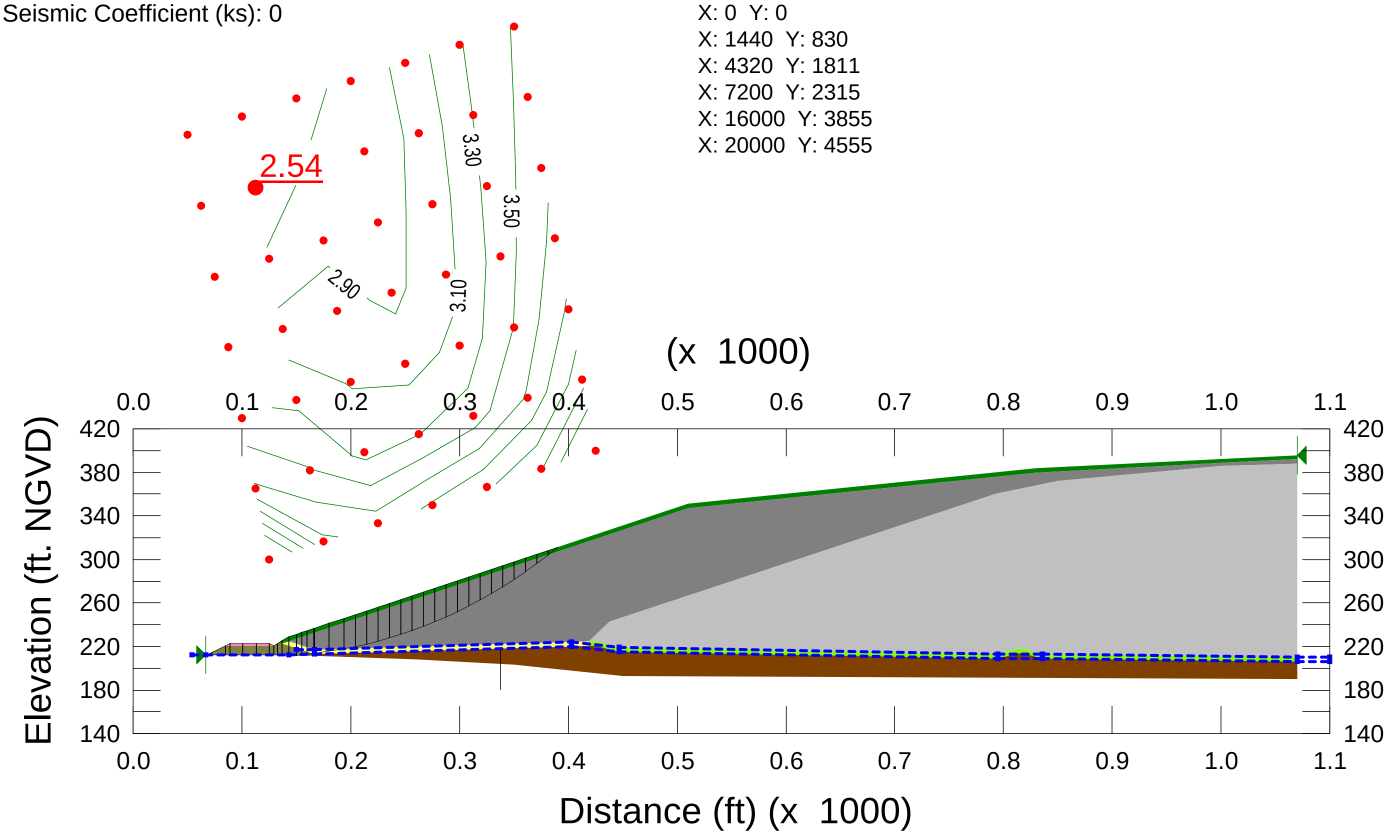
Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section D-D".gsz
Description: Foundation Closed
Analysis Name: 1 Foundation Closed
Date: 2/19/2015

Minimum Factor of Safety = 2.54

Name: Cover System   Model: Mohr-Coulomb   Unit Weight: 125   Cohesion: 0   Phi: 30   Phi-B: 0
Name: Solid Waste - Expansion   Model: Mohr-Coulomb   Unit Weight: 74   Cohesion: 0   Phi: 32   Phi-B: 0   Piezometric Line: 1
Name: Liner Peak Spec - Expansion   Model: Shear/Normal Fn.   Unit Weight: 120   Strength Function: Liner Peak Spec   Phi-B: 0   Piezometric Line: 1
Name: Gravel Roads   Model: Mohr-Coulomb   Unit Weight: 128   Cohesion: 0   Phi: 34   Phi-B: 0   Piezometric Line: 2
Name: Foundation Soils (Glacial Till)   Model: Mohr-Coulomb   Unit Weight: 132   Cohesion: 1000   Phi: 38   Phi-B: 0   Piezometric Line: 2
Name: Solid Waste - Cells 7&3A   Model: Mohr-Coulomb   Unit Weight: 74   Cohesion: 0   Phi: 32   Phi-B: 0   Piezometric Line: 1
Name: Liner Peak - Cells 7&3A   Model: Shear/Normal Fn.   Unit Weight: 120   Strength Function: Liner Peak Spec   Phi-B: 0   Piezometric Line: 1
Name: Till Road Base   Model: Mohr-Coulomb   Unit Weight: 128   Cohesion: 250   Phi: 34   Phi-B: 0   Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 1 Foundation Closed
Seismic Coefficient (ks): 0

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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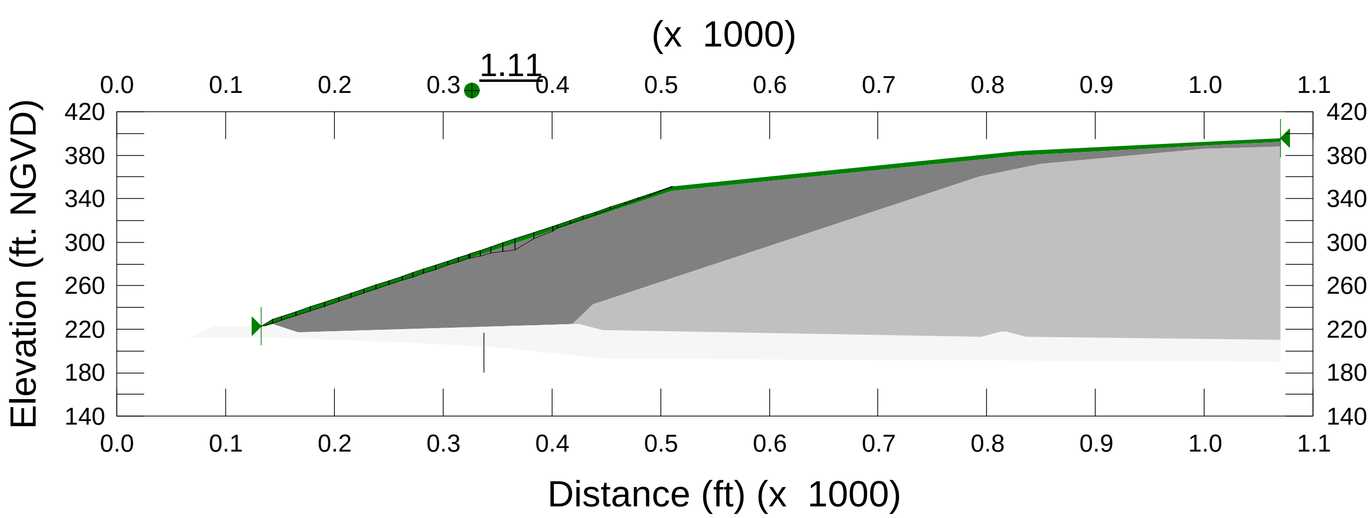
File Name: Cross-Section D-D".gsz
Description: Waste Closed; Seismic
Analysis Name: 5s Waste Closed s
Date: 2/19/2015

Minimum Factor of Safety = 1.11

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0

Method: Bishop, Ordinary and Janbu
Analysis Name: 5s Waste Closed s
Seismic Coefficient (ks): 0.18



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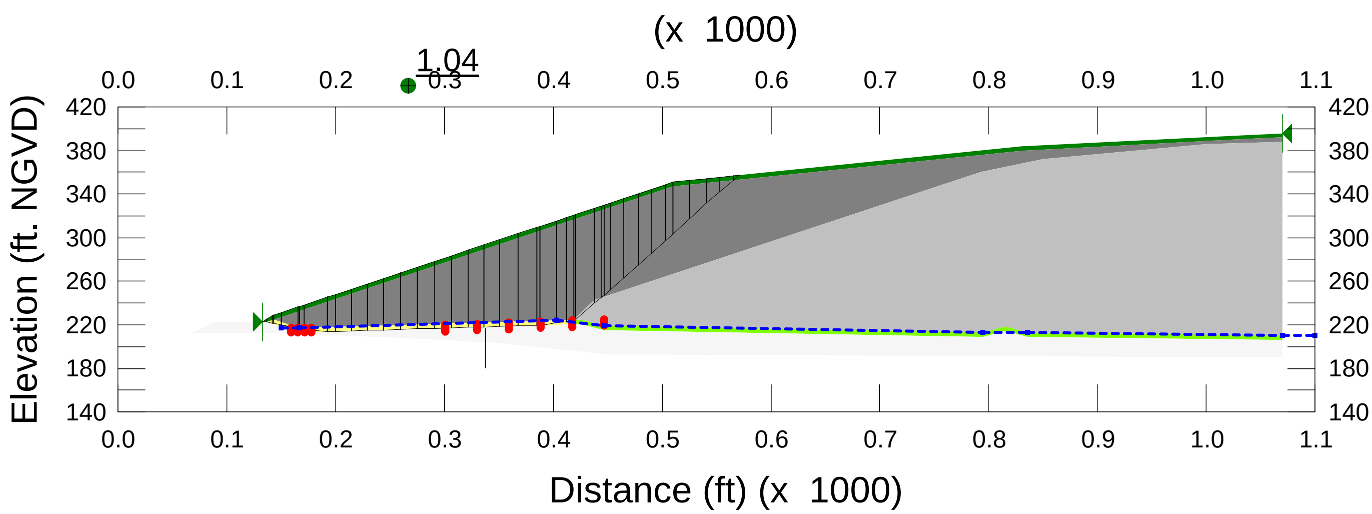
File Name: Cross-Section D-D''.gsz
Description: Liner Closed; Seismic
Analysis Name: 3s Liner Closed s
Date: 2/19/2015

Minimum Factor of Safety = 1.04

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste - Expansion Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak Spec - Expansion Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1
Name: Solid Waste - Cells 7&3A Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner Peak - Cells 7&3A Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner Peak Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 3s Liner Closed s
Seismic Coefficient (ks): 0.18

Name: Liner Peak Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 830
X: 4320 Y: 1811
X: 7200 Y: 2315
X: 16000 Y: 3855
X: 20000 Y: 4555



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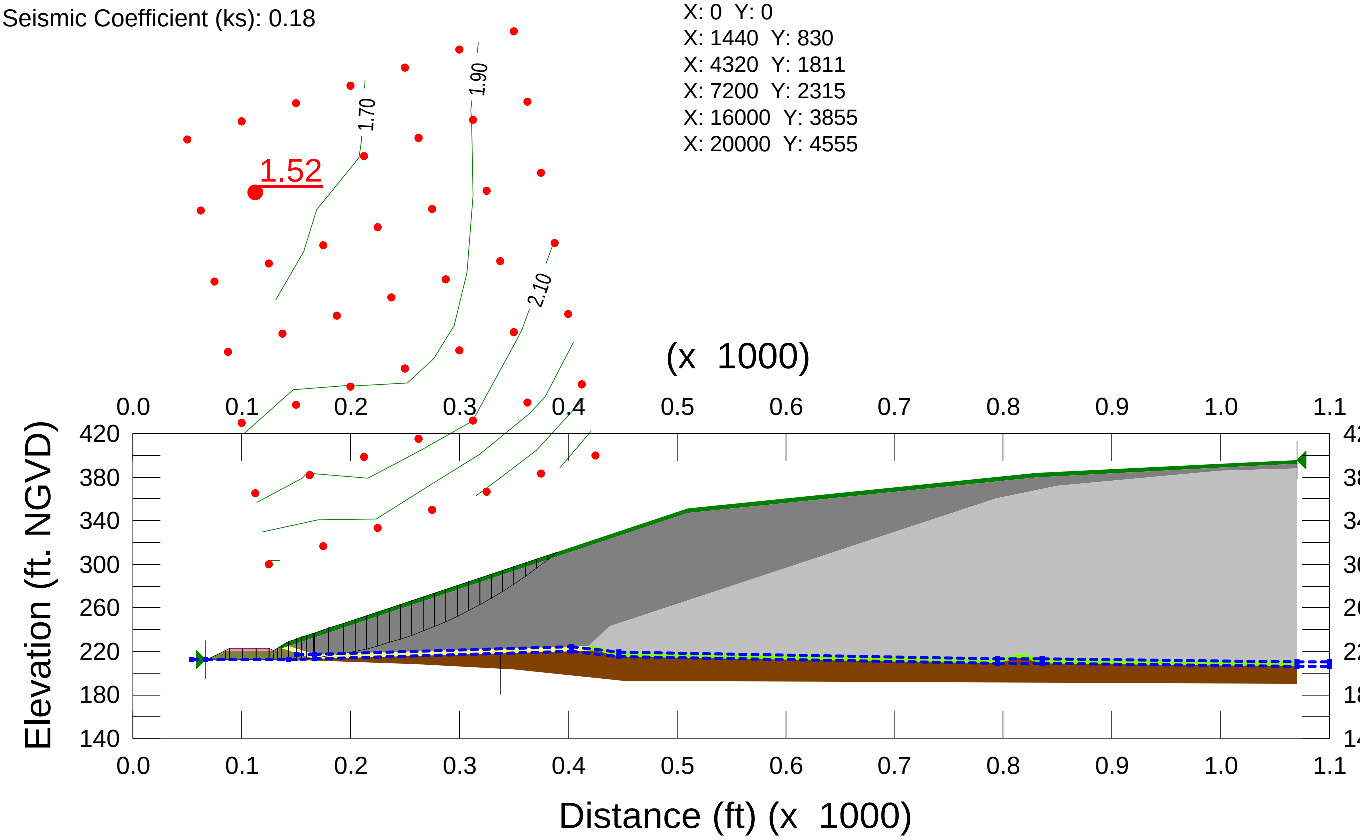
File Name: Cross-Section D-D''.gsz
Description: Foundation Closed; Seismic
Analysis Name: 1s Foundation Closed s
Date: 2/19/2015

Minimum Factor of Safety = 1.52

Name: Cover System   Model: Mohr-Coulomb   Unit Weight: 125   Cohesion: 0   Phi: 30   Phi-B: 0
Name: Solid Waste - Expansion   Model: Mohr-Coulomb   Unit Weight: 74   Cohesion: 0   Phi: 32   Phi-B: 0   Piezometric Line: 1
Name: Liner Peak Spec - Expansion   Model: Shear/Normal Fn.   Unit Weight: 120   Strength Function: Liner Peak Spec   Phi-B: 0   Piezometric Line: 1
Name: Gravel Roads   Model: Mohr-Coulomb   Unit Weight: 128   Cohesion: 0   Phi: 34   Phi-B: 0   Piezometric Line: 2
Name: Foundation Soils (Glacial Till)   Model: Mohr-Coulomb   Unit Weight: 132   Cohesion: 1000   Phi: 38   Phi-B: 0   Piezometric Line: 2
Name: Solid Waste - Cells 7&3A   Model: Mohr-Coulomb   Unit Weight: 74   Cohesion: 0   Phi: 32   Phi-B: 0   Piezometric Line: 1
Name: Liner Peak - Cells 7&3A   Model: Shear/Normal Fn.   Unit Weight: 120   Strength Function: Liner Peak Spec   Phi-B: 0   Piezometric Line: 1
Name: Till Road Base   Model: Mohr-Coulomb   Unit Weight: 128   Cohesion: 250   Phi: 34   Phi-B: 0   Piezometric Line: 2

Method: Bishop, Ordinary and Janbu
Analysis Name: 1s Foundation Closed s
Seismic Coefficient (ks): 0.18

Name: Liner Peak Spec
X: NormalStress   Y: ShearStress (psf)
X: 0   Y: 0
X: 1440   Y: 830
X: 4320   Y: 1811
X: 7200   Y: 2315
X: 16000   Y: 3855
X: 20000   Y: 4555



APPENDIX F-5

LIQUEFACTION ASSESSMENT

JRL EXPANSION
LIQUIFACTION POTENTIAL ASSESSMENT (BASED EPA, 1995)

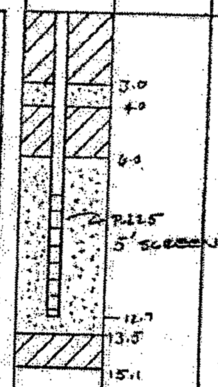
Exploration	Depth	N_{60}	Ground Surface Elevation	SPT Test Elevation	Phreatic Surface Elev.	Base of Liner System Elev.	Will Soil Remain After Liner is Constructed?	Top of Cover Elev.	Vertical Stresses: Existing Before Constuction total	Vertical Stresses: Existing Before Constuction effective	Vertical Stresses: After Construction total	Vertical Stresses: After Construction effective	rd	CSReq	CN	$(N_1)_{60}$	If (N1)60 >22 then Not Liquifiable	CSR	K-sigma	K-alpha	CSR-L	FOS
	(ft-bgs)	(bpf)	(ft-msl)	(ft-msl)	(ft-msl)	(ft-msl)		(ft-msl)	(psf)	(psf)	(psf)	(psf)				(bpf)						
	Note 1	Note 2	Note 3						Note 4		Note 5		Note 6	Note 7	Note 8	Note 9	Note 10	Note 11	Note 12	Note 13	Note 14	Note 15
B-225 (P-225)	1	12	212.8	211.8	212	212.7	Yes	378.66	138	126	12793	12781	1.00	0.11	0.40	9.00	Continue	0.18	0.4	2.0	0.144	1.3
B-225 (P-225)	6	109	212.8	206.8	212	212.7	Yes	378.66	828	504	13483	13159	0.99	0.11	0.39	81.75	Non-Liquifiable					
MW-302	3	32	202.1	199.1	199	203.1	Yes	282.26	414	414	6798	6798	0.99	0.11	0.54	24.00	Non-Liquifiable					
MW-302	6	78	202.1	196.1	199	203.1	Yes	282.26	828	647	7212	7031	0.99	0.11	0.53	58.50	Non-Liquifiable					
MW-304A	1	6	214.7	213.7	200	214.9	Yes	240.42	138	138	2442	2442	1.00	0.11	0.90	4.50	Continue	0.12	0.6	2.0	0.144	1.3
MW-304A	16	102	214.7	198.7	200	214.9	Yes	240.42	2208	2127	4512	4431	0.96	0.11	0.67	68.53	Non-Liquifiable					
P-04-05	1	8	201	200	198	195.3	No															
P-04-05	6	70	201	195	198	195.3	Yes	301.42	828	641	8282	8095	0.99	0.11	0.50	52.50	Non-Liquifiable					
P-04-05	11	70	201	190	198	195.3	Yes	301.42	1518	1019	8972	8473	0.97	0.11	0.49	34.01	Non-Liquifiable					
P-04-05	20	122	201	181	198	195.3	Yes	301.42	2760	1699	10214	9153	0.95	0.12	0.47	57.03	Non-Liquifiable					
P-04-05	22	62	201	179	198	195.3	Yes	301.42	3036	1850	10490	9305	0.95	0.12	0.46	28.74	Non-Liquifiable					
P-04-05	24	60	201	177	198	195.3	Yes	301.42	3312	2002	10766	9456	0.94	0.12	0.46	27.59	Non-Liquifiable					
P-04-05	26	96	201	175	198	195.3	Yes	301.42	3588	2153	11042	9607	0.94	0.12	0.46	43.80	Non-Liquifiable					
P-04-06	1	12	208.3	207.3	203	209	Yes	355.49	138	138	11463	11463	1.00	0.11	0.42	9.00	Continue	0.18	0.4	2.0	0.144	1.3
P-04-06	3	72	208.3	205.3	203	209	Yes	355.49	414	414	11739	11739	0.99	0.11	0.41	54.00	Non-Liquifiable					
P-04-06	5	76	208.3	203.3	203	209	Yes	355.49	690	690	12015	12015	0.99	0.11	0.41	57.00	Non-Liquifiable					
P-04-06	13	123	208.3	195.3	203	209	Yes	355.49	1794	1314	13119	12638	0.97	0.11	0.40	48.93	Non-Liquifiable					
P-04-06	17	145	208.3	191.3	203	209	Yes	355.49	2346	1616	13671	12941	0.96	0.11	0.39	57.00	Non-Liquifiable					
P-04-06	19	88	208.3	189.3	203	209	Yes	355.49	2622	1767	13947	13092	0.96	0.11	0.39	34.39	Non-Liquifiable					
P-04-06	21	88	208.3	187.3	203	209	Yes	355.49	2898	1918	14223	13243	0.95	0.11	0.39	34.20	Non-Liquifiable					
P-04-06	23	36	208.3	185.3	203	209	Yes	355.49	3174	2070	14499	13394	0.95	0.11	0.39	13.91	Continue	0.20	0.4	2.0	0.16	1.4
P-04-06	25	72	208.3	183.3	203	209	Yes	355.49	3450	2221	14775	13546	0.94	0.11	0.38	27.67	Non-Liquifiable					
P-04-06	27	102	208.3	181.3	203	209	Yes	355.49	3726	2372	15051	13697	0.94	0.11	0.38	38.98	Non-Liquifiable					
B-08-05	5.75	28	199.1	193.35	194	199.9	Yes	272.52	793.5	753	6666	6625	0.99	0.11	0.55	21.00	Continue	0.30	0.4	2.0	0.24	2.2
B-08-05	10	66	199.1	189.1	194	199.9	Yes	272.52	1380	1074	7252	6947	0.98	0.11	0.54	35.41	Non-Liquifiable					
B-08-07	6	38	211.7	205.7	209	210.1	Yes	378.11	828	622	13428	13222	0.99	0.11	0.39	28.50	Non-Liquifiable					
B-08-08	6	47	207.8	201.8	197.5	201.4	No															
B-08-08	12	56	207.8	195.8	197.5	201.4	Yes	270	1656	1550	6237	6131	0.97	0.11	0.57	31.98	Non-Liquifiable					
B-08-08	18	91	207.8	189.8	197.5	201.4	Yes	270	2484	2004	7065	6585	0.96	0.11	0.55	50.15	Non-Liquifiable					
B-08-08	24	80	207.8	183.8	197.5	201.4	Yes	270	3312	2457	7893	7038	0.94	0.12	0.53	42.65	Non-Liquifiable					
B-08-08	27	123	207.8	180.8	197.5	201.4	Yes	270	3726	2684	8307	7265	0.94	0.12	0.52	64.54	Non-Liquifiable					

1. Depth of middle of the SPT sample, from boring logs.
2. Boring logs show N-value in blows per foot, assumed to be N_{60} since not otherwise noted on logs.
3. Elevation, from boring logs. Site Datum
4. Assume total unit weight of overburden = 138 pcf.
5. Assume total unit weight of waste = 74 pcf; the 4 ft thick liner system weight is 120 pcf; and the 4 ft thick cover weight is 125 pcf.
6. Stress reduction factor (Use figure 5.3, (EPA, 1995)) {if depth is < 9.15m: rd= 1-0.00765*depth (m)}
7. Critical stress ratio induced by the design earthquake. (a_{max}/g = 0.17)
8. Blowcount correction factor (CN).
9. Normalized standardized SPT blowcount
10. EPA, 1995; Section 5.1: Soil Penetration Resistance: If (N1)60 >22 the soils are non-liquifiable.
11. Critical Stress Ratio (Use figure 5.5, (EPA, 1995)). Fines content of the samples based on logs are all greater than or equal to 35% (Silty/Clayey)
12. K-sigma is from Figure 5.7 in EPA, 1995.
13. K-alpha is from Figure 5.8 in EPA, 1995. The relative Density of the Basal Till is at least 70%. Till cohesion = 1,000 psf. When alpha is greater than plot, use k-alpha = 2
14. Stress level correction. At M=7.5 k_M = 1.0 from Fig 5.6 in EPA, 1995.
15. Factor of safety against liquifaction. Values greater than 1.0 are considered acceptable (not likely to liquify).

PROJECT: West Old Town Landfill	JOB NO. 9006	BORING NO. B225	
DATE COMPLETED: 03.17.90	WELLS INSTALLED: B225	DRILLING METHOD: Washed Boring	
GROUND SURFACE ELEVATION (FT): 212.8	DRILLING CONTRACTOR: Maine Test Boring, Inc	LOGGED BY: KAW	
BOREHOLE DIAMETER (IN): 3.5" O.D.	ROCK CORE DIAMETER (IN): N/A	SHEET 1 OF 1	

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N	MC(%)	% PASS #200	ATTERBERG LIMIT	PERMEABILITY (FT/DAY)
0	1D	0.5 Topsoil	12				
5	2D	Brown Sandy Gravelly Silt-Clay Trace of Cobbles (Basal Till)	109				Kh: 0.073
10	3D		—	10			
15		15.1 Refusal B.O.E.					
20							

INSTRUMENT LOG



NOTES

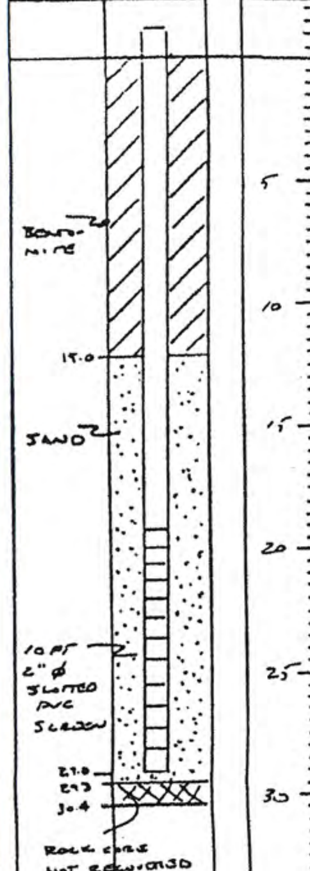
SEVEE & MAHER ENGINEERS

PROJECT WEST OLD TOWN LANDFILL JOB NO. 90006 BORING NO. B505 (MW 302)

DATE COMPLETED 03.10.92	DATE WELLS INSTALLED 03.10.92	DRILLING METHOD Washed Boring
GROUND SURFACE ELEVATION (FT) 202.1	DRILLING CONTRACTOR Maine Test Boring, Inc.	LOGGED BY KPN
BOREHOLE DIAMETER (IN) 4" ID	ROCK CORE DIAMETER (IN.) 3.875" OD (NX)	SHEET ___ OF ___

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N	RQD %			
	1D	Brown Silty Gravelly Sand Trace of Cobbles	32				
5	2D		78				
		8.2					
10	1R			25			
	2R			95			
15		Bedrock					
	3R			95			
20	4R			100			
25	5R			82			
30		30.4					
		BOE					

INSTRUMENT LOG

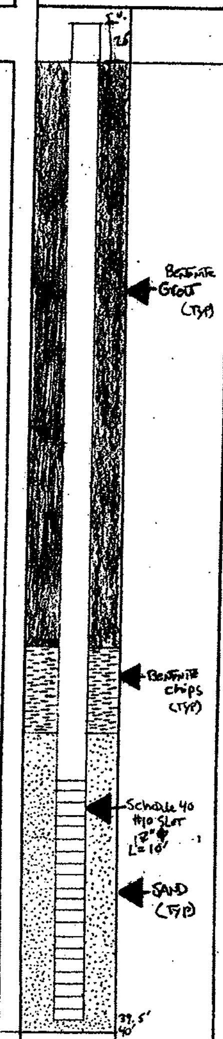


NOTES

PROJECT West Old Town Landfill Expansion	JOB NO. 03076.09	BORING NO. MW-304A
DATE COMPLETED 7/16/04	DATE WELLS INSTALLED 7/15/04	DRILLING METHOD Wash-Rotary
GROUND SURFACE ELEVATION (FT) 214.7'	DRILLING CONTRACTOR M.T.B.	LOGGED BY T. Riley / JCS
BOREHOLE DIAMETER (IN.) 4.5" O.D.	ROCK CORE DIAMETER (IN.) 2.5"	SHEET 1 OF 1

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N	RQD	% Passing #200 Screen	Water Content (%)
0	1D	0-0.X Topsoil Brown SILT / CLAY w/ a trace of medium sand, gravel and cobbles 2.5'	6			
5	2D	Olive silt w/ fine to medium sand w/ little gravel and cobbles	75/3.5'		57.7%	11.6%
10	3DA 3DB	10.5' (BASAL TILL) Brown fine to medium sand w/ little coarse sand (SAND LENSE) 15.5'	61 90			
15	4D	Becoming ... VERY SILTY with clayie layers 19.5' (BASAL TILL)	102		21.7%	18.2%
20	5D	Brown silty to clayey sand 24' (Washed Till)	50/0.3'			
25	1R	GRAY PHYLLITE ... WX		100%		
30	2R			91%		
35	3R			61%		
40	4R	40' B.O.E (Bedrock)		97%		

INSTRUMENT LOG



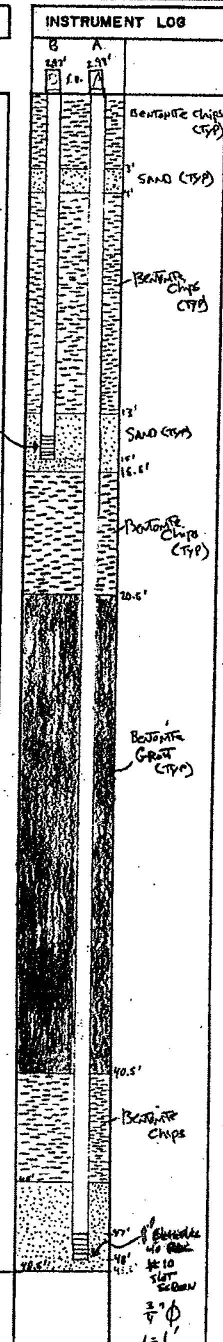
NOTES

5/90

SEVEE & MAHER ENGINEERS

PROJECT West Old Town Landfill Expansion		JOB NO. 03076.09	BORING NO. P-04-05
DATE COMPLETED 7/20/04	DATE WELLS INSTALLED 7/20/04		DRILLING METHOD Wash-Rotary
GROUND SURFACE ELEVATION (FT) 201.0'	DRILLING CONTRACTOR M.T.B		LOGGED BY T. Riley / JSS
BOREHOLE DIAMETER (IN) 4.5" O.D.	ROCK CORE DIAMETER (IN.) N/A		SHEET 1 OF 1

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N	% Passing #200 Screen	K cm/sec	Water Content %	
0	1D	0.2' 0-0.2' Topsoil	8				
		Mottled silty fine to medium sandy silt with a trace of clay, gravel					
6'	2D		70				
		Bedding... olive w/ trace of cobbles.					
	3D		70	60.2%		10.2%	
	4D		50/0.1'				
15'	5D		75/0.4'				1" Schedule 40 #10 slot PVC screen 3/4" ϕ L=1'
	6D	Increased clay content	50/0.3'				
	7D		122				
	8D		62				
	9D		60				
	10D		96				
	11D		50/0.1				
	12D		99				
31'	13D	Olive silty fine sand w/ some gravel, cobbles and a trace of coarse sand	50/0.2'				
	14D		50/0.4'		K_v =		
	BR			44.5%	5.5×10^{-7}	9.6%	
	15D	Brown silty fine to medium sand w/ coarse sand gravel and cobbles.	50/0.1'				
41'	16D		50/0.4'				
42'		Boulder					
	17D	Brown fine sandy silt w/ little coarse sand and gravel, trace of clay and cobbles.	50/0.2'	67%		14.3%	
	18D		50/0.1'				
	19D		65/0.5'				
48.5'		(Basal Till) B.O.E.					



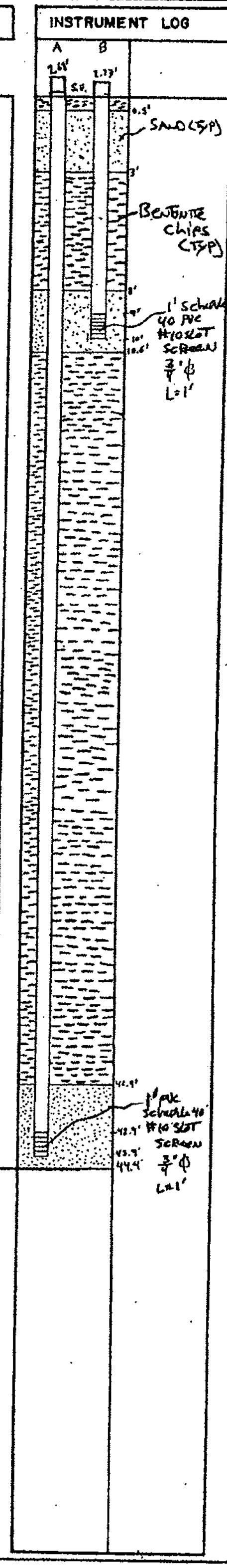
NOTES

5/90

SEVEE & MAHER ENGINEERS

PROJECT West Old Town Landfill Expansion	JOB NO. 03016.09	BORING NO. P-04-06	
DATE COMPLETED 7/22/04	DATE WELLS INSTALLED 7/21/04	DRILLING METHOD Wash Rotary	
GROUND SURFACE ELEVATION (FT) 208.3'	DRILLING CONTRACTOR M.T.B	LOGGED BY T. Riley / JGS	
BOREHOLE DIAMETER (IN) 4.5" O.D.	ROCK CORE DIAMETER (IN) 2.5"	SHEET 1 OF 1	

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N	RQD	% Passing #200 Screen	Water Content %
0	1D	0-0.3 Topsoil Brown silty gravelly fine to medium sand w/ trace of cobbles	12			
		2'				
	2D		72			
6	3D	Olive fine to medium sandy gravel w/ little coarse sand and gravel & trace of cobbles	76		62%	12.0%
	4D		50-0.1'			
	5D		50-0.2'			
10	6D		50-0.2'			
	7D		123			
15	8D		50-0.1'			
		16'				
	9D		145			
20	10D	Olive clayey silt w/ fine to medium sand w/ little coarse sand and gravel. Trace of cobbles.	88			
	11D		88			
	12D		36			
25	13D		72		49.8%	12.4%
	14D		102			
	15D	28.5' (Basal Till)	70-0.5'			
30	1R	Gray meta-graywacke ... wx		20%		
35	2R	...with siltstone laminae		100%?		
40	3R			100%		
		44.4' B.O.E (Bedrock)				
45						
50						
55						
60						



NOTES

5/90

SEVEE & MAHER ENGINEERS

PROJECT CASELLA - JRLF - OLD TOWN		JOB NO. 08097.01	BORING NO. B-08-05		
DATE COMPLETED 7/3/08	DATE WELLS INSTALLED NA		DRILLING METHOD DRIVE & WASH		
GROUND SURFACE ELEVATION (FT) 199.1	DRILLING CONTRACTOR MTB		LOGGED BY WCM / JGS		
BOREHOLE DIAMETER (IN) 4.5 (HW)	ROCK CORE DIAMETER (IN.) NA			SHEET 1 OF 1	

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N (BPF)	REC (FT)	WC (%)	>200 (%)	Kv (cm/s)	INSTRUMENT LOG	DEPTH (FT)
		OLIVE BROWN SANDY CLAYEY SILT WITH TRACE GRAVEL (BASAL TILL)						BENTONITE CHIPS	
5	1D		28						5
	1S			1.37	12.4	59	5.2 x 10⁻⁷		
10	2D	... COBBLE	66						10
		11.5' (BEDROCK?)						12 BOE	
15		REFUSAL							15
		BOE @ 12'							

NOTES

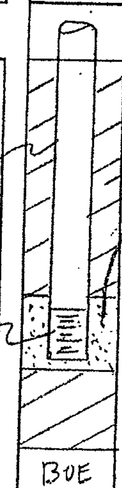
COLLECT TUBE SAMPLE OF TILL. ROLLER CONE 0.5' INTO ROCK. BACKFILL TO GROUND SURFACE WITH BENTONITE CHIPS

REFERENCE: FIELD BOOK # 508

PROJECT: CASELLA JRLF - OLD TOWN		JOB NO. 08097.01	BORING NO. B-08-07
DATE COMPLETED: 7/8/08	DATE WELLS INSTALLED: 7/8/08		DRILLING METHOD: DRIVE & WASH
GROUND SURFACE ELEVATION (FT): 211.7	DRILLING CONTRACTOR: MTB		LOGGED BY: WCM / JES
BOREHOLE DIAMETER (IN): 4.5" (HW)	ROCK CORE DIAMETER (IN.): NA		SHEET 1 OF 1

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N (BPF)	REC (FT)	WC (%)	>200 (%)	K (CM/S)
5	1D	OLIVE BROWN CLAYEY SILT WITH TRACE SAND AND GRAVEL (BASAL TILL)	38				1" Ø SCH 40 PVC RISER
10	1S			1.3	11	55	2' LONG x 1" Ø SLOTTED (0.01") PVC
15	2D	15.2' (BEDROCK?) 15.6	150/0.2				
20		REFUSAL					1S: KV = 2.9 x 10^{-8}
		BOE @ 15.6					K F = 1.4 x 10^{-6}

INSTRUMENT LOG



NOTES

COLLECTED TUBE SAMPLE OF TILL. ROLLER CONE 0.4' INTO ROCK. INSTALLED 1-INCH DIAMETER SCH 40 PVC PIEZOMETER P-08-07 IN BORING.

REFERENCE: FIELD BOOK # 508

PROJECT CASELLA - JRLF - OLD TOWN	JOB NO. 08097.01	BORING NO. B-08-08
DATE COMPLETED 7/8/08	DATE WELLS INSTALLED NA	DRILLING METHOD DRIVE & WASH
GROUND SURFACE ELEVATION (FT) 207.8	DRILLING CONTRACTOR MTB	LOGGED BY WCM / JEG
BOREHOLE DIAMETER (IN) 4.5 (HW)	ROCK CORE DIAMETER (IN.) NA	SHEET 1 OF 1

DEPTH (FT)	SAMPLE NO.	MATERIAL DESCRIPTION	N (BPF)		TUBE REC (FT)			INSTRUMENT LOG	DEPTH (FT)
5	1D	OLIVE BROWN CLAYEY SILT/ SILTY CLAY WITH SOME SAND AND TRACE GRAVEL	47					BENTONITE CHIPS	5
10	1S				0.9				10
	2D		56						
15									15
20	3D	... INCREASING SAND	91						20
25	4D	... SILTY ZONE	80						25
	5D	CLAYEY SILT AND SAND (BASAL TILL)	123						
30		29.3' / 30 (BEDROCK)						30' BOE	30
		REFUSAL							
		BOE @ 30'							

NOTES

COLLECTED TUBE SAMPLE OF TILL. ROLLER CONE 0.7' INTO ROCK. BACKFILL TO GROUND SURFACE WITH BENTONITE CHIPS.

REFERENCE: FIELD BOOK #508

JRL EXPANSION
LIQUIFACTION POTENTIAL ANALYSIS FOR SAND (BASED ON SEED AND IDRISS 1982)

Exploration	Depth	N	Ground Elev	Test Elev	Phreatic Surface	Landfill Design-Elev	Vertical Stress: Before Constuction total[4]	Vertical Stress: Before Constuction effective	Vertical Stress: After Construction total[5]	Vertical Stress: After Construction effective	rd[6]	CSReq[7]	CN[8]	N1-60[9]	CSR[10]	K-sigma[11]	CSR-L[12]	FOS[13]
	(ft-bgs)[1]	(bpf)[2]	(ft-msl)[3]	(ft-msl)	(ft-msl)	(ft-msl)	(psf)	(psf)	(psf)	(psf)								
MW-06-02	18	26	188.8	171	184	330	2484	1660	12933	12109	0.27	0.03	0.41	10.57	0.2	0.5	0.12	3.7
P-04-06A	22	32	208.3	186	191.3	380	3036	2724	15742	15430	0.11	0.01	0.36	11.52	0.2	0.5	0.12	9.3
P-04-06A	24	36	208.3	184	191.3	380	3312	2875	16018	15581	0.11	0.01	0.36	12.90	0.2	0.5	0.13	11.1
P-08-06	7	38	182.2	175	178.5	250	966	760	5983	5777	0.66	0.08	0.59	22.36	1	0.5	0.60	8.0
P-08-06	11.5	40	182.2	171	178.5	250	1587	1100	6604	6117	0.64	0.08	0.57	22.87	1	0.5	0.60	7.9
P-08-06	22	30	182.2	160	178.5	250	3036	1894	8053	6911	0.59	0.08	0.54	16.14	0.3	0.5	0.18	2.4
P-08-03A	14	35	168.9	155	166.3	280	1932	1221	10153	9442	0.43	0.05	0.46	16.11	0.3	0.5	0.18	3.5

1. ft-bgs - feet below ground surface
2. bpf - blows per foot
3. ft-msl - elevation in feet, datum = mean sea level
4. Assume total unit weight of overburden = 138 pcf.
5. Assume total unit weight of waste = 74 pcf.
6. Stress reduction factor (Use figure 5.3, (EPA, 1995))
7. Critical stress ratio induced by the design earthquake.
8. Blowcount correction factor
9. Normalized standardized SPT blowcount
10. Critical Stress Ratio (Use figure 5.5, (EPA, 1995))
11. Stress level correction
12. Corrected critical stress ratio resisting liquifaction (Use figures 5.6, 5.7 and 5.8 (EPA, 1995))
13. Factor of safety

PW-08-02
B-08-05
MW-302
MW-302R
MW-304A
P225
P-08-07
P-04-05B
P-08-08
B-08-18

MW-207
MW-212

	PointNo.	Northing(Y)	Easting(X)	TOP OF WASTE Elev(Z)	Phreatic High Elev	BASE GRADE
MW-304	240	478986.54	927168.78	236.42	200	214.9
B08-08	241	479710.51	926803.54	266.00	197.5	201.4
B04-05	242	480079.54	926554.76	297.42	198	195.3
B03-07	243	479750.33	926241.59	374.11	209	210.1
P-225	244	479575.83	926305.33	374.66	212	212.7
B04-06	245	479998.42	925785.89	351.49	203	209.0
B08-05	246	479742.63	925373.86	268.52	194	199.9
MW-302	247	479356.03	925546.81	278.26	199	203.1

APPENDIX F-6

DEFORMATION ASSESSMENT

JRL EXPANSION
DEFORMATION ANALYSIS (EPA, 1995 - Subtitle D Seismic Design Guidance for Landfills)

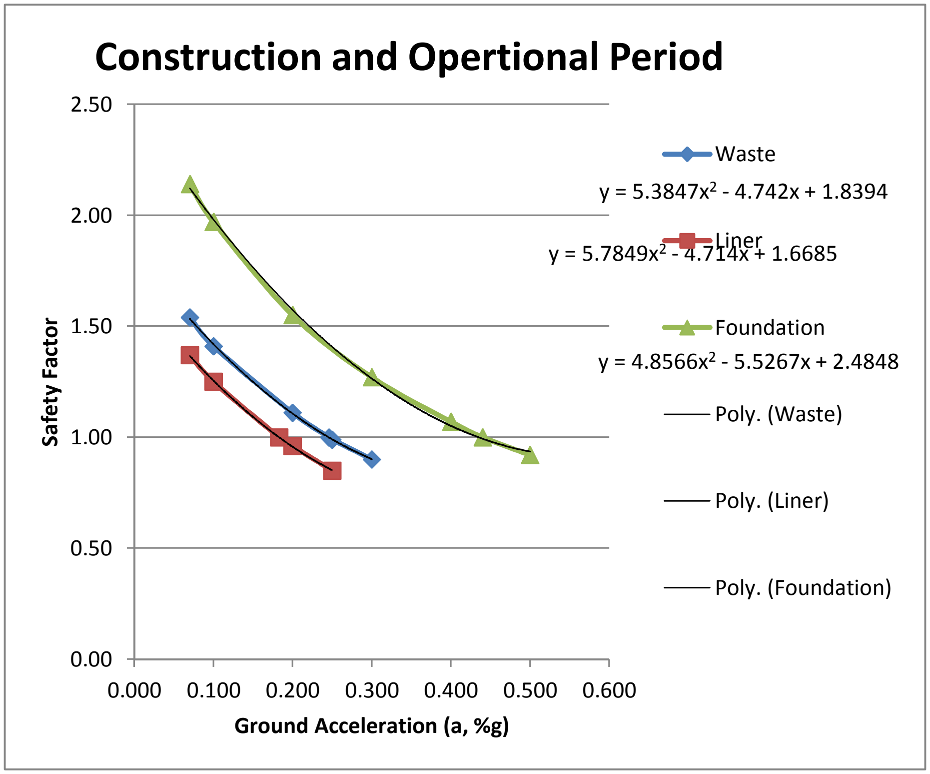
Cross-Section	Failure Location	Seismic Coefficient (Kmax)[1]	Minimum Safety Factor	Yield Accelation (Ky)[2]	Ky/Kmax	Deformation [3]
	Construction and Operational Period					
	Waste	0.07	2.14	0.440	6.3	<1 cm
	Liner	0.07	1.37	0.183	2.6	<1 cm
A-A'	Foundation	0.07	1.54	0.246	3.5	<1 cm
	Post-Closure Period					
	Waste	0.18	1.11	0.225	1.3	<1 cm
	Liner	0.18	1	0.180	1.0	<1 cm
	Foundation	0.18	1.62	0.445	2.5	<1 cm

Notes:
1) Ref: 2014 USGS PGA values for 2% in 50yrs and 10% in 50 yrs.
2) Acceleration which yields a safety factor of 1.0
3) Ref: EPA, 1995 Figure 6-6 (Makdisi and Seed, 1978)

Similar results would be produced for Cross-Sections B-B', C'C' and D-D'; where deformations would be predicted to be less than 1 cm and therefore have not been evaluated.

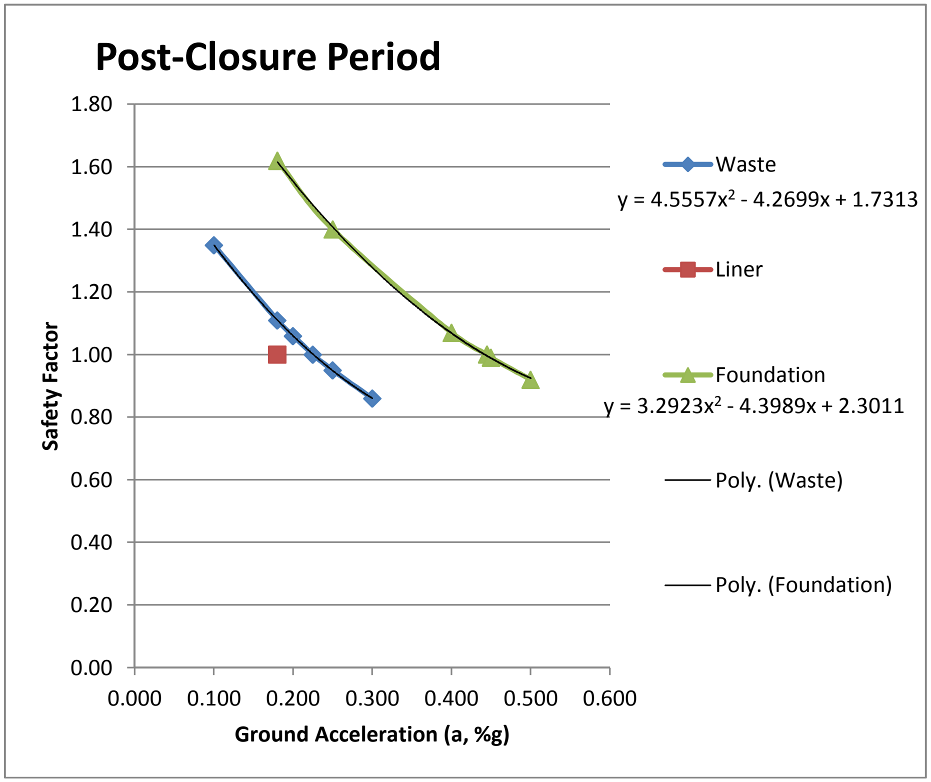
File Attached

	a	Safety Factor		Using Curve
Waste	0.070	1.54		
	0.100	1.41		
	0.200	1.11		
	0.246	1.00	0.246	0.999
	0.250	0.99		
	0.300	0.90		
Liner	0.070	1.37		
	0.100	1.25		
	0.183	1.00	0.183	1.000
	0.200	0.96		
	0.250	0.85		
Foundation	0.070	2.14		
	0.100	1.97		
	0.200	1.55		
	0.300	1.27		
	0.400	1.07		
	0.440	1.00	0.44	0.993
	0.500	0.92		



File Attached

	a	Safety Factor		Using Curve
Waste	0.100	1.35		
	0.180	1.11		
	0.200	1.06		
	0.225	1.00	0.225	1.001
	0.250	0.95		
	0.300	0.86		
Liner	0.180	1.00		
Foundation	0.180	1.62		
	0.250	1.40		
	0.400	1.07		
	0.445	1.00	0.445	0.996
	0.450	0.99		
	0.500	0.92		



APPENDIX F-7

SENSITIVITY ASSESSMENT

Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section A-A'.gsz
Description: Sensitivity Evaluation: Liner Closed; LD Interface Strength
Analysis Name: 3sen1 Liner Closed LD
Date: 2/19/2015

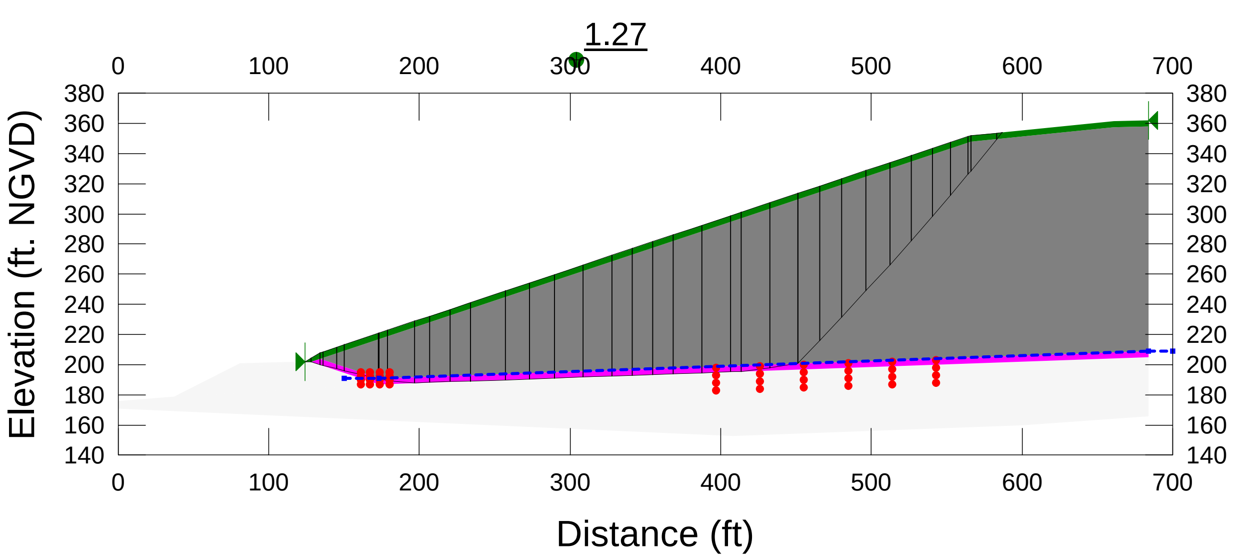
Minimum Factor of Safety = 1.27

Sensitivity Analysis, using Large Displacement Strengths for the Liner = Liner LD Spec values shown below

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner LD Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner LD Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 3sen1 Liner Closed LD
Seismic Coefficient (ks): 0

Name: Liner LD Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 463
X: 4320 Y: 924
X: 7200 Y: 1480
X: 16000 Y: 3179
X: 20000 Y: 3951



Directory: \\nserver\CFS\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Geotech\Stability\
File Name: Cross-Section C-C'.gsz
Description: Sensitivity Evaluation: Liner Closed; LD Interface Strength
Analysis Name: 3sen1 Liner Closed LD
Date: 2/19/2015

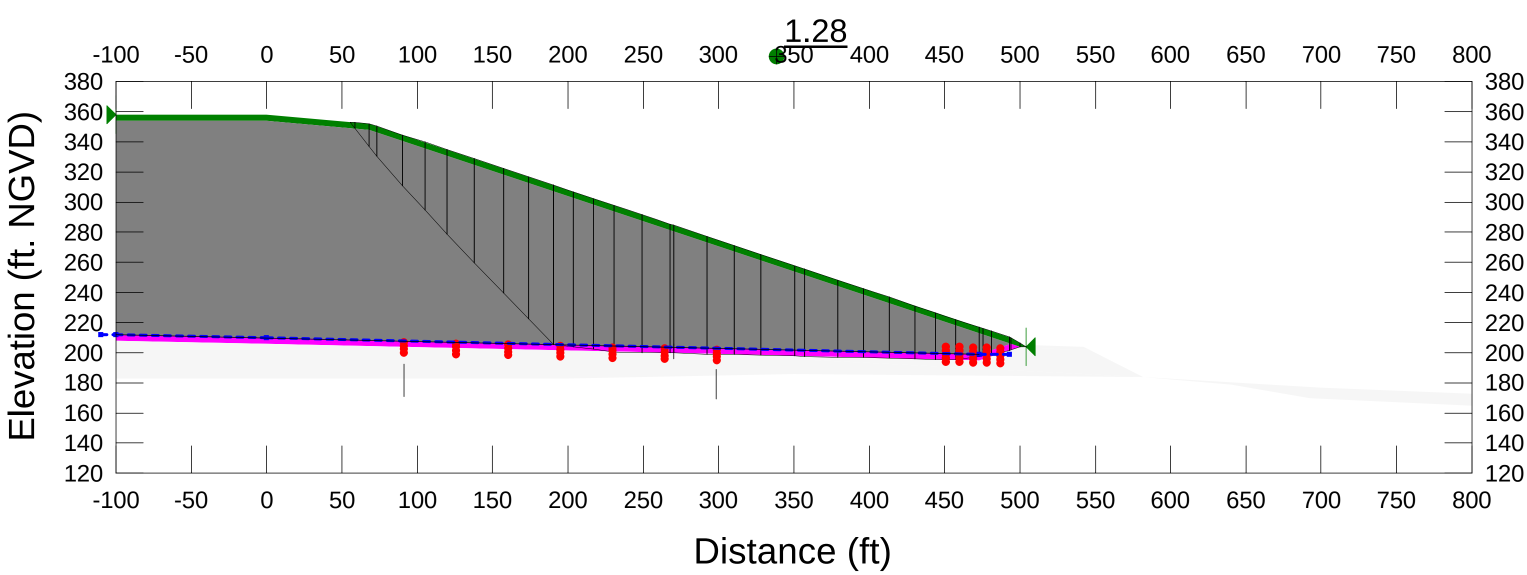
Minimum Factor of Safety = 1.28

Sensitivity Analysis, using Large Displacement Strengths for the Liner = Liner LD Spec Values shown below

Name: Cover System Model: Mohr-Coulomb Unit Weight: 125 Cohesion: 0 Phi: 30 Phi-B: 0
Name: Solid Waste Model: Mohr-Coulomb Unit Weight: 74 Cohesion: 0 Phi: 32 Phi-B: 0 Piezometric Line: 1
Name: Liner LD Spec Model: Shear/Normal Fn. Unit Weight: 120 Strength Function: Liner LD Spec Phi-B: 0 Piezometric Line: 1

Method: Spencer
Analysis Name: 3sen1 Liner Closed LD
Seismic Coefficient (ks): 0

Name: Liner LD Spec
X: NormalStress Y: ShearStress (psf)
X: 0 Y: 0
X: 1440 Y: 463
X: 4320 Y: 924
X: 7200 Y: 1480
X: 16000 Y: 3179
X: 20000 Y: 3951



APPENDIX F-8

SETTLEMENT COEFFICIENTS

SME
Sevee & Maher Engineers, Inc.

ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE

14101
20150522memo

MEMO TO: Project File

FROM: Brian Johnson, P.E.

DATE: May 22, 2015

SUBJECT: **DETERMINATION OF SITE SPECIFIC POST-FILLING SETTLEMENT COEFFICIENTS JUNIPER RIDGE LANDFILL, OLD TOWN, MAINE**

Sevee & Maher Engineers, Inc. (SME) has completed an evaluation of landfill settlement derived from aerial survey topography to estimate post-filling settlement coefficients specific to the in-place waste at the Juniper Ridge Landfill in Old Town, Maine. The evaluation utilized various locations (i.e., points) on the surface of the existing waste mass where waste thicknesses ranging from 30 feet, to more than 50 feet are present which had not been subjected to additional waste placement for several years, and where sufficient topographic survey(s) had been completed to allow settlement at various times to be calculated. The point locations were selected such that, primarily post-filling settlement (i.e. consolidation and decomposition) of the waste at the point of interest was occurring. The evaluation established a settlement coefficient representative of the in-place waste at JRL used to estimate post-filling waste settlement relative to post-closure cover performance.

POINT SELECTION

Fourteen points (identified as 1 through 14) were used in this evaluation and are located as shown on Figure 1. Table 1 summarizes the base data for each point. The bottom of waste elevation at each point was determined as the top of the leachate collection sand and is based on record drawings from the construction of each cell.

DATES OF TOPOGRAPHIC SURVEYS

Twenty-nine topographic surveys beginning 1/27/2006 and ending 7/31/2014 were used for the settlement evaluation. The survey dates corresponding to when the maximum waste elevation and maximum waste thickness occurred at each point are included in Table 1. Surveys subsequent to the date of maximum waste elevation were used to determine elevations (and hence waste thickness) at each point as the landfill surface settled. The calculated waste thicknesses following the date of maximum thickness are summarized in Table 2. Note that the settlement at Point 12 was evaluated over two distinct time intervals, because two maximum fill elevations occurred at that location (i.e., a filling followed by

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additional waste placement). Not all points were evaluated for each survey because in some cases settlements were minimal based on the comparison of the aerial surveys.

TABLE 1

POINTS USED IN EVALUATION OF SITE SPECIFIC SETTLEMENT FACTORS

Point Number	Cell	Northing	Easting	Bottom of Waste Elevation	Maximum Waste Elevation	Maximum Waste Thickness	Date When Maximum Waste Thickness was Surveyed
		Site Coordinates		feet	feet	feet	
1	1	925577	478460	173.3	200.5	27.2	4/29/2009
2	1	925697	478546	181.5	255	73.5	4/29/2006
3	1	925655	479117	210.5	257.6	47.1	10/31/2008
4	1	925704	478989	202.5	320.5	118	10/31/2008
5	2	925888	479134	213.5	250.5	37.0	4/26/2007
6	2	925949	478988	209.5	307	97.5	10/31/2007
9	3a	926175	479232	215.5	252	36.5	10/29/2007
10	3a	926182	479077	213.5	306.5	93.0	10/31/2008
11	3b	926344	479304	218	251	33.0	10/29/2007
12a	3b	926351	479161	216	258.5	84.5	10/29/2007
12b	3b	926351	479161	216	300.5	42.5	10/30/2013
7	4	925771	478291	174.5	212.5	84.5	10/30/2009
8	4	925929	478291	179.6	261	38.0	11/2/2011
13	5	925800	477958	165	210.5	81.4	11/2/2011
14	5	925935	478057	171.2	263.5	45.5	11/2/2011

TABLE 2

SUMMARY OF WASTE THICKNESSES

Point ID	1/27/2006	4/29/2006	7/31/2006	11/1/2006	1/30/2007	4/26/2007	7/31/2007	10/29/2007	1/31/2008	5/2/2008	10/31/2008	4/29/2009	10/30/2009	5/1/2010	11/12/2010	4/29/2011	11/2/2011	4/30/2012	11/6/2012	4/30/2013	10/30/2013	4/30/2014	7/31/2014
1				25.7				25.7			25.7	27.2	27.2	27.2	27.2		27.2		27.2		26.2		26.7
2	54	73.5	73.5	72.5	72			71.5			69		69		68		68		68		67		68
3	41	43	42.5	43.5	42.5			43			47.1		47.1		46.7		46.7		46.7		46.5		46.5
4	52	52.5	60.5	68	58.5	58	58.5	70.5	56.5	86.5	118	115	114.7	112.7	114.7		111.2		111.2		109.7		110
5				33	36	37	37	37	36	36	36	35.8	36		37		36		36		35.5		36
6				52.5				64.5	57.5	67.5	97.5	95	94.8	93	93		91.5		91.5		90.5		91
9						22.5	29.5	36.5	35	35	35	35	35		35		35		35		34.5		35
10						31		68	72	72	93	90.8	90	88.8	88.7		87.5		87.5		86.5		86.5
11					7	18.5	24.3	33	30.2	31	31	31	31		31		31		32		32		32
12a					6.5	23.5	31.5	42.5	40.4	40.2	40	40.3	40		40		40						
12b																			75	77	84.5	83.7	83.5
7												30.5	38	34.8	34.5	34.5	34.5		34.5		34		35.5
8										7.9	5.4	48.9	60.9		65.4	68.4	81.4	80.9	79.9	79.6	79.4		79.4
13												2	2	36	46	45.5	45.5	45.5	45.5	43.7	43	44.5	44.5
14												2.8	1.3	17.3	72.8	73.3	92.3	89.8	90.3	88.8	88.8	86.3	88.3

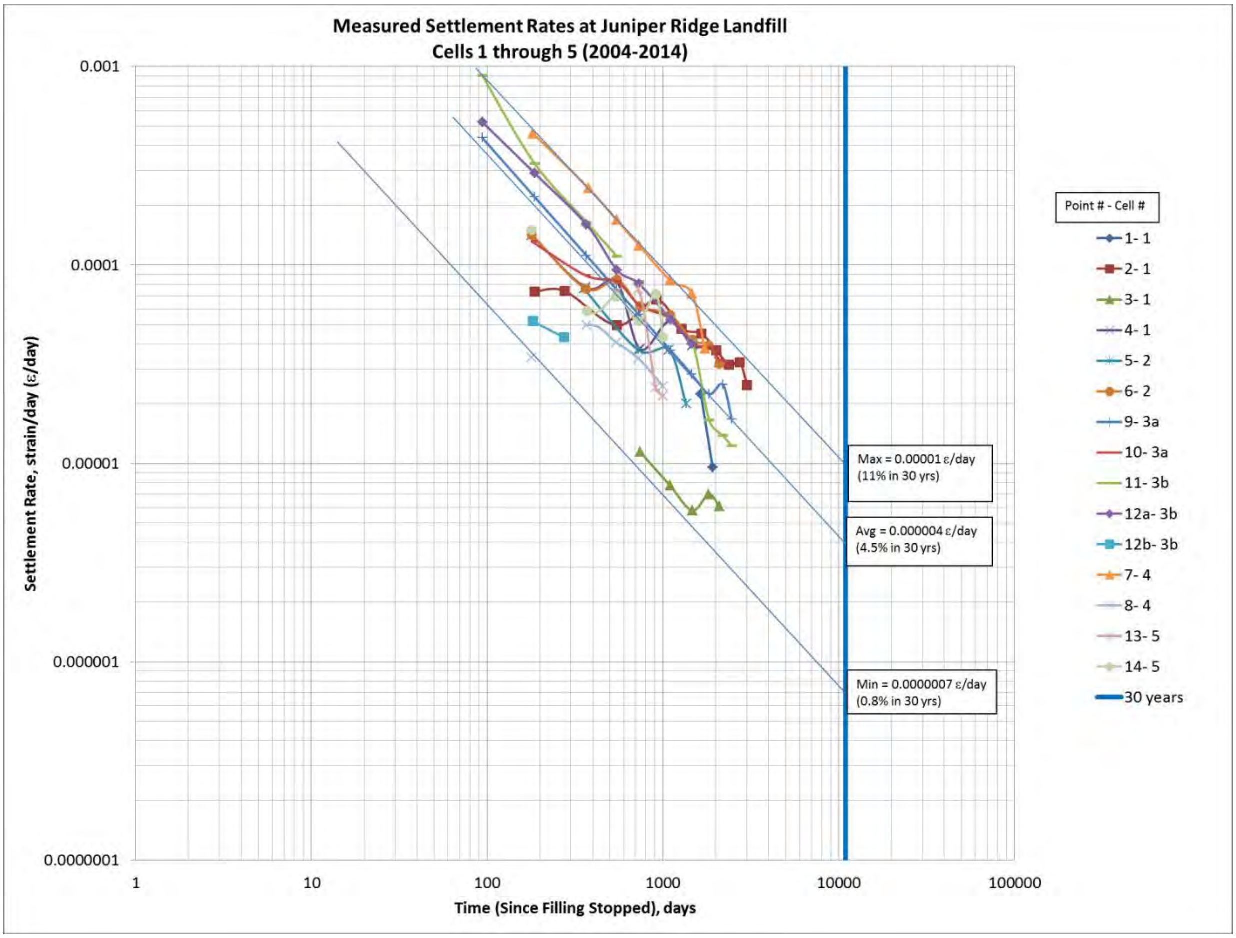
Notes:

1. Cells Shaded Blue are when the Maximum Waste Elevation Occurred.

STRAIN RATE

The strain rate per day (ε/day) was calculated for each point, using the date on which the maximum waste thickness occurred (Tables 1 and 2) as the start of settlement, as summarized in Figure 2. Figure 2 shows that the post-filling settlement decreases with time on a log-log basis. The log-log relationship between settlements is consistent with classical settlement theory when stress based consolidation and decomposition are combined. Using the site specific data in Figure 2, an average strain rate of 0.000004 ε/day in 30-years was developed, which equates to 4.5% ε in 30 years.

FIGURE 2



Measured Settlement Rates at Juniper Ridge Landfill
Cells 1 through 5 (2004-2014)
Settlement Rate, strain/day (ε/day)
0.001
0.0001
0.00001
0.000001
0.0000001
1
10
100
1000
10000
100000
Time (Since Filling Stopped), days
Max = 0.00001 ε/day (11% in 30 yrs)
Avg = 0.000004 ε/day (4.5% in 30 yrs)
Min = 0.0000007 ε/day (0.8% in 30 yrs)
Point # - Cell #
1- 1
2- 1
3- 1
4- 1
5- 2
6- 2
9- 3a
10- 3a
11- 3b
12a- 3b
12b- 3b
7- 4
8- 4
13- 5
14- 5
30 years

CONCLUSIONS

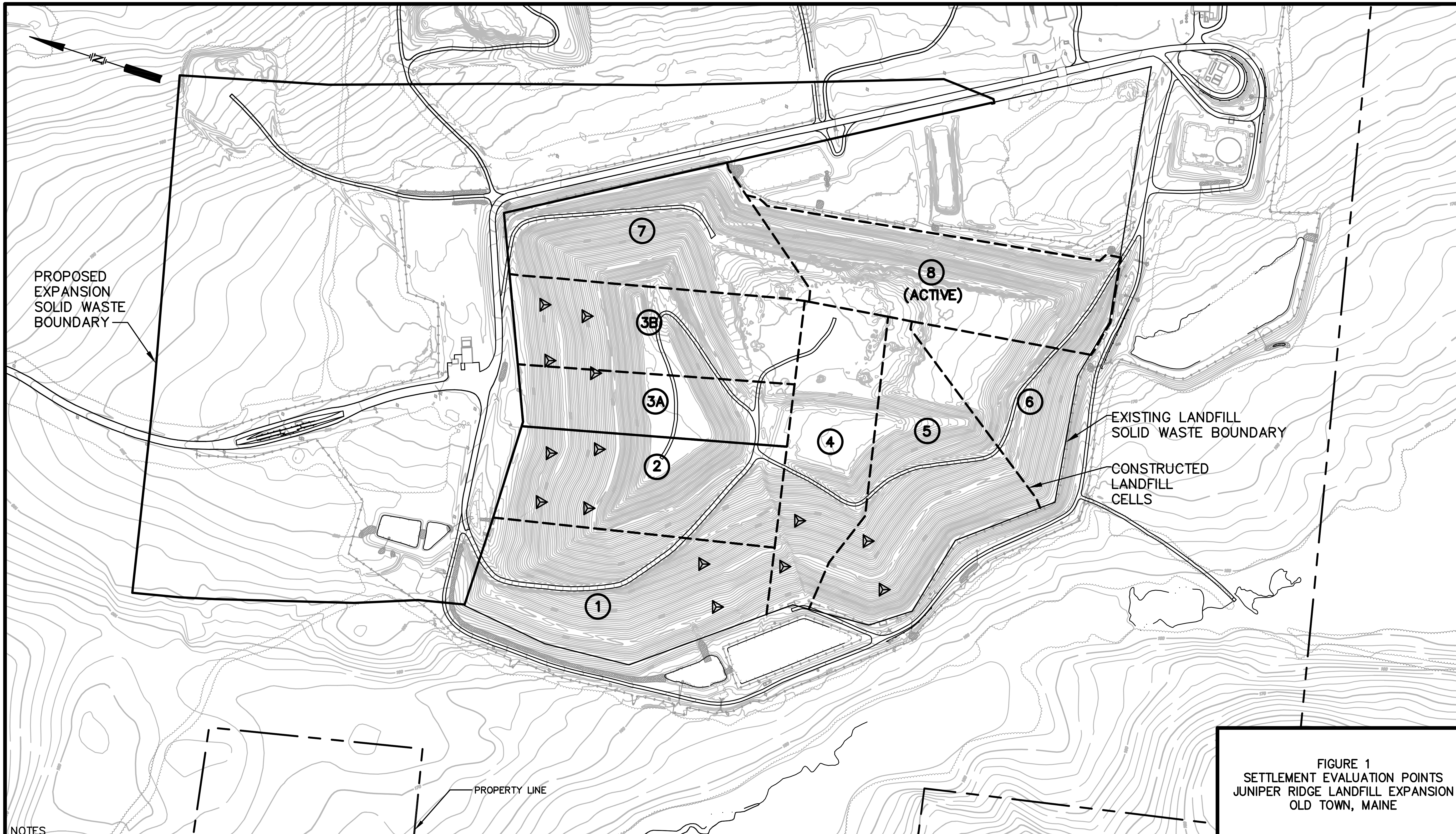
Based on the above described evaluation, the settlement of the waste at JRL 30-years after maximum fill heights are achieved (i.e., settlement after final cover is installed) can be estimated using Equation 1.

$$S_{30\text{-years}} = H * \varepsilon_{30\text{-years}} \qquad \text{(Equation 1)}$$

Where,

$S_{30\text{-years}}$ = Settlement after 30-years (feet);

H $\varepsilon_{30\text{-years}}$ = 4.5%.



NOTES

1. EXISTING GROUND CONTOURS FROM DECEMBER 31, 2014 AERIAL SURVEY PERFORMED BY AERIAL SURVEY AND PHOTO, INC. OF NORRIDGEWOCK, MAINE.
2. PROPERTY LINE LOCATIONS ARE A RESULT OF FIELD SURVEY PERFORMED BY HERRICK AND SALSBURY, INC. LAND SURVEYORS, ELLSWORTH, MAINE FOR TRYTON TREE FARM PROJECT, PATTEN CORPORATION–DOWNEAST, OLD TOWN, MAINE, FEBRUARY 23, 1988, REVISED APRIL 7, 1988.

DWG: FIGURES LMN: SETTLEMENT POINTS CTB: CONDUCTIVITY REV: 4/22/2015

FIGURE 1
SETTLEMENT EVALUATION POINTS
JUNIPER RIDGE LANDFILL EXPANSION
OLD TOWN, MAINE

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\\Nserver\cfs\Casella\OldTownLandfill\Expansion\9.35MCY-Expansion\Acad\Figures\FIGURES.dwg, 4/22/2015 1:29:53 PM, paf

APPENDIX F-9

SETTLEMENT ASSESSMENT

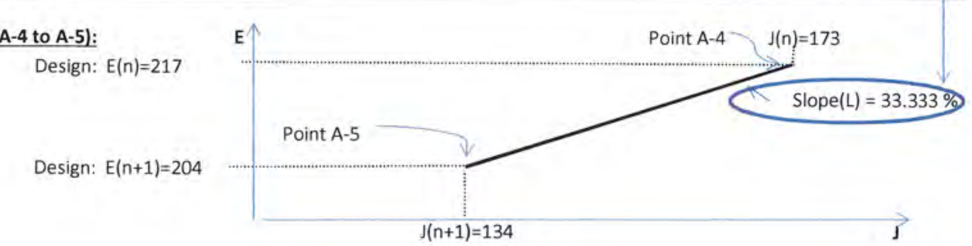
Settlement Evaluation; and Estimates of Post-Closure Geosynthetic Slopes and Strains

Project: Juniper Ridge Landfill, Expansion
Date: January 25, 2014 Calcs by: Brian Johnson, P.E., Sevee & Maher Engineers, Inc.

As Designed Point Information

Point	Elevations					Material Thicknesses				Horizontal Distances	Line Segment from Point n to n+1	Slopes	
	(A)	(B)	(C)	(D)	(E)	(F) = B-A	(G) = C-B	(H) = D-C	(I) = E-D	(J)		(K) = [D(n) - D(n+1)] / [J(n) - J(n+1)]	(L) = [E(n) - E(n+1)] / [J(n) - J(n+1)]
	Bedrock Surface	Bottom of Berm Fill	Bottom of Liner System	Bottom of Waste	Final Surface of Waste	Native Till	Berm Fill	Liner System	Waste			Liner Slope	Cover Slope
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)			
A-1	166	205	205	209	358	39	0	4	149	684	A-1 to A-2	4.348%	2.174%
A-2	164	204	204	208	357.5	40	0	4	149.5	661	A-2 to A-3	3.158%	10.000%
A-3	159	201	201	205	348	42	0	4	143	566	A-3 to A-4	3.562%	33.333%
A-4	163	187	187	191	217	24	0	4	26	173	A-4 to A-5	-33.333%	33.333%
A-5	165	185	200	204	204	20	15	4	0	134			
B-1	205	213	213	217	385	8	0	4	168	1200	A-1 to A-2	4.000%	4.000%
B-2	193	208	208	212	380	15	0	4	168	1075	A-2 to A-3	3.686%	7.862%
B-3	158	193	193	197	348	35	0	4	151	668	A-3 to A-4	3.780%	25.773%
B-4	127	171	171	175	198	44	0	4	23	86	A-4 to A-5	-23.913%	26.087%
B-5	122	172	182	186	186	50	10	4	0	40			
C-1	183	206	206	210	354	23	0	4	144	0	A-1 to A-2	-2.941%	-8.824%
C-2	183	204	204	208	348	21	0	4	140	68	A-2 to A-3	-1.961%	-33.333%
C-3	184	200	200	204	280	16	0	4	76	272	A-3 to A-4	-2.488%	-33.333%
C-4	185	188.5	195	199	213	3.5	6.5	4	14	473	A-4 to A-5	33.333%	-33.333%
C-5	185	189	202	206	206	4	13	4	0	494			
D-1	190	206	206	210	392	16	0	4	182	1070	A-1 to A-2	-1.667%	5.000%
D-2	191	210	210	214	380	19	0	4	166	830	A-2 to A-3	-1.250%	10.313%
D-3	193	214	214	218	347	21	0	4	129	510	A-3 to A-4	-7.692%	32.967%
D-4	196	221	221	225	317	25	0	4	92	419	A-4 to A-5	3.175%	33.333%
D-5	211	213	213	217	233	2	0	4	16	167	A-5 to A-6	-33.333%	33.333%
D-6	212	212	221	225	225	0	9	4	0	143			

Example of "As Designed Slope" (A-4 to A-5):



Settlement Evaluation; and Estimates of Post-Closure Geosynthetic Slopes and Strains

Project: Juniper Ridge Landfill, Expansion
Date: January 25, 2014 Calcs by: Brian Johnson, P.E., Sevee & Maher Engineers, Inc.

Elastic Settlements

	Material Thicknesses			**Stress due to Overlying Material**		**Elastic Strain**		**Elastic Settlement**	
	= (F)	= (G)	= (I)	(M) = I * γ_W	(N) = γ_c * T_c	(O) = (M+N) / E_T	(P) = (M+N) / E_B	(Q) = F * O	(R) = G * P
Point	Native Till	Berm Fill	Waste	Waste	Cover System	In Native Till	In Berm Fill	In Native Till	In Berm Fill
	(ft)	(ft)	(ft)	(psf)	(psf)	(ft/ft)	(ft/ft)	(ft)	(ft)
A-1	39		149	11026	500	0.004	0.008	0.312	
A-2	40		150	11063	500	0.004	0.008	0.321	
A-3	42		143	10582	500	0.004	0.008	0.323	
A-4	24		26	1924	500	0.001	0.002	0.040	
A-5	20	15	0	0	500	0.000	0.000	0.007	0.005
B-1	8		168	12432	500	0.004	0.009	0.072	
B-2	15		168	12432	500	0.004	0.009	0.135	
B-3	35		151	11174	500	0.004	0.008	0.284	
B-4	44		23	1702	500	0.001	0.002	0.067	
B-5	50	10	0	0	500	0.000	0.000	0.017	0.003
C-1	23		144	10656	500	0.004	0.008	0.178	
C-2	21		140	10360	500	0.004	0.008	0.158	
C-3	16		76	5624	500	0.002	0.004	0.068	
C-4	3.5	6.5	14	1036	500	0.000	0.001	0.004	0.007
C-5	4	13	0	0	500	0.000	0.000	0.001	0.005
D-1	16		182	13468	500	0.005	0.010	0.155	
D-2	19		166	12284	500	0.004	0.009	0.169	
D-3	21		129	9546	500	0.003	0.007	0.147	
D-4	25		92	6808	500	0.002	0.005	0.127	
D-5	2		16	1184	500	0.000	0.001	0.002	
D-6	0	9	0	0	500	0.000	0.000	0.000	0.003

Constants Used:

Elastic coefficient of Till(E_T)	2,880,000	
Elastic coefficient of Berm (E_B)	1,440,000	
Waste Density (γ_w)	74	pcf
Cover System Density (γ_c)	125	pcf
Thickness of Final Copver System (T_c)	4	ft

Settlement Evaluation; and Estimates of Post-Closure Geosynthetic Slopes and Strains

Project: Juniper Ridge Landfill, Expansion
Date: January 25, 2014

Calcs by: Brian Johnson, P.E., Sevee & Maher Engineers, Inc.

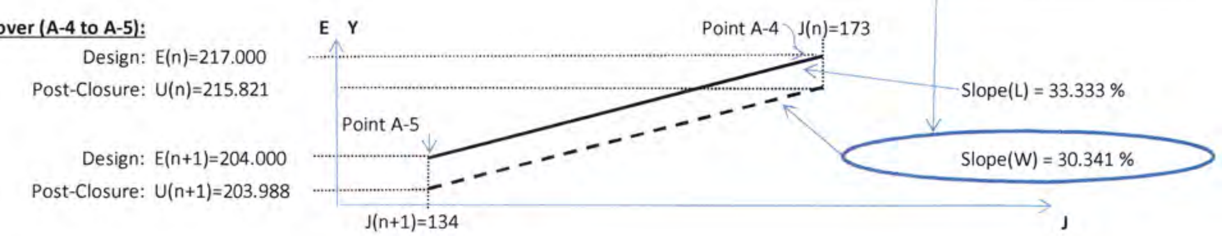
Estimated Settlement and Slopes

	Post-Closure Settlements			Post-Closure Elevations		Line Segment from Point n to n+1	Estimated Post-Closure Slopes		Are Slopes Acceptable?	
	= (Q)	= (R)	(S)= eW-avg * (TP-C*365)*I	(T)= D - (Q+R)	(U)= E - (Q+R+S)		(V) = [T(n) - T(n+1)] / [J(n) - J(n+1)]	(W) = [U(n) - U(n+1)] / [J(n) - J(n+1)]	Slope Stays in Same Direction, then Yes	Slope Stays in Same Direction, then Yes; If W < $S_{C\text{-}Max}$, then Yes
Point	Settlement of Till	Settlement of Berm	Settlement of Waste	Elevation of Top of Liner System	Elevation of Top of Cover System		Liner Slope	Cover Slope	Liner System	Cover System
	(ft)	(ft)	(ft)	(ft)	(ft)					
A-1	0.312		6.526	208.688	351.162	A-1 to A-2	4.387%	2.308%	Yes	Yes
A-2	0.321		6.548	207.679	350.631	A-2 to A-3	3.160%	9.702%	Yes	Yes
A-3	0.323		6.263	204.677	341.413	A-3 to A-4	3.490%	31.957%	Yes	Yes
A-4	0.040		1.139	190.960	215.821	A-4 to A-5	-33.406%	30.341%	Yes	Yes
A-5	0.007	0.005		203.988	203.988					
B-1	0.072		7.358	216.928	377.570	A-1 to A-2	4.050%	4.050%	Yes	Yes
B-2	0.135		7.358	211.865	372.507	A-2 to A-3	3.722%	7.716%	Yes	Yes
B-3	0.284		6.614	196.716	341.102	A-3 to A-4	3.743%	24.773%	Yes	Yes
B-4	0.067		1.007	174.933	196.925	A-4 to A-5	-24.014%	23.796%	Yes	Yes
B-5	0.017	0.003		185.979	185.979					
C-1	0.178		6.307	209.822	347.515	A-1 to A-2	-2.912%	-8.537%	Yes	Yes
C-2	0.158		6.132	207.842	341.710	A-2 to A-3	-1.917%	-31.915%	Yes	Yes
C-3	0.068		3.329	203.932	276.603	A-3 to A-4	-2.459%	-31.954%	Yes	Yes
C-4	0.004	0.007	0.613	198.989	212.376	A-4 to A-5	33.356%	-30.391%	Yes	Yes
C-5	0.001	0.005		205.994	205.994					
D-1	0.155		7.972	209.845	383.873	A-1 to A-2	-1.661%	4.714%	Yes	Yes
D-2	0.169		7.271	213.831	372.561	A-2 to A-3	-1.257%	9.799%	Yes	Yes
D-3	0.147		5.650	217.853	341.203	A-3 to A-4	-7.714%	31.165%	Yes	Yes
D-4	0.127		4.030	224.873	312.844	A-4 to A-5	3.125%	31.963%	Yes	Yes
D-5	0.002		0.701	216.998	232.297	A-5 to A-6	-33.330%	30.417%	Yes	Yes
D-6		0.003		224.997	224.997					

Constants Used:

Post-Closure Time ($T_{P\text{-}C}$):	30	years
Cover Slope is no Steeper than ($S_{C\text{-}Max}$):	33.333%	Slope
Average Waste Strain Rate (ε_W-avg)	0.000004	strain/day

Example "Estimated Post-Closure Slope" of Cover (A-4 to A-5):



Settlement Evaluation; and Estimates of Post-Closure Geosynthetic Slopes and Strains

Project: Juniper Ridge Landfill, Expansion
Date: January 25, 2014 Calcs by: Brian Johnson, P.E., Sevee & Maher Engineers, Inc.

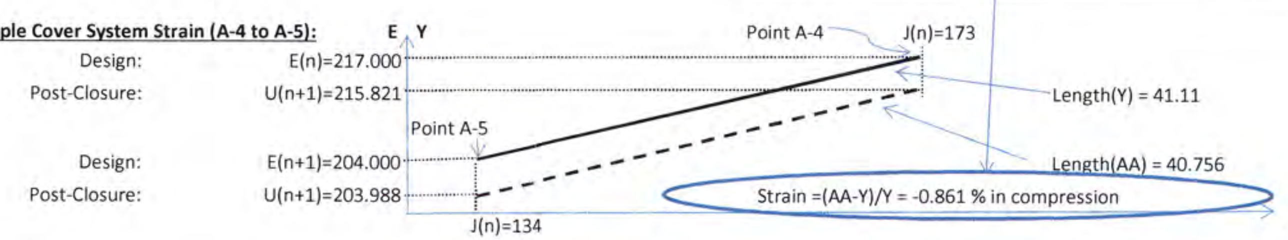
Estimated Strain in Liner and Cover

Line Segment from Point n to n+1	Design Segment Lengths		End of Post-Closure Segment Lengths		Strains on Geosynthetics (Positive Values = Tension)		Are Strains Acceptable?	
	(X) = $\{[D(n)-D(n+1)]^2 + [J(n)-J(n+1)]^2\}^{0.5}$	(Y) = $\{[E(n)-E(n+1)]^2 + [J(n)-J(n+1)]^2\}^{0.5}$	(Z) = $\{[T(n)-T(n+1)]^2 + [J(n)-J(n+1)]^2\}^{0.5}$	(AA) = $\{[U(n)-U(n+1)]^2 + [J(n)-J(n+1)]^2\}^{0.5}$	(AB)= (Z-X)/X	(AC)= (AA-Y)/Y	If AB < $LS_{c\text{-}max}$, then Yes	If AC < $CS_{c\text{-}max}$, then Yes
	Liner Length	Cover Length	Liner Length	Cover Length	Liner Strain	Cover Strain	Liner System	Cover System
	(ft)	(ft)	(ft)	(ft)				
A-1 to A-2	23.022	23.005	23.022	23.006	0.002%	0.003%	Yes	Yes
A-2 to A-3	95.047	95.474	95.047	95.446	0.000%	-0.029%	Yes	Yes
A-3 to A-4	393.249	414.258	393.239	412.580	-0.003%	-0.405%	Yes	Yes
A-4 to A-5	41.110	41.110	41.119	40.756	0.022%	-0.861%	Yes	Yes
A-1 to A-2	125.100	125.100	125.102	125.102	0.002%	0.002%	Yes	Yes
A-2 to A-3	407.276	408.256	407.282	408.210	0.001%	-0.011%	Yes	Yes
A-3 to A-4	582.416	601.019	582.408	599.592	-0.001%	-0.237%	Yes	Yes
A-4 to A-5	47.297	47.539	47.308	47.284	0.023%	-0.536%	Yes	Yes
A-1 to A-2	68.029	68.264	68.029	68.247	-0.001%	-0.025%	Yes	Yes
A-2 to A-3	204.039	215.035	204.037	214.137	-0.001%	-0.417%	Yes	Yes
A-3 to A-4	201.062	211.873	201.061	211.012	-0.001%	-0.406%	Yes	Yes
A-4 to A-5	22.136	22.136	22.137	21.948	0.007%	-0.847%	Yes	Yes
A-1 to A-2	240.033	240.300	240.033	240.266	0.000%	-0.014%	Yes	Yes
A-2 to A-3	320.025	321.697	320.025	321.533	0.000%	-0.051%	Yes	Yes
A-3 to A-4	91.269	95.818	91.270	95.317	0.002%	-0.523%	Yes	Yes
A-4 to A-5	252.127	265.631	252.123	264.560	-0.002%	-0.403%	Yes	Yes
A-5 to A-6	25.298	25.298	25.298	25.086	-0.001%	-0.840%	Yes	Yes

Allowable Tensile Strains:

Liner System, $LS_{c\text{-}max}$:	5.00%	Strain
Cover System, $CS_{c\text{-}max}$:	5.00%	Strain

Example Cover System Strain (A-4 to A-5):



APPENDIX G

LEACHATE QUALITY/WASTE CHARACTERIZATION

Leachate Location

REPORT PREPARED: 6/17/2015 13:01

FOR: Juniper Ridge Landfill

SUMMARY REPORT

Leachate - Field Data

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	Specific Conductance µmhos/cm @25°C	pH Standard Units	Temperature Degrees Celcius	Corrected Eh mV	Dissolved Oxygen mg/L	Alkalinity (CaCO3) (field) mg/L	Turbidity (field) NTU
LT-C4L									
4/15/2009	XX	LTC4LX325	29800	7.1	18.6	95	D2	D3	1100 >
7/7/2009	XX	LTC4LX369	20000 >	7.6	17.8	217	8	D3	400
10/28/2009	XX	LTC4LX3E4	24300	7.3	17.6	102	D2	D3	230
4/28/2010	XX	LTC4LX3J3	23200	7.3	17.7	145	2	1813	170
7/20/2010	XX	LTC4LX427	23400	6.9	21.8	33	D2	D3	D3
10/19/2010	XX	LTC4LX45B	28300	7.1	19.6	113	2	1313	20
4/27/2011	XX	LTC4LX49C	18420	6.9	17.4	109		1563	8.4
7/19/2011	XX	LTC4LX4DA	30700	7	28.3	115	2	1688	44
10/26/2011	XX	LTC4LX4H5	15850	7.1	18.3	100	1	750	6.1
4/24/2012	XX	LTC4LX51F	11470	6.7	15.7	-27	2	688	14.9
7/24/2012	XX	LTC4LX56E	25300	6.8	24.8	-93	3	D3	D3
10/23/2012	XX	LTC4LX5D5	19800	6.9	17.3	-33	D2	D3	D3
4/23/2013	XX	LTC4LX5HG	18590	7.1	17.1	92	1	1500	18.9
LT-C4LR									
7/30/2013	XX	LTC4LX641	23400	6.7	23.6	44	D2	D3	D3
10/29/2013	XX	LTC4LX66E	24100	6.8	11.3	92	D2	D3	D3
4/22/2014	XX	LTC4LX6EH	15370	7.2	13.3	134	D2	D3	D3
7/30/2014	XX	LTC4LX6J4	23800	7.2	22.3	-30	D2	D3	D3
10/21/2014	XX	LTC4LX72F	21300	7.2	15.8	238	D2	D3	D3
4/28/2015	XX	LTC4LX78C	22600	7.5	12.1	-151	D2		D3

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

D2 - Sample too dark to read D.O. reading.
D3 - Sample too dark to take reading.

REPORT PREPARED: 6/17/2015 13:02 FOR: Juniper Ridge Landfill	SUMMARY REPORT Leachate - Inorganics (part 1 of 2)	Page 1 of 1 SEVEE & MAHER ENGINEERS, INC. 4 BLANCHARD ROAD CUMBERLAND CENTER, ME 04021

(LT-C4L) Date	Type	Sample ID	Total Kjeldahl Nitrogen mg/L	Ammonia (N) mg/L	Nitrate (N) mg/L	Phosphate Phosphorus mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	Sulfate mg/L	Sulfide mg/L	Ca-mg Hardness (CaCO3) mg/L	Bicarbonate (CaCO3) mg/L	Alkalinity (CaCO3) mg/L	Organic Carbon mg/L	Biochemical Oxygen Demand mg/L
LT-C4L															
4/15/2009	XX	LTC4LX325	630	318	10 U		19657	145	143 J	11	6212	3290	3290	1970	4050
7/7/2009	XX	LTC4LX369	740	708	30 U	1.1	19816	230	342 J	7		2830		1670	2360
10/28/2009	XX	LTC4LX3E4	810	624	20 U	0.88	14060	52	120 U	1.5		2750		475	677
4/28/2010	XX	LTC4LX3J3	910	697	20 U		15180	59	120 U	0.44	2856	3210	3210	474	1000 U
7/20/2010	XX	LTC4LX427	880	714	20 U	1.2	15250	38	120 U	2.5		3360		366	139
10/19/2010	XX	LTC4LX45B	790	666	5.6 J	0.76	16940	44	63	1.1		2700		307	152
4/27/2011	XX	LTC4LX49C	500	74	6 U		10570	5	72 J	0.18	1831	2280	2280	184	39
7/19/2011	XX	LTC4LX4DA	810	666	10 U	0.92	14820	44	60 U	0.3		2800		270	45
10/26/2011	XX	LTC4LX4H5	510	442	5 U	0.59	8250	11	64.6 J	3.7		1400		182	47
4/24/2012	XX	LTC4LX51F	290	274	15 U		6080	108	133	1.6	1941	1370	1370	935	1120 G
7/24/2012	XX	LTC4LX56E	710	742	6 U	0.77	15210	106	50.2	3		3630		2120	3090
10/23/2012	XX	LTC4LX5D5	490	459	17.9	0.46	14570	36	213	16		2740		1740	3190
4/23/2013	XX	LTC4LX5HG	697	574	30 U		10700	34	200 U	2.3	2424	2950	2950	935	1750
LT-C4LR															
7/30/2013	XX	LTC4LX641	742	630	1210	1.39	15050	625	400 U	78		3700		2560	4850
10/29/2013	XX	LTC4LX66E	880	840	5	0.79	17400	140	10.4	5.6		3980		2450	855
4/22/2014	XX	LTC4LX6EH	520	434	45 U		8600	28	300 U	4	1889	2010	2010	364	434
7/30/2014	XX	LTC4LX6J4	850	708	348		12040	64	2250			3200		761	
10/21/2014	XX	LTC4LX72F	820	700	30 U	0.83	13280	44	200 U	6		2740		460	448
4/28/2015	XX	LTC4LX78C	800	636	48 U		10080	38	320 U	40	1738	3560	3560	580	1284

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

G - Greater than specified amount.

J - Analyte was positively identified/Associated value is an estimate below reporting limit.

U - Not Detected above the reported sample detection limit.

REPORT PREPARED: 6/17/2015 13:02

FOR: Juniper Ridge Landfill

SUMMARY REPORT

Leachate - Inorganics (part 2 of 2)

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	Chemical Oxygen Demand mg/L	Chloride mg/L	Bromide mg/L	Cyanide ug/L	Tannin & Lignins (Tannic Acid) mg/L
LT-C4L							
4/15/2009	XX	LTC4LX325	6640	10100	92.3	0.009	
7/7/2009	XX	LTC4LX369	4684	21500			97
10/28/2009	XX	LTC4LX3E4	2822	17400			44
4/28/2010	XX	LTC4LX3J3	2429	18000	188	0.007	
7/20/2010	XX	LTC4LX427	2108	19900			53
10/19/2010	XX	LTC4LX45B	2340	18700			52
4/27/2011	XX	LTC4LX49C	1740	5910	23.3	0.006	
7/19/2011	XX	LTC4LX4DA	959	10300			3.6
10/26/2011	XX	LTC4LX4H5	1420	4300			24
4/24/2012	XX	LTC4LX51F	2960	2560	32.7	5 U	
7/24/2012	XX	LTC4LX56E	6700	6350			67
10/23/2012	XX	LTC4LX5D5	5900	9880			84
4/23/2013	XX	LTC4LX5HG	3280	5610	73.3	5	
LT-C4LR							
7/30/2013	XX	LTC4LX641	8110	24300	38.8		480
10/29/2013	XX	LTC4LX66E	8080	5970	95		102
4/22/2014	XX	LTC4LX6EH	1620	7650	63.6	5 U	
7/30/2014	XX	LTC4LX6J4	2760	13950	39		75
10/21/2014	XX	LTC4LX72F	2320	7070	100		100
4/28/2015	XX	LTC4LX78C	2955	5420	57	5 U	

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

U - Not Detected above the reported sample detection limit.

REPORT PREPARED: 6/17/2015 13:02

FOR: Juniper Ridge Landfill

SUMMARY REPORT

Leachate - Metal (part 1 of 2)

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	Aluminum mg/L	Antimony mg/L	Arsenic mg/L	Barium mg/L	Beryllium mg/L	Cadmium mg/L	Calcium mg/L	Chromium mg/L	Cobalt mg/L	Copper mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L
LT-C4L																
4/15/2009	XX	LTC4LX325	0.55	0.065	0.093	1.3	0.001 U	0.006	1759	0.072	0.02 J	0.036	42.8	0.024	442	8.5
7/7/2009	XX	LTC4LX369			0.112			0.001 U	1387			0.009	43.3		514	5
10/28/2009	XX	LTC4LX3E4			0.075			0.0015	687			0.022	26.3		386	2.77
4/28/2010	XX	LTC4LX3J3	0.429	0.005	0.107	1.873	0.0002 U	0.001	565	0.065	0.014	0.004	20.9	0.068	351	2.18
7/20/2010	XX	LTC4LX427			0.099			0.0009	520			0.007	11.9		378	2.08
10/19/2010	XX	LTC4LX45B			0.113			0.004	658			0.01 J	16.8		415	1.8
4/27/2011	XX	LTC4LX49C	0.201	0.018	0.085	1.469	0.0002 U	0.0032	344	0.024	0.012	0.011	9.61	0.002 J	236	2.45
7/19/2011	XX	LTC4LX4DA			0.121			0.012	469			0.005 U	12.7		372	2.3
10/26/2011	XX	LTC4LX4H5			0.059			0.0099	305			0.008	19.7		205	2.24
4/24/2012	XX	LTC4LX51F	0.25	0.025 U	0.07	0.915	0.003 U	0.005	482	0.025	0.05 U	0.015 U	63	0.015 U	179	23.6
7/24/2012	XX	LTC4LX56E			0.11			0.003 U	845			0.056	82		466	26
10/23/2012	XX	LTC4LX5D5			0.177			0.004	934			0.024	45.3		433	14
4/23/2013	XX	LTC4LX5HG	0.223	0.005 U	0.102	1.285	0.0006 U	0.0013	474	0.038	0.014	0.017	30.3	0.003 U	301	8.03
LT-C4LR																
7/30/2013	XX	LTC4LX641			0.137			0.0146	958			0.065	179		433	23.4
10/29/2013	XX	LTC4LX66E			0.16			0.004	860			0.018	100		532	16.7
4/22/2014	XX	LTC4LX6EH	0.22	0.005 U	0.131	1.222	0.0006 U	0.0061	329	0.049	0.016	0.033	13.2	0.022	259	2.73
7/30/2014	XX	LTC4LX6J4			0.143			0.0038	311			0.003 U	28.6		289	3.8
10/21/2014	XX	LTC4LX72F			0.186			0.009	406			0.005	27.3		355	4.23
4/28/2015	XX	LTC4LX78C	0.556	0.026	0.209	1.316	0.0012	0.0161	259	0.093	0.034	0.047	11	0.095	265	1.8

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

J - Analyte was positively identified/Associated value is an estimate below reporting limit.

U - Not Detected above the reported sample detection limit.

REPORT PREPARED: 6/17/2015 13:02

FOR: Juniper Ridge Landfill

SUMMARY REPORT

Leachate - Metal (part 2 of 2)

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	Mercury mg/L	Nickel mg/L	Potassium mg/L	Selenium mg/L	Silver mg/L	Sodium mg/L	Thallium mg/L	Vanadium mg/L	Zinc mg/L	Tin mg/L
LT-C4L												
4/15/2009	XX	LTC4LX325	0.0002 U	0.153	1619	0.01 U	0.055	2212	0.005 U	0.02 U	0.604	0.12
7/7/2009	XX	LTC4LX369		0.119	1801			2454				
10/28/2009	XX	LTC4LX3E4		0.091	1775			2612				
4/28/2010	XX	LTC4LX3J3	0.0002 U	0.106	1982	0.021	0.0003 J	2448	0.012	0.025	0.053	0.014 J
7/20/2010	XX	LTC4LX427		0.101	1659			2130				
10/19/2010	XX	LTC4LX45B		0.078	1779			2265				
4/27/2011	XX	LTC4LX49C	0.0002 U	0.061	1135	0.016	0.0007 J	1520	0.001 U	0.017	0.011	0.005 U
7/19/2011	XX	LTC4LX4DA		0.079	1806			2590				
10/26/2011	XX	LTC4LX4H5		0.03	1066			1580				
4/24/2012	XX	LTC4LX51F	0.0005 U	0.045	714	0.025	0.005 U	1024	0.02 U	0.05 U	0.155	0.075 U
7/24/2012	XX	LTC4LX56E		0.122	1719			2337				
10/23/2012	XX	LTC4LX5D5		0.084	1100			1842				
4/23/2013	XX	LTC4LX5HG	0.0005 U	0.079	1237	0.01	0.001 U	1844	0.004 U	0.01	0.016	0.019
LT-C4LR												
7/30/2013	XX	LTC4LX641		0.304	1234			1910				
10/29/2013	XX	LTC4LX66E		0.23	1622			2290				
4/22/2014	XX	LTC4LX6EH	0.0005 U	0.073	941	0.035	0.001 U	1633	0.004 U	0.027	0.101	0.015 U
7/30/2014	XX	LTC4LX6J4		0.146	1140			1948				
10/21/2014	XX	LTC4LX72F		0.094	1472			2316				
4/28/2015	XX	LTC4LX78C	0.0005 U	0.141	1118	0.052	0.0021	3401	0.008 U	0.063	0.258	0.157

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

J - Analyte was positively identified/Associated value is an estimate below reporting limit.

U - Not Detected above the reported sample detection limit.

SUMMARY REPORT

Leachate - VOAs Part 1 of 4

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	Chloromethane ug/L	Bromomethane ug/L	Vinyl Chloride ug/L	Chloroethane ug/L	Methylene Chloride ug/L	Acetone ug/L	Carbon Disulfide ug/L	1,1-Dichloroethene ug/L	1,1-Dichloroethane ug/L	trans-1,2-Dichloroethene ug/L	Chloroform ug/L	1,2-Dichloroethane ug/L	Methyl Ethyl Ketone ug/L	1,1,1-Trichloroethane ug/L	Carbon Tetrachloride ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	50 U	50 U	50 U	50 U	250 U	3880	50 U	50 U	50 U	50 U	50 U	50 U	11700	50 U	50 U
7/7/2009	XX	LTC4LX369	25 U	25 U	25 U	25 U	125 U	4020	25 U	25 U	25 U	25 U	25 U	25 U	9080	25 U	25 U
10/28/2009	XX	LTC4LX3E4	10 U	10 U	10 U	10 U	50 U	764	10 U	10 U	10 U	10 U	10 U	10 U	2570	10 U	10 U
4/28/2010	XX	LTC4LX3J3	2.5 U	5 U	2.5 U	2.5 U	25 U	444	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	3.8 J	1360	2.5 U	2.5 U
7/20/2010	XX	LTC4LX427	2.5 U	5 U	2.5 U	2.5 U	25 U	365	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	5.8	25 U	2.5 U	2.5 U
10/19/2010	XX	LTC4LX45B	0.5 U	1 U	0.75 J	0.5 U	5 U	475	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	604	0.5 U	0.5 U
4/27/2011	XX	LTC4LX49C	5 U	10 U	5 U	5 U	50 U	100 U	5 U	5 U	5 U	5 U	5 U	5 U	50 U	5 U	5 U
7/19/2011	XX	LTC4LX4DA	0.5 U	1 U	0.5 U	0.5 U	5 U	136	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	12	0.5 U	0.5 U
10/26/2011	XX	LTC4LX4H5	0.5 U	1 U	0.7 J	0.5 U	5 U	117	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	97	0.5 U	0.5 U
4/24/2012	XX	LTC4LX51F	5 U	10 U	5 U	5 U	25 U	974	5 U	5 U	5 U	5 U	5 U	10	3440	5 U	5 U
7/24/2012	XX	LTC4LX56E	5 U	10 U	5 U	5 U	25 U	2460	5 U	5 U	5 U	5 U	5 U	5 U	9540	5 U	5 U
10/23/2012	XX	LTC4LX5D5	25 U	50 U	25 U	25 U	125 U	2710	25 U	25 U	25 U	25 U	25 U	25 U	7490	25 U	25 U
4/23/2013	XX	LTC4LX5HG	25 U	50 U	25 U	25 U	125 U	1310	25 U	25 U	25 U	25 U	25 U	25 U	4110	25 U	25 U
LT-C4LR																	
7/30/2013	XX	LTC4LX641	250 U	100 U	100 U	100 U	300 U	4400	500 U	50 U	75 U	75 U	75 U	50 U	23000 E	50 U	50 U
10/29/2013	XX	LTC4LX66E	400 U	400 U	400 U	1000 U	1000 U	4000	400 U	200 U	200 U	200 U	200 U	200 U	20000	200 U	200 U
4/22/2014	XX	LTC4LX6EH	40 U	40 U	40 U	100 U	100 U	1000	40 U	20 U	20 U	20 U	20 U	20 U	1400	20 U	20 U
7/30/2014	XX	LTC4LX6J4	2 U	2 U	2 U	5 U	5 U	60	5 U	1 U	2 U	2 U	2 U	2 U	200	2 U	2 U
10/21/2014	XX	LTC4LX72F	20 U	20 U	20 U	50 U	50 U	400	20 U	10 U	10 U	10 U	10 U	10 U	1200	10 U	10 U
4/28/2015	XX	LTC4LX78C	20 U	20 U	20 U	50 U	50 U	2400	20 U	10 U	10 U	10 U	10 U	10 U	4400	10 U	10 U
QCBT																	
5/4/2004	XX	BTXXXX00H	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
6/9/2004	XX	BTXXXX035	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
7/26/2004	XX	BTXXXX046	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
10/27/2004	XX	BTXXXX060	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
1/17/2005	XX	BTXXXX111	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
3/9/2005	XX	BTXXXX11E	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
3/21/2005	XX	BTXXXX142	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
5/11/2005	XX	BTXXXX121	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
7/25/2005	XX	BTXXXX17G	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
7/27/2005	XX	BTXXXX187	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
9/20/2005	XX	BTXXXX1A7	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
9/21/2005	XX	BTXXXX1AI	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
9/22/2005	XX	BTXXXX1AJ	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
4/19/2006	XX	BTXXXX1FE	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
5/22/2006	XX	BTXXXX1F2	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
5/23/2006	XX	BTXXXX1FD	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
5/24/2006	XX	BTXXXX1ID	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
7/25/2006	XX	BTXXXX1HJ	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
9/13/2006	XX	BTXXXX20C	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
5/14/2007	XX	BTXXXX23J	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
5/15/2007	XX	BTXXXX244	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
5/16/2007	XX	BTXXXX245	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
7/24/2007	XX	BTXXXX283	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
9/11/2007	XX	BTXXXX2AD	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
5/19/2008	XX	BTXXXX2EC	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
5/21/2008	XX	BTXXXX2ED	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U

SUMMARY REPORT

Leachate - VOAs Part 1 of 4

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(QCBT)

Date	Type	Sample ID	Chloromethane ug/L	Bromomethane ug/L	Vinyl Chloride ug/L	Chloroethane ug/L	Methylene Chloride ug/L	Acetone ug/L	Carbon Disulfide ug/L	1,1-Dichloroethene ug/L	1,1-Dichloroethane ug/L	trans-1,2-Dichloroethene ug/L	Chloroform ug/L	1,2-Dichloroethane ug/L	Methyl Ethyl Ketone ug/L	1,1,1-Trichloroethane ug/L	Carbon Tetrachloride ug/L
7/29/2008	XX	BTXXXX2HB	2 U	2 U	2 U	2 U	5 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
10/29/2008	XX	BTXXXX301	1 U	1 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
4/13/2009	XX	BTXXXX33D	1 U	1 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
4/15/2009	XX	BTXXXX33E	1 U	1 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
7/7/2009	XX	BTXXXX37H	1 U	1 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
10/28/2009	XX	BTXXXX3AJ	1 U	1 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
4/26/2010	XX	BTXXXX40A	0.5 U	1 U	0.5 U	0.5 U	5 U	10 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	0.5 U	0.5 U
4/27/2010	XX	BTXXXX40B	0.5 U	1 U	0.5 U	0.5 U	5 U	10 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	0.5 U	0.5 U
4/28/2010	XX	BTXXXXHG1	0.5 U	1 U	0.5 U	0.5 U	5 U	10 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	0.5 U	0.5 U
7/20/2010	XX	BTXXXX43F	0.5 U	1 U	0.5 U	0.5 U	5 U	10 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	0.5 U	0.5 U
10/19/2010	XX	BTXXXX46I	0.5 U	1 U	0.5 U	0.5 U	5 U	10 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	0.5 U	0.5 U
4/25/2011	XX	BTXXXX4AJ	0.5 U	1 U	0.5 U	0.5 U	5 U	10 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	0.5 U	0.5 U
4/26/2011	XX	BTXXXX4B0	0.5 U	1 U	0.5 U	0.5 U	5 U	10 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	0.5 U	0.5 U
4/27/2011	XX	BTXXXX4B5	0.5 U	1 U	0.5 U	0.5 U	5 U	14	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	0.5 U	0.5 U
7/19/2011	XX	BTXXXX4F3	0.5 U	1 U	0.5 U	0.5 U	5 U	10 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	0.5 U	0.5 U
10/26/2011	XX	BTXXXX4G8	0.5 U	1 U	0.5 U	0.5 U	5 U	10 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	0.5 U	0.5 U
4/23/2012	XX	BTXXXX532	1 U	2 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
4/24/2012	XX	BTXXXX533	1 U	2 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
4/25/2012	XX	BTXXXX538	1 U	2 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
7/24/2012	XX	BTXXXX585	1 U	2 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
10/23/2012	XX	BTXXXX5C8	1 U	2 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
4/22/2013	XX	BTXXXX5J3	1 U	2 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
4/23/2013	XX	BTXXXX5J4	1 U	2 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
4/24/2013	XX	BTXXXX5J8	1 U	2 U	1 U	1 U	5 U	10 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	1 U	1 U
7/30/2013	XX	BTXXXX65D	2.5 U	1 U	1 U	1 U	3 U	5 U	5 U	0.5 U	0.75 U	0.75 U	0.75 U	0.5 U	5 U	0.5 U	0.5 U
10/29/2013	XX	BTXXXX68C	2 U	2 U	2 U	5 U	5 U	10 U	5 U	1 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
4/21/2014	XX	BTXXXX6G4	2 U	2 U	2 U	5 U	5 U	10 U	5 U	1 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
4/22/2014	XX	BTXXXX6G5	2 U	2 U	2 U	5 U	5 U	10 U	5 U	1 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
7/30/2014	XX	BTXXXX70B	2 U	2 U	2 U	5 U	5 U	10 U	5 U	1 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
10/21/2014	XX	BTXXXX748	2 U	2 U	2 U	5 U	5 U	10 U	5 U	1 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
4/27/2015	XX	BTXXXX79E	2 U	2 U	2 U	5 U	5 U	10 U	5 U	1 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
4/27/2015	XX	BTXXXX79F	2 U	2 U	2 U	5 U	5 U	10 U	5 U	1 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U
4/27/2015	XX	BTXXXX79J	2 U	2 U	2 U	5 U	5 U	10 U	5 U	1 U	2 U	2 U	2 U	2 U	10 U	2 U	2 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

E - Compound exceeded upper level of calibration range and required dilution.
J - Analyte was positively identified/Associated value is an estimate below reporting limit.
U - Not Detected above the reported sample detection limit.

REPORT PREPARED: 6/17/2015 13:03

FOR: Juniper Ridge Landfill

SUMMARY REPORT

Leachate - VOAs Part 2 of 4

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	Vinyl Acetate ug/L	Bromodichloromethane ug/L	1,2-Dichloropropane ug/L	cis-1,3-Dichloropropene ug/L	Trichloroethene ug/L	Dibromochloromethane ug/L	1,1,2-Trichloroethane ug/L	Benzene ug/L	trans-1,3-Dichloropropene ug/L	Bromoform ug/L	4-Methyl-2-Pentanone ug/L	2-Hexanone ug/L	Tetrachloroethene ug/L	1,1,2,2-Tetrachloroethane ug/L	Toluene ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	500 U	500 U	50 U	50 U	50 U
7/7/2009	XX	LTC4LX369	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	289	250 U	25 U	25 U	25 U
10/28/2009	XX	LTC4LX3E4	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	100 U	100 U	10 U	10 U	13
4/28/2010	XX	LTC4LX3J3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	4.4 J	2.5 U	2.5 U	25 U	25 U	2.5 U	2.5 U	15
7/20/2010	XX	LTC4LX427	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	4.6 J	2.5 U	2.5 U	25 U	25 U	2.5 U	2.5 U	15
10/19/2010	XX	LTC4LX45B	0.5 U	0.5 U	0.81 J	0.5 U	0.5 U	0.5 U	0.5 U	5	0.5 U	0.72 J	38	5 U	0.5 U	0.5 U	18
4/27/2011	XX	LTC4LX49C	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	50 U	50 U	5 U	5 U	11
7/19/2011	XX	LTC4LX4DA	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	3.2	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	7.4
10/26/2011	XX	LTC4LX4H5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	4.6	0.5 U	0.5 U	7.8 J	5 U	0.5 U	0.5 U	13
4/24/2012	XX	LTC4LX51F	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	50 U	50 U	5 U	5 U	13
7/24/2012	XX	LTC4LX56E	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	55	50 U	5 U	5 U	6.8
10/23/2012	XX	LTC4LX5D5	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	250 U	250 U	25 U	25 U	25 U
4/23/2013	XX	LTC4LX5HG	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	250 U	250 U	25 U	25 U	25 U
LT-C4LR																	
7/30/2013	XX	LTC4LX641	500 U	50 U	180 U	50 U	50 U	50 U	75 U	50 U	50 U	200 U	500 U	500 U	50 U	50 U	75 U
10/29/2013	XX	LTC4LX66E	2000 U	100 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	400 U	2000 U	2000 U	200 U	200 U	200 U
4/22/2014	XX	LTC4LX6EH	200 U	10 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	40 U	200 U	200 U	20 U	20 U	20 U
7/30/2014	XX	LTC4LX6J4	10 U	0.5 U	2 U	2 U	2 U	2 U	2 U	1 U	2 U	2 U	10 U	10 U	2 U	2 U	1 U
10/21/2014	XX	LTC4LX72F	100 U	5 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	20 U	100 U	100 U	10 U	10 U	10 U
4/28/2015	XX	LTC4LX78C	100 U	5 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	20 U	100 U	100 U	10 U	10 U	10
QCBT																	
5/4/2004	XX	BTXXXX00H	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
6/9/2004	XX	BTXXXX035	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
7/26/2004	XX	BTXXXX046	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
10/27/2004	XX	BTXXXX060	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
1/17/2005	XX	BTXXXX111	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
3/9/2005	XX	BTXXXX11E	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
3/21/2005	XX	BTXXXX142	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
5/11/2005	XX	BTXXXX121	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
7/25/2005	XX	BTXXXX17G	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
7/27/2005	XX	BTXXXX187	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
9/20/2005	XX	BTXXXX1A7	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
9/21/2005	XX	BTXXXX1AI	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
9/22/2005	XX	BTXXXX1AJ	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
4/19/2006	XX	BTXXXX1FE	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
5/22/2006	XX	BTXXXX1F2	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
5/23/2006	XX	BTXXXX1FD	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
5/24/2006	XX	BTXXXX1ID	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
7/25/2006	XX	BTXXXX1HJ	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
9/13/2006	XX	BTXXXX20C	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
5/14/2007	XX	BTXXXX23J	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
5/15/2007	XX	BTXXXX244	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
5/16/2007	XX	BTXXXX245	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
7/24/2007	XX	BTXXXX283	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
9/11/2007	XX	BTXXXX2AD	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
5/19/2008	XX	BTXXXX2EC	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
5/21/2008	XX	BTXXXX2ED	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U

SUMMARY REPORT

Leachate - VOAs Part 2 of 4

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(QCBT)

Date	Type	Sample ID	Vinyl Acetate ug/L	Bromodichloromethane ug/L	1,2-Dichloropropane ug/L	cis-1,3-Dichloropropene ug/L	Trichloroethene ug/L	Dibromochloromethane ug/L	1,1,2-Trichloroethane ug/L	Benzene ug/L	trans-1,3-Dichloropropene ug/L	Bromoform ug/L	4-Methyl-2-Pentanone ug/L	2-Hexanone ug/L	Tetrachloroethene ug/L	1,1,2,2-Tetrachloroethane ug/L	Toluene ug/L
7/29/2008	XX	BTXXXX2HB	15 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U	10 U	2 U	2 U	2 U
10/29/2008	XX	BTXXXX301	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
4/13/2009	XX	BTXXXX33D	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
4/15/2009	XX	BTXXXX33E	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
7/7/2009	XX	BTXXXX37H	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
10/28/2009	XX	BTXXXX3AJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
4/26/2010	XX	BTXXXX40A	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	0.5 U
4/27/2010	XX	BTXXXX40B	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	0.5 U
4/28/2010	XX	BTXXXXHG1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	0.5 U
7/20/2010	XX	BTXXXX43F	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	0.5 U
10/19/2010	XX	BTXXXX46I	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	0.5 U
4/25/2011	XX	BTXXXX4AJ	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	0.5 U
4/26/2011	XX	BTXXXX4B0	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	0.5 U
4/27/2011	XX	BTXXXX4B5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	0.5 U
7/19/2011	XX	BTXXXX4F3	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	0.5 U
10/26/2011	XX	BTXXXX4G8	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	5 U	0.5 U	0.5 U	0.5 U
4/23/2012	XX	BTXXXX532	2 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
4/24/2012	XX	BTXXXX533	2 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
4/25/2012	XX	BTXXXX538	2 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
7/24/2012	XX	BTXXXX585	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
10/23/2012	XX	BTXXXX5C8	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
4/22/2013	XX	BTXXXX5J3	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
4/23/2013	XX	BTXXXX5J4	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
4/24/2013	XX	BTXXXX5J8	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	10 U	10 U	1 U	1 U	1 U
7/30/2013	XX	BTXXXX65D	5 U	0.5 U	1.8 U	0.5 U	0.5 U	0.5 U	0.75 U	0.5 U	0.5 U	2 U	5 U	5 U	0.5 U	0.5 U	0.75 U
10/29/2013	XX	BTXXXX68C	10 U	0.5 U	2 U	2 U	2 U	2 U	2 U	1 U	2 U	2 U	10 U	10 U	2 U	2 U	1 U
4/21/2014	XX	BTXXXX6G4	10 U	0.5 U	2 U	2 U	2 U	2 U	2 U	1 U	2 U	2 U	10 U	10 U	2 U	2 U	1 U
4/22/2014	XX	BTXXXX6G5	10 U	0.5 U	2 U	2 U	2 U	2 U	2 U	1 U	2 U	2 U	10 U	10 U	2 U	2 U	1 U
7/30/2014	XX	BTXXXX70B	10 U	0.5 U	2 U	2 U	2 U	2 U	2 U	1 U	2 U	2 U	10 U	10 U	2 U	2 U	1 U
10/21/2014	XX	BTXXXX748	10 U	0.5 U	2 U	2 U	2 U	2 U	2 U	1 U	2 U	2 U	10 U	10 U	2 U	2 U	1 U
4/27/2015	XX	BTXXXX79E	10 U	0.5 U	2 U	2 U	2 U	2 U	2 U	1 U	2 U	2 U	10 U	10 U	2 U	2 U	1 U
4/27/2015	XX	BTXXXX79F	10 U	0.5 U	2 U	2 U	2 U	2 U	2 U	1 U	2 U	2 U	10 U	10 U	2 U	2 U	1 U
4/27/2015	XX	BTXXXX79J	10 U	0.5 U	2 U	2 U	2 U	2 U	2 U	1 U	2 U	2 U	10 U	10 U	2 U	2 U	1 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

J - Analyte was positively identified/Associated value is an estimate below reporting limit.

U - Not Detected above the reported sample detection limit.

SUMMARY REPORT

Leachate - VOAs Part 3 of 4

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)			Chlorobenzene	Ethylbenzene	Styrene	o-Xylene	m,p-Xylene	Trichlorofluoromethane	cis-1,2-Dichloroethene	Bromochloromethane	Dibromomethane	1,2-Dibromoethane	1,1,1,2-Tetrachloroethane	1,2,3-Trichloropropane	1,2-Dibromo-3-Chloropropane	1,4-Dichlorobenzene	1,2-Dichlorobenzene
Date	Type	Sample ID	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U		
7/7/2009	XX	LTC4LX369	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
10/28/2009	XX	LTC4LX3E4	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4/28/2010	XX	LTC4LX3J3	2.5 U	5.9	2.5 U	3.1 J	7.2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
7/20/2010	XX	LTC4LX427	2.5 U	5.5	2.5 U	3.7 J	8.5	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
10/19/2010	XX	LTC4LX45B	0.5 U	7.9	1.4 J	5.3	12	0.5 U	1.1 J	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.3	0.5 U
4/27/2011	XX	LTC4LX49C	5 U	5 U	5 U	5 U	7.3 J	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U		
7/19/2011	XX	LTC4LX4DA	0.5 U	3.8	0.5 U	2.5	5.4	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.69 J	0.5 U
10/26/2011	XX	LTC4LX4H5	0.5 U	6.7	1	4.2	9.5	0.5 U	0.7 J	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.1	0.5 U
4/24/2012	XX	LTC4LX51F	5 U	5.8	5 U	5 U	6.9	6.4	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
7/24/2012	XX	LTC4LX56E	5 U	5 U	5 U	5 U	5	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
10/23/2012	XX	LTC4LX5D5	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
4/23/2013	XX	LTC4LX5HG	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
LT-C4LR																	
7/30/2013	XX	LTC4LX641	50 U	50 U	100 U	100 U	100 U	250 U	50 U	250 U	500 U	200 U	50 U	500 U	250 U	250 U	250 U
10/29/2013	XX	LTC4LX66E	200 U	200 U	200 U	200 U	200 U	1000 U	200 U	200 U	200 U	400 U	200 U	200 U	400 U	200 U	200 U
4/22/2014	XX	LTC4LX6EH	20 U	20 U	20 U	20 U	20 U	100 U	20 U	20 U	20 U	40 U	20 U	20 U	40 U	9.6 U	9.6 U
7/30/2014	XX	LTC4LX6J4	2 U	1 U	1 U	1 U	1 U	5 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	1 U	1 U
10/21/2014	XX	LTC4LX72F	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	20 U	10 U	10 U	20 U	10 U	10 U
4/28/2015	XX	LTC4LX78C	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U	20 U	10 U	10 U	20 U	10 U	10 U
QCBT																	
5/4/2004	XX	BTXXXX00H	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
6/9/2004	XX	BTXXXX035	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
7/26/2004	XX	BTXXXX046	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
10/27/2004	XX	BTXXXX060	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
1/17/2005	XX	BTXXXX111	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
3/9/2005	XX	BTXXXX11E	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
3/21/2005	XX	BTXXXX142	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
5/11/2005	XX	BTXXXX121	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
7/25/2005	XX	BTXXXX17G	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
7/27/2005	XX	BTXXXX187	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
9/20/2005	XX	BTXXXX1A7	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
9/21/2005	XX	BTXXXX1AI	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
9/22/2005	XX	BTXXXX1AJ	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
4/19/2006	XX	BTXXXX1FE	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
5/22/2006	XX	BTXXXX1F2	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
5/23/2006	XX	BTXXXX1FD	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
5/24/2006	XX	BTXXXX1ID	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
7/25/2006	XX	BTXXXX1HJ	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
9/13/2006	XX	BTXXXX20C	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
5/14/2007	XX	BTXXXX23J	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
5/15/2007	XX	BTXXXX244	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
5/16/2007	XX	BTXXXX245	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
7/24/2007	XX	BTXXXX283	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
9/11/2007	XX	BTXXXX2AD	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
5/19/2008	XX	BTXXXX2EC	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
5/21/2008	XX	BTXXXX2ED	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U

REPORT PREPARED: 6/17/2015 13:03

FOR: Juniper Ridge Landfill

SUMMARY REPORT

Leachate - VOAs Part 3 of 4

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(QCBT)

Date	Type	Sample ID	Chlorobenzene	Ethylbenzene	Styrene	o-Xylene	m,p-Xylene	Trichlorofluoromethane	cis-1,2-Dichloroethene	Bromochloromethane	Dibromomethane	1,2-Dibromoethane	1,1,1,2-Tetrachloroethane	1,2,3-Trichloropropane	1,2-Dibromo-3-Chloropropane	1,4-Dichlorobenzene	1,2-Dichlorobenzene
			ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
7/29/2008	XX	BTXXXX2HB	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
10/29/2008	XX	BTXXXX301	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
4/13/2009	XX	BTXXXX33D	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
4/15/2009	XX	BTXXXX33E	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
7/7/2009	XX	BTXXXX37H	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
10/28/2009	XX	BTXXXX3AJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
4/26/2010	XX	BTXXXX40A	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
4/27/2010	XX	BTXXXX40B	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
4/28/2010	XX	BTXXXXHG1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
7/20/2010	XX	BTXXXX43F	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
10/19/2010	XX	BTXXXX46I	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
4/25/2011	XX	BTXXXX4AJ	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
4/26/2011	XX	BTXXXX4B0	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
4/27/2011	XX	BTXXXX4B5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
7/19/2011	XX	BTXXXX4F3	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
10/26/2011	XX	BTXXXX4G8	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
4/23/2012	XX	BTXXXX532	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
4/24/2012	XX	BTXXXX533	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
4/25/2012	XX	BTXXXX538	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
7/24/2012	XX	BTXXXX585	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
10/23/2012	XX	BTXXXX5C8	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
4/22/2013	XX	BTXXXX5J3	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
4/23/2013	XX	BTXXXX5J4	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
4/24/2013	XX	BTXXXX5J8	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
7/30/2013	XX	BTXXXX65D	0.5 U	0.5 U	1 U	1 U	1 U	2.5 U	0.5 U	2.5 U	5 U	2 U	0.5 U	5 U	2.5 U	2.5 U	2.5 U
10/29/2013	XX	BTXXXX68C	2 U	1 U	1 U	1 U	1 U	5 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	1 U	1 U
4/21/2014	XX	BTXXXX6G4	2 U	1 U	1 U	1 U	1 U	5 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	1 U	1 U
4/22/2014	XX	BTXXXX6G5	2 U	1 U	1 U	1 U	1 U	5 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	1 U	1 U
7/30/2014	XX	BTXXXX70B	2 U	1 U	1 U	1 U	1 U	5 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	1 U	1 U
10/21/2014	XX	BTXXXX748	2 U	1 U	1 U	1 U	1 U	5 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	1 U	1 U
4/27/2015	XX	BTXXXX79E	2 U	1 U	1 U	1 U	1 U	5 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	1 U	1 U
4/27/2015	XX	BTXXXX79F	2 U	1 U	1 U	1 U	1 U	5 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	1 U	1 U
4/27/2015	XX	BTXXXX79J	2 U	1 U	1 U	1 U	1 U	5 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	1 U	1 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

J - Analyte was positively identified/Associated value is an estimate below reporting limit.

U - Not Detected above the reported sample detection limit.

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	Acrylonitrile ug/L	trans-1,4-Dichloro-2-butene ug/L	Iodomethane ug/L
LT-C4L					
4/15/2009	XX	LTC4LX325	50 U	50 U	50 U
7/7/2009	XX	LTC4LX369	25 U	25 U	25 U
10/28/2009	XX	LTC4LX3E4	10 U	10 U	10 U
4/28/2010	XX	LTC4LX3J3	2.5 U	2.5 U	2.5 U
7/20/2010	XX	LTC4LX427	2.5 U	2.5 U	2.5 U
10/19/2010	XX	LTC4LX45B	0.5 U	0.5 U	0.5 U
4/27/2011	XX	LTC4LX49C	5 U	5 U	5 U
7/19/2011	XX	LTC4LX4DA	0.5 U	0.5 U	0.5 U
10/26/2011	XX	LTC4LX4H5	0.5 U	0.5 U	0.5 U
4/24/2012	XX	LTC4LX51F	5 U	5 U	5 U
7/24/2012	XX	LTC4LX56E	5 U	5 U	35
10/23/2012	XX	LTC4LX5D5	25 U	25 U	25 U
4/23/2013	XX	LTC4LX5HG	25 U	25 U	25 U
LT-C4LR					
7/30/2013	XX	LTC4LX641	500 U	250 U	500 U
10/29/2013	XX	LTC4LX66E	4000 U	1000 U	1000 U
4/22/2014	XX	LTC4LX6EH	400 U	100 U	100 U
7/30/2014	XX	LTC4LX6J4	20 U	5 U	5 U
10/21/2014	XX	LTC4LX72F	200 U	50 U	50 U
4/28/2015	XX	LTC4LX78C	200 U	50 U	50 U
QCBT					
5/4/2004	XX	BTXXXX00H	2 U	2 U	2 U
6/9/2004	XX	BTXXXX035	2 U	2 U	2 U
7/26/2004	XX	BTXXXX046	2 U	2 U	2 U
10/27/2004	XX	BTXXXX060	2 U	2 U	2 U
1/17/2005	XX	BTXXXX111	2 U	2 U	2 U
3/9/2005	XX	BTXXXX11E	2 U	2 U	2 U
3/21/2005	XX	BTXXXX142	2 U	2 U	2 U
5/11/2005	XX	BTXXXX121	2 U	2 U	2 U
7/25/2005	XX	BTXXXX17G	2 U	2 U	2 U
7/27/2005	XX	BTXXXX187	2 U	2 U	2 U
9/20/2005	XX	BTXXXX1A7	2 U	2 U	2 U
9/21/2005	XX	BTXXXX1AI	2 U	2 U	2 U
9/22/2005	XX	BTXXXX1AJ	2 U	2 U	2 U
4/19/2006	XX	BTXXXX1FE	2 U	2 U	2 U
5/22/2006	XX	BTXXXX1F2	2 U	2 U	2 U
5/23/2006	XX	BTXXXX1FD	2 U	2 U	2 U
5/24/2006	XX	BTXXXX1ID	2 U	2 U	2 U
7/25/2006	XX	BTXXXX1HJ	2 U	2 U	2 U
9/13/2006	XX	BTXXXX20C	2 U	2 U	2 U
5/14/2007	XX	BTXXXX23J	2 U	2 U	2 U
5/15/2007	XX	BTXXXX244	2 U	2 U	2 U
5/16/2007	XX	BTXXXX245	2 U	2 U	2 U
7/24/2007	XX	BTXXXX283	2 U	2 U	2 U
9/11/2007	XX	BTXXXX2AD	2 U	2 U	2 U
5/19/2008	XX	BTXXXX2EC	2 U	2 U	2 U
5/21/2008	XX	BTXXXX2ED	2 U	2 U	2 U

SUMMARY REPORT

Leachate - VOAs Part 4 of 4

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(QCBT)

Date	Type	Sample ID	Acrylonitrile ug/L	trans-1,4-Dichloro-2-butene ug/L	Iodomethane ug/L
7/29/2008	XX	BTXXXX2HB	2 U	2 U	2 U
10/29/2008	XX	BTXXXX301	1 U	1 U	1 U
4/13/2009	XX	BTXXXX33D	1 U	1 U	1 U
4/15/2009	XX	BTXXXX33E	1 U	1 U	1 U
7/7/2009	XX	BTXXXX37H	1 U	1 U	1 U
10/28/2009	XX	BTXXXX3AJ	1 U	1 U	1 U
4/26/2010	XX	BTXXXX40A	0.5 U	0.5 U	0.5 U
4/27/2010	XX	BTXXXX40B	0.5 U	0.5 U	0.5 U
4/28/2010	XX	BTXXXXHG1	0.5 U	0.5 U	0.5 U
7/20/2010	XX	BTXXXX43F	0.5 U	0.5 U	0.5 U
10/19/2010	XX	BTXXXX46I	0.5 U	0.5 U	0.5 U
4/25/2011	XX	BTXXXX4AJ	0.5 U	0.5 U	0.5 U
4/26/2011	XX	BTXXXX4B0	0.5 U	0.5 U	0.5 U
4/27/2011	XX	BTXXXX4B5	0.5 U	0.5 U	0.5 U
7/19/2011	XX	BTXXXX4F3	0.5 U	0.5 U	0.5 U
10/26/2011	XX	BTXXXX4G8	0.5 U	0.5 U	0.5 U
4/23/2012	XX	BTXXXX532	1 U	1 U	1 U
4/24/2012	XX	BTXXXX533	1 U	1 U	1 U
4/25/2012	XX	BTXXXX538	1 U	1 U	1 U
7/24/2012	XX	BTXXXX585	1 U	1 U	1.5
10/23/2012	XX	BTXXXX5C8	1 U	1 U	1 U
4/22/2013	XX	BTXXXX5J3	1 U	1 U	1 U
4/23/2013	XX	BTXXXX5J4	1 U	1 U	1 U
4/24/2013	XX	BTXXXX5J8	1 U	1 U	1 U
7/30/2013	XX	BTXXXX65D	5 U	2.5 U	5 U
10/29/2013	XX	BTXXXX68C	20 U	5 U	5 U
4/21/2014	XX	BTXXXX6G4	20 U	5 U	5 U
4/22/2014	XX	BTXXXX6G5	20 U	5 U	5 U
7/30/2014	XX	BTXXXX70B	20 U	5 U	5 U
10/21/2014	XX	BTXXXX748	20 U	5 U	5 U
4/27/2015	XX	BTXXXX79E	20 U	5 U	5 U
4/27/2015	XX	BTXXXX79F	20 U	5 U	5 U
4/27/2015	XX	BTXXXX79J	20 U	5 U	5 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

U - Not Detected above the reported sample detection limit.

SUMMARY REPORT

Pesticides, Herbicides and PCB's Part 1 of 2

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	alpha-BHC ug/L	beta-BHC ug/L	delta-BHC ug/L	gamma-BHC (Lindane) ug/L	Heptachlor ug/L	Aldrin ug/L	Heptachlor Epoxide ug/L	Endosulfan I ug/L	Dieldrin ug/L	4,4'-DDE ug/L	Endrin ug/L	Endosulfan II ug/L	4,4'-DDD ug/L	Endosulfan Sulfate ug/L	4,4'-DDT ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	0.047 U	0.047 U	0.047 U	0.055	0.047 U	0.047 U	0.047 U	0.047 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U
4/28/2010	XX	LTC4LX3J3	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U
4/27/2011	XX	LTC4LX49C	0.0065 U	0.0059 U	0.012 U	0.0068 U	0.0075 U	0.007 U	0.43	0.006 U	0.0061 U	0.0046 U	0.0079 U	0.0054 U	0.0085 U	0.0063 U	0.0084 U
4/24/2012	XX	LTC4LX51F	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U
4/23/2013	XX	LTC4LX5HG	0.048 U	0.048 U	0.048 U	0.048 U	0.048 U	0.048 U	0.048 U	0.048 U	0.097 U	0.097 U	0.097 U	0.097 U	0.097 U	0.097 U	0.097 U
LT-C4LR																	
4/22/2014	XX	LTC4LX6EH	0.048 U	0.048 U	0.048 U	0.048 U	0.048 U	0.048 U	0.048 U	0.048 U	0.095 U	0.095 U	0.095 U	0.095 U	0.095 U	0.095 U	0.095 U
4/28/2015	XX	LTC4LX78C	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U	0.094 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

U - Not Detected above the reported sample detection limit.

SUMMARY REPORT

Pesticides, Herbicides and PCB's Part 2 of 2

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L) Date	Type	Sample ID	Methoxychlor ug/L	Toxaphene ug/L	Aroclor-1016 ug/L	Aroclor-1221 ug/L	Aroclor-1232 ug/L	Aroclor-1242 ug/L	Aroclor-1248 ug/L	Aroclor-1254 ug/L	Aroclor-1260 ug/L	Endrin Aldehyde ug/L	Chlordane (technical) ug/L	2,4-Dichlorophenoxyacetic Acid ug/L	2,4,5-Trichlorophenoxypropionic Acid ug/L	2,4,5,-T ug/L	2-sec-Butyl-4-6-dinitrophenol (Dinoseb) ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	0.47 U	0.94 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.094 U	0.47 U	14 U	14 U	14 U	24 U
4/28/2010	XX	LTC4LX3J3	0.47 U	0.94 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.094 U	0.47 U	2.8 U	2.8 U	2.8 U	4.7 U
4/27/2011	XX	LTC4LX49C	0.0079 U	0.16 U	0.14 U	0.19 U	0.085 U	0.17 U	0.19 U	0.075 U	0.16 U	0.0058 U		0.28 U	0.19 U	0.5 U	0.21 U
4/24/2012	XX	LTC4LX51F	0.47 U	0.94 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.094 U	0.47 U	2.8 U	2.8 U	2.8 U	4.8 U
4/23/2013	XX	LTC4LX5HG	0.48 U	0.97 U	0.48 U	0.48 U	0.48 U	0.48 U	0.48 U	0.48 U	0.48 U	0.097 U	0.48 U	2.9 U	2.9 U	2.9 U	4.8 U
LT-C4LR																	
4/22/2014	XX	LTC4LX6EH	0.48 U	0.95 U	0.48 U	0.48 U	0.48 U	0.48 U	0.48 U	0.48 U	0.48 U	0.095 U	0.48 U	3.1 U	3.1 U	3.1 U	5.2 U
4/28/2015	XX	LTC4LX78C	0.47 U	0.94 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.47 U	0.094 U	0.47 U	2.8 U	2.8 U	2.8 U	4.7 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

U - Not Detected above the reported sample detection limit.

REPORT PREPARED: 6/17/2015 12:58 FOR: Juniper Ridge Landfill	SUMMARY REPORT Semi-VOA - ALL Part 1 of 7	Page 1 of 1 SEVEE & MAHER ENGINEERS, INC. 4 BLANCHARD ROAD CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	Phenol ug/L	Bis(2-Chloroethyl)ether ug/L	2-Chlorophenol ug/L	1,3-Dichlorobenzene (SVOC) ug/L	1,4-Dichlorobenzene (SVOC) ug/L	Benzyl Alcohol ug/L	1,2-Dichlorobenzene (SVOC) ug/L	2-Methylphenol ug/L	Bis(2-Chloroisopropyl)ether ug/L	N-Nitroso-di-n-propylamine ug/L	Hexachloroethane ug/L	Nitrobenzene ug/L	Isophorone ug/L	2-Nitrophenol ug/L	2,4-Dimethylphenol ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	410 E	28 U	28 U	28 U	28 U	57 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U
4/28/2010	XX	LTC4LX3J3	70	9 U	9 U	9 U		19 U		9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U
4/27/2011	XX	LTC4LX49C	13	2 U	3 U	2 U	2 U		2 U	10	2 U	2 U	2 U	3 U	2 U	2 U	4 U
4/24/2012	XX	LTC4LX51F	9.5 U	9.5 U	9.5 U	9.5 U		19 U		9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U
4/23/2013	XX	LTC4LX5HG	140	110 U	110 U	110 U		230 U		110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U
LT-C4LR																	
4/22/2014	XX	LTC4LX6EH	160	9.6 U	9.6 U	9.6 U		19 U		12	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U
4/28/2015	XX	LTC4LX78C	110	47 U	47 U	47 U	47 U	94 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

E - Compound exceeded upper level of calibration range and required dilution.

U - Not Detected above the reported sample detection limit.

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L) Date	Type	Sample ID	Bis(2-Chloroethoxy)methane ug/L	2,4-Dichlorophenol ug/L	1,2,4-Trichlorobenzene (SVOC) ug/L	Naphthalene (SVOC) ug/L	4-Chloroaniline ug/L	Hexachlorobutadiene (SVOC) ug/L	4-Chloro-3-Methylphenol ug/L	2-Methylnaphthalene ug/L	Hexachlorocyclopentadiene ug/L	2,4,6-Trichlorophenol ug/L	2,4,5-Trichlorophenol ug/L	2-Chloronaphthalene ug/L	2-Nitroaniline ug/L	Dimethylpthalate ug/L	Acenaphthylene ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	28 U	28 U	28 U	300	28 U	28 U	28 U	28 U	28 U	28 U	71 U	28 U	71 U	28 U	28 U
4/28/2010	XX	LTC4LX3J3	9 U	9 U	9 U	10	9 U	9 U	9 U	9 U	9 U	9 U	24 U	9 U	24 U	9 U	9 U
4/27/2011	XX	LTC4LX49C	2 U	3 U	2 U	6 J	2 U	2 U	4 J	3 U	1 U	3 U	3 U	3 U	2 U	2 U	1 U
4/24/2012	XX	LTC4LX51F	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	24 U	9.5 U	24 U	9.5 U	9.5 U
4/23/2013	XX	LTC4LX5HG	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	280 U	110 U	280 U	110 U	110 U
LT-C4LR																	
4/22/2014	XX	LTC4LX6EH	9.6 U	9.6 U	9.6 U	12	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	24 U	9.6 U	24 U	9.6 U	9.6 U
4/28/2015	XX	LTC4LX78C	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	120 U	47 U	120 U	47 U	47 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

J - Analyte was positively identified/Associated value is an estimate below reporting limit.

U - Not Detected above the reported sample detection limit.

SUMMARY REPORT

Semi-VOA - ALL Part 3 of 7

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L) Date	Type	Sample ID	2,6-Dinitrotoluene ug/L	3-Nitroaniline ug/L	Acenaphthene ug/L	2,4-Dinitrophenol ug/L	4-Nitrophenol ug/L	Dibenzofuran ug/L	2,4-Dinitrotoluene ug/L	Diethylphthalate ug/L	4-Chlorophenyl-phenylether ug/L	Fluorene ug/L	4-Nitroaniline ug/L	4,6-Dinitro-2-methylphenol ug/L	N-Nitrosodiphenylamine ug/L	4-Bromophenyl-phenylether ug/L	Hexachlorobenzene ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	28 U	71 U	28 U	71 U	71 U	28 U	28 U	28 U	28 U	28 U	71 U	71 U	28 U	28 U	28 U
4/28/2010	XX	LTC4LX3J3	9 U	24 U	9 U	24 U	24 U	9 U	9 U	9 U	9 U	9 U	24 U	24 U	9 U	9 U	9 U
4/27/2011	XX	LTC4LX49C	2 U	1 U	2 J	1 U	2 U	2 U	2 U	2 J	2 U	2 U	2 U	2 U	4 U	2 U	2 U
4/24/2012	XX	LTC4LX51F	9.5 U	24 U	9.5 U	24 U	24 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	24 U	24 U	9.5 U	9.5 U	9.5 U
4/23/2013	XX	LTC4LX5HG	110 U	280 U	110 U	280 U	280 U	110 U	110 U	110 U	110 U	110 U	280 U	280 U	110 U	110 U	110 U
LT-C4LR																	
4/22/2014	XX	LTC4LX6EH	9.6 U	24 U	9.6 U	24 U	24 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	24 U	24 U	9.6 U	9.6 U	9.6 U
4/28/2015	XX	LTC4LX78C	47 U	120 U	47 U	120 U	120 U	47 U	47 U	47 U	47 U	47 U	120 U	120 U	47 U	47 U	47 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

J - Analyte was positively identified/Associated value is an estimate below reporting limit.

U - Not Detected above the reported sample detection limit.

REPORT PREPARED: 6/17/2015 12:58

FOR: Juniper Ridge Landfill

SUMMARY REPORT

Semi-VOA - ALL Part 4 of 7

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	Pentachlorophenol ug/L	Phenanthrene ug/L	Anthracene ug/L	Di-n-butylphthalate ug/L	Fluoranthene ug/L	Pyrene ug/L	Butylbenzylphthalate ug/L	3,3-Dichlorobenzidine ug/L	Benzo(a)Anthracene ug/L	Chrysene ug/L	Bis(2-Ethylhexyl)phthalate ug/L	Di-n-octylphthalate ug/L	Benzo(b)Fluoranthene ug/L	Benzo(k)Fluoranthene ug/L	Benzo(a)Pyrene ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	71 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U
4/28/2010	XX	LTC4LX3J3	24 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U
4/27/2011	XX	LTC4LX49C	2 U	2 U	2 U	2 U	2 U	2 U	2 U	1 U	1 U	2 U	2 U	2 U	1 U	2 U	1 U
4/24/2012	XX	LTC4LX51F	24 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U
4/23/2013	XX	LTC4LX5HG	280 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U
LT-C4LR																	
4/22/2014	XX	LTC4LX6EH	24 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U
4/28/2015	XX	LTC4LX78C	120 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

U - Not Detected above the reported sample detection limit.

REPORT PREPARED: 6/17/2015 12:58

FOR: Juniper Ridge Landfill

SUMMARY REPORT

Semi-VOA - ALL Part 5 of 7

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L) Date	Type	Sample ID	Indeno(1,2,3-c,d)Pyrene ug/L	Dibenz(a,h)Anthracene ug/L	Benzo(g,h,i)perylene ug/L	N-Nitrosodimethylamine ug/L	2,3,4,6-Tetrachlorophenol ug/L	2,6-Dichlorophenol ug/L	3&4-Methylphenol ug/L	2-Acetylaminofluorene ug/L	4-Aminobiphenyl ug/L	2-sec-Butyl-4-6-dinitrophenol (Dinoseb) ug/L	1,3-Dinitrobenzene (m-Dinitrobenzene) ug/L	Ethyl methanesulfonate ug/L	Hexachloropropene ug/L	Isosafrole ug/L	Methapyrilene ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	28 U	28 U	28 U	57 U	28 U	28 U	2800	28 U	28 U	24 U	28 U	28 U	28 U	57 U	71 U
4/28/2010	XX	LTC4LX3J3	9 U	9 U	9 U	9 U	9 U	9 U	450	9 U	9 U	4.7 U	9 U	9 U	9 U	9 U	9 U
4/27/2011	XX	LTC4LX49C	2 U	2 U	1 U				23			0.21 U					
4/24/2012	XX	LTC4LX51F	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	4.8 U	9.5 U	9.5 U	9.5 U	9.5 U	24 U
4/23/2013	XX	LTC4LX5HG	110 U	110 U	110 U	110 U	110 U	110 U	1000	110 U	110 U	4.8 U	110 U	110 U	110 U	110 U	280 U
LT-C4LR																	
4/22/2014	XX	LTC4LX6EH	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	690	9.6 U	9.6 U	5.2 U	9.6 U	9.6 U	9.6 U	9.6 U	24 U
4/28/2015	XX	LTC4LX78C	47 U	47 U	47 U	47 U	47 U	47 U	890	47 U	47 U	4.7 U	47 U	47 U	47 U	47 U	120 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

U - Not Detected above the reported sample detection limit.

REPORT PREPARED: 6/17/2015 12:58

FOR: Juniper Ridge Landfill

SUMMARY REPORT

Semi-VOA - ALL Part 6 of 7

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	3-Methylcholanthrene ug/L	Methyl methanesulfonate ug/L	1-Naphthaleneamine (1-Naphthylamine) ug/L	2-Naphthaleneamine (2-Naphthylamine) ug/L	1,4-Naphthoquinone ug/L	5-Nitro-o-toluidine ug/L	N-Nitrosodiethylamine ug/L	N-Nitrosodi-n-butylamine ug/L	N-Nitrosomethylethylamine ug/L	N-Nitrosopiperidine ug/L	N-Nitrosopyrrolidine ug/L	Pentachlorobenzene ug/L	Pentachloronitrobenzene ug/L	Phenacetin ug/L	p-Phenylenediamine ug/L
LT-C4L																	
4/15/2009	XX	LTC4LX325	28 U	57 U	28 U	28 U	28 U	57 U	57 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U	28 U
4/28/2010	XX	LTC4LX3J3	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U	9 U
4/24/2012	XX	LTC4LX51F	9.5 U	9.5 U	9.5 U	9.5 U	24 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	9.5 U	24 U
4/23/2013	XX	LTC4LX5HG	110 U	110 U	110 U	110 U	280 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	110 U	280 U
LT-C4LR																	
4/22/2014	XX	LTC4LX6EH	9.6 U	9.6 U	9.6 U	9.6 U	24 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U	24 U
4/28/2015	XX	LTC4LX78C	47 U	47 U	47 U	47 U	120 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	47 U	120 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

U - Not Detected above the reported sample detection limit.

REPORT PREPARED: 6/17/2015 12:58

FOR: Juniper Ridge Landfill

SUMMARY REPORT

Semi-VOA - ALL Part 7 of 7

SEVEE & MAHER ENGINEERS, INC.
4 BLANCHARD ROAD
CUMBERLAND CENTER, ME 04021

(LT-C4L)

Date	Type	Sample ID	Pronamide ug/L	1,2,4,5-Tetrachlorobenzene ug/L	1,3,5-Trinitrobenzene (sym-Trinitrobenzene) ug/L	Safrole ug/L	O-Toluidine ug/L	p-(Dimethylamino)azobenzene ug/L	7,12-Dimethylbenz(a)anthracene ug/L	Acetophenone ug/L
LT-C4L										
4/15/2009	XX	LTC4LX325	28 U	28 U	28 U	28 U	28 U	57 U	28 U	28 U
4/28/2010	XX	LTC4LX3J3	9 U	9 U	9 U	9 U	24 U	9 U	9 U	9 U
4/24/2012	XX	LTC4LX51F	9.5 U	9.5 U	9.5 U	9.5 U	24 U	9.5 U	9.5 U	9.5 U
4/23/2013	XX	LTC4LX5HG	110 U	110 U	110 U	110 U	280 U	110 U	110 U	110 U
LT-C4LR										
4/22/2014	XX	LTC4LX6EH	9.6 U	9.6 U	9.6 U	9.6 U	24 U	9.6 U	9.6 U	11
4/28/2015	XX	LTC4LX78C	47 U	47 U	47 U	47 U	120 U	47 U	47 U	47 U

Notes: TYPE - Sample Type Qualifier where D = Duplicate Sample.

Blank Cells appear when a parameter was not analyzed.

Concentration Qualifier Notes:

U - Not Detected above the reported sample detection limit.

APPENDIX H

WASTE COMPATIBILITY TEST RESULTS

A Final Report:

Laboratory Testing of HDPE Geomembrane for Waste Containment EPA Method 9090A

August 1998

Submitted to:
Solmax International
2801 Marie-Victorin
Varennes, Quebec
Canada J3X 1P7

Attn: **Mr. Stephan Henes**

Submitted by:

TRI/Environmental, Inc.
9063 Bee Caves Rd.
Austin, Texas 78733

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

August 17, 1998

Mr. Stephan Henes
Solmax International
2801 Marie-Victorin
Varennes, Quebec
Canada J3X 1P7

Dear Mr. Henes:

TRI/Environmental, Inc. (TRI) is pleased to present this Final Report for a HDPE geomembrane chemical compatibility study via EPA Method 9090A.

TRI thanks Solmax International for the opportunity to participate in this project. Please call me if you have any questions or require any additional information.

Respectfully submitted,

Sam R. Allen (09-04-99)

Sam R. Allen
Vice President and Division Manager
Geosynthetics Services

FOREWORD

The testing reported herein is based upon accepted industry practice as well as the test method listed. TRI/Environmental Inc. (TRI) neither accepts responsibility for nor makes claim as to the final use and purpose of the materials tested.

Tests were performed under laboratory conditions and not under actual usage conditions. TRI can give no conclusions as to the serviceability, life expectancy or general durability of the products tested when used in a lining and/or leachate collection system.

1.0 INTRODUCTION

This report describes the work performed by TRI/Environmental, Inc. (TRI) to determine the chemical compatibility of a single liner product with one waste leachate. The product selected for testing was a high density polyethylene (HDPE) geomembrane. The objective was to determine the resistance of the geomembrane to changes caused by exposure to leachate. Changes in physical and mechanical properties were measured after exposure to the leachate at 23°C and 50°C for 30, 60, 90 and 120 days following the exposure regime specified in United States Environmental Protection Agency (EPA) Method 9090A.

Methods, results and discussion are provided in the sections which follow. Test results are provided in the Tables of Results which accompany this report.

2.0 METHODS

2.1 Materials

The material received for this study was received and tested under TRI Log number E2068-94-05. Table 1 describes the product selected for evaluation in this chemical compatibility study.

Table 1. List of geomembranes evaluated in chemical compatibility study

Geosynthetic	Source
60 mil textured HDPE geomembrane, roll #5208	Solmax

2.2 Leachate

The waste leachate used was stock municipal waste leachate maintained at TRI laboratories in Austin. The leachate was characterized as follows.

Table 2. Characterization of leachate used in chemical compatibility study

Parameter (units)	Level
Biological oxygen demand (mg/L)	2,130
Chemical Oxygen Demand (mg/L)	6,180
Conductivity (umhos/cm)	41,700
N-Ammonia (mg/L)	3,000
pH (units)	8.6

Table 2. Characterization of leachate used in chemical compatibility study	
Parameter (units)	**Level**
Volatile Acids (mg/L)	10,000

2.3 Exposure Conditions

Geomembrane coupons were exposed to the waste leachate following the specifications of EPA Method 9090A as they relate to exposure to waste fluids. The tanks used for these exposures were maintained at 23 ±2°C and 50 ± 2°C throughout the 120-day exposure period. Tanks were constructed from glass, fitted with stirrers and heated with a circulating hot water heat exchanger system. The 50°C tanks were sealed with a lid, and a reflux condenser was installed to minimize loss of volatile leachate components.

2.4 Testing Procedures

The following table lists tests performed on the HDPE geomembrane product. The number of test replicates was doubled for baseline determinations on unexposed material.

Table 3. Tests performed on HDPE geomembrane

Test or Physical Property	Method	Number of replicate specimens
Dimensions and weight	EPA 9090A	3
Hardness	ASTM D 2240 D scale	5
Volatiles and Extractables	EPA SW 870, Appendix III	2
Specific Gravity	ASTM D 792	2
Tensile Properties	ASTM D 638	5
Modulus of Elasticity	ASTM D 882	5
Hydrostatic Resistance	ASTM D 751 Method A	5
Tear Strength	ASTM D 1004	5
Puncture Resistance	FTMS 101C Method 2065	2

Note that tensile properties were determined in accordance with ASTM D638 procedures as modified by National Sanitation Foundation (NSF) Standard 54 - 93, which gives specific methods for testing HDPE geomembranes. The tensile tests were performed on a screw-type tensile testing machine. The Type IV die was used. Load measurement were made by a strain-gage bridge load cell with calibration certified by an outside standards service. Elongation was determined by crosshead movement as recorded by Series IX Instron data acquisition software. The rate of grip separation was 2 inches per minute. Gauge length ratios of 1.3 inches for yield values, and 2.5 inches for break values were used to calculate elongation from grip movement. The parameters reported for ASTM D638 testing included: tensile stress at yield, tensile strength at break, elongation at yield and elongation at break.

3.0 RESULTS AND DISCUSSION

Test results are presented in the Tables of Test Results (raw data) and graphical presentations are presented in Appendix A.

In considering these results, it must be determined through engineering judgment whether observed differences in the value of test results measured before and after immersion are due to product variability, unidentified factors relating to the test procedure, or leachate interaction with the products. Any significant chemical interaction with leachate would be expected to result in degradation trends which are consistent across the various properties being evaluated, and not isolated to one set of test results only. However, with each type of material there may be specific properties which are highly sensitive to leachate-induced effects. These factors must be considered in evaluating the various test results for a given product.

Also of critical importance is the issue of product variability. With geomembranes, a range of physical and mechanical index test values covering 15% or more of the average is not uncommon. This can be traced to variability inherent in the product, and the randomness associated with the onset of failure under the specified testing conditions. However, in chemical compatibility testing the statistical sampling of a broad range of manufactured product is not possible. Therefore, the small size of the sample population tested at each time point must be taken into consideration. The criteria to be applied in evaluating data measured before and after leachate immersion should be that property changes, if observed, are consistent and so great that product variability and experimental factors can be ruled out.

In this report, standard deviations (STD) are reported for most measurements involving three or more replicate specimens. In statistics, the standard deviation is defined as root of the mean squared deviations of individual test results about the mean value. The standard deviation is a quantitative measure of variability within a group of measurements.

One related measure of variability observed within a sample set, relative to the magnitude of the mean value itself, is the *coefficient of variation or variance* (COV). The coefficient of variance is defined as the standard deviation divided by the mean associated with a group of specimens, and may be expressed as a percentage. The COV provides an indication of what proportion of the mean value may be attributable to random experimental factors or product variability. It is useful to consider apparent changes in property values against the criterion of COV since observed changes which fall below the COV may not be significant. This approach was used in preparing the tables below.

The term *range* refers to the difference between the extreme highest and lowest points within a group of measured values. Considering range as a percentage of the mean values provides another measure of variability within a dataset.

In the table below, the high and low extremes for percentage change in mean values are listed for comparison against COV and range as a percentage of mean from the baseline sample group. The high and low percentage changes are the extremes from data measured at 30, 60, 90 and 120 days.

Table 4. Baseline COV and Range of Percent Change Results

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Stress at yield (MD)	4	10	+7	-3
Stress at break (MD)	13	41	+10	-23
Elongation at yield (MD)	4	12	+9	-5
Elongation at break (MD)	11	36	+4	-13
Modulus (MD)	9	24	+14	-12
Tear strength (MD)	4	10	+7	-8
Puncture Resistance	1	4	+8	-3
Hydrostatic resistance	1	3	0	-1

4.0 CONCLUSION

While changes in certain measured mechanical properties were noted, they were not observed to be consistent throughout the exposure period. The effects of product variability and experimental factors could not be ruled out as causes for observed changes. The data, considered together, do not support the conclusion that observed changes were caused by the test exposures.

TRI/Environmental, Inc. is pleased to have been selected to participate in this project. We trust that the information provided in this report meets your requirements for technical documentation of this chemical compatibility study. Please do not hesitate to call if we can provide any further information (1-800-880-8378).

Respectfully submitted,

Sam R. Allen (09.04.98)

Sam R. Allen
Vice President and Division Manager
Geosynthetics Services

EPA METHOD 9090A TEST RESULTS

TRI LOG #: E2068-94-05

GEOSYNTHETIC DIMENSIONS - HDPE

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

Report Date: August 17, 1998

Exposure Time and Temperature

Test Parameters	Temp.	30 Day Baseline	30 Day Exposed	30 Day % Change	60 Day Baseline	60 Day Exposed	60 Day % Change	90 Day Baseline	90 Day Exposed	90 Day % Change	120 Day Baseline	120 Day Exposed	120 Day % Change
GEOMEMBRANE: SOLMAX 60 mil TEXTURED HDPE - ROLL # 5208													
Thickness (mils)	23C	68	67	-1.5	65	65	0.0	62	62	0.0	63	63	0.0
	50C	65	65	0.0	67	67	0.0	63	64	1.6	64	64	0.0
Length (inches)	23C	9.97	9.99	0.2	9.98	9.99	0.1	9.96	9.98	0.2	10.00	10.01	0.1
	50C	9.98	10.00	0.2	9.98	9.98	0.0	10.00	10.00	0.0	10.00	9.99	-0.1
Width (inches)	23C	7.97	7.98	0.1	7.96	7.97	0.1	8.00	7.99	-0.1	8.00	8.00	0.0
	50C	8.00	8.00	0.0	7.95	7.96	0.1	8.00	8.00	0.0	8.00	7.98	-0.2
Mass (g)	23C	83.70	83.72	0.0	84.82	84.87	0.1	85.42	85.99	0.7	84.88	84.55	-0.4
	50C	88.76	88.81	0.1	89.56	89.77	0.2	88.66	89.35	0.8	87.01	86.65	-0.4

SRL 09.04.99
Quality Review/Date

Client: SOLMAX, File: 609-dim.wb1

EPA METHOD 9090A TEST RESULTS

TRI LOG #: E2068-94-05

60 MIL TEXTURED HDPE GEOMEMBRANE

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

Report Date: August 17, 1998

Exposure Time and Temperature

Test Parameters	30 Day Baseline	30 Day 23C	30 Day 50C	60 Day Baseline	60 Day 23C	60 Day 50C	90 Day Baseline	90 Day 23C	90 Day 50C	120 Day Baseline	120 Day 23C	120 Day 50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED HDPE - ROLL # 5208												
Tensile Properties:	2648	2649	2803	2643	2766	2776	2489	2906	2647	2703	2623	2691
Tensile Stress @ Yield (psi)	2525	2620	2738	2893	2601	2659	2547	2386	2776	2628	2780	2924
ASTM D638	2448	2429	2629	2732	2655	2996	2631	2711	2651	2642	2618	2905
Machine Direction	2716			2780			2650			2656		
	2514			2711			2646			2670		
	2505			2788			2511			2635		
Average	2559	2566	2723	2758	2674	2810	2579	2668	2591	2656	2674	2840
STD	92	98	72	77	69	140	66	214	60	25	75	106
Coefficient of Variation	4	4	3	3	3	5	3	8	2	1	3	4
% Change		0	6		-3	2		3	4		1	7
Tensile Properties:	3429	3999	2859	4007	4016	3392	3952	3719	3427	3471	4307	3131
Tensile Strength @ Break (psi)	4207	3772	3437	4300	3807	1930	3739	3950	3946	4311	4267	4381
ASTM D638	2757	2589	3971	3778	2782	3786	2690	2201	3971	3933	4048	3329
Machine Direction	3917			3662			4110			3597		
	3308			3919			3798			3459		
	3547						3507			4159		
Average	3528	3453	3422	3933	3535	3036	3633	3290	3781	3822	4207	3614
STD	459	618	454	218	539	798	461	776	251	334	114	549
Coefficient of Variation	13	18	13	6	15	26	13	24	7	9	3	15
% Change		-2	-3		-10	-23		-9	4		10	-5
Tensile Properties:	16	18	17	15	16	17	14	14	16	15	13	15
Elongation @ Yield (%)	18	16	18	15	15	16	14	14	15	14	15	15
ASTM D638	17	21	16	14	16	16	15	14	15	13	12	13
Machine Direction	18			17			16			14		
	17			16			14			14		
	18			13			15			14		
Average	17	18	17	15	16	16	15	14	15	14	13	14
STD	1	2	1	1	0	0	1	0	0	1	1	1
Coefficient of Variation	4	11	5	9	3	3	5	0	3	4	9	7
% Change		6	-2		4	9		-5	5		-5	2

SRA 09.04.98
Quality Review/Date

Client: SOLMAX, File: 945-solm .WB1

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

Report Date: August 17, 1998

Exposure Time and Temperature

Test Parameters		30 Day			60 Day			90 Day			120 Day	
	Baseline	23C	50C	Baseline	23C	50C	Baseline	23C	50C	Baseline	23C	50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED HDPE - ROLL # 5208												
Tensile Properties:	605	726	474	686	660	584	699	574	605	668	714	529
Elongation @ Break (%)	745	667	583	691	684	559	648	717	655	717	679	694
ASTM D638	513	471	706	639	613	622	470	546	676	647	672	617
Machine Direction	689			691			682			621		
	609			657			628			633		
	658			712			640			692		
Average	637	621	588	679	652	588	628	612	645	663	688	613
STD	73	109	95	24	29	26	75	75	30	33	18	67
Coefficient of Variation	11	18	16	4	5	4	12	12	5	5	3	11
% Change		-2	-8		-4	-13		-2	3		4	-7
Tensile Properties:	589	555	450	640	600	570	640	540	530	630	620	500
Set after Break (%)	661	610	550	650	620	500	630	610	630	670	620	630
ASTM D638	422	490	700	580	560	620	480	590	650	590	650	590
Machine Direction	632			640			620			620		
	596			620			600			630		
	630			640			660			660		
Average	588	552	567	628	593	563	605	580	603	633	630	573
STD	78	49	103	23	25	49	59	29	52	26	14	54
Coefficient of Variation	13	9	18	4	4	9	10	5	9	4	2	9
% Change		-6	-4		-6	-10		-4	-0		-1	-9
Tensile Properties:	1975	1979	2171	2059	2160	2192	2030	2319	2105	2138	2113	2084
Tensile Stress @ 100% Elongation (psi)	2005	2116	2191	2103	2017	2006	2049	1919	2137	2118	2198	2301
ASTM D638	1968	1865	2154	2218	2126	2200	2152	2068	2079	2107	1979	2258
Machine Direction	2069			2321			2095			2147		
	1911			2100			2186			2179		
	1923			2461			1942			2032		
Average	1975	1987	2172	2210	2101	2133	2076	2102	2107	2120	2097	2214
STD	53	103	15	142	61	90	81	165	24	46	90	94
Coefficient of Variation	3	5	1	6	3	4	4	8	1	2	4	4
% Change		1	10		-5	-4		1	2		-1	4
Tensile Properties:	2051	1927	2053	2165	2111	2203	2033	2327	2093	2068	2269	2112
Tensile Stress @ 200% Elongation (psi)	1915	2122	2192	2223	2041	1955	2036	1944	2209	2131	2244	2435
ASTM D638	1930	1946	2313	2136	2110	2291	2204	2122	1974	2236	2139	2412
Machine Direction	2053			2219			2244			2212		
	2029			2110			2110			2222		
	1929			2510			2061			2105		
Average	1985	1998	2186	2227	2087	2150	2115	2131	2092	2162	2217	2320
STD	61	88	106	133	33	142	82	156	96	64	56	147
Coefficient of Variation	3	4	5	6	2	7	4	7	5	3	3	6
% Change		1	10		-6	-3		1	-1		3	7

SIC4 09-04-99
Quality Review/Date

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

Report Date August 17, 1998

Exposure Time and Temperature

		30 Day			60 Day			90 Day			120 Day	
Test Parameters	Baseline	23C	50C	Baseline	23C	50C	Baseline	23C	50C	Baseline	23C	50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED HDPE - ROLL # 5208												
Tensile Properties:	2680	2899	2769	2822	2793	2913	2803	2576	3085	2981	2858	2876
Tensile Stress @ Yield (psi)	2626	2705	2852	2741	2938	2792	2632	2653	2833	2738	2630	2877
ASTM D638	2541	2581	2853	2848	2785	2837	2543	2736	2973	2637	2658	2868
Transverse Direction	2558			2752			2652			2809		
	2535			2760			2719			2838		
	2504			2792			2743			2941		
Average	2574	2728	2825	2786	2839	2847	2682	2655	2964	2824	2715	2874
STD	60	131	39	39	70	50	84	65	103	116	102	4
Coefficient of Variation	2	5	1	1	2	2	3	2	3	4	4	0
% Change		6	10		2	2		-1	11		-4	2
Tensile Properties:	2947	3207	2930	3210	3792	2610	3591	2215	3410	2303	3000	3124
Tensile Strength @ Break (psi)	3023	3243	2986	3104	3807	3379	3446	2962	2998	3350	3635	3025
ASTM D638	3135	3338	3399	3224	3710	3924	2908	3972	2711	3132	3867	3058
Transverse Direction	3070			3360			3379			3993		
	2642			3590			3009			3050		
	2834			3076			3478			3038		
Average	2942	3263	3105	3261	3770	3304	3302	3050	3040	3144	3501	3069
STD	164	55	209	174	43	539	252	720	287	498	366	41
Coefficient of Variation	6	2	7	5	1	16	8	24	9	16	10	1
% Change		11	6		16	1		-8	-8		11	-2
Tensile Properties:	16	17	16	15	16	15	14	13	13	13	13	15
Elongation @ Yield (%)	16	16	16	16	14	15	14	14	14	13	15	14
ASTM D638	16	17	17	15	16	15	13	13	14	15	12	14
Transverse Direction	16			15			15			14		
	17			16			15			13		
	15			16			14			13		
Average	16	17	16	16	15	15	14	13	14	14	13	14
STD	1	0	0	1	1	0	1	0	0	1	1	0
Coefficient of Variation	4	3	3	3	6	0	5	4	3	6	9	3
% Change		4	2		-1	-3		-6	-4		-1	6
Tensile Properties:	546	567	530	596	695	684	622	576	538	637	687	525
Elongation @ Break (%)	576	592	517	635	636	632	620	523	506	596	658	521
ASTM D638	597	640	608	577	673	684	551	672	456	592	684	529
Transverse Direction	597			610			618			633		
	501			662			531			526		
	565			564			602			457		
Average	564	600	552	607	668	667	591	590	500	574	676	525
STD	33	30	40	33	24	25	36	62	34	64	13	3
Coefficient of Variation	6	5	7	5	4	4	6	10	7	11	2	1
% Change		6	-2		10	10		-0	-15		18	-8

SRT 09.04.99
Quality Review/Date

Client: SOLMAX, File: 945-solm .WB1

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

Report Date: August 17, 1998

Exposure Time and Temperature

GEOMEMBRANE: SOLMAX 60 mil TEXTURED HDPE - ROLL # 5208

Test Parameters	30 Day Baseline	30 Day 23C	30 Day 50C	60 Day Baseline	60 Day 23C	60 Day 50C	90 Day Baseline	90 Day 23C	90 Day 50C	120 Day Baseline	120 Day 23C	120 Day 50C
Tensile Properties:	528	590	530	490	630	670	620	480	510	530	660	470
Set after Break (%)	540	570	540	580	600	600	560	540	470	630	580	540
ASTM D638	603	670	600	540	620	630	520	630	500	580	620	520
Transverse Direction	580			560			580			500		
	480			640			560			470		
	550			530			570			560		
Average	547	610	557	557	617	633	568	550	493	545	620	510
STD	39	43	31	46	12	29	30	62	17	53	33	29
Coefficient of Variation	7	7	6	8	2	5	5	11	3	10	5	6
% Change		12	2		11	14		-3	-13		14	-6
Tensile Properties:	1855	2049	1976	2014	2029	2017	2064	1900	2343	2120	2099	2173
Tensile Stress @ 100% Elongation (psi)	1981	2164	2063	2042	2057	2033	1992	1960	2031	1973	2000	2184
ASTM D638	1894	1875	2051	1985	1991	1965	1925	2084	2243	1949	2099	2112
Transverse Direction	1879			1996			1978			1933		
	1909			1966			2037			2114		
	1813			2003			2092			2117		
Average	1889	2029	2030	2001	2026	2005	2015	1981	2206	2034	2066	2156
STD	52	119	38	24	27	29	56	77	130	83	47	32
Coefficient of Variation	3	6	2	1	1	1	3	4	6	4	2	1
% Change		7	7		1	0		-2	9		2	6
Tensile Properties:	2001	2230	2140	1960	2063	2154	2110	2070	2411	2111	2112	2173
Tensile Stress @ 200% Elongation (psi)	1959	1997	2287	1977	2198	2036	2094	2188	2274	2060	1977	2184
ASTM D638	1883	1951	2092	2130	2262	2176	1920	2113	2236	2157	1976	2112
Transverse Direction	1894			2021			1979			2071		
	1904			2034			2098			2028		
	1832			2103			2029			2114		
Average	1912	2059	2173	2038	2174	2122	2038	2124	2307	2090	2022	2156
STD	54	122	83	62	83	61	70	49	75	42	64	32
Coefficient of Variation	3	6	4	3	4	3	3	2	3	2	3	1
% Change		8	14		7	4		4	13		-3	3
Modulus of Elasticity:	70644	73204	78480	59111	82198	60637	88225	93041	90817	86064	77409	100973
Tangential (psi)	75228	63342	79443	80482	80299	55160	96060	80782	96047	92464	78106	78877
ASTM D882	58675	79013	66809	82828	75488	67210	78987	94857	84229	87198	81733	89756
Machine Direction	74413			67188			93845			85945		
	66482			69939			98644			88026		
	74905			58022			92562			76861		
Average	70058	71853	74911	69595	79328	61002	91387	89560	90364	86093	79083	89869
STD	6510	7922	7033	9517	2824	4926	6399	6251	4835	4669	1896	9021
Coefficient of Variation	9	11	9	14	4	8	7	7	5	5	2	10
% Change		3	7		14	-12		-2	-1		-8	4

SZA 09.04.99
Quality Review/Date

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

Report Date August 17, 1998

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	50C	Baseline	60 Day 23C	50C	Baseline	90 Day 23C	50C	Baseline	120 Day 23C	50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED HDPE - ROLL # 5208												
Modulus of Elasticity:	68824	66267	64814	74443	67481	51166	91068	96451	98962	86184	85325	95277
Tangential (psi)	75703	63804	69670	89596	67069	66527	87564	90012	97964	85069	94018	89320
ASTM D882	48426	55667	67199	61057	72639	81059	96630	88136	86942	78951	88647	77268
Transverse Direction	78404			36407			93845			90728		
	65292			66296			80976			90117		
	79774			52288			78544			86050		
Average	69404	61913	67228	63348	69063	66251	88105	91533	94623	86183	89330	87288
STD	11709	5547	2428	16704	2534	12205	6544	3561	5446	3866	3582	7491
Coefficient of Variation	17	9	4	26	4	18	7	4	6	4	4	9
% Change		-11	-3		9	5		4	7		4	1
Indentation Hardness:	58	57	58	57	57	57	57	56	57	57	57	57
Reading	55	57	56	58	57	58	58	56	56	57	56	58
ASTM D2240	57	56	56	59	58	58	58	57	58	58	58	57
(with TYPE D DUROMETER)	58			58			56			56		
	57			57			58			54		
	57			58			58			59		
Average	57	57	57	58	57	58	58	56	57	57	57	57
STD	1	1	1	0	0	0	1	0	1	2	1	0
Coefficient of Variation	2	1	2	1	1	1	1	1	1	3	1	1
% Change		-1	-1		-1	0		-2	-1		0	1
Specific Gravity:	0.947	0.947	0.947	0.947	0.946	0.947	0.947	0.947	0.947	0.947	0.946	0.947
Specific Gravity (grams/cu.cm)	0.948	0.947	0.948	0.947	0.947	0.947	0.947	0.946	0.947	0.947	0.947	0.947
ASTM D792, Method A	0.948	0.947	0.947	0.947	0.947	0.947	0.948	0.947	0.947	0.946	0.947	0.947
	0.948			0.949			0.947			0.948		
	0.947			0.946			0.947			0.947		
	0.947			0.948			0.947			0.947		
Average	0.948	0.947	0.947	0.947	0.947	0.947	0.947	0.947	0.947	0.947	0.947	0.947
STD	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Coefficient of Variation	0.058	0.000	0.061	0.100	0.050	0.000	0.039	0.050	0.000	0.061	0.050	0.000
% Change		-0.05	-0.02		-0.07	-0.04		-0.05	-0.02		-0.04	0.00
Environmental Stress Crack Resistance:												
ASTM D1693, Condition B												
Machine Direction (% Failed)	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0
Transverse Direction (% Failed)	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0

SR 09-04-99
Quality Review/Date

Client: SOLMAX, File: 945-solm .WB1

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

Report Date: August 17, 1998

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	50C	Baseline	60 Day 23C	50C	Baseline	90 Day 23C	50C	Baseline	120 Day 23C	50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED HDPE - ROLL # 5208												
Puncture Resistance:	105	102	99	104	106	100	100	104	110	101	104	107
Load @ Rupture (lbs)	103	109	101	100	102	102	102	107	110	105	99	107
FTMS 101C Method 2065	103	102	98	101	95	107	100	106	106	105	101	108
	102			105			99			104		
	101			99			102			105		
	101			99			102			103		
Average	103	104	99	101	101	103	101	106	109	104	101	107
STD	1	3	1	2	5	3	1	1	2	1	2	0
Coefficient of Variation	1	3	1	2	5	3	1	1	2	1	2	0
% Change		2	-3		-0	2		5	8		-2	3
Volatiles and Extractables:	-0.13	-0.03	-0.20	-0.08	-0.03	-0.08	-0.05	-0.03	-0.05	-0.03	-0.05	-0.10
Diameter Change (%)	-0.25	-0.13	-0.05	-0.03	0.05	-0.03	-0.03	-0.05	-0.05	-0.05	0.00	-0.05
SW 870 - Appendix III-D	0.00			0.00			-0.10			0.00		
Machine Direction	0.05			-0.08			-0.05			-0.05		
Average	-0.08	-0.08	-0.13	-0.05	0.01	-0.06	-0.06	-0.04	-0.05	-0.03	-0.03	-0.08
STD	0.12	0.05	0.08	0.03	0.04	0.03	0.03	0.01	0.00	0.02	0.03	0
Volatiles and Extractables:	0.38	0.28	0.23	0.05	0.13	0.20	0.08	0.10	0.08	0.08	0.08	0.20
Diameter Change (%)	0.28	0.18	0.28	0.15	0.13	0.23	0.13	0.18	0.08	0.03	-0.03	0.18
SW 870 - Appendix III-D	0.08			0.18			0.13			0.10		
Transverse Direction	0.18			0.05			0.1			0.03		
Average	0.23	0.23	0.26	0.11	0.13	0.22	0.11	0.14	0.08	0.06	0.03	0.19
STD	0.11	0.05	0.03	0.06	0.00	0.01	0.02	0.04	0.00	0.03	0.06	0.01
Volatiles and Extractables:	0.05	0.06	0.05	0.05	0.07	0.05	0.05	0.05	0.06	0.06	0.06	0.11
% Volatiles	0.05	0.05	0.06	0.05	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.06
SW 870 - Appendix III-D	0.06			0.06			0.05			0.05		
	0.05			0.06			0.05			0.05		
Average	0.05	0.06	0.06	0.06	0.07	0.06	0.05	0.05	0.06	0.05	0.06	0.09
STD	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.03
Volatiles and Extractables:	0.18	-0.10	0.18	0.20	0.22	0.22	0.22	0.20	0.22	0.21	0.21	0.29
% Extractables	0.24	0.21	0.19	0.20	0.21	0.20	0.20	0.23	0.22	0.22	0.21	0.22
SW 870 - Appendix III-D	0.17			0.21			0.21			0.21		
	0.23			0.21			0.14			0.21		
Average	0.21	0.06	0.19	0.21	0.22	0.21	0.19	0.22	0.22	0.21	0.21	0.26
STD	0.03	0.16	0.01	0.01	0.01	0.01	0.03	0.01	0.00	0.00	0.00	0.03

SR4 09-04-99
Quality Review/Date

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

Report Date: August 17, 1998

Exposure Time and Temperature

Test Parameters	30 Day Baseline	30 Day 23C	30 Day 50C	60 Day Baseline	60 Day 23C	60 Day 50C	90 Day Baseline	90 Day 23C	90 Day 50C	120 Day Baseline	120 Day 23C	120 Day 50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED HDPE - ROLL # 5208												
Tear Resistance:	61	54	59	59	55	60	65	55	58	58	61	64
Tear Resistance (lbs)	55	55	53	60	54	58	61	57	56	58	59	62
ASTM D1004	57	54	55	59	54	57	61	57	55	57	56	57
Machine Direction	58			57			60			55		
	58			54			59			56		
	60			63			60			57		
Average	58	54	56	59	54	58	61	56	56	57	59	61
STD	2	1	3	3	0	1	2	1	1	1	2	3
Coefficient of Variation	4	1	5	5	1	2	3	2	2	2	4	5
% Change		-7	-4		-7	-1		-8	-8		3	7
Tear Resistance:	56	56	59	57	58	61	59	57	62	55	56	62
Tear Resistance (lbs)	56	54	58	57	56	60	57	55	58	58	55	61
ASTM D1004	53	54	59	56	58	60	59	54	59	56	56	61
Transverse Direction	56			54			60			58		
	53			55			60			56		
	56			55			59			57		
Average	55	55	59	56	57	60	59	55	60	57	56	61
STD	2	1	1	1	1	0	1	1	2	1	0	0
Coefficient of Variation	3	2	1	2	2	1	2	2	3	2	1	1
% Change		-1	7		3	8		-6	1		-2	8
Hydrostatic Resistance:	530	530	530	525	520	530	520	515	520	520	520	520
Load @ Rupture (psi)	520	520	530	525	525	525	515	515	515	510	525	515
ASTM D751	535	525	530	525	520	525	510	520	525	530	520	515
	535			530			530			520		
	530			515			530			525		
	525			535			520			525		
Average	529	525	530	526	522	527	521	517	520	522	522	517
STD	6	5	0	6	2	2	7	2	4	6	2	2
Coefficient of Variation	1	1	0	1	0	0	1	0	1	1	0	0
% Change		-1	0		-1	0		-1	-0		0	-1

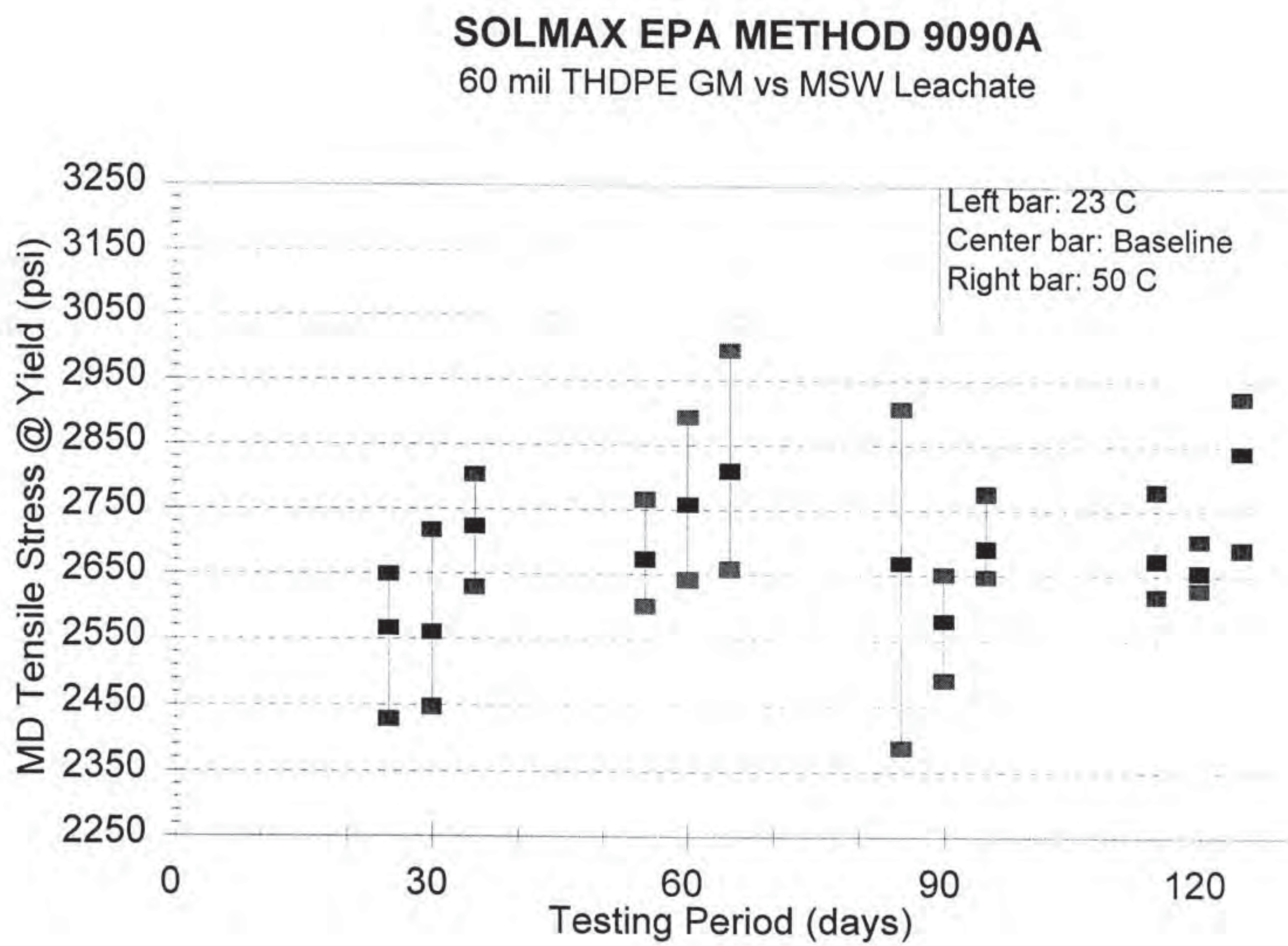
SRA 09.04.98
Quality Review/Date

Client: SOLMAX, File: 945-solm .WB1

EPA METHOD 9090A TEST RESULTS

TRI LOG #: E2068-94-05

GRAPHS OF SELECTED TEST RESULTS - HDPE



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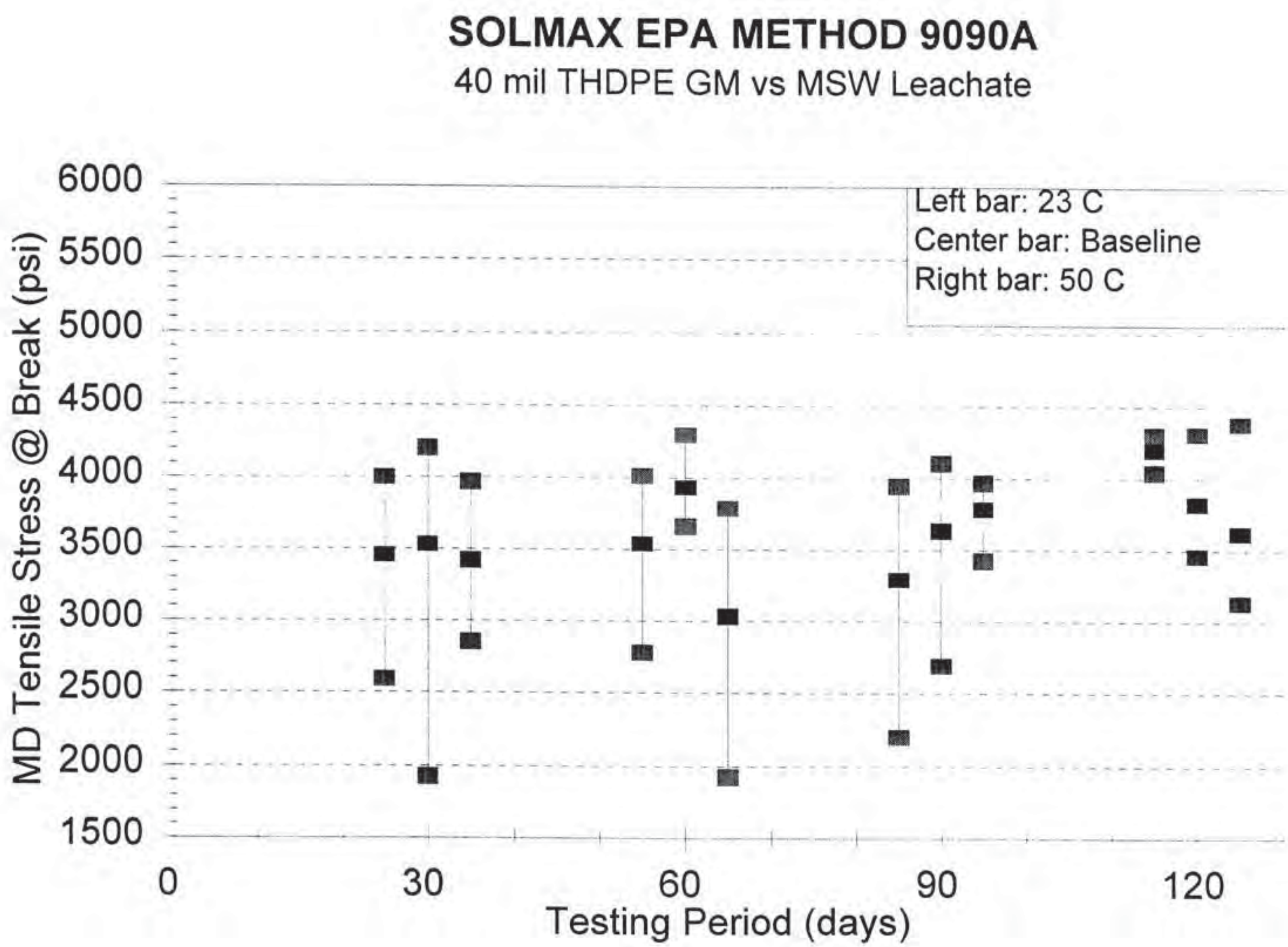

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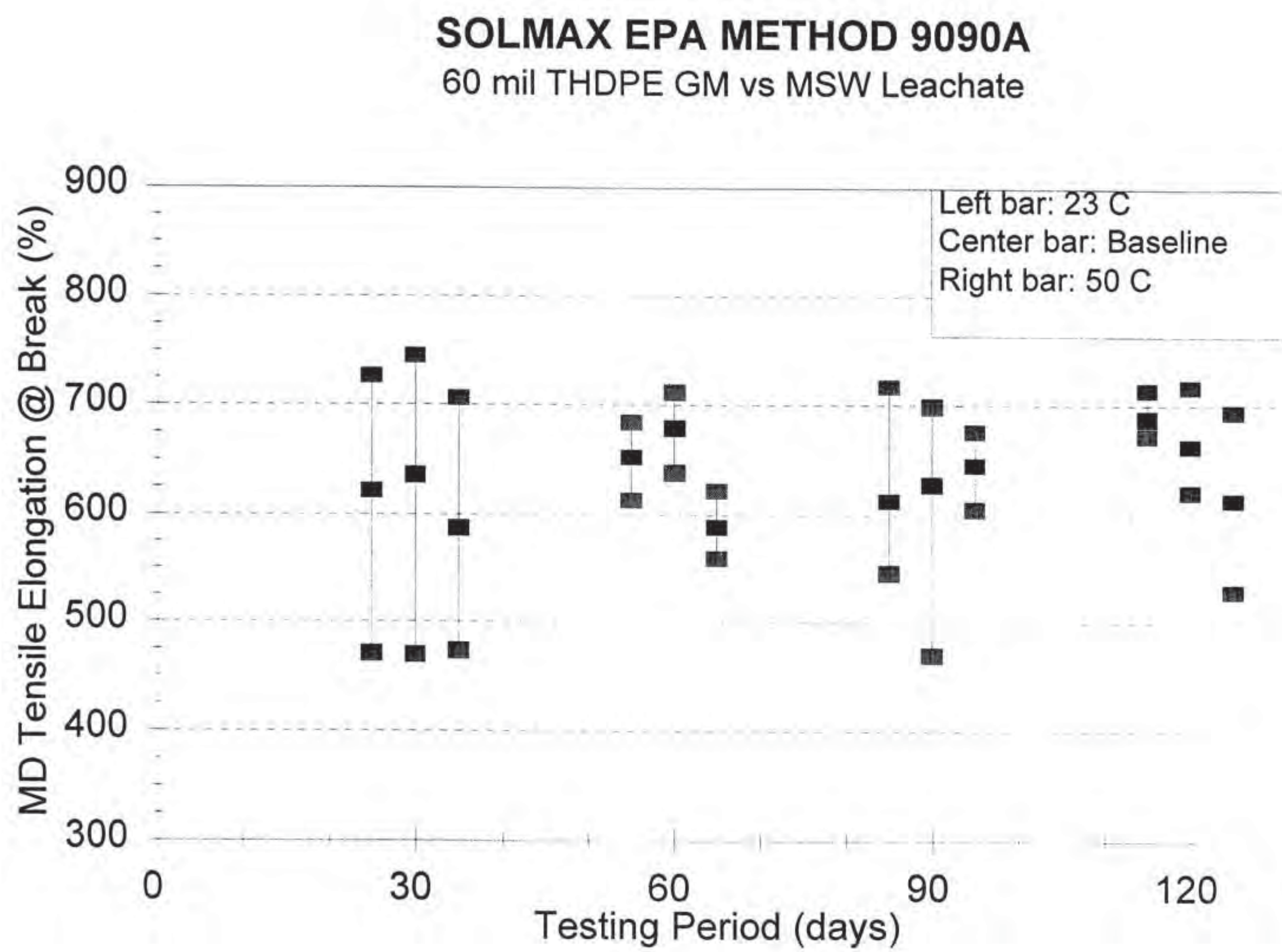

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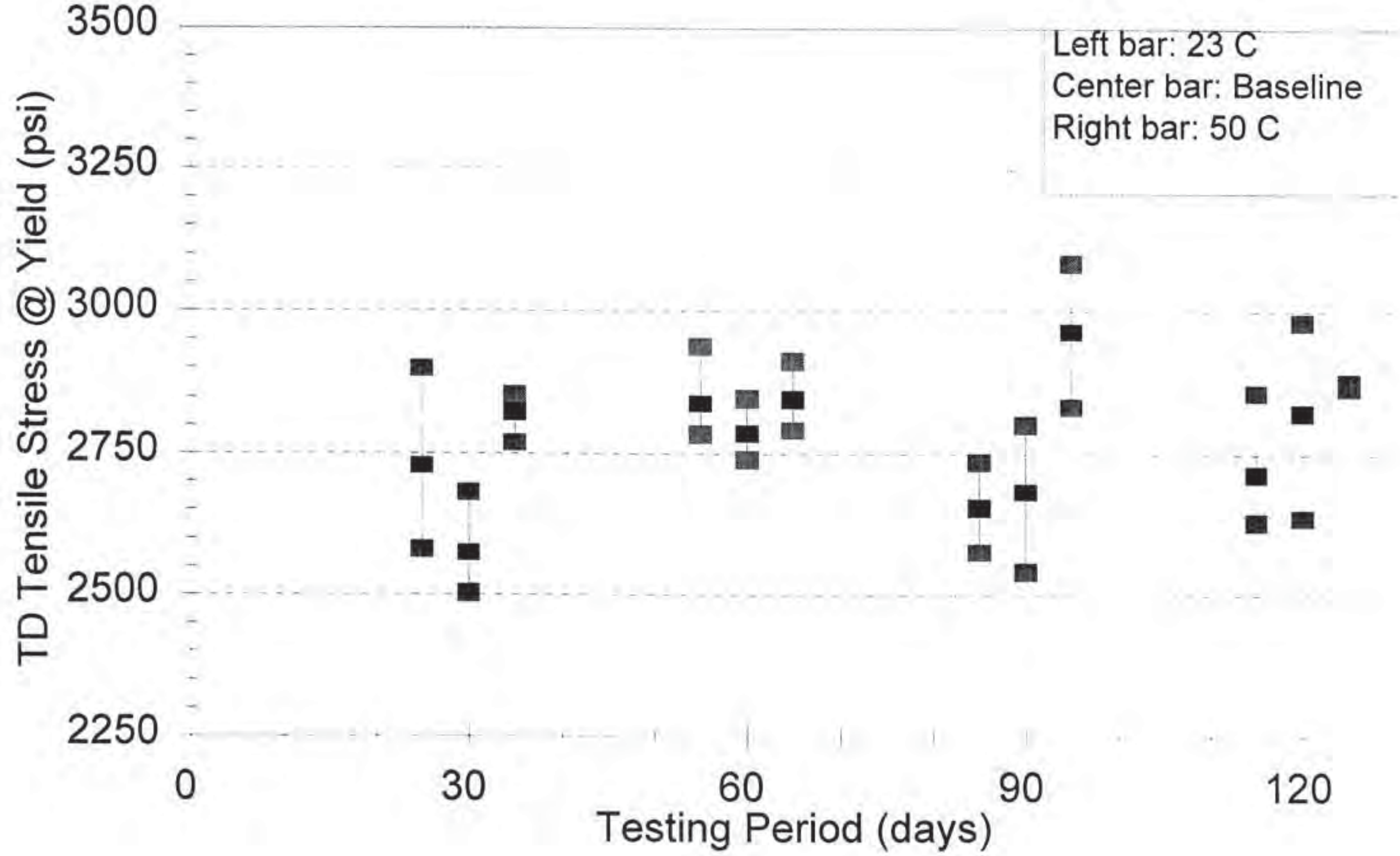
SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



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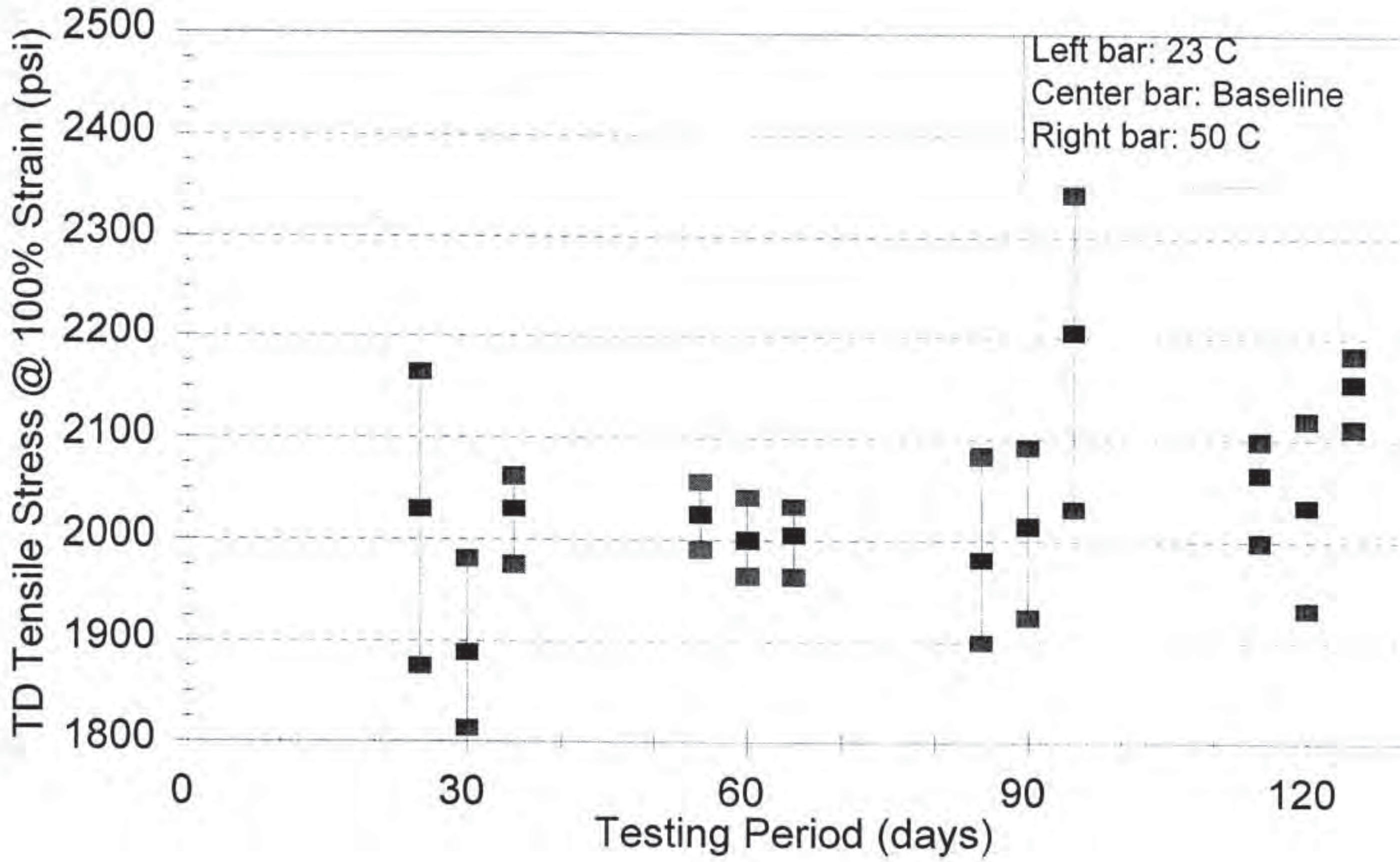
SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



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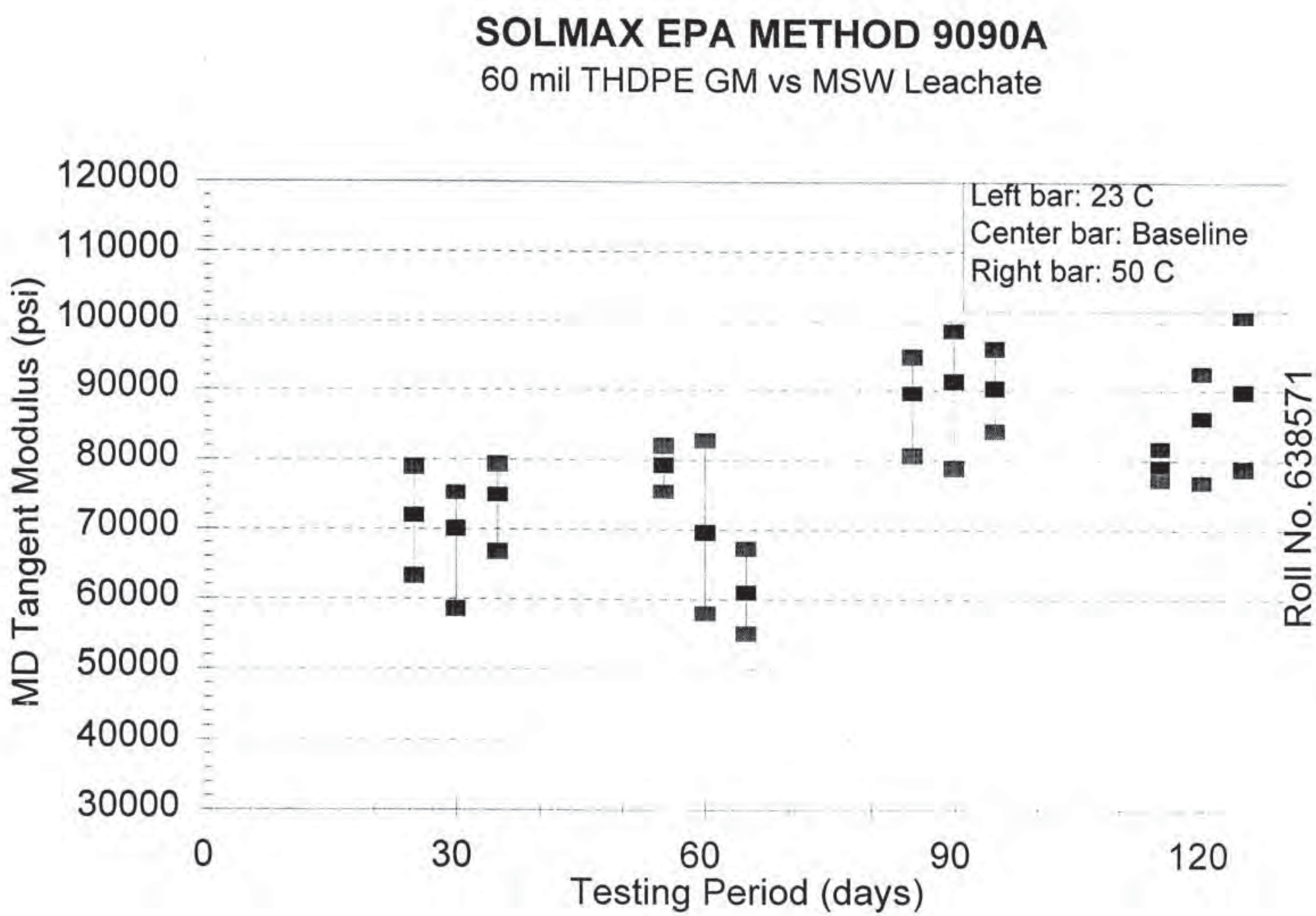

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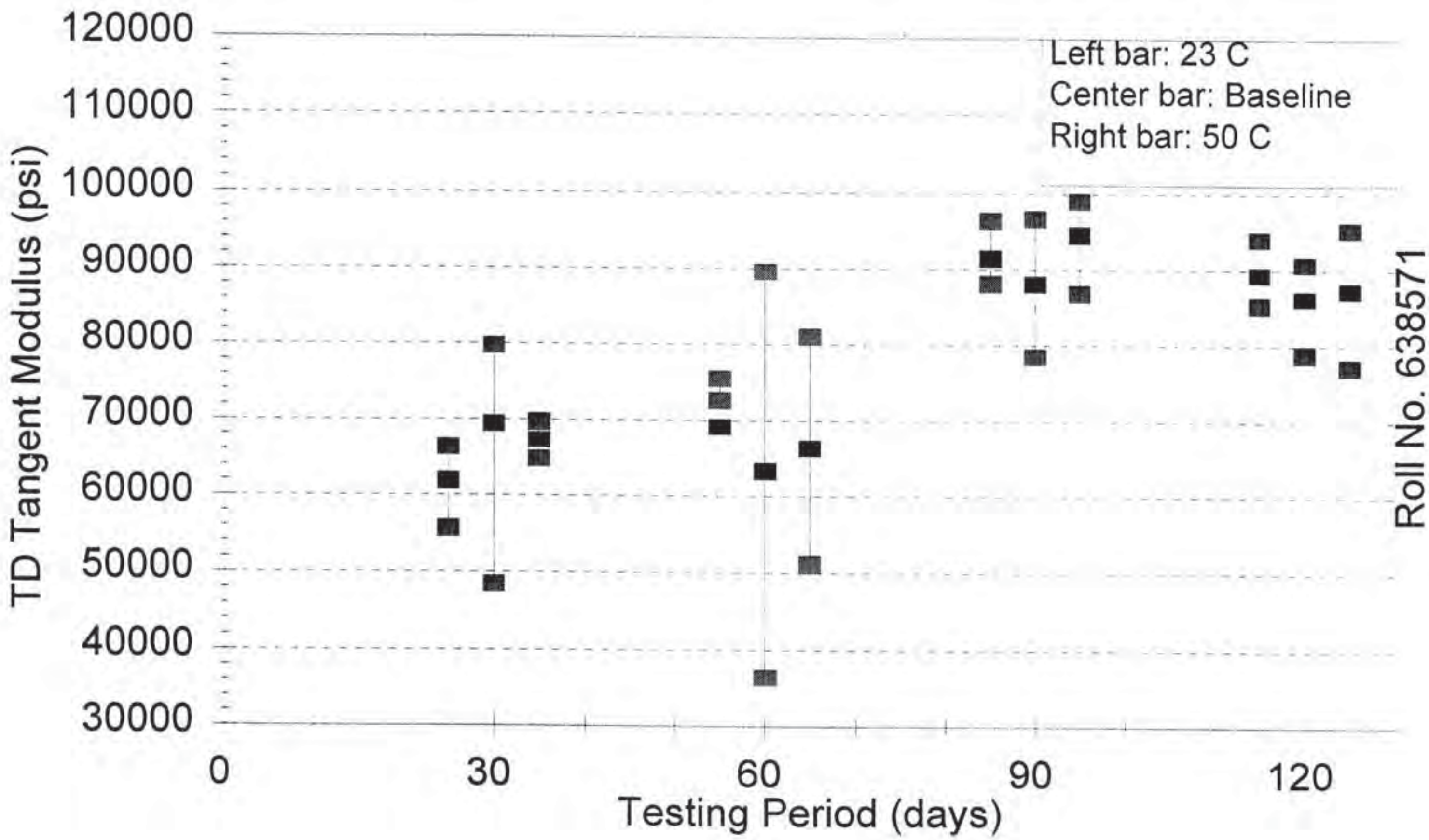
SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



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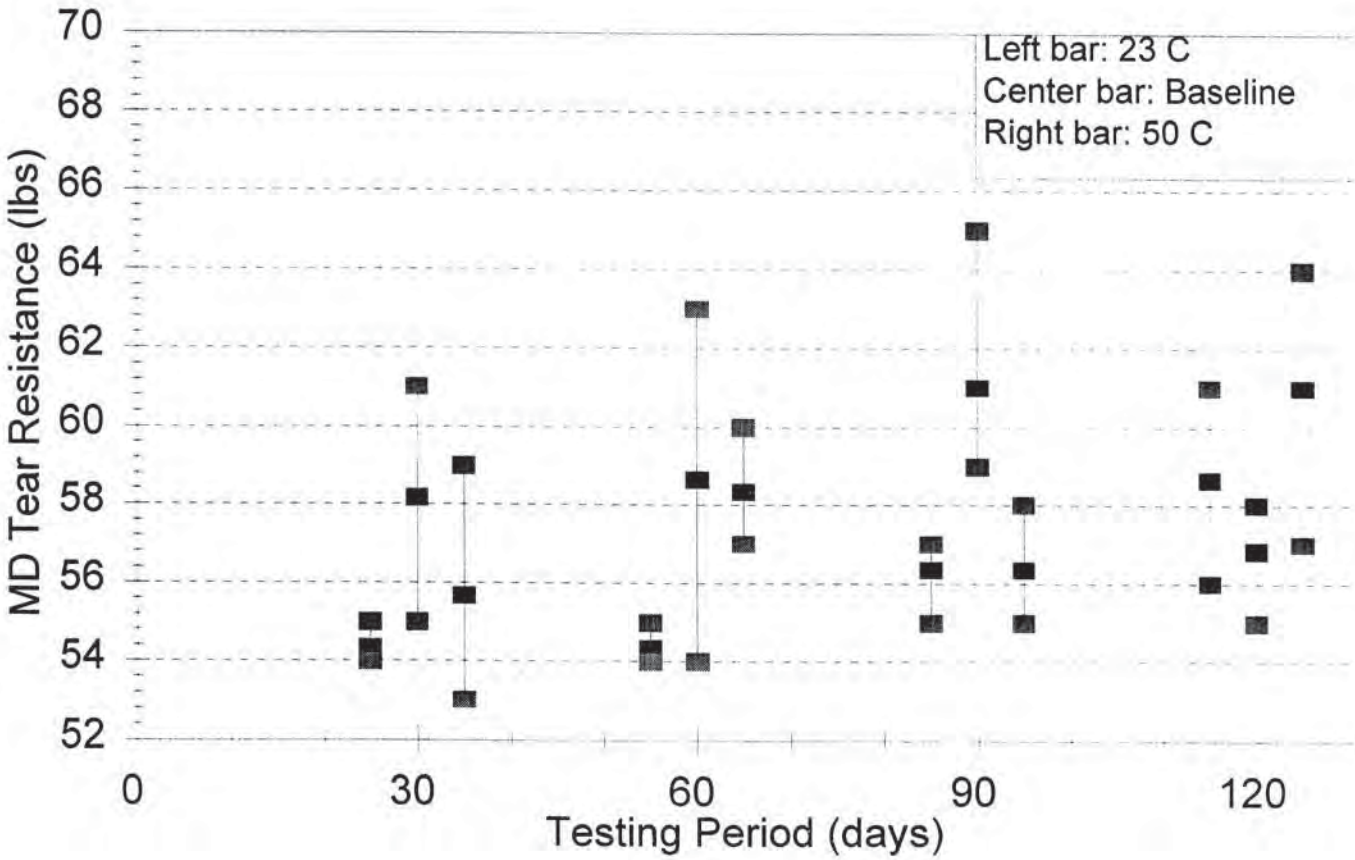
SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



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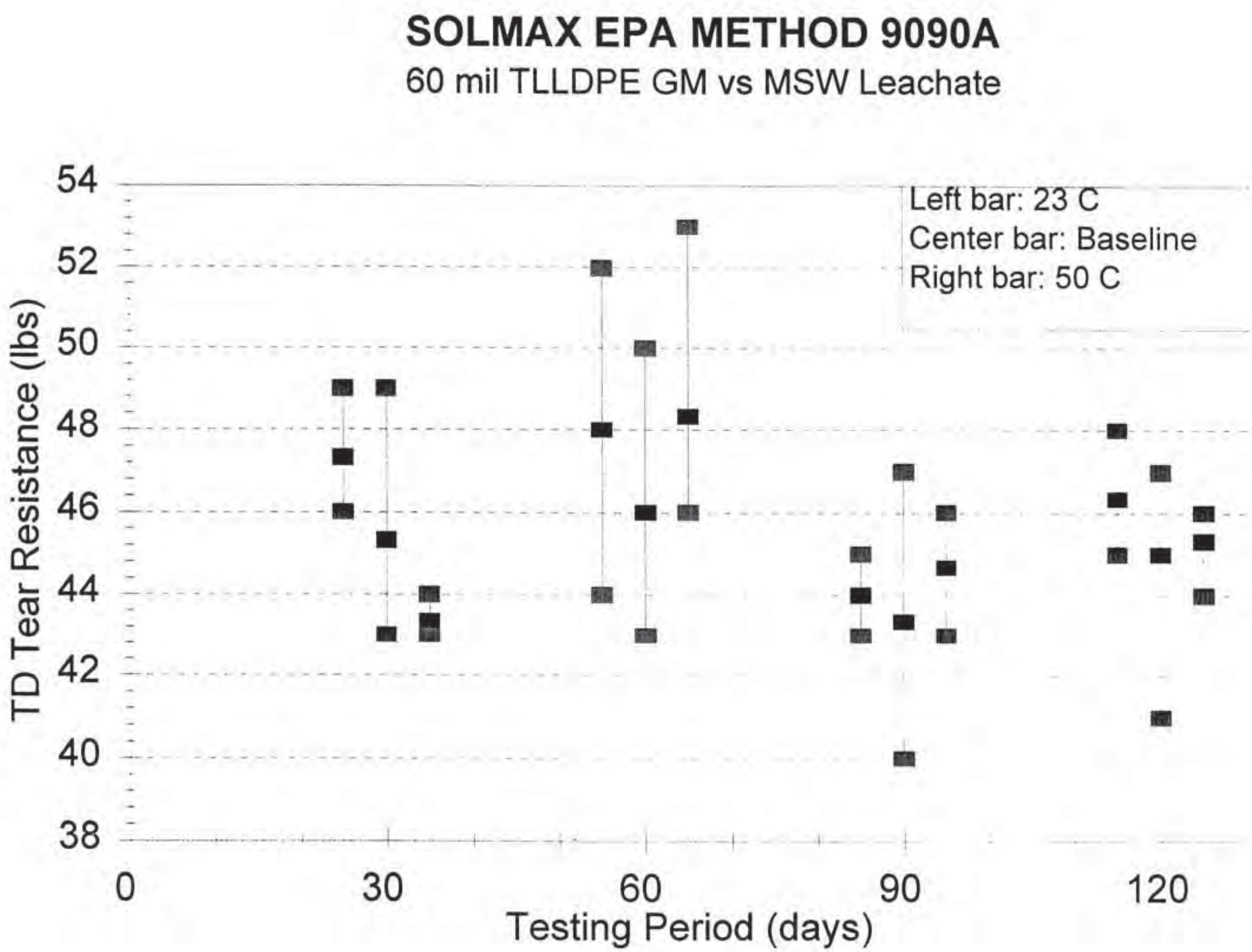

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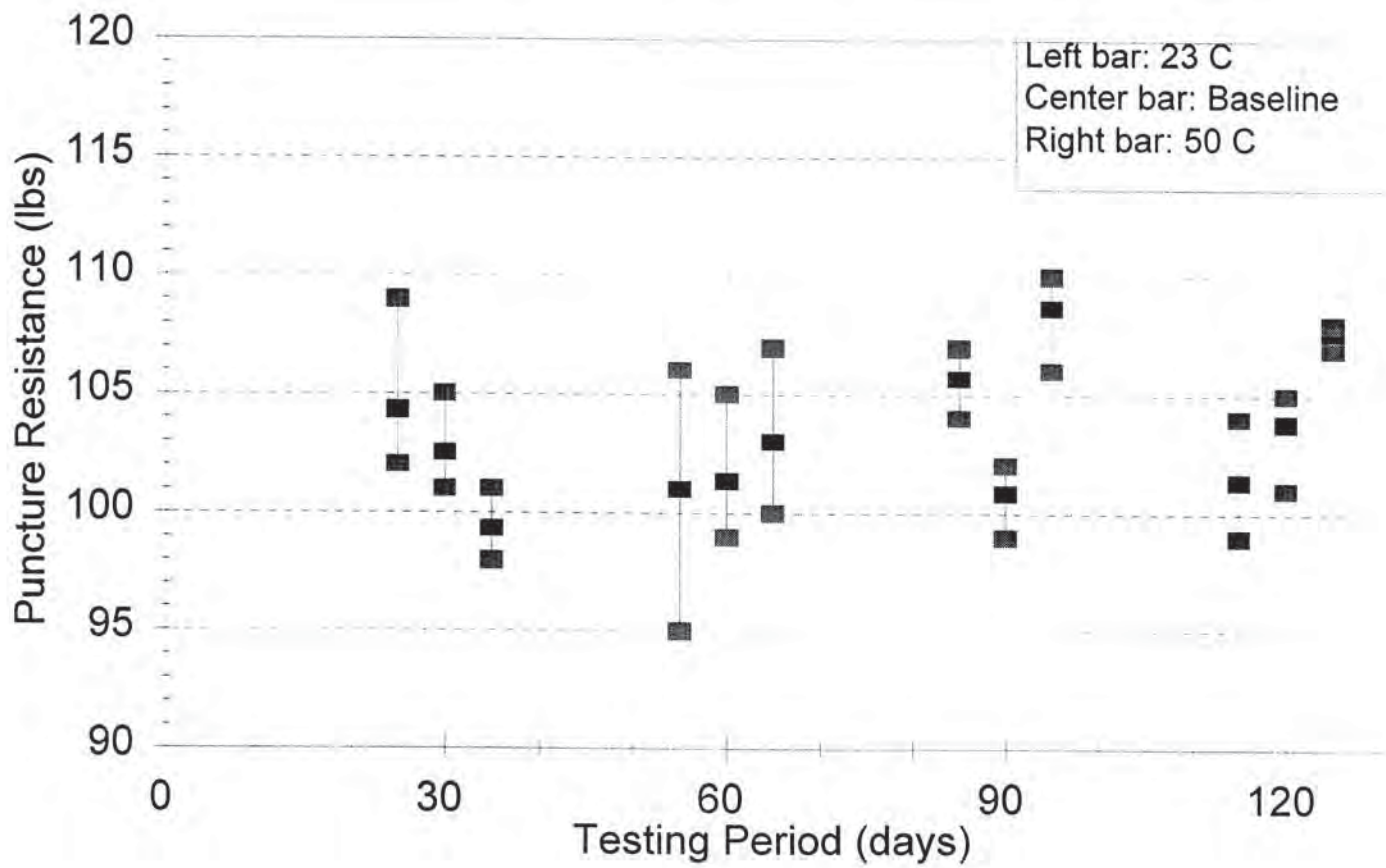
SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



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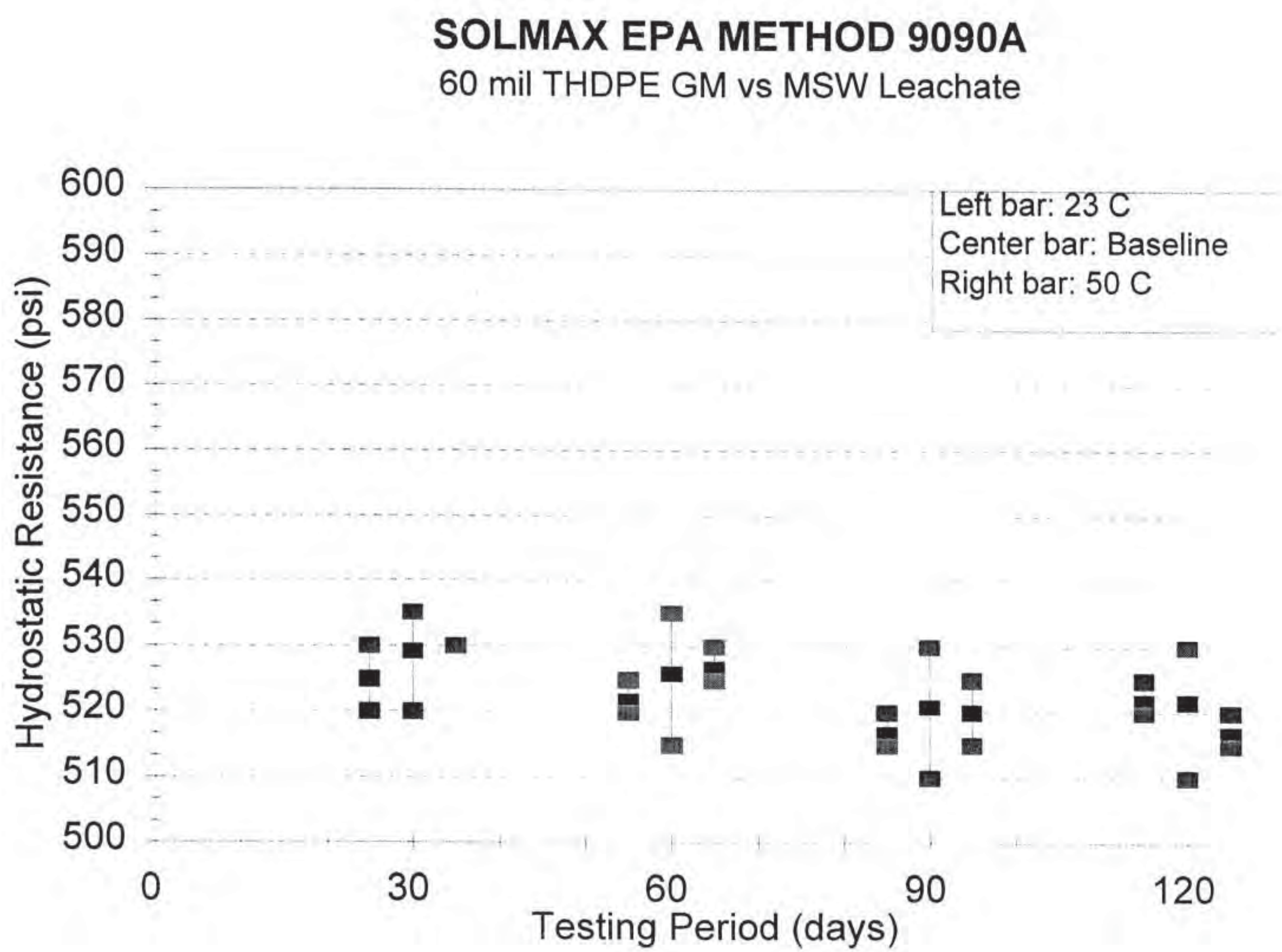

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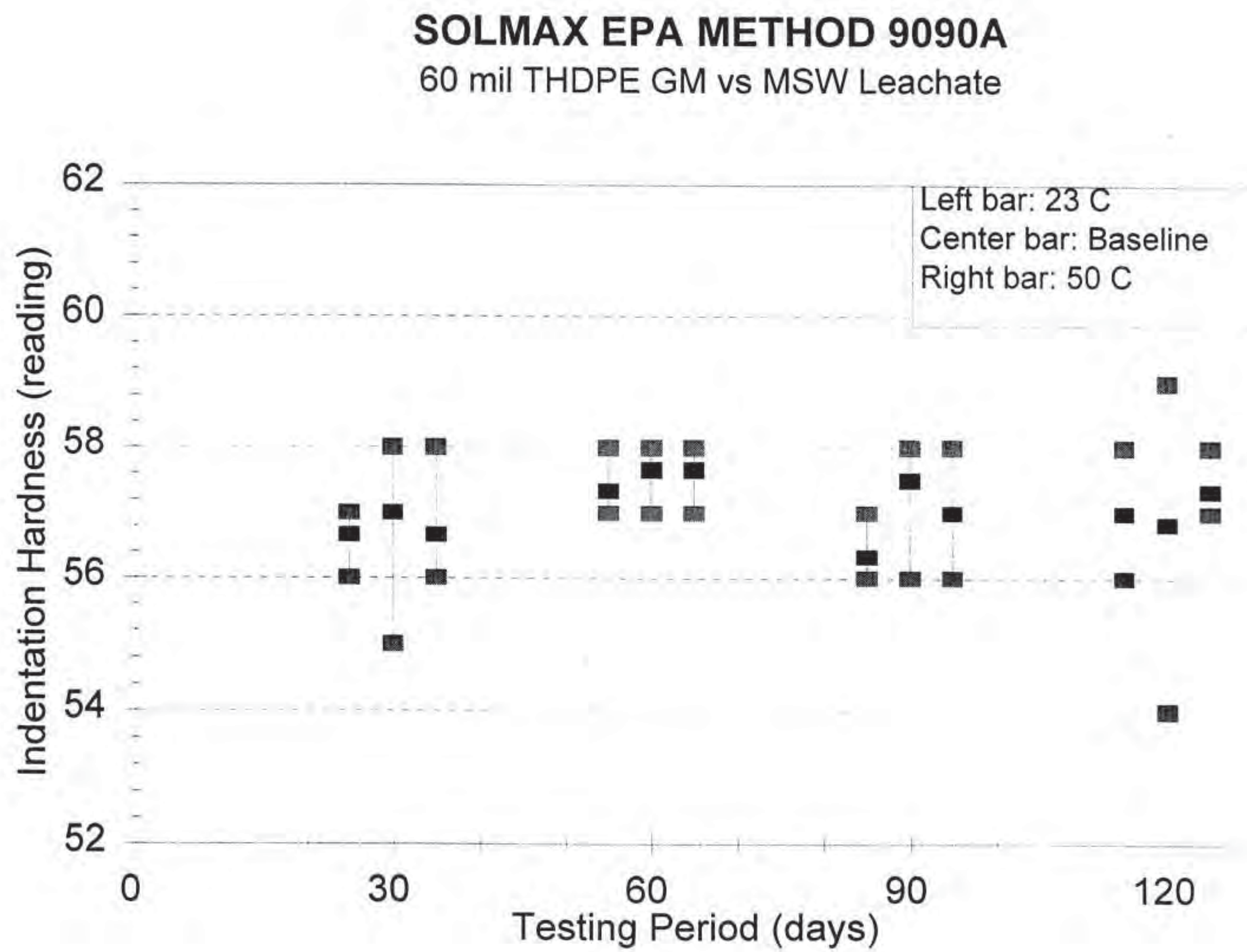

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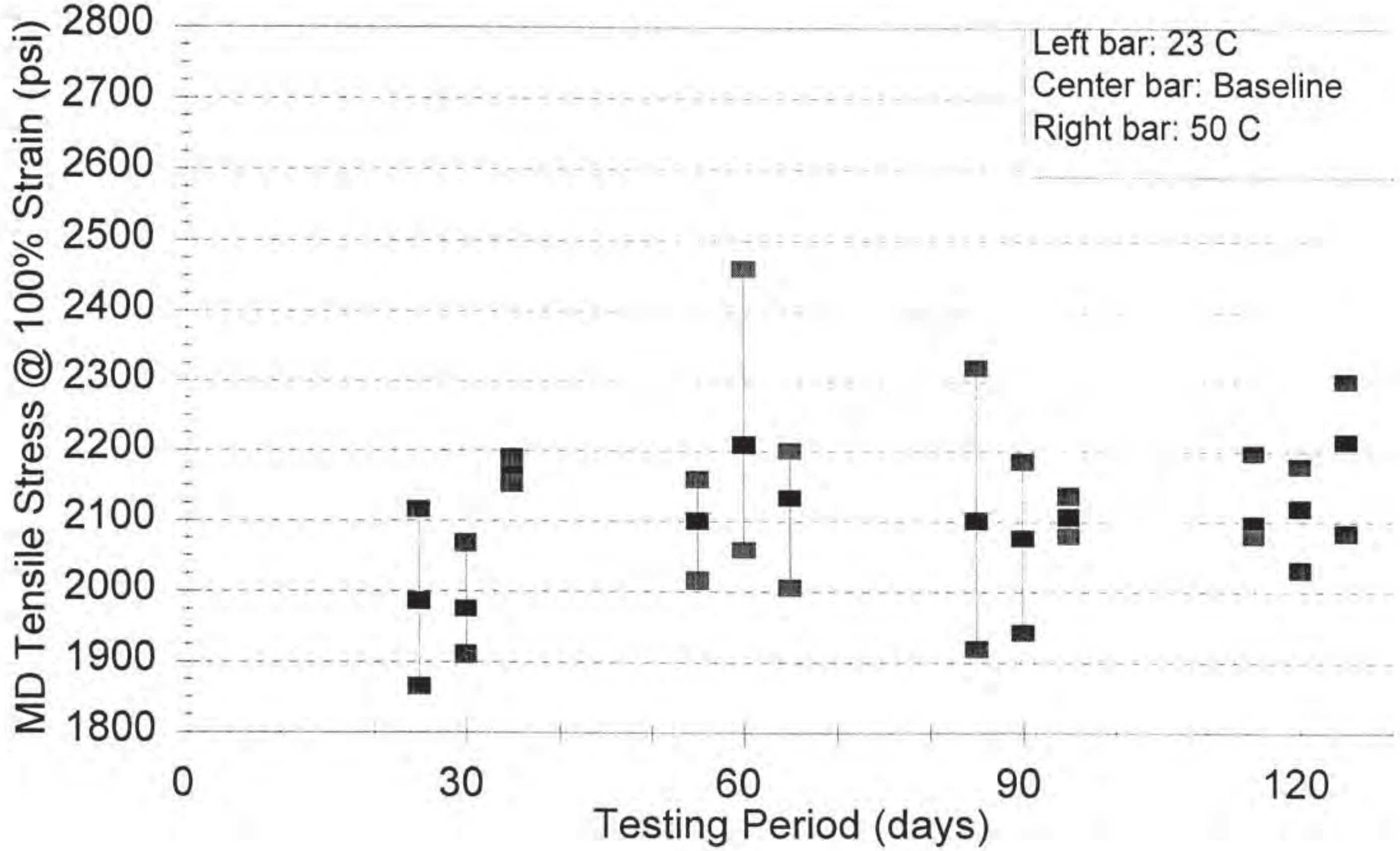
SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



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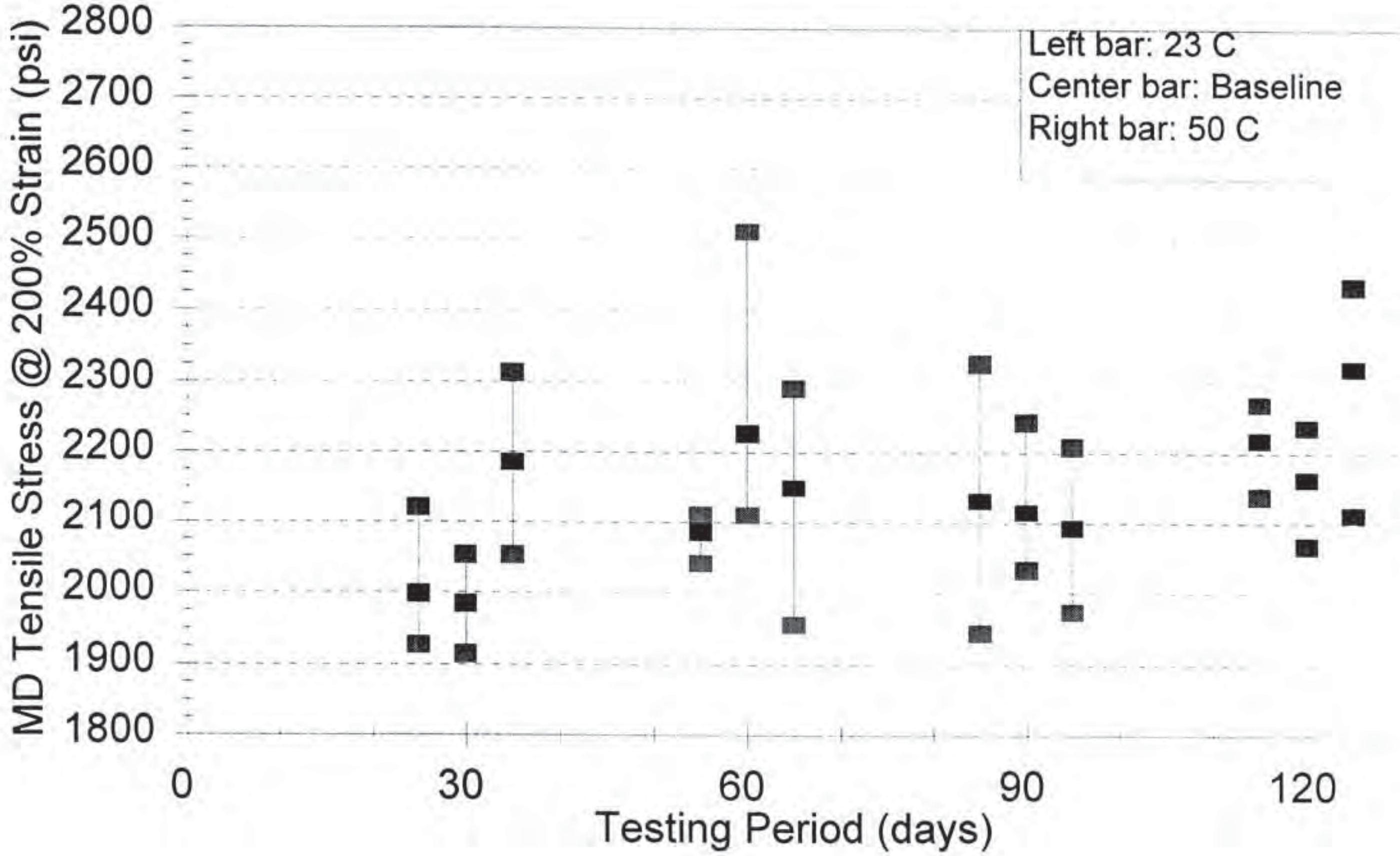
SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



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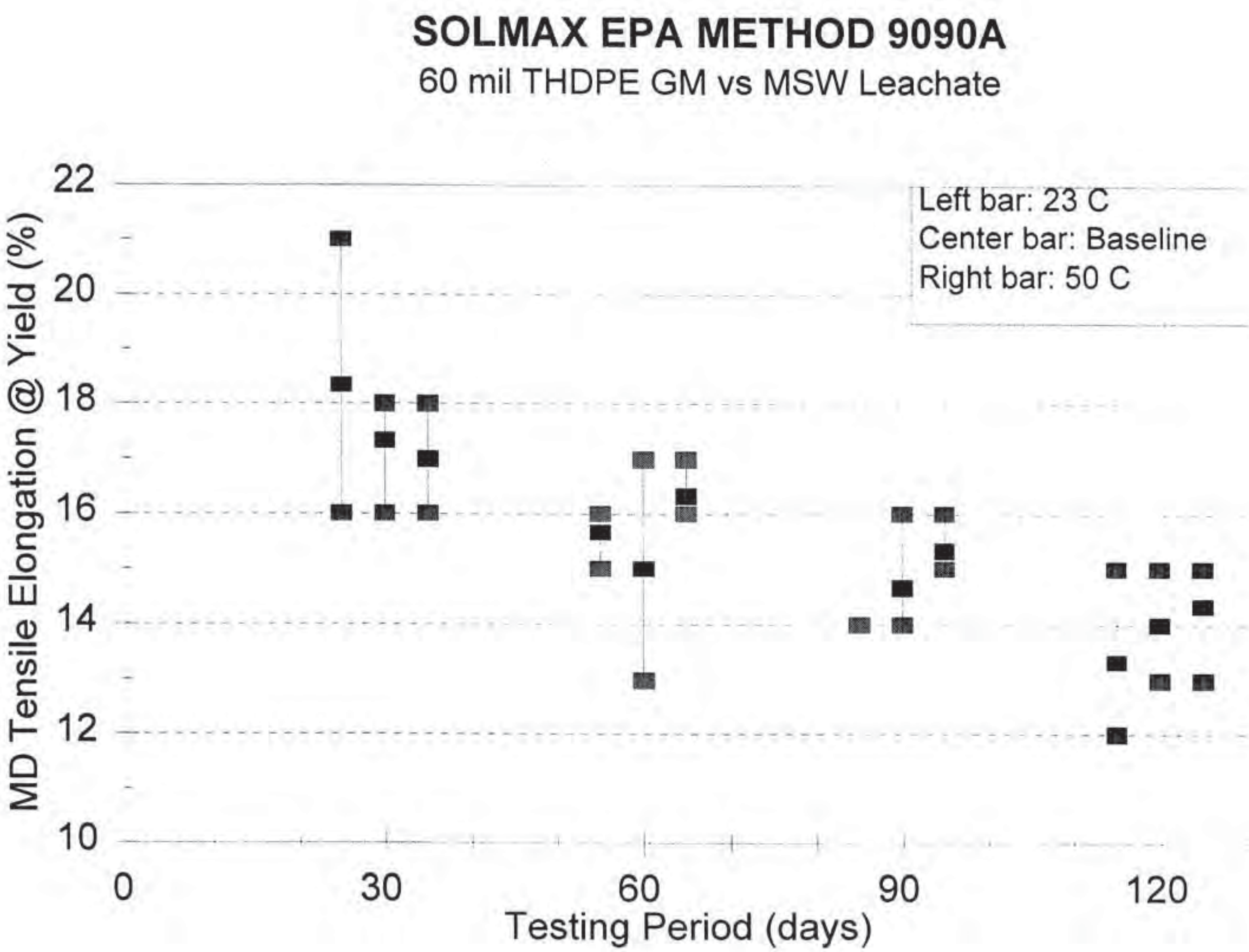

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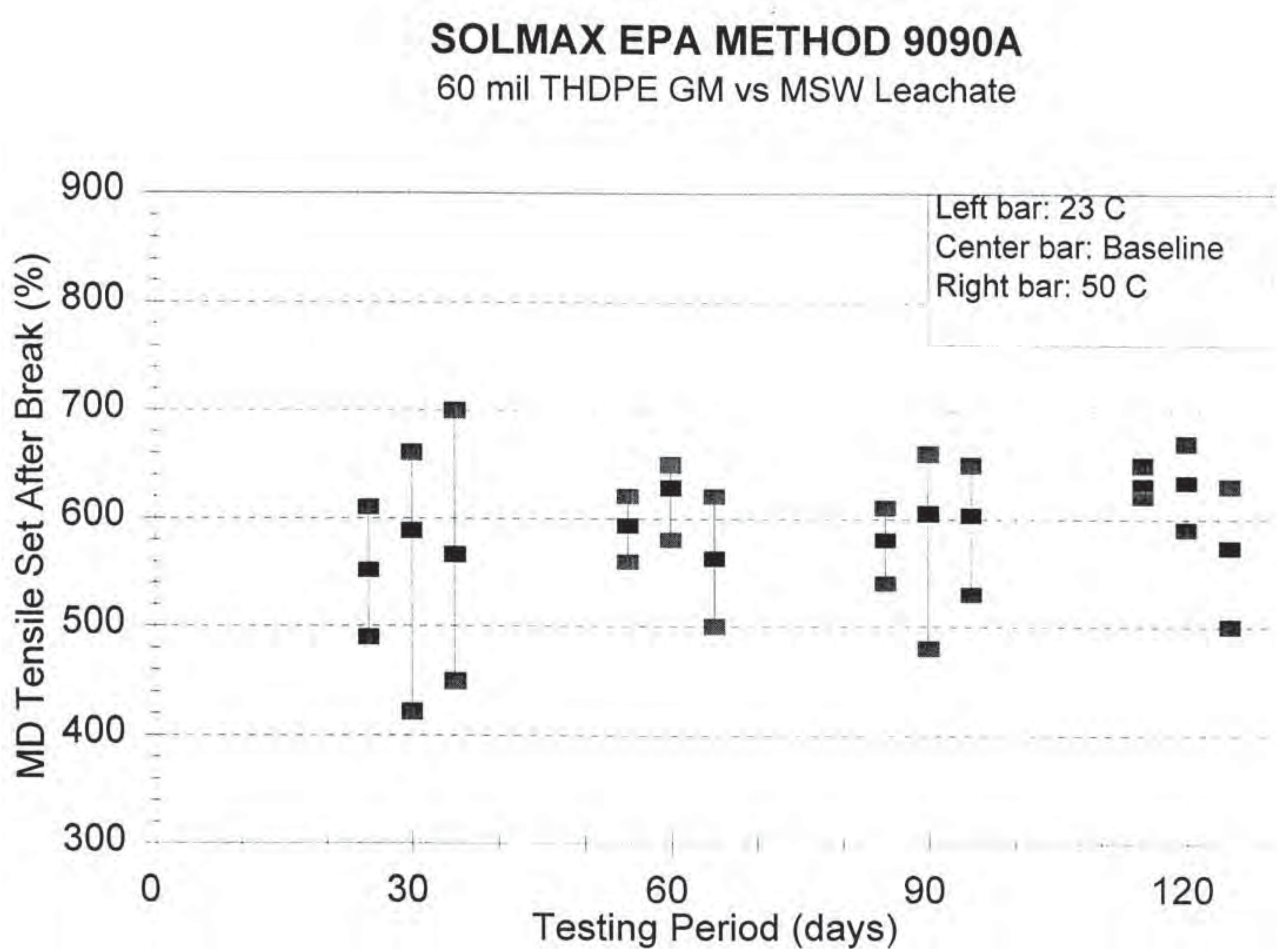

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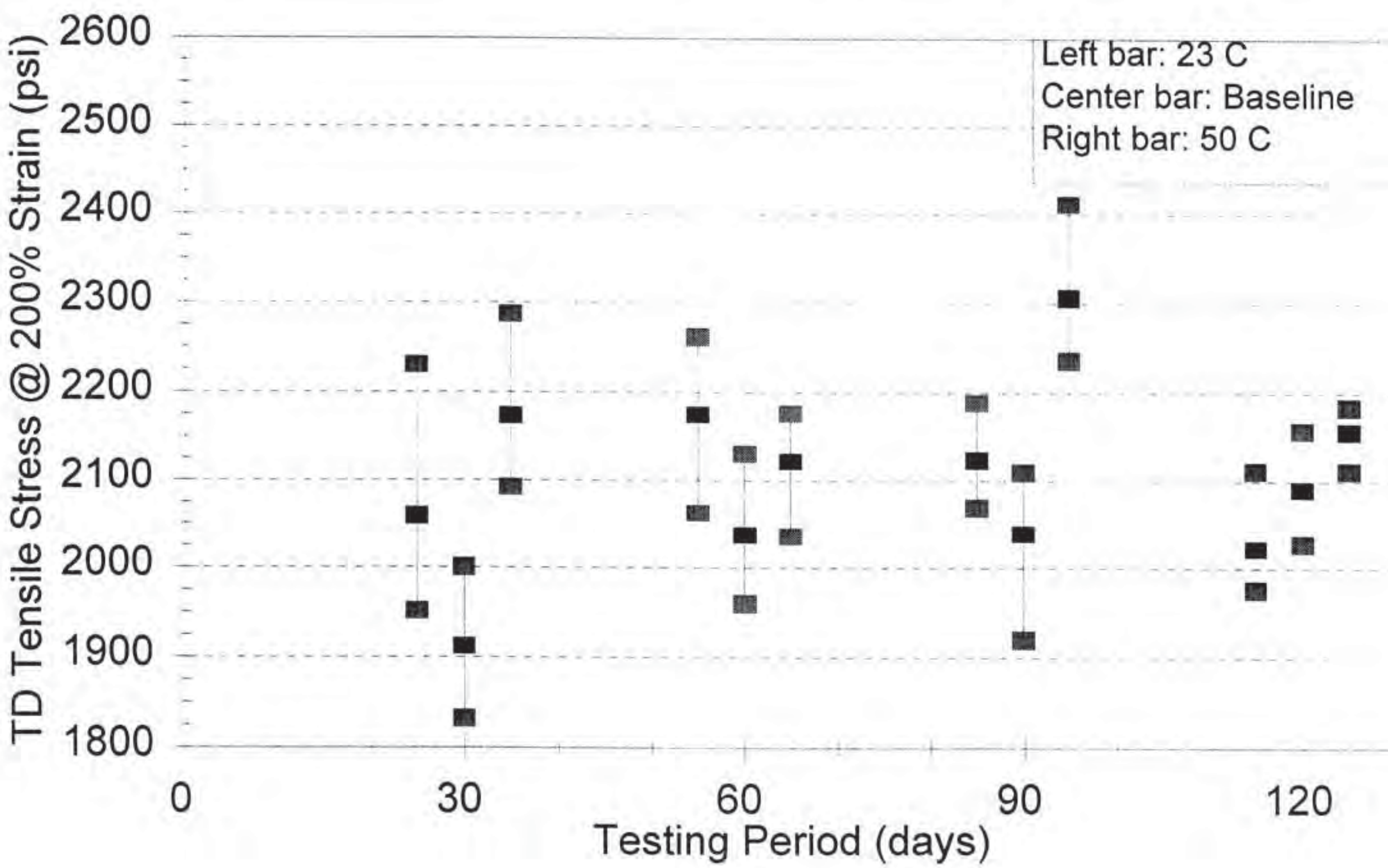
SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



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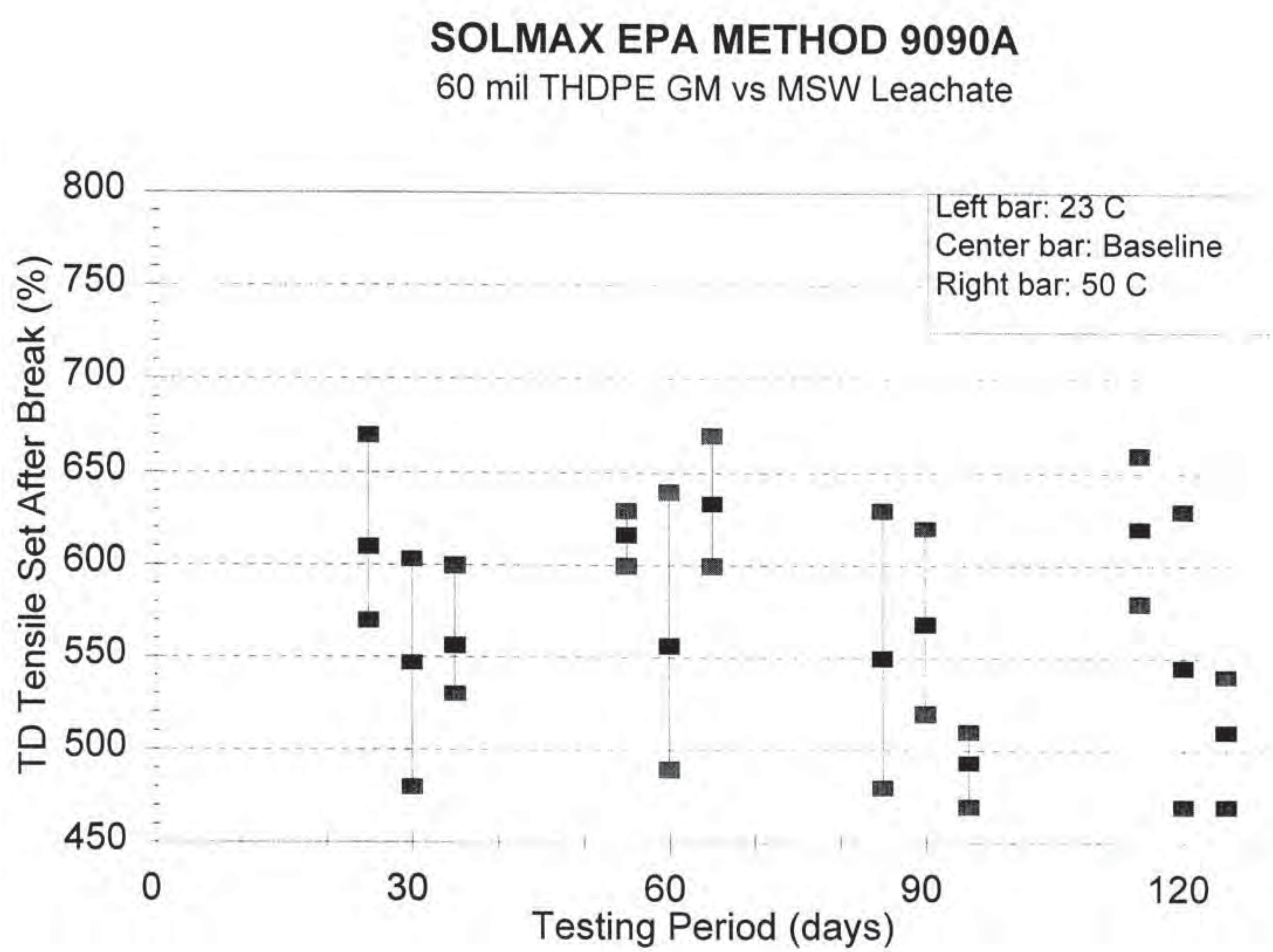
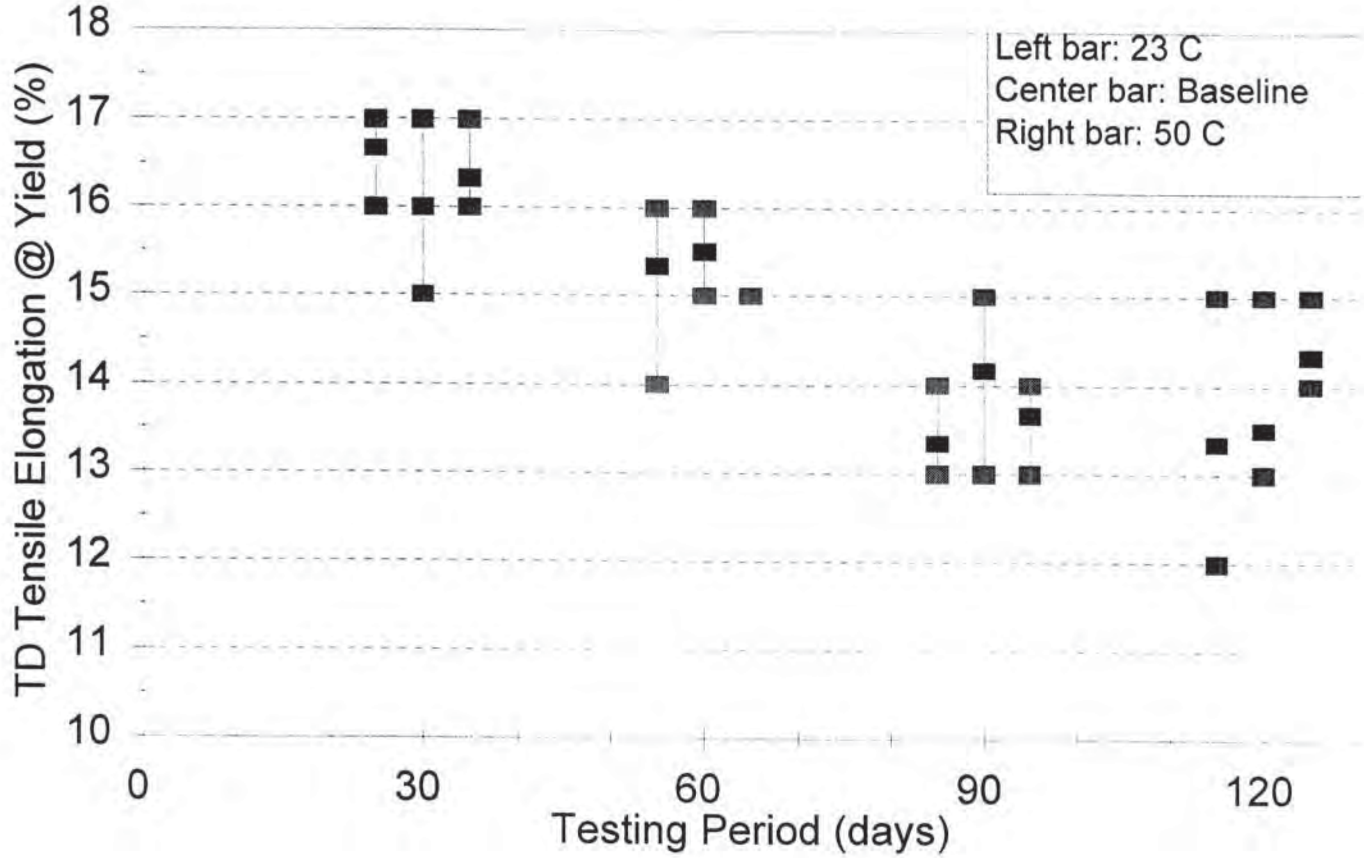


Client: SOLMAX, File: 945-solm.wb1

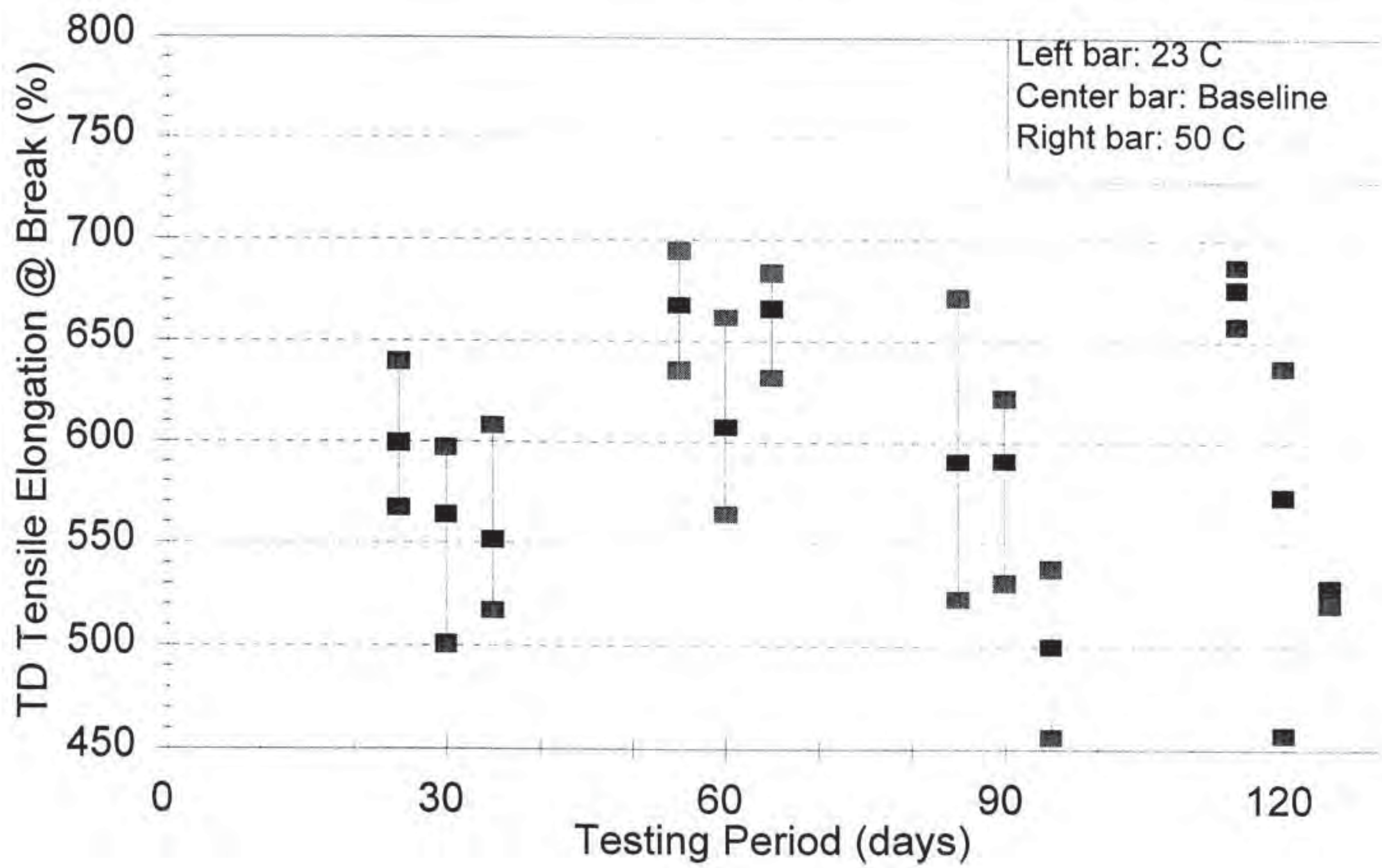
SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



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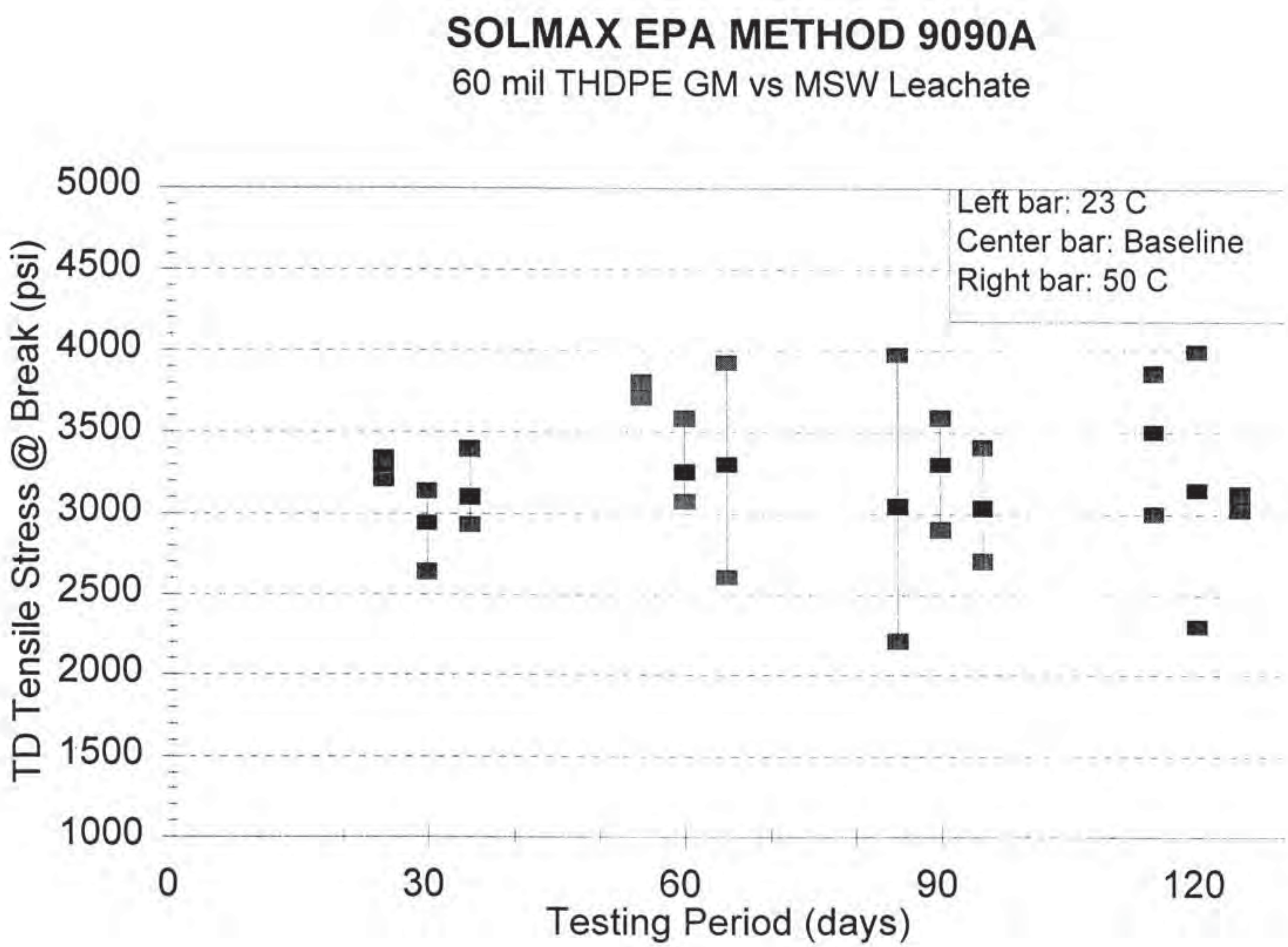

Client: SOLMAX, File: 945-solm.wb1

A Final Report:

Laboratory Testing of LLDPE Geomembrane for Waste Containment EPA Method 9090A

August 1998

Submitted to:
Solmax International
2801 Marie-Victorin
Varennes, Quebec
Canada J3X 1P7

Attn: **Mr. Stephan Henes**

Submitted by:

TRI/Environmental, Inc.
9063 Bee Caves Rd.
Austin, Texas 78733

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

August 17, 1998

Mr. Stephan Henes
Solmax International
2801 Marie-Victorin
Varennes, Quebec
Canada J3X 1P7

Dear Mr. Henes:

TRI/Environmental, Inc. (TRI) is pleased to present this Final Report for a LLDPE geomembrane chemical compatibility study via EPA Method 9090A.

TRI thanks Solmax International for the opportunity to participate in this project. Please call me if you have any questions or require any additional information.

Respectfully submitted,

Sam R. Allen (09.04.99)

Sam R. Allen
Vice President and Division Manager
Geosynthetics Services

9063 Bee Caves Road • Austin, TX 78733-6201 • (512) 263-2101 • FAX (512) 263-2558

FOREWORD

The testing reported herein is based upon accepted industry practice as well as the test method listed. TRI/Environmental Inc. (TRI) neither accepts responsibility for nor makes claim as to the final use and purpose of the materials tested.

Tests were performed under laboratory conditions and not under actual usage conditions. TRI can give no conclusions as to the serviceability, life expectancy or general durability of the products tested when used in a lining and/or leachate collection system.

1.0 INTRODUCTION

This report describes the work performed by TRI/Environmental, Inc. (TRI) to determine the chemical compatibility of a single liner product with one waste leachate. The product selected for testing was a linear low density polyethylene (LLDPE) geomembrane. The objective was to determine the resistance of the geomembrane to changes caused by exposure to leachate. Changes in physical and mechanical properties were measured after exposure to the leachate at 23°C and 50°C for 30, 60, 90 and 120 days following the exposure regime specified in United States Environmental Protection Agency (EPA) Method 9090A.

Methods, results and discussion are provided in the sections which follow. Test results are provided in the Tables of Results which accompany this report.

2.0 METHODS

2.1 Materials

The material received for this study was received and tested under TRI Log number E2068-94-05. Table 1 describes the product selected for evaluation in this chemical compatibility study.

Table 1. List of geomembranes evaluated in chemical compatibility study

Geosynthetic	Source
60 mil textured LLDPE geomembrane, roll #3299	Solmax

2.2 Leachate

The waste leachate used was stock municipal waste leachate maintained at TRI laboratories in Austin. The leachate was characterized as follows.

Table 2. Characterization of leachate used in chemical compatibility study

Parameter (units)	Level
Biological oxygen demand (mg/L)	2,130
Chemical Oxygen Demand (mg/L)	6,180
Conductivity (umhos/cm)	41,700
N-Ammonia (mg/L)	3,000
pH (units)	8.6

Table 2. Characterization of leachate used in chemical compatibility study

Parameter (units)	Level
Volatile Acids (mg/L)	10,000

2.3 Exposure Conditions

Geomembrane coupons were exposed to the waste leachate following the specifications of EPA Method 9090A as they relate to exposure to waste fluids. The tanks used for these exposures were maintained at 23 ±2°C and 50 ± 2°C throughout the 120-day exposure period. Tanks were constructed from glass, fitted with stirrers and heated with a circulating hot water heat exchanger system. The 50°C tanks were sealed with a lid, and a reflux condenser was installed to minimize loss of volatile leachate components.

2.4 Testing Procedures

The following table lists tests performed on the HDPE geomembrane product. The number of test replicates was doubled for baseline determinations on unexposed material.

Table 3. Tests performed on HDPE geomembrane

Test or Physical Property	Method	Number of replicate specimens
Dimensions and weight	EPA 9090A	3
Hardness	ASTM D 2240 D scale	5
Volatiles and Extractables	EPA SW 870, Appendix III	2
Specific Gravity	ASTM D 792	2
Tensile Properties	ASTM D 638	5
Modulus of Elasticity	ASTM D 882	5
Hydrostatic Resistance	ASTM D 751 Method A	5
Tear Strength	ASTM D 1004	5
Puncture Resistance	FTMS 101C Method 2065	2

Note that tensile properties were determined in accordance with ASTM D638 procedures as modified by National Sanitation Foundation (NSF) Standard 54 - 93, which gives specific methods for testing HDPE geomembranes. The tensile tests were performed on a screw-type tensile testing machine. The Type IV die was used. Load measurement were made by a strain-gage bridge load cell with calibration certified by an outside standards service. Elongation was determined by crosshead movement as recorded by Series IX Instron data acquisition software. The rate of grip separation was 2 inches per minute. Gauge length ratios of 1.3 inches for yield values, and 2.5 inches for break values were used to calculate elongation from grip movement. The parameters reported for ASTM D638 testing included: tensile stress at yield, tensile strength at break, elongation at yield and elongation at break.

3.0 RESULTS AND DISCUSSION

Test results are presented in the Tables of Test Results (raw data) and graphical presentations are presented in Appendix A.

In considering these results, it must be determined through engineering judgment whether observed differences in the value of test results measured before and after immersion are due to product variability, unidentified factors relating to the test procedure, or leachate interaction with the products. Any significant chemical interaction with leachate would be expected to result in degradation trends which are consistent across the various properties being evaluated, and not isolated to one set of test results only. However, with each type of material there may be specific properties which are highly sensitive to leachate-induced effects. These factors must be considered in evaluating the various test results for a given product.

Also of critical importance is the issue of product variability. With geomembranes, a range of physical and mechanical index test values covering 15% or more of the average is not uncommon. This can be traced to variability inherent in the product, and the randomness associated with the onset of failure under the specified testing conditions. However, in chemical compatibility testing the statistical sampling of a broad range of manufactured product is not possible. Therefore, the small size of the sample population tested at each time point must be taken into consideration. The criteria to be applied in evaluating data measured before and after leachate immersion should be that property changes, if observed, are consistent and so great that product variability and experimental factors can be ruled out.

In this report, standard deviations (STD) are reported for most measurements involving three or more replicate specimens. In statistics, the standard deviation is defined as root of the mean squared deviations of individual test results about the mean value. The standard deviation is a quantitative measure of variability within a group of measurements.

One related measure of variability observed within a sample set, relative to the magnitude of the mean value itself, is the *coefficient of variation or variance* (COV). The coefficient of variance is defined as the standard deviation divided by the mean associated with a group of specimens, and may be expressed as a percentage. The COV provides an indication of what proportion of the mean value may be attributable to random experimental factors or product variability. It is useful to consider apparent changes in property values against the criterion of COV since observed changes which fall below the COV may not be significant. This approach was used in preparing the tables below.

The term *range* refers to the difference between the extreme highest and lowest points within a group of measured values. Considering range as a percentage of the mean values provides another measure of variability within a dataset.

In the table below, the high and low extremes for percentage change in mean values are listed for comparison against COV and range as a percentage of mean from the baseline sample group. The high and low percentage changes are the extremes from data measured at 30, 60, 90 and 120 days.

Table 4. Baseline COV and Range of Percent Change Results

Test	Baseline COV (%)	Baseline Range as % of Mean	High Observed % Change	Low Observed % Change
Stress at yield (MD)	7	21	+7	-4
Stress at break (MD)	6	15	+9	-15
Elongation at yield (MD)	2	4	+12	-3
Elongation at break (MD)	4	11	+2	-4
Modulus (MD)	12	35	+8	-11
Tear strength (MD)	3	7	+13	-4
Puncture Resistance	3	9	+2	-7
Hydrostatic resistance	1	3	+1	-3

4.0 CONCLUSION

While changes in certain measured mechanical properties were noted, they were not observed to be consistent throughout the exposure period. The effects of product variability and experimental factors could not be ruled out as causes for observed changes. The data, considered together, do not support the conclusion that observed changes were caused by the test exposures.

TRI/Environmental, Inc. is pleased to have been selected to participate in this project. We trust that the information provided in this report meets your requirements for technical documentation of this chemical compatibility study. Please do not hesitate to call if we can provide any further information (1-800-880-8378).

Respectfully submitted,

Sam R. Allen (09-04-99)

Sam R. Allen
Vice President and Division Manager
Geosynthetics Services

EPA METHOD 9090A TEST RESULTS

TRI LOG #: E2068-94-05

GEOSYNTHETIC DIMENSIONS - LLDPE

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

Report Date: August 17, 1998

Exposure Time and Temperature

Test Parameters	Temp.	30 Day Baseline	30 Day Exposed	30 Day % Change	60 Day Baseline	60 Day Exposed	60 Day % Change	90 Day Baseline	90 Day Exposed	90 Day % Change	120 Day Baseline	120 Day Exposed	120 Day % Change
GEOMEMBRANE: SOLMAX 60 mil TEXTURED LLDPE - ROLL # 3299													
Thickness (mils)	23C	64	64	0.0	68	67	-1.5	65	65	0.0	70	70	0.0
	50C	68	68	0.0	66	65	-1.5	68	68	0.0	65	64	-1.5
Length (inches)	23C	9.98	9.99	0.1	9.97	9.97	0.0	9.96	9.97	0.1	9.98	9.98	0.0
	50C	9.98	9.99	0.1	9.94	9.95	0.1	10.00	10.00	0.0	10.00	9.99	-0.1
Width (inches)	23C	7.99	8.00	0.1	7.99	8.00	0.1	8.00	8.00	0.0	7.99	7.98	-0.1
	50C	7.99	7.99	0.0	8.00	8.00	0.0	8.00	8.00	0.0	8.00	8.00	0.0
Mass (g)	23C	87.93	87.90	-0.0	84.84	84.91	0.1	86.04	86.72	0.8	87.80	88.49	0.8
	50C	85.46	85.50	0.0	84.75	84.86	0.1	86.32	87.13	0.9	86.39	86.94	0.6

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EPA METHOD 9090A TEST RESULTS

TRI LOG #: E2068-94-05

60 MIL TEXTURED LLDPE GEOMEMBRANE

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

August 17, 1998

Exposure Time and Temperature

Test Parameters	30 Day			60 Day			90 Day			120 Day		
	Baseline	23C	50C	Baseline	23C	50C	Baseline	23C	50C	Baseline	23C	50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED LLDPE - ROLL # 3299												
Tensile Properties:	1716	1531	1742	1679	1582	1667	1587	1614	1694	1583	1699	1662
Tensile Stress @ Yield (psi)	1977	1753	1601	1537	1617	1643	1684	1627	1637	1627	1723	1672
ASTM D638	1815	1726	1687	1623	1492	1623	1682	1688	1688	1566	1716	1676
Machine Direction	1636			1563			1663			1549		
	1610			1513			1572			1654		
	1704			1673			1472			1636		
Average	1743	1670	1677	1598	1564	1644	1610	1643	1673	1603	1713	1670
STD	123	99	58	65	53	18	76	32	26	39	10	6
Coefficient of Variation	7	6	3	4	3	1	5	2	2	2	1	0
% Change		-4	-4		-2	3		2	4		7	4
Tensile Properties:	3878	3326	3854	4033	3703	3464	3811	3138	3564	3288	4320	3706
Tensile Strength @ Break (psi)	3943	3680	2998	3677	3637	3026	3819	3698	3696	3822	3786	3939
ASTM D638	3862	3648	4068	3466	3203	2938	3700	3909	3608	3321	3674	4087
Machine Direction	3548			3726			3668			4029		
	3373			3392			3521			3392		
	3902			3817			3512			3848		
Average	3751	3551	3640	3685	3514	3143	3672	3582	3623	3617	3927	3911
STD	213	160	462	214	222	230	123	325	55	292	282	157
Coefficient of Variation	6	5	13	6	6	7	3	9	2	8	7	4
% Change		-5	-3		-5	-15		-2	-1		9	8
Tensile Properties:	22	23	24	21	22	21	21	20	22	16	19	20
Elongation @ Yield (%)	22	24	24	23	21	23	20	21	22	19	18	21
ASTM D638	23	21	23	22	22	23	19	19	22	21	20	22
Machine Direction	23			22			21			19		
	23			21			22			17		
	23			21			21			20		
Average	23	23	24	22	22	22	21	20	22	19	19	21
STD	0	1	0	1	0	1	1	1	0	2	1	1
Coefficient of Variation	2	6	2	3	2	4	5	4	0	9	4	4
% Change		0	4		0	3		-3	6		2	12

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TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

August 17, 1998

Exposure Time and Temperature

Test Parameters	30 Day Baseline	30 Day 23C	30 Day 50C	60 Day Baseline	60 Day 23C	60 Day 50C	90 Day Baseline	90 Day 23C	90 Day 50C	120 Day Baseline	120 Day 23C	120 Day 50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED LLDPE - ROLL # 3299												
Tensile Properties:	735	698	728	740	699	651	710	668	669	720	769	665
Elongation @ Break (%)	656	679	612	742	684	705	678	684	709	708	662	699
ASTM D638	686	689	784	647	660	706	669	695	666	637	648	718
Machine Direction	700			750			681			747		
	661			672			684			622		
	724			713			699			707		
Average	694	689	708	711	681	687	687	682	681	690	693	694
STD	29	8	72	39	16	26	14	11	20	45	54	22
Coefficient of Variation	4	1	10	5	2	4	2	2	3	7	8	3
% Change		-1	2		-4	-3		-1	-1		0	1
Tensile Properties:	600	700	490	650	600	550	540	470	540	530	580	520
Set after Break (%)	490	560	500	630	570	600	500	520	560	540	530	570
ASTM D638	570	550	550	540	550	600	540	570	530	500	470	560
Machine Direction	580			650			570			570		
	570			560			580			500		
	600			600			520			600		
Average	568	603	513	605	573	583	542	520	543	540	527	550
STD	37	68	26	43	21	24	27	41	12	36	45	22
Coefficient of Variation	7	11	5	7	4	4	5	8	2	7	9	4
% Change		6	-10		-5	-4		-4	0		-2	2
Tensile Properties:	1599	1425	1588	1515	1426	1563	1538	1523	1623	1552	1617	1538
Tensile Stress @ 100% Elongation (psi)	1845	1607	1479	1382	1559	1510	1543	1583	1513	1532	1650	1599
ASTM D638	1654	1589	1551	1465	1402	1478	1627	1624	1600	1477	1633	1538
Machine Direction	1483			1455			1519			1378		
	1496			1382			1475			1622		
	1608			1531			1359			1564		
Average	1614	1540	1539	1455	1462	1517	1510	1577	1579	1521	1633	1558
STD	120	82	45	58	69	35	81	41	47	77	13	29
Coefficient of Variation	7	5	3	4	5	2	5	3	3	5	1	2
% Change		-5	-5		1	4		4	5		7	2
Tensile Properties:	1661	1488	1652	1632	1558	1554	1625	1596	1630	1600	1676	1592
Tensile Stress @ 200% Elongation (psi)	1912	1701	1596	1519	1623	1600	1614	1641	1596	1574	1706	1609
ASTM D638	1704	1666	1614	1557	1431	1586	1645	1675	1652	1541	1706	1619
Machine Direction	1570			1509			1589			1578		
	1590			1454			1579			1578		
	1720			1589			1460			1666		
Average	1693	1618	1621	1543	1537	1580	1585	1637	1626	1590	1696	1607
STD	112	93	23	58	80	19	60	32	23	38	14	11
Coefficient of Variation	7	6	1	4	5	1	4	2	1	2	1	1
% Change		-4	-4		-0	2		3	3		7	1

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TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

August 17, 1998

Exposure Time and Temperature

		30 Day			60 Day			90 Day			120 Day	
Test Parameters	Baseline	23C	50C	Baseline	23C	50C	Baseline	23C	50C	Baseline	23C	50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED LLDPE - ROLL # 3299												
Tensile Properties:	1575	1769	1711	1372	1612	1687	1638	1562	1692	1658	1733	1677
Tensile Stress @ Yield (psi)	1711	1689	1682	1376	1704	1585	1672	1693	1695	1584	1610	1738
ASTM D638	1732	1675	1688	1609	1551	1584	1688	1647	1563	1666	1704	1664
Transverse Direction	1684			1529			1681			1626		
	1749			1521			1585			1683		
	1630			1545			1676			1665		
Average	1680	1711	1694	1492	1622	1619	1657	1634	1650	1647	1682	1693
STD	61	41	12	88	63	48	36	54	62	33	52	32
Coefficient of Variation	4	2	1	6	4	3	2	3	4	2	3	2
% Change		2	1		9	8		-1	-0		2	3
Tensile Properties:	2849	3600	3467	3269	3409	3417	2297	2756	3310	3240	3747	3308
Tensile Strength @ Break (psi)	3093	3114	3493	2677	3097	1661	3347	3590	3597	3101	3390	3615
ASTM D638	3540	3050	3466	3253	2850	3100	3365	2539	2357	3132	3415	3731
Transverse Direction	3208			3387			2154			3174		
	3560			3161			3026			3118		
	3181			2992			3485			4045		
Average	3239	3255	3475	3123	3119	2726	2946	2962	3088	3302	3517	3551
STD	249	246	12	233	229	764	529	453	530	336	163	178
Coefficient of Variation	8	8	0	7	7	28	18	15	17	10	5	5
% Change		0	7		-0	-13		1	5		7	8
Tensile Properties:	23	23	23	24	20	23	19	23	20	20	19	21
Elongation @ Yield (%)	23	24	24	22	21	22	19	20	19	19	18	22
ASTM D638	23	24	23	21	22	23	20	20	22	20	19	22
Transverse Direction	23			21			19			18		
	24			21			19			20		
	23			21			22			19		
Average	23	24	23	22	21	23	20	21	20	19	19	22
STD	0	0	0	1	1	0	1	1	1	1	0	0
Coefficient of Variation	2	2	2	5	4	2	6	7	6	4	3	2
% Change		2	1		-3	5		7	3		-3	12
Tensile Properties:	607	665	669	684	670	643	587	644	632	612	669	614
Elongation @ Break (%)	593	620	683	607	580	667	614	652	665	717	624	636
ASTM D638	660	600	678	614	644	629	625	580	515	605	633	594
Transverse Direction	626			680			665			697		
	673			625			585			566		
	640			636			639			730		
Average	633	628	677	641	631	646	619	625	604	655	642	615
STD	28	27	6	30	38	16	28	32	64	63	19	17
Coefficient of Variation	4	4	1	5	6	2	5	5	11	10	3	3
% Change		-1	7		-2	1		1	-2		-2	-6

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TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

August 17, 1998

Exposure Time and Temperature

Test Parameters	30 Day Baseline	30 Day 23C	30 Day 50C	60 Day Baseline	60 Day 23C	60 Day 50C	90 Day Baseline	90 Day 23C	90 Day 50C	120 Day Baseline	120 Day 23C	120 Day 50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED LLDPE - ROLL # 3299												
Tensile Properties:	601	550	510	580	570	540	480	540	560	640	550	520
Set after Break (%)	470	500	540	500	480	570	530	520	540	480	450	530
ASTM D638	540	500	580	520	550	520	520	470	420	460	550	480
Transverse Direction	500			580			500			520		
	600			530			470			500		
	590			540			520			530		
Average	550	517	543	542	533	543	503	510	507	522	517	510
STD	51	24	29	30	39	21	22	29	62	58	47	22
Coefficient of Variation	9	5	5	5	7	4	4	6	12	11	9	4
% Change		-6	-1		-2	0		1	1		-1	-2
Tensile Properties:	1483	1671	1565	1308	1488	1539	1502	1527	1526	1522	1656	1566
Tensile Stress @ 100% Elongation (psi)	1612	1555	1563	1231	1609	1447	1607	1653	1565	1477	1547	1566
ASTM D638	1637	1564	1597	1494	1401	1419	1590	1571	1457	1554	1604	1548
Transverse Direction	1561			1477			1515			1603		
	1664			1418			1510			1619		
	1486			1392			1562			1536		
Average	1574	1597	1575	1387	1499	1468	1548	1584	1516	1552	1602	1560
STD	70	53	16	92	85	51	41	52	45	48	45	8
Coefficient of Variation	4	3	1	7	6	3	3	3	3	3	3	1
% Change		1	0		8	6		2	-2		3	1
Tensile Properties:	1475	1696	1660	1457	1559	1557	1565	1632	1631	1632	1713	1650
Tensile Stress @ 200% Elongation (psi)	1658	1607	1636	1337	1642	1497	1655	1648	1675	1534	1610	1648
ASTM D638	1707	1638	1605	1525	1518	1515	1652	1602	1508	1636	1660	1636
Transverse Direction	1594			1470			1596			1663		
	1708			1464			1614			1685		
	1602			1420			1658			1619		
Average	1624	1647	1634	1446	1573	1523	1623	1627	1605	1628	1661	1645
STD	80	37	23	57	52	25	35	19	71	47	42	6
Coefficient of Variation	5	2	1	4	3	2	2	1	4	3	3	0
% Change		1	1		9	5		0	-1		2	1
Modulus of Elasticity:	37122	36561	35758	46904	42624	33524	41961	47255	40423	38936	46237	40267
Tangential (psi)	38193	42626	38545	34519	40227	39892	40727	47428	41311	45310	40892	39000
ASTM D882	33492	42215	45068	41773	43385	43504	43654	41129	42985	45471	42786	39655
Machine Direction	44921			44899			42832			43001		
	38553			42176			41436			45316		
	31910			46819			43760			48176		
Average	37365	40467	39790	42848	42079	38973	42395	45271	41573	44368	43305	39641
STD	4561	3389	4778	4231	1346	4126	1120	2929	1062	2854	2213	517
Coefficient of Variation	12	8	12	10	3	11	3	6	3	6	5	1
% Change		8	6		-2	-9		7	-2		-2	-11

SR 09.04.99
Quality Review/Date

Client: SOLMAX, File: 609-solm .WB1

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

August 17, 1998

Exposure Time and Temperature

	30 Day			60 Day			90 Day			120 Day		
Test Parameters	Baseline	23C	50C	Baseline	23C	50C	Baseline	23C	50C	Baseline	23C	50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED LLDPE - ROLL # 3299												
Modulus of Elasticity:	30734	35367	35044	40397	39310	40387	35362	41901	41901	35875	43418	41390
Tangential (psi)	41752	35479	37057	44046	43640	36248	39619	39840	39840	43090	44343	40196
ASTM D882	40528	35600	37499	37524	45699	46022	38806	39649	39649	42530	42081	44505
Transverse Direction	42841			44149			41702			41587		
	44419			41557			45890			37131		
	43232			44826			46589			40946		
Average	40584	35482	36533	42083	42883	40886	41328	40463	40463	40193	43281	42030
STD	5004	117	1309	2567	2663	4006	3948	1020	1020	2720	929	1816
Coefficient of Variation	12	0	4	6	6	10	10	3	3	7	2	4
% Change		-13	-10		2	-3		-2	-2		8	5
Indentation Hardness:	50	51	50	51	50	50	50	50	50	50	50	50
Reading	50	50	51	50	50	50	51	50	51	50	49	49
ASTM D2240	51	49	51	50	51	50	51	50	50	51	50	49
(with TYPE D DUROMETER)	53			51			51			49		
	50			51			51			49		
	51			50			50			51		
Average	51	50	51	51	50	50	51	50	50	50	50	49
STD	1	1	1	1	0	0	0	0	0	1	0	0
Coefficient of Variation	2	2	1	1	1	0	1	0	1	2	1	1
% Change		-2	-0		-0	-1		-1	-1		0	-1
Specific Gravity:	0.927	0.927	0.927	0.926	0.927	0.926	0.927	0.927	0.926	0.927	0.927	0.928
Specific Gravity (grams/cu.cm)	0.927	0.926	0.927	0.926	0.927	0.926	0.927	0.927	0.928	0.926	0.927	0.927
ASTM D792, Method A	0.927	0.927	0.928	0.927	0.926	0.927	0.926	0.926	0.926	0.926	0.926	0.927
	0.927			0.927			0.928			0.927		
	0.928			0.927			0.928			0.928		
	0.927			0.926			0.927			0.927		
Average	0.927	0.927	0.927	0.927	0.927	0.926	0.927	0.927	0.927	0.927	0.927	0.927
STD	0.000	0.001	0.001	0.001	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.000
Coefficient of Variation	0.044	0.062	0.062	0.054	0.051	0.051	0.074	0.051	0.102	0.074	0.051	0.051
% Change		-0.05	0.02		0.02	-0.02		-0.05	-0.05		-0.02	0.05
Environmental Stress Crack Resistance:												
ASTM D1693, Condition B												
Machine Direction (% Failed)	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0
Transverse Direction (% Failed)	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0

SR 09.04.99
Quality Review/Date

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

August 17, 1998

Exposure Time and Temperature

Test Parameters	30 Day Baseline	30 Day 23C	30 Day 50C	60 Day Baseline	60 Day 23C	60 Day 50C	90 Day Baseline	90 Day 23C	90 Day 50C	120 Day Baseline	120 Day 23C	120 Day 50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED LLDPE - ROLL # 3299												
Puncture Resistance:	87	88	85	94	90	92	96	102	98	94	100	95
Load @ Rupture (lbs)	81	86	92	91	85	96	101	94	99	96	98	93
FTMS 101C Method 2065	83	83	87	98	85	88	102	95	94	99	96	89
	88			93			108			94		
	89			90			107			95		
	88			93			97			99		
Average	86	86	88	93	87	92	102	97	97	96	98	92
STD	3	2	3	3	2	3	5	4	2	2	2	2
Coefficient of Variation	3	2	3	3	3	4	4	4	2	2	2	3
% Change		-0	2		-7	-1		-5	-5		2	-4
Volatiles and Extractables:	0.00	0.05	-0.05	-0.36	-0.20	-0.18	-0.05	-0.05	-0.05	-0.08	-0.05	-0.08
Diameter Change (%)	-0.13	-0.05	0.00	-0.10	-0.08	-0.25	-0.03	0.00	-0.03	0.00	-0.10	0.00
SW 870 - Appendix III-D	-0.05			-0.25			-0.03			-0.06		
Machine Direction	-0.20			-0.23			-0.03			0.03		
Average	-0.10	0.00	-0.03	-0.24	-0.14	-0.22	-0.04	-0.03	-0.04	-0.03	-0.08	-0.04
STD	0.08	0.05	0.03	0.09	0.06	0.04	0.01	0.03	0.01	0.04	0.02	-100
Volatiles and Extractables:	0.10	0.28	0.20	0.48	0.23	0.43	0.10	0.10	0.08	0.10	0.05	0.15
Diameter Change (%)	0.38	0.28	0.23	0.38	0.41	0.40	0.05	0.08	0.13	0.13	0.08	0.03
SW 870 - Appendix III-D	0.15			0.3			0.00			0.10		
Transverse Direction	0.38			0.13			0.15			0.13		
Average	0.25	0.28	0.22	0.32	0.32	0.42	0.08	0.09	0.11	0.12	0.07	0.09
STD	0.13	0.00	0.01	0.13	0.09	0.01	0.06	0.01	0.02	0.01	0.02	0.06
Volatiles and Extractables:	0.06	0.07	0.07	0.05	0.05	0.06	0.09	0.08	0.08	0.05	0.06	0.06
% Volatiles	0.07	0.06	0.08	0.05	0.05	0.05	0.08	0.08	0.09	0.05	0.05	0.06
SW 870 - Appendix III-D	0.06			0.06			0.08			0.05		
	0.07			0.05			0.08			0.05		
Average	0.07	0.07	0.08	0.05	0.05	0.06	0.08	0.08	0.09	0.05	0.06	0.06
STD	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00
Volatiles and Extractables:	0.24	0.24	0.02	0.23	0.19	0.23	0.31	0.32	0.30	0.21	0.22	0.22
% Extractables	0.24	0.11	0.24	0.22	0.24	0.21	0.28	0.31	0.33	0.21	0.22	0.22
SW 870 - Appendix III-D	0.24			0.25			0.29			0.22		
	0.23			0.25			0.31			0.22		
Average	0.24	0.18	0.13	0.24	0.22	0.22	0.30	0.32	0.32	0.22	0.22	0.22
STD	0.00	0.07	0.11	0.01	0.03	0.01	0.01	0.00	0.02	0.01	0.00	0.00

SZA 09·04·99
Quality Review/Date

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Exposed to MSW Leachate

August 17, 1998

Exposure Time and Temperature

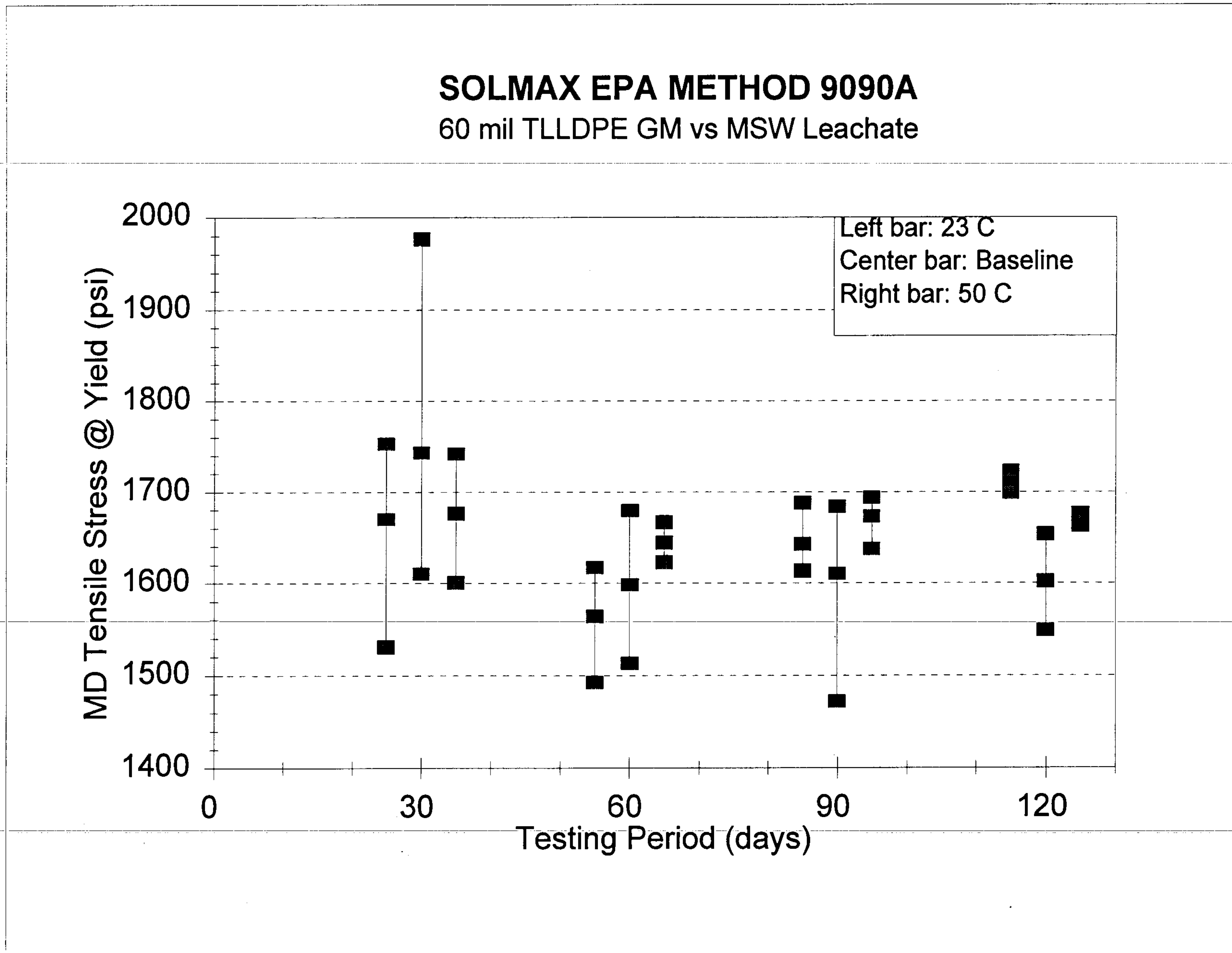
Test Parameters	30 Day Baseline	30 Day 23C	30 Day 50C	60 Day Baseline	60 Day 23C	60 Day 50C	90 Day Baseline	90 Day 23C	90 Day 50C	120 Day Baseline	120 Day 23C	120 Day 50C
GEOMEMBRANE: SOLMAX 60 mil TEXTURED LLDPE - ROLL # 3299												
Tear Resistance:	47	48	43	46	51	47	43	46	47	42	47	45
Tear Resistance (lbs)	45	44	44	45	51	48	46	43	45	45	48	50
ASTM D1004	47	44	44	45	46	52	43	47	46	41	46	46
Machine Direction	44			43			43			47		
	45			42			43			43		
	46			42			42			46		
Average	46	45	44	44	49	49	43	45	46	44	47	47
STD	1	2	1	2	2	2	1	2	1	2	1	2
Coefficient of Variation	3	5	1	4	5	4	3	4	2	5	2	5
% Change		-1	-4		13	12		5	6		7	7
Tear Resistance:	46	49	43	44	48	46	41	45	46	41	45	46
Tear Resistance (lbs)	44	46	44	48	44	53	47	44	45	46	48	46
ASTM D1004	49	47	43	44	52	46	40	43	43	47	46	44
Transverse Direction	44			50			46			45		
	46			43			40			44		
	43			47			46			47		
Average	45	47	43	46	48	48	43	44	45	45	46	45
STD	2	2	1	3	3	3	3	1	1	2	1	1
Coefficient of Variation	5	3	1	5	7	7	7	2	3	5	3	2
% Change		4	-4		4	5		2	3		3	1
Hydrostatic Resistance:	340	345	350	355	350	350	350	355	345	355	350	345
Load @ Rupture (psi)	340	345	350	355	345	355	355	355	355	350	355	350
ASTM D751	345	345	340	350	345	350	355	350	355	350	340	345
	345			350			345			395		
	340			355			340			345		
	350			345			355			355		
Average	343	345	347	352	347	352	350	353	352	358	348	347
STD	4	0	6	4	2	2	6	2	5	17	6	2
Coefficient of Variation	1	0	2	1	1	1	2	1	1	5	2	1
% Change		0	1		-1	0		1	0		-3	-3

SRH 09.04.99
Quality Review/Date

EPA METHOD 9090A TEST RESULTS

TRI LOG #: E2068-94-05

GRAPHS OF SELECTED TEST RESULTS - LLDPE



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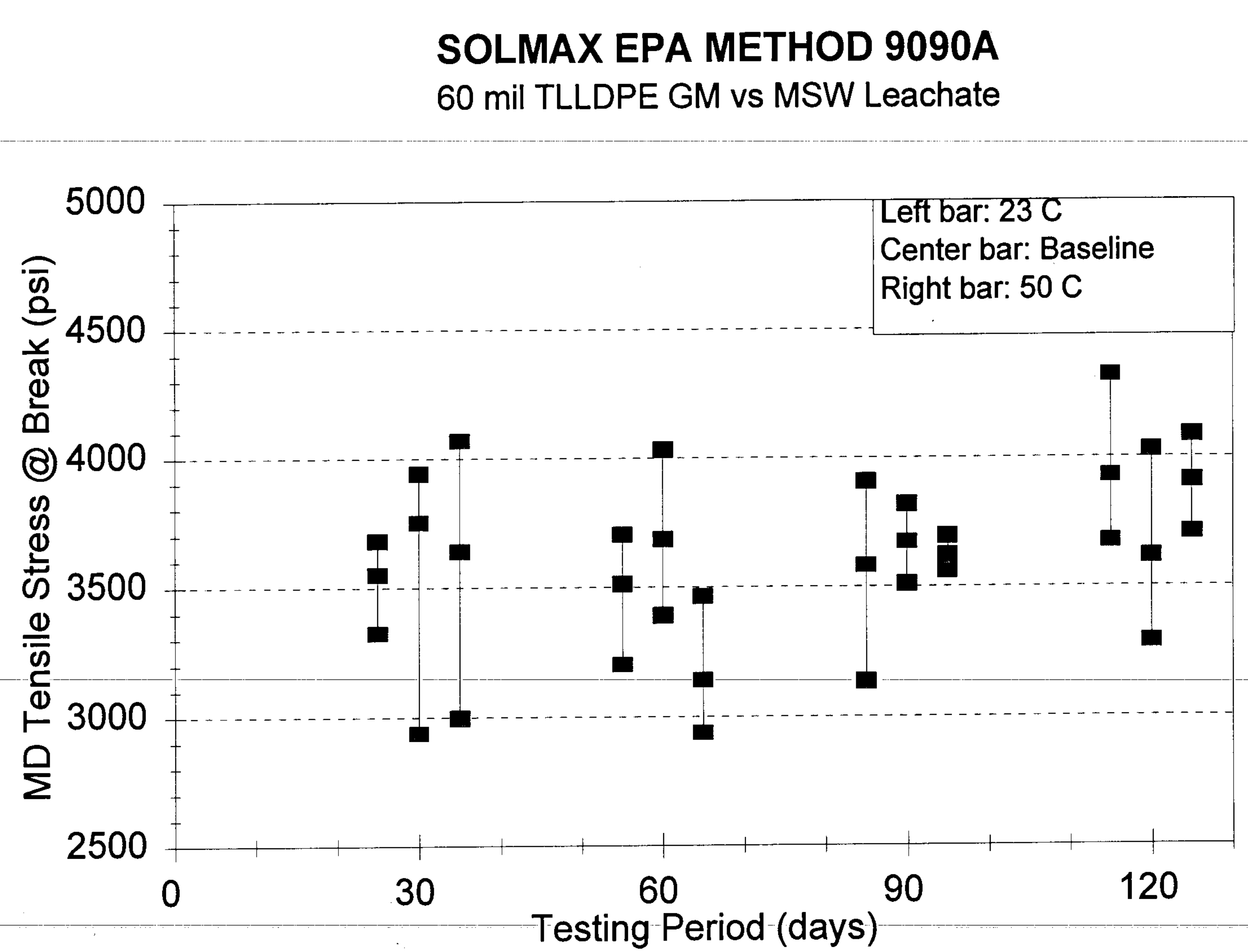

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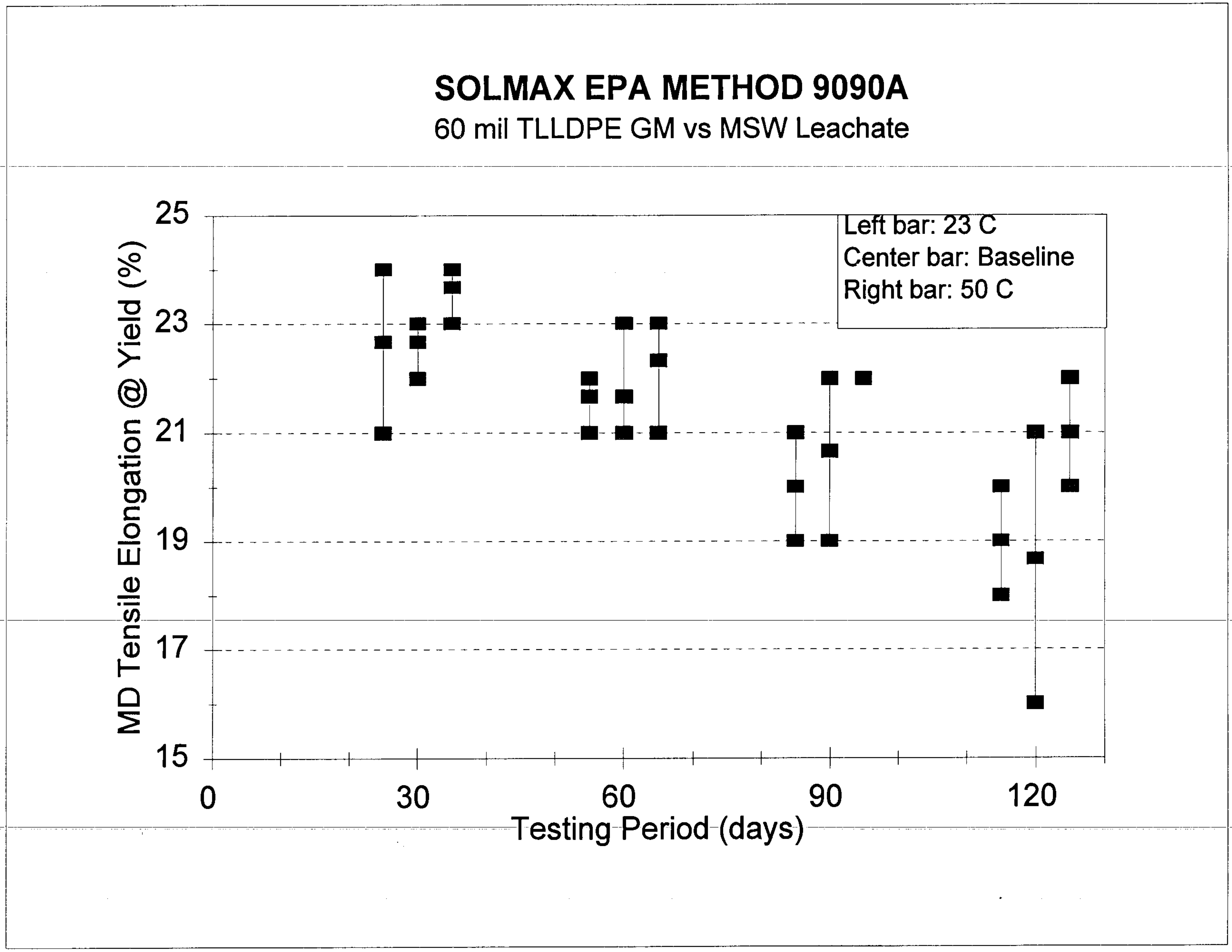

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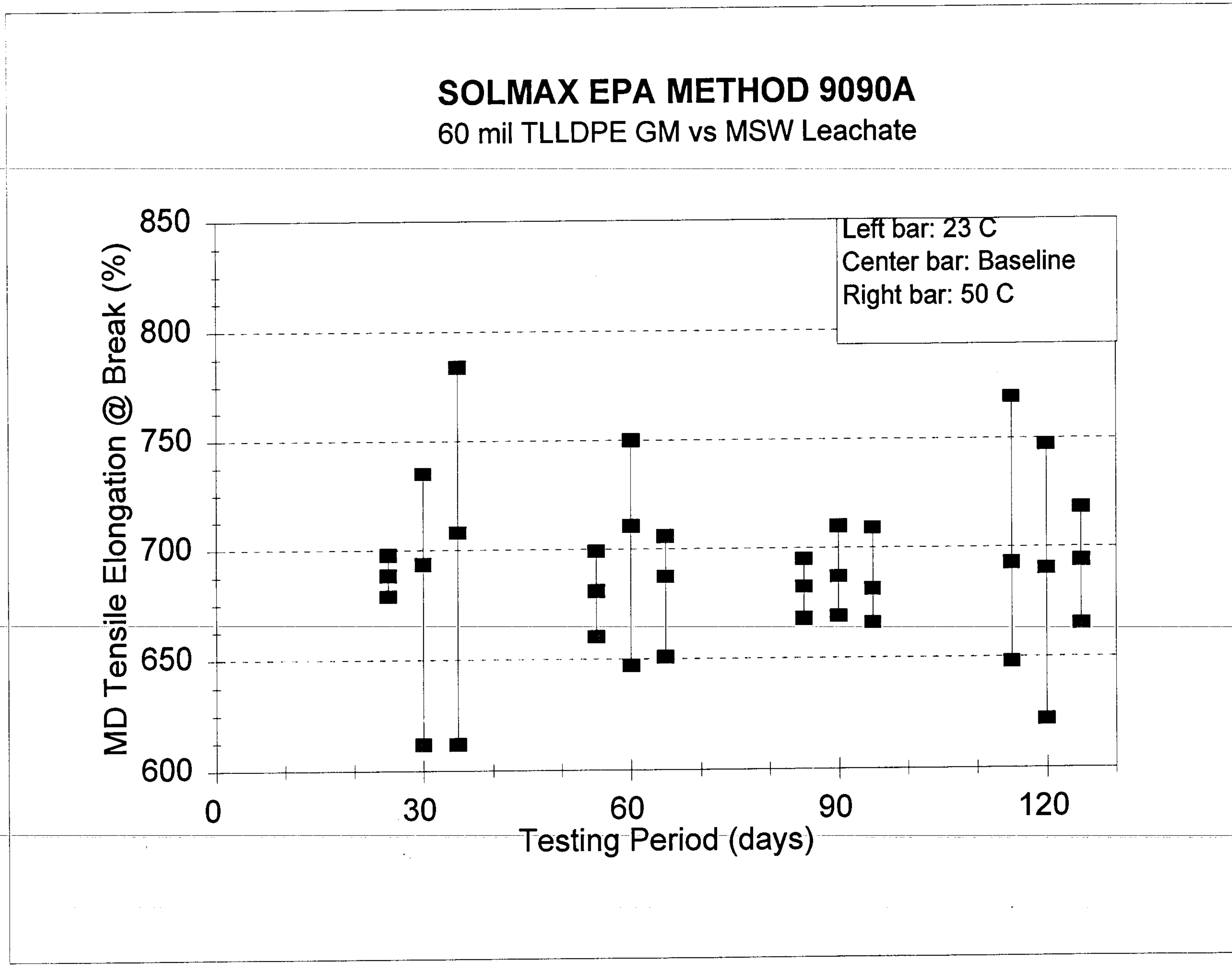

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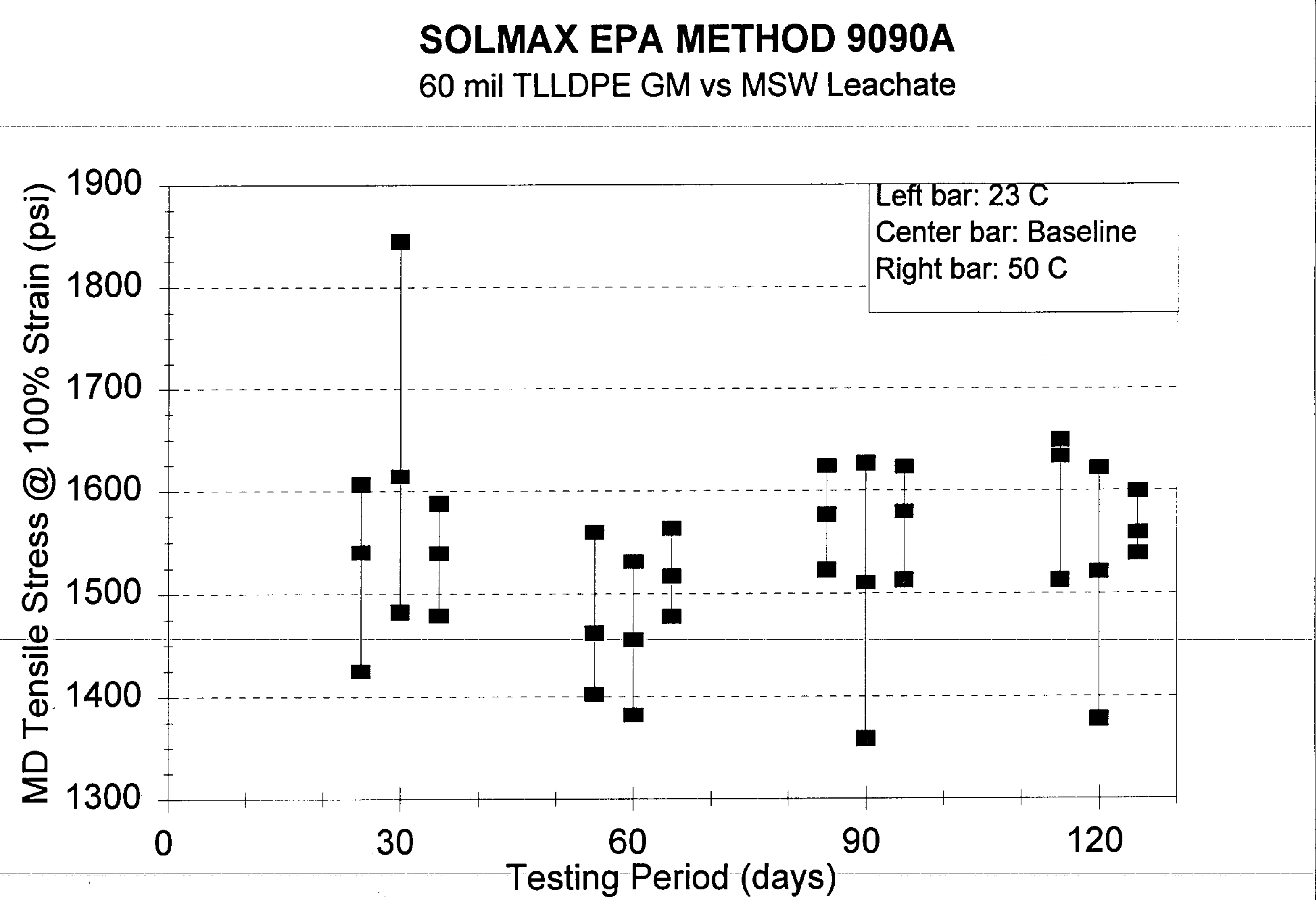

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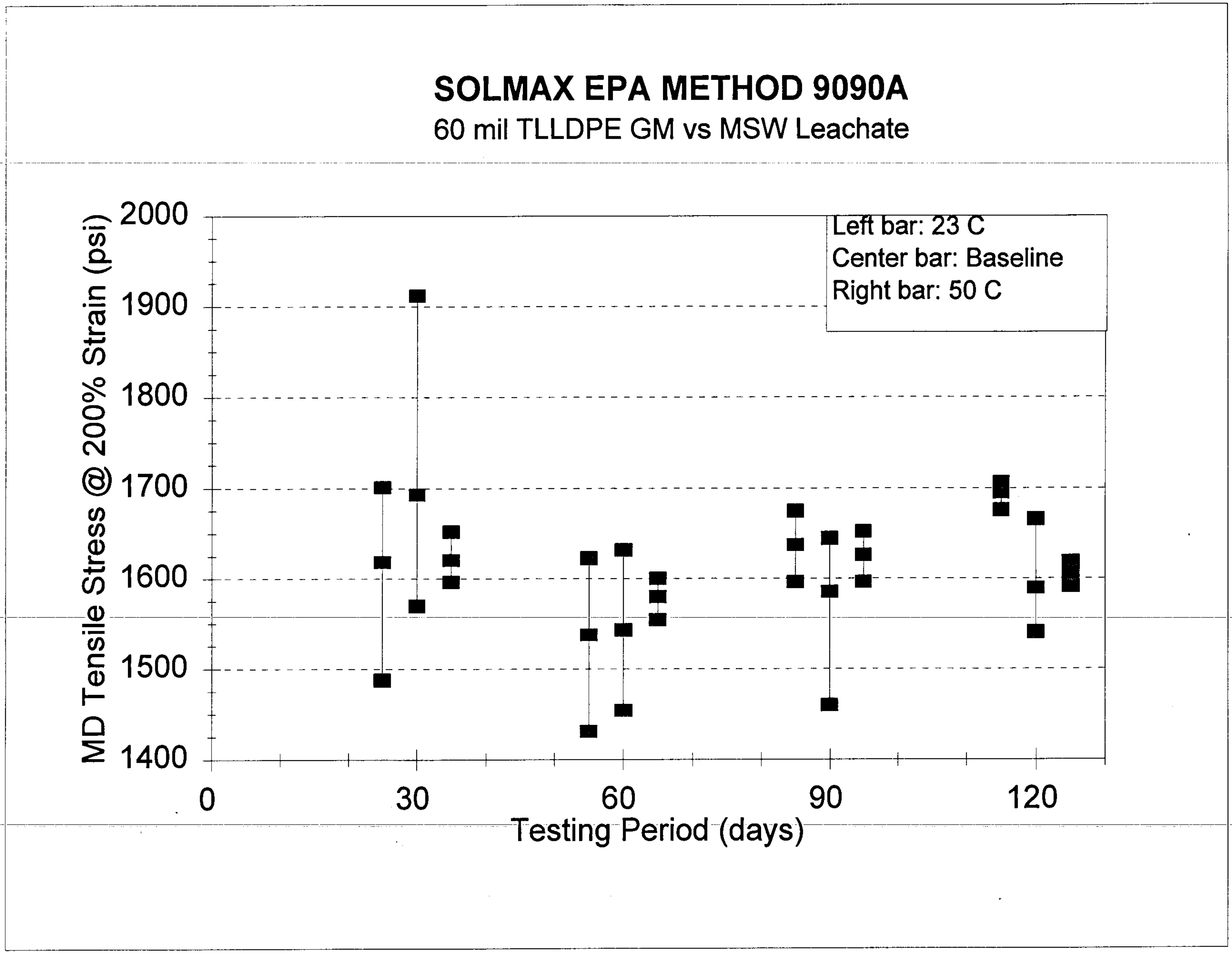

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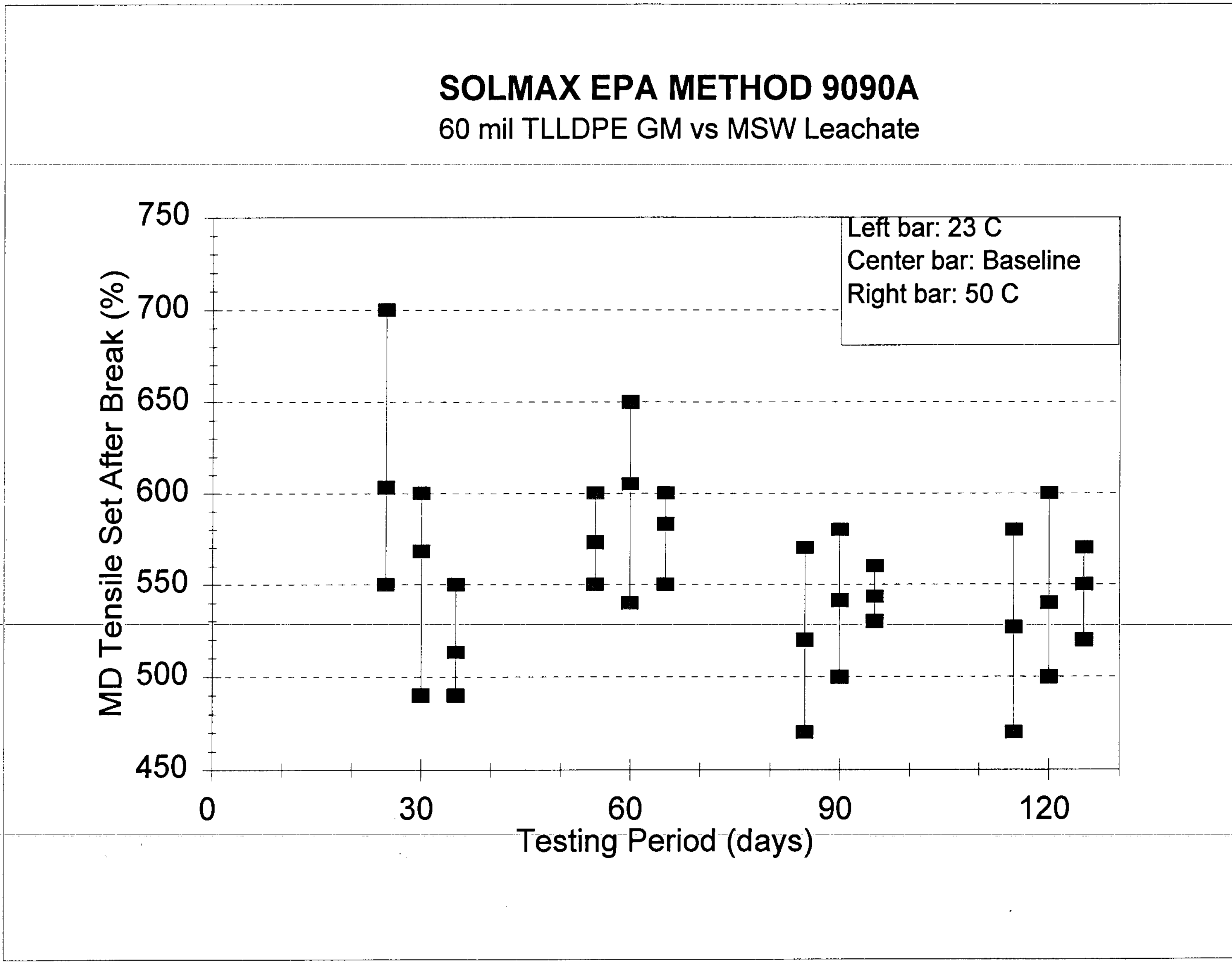

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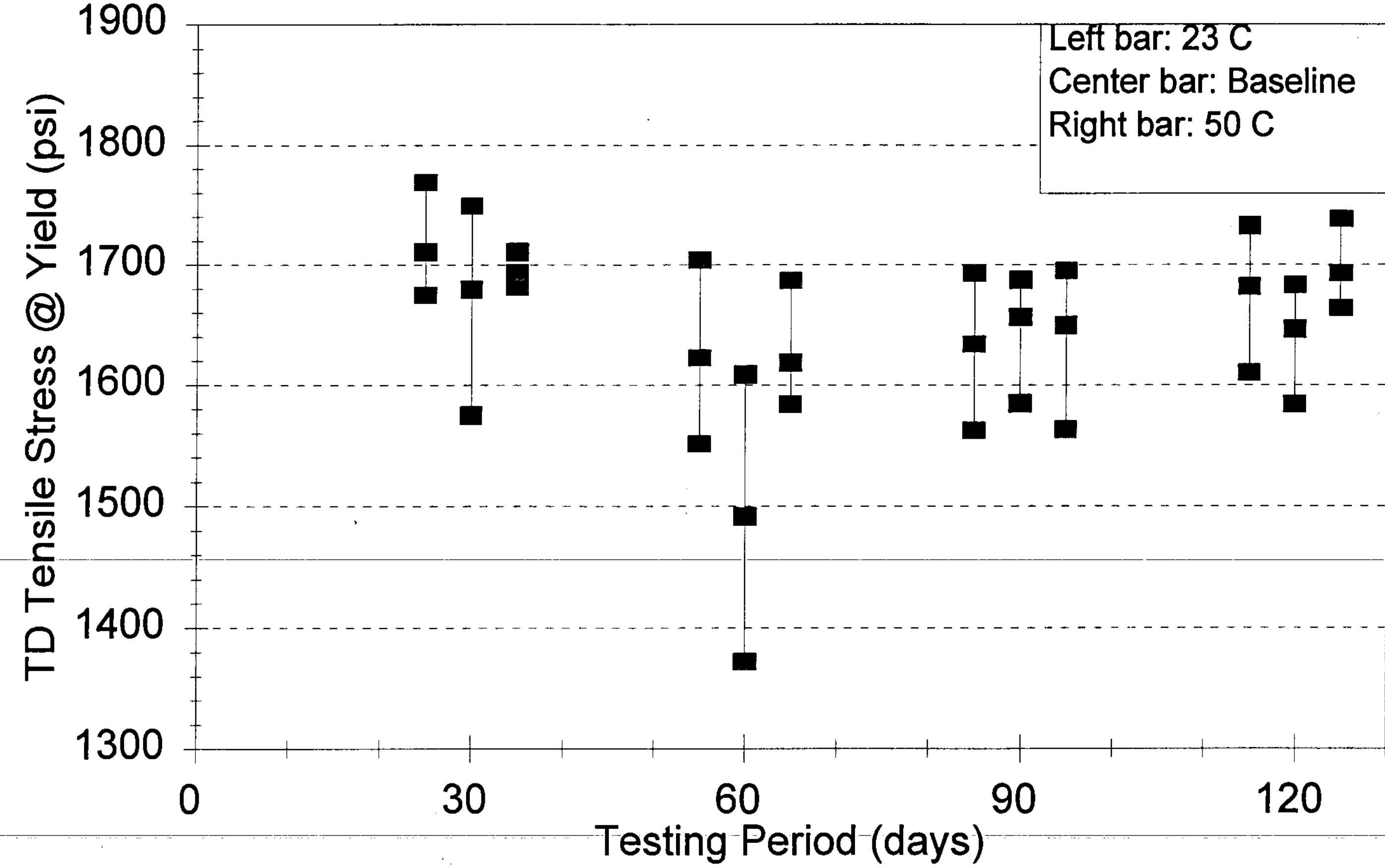
SOLMAX EPA METHOD 9090A

60 mil TLLDPE GM vs MSW Leachate



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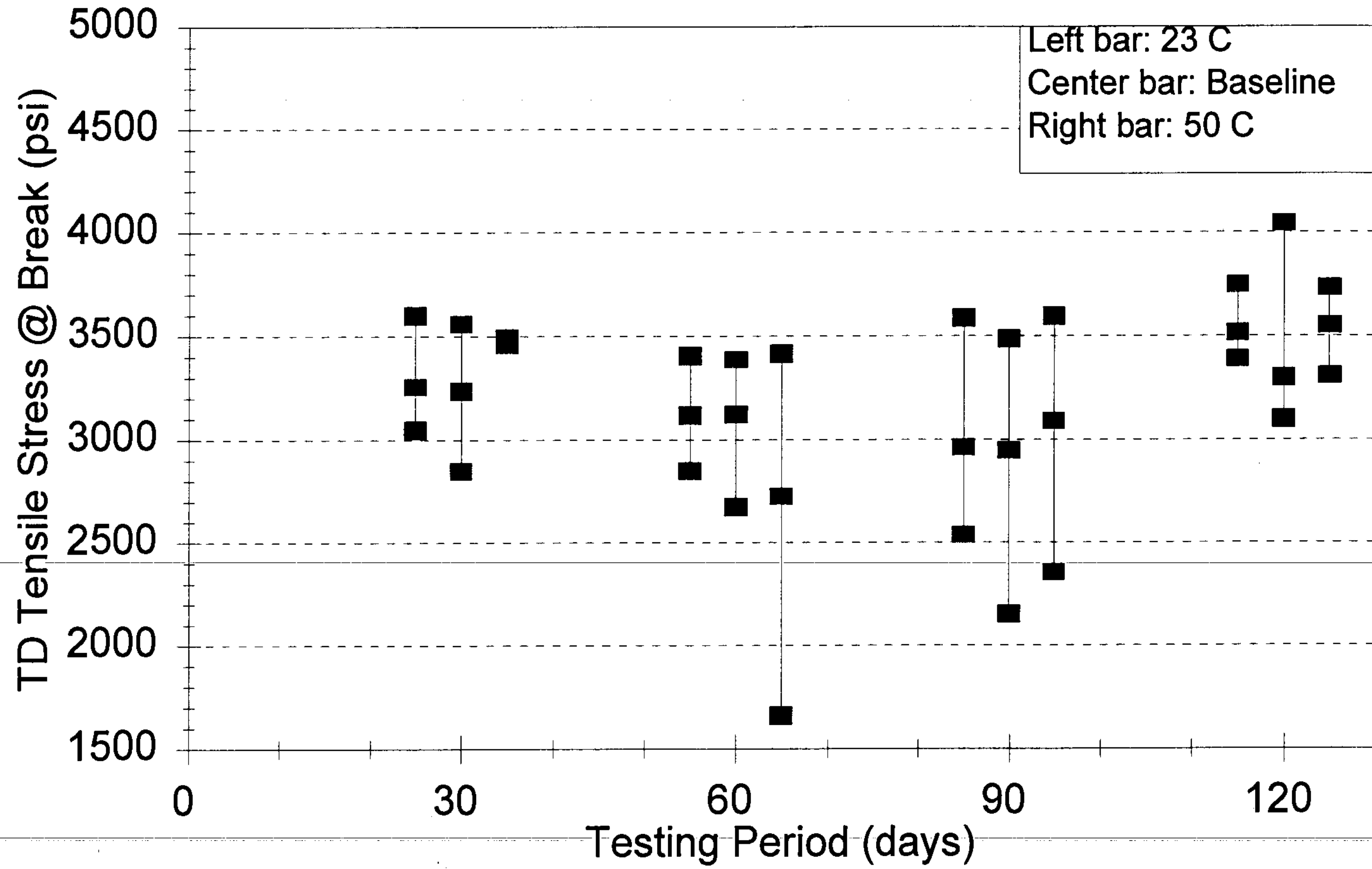
SOLMAX EPA METHOD 9090A

60 mil TLLDPE GM vs MSW Leachate



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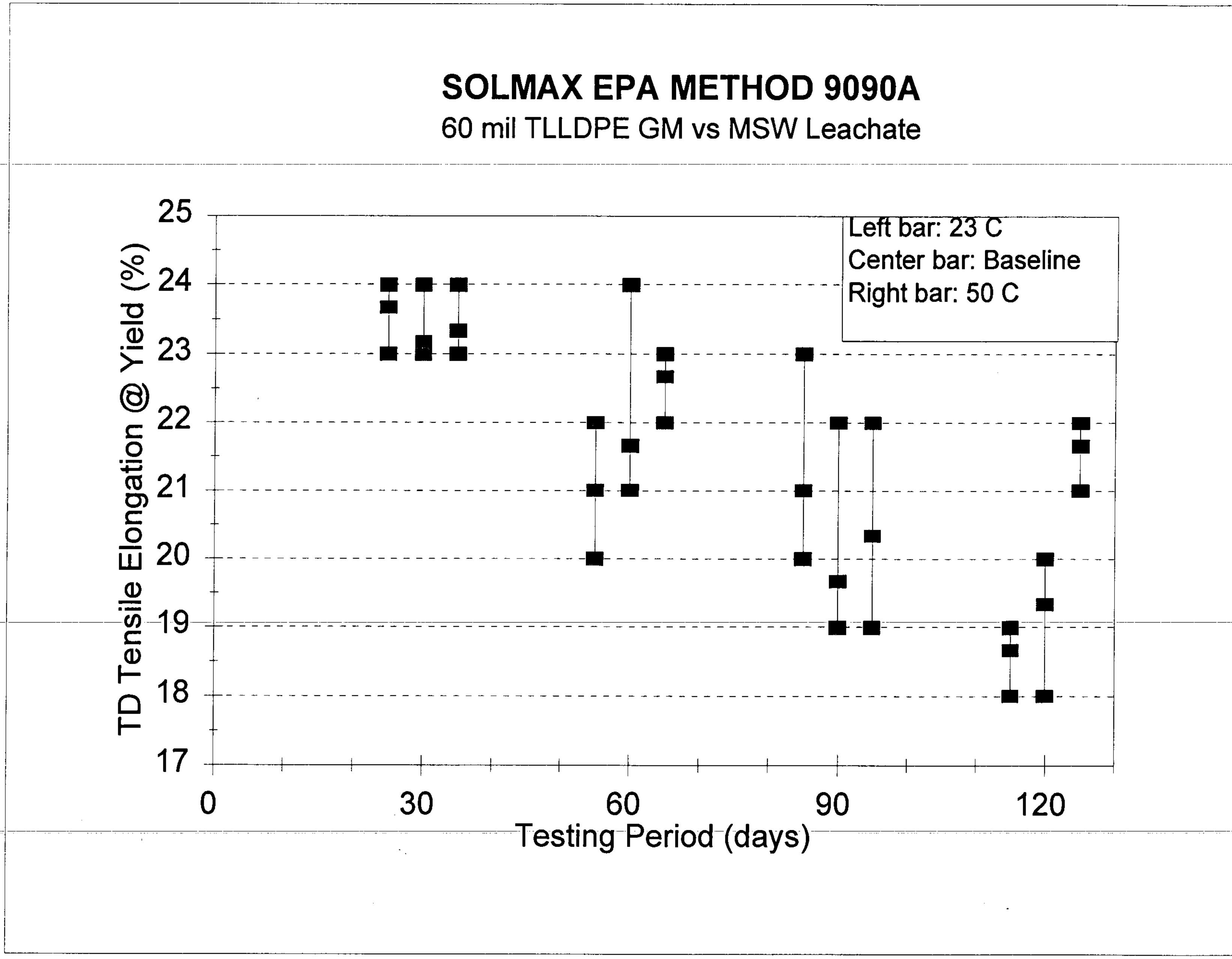

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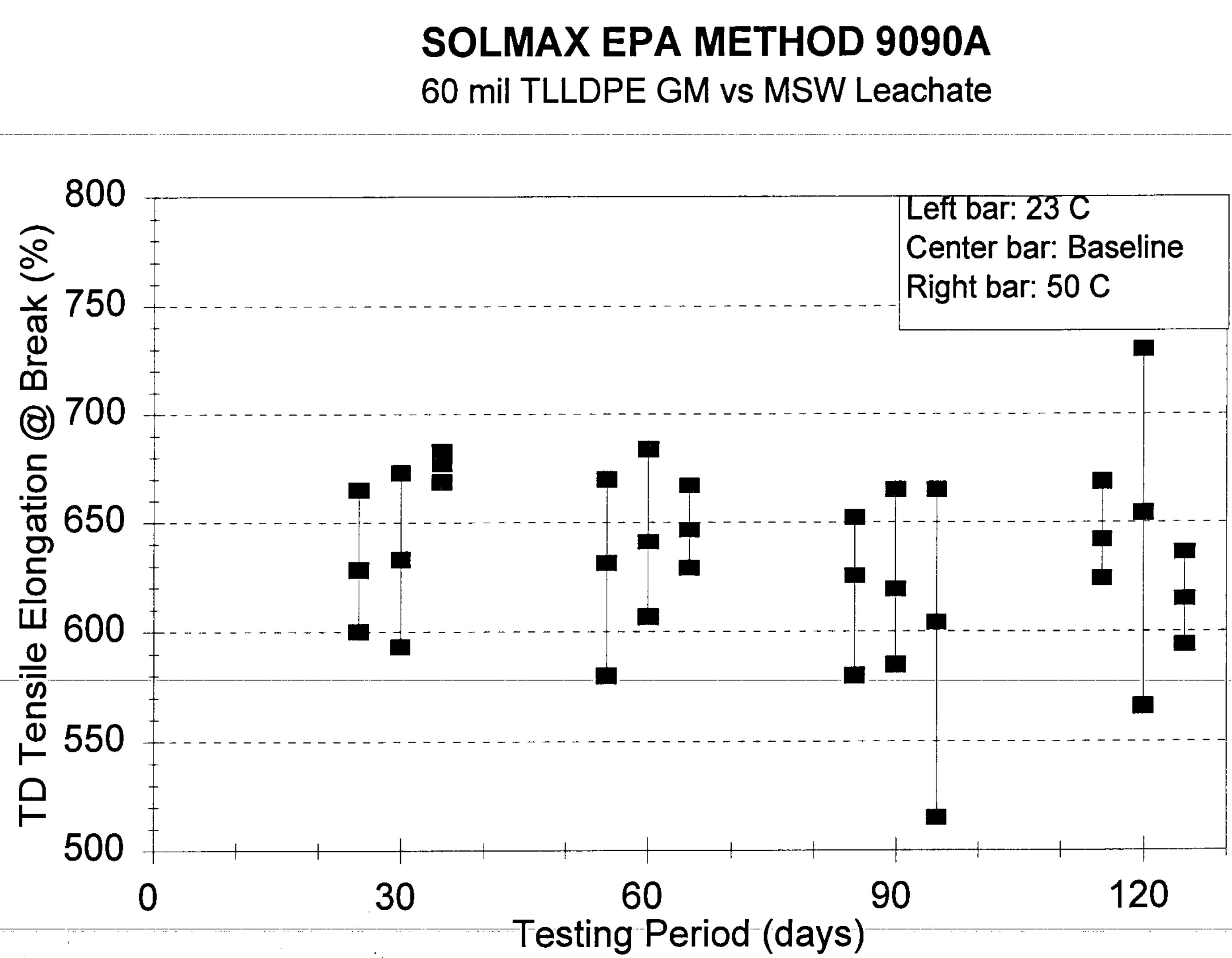

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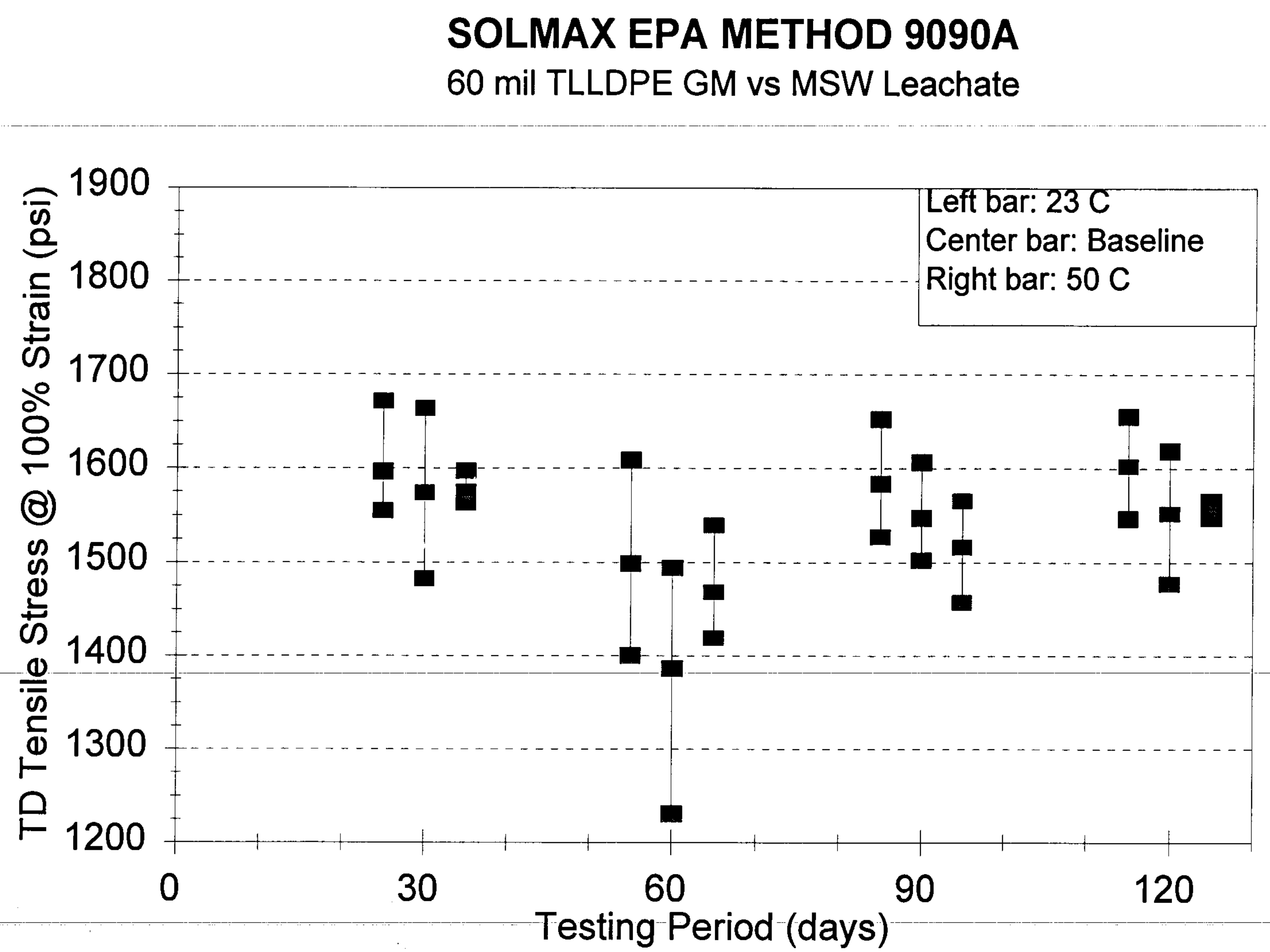

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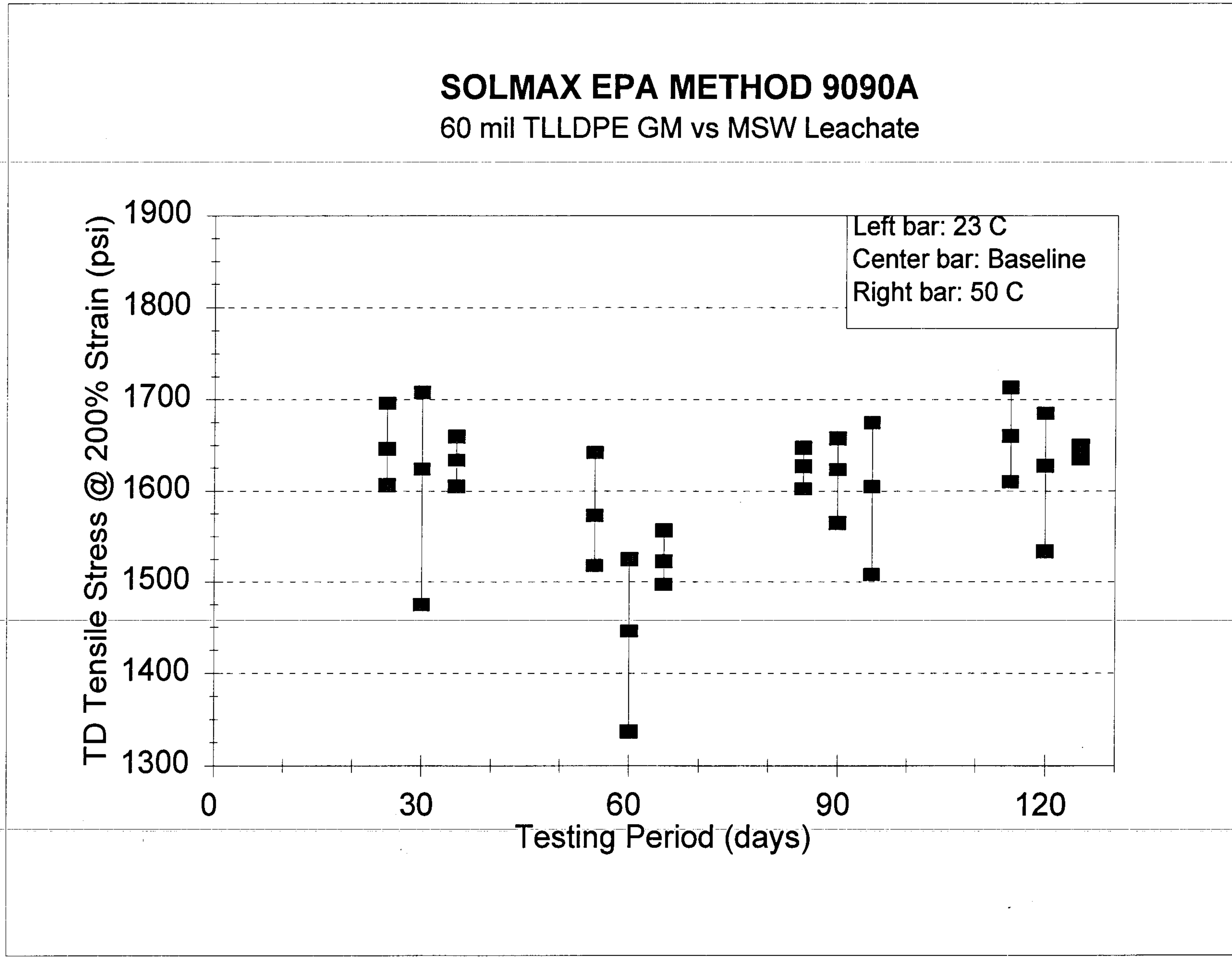

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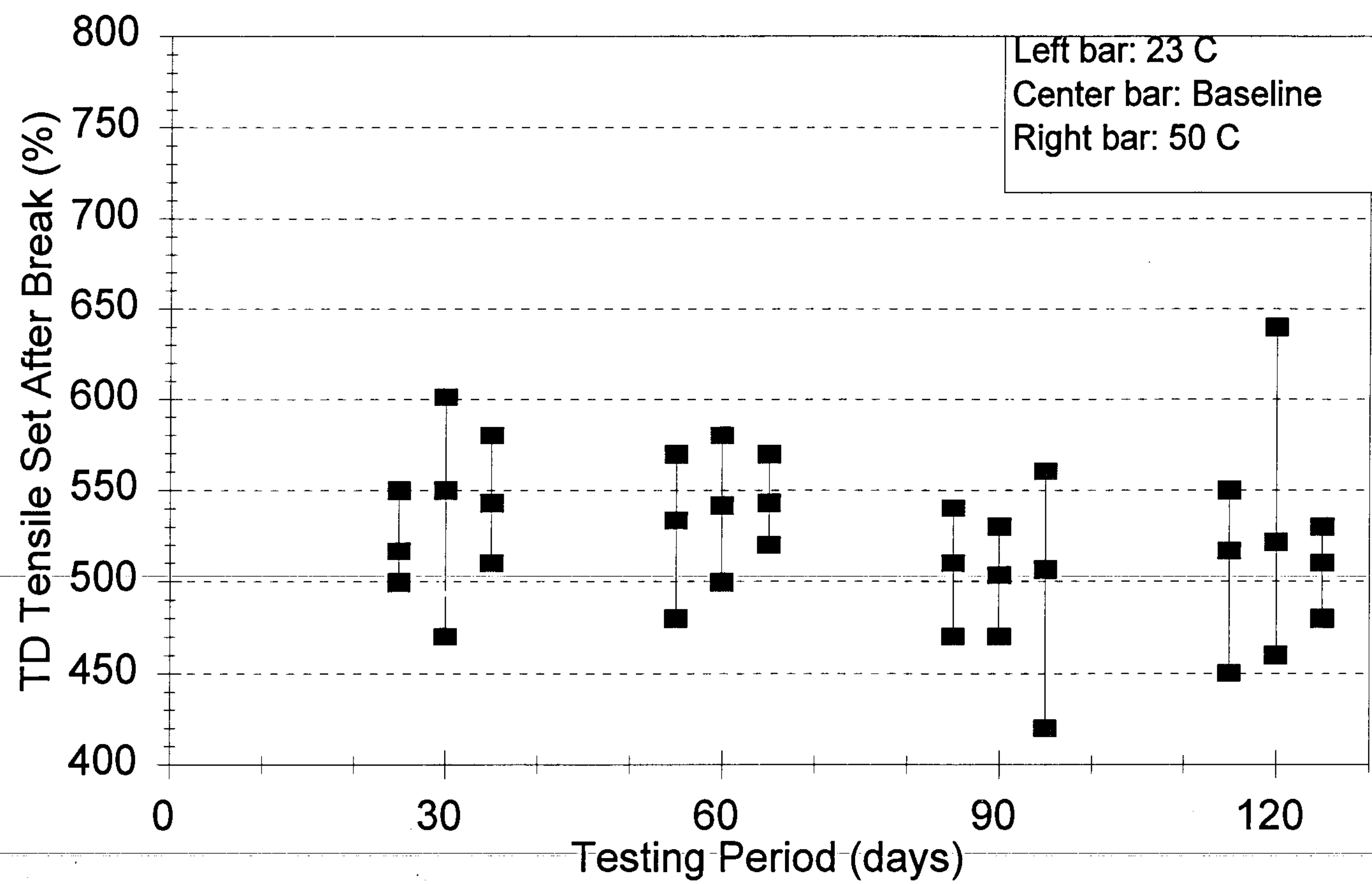
SOLMAX EPA METHOD 9090A

60 mil TLLDPE GM vs MSW Leachate



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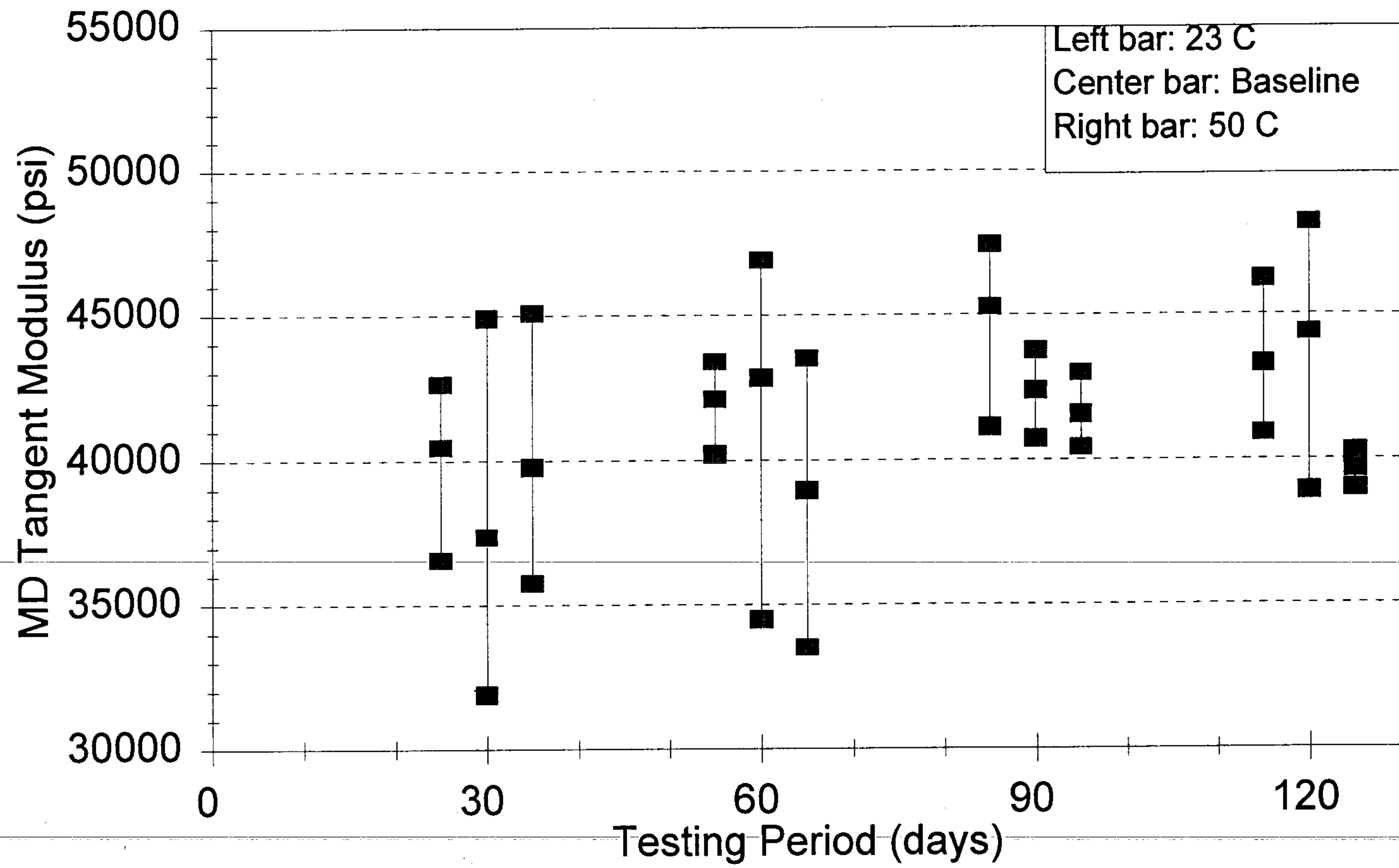
SOLMAX EPA METHOD 9090A

60 mil TLLDPE GM vs MSW Leachate



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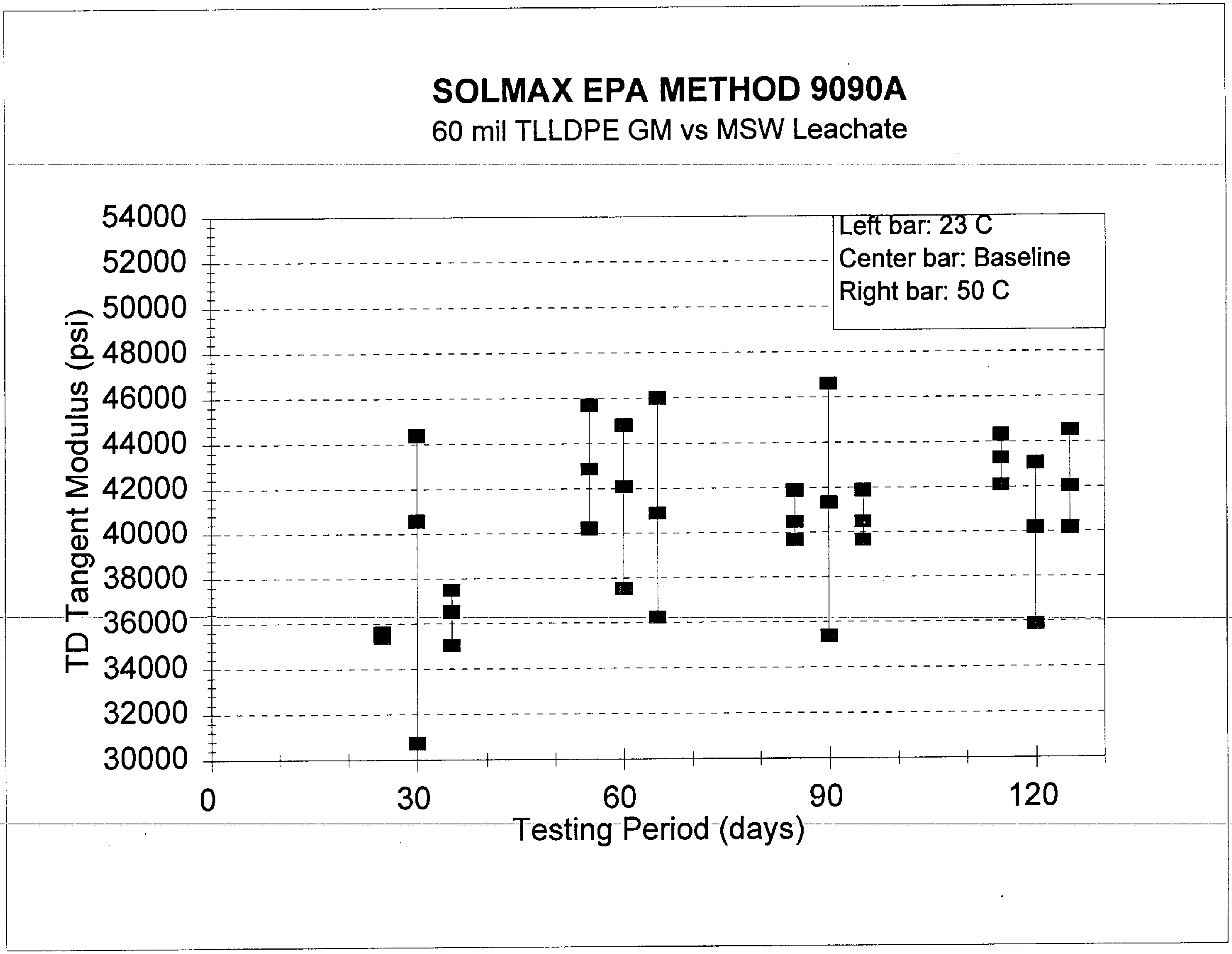

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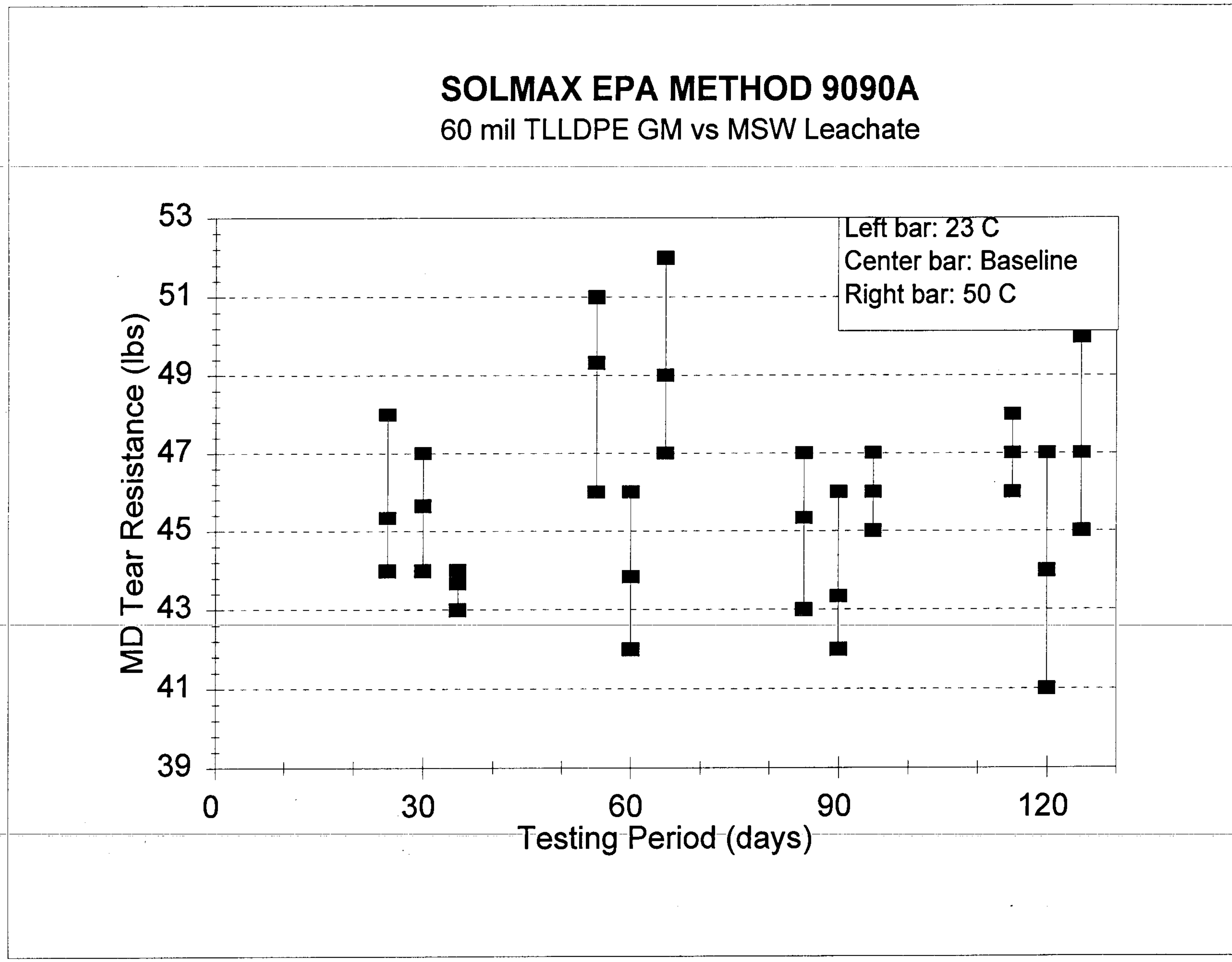

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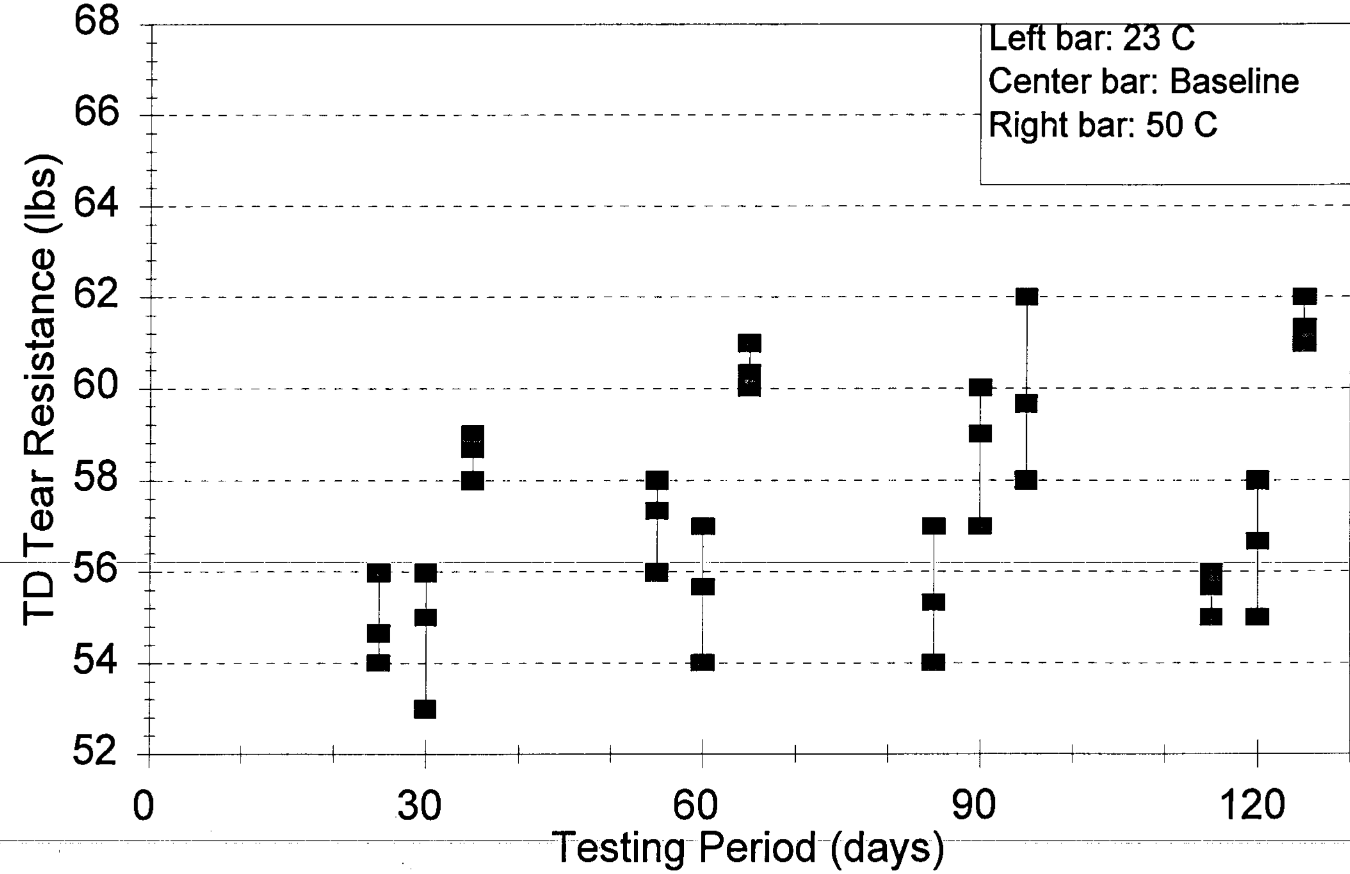
SOLMAX EPA METHOD 9090A

60 mil THDPE GM vs MSW Leachate



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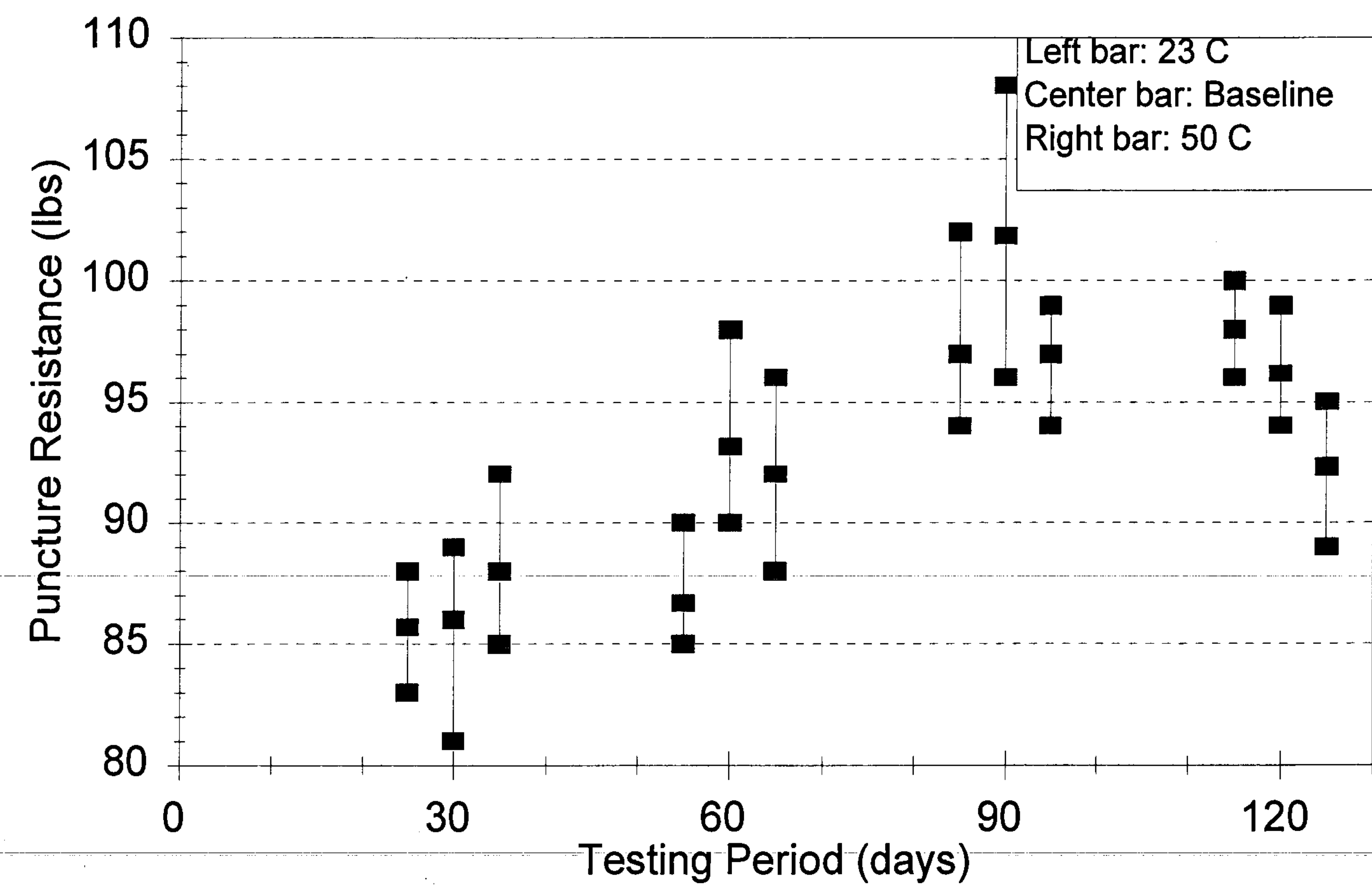
SOLMAX EPA METHOD 9090A

60 mil TLLDPE GM vs MSW Leachate



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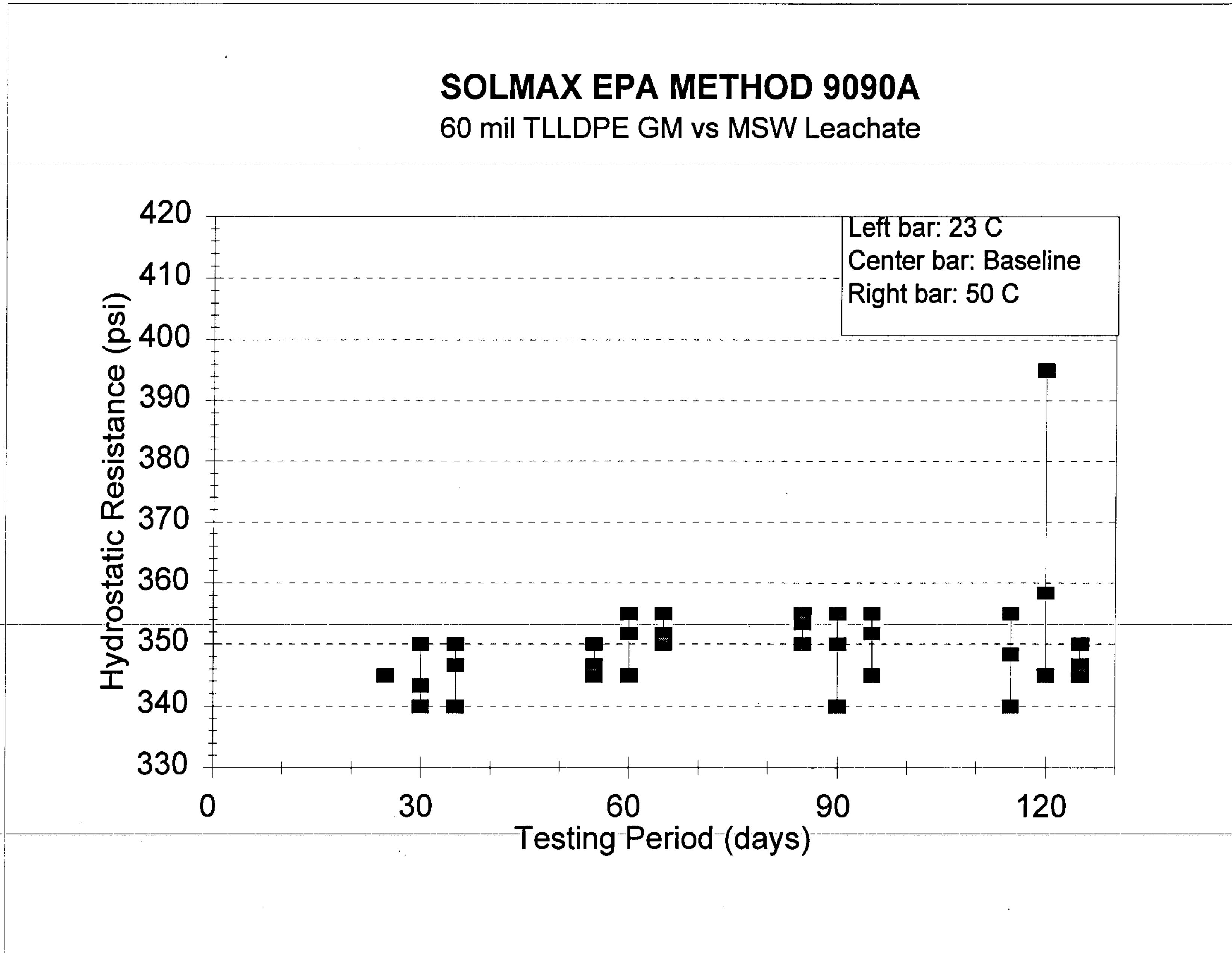

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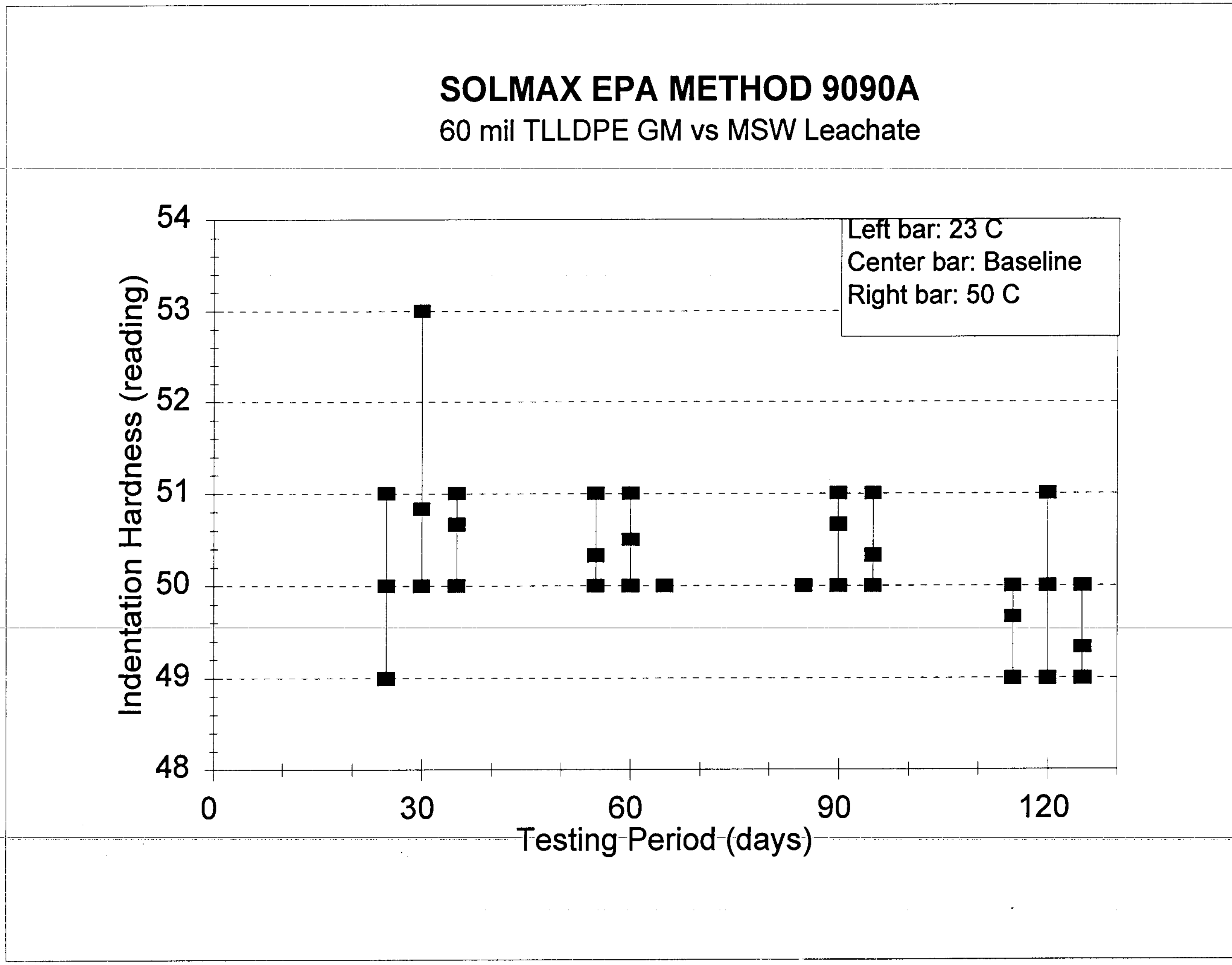


Client: SOLMAX, File: 945-solm.wb1

A Final Report:

Laboratory Testing of SKAPS Industries HDPE Geonet EPA Method 9090A

January 2003

Submitted to:

SKAPS Industries
571 Industrial Parkway
Commerce, GA 30529

Attn: **Mr. Perry Vyas**

Submitted by:

TRI/Environmental, Inc.
9063 Bee Caves Rd.
Austin, Texas 78733

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

January 10, 2003

Mr. Perry Vyas
SKAPS Industries
571 Industrial Parkway
Commerce, GA 30529

Dear Mr. Vyas:

TRI/Environmental, Inc. (TRI) is pleased to present this Final Report for a geonet chemical compatibility study performed in general accordance with EPA Method 9090A.

TRI is very pleased to be of service to SKAPS Industries. Please call me if you have any questions or require any additional information.

Respectfully submitted,

Sam R. Allen

Sam R. Allen
Vice President and Division Manager
Geosynthetic Services Division

9063 Bee Caves Road, Austin, TX 78733 / 512 263 2101 / fax: 512 263 2558

FOREWORD

The testing reported herein is based upon accepted industry practice as well as the test method listed. TRI/Environmental Inc. (TRI) neither accepts responsibility for nor makes claim as to the final use and purpose of the materials tested.

Tests were performed under laboratory conditions and not under actual usage conditions. TRI can give no conclusions as to the serviceability, life expectancy or general durability of the products tested when used in a lining and/or leachate collection system.

1.0 INTRODUCTION

This report describes the work performed by TRI/Environmental, Inc. (TRI) to determine the chemical compatibility of one HDPE geonet product with one waste leachate. The objective was to determine the resistance of the geonet to changes caused by exposure to leachate. Changes in physical, mechanical and hydraulic properties were measured after exposure to the leachate at 23°C and 50°C for 30, 60, 90 and 120 days. Exposures were performed in accordance with the exposure regimen specified in United States Environmental Protection Agency (EPA) Method 9090A.

All samples were logged in and all testing performed under TRI log number E2173-46-05. Methods, results and discussion are provided in the sections which follow. Test results are provided in the Tables of Results which accompany this report.

2.0 METHODS

2.1 Materials

The material selected for evaluation in this chemical compatibility study was Skaps Industries HDPE biplaner geonet.

2.2 Leachate

The waste leachate used was supplied by TRI and was a synthetic MSW leachate approximating the PaDER leachate recipe.

2.3 Exposure Conditions

Geonet specimens were exposed to the waste leachate following the specifications of EPA Method 9090A as they relate to exposure to waste fluids. The tanks used for these exposures were maintained at 23 ± 2°C and 50 ± 2°C throughout the 120-day exposure period. Tanks were constructed from chemically resistant glass fitted with stirrers. The 50°C tanks were heated with a circulating hot water heat exchanger system. They were also sealed with a lid, and a reflux condenser was installed to minimize loss of volatile leachate components.

2.4 Testing Procedures

Table 1 lists tests performed on the geonet. The number of test replicates was doubled for baseline determinations on unexposed material.

Table 1. Tests performed on Skaps Industries HDPE Geonet		
Test or Physical Property	**Method**	**Number of replicate specimens**
Dimensions and weight	EPA 9090	2 readings
Strip Tensile Strength	ASTM D 5035	3 MD & TD readings
Strip Tensile Elongation	ASTM D 5035	3 MD & TD readings
Compressive Strength	ASTM D 1621	3 readings
Transmissivity	ASTM D 4716	3 readings
CBR Puncture	ASTM D 6241	3 readings
Volatiles and Extractables	SW870 - Appendix III-D	2 readings

3.0 RESULTS AND DISCUSSION

Test results are presented in the Test Results section which is included with this report. Test results are presented in tabular form as well as graphical form.

In considering these results, it must be determined through engineering judgment whether observed differences in the value of test results measured before and after immersion are due to product variability, unidentified factors relating to the test procedure, or leachate interaction with the product. Any significant chemical interaction with leachate would be expected to result in degradation trends which are consistent across the various properties being evaluated, and not isolated to one set of test results only. However, with each type of material there may be specific properties which are highly sensitive to leachate-induced effects. These factors must be considered in evaluating the various test results for a given product.

Also of critical importance is the issue of product variability. With HDPE geonets, a range of physical and mechanical index test values covering 20% or more of the average is not uncommon. This can be traced to variability inherent in the product, and the randomness associated with the onset of failure under the specified testing conditions. However, in chemical compatibility testing the statistical sampling of a broad range of manufactured product is not possible. Therefore, the small size of the sample population tested at each time point must be taken into consideration. The criteria to be applied in evaluating data measured before and after leachate immersion should be that property changes, if observed, are consistent and so great that product variability and experimental factors can be ruled out.

In this report, standard deviations (STD) are reported for measurements involving three or more replicate specimens. In statistics, the standard deviation is defined as root of the mean squared deviations of individual test results about the mean value. The standard deviation is a quantitative measure of variability within a group of measurements.

One related measure of variability observed within a sample set, relative to the magnitude of the mean value itself, is the *coefficient of variation or variance* (COV). The coefficient of variance is defined as the standard deviation divided by the mean associated with a group of specimens, and may be expressed as a percentage. The COV provides an indication of what proportion of the mean value may be attributable to random experimental factors or product variability. It is useful to consider apparent changes in property values against the criterion of COV since observed changes which fall below the COV may not be significant. This approach was used in preparing the tables in the next section.

The term *range* refers to the difference between the extreme highest and lowest points within a group of measured values. Considering range as a percentage of the mean values provides another measure of variability within a dataset.

In the tables, the high and low extremes for percentage change in mean values are listed for comparison against COV and range as a percentage of mean from the baseline sample group. The high and low percentage changes are the extremes from data measured at 30, 60, 90 and 120 days.

Skaps Industries HDPE Biplaner Geonet

Table 2 illustrates the range of variability in baseline data compared with some of the observed changes in average test values measured after immersion for the geonet.

Table 2. Baseline coefficients of variation and range of percentage change results

Test	Baseline COV (%)*	Baseline Range as % of Mean*	High Observed % Change	Low Observed % Change
Strip Tensile Strength (MD)	7	17	9	-9
Strip Tensile Elongation @ Maximum Load (MD)	6	18	9	-8
Compressive Strength	6	17	4	-6
Transmissivity	2.18	6.63	-0.17	-9.54
CBR Puncture	7	20	9	-9

4.0 CONCLUSION

Changes in certain measured physical and mechanical properties were noted for the geonet. However, the observed variances were random and are believed to be the effects of product variability and experimental factors. In the opinion of the authors, the data, considered together, support the conclusion that observed variances were not caused by exposure to the test leachate.

TRI/Environmental, Inc. is pleased to have been selected to participate in this project. We trust that the information provided in this report meets your requirements for technical documentation of this chemical compatibility study. Please do not hesitate to call if you have any questions or require any additional information.

Respectfully submitted,

Sam R. Allen

Sam R. Allen
Vice President and Division Manager
Geosynthetic Services Division

TRI/Environmental, Inc.

APPENDIX:

EPA METHOD 9090A TEST RESULTS

SKAPS INDUSTRIES HDPE GEONET TEST RESULTS

Dimensions

TRI LOG NUMBER: E2173-46-05

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Client: Skaps Industries

Report Date: January 2003
TRI Log Number: E2173-46-05

Exposure Time and Temperature

Test Parameters	Temp.	30 Day Baseline	30 Day Exposed	30 Day % Change	60 Day Baseline	60 Day Exposed	60 Day % Change	90 Day Baseline	90 Day Exposed	90 Day % Change	120 Day Baseline	120 Day Exposed	120 Day % Change
GEONET: HDPE GEONET EXPOSED TO PADER MSW SYNTHETIC LEACHATE													
Thickness (mils)	23C	224	228	1.8	234	234	0.0	230	230	0.0	228	228	0.0
	50C	232	232	0.0	228	229	0.4	230	231	0.4	229	229	0.0
Length (inches)	23C	6.00	6.00	0.0	6.00	5.85	-2.5	6.00	5.96	-0.7	6.02	6.01	-0.2
	50C	6.00	5.83	-2.8	6.00	5.89	-1.8	6.00	6.00	0.0	5.99	6.00	0.2
Width (inches)	23C	4.04	4.06	0.5	4.01	4.02	0.2	4.01	4.04	0.7	4.02	4.04	0.5
	50C	4.02	4.02	0.0	4.01	4.01	0.0	4.03	4.03	0.0	4.03	4.01	-0.5
Mass (g)	23C	14.91	14.92	0.1	15.46	15.47	0.1	15.30	15.31	0.1	15.23	15.25	0.1
	50C	17.06	17.06	0.0	16.86	16.86	0.0	17.05	17.05	0.0	14.93	14.93	0.0

EPA METHOD 9090A TEST RESULTS

SKAPS INDUSTRIES HDPE GEONET TEST RESULTS

TRI LOG NUMBER: E2173-46-05

NOTE ON TEST RESULTS

This section includes generated test data provided in both tabular and graphical form. Each graph is represented by a series of "I" beam plots. Each "I" beam represents a single test population and illustrates the high and low value as the end points, and the mean as a central box on the beam.

At each testing period, two "I" beams are shown. The left beam represents the 23°C exposed specimens while the right beam represents the 50°C specimens. The initial "I" beam represents the baseline or unexposed test specimens.

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Client: Skaps Industries

Report Date: January 2003
TRI Log Number: E2173-46-05

Exposure Time and Temperature

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
GEONET: HDPE GEONET EXPOSED TO PaDER MSW SYNTHETIC LEACHATE									
Strip Tensile Properties:	143	158	173	130	167	131	166	168	133
Maximum Strength (lbs)	167	144	162	153	152	167	148	165	150
ASTM D5035	153	151	147	149	173	126	157	172	144
Machine Direction	150								
	170								
	144								
Average	155	151	161	144	164	141	157	168	142
STD	11	6	11	10	9	18	7	3	7
Coefficient of Variation	7	4	7	7	5	13	5	2	5
% Change		-2	4	-7	6	-9	2	9	-8
Strip Tensile Properties:	33	34	35	30	35	35	31	35	33
Elongation @ Max. Strength (%)	36	28	32	35	42	34	33	36	28
ASTM D5035	35	33	24	32	31	31	35	33	31
Machine Direction	30								
	31								
	33								
Average	33	32	30	32	36	33	33	35	31
STD	2	3	5	2	5	2	2	1	2
Coefficient of Variation	6	8	15	6	13	5	5	4	7
% Change		-4	-8	-2	9	1	0	5	-7

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Client: Skaps Industries

Report Date: January 2003
TRI Log Number: E2173-46-05

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
				Exposure Time and Temperature					

GEONET: HDPE GEONET EXPOSED TO PaDER MSW SYNTHETIC LEACHATE

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Strip Tensile Properties:	56	55	60	57	49	59	53	60	47
Maximum Strength (lbs)	57	53	59	57	56	54	53	61	59
ASTM D5035	64	51	60	56	62	51	52	58	56
Transverse Direction	57								
	51								
	53								
Average	56	53	60	57	56	55	53	60	54
STD	4	2	0	0	5	3	0	1	5
Coefficient of Variation	7	3	1	1	10	6	1	2	9
% Change		-6	6	1	-1	-3	-7	6	-4
Strip Tensile Properties:	129	171	163	151	169	148	155	135	165
Elongation @ Max. Strength (%)	172	160	139	159	157	141	168	147	177
ASTM D5035	153	115	133	160	189	149	167	149	148
Transverse Direction	133								
	151								
	149								
Average	148	149	145	157	172	146	163	144	163
STD	14	24	13	4	13	4	6	6	12
Coefficient of Variation	10	16	9	3	8	2	4	4	7
% Change		1	-2	6	16	-1	10	-3	10

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Client: Skaps Industries

Report Date: January 2003
TRI Log Number: E2173-46-05

Exposure Time and Temperature

Test Parameters	Baseline	30 Day		60 Day		90 Day		120 Day	
		23C	50C	23C	50C	23C	50C	23C	50C
GEONET: HDPE GEONET EXPOSED TO PaDER MSW SYNTHETIC LEACHATE									
Compressive Strength:	35951	36083	33732	25141	34508	39672	33045	35164	31349
Strength at Rib Layover (psf)	35677	31833	39106	40149	23798	32742	32879	34119	33234
ASTM D1621	38252	34801	31922	37048	42045	37877	39494	40486	36492
	36837								
	32100								
	33888								
Average	35451	34239	34920	34113	33450	36764	35139	36590	33692
STD	1989	1780	3051	6469	7487	2937	3080	2788	2124
Coefficient of Variation	6	5	9	19	22	8	9	8	6
% Change		-3	-1	-4	-6	4	-1	3	-5
Transmissivity:	1.96E-03	1.88E-03	1.91E-03	1.77E-03	1.94E-03	1.87E-03	1.90E-03	1.96E-03	1.90E-03
(m2/sec)	1.95E-03	1.88E-03	1.69E-03	1.76E-03	1.91E-03	1.84E-03	1.93E-03	1.96E-03	1.96E-03
ASTM D4716	2.01E-03	1.89E-03	1.94E-03	1.78E-03	1.84E-03	1.82E-03	1.95E-03	1.94E-03	1.89E-03
	1.94E-03								
	2.00E-03								
	1.88E-03								
Average	1.96E-03	1.88E-03	1.91E-03	1.77E-03	1.90E-03	1.84E-03	1.93E-03	1.95E-03	1.92E-03
STD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coefficient of Variation	2.18	0.25	1.07	0.46	2.21	1.11	1.07	0.48	1.61
% Change		-3.75	-2.21	-9.54	-3.07	-5.79	-1.53	-0.17	-2.04
CBR Puncture:	292	238	292	279	345	296	308	279	256
Puncture Resistance (lbs)	235	247	298	289	276	278	311	265	275
ASTM D6241	280	270	265	240	273	255	289	246	288
	285								
	286								
	284								
Average	277	252	285	269	298	276	303	263	273
STD	19	13	14	21	33	17	10	14	13
Coefficient of Variation	7	5	5	8	11	6	3	5	5
% Change		-9	3	-3	8	-0	9	-5	-1

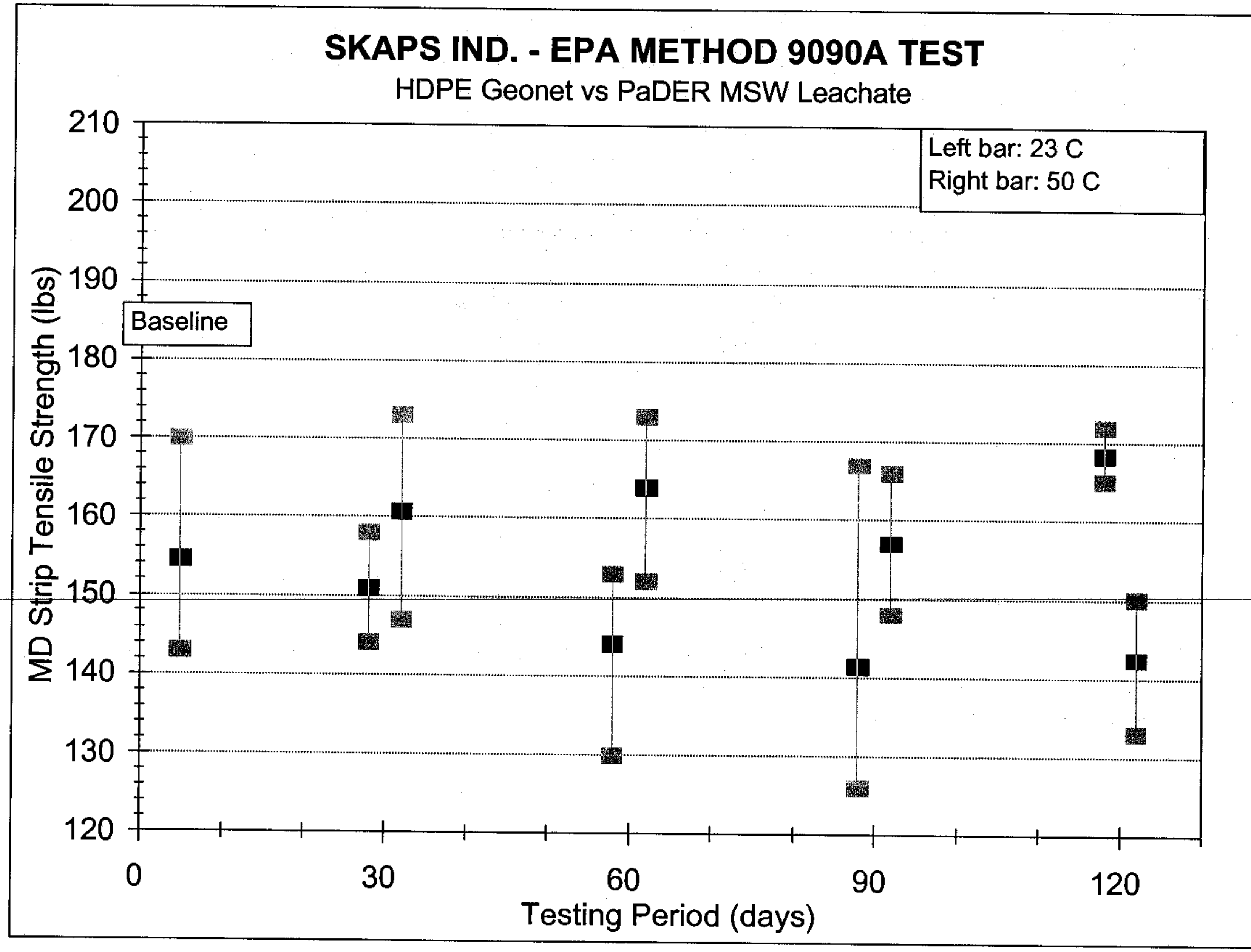
TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Client: Skaps Industries

Report Date: January 2003
TRI Log Number: E2173-46-05

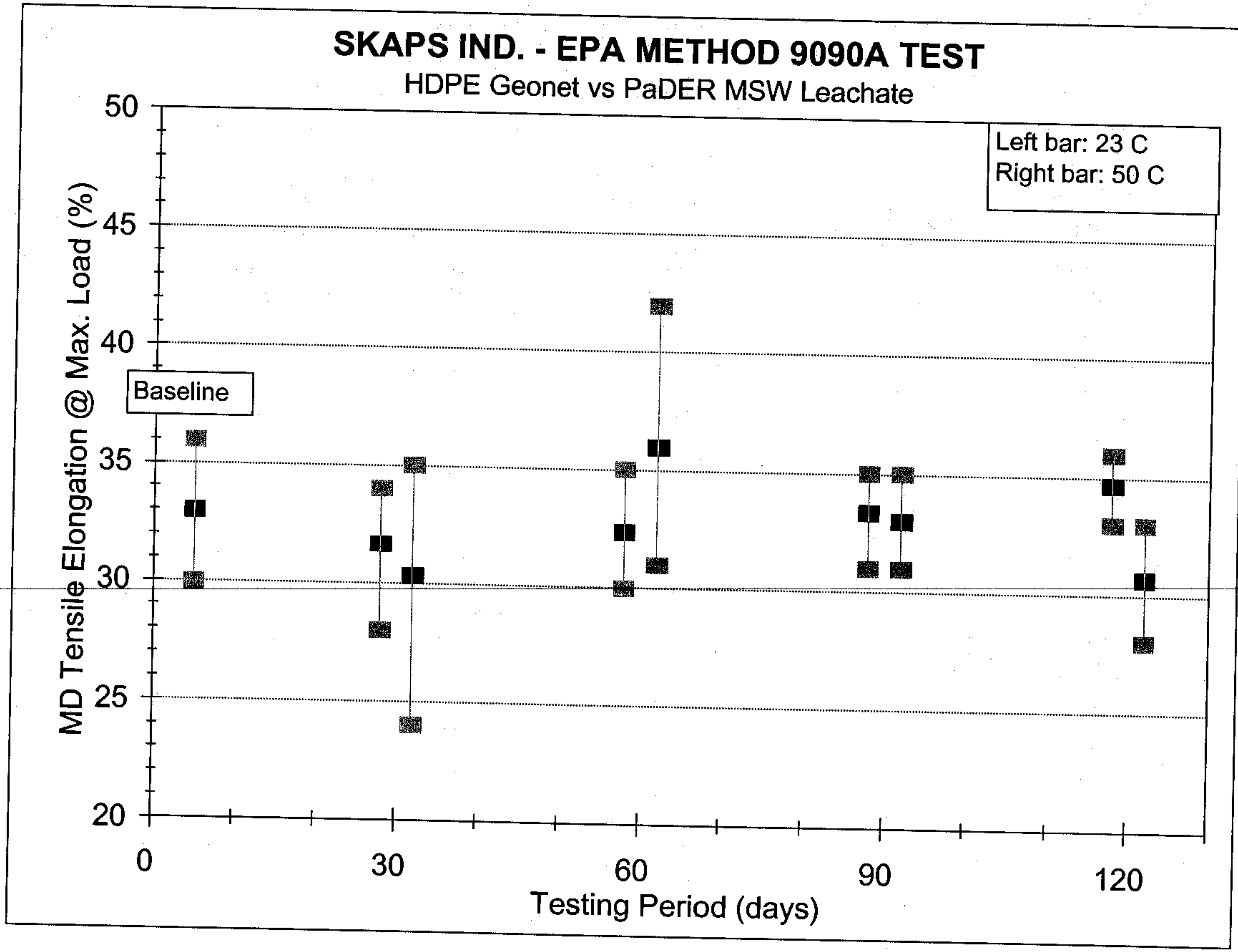
Exposure Time and Temperature

GEONET: HDPE GEONET EXPOSED TO PaDER MSW SYNTHETIC LEACHATE

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Volatiles and Extractables:	-1.51	-1.51	-1.01	-2.00	-0.51	0.00	-1.00	-0.50	-1.01
Machine Diameter Change (%)	-3.02	-2.51	-1.51	-1.01	-1.50	-1.01	-2.01	-2.53	-0.51
SW 870 - Appendix III-D	-2.51								
	-1.01								
Average	-2.01	-2.01	-1.26	-1.51	-1.01	-0.51	-1.51	-1.52	-0.76
STD	0.79	0.50	0.25	0.50	0.50	0.51	0.50	1.02	0.25
Volatiles and Extractables:	-3.02	-3.48	-1.51	-1.04	-1.01	-1.49	-0.51	-1.03	-1.54
Transverse Diameter Change (%)	-3.98	-3.48	-1.00	-3.05	-1.00	-1.52	-1.02	-1.54	-1.53
SW 870 - Appendix III-D	-1.99								
	-0.50								
Average	-2.37	-3.48	-1.26	-2.05	-1.01	-1.51	-0.77	-1.29	-1.54
STD	1.29	0.00	0.26	1.01	0.01	0.02	0.26	0.25	0.00
Volatiles and Extractables:	0.07	0.11	0.09	0.11	0.16	0.12	0.11	0.12	0.11
% Volatiles	0.07	0.11	0.12	0.10	0.16	0.08	0.10	0.13	0.08
SW 870 - Appendix III-D	0.07								
	0.07								
Average	0.07	0.11	0.11	0.11	0.16	0.10	0.11	0.13	0.10
STD	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.01	0.01
Volatiles and Extractables:	0.16	0.25	0.21	0.16	0.13	0.22	0.08	0.18	0.10
% Extractables	0.14	0.18	0.25	0.32	0.30	0.27	0.19	0.35	0.30
SW 870 - Appendix III-D	0.16								
	0.25								
Average	0.18	0.22	0.23	0.24	0.22	0.25	0.14	0.27	0.20
STD	0.04	0.04	0.02	0.08	0.09	0.03	0.05	0.08	0.10



TRI Geosynthetics Division Client: Skaps Industries, File: 465-skaps-gn .WB1



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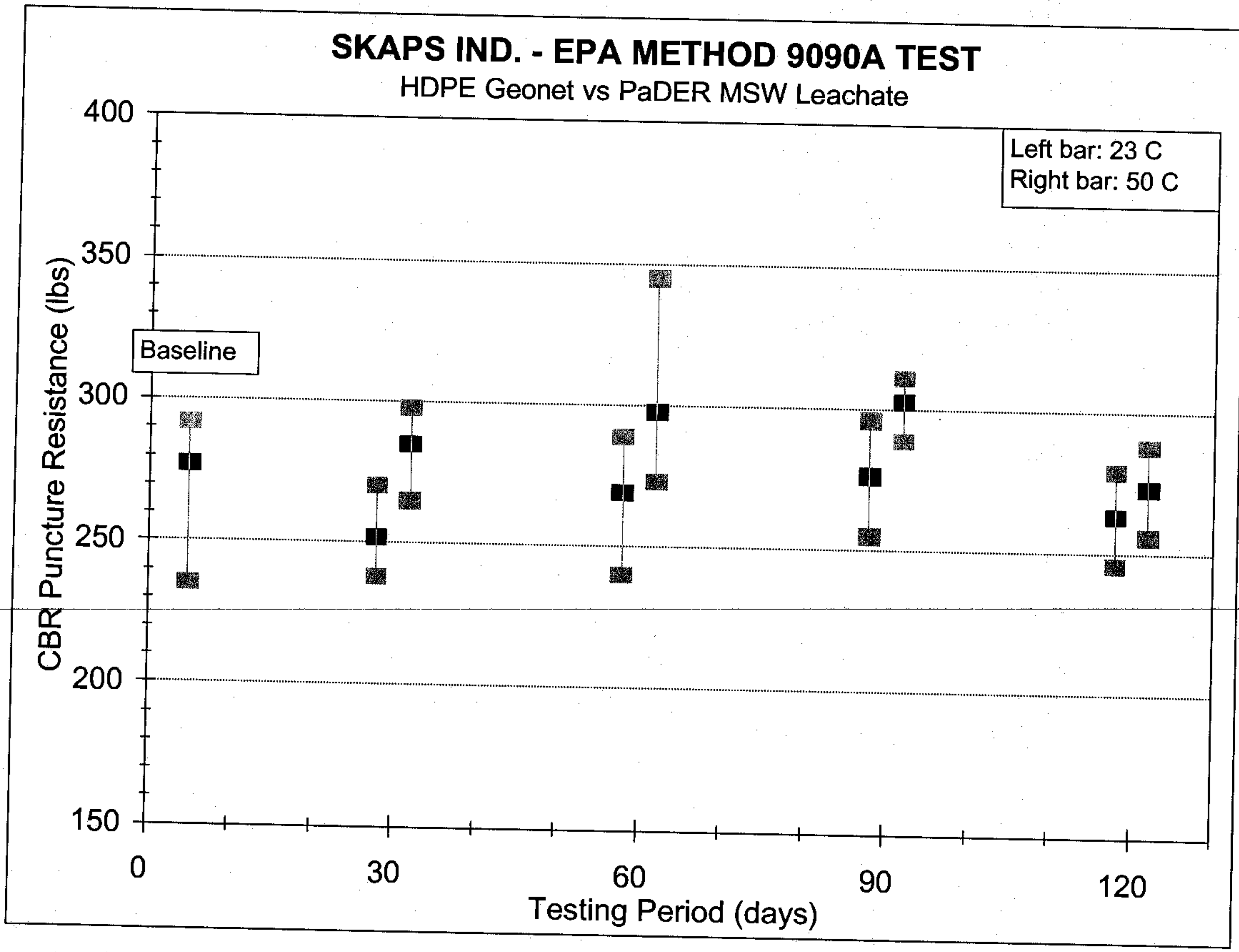

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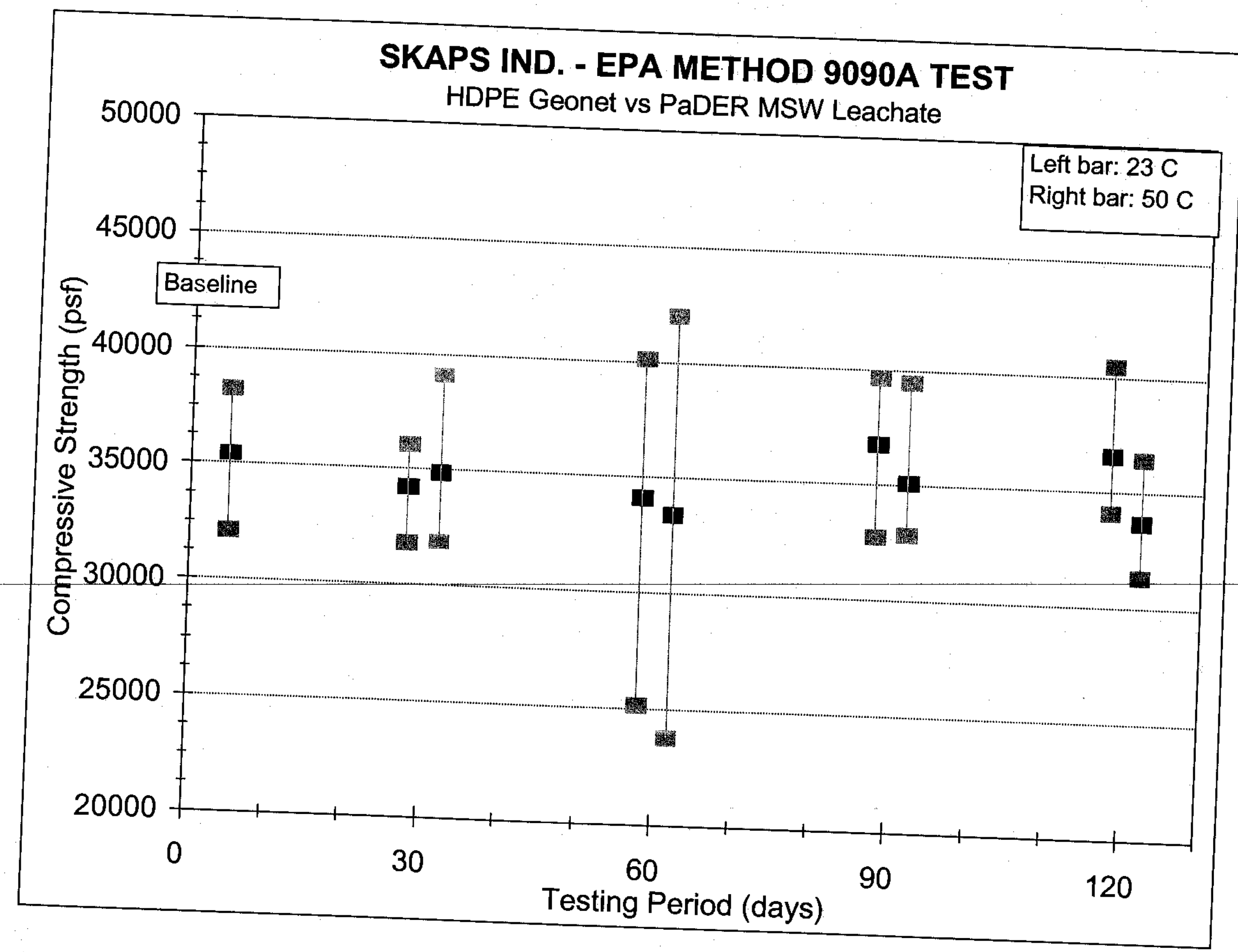

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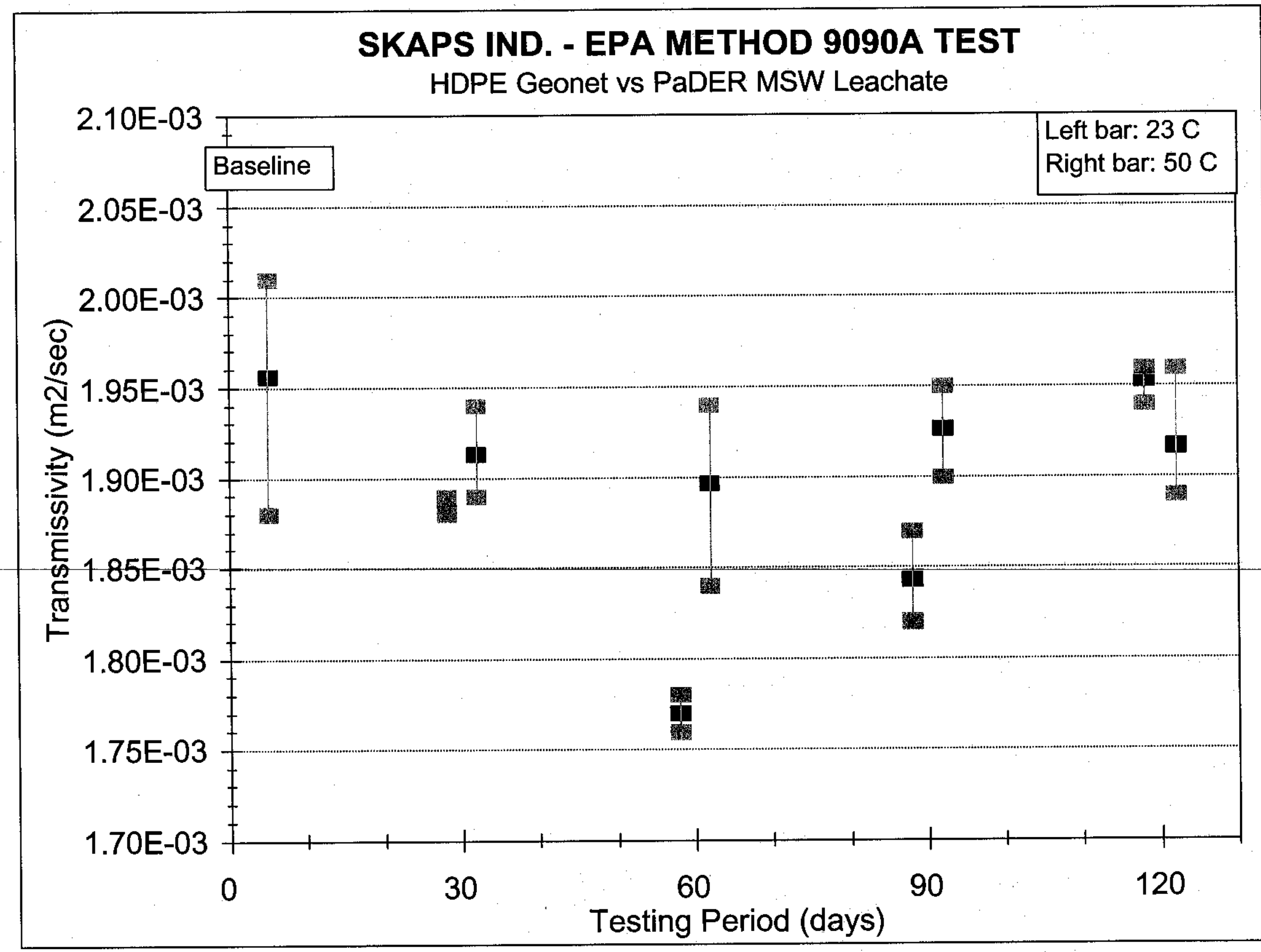


TRI Geosynthetics Division Client: Skaps Industries, File: 465-skaps-gn .WB1

A Final Report:

Laboratory Testing of Geotextile for Waste Containment EPA Method 9090A

February 2004

Submitted to:

Skaps Industries
571 Industrial Parkway
Commerce, GA 30529

Attn: **Mr. Anurag**

Submitted by:

TRI/Environmental, Inc.
9063 Bee Caves Rd.
Austin, Texas 78733

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

February 11, 2004

Mr. Anurag
Skaps Industries
571 Industrial Parkway
Commerce, GA 30529

Dear Mr. Anarag:

TRI/Environmental, Inc. (TRI) is pleased to present this Final Report for a geotextile chemical resistance study performed in general accordance with EPA Method 9090A as applied by ASTM D 6389-99, *Standard Practice for Tests to Evaluate the Chemical Resistance of Geotextiles to Liquids*.

TRI is very pleased to be of service to Skaps Industries. Please call me if you have any questions or require any additional information (800 880 8378).

Respectfully submitted,

Sam R. Allen
Vice President and Division Manager
Geosynthetic Services Division
www.GeosyntheticTesting.com

FOREWORD

The testing reported herein is based upon accepted industry practice as well as the test method listed. TRI/Environmental Inc. (TRI) neither accepts responsibility for nor makes claim as to the final use and purpose of the materials tested.

Tests were performed under laboratory conditions and not under actual usage conditions. TRI can give no conclusions as to the serviceability, life expectancy or general durability of the products tested when used in a lining and/or leachate collection system.

1.0 INTRODUCTION

This report describes the work performed by TRI/Environmental, Inc. (TRI) to determine the chemical compatibility of one geotextile product with one synthetic waste leachate. The objective was to determine the resistance of the geotextile to changes caused by exposure to leachate. Changes in physical, mechanical and hydraulic properties were measured after exposure to the leachate at 23°C and 50°C for 30, 60, 90 and 120 days. Exposures were performed in accordance with the exposure regimen specified in United States Environmental Protection Agency (EPA) Method 9090A.

All samples were logged in and all testing performed under TRI log number E2183-79-10. Methods, results and discussion are provided in the sections which follow. Test results are provided in the Tables of Results which accompany this report.

2.0 METHODS

2.1 Materials

The material selected for evaluation in this chemical compatibility study was Skaps.GTE 160 polypropylene staple fiber nonwoven needlepunched geotextile.

2.2 Leachate

The waste leachate used was supplied by TRI and was a synthetic MSW leachate approximating the PaDER leachate recipe.

2.3 Exposure Conditions

Geotextile specimens were exposed to the waste leachate following the specifications of EPA Method 9090A as they relate to exposure to waste fluids. The tanks used for these exposures were maintained at 23 ± 2ºC and 50 ± 2ºC throughout the 120-day exposure period. Tanks were constructed from chemically resistant glass fitted with stirrers. The 50ºC tanks were heated with a circulating hot water heat exchanger system. They were also sealed with a lid, and a reflux condenser was installed to minimize loss of volatile leachate components.

2.4 Testing Procedures

Table 1 lists tests performed on the geotextile. The number of test replicates was doubled for baseline determinations on unexposed material.

Table 1. Tests performed on TNS - Nevown, Inc. nonwoven geotextile

Test or Physical Property	Method	Number of replicate specimens
Dimensions and weight	EPA 9090A	2 readings
Grab Tensile Strength	ASTM D 4632	3 MD & TD readings
Grab Tensile Elongation	ASTM D 4632	3 MD & TD readings
Trapezoidal Tear Strength	ASTM D 4533	3 MD & TD readings
Puncture Resistance	ASTM D 4833	3 readings
Mullen Burst	ASTM D 3786	3 readings
Permittivity	ASTM D 4491	3 readings

3.0 RESULTS AND DISCUSSION

Test results are presented in the Test Results section which is included with this report. Test results are presented in tabular form as well as graphical form.

In considering these results, it must be determined through engineering judgment whether observed differences in the value of test results measured before and after immersion are due to product variability, unidentified factors relating to the test procedure, or leachate interaction with the product. Any significant chemical interaction with leachate would be expected to result in degradation trends which are consistent across the various properties being evaluated, and not isolated to one set of test results only. However, with each type of material there may be specific properties which are highly sensitive to leachate-induced effects. These factors must be considered in evaluating the various test results for a given product.

Also of critical importance is the issue of product variability. With nonwoven geotextiles, a range of physical and mechanical index test values covering 20% or more of the average is not uncommon. This can be traced to variability inherent in the product, and the randomness associated with the onset of failure under the specified testing conditions. However, in chemical compatibility testing the statistical sampling of a broad range of manufactured product is not possible. Therefore, the small size of the sample population tested at each time point must be taken into consideration. The criteria to be applied in evaluating data measured before and after leachate immersion should be that property changes, if observed, are consistent and so great that product variability and experimental factors can be ruled out.

In this report, standard deviations (STD) are reported for measurements involving three or more replicate specimens. In statistics, the standard deviation is defined as root of the mean squared deviations of individual test results about the mean value. The standard deviation is a quantitative measure of variability within a group of measurements.

One related measure of variability observed within a sample set, relative to the magnitude of the mean value itself, is the *coefficient of variation or variance* (COV). The coefficient of variance is defined as the standard deviation divided by the mean associated with a group of specimens, and may be expressed as a percentage. The COV provides an indication of what proportion of the mean value may be attributable to random experimental factors or product variability. It is useful to consider apparent changes in property values against the criterion of COV since observed changes which fall below the COV may not be significant. This approach was used in preparing the tables in the next section.

The term *range* refers to the difference between the extreme highest and lowest points within a group of measured values. Considering range as a percentage of the mean values provides another measure of variability within a dataset.

In the tables, the high and low extremes for percentage change in mean values are listed for comparison against COV and range as a percentage of mean from the baseline sample group. The high and low percentage changes are the extremes from data measured at 30, 60, 90 and 120 days.

SKAPS GTE 160 nonwoven polypropylene geotextile

Table 2 illustrates the range of variability in baseline data compared with some of the observed changes in average test values measured after immersion for the geotextile.

Table 2. Baseline coefficients of variation and range of percentage change results for geotextile

Test	Baseline COV (%)*	Baseline Range as % of Mean*	High Observed % Change	Low Observed % Change
Grab Tensile Strength (MD)	8	22	12	-1
Grab Tensile Elongation @ Maximum Load (MD)	8	24	2	-4
Trapezoidal Tear Strength (MD)	8	22	7	-8
Puncture Strength	17	50	3	-9
Mullen Burst Strength	8	26	5	-9

4.0 CONCLUSION

While some changes in certain measured physical and mechanical properties were noted for the geotextile, the observed variances were random and are believed to be the effects of product variability and experimental factors.

TRI/Environmental, Inc. is pleased to have been selected to participate in this project. We trust that the information provided in this report meets your requirements for technical documentation of this chemical compatibility study. Please do not hesitate to call if you have any questions or require any additional information.

Respectfully submitted,

Sam R. Allen
Vice President and Division Manager
Geosynthetic Services Division

TRI/Environmental, Inc.

APPENDIX:

EPA METHOD 9090A TEST RESULTS

SKAPS GTE 160 Nonwoven Geotextile TEST RESULTS

Dimensions

TRI LOG NUMBER: E2183-79-10

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Client: Skaps Industries

Report Date: February 2004
TRI Log Number: E2189-79-10

Exposure Time and Temperature

		30 Day			60 Day			90 Day			120 Day		
Test Parameters	Temp.	Baseline	Exposed	% Change	Baseline	Exposed	% Change	Baseline	Exposed	% Change	Baseline	Exposed	% Change

GEOTEXTILE: POLYPROPYLENE NONWOVEN EXPOSED TO PaDER SYNTHETIC MSW LEACHATE
GEOTEXTILE ROLL ID: GTE-160

Test Parameters	Temp.	30 Day Baseline	30 Day Exposed	30 Day % Change	60 Day Baseline	60 Day Exposed	60 Day % Change	90 Day Baseline	90 Day Exposed	90 Day % Change	120 Day Baseline	120 Day Exposed	120 Day % Change
Thickness (mils)	23C	115	112	-2.6	112	112	0.0	118	118	0.0	108	107	-0.9
	50C	107	104	-2.8	118	117	-0.8	117	113	-3.4	114	117	2.6
Length (inches)	23C	8.06	8.04	-0.2	8.07	8.03	-0.5	8.10	8.00	-1.2	8.05	8.00	-0.6
	50C	8.08	7.97	-1.4	8.06	7.96	-1.2	8.08	7.95	-1.6	8.01	7.94	-0.9
Width (inches)	23C	4.05	4.01	-1.0	4.02	4.00	-0.5	4.00	3.96	-1.0	3.98	3.95	-0.8
	50C	4.00	3.92	-2.0	4.01	3.99	-0.5	4.06	4.02	-1.0	4.06	4.04	-0.5
Mass (g)	23C	4.88	4.87	-0.2	4.88	4.95	1.4	5.01	5.01	0.0	6.55	6.51	-0.6
	50C	4.38	4.38	0.0	5.15	5.08	-1.4	5.08	5.05	-0.6	5.60	5.53	-1.2

EPA METHOD 9090A TEST RESULTS

SKAPS GTE 160 Nonwoven Geotextile TEST RESULTS

TRI LOG NUMBER: E2183-79-10

NOTE ON TEST RESULTS

This section includes generated test data provided in both tabular and graphical form. Each graph is represented by a series of "I" beam plots. Each "I" beam represents a single test population and illustrates the high and low value as the end points, and the mean as a central box on the beam.

At each testing period, two "I" beams are shown. The left beam represents the 23°C exposed specimens while the right beam represents the 50°C specimens. The initial "I" beam represents the baseline or unexposed test specimens.

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Client: Skaps Industries

Report Date: February 2004
TRI Log Number: E2183-79-10

		Exposure Time and Temperature							
		30 Day		60 Day		90 Day		120 Day	
Test Parameters	Baseline	23C	50C	23C	50C	23C	50C	23C	50C

GEOTEXTILE: POLYPROPYLENE NONWOVEN EXPOSED TO PaDER SYNTHETIC MSW LEACHATE
GEOTEXTILE ROLL ID: GTE-160

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Grab Tensile Properties:	221	206	183	182	215	208	204	214	230
Maximum Strength (lbs)	177	185	208	184	223	196	199	246	205
ASTM D4632	202	211	222	232	240	215	192	161	218
Machine Direction	204								
	187								
	215								
Average	201	201	204	199	226	206	198	207	218
STD	15	11	16	23	10	8	5	35	10
Coefficient of Variation	8	6	8	12	5	4	2	17	5
% Change		-0	2	-1	12	3	-1	3	8
Grab Tensile Properties:	96	94	93	99	100	91	103	95	108
Elongation @ Max. Strength (%)	89	105	100	106	105	98	99	107	98
ASTM D4632	95	107	101	100	103	101	100	103	103
Machine Direction	104								
	109								
	113								
Average	101	102	98	102	103	97	101	102	103
STD	8	6	4	3	2	4	2	5	4
Coefficient of Variation	8	6	4	3	2	4	2	5	4
% Change		1	-3	1	2	-4	-0	1	2

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Client: Skaps Industries

Report Date: February 2004
TRI Log Number: E2183-79-10

		Exposure Time and Temperature							
		30 Day		60 Day		90 Day		120 Day	
Test Parameters	Baseline	23C	50C	23C	50C	23C	50C	23C	50C

GEOTEXTILE: POLYPROPYLENE NONWOVEN EXPOSED TO PaDER SYNTHETIC MSW LEACHATE
GEOTEXTILE ROLL ID: GTE-160

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Grab Tensile Properties:	321	345	289	308	338	323	290	285	274
Maximum Strength (lbs)	325	343	310	338	277	317	309	303	309
ASTM D4632	282	252	282	287	252	329	292	310	298
Transverse Direction	288								
	220								
	258								
Average	282	313	294	311	289	323	297	299	294
STD	36	43	12	21	36	5	9	11	15
Coefficient of Variation	13	14	4	7	12	2	3	4	5
% Change		11	4	10	2	14	5	6	4
Grab Tensile Properties:	98	97	93	97	98	93	99	91	93
Elongation @ Max. Strength (%)	115	112	104	109	99	100	99	103	104
ASTM D4632	94	94	103	97	85	93	92	94	95
Transverse Direction	83								
	95								
	99								
Average	97	101	100	101	94	95	97	96	97
STD	9	8	5	6	6	3	3	5	5
Coefficient of Variation	10	8	5	6	7	3	3	5	5
% Change		4	3	4	-3	-2	-1	-1	0

TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Client: Skaps Industries

Report Date: February 2004
TRI Log Number: E2183-79-10

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
		Exposure Time and Temperature							

GEOTEXTILE: POLYPROPYLENE NONWOVEN EXPOSED TO PaDER SYNTHETIC MSW LEACHATE
GEOTEXTILE ROLL ID: GTE-160

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Mullen Burst Strength:	455	380	415	390	450	450	435	415	380
Burst Strength (psi)	420	400	380	400	430	415	410	405	385
ASTM D3786	425	345	415	400	410	410	380	365	350
	400								
	350								
	405								
Average	409	375	403	397	430	425	408	395	372
STD	32	23	16	5	16	18	22	22	15
Coefficient of Variation	8	6	4	1	4	4	6	5	4
% Change		-8	-1	-3	5	4	-0	-3	-9
Permittivity:	1.63	1.61	1.79	1.53	1.66	1.97	1.83	1.78	1.72
(sec -1)	1.81	1.64	1.64	1.97	1.97	1.76	1.86	1.67	1.61
ASTM D4491	1.63	1.53	1.88	1.97	1.83	1.88	1.81	1.91	2.00
	1.79								
	1.76								
	1.68								
Average	1.72	1.59	1.77	1.82	1.82	1.87	1.83	1.79	1.78
STD	0.07	0.05	0.10	0.21	0.13	0.09	0.02	0.10	0.16
Coefficient of Variation	4.28	2.91	5.59	11.38	6.96	4.60	1.12	5.49	9.24
% Change		-7	3	6	6	9	7	4	3
Trapezoidal Tear	87	97	78	95	94	89	85	102	88
Tear Strength - (lbs)	86	87	94	82	91	78	101	70	104
ASTM D4533	105	112	82	77	109	106	111	87	99
Machine Direction	92								
	85								
	95								
Average	92	99	85	85	98	91	99	86	97
STD	7	10	7	8	8	12	11	13	7
Coefficient of Variation	8	10	8	9	8	13	11	15	7
% Change		8	-8	-8	7	-1	8	-6	6

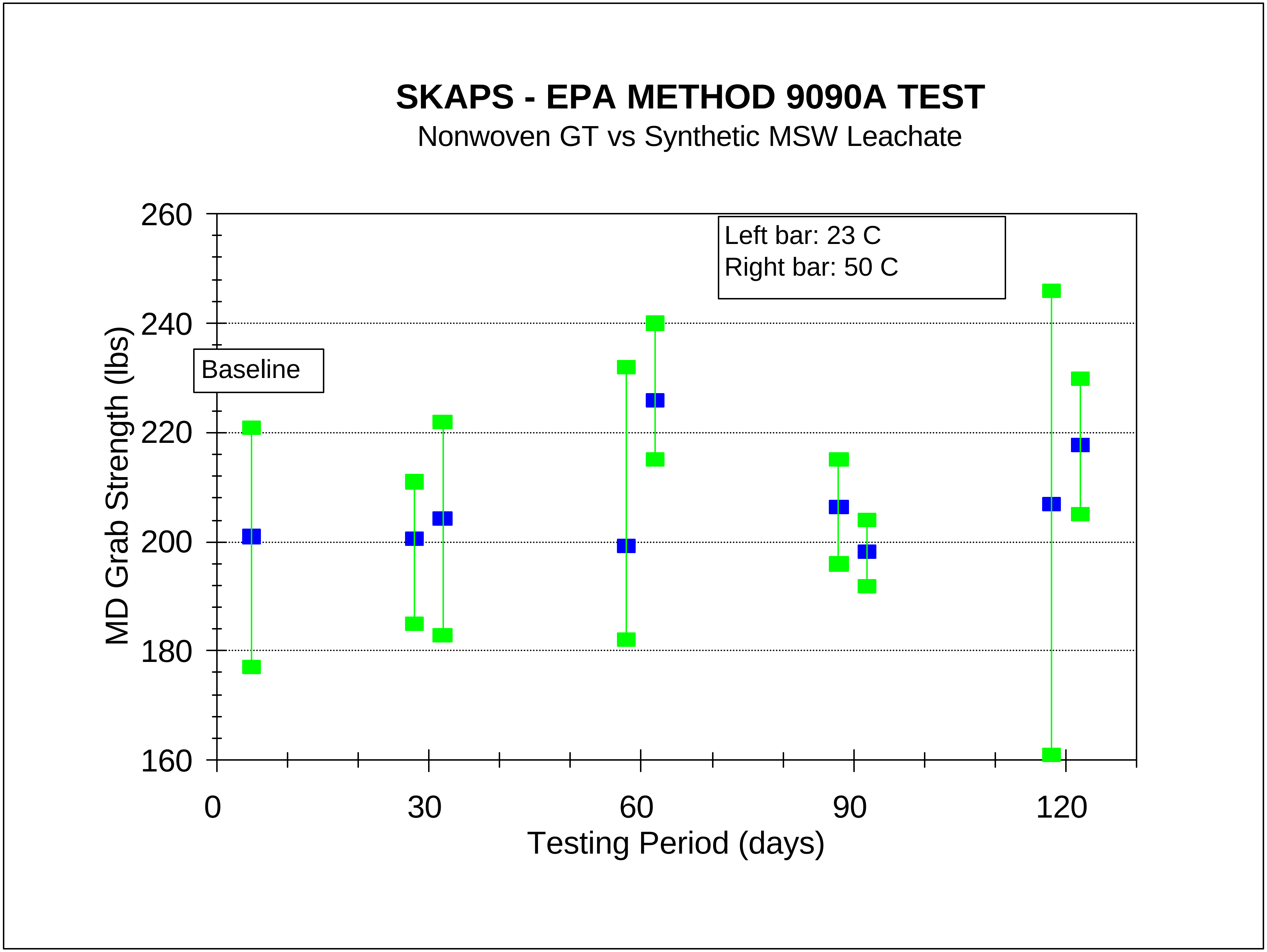
TABLE OF CHEMICAL COMPATIBILITY TEST RESULTS
Client: Skaps Industries

Report Date: February 2004
TRI Log Number: E2183-79-10

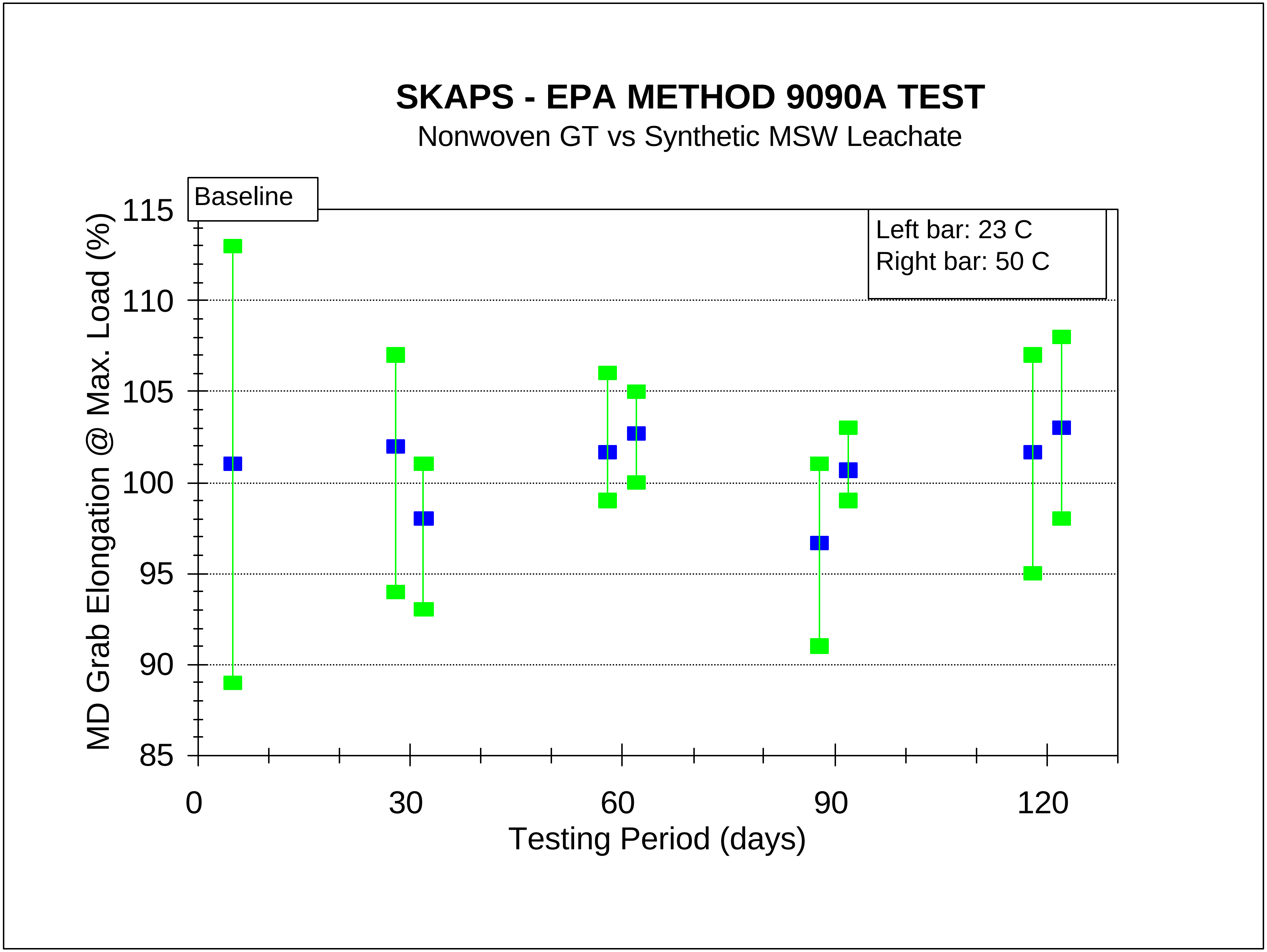
		Exposure Time and Temperature							
		30 Day		60 Day		90 Day		120 Day	
Test Parameters	Baseline	23C	50C	23C	50C	23C	50C	23C	50C

GEOTEXTILE: POLYPROPYLENE NONWOVEN EXPOSED TO PaDER SYNTHETIC MSW LEACHATE
GEOTEXTILE ROLL ID: GTE-160

Test Parameters	Baseline	30 Day 23C	30 Day 50C	60 Day 23C	60 Day 50C	90 Day 23C	90 Day 50C	120 Day 23C	120 Day 50C
Trapezoidal Tear	150	189	164	137	156	200	145	196	146
Tear Strength - (lbs)	165	179	162	174	156	151	181	158	175
ASTM D4533	140	155	147	176	168	176	173	135	140
Transverse Direction	208								
	161								
	162								
Average	164	174	158	162	160	176	166	163	154
STD	21	14	8	18	6	20	15	25	15
Coefficient of Variation	13	8	5	11	4	11	9	15	10
% Change		6	-4	-1	-3	7	1	-1	-6
Puncture	147	119	118	129	130	131	150	145	117
Puncture Strength (lbs)	165	127	158	149	132	120	112	148	126
ASTM D4833	143	120	133	114	118	136	147	118	161
	134								
	99								
	112								
Average	133	122	136	131	127	129	136	137	135
STD	22	4	16	14	6	7	17	13	19
Coefficient of Variation	17	3	12	11	5	5	13	10	14
% Change		-9	2	-2	-5	-3	2	3	1



Client: Skaps, File: E2183-79-10



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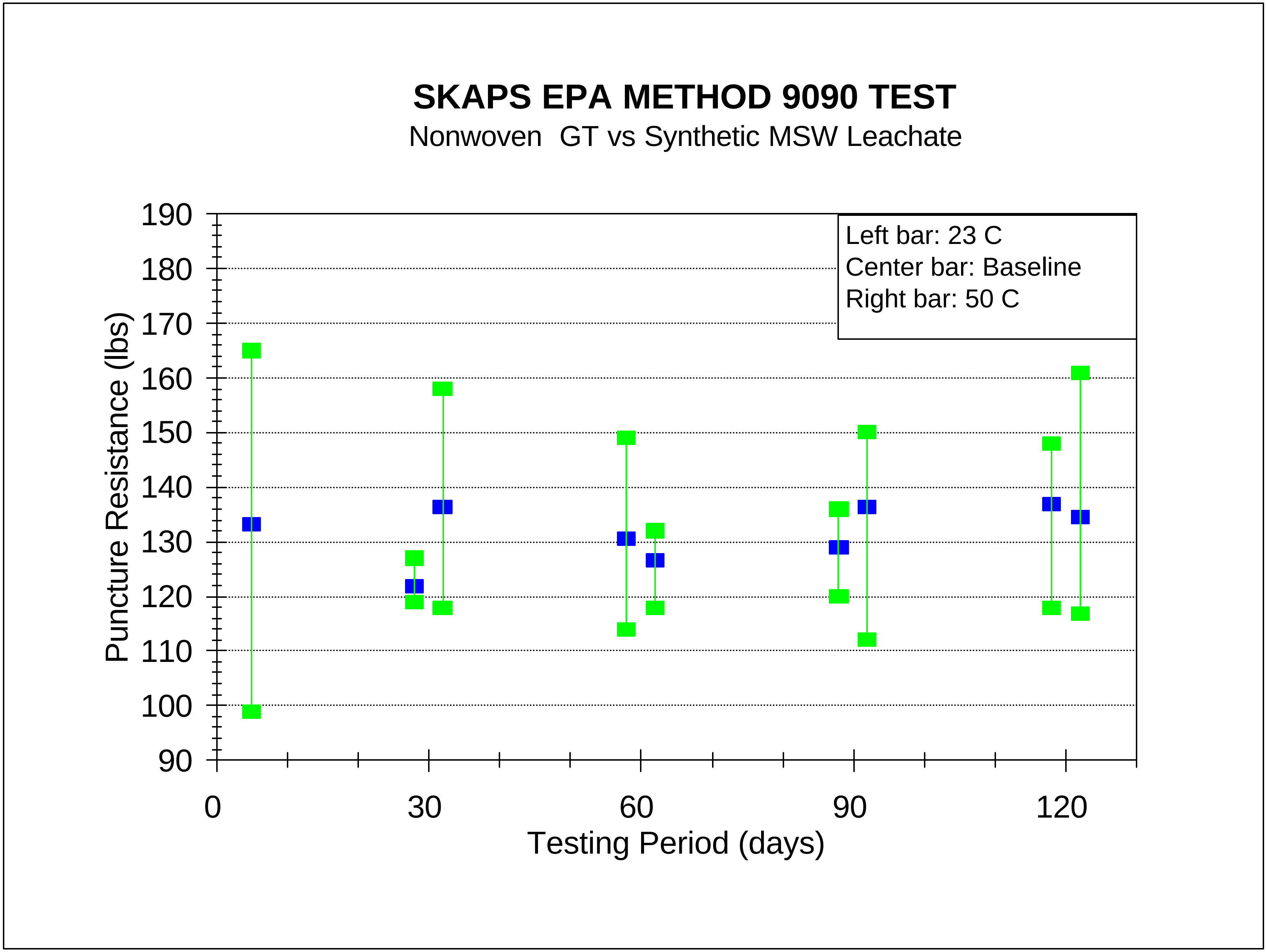
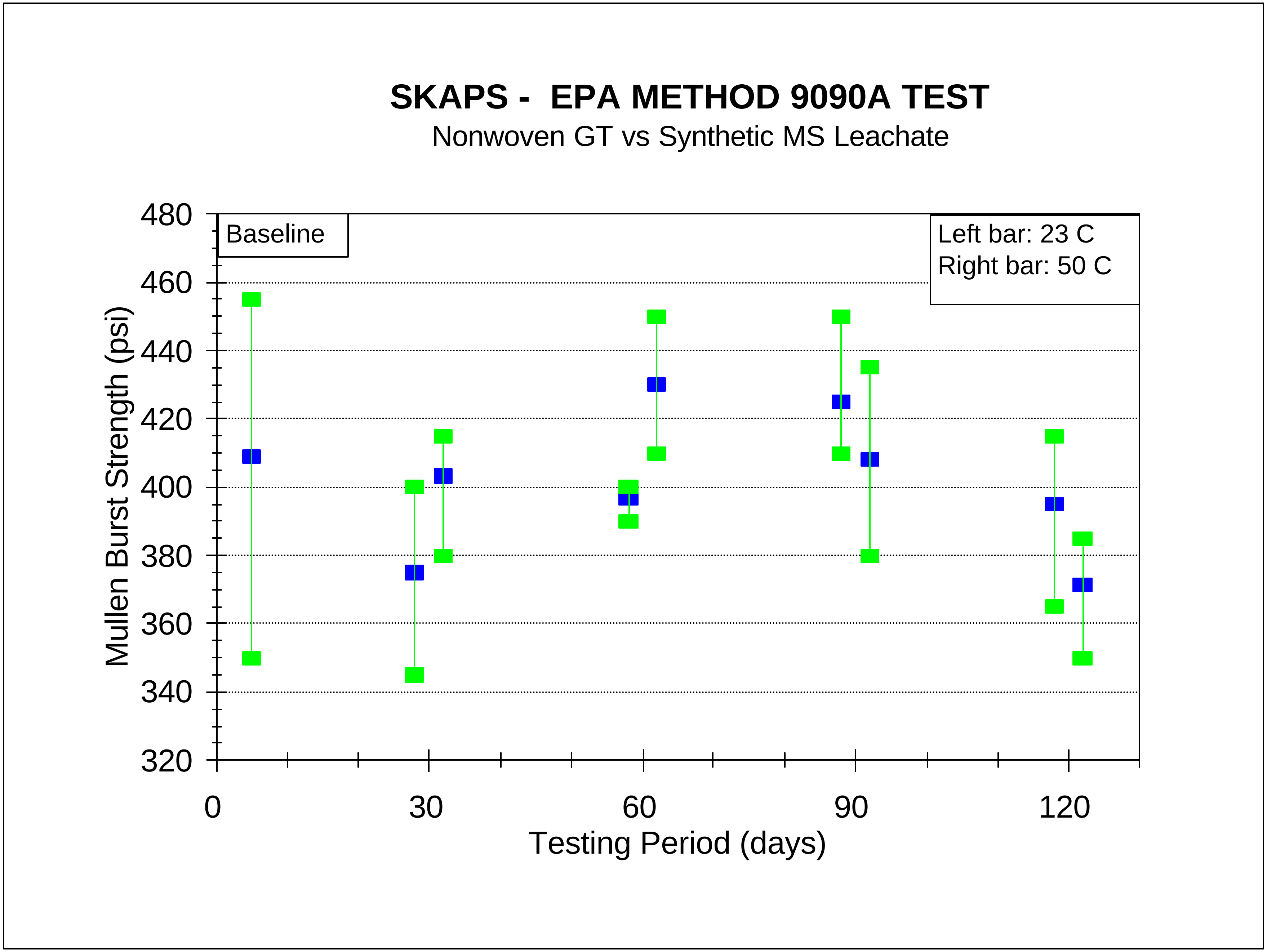


SKAPS EPA METHOD 9090 TEST
Nonwoven GT vs Synthetic MSW Leachate
Left bar: 23 C
Center bar: Baseline
Right bar: 50 C
Puncture Resistance (lbs)
190
180
170
160
150
140
130
120
110
100
90
0
30
60
90
120
Testing Period (days)



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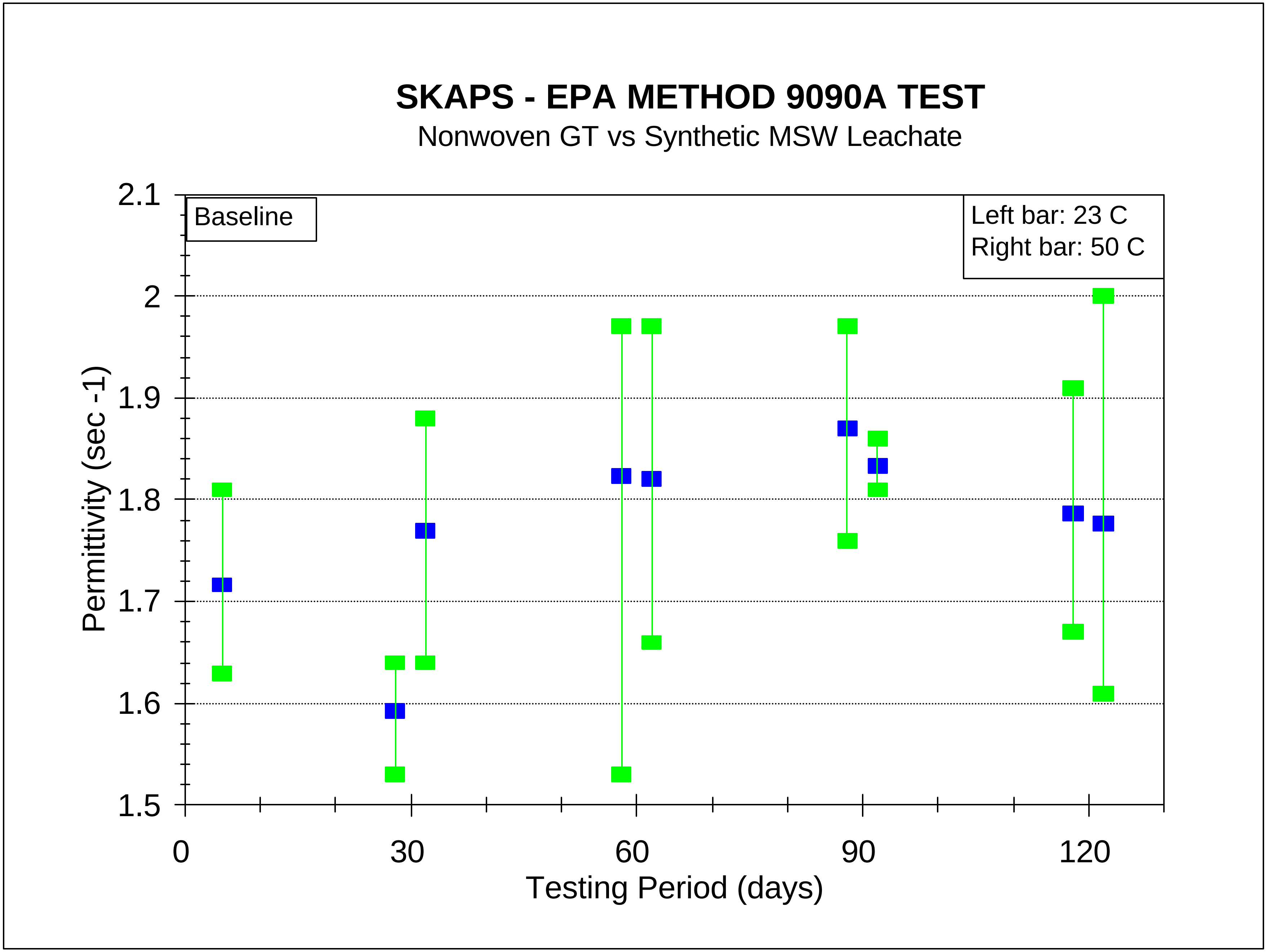


Client: Skaps, File: E2183-79-10

EPA 9090 TESTING OF 82 TEX WOVEN GEOTEXTILE

Samples of 82 Tex, a woven polypropylene geotextile manufactured by Synthetic Industries, were tested for compatibility with landfill leachate sampled from the Lakeview Landfill Disposal facility located in Erie, Pennsylvania. Numerous laboratory tests were completed on specimens subjected to leachate to determine if conditions found in a landfill will adversely affect the properties of 82 Tex. Laboratory tests include:

Grab Strength	ASTM D-4632
Trapezoidal Tear	ASTM D 4533
Puncture	ASTM D 4833
Mullen Burst	ASTM D 3786
Permittivity	ASTM D 4491
Dimensional Stability	ASTM D 4591
Thickness	ASTM D 5199
Mass/Unit Area	ASTM D 3776

The above testing was conducted at temperatures of 23℃ and 50℃ to model potential conditions that a geotextile would experience in a landfill application. Testing was conducted after exposure to leachate at intervals of 30, 60, 90 and 120 days. Initial baseline testing of specimens not immersed in leachate was also conducted for comparison purposes.

Test data shows that the fabric performed well when subjected to the leachate and temperature conditions used in the testing program. Variations in test results can be attributed the general variability of the material itself. Graphical representation of test data in the form of percent change from specimens not immersed in leachate can be viewed in the document.

TR-227 Revised 1/01

Final Report
EPA 9090 Testing
82 Tex Woven Geotextile

Synthetic Industries

Performed For:

Synthetic Industries
Construction Products Division
4019 Industry Drive
Chattanooga, TN 37416

Performed By:

J&L Testing Company, Inc.
938 South Central Avenue
Canonsburg, PA 15317

May 4, 1994
Job No: 93R1419

J&L TESTING COMPANY, INC.

GEOTECHNICAL AND GEOSYNTHETICS MATERIALS TESTING AND RESEARCH

May 4, 1994
93R1419

Synthetic Industries
Construction Products Division
4019 Industry Drive
Chattanooga, TN 37416

Attention: Mr. Rick Riggs

RE: **FINAL REPORT**
EPA 9090 TESTING
82 TEX WOVEN GEOTEXTILE
SYNTHETIC INDUSTRIES

Dear Mr. Riggs:

We are pleased to submit herein the final test results for EPA 9090 testing performed on Synthetic Industries 82 Tex woven geotextile. The test was performed using leachate from the Lakeview Landfill Disposal Facility located in Erie, Pennsylvania, owned and operated by Waste Management of North America. Results of the tests are presented in Appendix A with a description of the leachate presented in Appendix B.

Upon receipt of the material, coupons were cut from the sheet to statistically sample the material per ASTM protocols. These samples were then randomly selected for the initial baseline testing and for immersion in the 23°C and 50°C temperature controlled 22 gallon glass tanks. Initial baseline/reference tests included:

Grab Strength	ASTM D-4632	Machine & Cross Direction
Trap Tear	ASTM D-4533	Machine & Cross Direction
Puncture	ASTM D-4833	
Mullen Burst	ASTM D-3786	
Permittivity	ASTM D-4491	
Dimensional Stability	ASTM D-4594	
Thickness	ASTM D-5199	
Mass/Unit Area	ASTM D-3776	

At 30, 60, 90 and 120 day intervals, randomly sampled coupons were extracted from each of the two temperature controlled tanks and these samples were tested for the same property characteristics as the baseline sample. The results are presented on the attached tables and the percent differences in the results are compared to the baseline samples and plotted as shown in Appendix A.

Each of the plots are discussed below:

Grab Strength (Machine and Cross Direction)

In the machine direction the data, on average, indicates little change in the material and probably within the range of the statistical differences of the product itself. In the cross direction there is a slightly downward trend in strength averaging about 6% strength loss over 120 days. However, the woven fibers tend to slightly loosen during exposure in the tank due to the recirculating system of the apparatus. This may have caused the slight loss in strength.

Trapezoidal Tear Strength (Machine and Cross Direction)

Both machine and cross direction tests indicated a variation in data, however, on the average, the strength essentially remained unchanged over the 120 day test period.

Puncture Strength

No significant changes in the material occurred over the 120 test period except for the statistical differences in the material itself.

Mullen Burst

Similar to puncture strength, no significant changes were observed. The data may appear to indicate a strength gain, however, this could be attributed to the variations of the product through random sampling procedures.

Permittivity

The data shows a general downward trend. Inspection of the samples revealed a build-up of sediments, over time, on the fabric from the leachate. These sediments tend to retard flow during the permittivity test.

Dimensions

No significant changes were observed.

Thickness

The only anomaly in this test are the results at 120 days. A careful inspection of the fabric sample used for thickness indicated a slight build-up of leachate residue on the material. This accounted for the slight increase in thickness. Had these accumulations been scraped off the fibers, the thickness would have been comparable to the other tests.

Mass/Unit Area

The data appears to show a slight downward trend in mass/unit area. However, the loss is generally less than 2% and probably within the statistical variation of the material itself.

In summary, the fabric performs well although there were some noted variations in the product. For the most part, these variations can be attributed to leachate particulate accumulations on the material over time, some loosening of the fibers associated with the recirculation system of the tanks and the general variability of the material.

Should you have any questions, please do not hesitate to call.

Sincerely,

J&L TESTING COMPANY, INC.

John Boschuk, Jr., P.E., REP
Director - Research & Development

Enclosure
JB/lao
(L100.156)

SYNTHETIC INDUSTRIES

J & L TESTING CO., INC. TEST RESULTS

82 TEX WOVEN GEOTEXTILE

INITIAL (UNIMMERSED)

MECHANICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
GRAB TENSILE	lbs							
MD		179.6	151.7	152.0			161.1	13.082
CD		157.3	154.4	180.2			164.0	11.540
TRAP TEAR	lbs							
MD		60.1	68.6	61.3			63.3	3.756
CD		61.9	58.8	58.3			59.7	1.592
PUNCTURE	lbs	85.8	77.0	87.4			83.4	4.572
MULLEN BURST	psi	310	312	322	325	308	315	6.800
PERMITTIVITY	sec-1							
23 deg.spec.		0.15	0.18	0.16			0.16	0.012
50 deg.spec.		0.15	0.18	0.16			0.16	0.012

SYNTHETIC INDUSTRIES

J & L TESTING CO.,INC. TEST RESULTS

SUMMARY OF TEST DATA

82 TEX WOVEN GEOTEXTILE

IMMERSION PERIOD

MECHANICAL PROPERTY	IMMERS. TEMP.	DIR.	INITIAL VALUE	30-DAY VALUE	30-DAY %CHANGE	60-DAY VALUE	60-DAY %CHANGE Initial	60-DAY %CHANGE Prev.	90-DAY VALUE	90-DAY %CHANGE Initial	90-DAY %CHANGE Prev.	120 DAY VALUE	120 DAY %CHANGE Initial	120 DAY %CHANGE Prev.
GRAB STRENGTH	23	MD	161.1	151.8	-5.77	176.6	9.62	16.34	160.1	-0.62	-9.3	145.3	-9.81	-9.2
(lbs)		CD	164.0	158.4	-3.41	166.8	1.71	5.30	156.4	-4.63	-6.2	157.1	-4.21	0.4
	50	MD	161.1	166.1	3.10	163.2	1.30	-1.75	149.4	-7.26	-8.5	169.2	5.03	13.3
		CD	164.0	167.2	1.95	158.1	-3.60	-5.44	163.5	-0.30	3.4	149.9	-8.60	-8.3
TRAP TEAR	23	MD	63.3	54.3	-14.22	78.2	23.54	44.01	74.1	17.06	-5.2	64.4	1.74	-13.1
(lbs)		CD	59.6	51.6	-13.42	91.5	53.52	77.33	89.8	50.67	-1.9	64.4	8.05	-28.3
	50	MD	63.3	54.9	-13.27	76.8	21.33	39.89	76.9	21.48	0.1	66.1	4.42	-14.0
		CD	59.6	53.7	-9.90	89.0	49.33	65.74	65.7	10.23	-26.2	62.4	4.70	-5.0
PUNCTURE	23		83.4	85.8	2.88	72.1	-13.55	-15.97	83.5	0.12	15.8	96.1	15.23	15.1
(lbs)	50		83.4	92.5	10.91	83.4	0.00	-9.84	83.5	0.12	0.1	93.2	11.75	11.6
MULLEN BURST	23		315	314	-0.32	337	6.98	7.32	333	5.71	-1.2	324	2.86	-2.7
	50		315	323	2.54	335	6.35	3.72	325	3.17	-3.0	326	3.49	0.3
PERMITTIVITY	23		0.16	0.16	0.00	0.12	-25.00	-25.00	0.15	-6.25	25.0	0.12	-25.00	-20.0
	50		0.16	0.17	6.25	0.13	-18.75	-23.53	0.17	6.25	30.8	0.12	-25.00	-29.4

PHYSICAL PROPERTY	IMMERS. TEMP.	30 DAY %CHANGE	60 DAY %CHANGE	90 DAY %CHANGE	120 DAY %CHANGE
DIMENSIONS	23	0.00	0.08	0.14	0.00
(Ave.both dir.)	50	-0.06	-0.08	0.30	0.00
THICKNESS	23	0.45	0.01	-0.01	11.46
	50	0.47	0.02	1.45	8.66
MASS/UNIT AREA	23	3.31	-0.42	-2.45	-0.68
	50	-0.44	0.62	-1.28	-2.09

SYNTHETIC INDUSTRIES J & L TESTING CO., INC. TEST RESULTS

82 TEX WOVEN GEOTEXTILE

30 DAY, 23 DEGREE

MECHANICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
GRAB TENSILE	lbs							
MD		157.5	148.4	149.4			151.8	4.075
CD		160.7	151.2	163.2			158.4	5.169
TRAP TEAR	lbs							
MD		51.8	53.8	57.3			54.3	2.273
CD		50.4	55.9	48.5			51.6	3.138
PUNCTURE	lbs	87.3	81.5	88.6			85.8	3.087
MULLEN BURST	psi	310	340	310	320	290	314	16.248
PERMITTIVITY	sec-1	0.16	0.15	0.16			0.16	0.005

PHYSICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
DIMENSIONS	in							
Initial Length		20.13	20.00					
Final Length		20.13	20.00					
% Change		0.00	0.00				0.00	0.000
Initial Width		13.94	14.16					
Final Width		13.94	14.16					
% Change		0.00	0.00				0.00	0.000
THICKNESS	mils							
Initial		11	11					
Final		11	11					
% Change		-0.90	1.80				0.45	1.351
MASS/UNIT AREA	oz/sy							
Initial		3.19	3.44					
Final		3.42	3.42					
% Change		7.21	-0.58				3.31	3.896

SYNTHETIC INDUSTRIES — J & L TESTING CO., INC. TEST RESULTS

82 TEX WOVEN GEOTEXTILE

30 DAY, 50 DEGREE

MECHANICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
GRAB TENSILE	lbs							
MD		167.8	173.2	157.2			166.1	6.646
CD		158.5	172.0	171.0			167.2	6.142
TRAP TEAR	lbs							
MD		55.7	54.3	54.6			54.9	0.602
CD		51.3	56.4	53.5			53.7	2.089
PUNCTURE	lbs	97.0	84.3	96.2			92.5	5.807
MULLEN BURST	psi	340	310	325	330	310	323	11.662
PERMITTIVITY	sec-1	0.17	0.17	0.17			0.17	0.000

PHYSICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
DIMENSIONS	in							
Initial Length		20.13	19.94					
Final Length		20.19	19.88					
% Change		0.30	-0.30				-0.00	0.299
Initial Width		14.06	14.03					
Final Width		14.06	14.00					
% Change		0.00	-0.21				-0.11	0.107
THICKNESS	mils							
Initial		11	11					
Final		11	11					
% Change		1.83	-0.89				0.47	1.364
MASS/UNIT AREA	oz/sy							
Initial		3.42	3.46					
Final		3.40	3.45					
% Change		-0.58	-0.29				-0.44	0.148

SYNTHETIC INDUSTRIES J & L TESTING CO., INC. TEST RESULTS

82 TEX WOVEN GEOTEXTILE

60 DAY, 23 DEGREE

MECHANICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
GRAB TENSILE	lbs							
MD		191.7	178.6	159.6			176.6	13.178
CD		164.6	171.7	164.1			166.8	3.471
TRAP TEAR	lbs							
MD		74.4	83.6	76.7			78.2	3.909
CD		82.0	91.2	101.3			91.5	7.882
PUNCTURE	lbs	75.1	63.7	77.6			72.1	6.069
MULLEN BURST	psi	360	336	314	334	340	337	14.675
PERMITTIVITY	sec-1	0.11	0.10	0.14			0.12	0.017

PHYSICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
DIMENSIONS	in							
Initial Length		20.00	19.94					
Final Length		20.00	20.00					
% Change		0.00	0.30				0.15	0.150
Initial Width		13.97	14.00					
Final Width		13.97	14.00					
% Change		0.00	0.00				0.00	0.000
THICKNESS	mils							
Initial		111	110					
Final		109	112					
% Change		-1.80	1.82				0.01	1.810
MASS/UNIT AREA	oz/sy							
Initial		3.55	3.59					
Final		3.55	3.56					
% Change		0.00	-0.84				-0.42	0.418

SYNTHETIC INDUSTRIES

J & L TESTING CO., INC. TEST RESULTS

82 TEX WOVEN GEOTEXTILE

60 DAY, 50 DEGREE

MECHANICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
GRAB TENSILE	lbs							
MD		165.3	157.9	166.4			163.2	3.774
CD		153.8	160.1	160.4			158.1	3.043
TRAP TEAR	lbs							
MD		94.8	69.5	66.2			76.8	12.776
CD		97.8	75.1	94.2			89.0	9.961
PUNCTURE	lbs	83.7	82.4	84.2			83.4	0.763
MULLEN BURST	psi	340	330	342	326	337	335	6.066
PERMITTIVITY	sec-1	0.13	0.13	0.14			0.13	0.005

PHYSICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
DIMENSIONS	in							
Initial Length		20.00	20.06					
Final Length		20.00	20.00					
% Change		0.00	-0.30				-0.15	0.150
Initial Width		14.06	14.44					
Final Width		14.06	14.44					
% Change		0.00	0.00				0.00	0.000
THICKNESS	mils							
Initial		110	115					
Final		111	114					
% Change		0.91	-0.87				0.02	0.889
MASS/UNIT AREA	oz/sy							
Initial		3.45	3.34					
Final		3.40	3.43					
% Change		-1.45	2.69				0.62	2.072

SYNTHETIC INDUSTRIES J & L TESTING CO., INC. TEST RESULTS

82 TEX WOVEN GEOTEXTILE

90 DAY, 23 DEGREE

MECHANICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
GRAB TENSILE	lbs							
MD		162.2	162.9	155.3			160.1	3.430
CD		163.7	161.7	143.8			156.4	8.947
TRAP TEAR	lbs							
MD		72.8	68.9	80.7			74.1	4.909
CD		72.2	102.9	94.3			89.8	12.931
PUNCTURE	lbs	80.6	84.9	84.9			83.5	2.046
MULLEN BURST	psi	330	345	340	320	330	333	8.718
PERMITTIVITY	sec-1	0.16	0.14	0.16			0.15	0.009

PHYSICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
DIMENSIONS	in							
Initial Length		20.13	19.13					
Final Length		20.13	19.06					
% Change		0.00	-0.34				-0.17	0.170
Initial Width		14.69	14.06					
Final Width		14.75	14.13					
% Change		0.41	0.46				0.44	0.027
THICKNESS	mils							
Initial		11	11					
Final		11	11					
% Change		-1.80	1.79				-0.01	1.794
MASS/UNIT AREA	oz/sy							
Initial		3.45	3.47					
Final		3.42	3.33					
% Change		-0.85	-4.04				-2.45	1.592

SYNTHETIC INDUSTRIES

J & L TESTING CO., INC. TEST RESULTS

82 TEX WOVEN GEOTEXTILE

90 DAY, 50 DEGREE

MECHANICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
GRAB TENSILE	lbs							
MD		144.2	141.6	162.4			149.4	9.253
CD		164.6	160.3	165.7			163.5	2.330
TRAP TEAR	lbs							
MD		77.2	74.2	79.2			76.9	2.055
CD		66.9	59.8	70.4			65.7	4.410
PUNCTURE	lbs	92.0	73.1	85.4			83.5	7.826
MULLEN BURST	psi	320	320	322	334	330	325	5.741
PERMITTIVITY	sec−1	0.18	0.16	0.15			0.17	0.013

PHYSICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
DIMENSIONS	in							
Initial Length		20.13	19.88					
Final Length		20.25	19.94					
% Change		0.62	0.30				0.46	0.160
Initial Width		14.09	14.06					
Final Width		14.19	14.00					
% Change		0.71	−0.44				0.13	0.577
THICKNESS	mils							
Initial		12	11					
Final		11	11					
% Change		−1.72	4.63				1.45	3.177
MASS/UNIT AREA	oz/sy							
Initial		3.43	3.58					
Final		3.35	3.57					
% Change		−2.24	−0.31				−1.28	0.966

SYNTHETIC INDUSTRIES — J & L TESTING CO., INC. TEST RESULTS

82 TEX WOVEN GEOTEXTILE

120 DAY, 23 DEGREE

MECHANICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
GRAB TENSILE	lbs							
MD		139.4	145.7	150.8			145.3	4.674
CD		167.3	156.0	147.9			157.1	7.944
TRAP TEAR	lbs							
MD		67.9	66.4	59.0			64.4	3.909
CD		61.6	60.2	71.4			64.4	4.979
PUNCTURE	lbs	92.0	89.8	106.6			96.1	7.452
MULLEN BURST	psi	320	335	310	335	320	324	9.695
PERMITTIVITY	sec-1	0.12	0.11	0.12			0.12	0.005

PHYSICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
DIMENSIONS	in							
Initial Length		19.94	20.10					
Final Length		19.94	20.10					
% Change		0.00	0.00				0.00	0.000
Initial Width		14.12	14.00					
Final Width		14.12	14.00					
% Change		0.00	0.00				0.00	0.000
THICKNESS	mils							
Initial		11	11					
Final		13	13					
% Change		12.39	10.53				11.46	0.932
MASS/UNIT AREA	oz/sy							
Initial		3.55	3.46					
Final		3.49	3.47					
% Change		-1.83	0.47				-0.68	1.148

SYNTHETIC INDUSTRIES

J & L TESTING CO., INC. TEST RESULTS

82 TEX WOVEN GEOTEXTILE

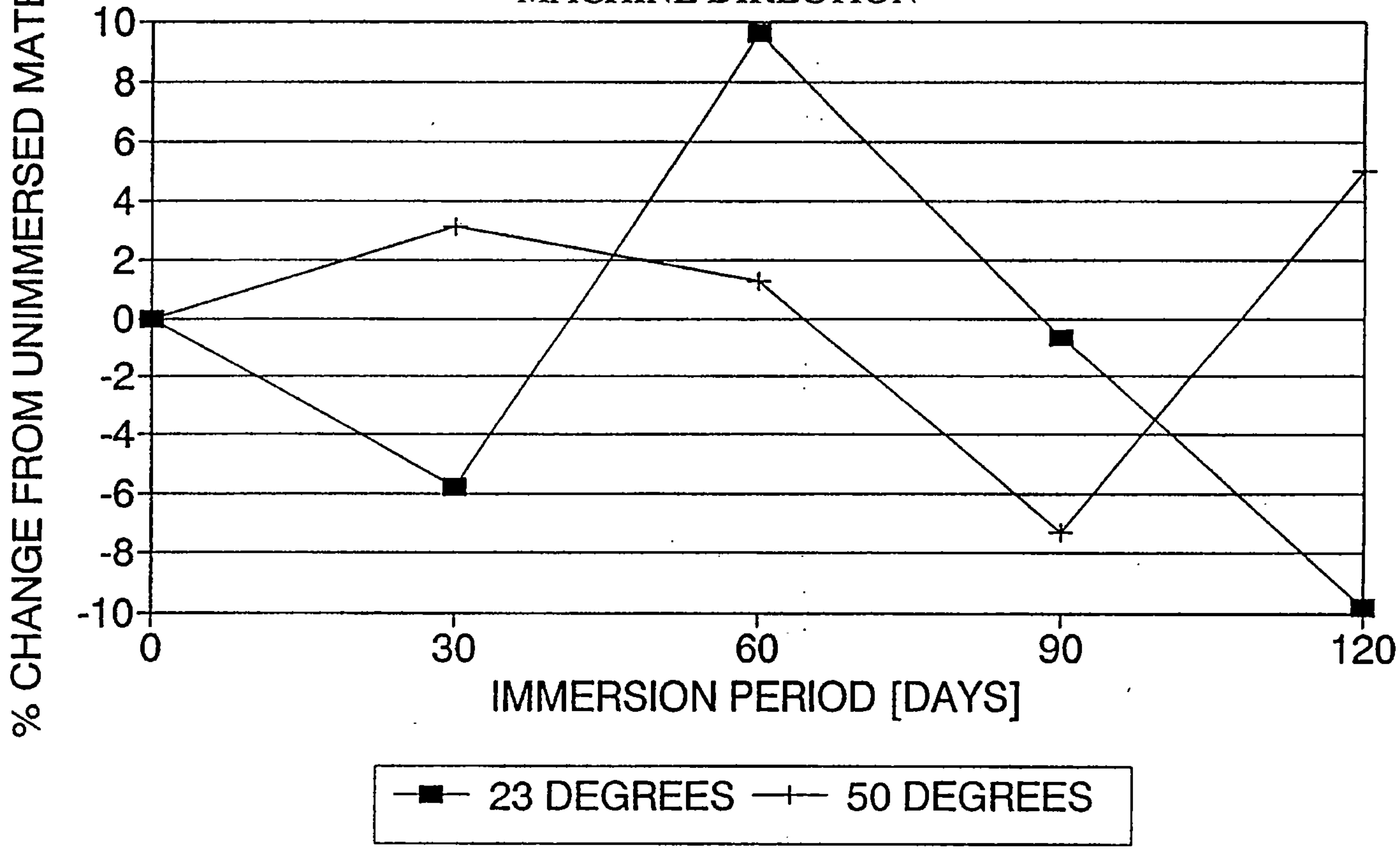
120 DAY, 50 DEGREE

MECHANICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
GRAB TENSILE	lbs							
MD		164.6	170.4	172.6			169.2	3.366
CD		141.7	153.1	154.7			149.9	5.780
TRAP TEAR	lbs							
MD		66.6	67.4	64.2			66.1	1.380
CD		58.9	62.6	65.8			62.4	2.806
PUNCTURE	lbs	95.5	91.1	93.1			93.2	1.807
MULLEN BURST	psi	325	310	335	330	330	326	8.602
PERMITTIVITY	sec−1	0.12	0.11	0.11			0.12	0.003

PHYSICAL PROPERTY	UNITS	SPEC 1	SPEC 2	SPEC 3	SPEC 4	SPEC 5	MEAN	STD.DEV.
DIMENSIONS	in							
Initial Length		20.12	19.90					
Final Length		20.12	19.90					
% Change		0.00	0.00				0.00	0.000
Initial Width		14.00	14.00					
Final Width		14.00	14.00					
% Change		0.00	0.00				0.00	0.000
THICKNESS	mils							
Initial		12	12					
Final		13	13					
% Change		9.57	7.76				8.66	0.903
MASS/UNIT AREA	oz/sy							
Initial		3.49	3.57					
Final		3.37	3.54					
% Change		−3.26	−0.92				−2.09	1.169

SYNTHETIC INDUSTRIES
82 TEX WOVEN GEOTEXTILE

GRAB STRENGTH [lbs]
MACHINE DIRECTION

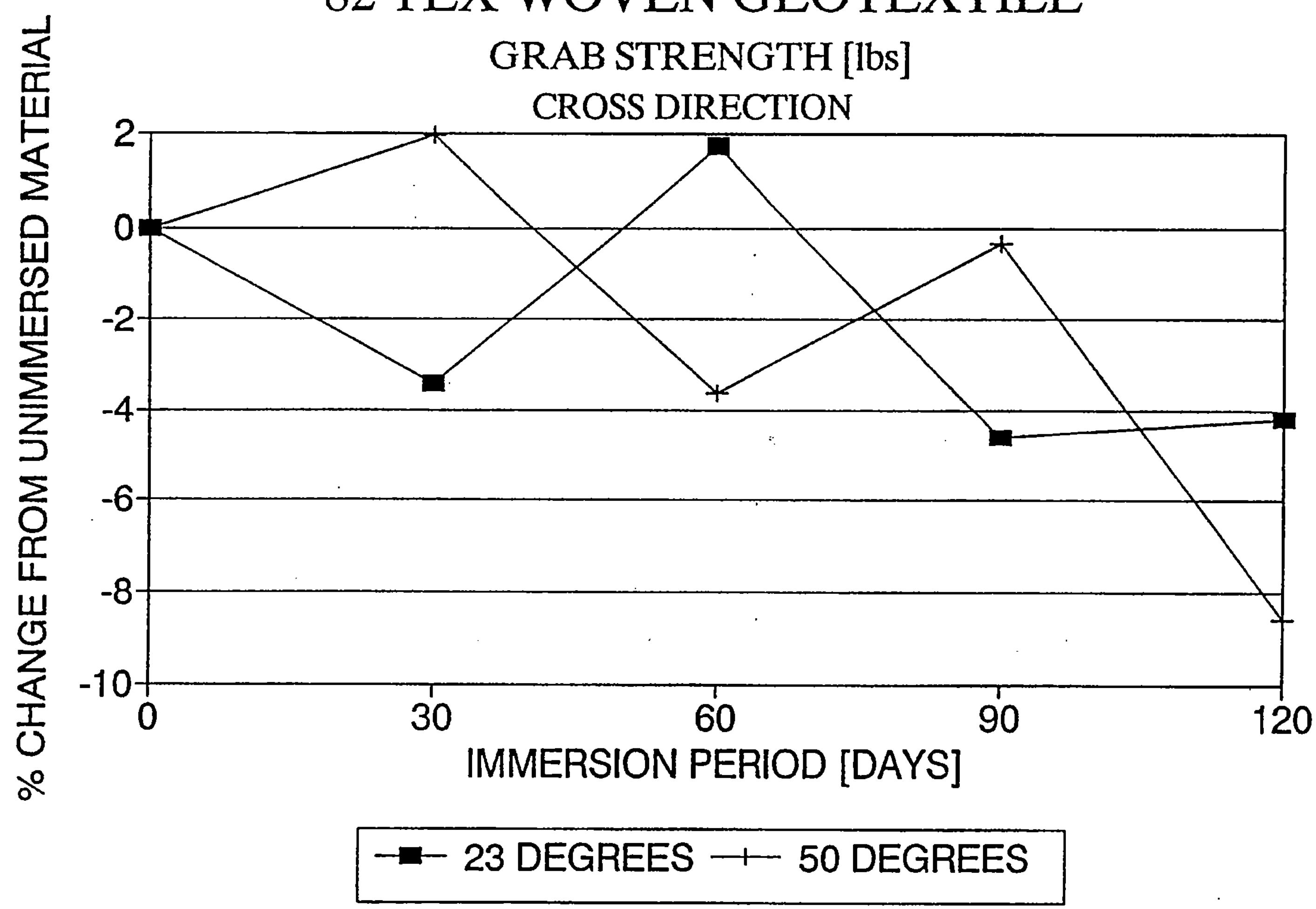


J&L TESTING COMPANY, INC.

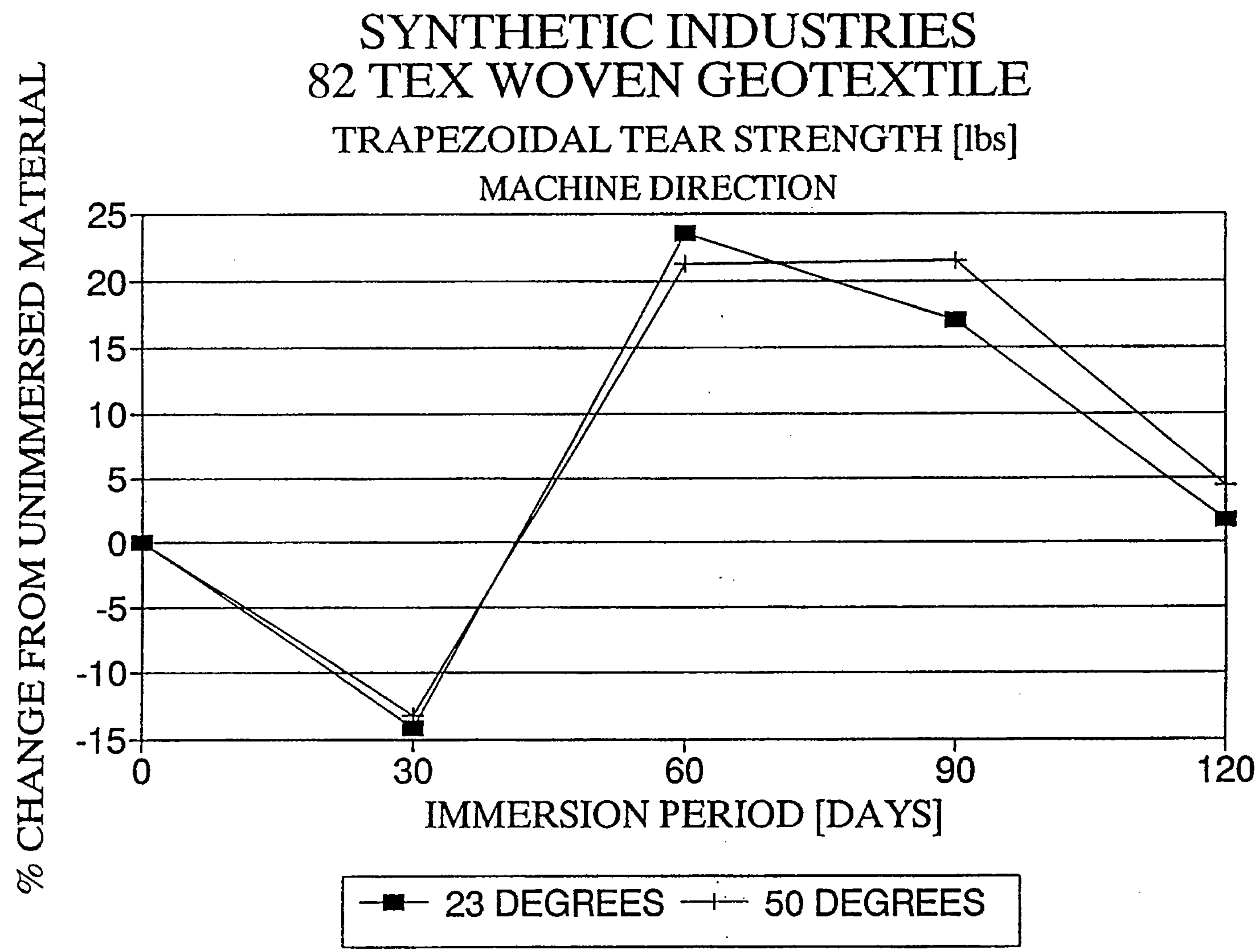
SYNTHETIC INDUSTRIES
82 TEX WOVEN GEOTEXTILE

GRAB STRENGTH [lbs]

CROSS DIRECTION



J&L TESTING COMPANY, INC.



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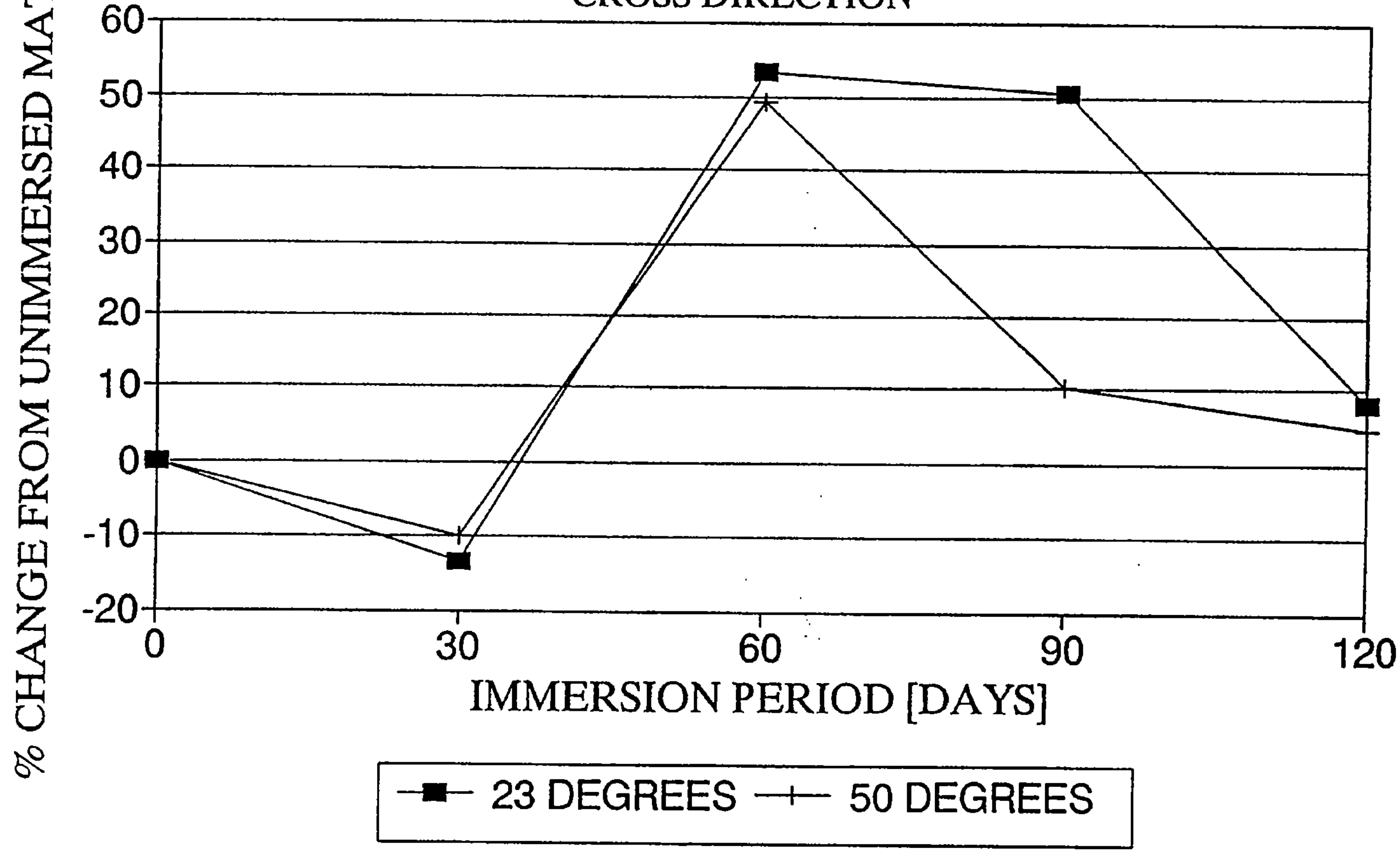
SYNTHETIC INDUSTRIES
82 TEX WOVEN GEOTEXTILE

TRAPEZOIDAL TEAR STRENGTH [lbs]

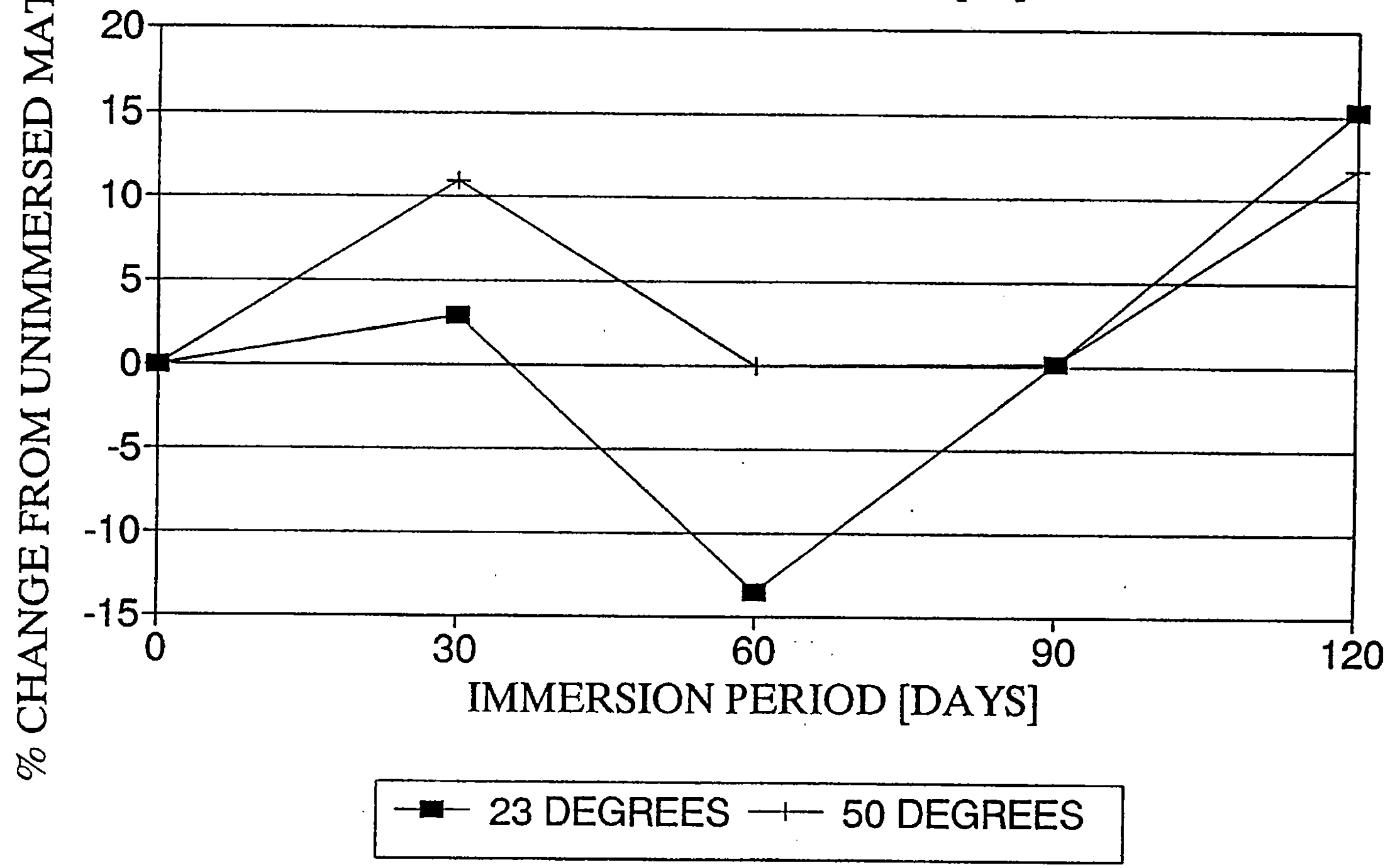
CROSS DIRECTION



J&L TESTING COMPANY, INC.

SYNTHETIC INDUSTRIES
82 TEX WOVEN GEOTEXTILE

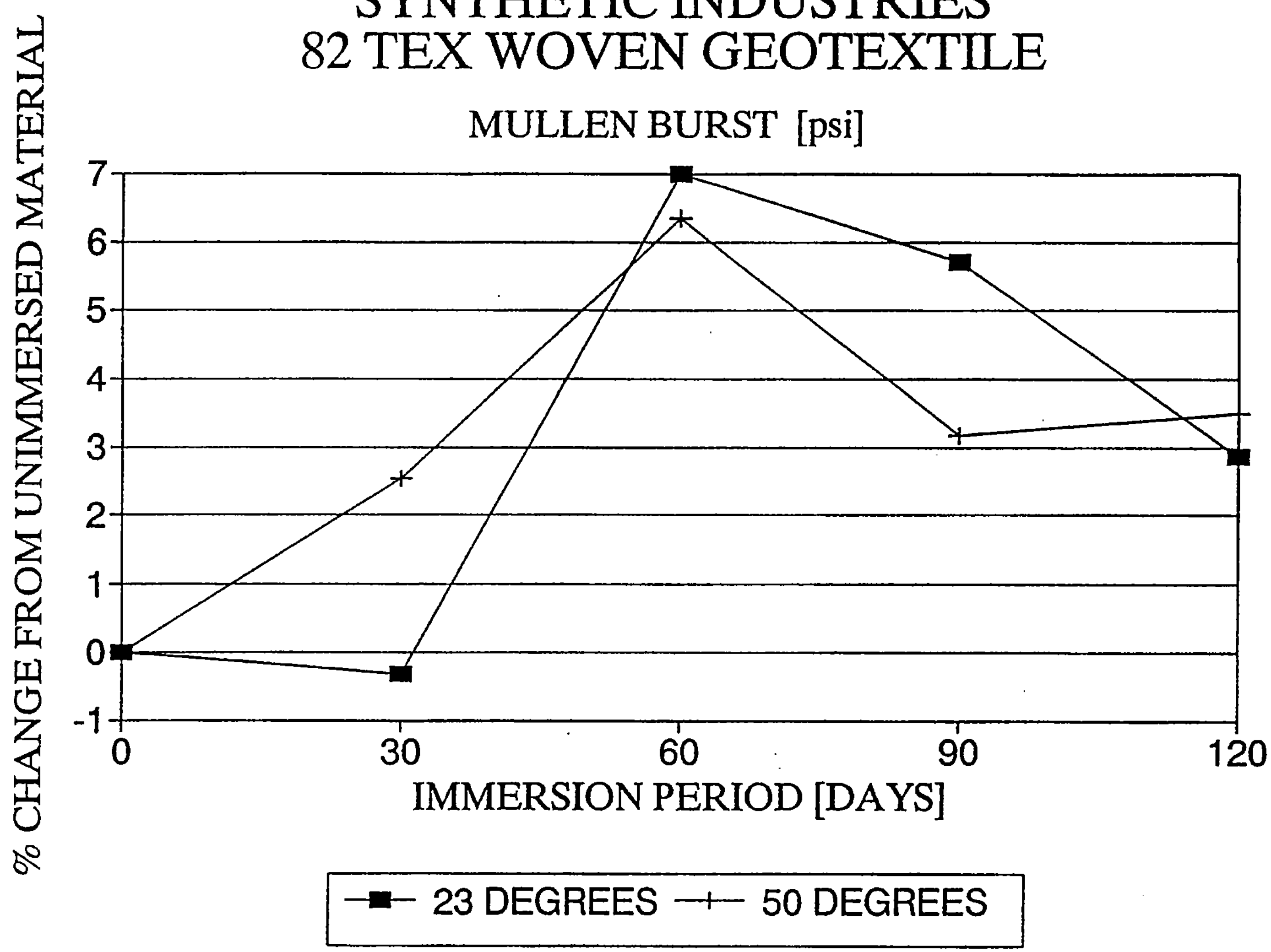
PUNCTURE STRENGTH [lbs]



J&L TESTING COMPANY, INC.

SYNTHETIC INDUSTRIES
82 TEX WOVEN GEOTEXTILE

MULLEN BURST [psi]



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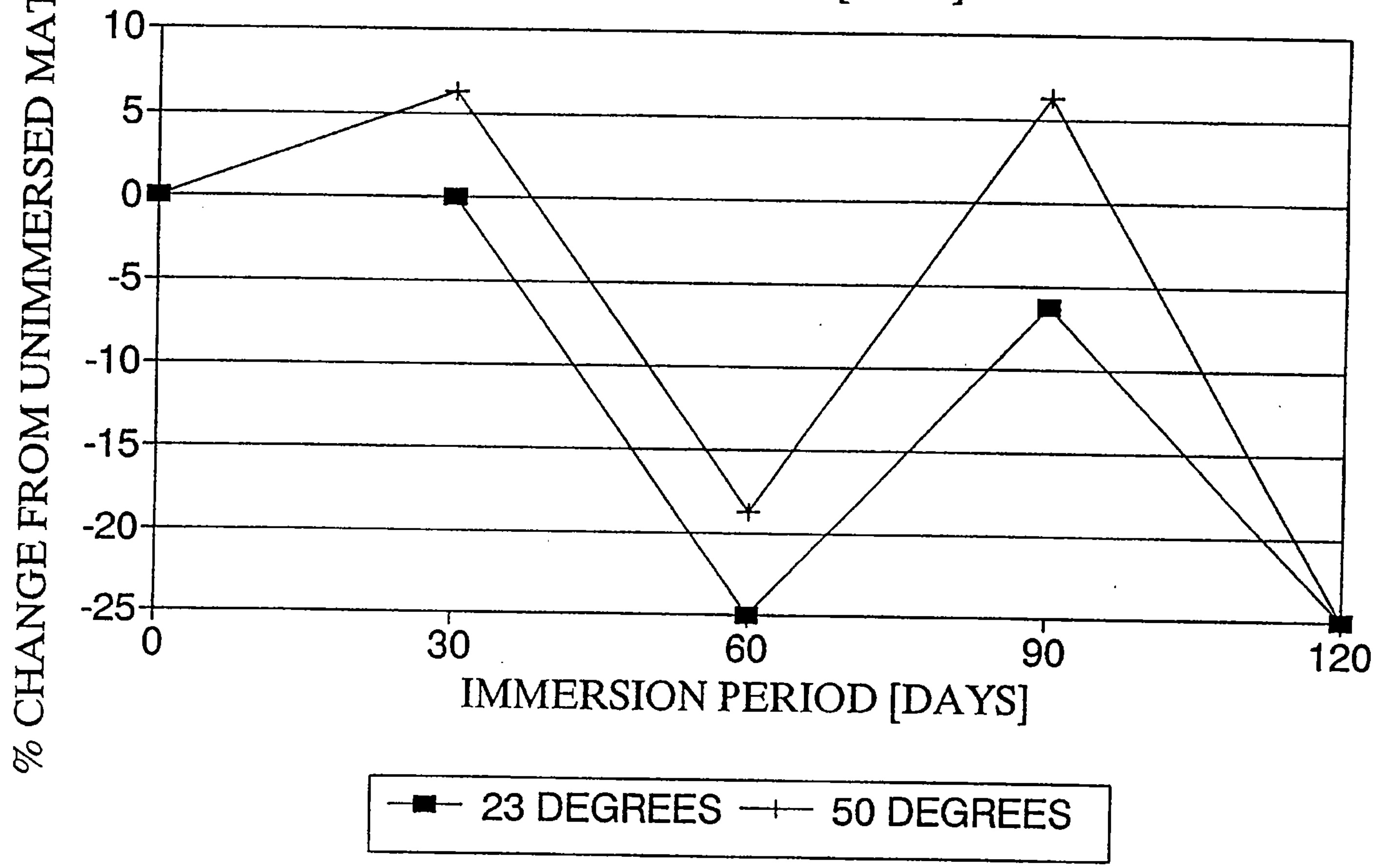
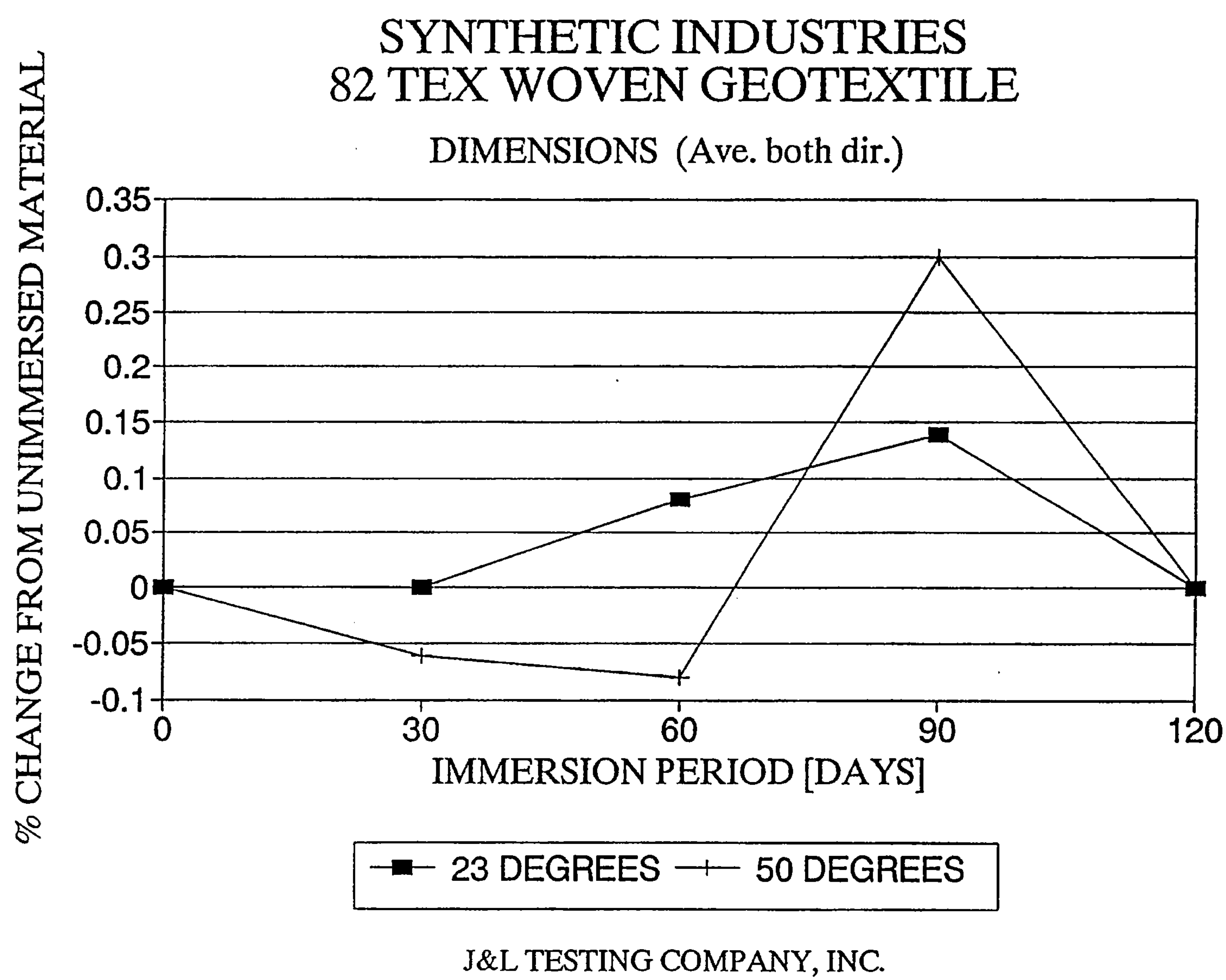
SYNTHETIC INDUSTRIES
82 TEX WOVEN GEOTEXTILE

PERMITTIVITY [Sec.-1]

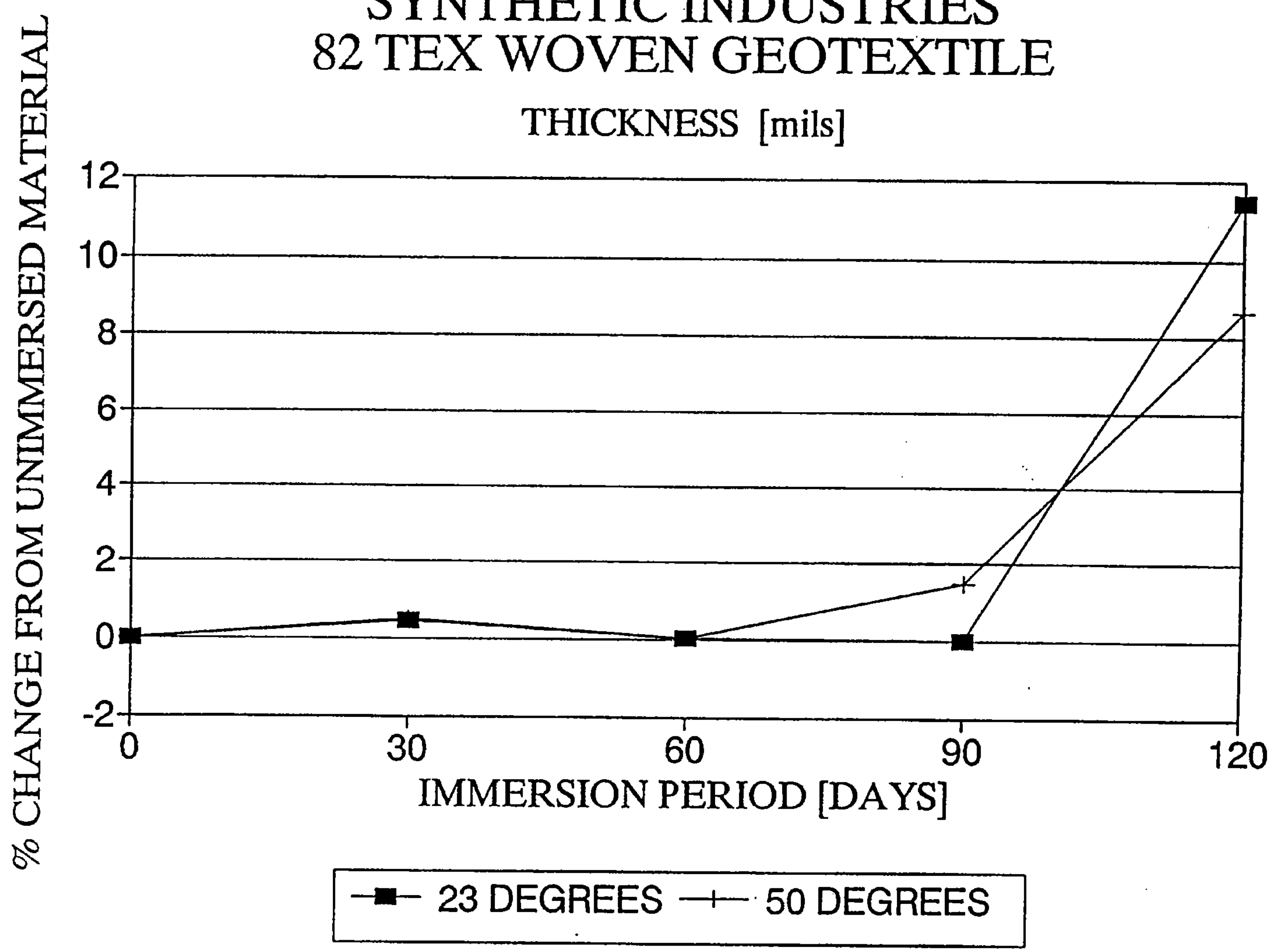


J&L TESTING COMPANY, INC.


SYNTHETIC INDUSTRIES
82 TEX WOVEN GEOTEXTILE
DIMENSIONS (Ave. both dir.)
% CHANGE FROM UNIMMERSED MATERIAL
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
0
30
60
90
120
IMMERSION PERIOD [DAYS]
23 DEGREES
50 DEGREES
J&L TESTING COMPANY, INC.

SYNTHETIC INDUSTRIES
82 TEX WOVEN GEOTEXTILE

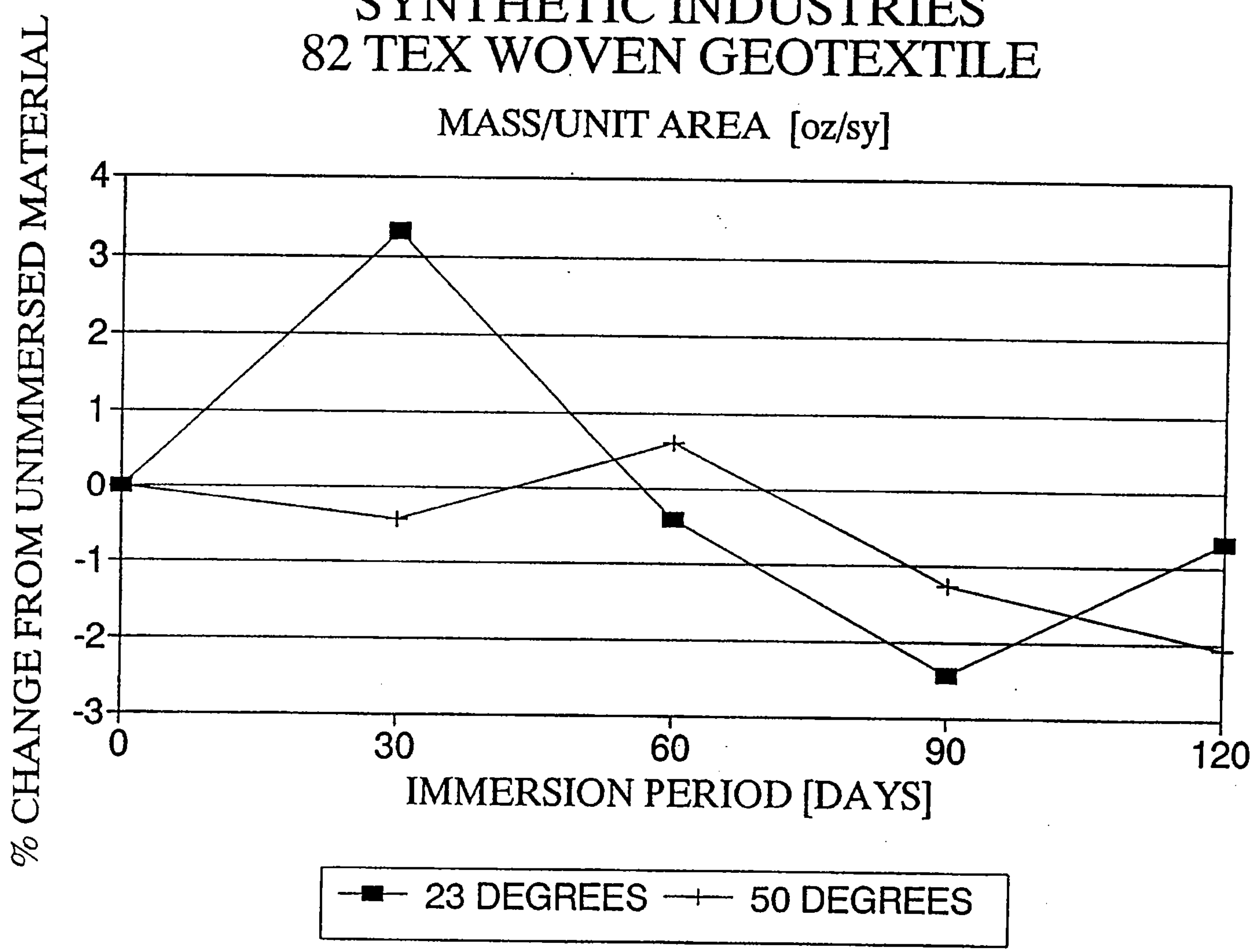
THICKNESS [mils]



J&L TESTING COMPANY, INC.

SYNTHETIC INDUSTRIES
82 TEX WOVEN GEOTEXTILE

MASS/UNIT AREA [oz/sy]



J&L TESTING COMPANY, INC.

WMX ENVIRONMENTAL MONITORING LABORATORIES, INC

C L I E N T   R E P O R T

Site: 426 - Lake View Landfill
Disposal Facility
851 Robinson Road East
Erie PA 16509

Sample Point: METPIT
Sample Type: LEACHATE
Sample Number: AI5461

EMS: 93-14364
MF: 425932
REV: 02

Sampled: 4-NOV-1993
Received: 5-NOV-1993
Reported: 6-DEC-1993

Analyte	Result	EML RL	Units	Comments	Method
FIELD DATA:					
DEPTH TO LEACHATE	NA		FT		FDCXDATA01
LEACHATE ELEVATION	NA		FT MSL		FDCXDATA01
PH FIELD	6.99		PH UNITS		FDPHQUAD01
PH FIELD	6.98		PH UNITS		FDPHQUAD01
PH FIELD	6.97		PH UNITS		FDPHQUAD01
PH FIELD	6.95		PH UNITS		FDPHQUAD01
SAMPLE COLLECTORS NAME	R. WAGNER				FDXSAMPLER
SAMPLING EQUIPMENT	N				FDCXDATA01
SAMPLING MATERIAL	PLAS/BOTT				FDCXDATA01
SPECIFIC CONDUCTANCE FIELD	2910		UMHOS/CM		FDSPCOND04
SPECIFIC CONDUCTANCE FIELD	2900		UMHOS/CM		FDSPCOND04
SPECIFIC CONDUCTANCE FIELD	2900		UMHOS/CM		FDSPCOND04
SPECIFIC CONDUCTANCE FIELD	2890		UMHOS/CM		FDSPCOND04
WATER TEMPERATURE IN DEGREES CELSIUS	8.4		DEGREES C		FDXTEMPC01
CHEMICAL METHODS & ROBOTICS:					
CHEMICAL OXYGEN DEMAND	418	50.	MG/L	DL	CRCODXXX01
NITROGEN, AMMONIA	45.2	1.00	MG/L	DL	CRN2NH3X01
PH	6.79	0.05	PH UNITS		CRPHXQUD04
PH	6.79	0.05	PH UNITS		CRPHXQUD04
PH	6.79	0.05	PH UNITS		CRPHXQUD04
PH	6.78	0.05	PH UNITS		CRPHXQUD04
PHENOLS	.069	0.0050	MG/L	NQ,PX	CRPNLRAX01
SOLIDS, TOTAL SUSPENDED	2020	3.	MG/L		CRTSSXXX01
SOLIDS,TOTAL DISSOLVED	1360	10.	MG/L	DL	CRTDSXXX01
SPECIFIC CONDUCTANCE	2460	1.0	UMHOS/CM		CRCNDQUD04
SPECIFIC CONDUCTANCE	2450	1.0	UMHOS/CM		CRCNDQUD04
SPECIFIC CONDUCTANCE	2450	1.0	UMHOS/CM		CRCNDQUD04
SPECIFIC CONDUCTANCE	2450	1.0	UMHOS/CM		CRCNDQUD04
INORGANICS:					
ALKALINITY,BICARBONATE	1110	10.	MG/L		INALKBIC01
BIOCHEMICAL OXYGEN DEMAND	200	120.	MG/L	DL,NQ	INBODXXX01
CALCIUM-TOTAL	292000	5000	UG/L	DL	INICPTOTCA
CHLORIDE	187	2.5	MG/L	DL	INCHLORI01
IRON-TOTAL	549000	100.	UG/L		INICPTOTFE
LEAD-TOTAL	112	16.0	UG/L	DL	INGFAATOPB
MANGANESE-TOTAL	17500	56.0	UG/L	DL	INICPTOTMN
NICKEL-TOTAL	306	200.	UG/L	DL	INICPTOTNI
SODIUM-TOTAL	142000	8000	UG/L	DL	INICPTOTNA
SULFATE	113	25.0	MG/L	DL	INSULFAT01
ZINC-TOTAL	3110	84.0	UG/L	DL	INICPTOTZN
VOLATILE ORGANICS:					

NA - Not Analyzed   ND - Not Detected   TBK - Trip Blank

Item	Additional Comment Explanations (NQ/DL)
CHEMICAL OXYGEN DEMAND	Dilution factor 5 applied.
NITROGEN, AMMONIA	Dilution factor 50 applied.
PHENOLS	CLOUDY SAMPLE. RESULTS WERE OBTAINED FROM METHOD 420.1 TO ELIMINATE MATRIX PROBLEMS.
SOLIDS,TOTAL DISSOLVED	Dilution factor 2 applied.
BIOCHEMICAL OXYGEN DEMAND	Dilution factor 60 applied. DILUTION WATER DEPLETED MORE THAN 0.2 MG/L D.O.
CALCIUM-TOTAL	Dilution factor 5 applied.
CHLORIDE	Dilution factor 5 applied.
LEAD-TOTAL	Dilution factor 05 applied.
MANGANESE-TOTAL	Dilution factor 5 applied.
NICKEL-TOTAL	Dilution factor 5 applied.
SODIUM-TOTAL	Dilution factor 5 applied.
SULFATE	Dilution factor 5 applied.
ZINC-TOTAL	Dilution factor 5 applied.
VOMSAAN101	Dilution factor 10 applied. SAMPLE FOAMED THEREFORE DILUTION WAS NECESSARY.

WMX ENVIRONMENTAL MONITORING LABORATORIES, INC

CLIENT REPORT

Site: 425 - Lake View Landfill
Disposal Facility
851 Robinson Road East
Erie PA 16509

Sample Point: METPIT
Sample Type: LEACHATE
Sample Number: AI5461

EMS: 93-14364
MP: 425932
MSV: 02

Sampled: 4-NOV-1993
Received: 5-NOV-1993
Reported: 6-DEC-1993

Analyte	Result	EML RL	Units	Comments	Method
1,1,1-TRICHLOROETHANE	ND	50.	UG/L		VOMSAAN101
1,1-DICHLOROETHANE	ND	50.	UG/L		VOMSAAN101
1,1-DICHLOROETHENE	ND	50.	UG/L		VOMSAAN101
1,2-DIBROMOETHANE	ND	80.	UG/L		VOMSAAN101
1,2-DICHLOROETHANE	ND	50.	UG/L		VOMSAAN101
BENZENE	ND	40.	UG/L		VOMSAAN101
CIS-1,2-DICHLOROETHENE	ND	80.	UG/L		VOMSAAN101
ETHYLBENZENE	70.	40.	UG/L		VOMSAAN101
METHYLENE CHLORIDE	170.	50.	UG/L		VOMSAAN101
TETRACHLOROETHENE	ND	40.	UG/L		VOMSAAN101
TOLUENE	170.	40.	UG/L		VOMSAAN101
TRANS-1,2-DICHLOROETHENE	ND	100	UG/L		VOMSAAN101
TRICHLOROETHENE	ND	40.	UG/L		VOMSAAN101
VINYL CHLORIDE	ND	80.	UG/L		VOMSAAN101
XYLENE (TOTAL)	140.	80.	UG/L		VOMSAAN101

NA - Not Analyzed   ND - Not Detected   TBK - Trip Blank

NMX ENVIRONMENTAL MONITORING LABORATORIES, INC

CLIENT REPORT

Site: 425 - Lake View Landfill
Disposal Facility
851 Robinson Road East
Erie PA 16509

Sample Point: METPIT
Sample Type: LEACHATE
Sample Number: AI2506

ENS: 93-13793
MP: 425932
REV: 02

Sampled: 29-DEC-1993
Received: 31-DEC-1993
Reported: 19-JAN-1994

Analyte	Result	EML RL	Units	Comments	Method
FIELD DATA:					
DEPTH TO LEACHATE	NA		FT		FDCXDATA01
LEACHATE ELEVATION	NA		FT MSL		FDCXDATA01
PH FIELD	7.59		PH UNITS		FDPHQUAD01
PH FIELD	7.56		PH UNITS		FDPHQUAD01
PH FIELD	7.59		PH UNITS		FDPHQUAD01
PH FIELD	7.60		PH UNITS		FDPHQUAD01
SAMPLE COLLECTORS NAME	C. FERRICK				FDXSAMPLER
SAMPLING EQUIPMENT	Y				FDCXDATA01
SAMPLING MATERIAL	GLASS				FDCXDATA01
SPECIFIC CONDUCTANCE FIELD	2360		UMHOS/CM		FDSPCOND04
SPECIFIC CONDUCTANCE FIELD	2360		UMHOS/CM		FDSPCOND04
SPECIFIC CONDUCTANCE FIELD	2350		UMHOS/CM		FDSPCOND04
SPECIFIC CONDUCTANCE FIELD	2360		UMHOS/CM		FDSPCOND04
WATER TEMPERATURE IN DEGREES CELSIUS	4.5		DEGREES C		FDXTEMPC01
CHEMICAL METHODS & ROBOTICS:					
NITROGEN, AMMONIA	34.5	0.40	MG/L	DL	CRN2NH3X01
NITROGEN, NITRATE	.15	0.050	MG/L		CRNO3HYD01
PH	7.56	0.05	PH UNITS		CRPHXQUD04
PH	7.55	0.05	PH UNITS		CRPHXQUD04
PH	7.56	0.05	PH UNITS		CRPHXQUD04
PH	7.56	0.05	PH UNITS		CRPHXQUD04
PHENOLS	ND	0.050	MG/L	NQ	CRPNHRAX01
SOLIDS, TOTAL SUSPENDED	28	3.	MG/L		CRTSSXXX01
SPECIFIC CONDUCTANCE	1770	1.0	UMHOS/CM		CRCNDQUD04
SPECIFIC CONDUCTANCE	1770	1.0	UMHOS/CM		CRCNDQUD04
SPECIFIC CONDUCTANCE	1170	1.0	UMHOS/CM		CRCNDQUD04
SPECIFIC CONDUCTANCE	1170	1.0	UMHOS/CM		CRCNDQUD04
TOTAL ORGANIC CARBON	70.3	1.0	MG/L		CRTOCQUD01
TOTAL ORGANIC CARBON	71.8	1.0	MG/L		CRTOCQUD01
TOTAL ORGANIC CARBON	70.5	1.0	MG/L		CRTOCQUD01
TOTAL ORGANIC CARBON	70.1	1.0	MG/L		CRTOCQUD01
TURBIDITY	35	1.0	NTU	TX	CRTURBID01
INORGANICS:					
BIOCHEMICAL OXYGEN DEMAND	131	120.	MG/L	DL,NQ	INBODXXX01
IRON-TOTAL	5840	100.	UG/L		INICPTCTFE
LEAD-TOTAL	ND	16.0	UG/L	DL	INGFAATCPB
NICKEL-TOTAL	ND	40.0	UG/L		INICPTCTNI
ZINC-TOTAL	42.5	20.0	UG/L		INICPTCTZN

NA = Not Analyzed   ND = Not Detected   TBK = Trip Blank

Item	Additional Comment Explanations (NQ/DL)
NITROGEN, AMMONIA	Dilution factor 20 applied.
PHENOLS	CLOUDY SAMPLE AND RESULTS WERE DETERMINED FROM METHOD 420.1 TO ELIMINATE MATRIX PROBLEMS.
INBODXXX01	EMPTY - ALIQUOT FROM : AI2506-D0
BIOCHEMICAL OXYGEN DEMAND	GLUCOSE-GLUTAMIC ACID RESULTS WERE NOT WITHIN THE CONTROL LIMITS. HOWEVER APG STANDARDS ARE WITHIN THE CONTROL LIMITS. Dilution factor 60 applied.
LEAD-TOTAL	Dilution factor 05 applied.

APPENDIX I

LANDFILL GAS DESIGN REPORT

SANBORN | HEAD

Building Trust. Engineering Success.

LFG SYSTEM EXPANSION DESIGN REPORT

JUNIPER RIDGE LANDFILL

OLD TOWN, MAINE

STATE OF MAINE
Eric
S.
Steinhauser
10809
LICENSED
PROFESSIONAL ENGINEER

Prepared for NEWSME Landfill Operations, LLC
File No. 2536.27
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TABLE OF CONTENTS

1.0 INTRODUCTION

Sanborn, Head & Associates, Inc. (Sanborn Head) prepared this Landfill Gas System Expansion Design Report in support of the proposed 9.35 million cubic yard (yd^3) expansion of the Juniper Ridge Landfill (JRL). The proposed landfill expansion will be located predominately to the north of the existing landfill. The purpose of this report is to provide an estimate of future landfill gas (LFG) generation along with a description of the proposed gas collection and control system (GCCS) and how it connects to the existing GCCS infrastructure.

This document fulfills the application submittal requirements of the Maine Solid Waste Management Rules Chapters 401, Section 2.F(6) for a landfill engineering report on the gas management system, and 4.C(11) for landfill operations. Engineering drawings, technical specifications, construction quality assurance (CQA) plan, operations and maintenance (O&M) plan, and supporting calculations are provided as appendices to this report.

2.0 BACKGROUND

Located on the western side of Interstate 95 in Old Town, Maine, the JRL is owned by the State of Maine Bureau of General Services (BGS) and operated by NEWSME Landfill Operations, LLC (NEWSME). The original solid waste facility license for JRL was issued on July 28, 1993 by the Maine Department of Environmental Protection (MaineDEP). At that time, the facility was owned by the James River Paper Company, and was licensed for disposal of pulp and papermaking residuals generated from a paper mill in Old Town, Maine. Solid waste disposal activities have occurred since 1997.

In April 2004, the MaineDEP issued Amendment Order #S-020700-SD-N-A to the JRL license that authorized a vertical expansion to the JRL that increased the disposal capacity by 10 million cubic yards (yd^3) to approximately 10.28 million yd^3. The April 2004 Amendment Order allowed the disposal of non-hazardous waste streams generated in Maine, including construction and demolition debris and processing residues, residues (ash, front-end process, and oversized bulky wastes) generated by municipal solid waste (MSW) incinerators located in Maine, a limited amount of MSW bypass from the incinerators, water/wastewater treatment plant sludge; and smaller amounts of miscellaneous, non-hazardous waste.

The JRL is licensed as a Secure (i.e., lined with leachate collection) Landfill and is divided into discrete cells. At present, Cell 8 is being filled, and construction of Cell 9 is scheduled for 2015.

The JRL currently accepts approximately 1,700 tons of waste per day. Near the end of 2014, the site had approximately 3.9 million yd^3 of remaining airspace, and as such, the available licensed capacity is expected to be reached in early 2019.[1] The proposed 9.35

[1] Approximately 665,000 cubic yards of currently licensed capacity will not be realized until the 9.35 million cubic yard landfill expansion is constructed as the capacity is available from waste placement on the eastern and northern sideslopes of the existing landfill that abuts the expansion cells.

million yd^3 landfill expansion is projected to provide airspace through approximately 2031. Based on an estimated waste placement density of 0.86 tons per yd^3, the additional waste to be accepted at the JRL from 2015 through closure, including the expansion, is approximately 11.395 million tons.

3.0 FACILITY DESCRIPTION

The JRL has an active GCCS that was initially designed to combust methane as a greenhouse gas control measure, and to address nuisance odors from hydrogen sulfide in the LFG. Because the JRL is now required to comply with the air resource requirements from MaineDEP and the U.S. Environmental Protection Agency's (USEPA's) New Source Performance Standards (NSPS) for MSW landfills, the objectives of the GCCS also include reducing emissions of regulated air pollutants and greenhouse gases and limiting the potential for odors. The GCCS actively collects LFG while maintaining anaerobic conditions within the waste mass through the use of synthetic intermediate cover to limit air intrusion into the waste as well as the release of fugitive emissions. NEWSME monitors the GCCS by documenting the rate of LFG extraction and the concentration (percent by volume) of methane, oxygen, carbon dioxide, and balance gas (primarily nitrogen) contained in the LFG.

The GCCS is regularly expanded by adding gas extraction points and related infrastructure. LFG is currently managed in Cells 1 through 8 using gas collection trenches (GCTs) and/or vertical gas extraction wells. Vertical extraction wells have been installed in areas where the outer slopes of the cells are filled to final grades. The vacuum applied at each extraction location may be adjusted with a manually controlled valve on the extraction location wellhead. At the end of 2014, there were 63 vertical wells and 79 GCTs installed throughout Cells 1 through 8. LFG is also collected from condensate traps and leachate collection system cleanouts as needed to remove gas that may be released from the liquids in the pipes. The existing LFG collection and control system is depicted on an as-built drawing included as Figure 1.

LFG extracted from the waste mass passes through a moisture separator to remove the remaining condensate before it is treated for total sulfur (mostly hydrogen sulfide) removal (see description below) and then combusted in Flare #4, or backup Flares #2 and #3. Flare #4 is rated for 106.5 million British thermal units per hour (MMBtu/hr), which is equivalent to 3,550 standard cubic feet per minute (scfm) of LFG at 50 percent methane (CH_4). Flare #3 is rated 40.5 MMBtu/hr (equivalent to 1,350 scfm at 50 percent CH_4) and Flare #2 is rated for 22.5 MMBtu/hr (equivalent to 750 scfm at 50 percent CH_4). Flares #2 and #3 are licensed as backup combustion devices and are limited to 100 hours per year of operation. In 2013, a sulfur removal system using Sulfatreat® media was installed next to the flare to maintain the required sulfur emission levels at the combustion flare. In early 2015, NEWSME began operating a Thiopaq® sulfur removal system to reduce the total sulfur (mostly hydrogen sulfide) in the LFG prior to combustion to decrease emissions of sulfur dioxide). The Sulfatreat® sulfur removal system remains on site to be used as needed to maintain the required sulfur levels.

In the future, LFG may be combusted in a LFG-to-energy (LFGTE) facility. The future LFGTE facility is anticipated to handle approximately 2,170 scfm at 50 percent CH_4: three engine-generators rated for a total approximately 1,650 scfm and an open flare rated for approximately 520 scfm. The LFGTE facility operator will maintain the 520 scfm flare for LFG delivered to the facility in excess of the flow required for the engines. JRL will not deliver LFG to the facility in excess of its 2,170 scfm capacity. LFG collection in excess of the flow delivered to the LFGTE facility will be combusted in the JRL flare system.

4.0 LANDFILL GAS GENERATION ESTIMATES

Estimates for future LFG generation and collection (LFG projections) were revised by Sanborn Head to reflect waste acceptance rate estimates, updated LFG collection rate data, and the future landfill expansion volume (i.e., 9.35 million yd^3). Tabulated waste acceptance rates and degradable waste portions can be found in Appendix A. The LFG generation rate estimates are based on modeling with the USEPA's *Landfill Gas Emissions Model, Version 3.02* (LandGEM). LandGEM uses a first order decay equation from 40 Code of Federal Regulations (CFR) Part 60.754. Model inputs include default or user-defined LFG generation constants. The results of the LandGEM model are provided in Appendix A.

According to LandGEM, the peak LFG collection rate, assuming LFG at 50 percent CH_4, is approximately 3,600 scfm in 2031, the year the expanded JRL is projected to reach capacity. To account for potentially lower methane concentrations in the LFG, the main LFG header pipe was sized for the projected maximum LFG flow rate at 40 percent CH_4 or approximately 4,500 scfm. Figure 2 presents a graph that depicts projected LFG collection rates assuming LFG at 40 percent CH_4. As noted above, the rated capacity of Flare #4 is approximately 3,550 scfm at 50 percent CH_4 or approximately 4,500 scfm at 40 percent CH_4. Therefore, Flare #4 is adequate for the proposed expansion.

5.0 PROPOSED LFG EXTRACTION SYSTEM EXPANSION

The design of the LFG extraction system for the proposed 9.35 million yd^3 landfill expansion is shown on Sheet 2 of the Engineering Drawings provided in Appendix B. The sequential development (i.e., phasing) of the construction of the expanded LFG system is depicted on Sheets 3 through 8. Descriptions of the components of the LFG extraction system are provided below.

5.1 Vertical Extraction Wells

Vertical extraction wells will be installed at the locations indicated on the Engineering Drawings (see Appendix B) when waste in those areas reaches final grade. The wells were spaced assuming an effective radius of influence of approximately 100 feet. In addition, the wells were located in areas where the waste thickness was greater than 60 feet. The LFG extraction well schedule provided on the Engineering Drawings includes the proposed location of each well (by northing and easting), and the elevations of the ground surface and the base of the wells.

The wells will be drilled using a 30-inch diameter bucket auger advanced to a design depth of 15 feet above the top of the primary liner sand cover. The wells will be constructed of 8-

inch diameter schedule 80 polyvinyl chloride pipe. The lower portion of the pipe will be slotted with rows of four, ⅛- to ¼-inch wide by 8-inch long saw cuts spaced 90 degrees apart circumferentially and offset 45 degrees from row to row.

The slotted sections of each well will extend from about 15 feet below grade to the bottom of the well. The annular space between the slotted portion of the well and borehole wall will be backfilled with 2-inch nominal diameter ballast stone. A 12-inch thick filter of sand and gravel will be placed above the stone, which in turn will be overlain by a minimum 12-inch thick bentonite seal. Common fill, a soil with minimum 35 percent of its particles passing through the No. 200 sieve, will be placed above the bentonite seal to the waste surface. The well construction detail is presented on Sheet 9 of the Engineering Drawings (Appendix B).

5.2 Gas Collection Trenches

The GCTs will be constructed as an interim method of gas extraction until vertical extraction wells can be installed at final grades. The GCTs are designed assuming an elliptical effective radius of influence with a vertical radius of 20 feet and horizontal reach of 100 feet. The 4-foot wide by 5-foot deep collection trenches will be constructed within the waste mass during active filling to capture LFG early in its generation phase and reduce the potential for LFG migration and associated odors. Each GCT will consist of a 6-inch diameter perforated high-density polyethylene (HDPE) pipe embedded within a coarse aggregate (e.g., ballast stone or tire chips). Intermediate cover will be placed above the trenches. The trench construction detail is presented on Sheet 12 of the Engineering Drawings (Appendix B). For clarity the Engineering Drawings do not show the locations of interim GCCS infrastructure (including GCT's) to be installed within each cell. The actual locations of the GCT installations will be positioned based on the effective radius of influence described above.

5.3 Conveyance Pipe

The vertical LFG extraction wells and the GCTs will be connected to the existing GCCS and conveyed to the sulfur scrubbing system and then to Flare #4 using a series of SDR-17 HDPE pipes ranging from 4 inches to 24 inches in diameter. HDPE pipe was selected because it is relatively chemically inert and has more flexibility than more rigid alternatives to accommodate the anticipated settlement and deformation common to landfills.

The majority of the LFG conveyance header and lateral pipes will be located in the waste mass and will be sloped to promote drainage of condensate generated in the pipes and to allow for future waste settlement when possible. Conveyance pipes will pass through condensate traps located at low points, within the limit of waste (i.e., lined portion of the landfill expansion) to remove liquid from the system. A proposed 24-inch diameter perimeter LFG conveyance header pipe will be located outside the limit of waste along the east perimeter road of the expansion. The proposed east perimeter header pipe will connect to the existing 24-inch diameter header pipe at the southeast corner of the site. The proposed LFG conveyance pipes located inside the limit of waste on the west side of the landfill expansion will connect to the existing 24-inch diameter perimeter header pipe located on the northwest side of Cell 1 just outside the limit of waste. A small section of the

LFG header pipe that will serve Cell 16 will be buried outside the limit of waste along the western perimeter berm. The locations of these connections are shown on the Engineering Drawings contained in Appendix B. Technical specifications for the HDPE pipe can be found in Appendix C.

Pipe sizing calculations and sizing verification checks for critical LFG conveyance pipes were performed based on the results of the LandGEM model assuming 0.1 scfm of CH_4 generation per pound of waste per year. The pipes were sized for gas generated in the waste tributary to each pipe. Smaller diameter pipes (i.e., less flow, less critical) were sized based on the number of extraction points connected and industry experience, with considerations for friction losses in long lengths of smaller diameter pipes. The pipe sizing criteria allows for a head loss, estimated by the low pressure Mueller equation, of one inch of water column per 100 feet of pipe. The pipe sizing calculations are provided in Appendix A.

Joined sections of the HDPE pipe will be fusion welded, and with the exception of 50-feet of solid pipe installed in each collection trench, the solid pipe and fittings will be pneumatically pressure tested during construction.

The sequential construction (i.e., phasing) of the GCCS for Cells 11 through 16 is depicted on Sheets 3 through 8 of the Engineering Drawings provided in Appendix B.

5.4 Wellheads

Flow control and sampling will be performed using wellheads installed between gas extraction locations and the gas conveyance pipes. A detail of the wellhead is provided on Sheet 9. Flexible hose will be provided between the wellhead and the conveyance pipe to accommodate differential movement. Sample ports will be provided in the wellhead to allow monitoring of gas flow and composition. A valve will be provided at the wellhead to regulate the flow based on the monitoring results.

5.5 Condensate Collection

As mentioned above, condensate traps will be provided at low points in the conveyance pipe to remove liquid. The traps consist of U-shaped tubes filled with liquid that provide a seal between the vacuum side of the system and the atmospheric pressure side of the system. Condensate collected in the traps will drain to a primary leachate collection system sideriser cleanout pipe.

A condensate knockout structure will be located outside the landfill limit of waste at the northern limit of the 24-inch diameter perimeter header in the vicinity of Cell 13. The structure is intended to remove LFG condensate from the upgradient header and lateral conveyance pipes and pump condensate to the nearest primary leachate collection system sideriser cleanout pipe for Cell 13. The condensate knockout is a Class 1 Division 1 Group D classified space, and as such, is intended to include explosion-proof or intrinsically-safe electrical equipment. The structure is also considered to be a confined space with entry by permit only. A detail of the knockout structure is shown on Sheet 12 of the engineering drawings provided in Appendix B.

6.0 OPERATIONS AND MAINTENANCE

The operations and maintenance (O&M) manual for the expanded LFG system is provided in Appendix E. The Q&M manual identifies typical LFG characteristics, hazards, and related precautionary measures. It includes general descriptions of system components, their function, and procedures for maintenance and monitoring. In general, the operation and maintenance of the expanded LFG system will adhere to methods and practices currently employed at the site.

7.0 CONCLUSION

In Summary, the LFG system design described in this report will collect LFG generated from existing and future waste placement at the JRL (including the expanded JRL) and convey it to the existing blower, then to the sulfur scrubbing system for treatment, and finally to the flare station or future LFGTE facility for combustion. This document and appendices fulfill the application submittal requirements of the Maine Solid Waste Management Rules Chapters 401, Section 2.F(6) for a landfill engineering report on the gas management system, and 4.C(11) for landfill operations.

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FIGURE 1

LANDFILL GAS COLLECTION AND CONTROL SYSTEM PLAN (AS-BUILT)

MAINE STATE PLANE

CURRENT ACTIVE LFG COLLECTION SOURCES:

VERTICAL WELLS
GW-02
GW-03
GW-04
GW-05
GW-06
GW-09
GW-10
GW-11
GW-12
GW-13
GW-14
GW-15
GW-16
GW-18
GW-19R
GW-20R
GW-21
GW-22R
GW-23R
GW-24
GW-25
GW-28
GW-29
GW-30R
GW-31R
GW-32
GW-36
GW-37
GW-38
GW-39
GW-46
GW-47
GW-48
GW-54
GW-55
GW-56
GW-57
GW-64
GW-65
GW-66
GW--7
GW-74
GW-75
GW-82
GW-83
GW-90
GW-91
GW--A
GW--D
GW--E
GW--F
GW-G2
GW-H2
GW--I
GW--J
GW--K
GW--L
GW--M
GW--N
GW--O
GW--P
GW--S
GW--T

HORIZONTAL COLLECTION TRENCHES
GCT-01
GCT-17
GCT-18
GCT-201
GCT-2A1
GCT-2A2
GCT-3A1
GCT-3A2
GCT-3A3
GCT-3A4
GCT-3A5
GCT-3B1
GCT-3B2
GCT-3B3
GCT-3B4
GCT-401
GCT-401A
GCT-402
GCT-402A
GCT-403
GCT-404
GCT-404A
GCT-405A
GCT-406
GCT-406A
GCT-501
GCT-502
GCT-503
GCT-504
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GCT-506
GCT-507
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GCT-802
GCT-803
GCT-804
GCT-805
GCT-806
GCT-807
GCT-808
GCT-809
GCT-810
GCT-811
GCT-812
GCT-813
GCT-814
GCT-815
GCT-816
GCT-817
GCT-818
GCT-819

OTHER
3W-01
3W-02
7SOUTH
L7WEST
LC--5
LC--6
LGV401
LGV402
LGV403
LGV404
LPC-1
LPC-3
LPC-4
LPC4A
LPC-2

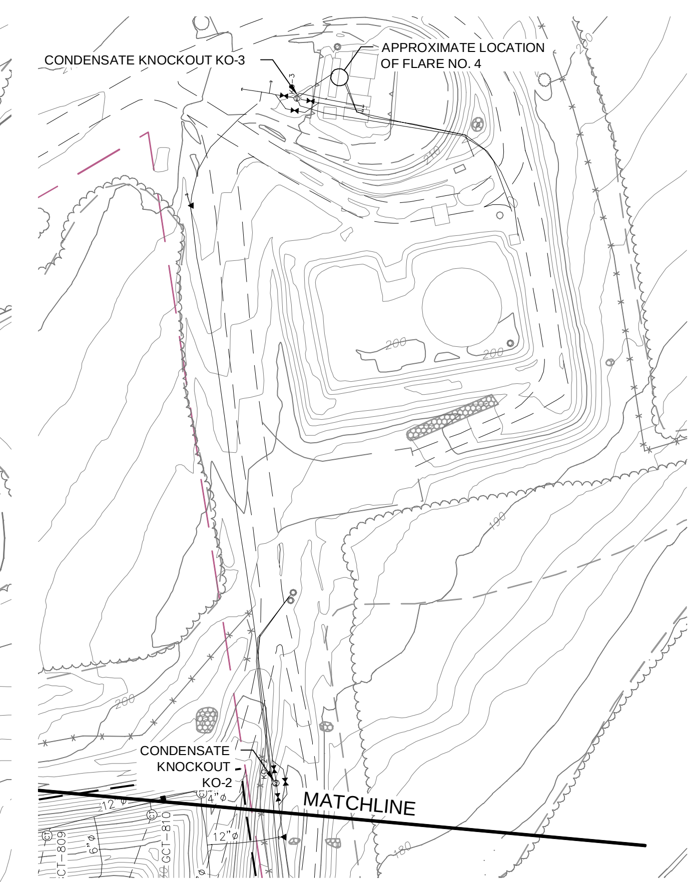
NOTES:

1. THE EXISTING LANDFILL GAS EXTRACTION SYSTEM INFRASTRUCTURE FEATURES SHOWN ARE BASED ON A COMBINATION OF DESIGN AND AS-BUILT DOCUMENTATION AVAILABLE TO SANBORN, HEAD & ASSOCIATES, INC. (SANBORN HEAD). ACTUAL LOCATIONS OF INDIVIDUAL FEATURES MAY BE DIFFERENT THAN SHOWN.
2. BASE MAP WAS PREPARED BY AERIAL SURVEY & PHOTO INC., OF NORRIDGEWOCK, MAINE. PHOTO DATE JULY 31, 2014. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE.

LEGEND:

EXISTING

- 190 — 10-FOOT CONTOUR
- 2-FOOT CONTOUR
- LIMIT OF WASTE CONTAINMENT
- CELL LIMIT
- EDGE OF ROAD
- LANDFILL GAS CONVEYANCE PIPE
- LANDFILL GAS COLLECTION TRENCH (PERFORATED PIPE)
- LIMIT OF MARSH
- FENCE LINE
- GW-9 — LANDFILL GAS EXTRACTION WELL
- GCT-21 — COLLECTION TRENCH WELLHEAD
- COLLECTION TRENCH TERMINATION
- PIPE END CAP
- LEACHATE COLLECTION PIPE CLEANOUT
- LEACHATE COLLECTION INLET
- LANDFILL GAS EXTRACTION WELLHEAD
- RIPRAP AREAS



SANBORN HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: J. DORIS
PROJECT MGR: J. DORIS
PIC: D. ADAMS
DATE: JANUARY 2015

JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LANDFILL GAS COLLECTION AND CONTROL SYSTEM PLAN

PROJECT NUMBER: 2343.01

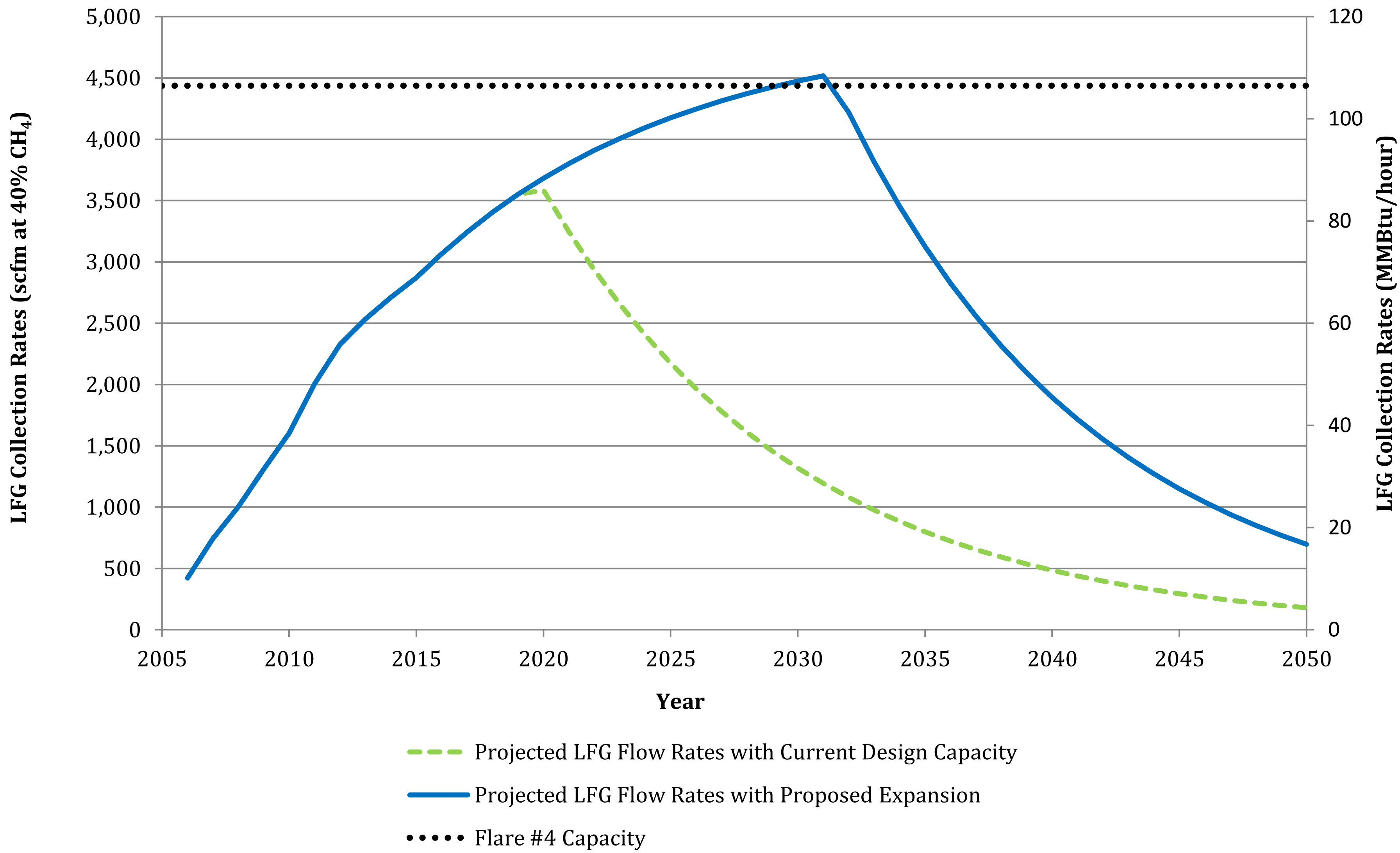
FIGURE NUMBER: 1

FIGURE 2

PROJECTED LFG COLLECTION RATES WITH AND WITHOUT PROPOSED EXPANSION

Figure 2
Projected LFG Collection Rates
With and Without Proposed Expansion

Juniper Ridge Landfill
Old Town, Maine



Sanborn, Head & Associates, Inc.

APPENDIX A

CALCULATIONS

Waste Acceptance Rates and Degradable Waste Portions
1997 through 2003

Juniper Ridge Landfill
Old Town, Maine

Material	1997			1998			1999			2000		
	Waste Accepted (tons)	Gas Production Potential (%)	Degradable Waste (tons)	Waste Accepted (tons)	Gas Production Potential (%)	Degradable Waste (tons)	Waste Accepted (tons)	Gas Production Potential (%)	Degradable Waste (tons)	Waste Accepted (tons)	Gas Production Potential (%)	Degradable Waste (tons)
Lime	1,589	0	0	1,008	0	0	190	0	0	420	0	0
WWTP Sludge	22,180	100	22,180	26,198	100	26,198	29,164	100	29,164	32,250	100	32,250
Flyash	0	0	0	0	0	0	1,349	0	0	5,924	0	0
Wood Waste	1,406	0	0	3,908	0	0	3,743	0	0	2,600	0	0
Miscellaneous	1,194	10	119	1,411	10	141	40	10	4	355	10	36
Sub-Total	26,369		**22,299**	32,525		**26,339**	34,486		**29,168**	41,549		**32,286**

Material	2001			2002			2003		
	Waste Accepted (tons)	Gas Production Potential (%)	Degradable Waste (tons)	Waste Accepted (tons)	Gas Production Potential (%)	Degradable Waste (tons)	Waste Accepted (tons)	Gas Production Potential (%)	Degradable Waste (tons)
Lime	1,721	0	0	1,023	0	0	2,233	0	0
WWTP Sludge	30,263	100	30,263	38,785	100	38,785	44,113	100	44,113
Flyash	5,529	0	0	4,930	0	0	7,967	0	0
Wood Waste	1,371	0	0	2,341	0	0	5,331	0	0
Miscellaneous	2,685	10	269	611	10	61	128	10	13
Sub-Total	41,569		**30,532**	47,690		**38,846**	59,772		**44,126**

Notes:

1. The quantity of each waste type accepted and total waste acceptance rates for 1997 through 2002 were taken from information included in a table titled "Oldtownhistorical waste quantities," attached to an October 1, 2003 e-mail to James Chabot of Sanborn Head from Mike Booth of Sevee & Maher Engineers (SME) with subject heading "Old Town Landfill."

2. The 2003 waste acceptance rates and percentage of each waste type accepted were taken from information included in a table titled "Waste Volume Percentages for West Old Town Landfill" attached to a March 25, 2005 e-mail to Sanborn Head from Tom Gilbert of NEWSME Landfill Operations, LLC with subject heading "ptl & wotl waste percentages."

3. Gas production potentials of waste types accepted from 1997 through 2002 are based on discussions between James Chabot and David Adams of Sanborn Head and Mike Booth of SME on October 21, 2003.

4. Gas production potentials of waste types accepted for 2003 are based on percentages used to estimate degradable waste portions at the Juniper Ridge Landfill.

Waste Acceptance Rates and Degradable Waste Portions
2004 through 2014

Juniper Ridge Landfill
Old Town, Maine

Waste Categoy	Assumed % Degradable	2004 (tons)	2004 (degradable tons)	2005 (tons)	2005 (degradable tons)	2006 (tons)	2006 (degradable tons)	2007 (tons)	2007 (degradable tons)	2008 (tons)	2008 (degradable tons)	2009 (tons)	2009 (degradable tons)
WWTP and miscellaneous biosolids/sludge material	100	26,686	26,686	35,336	35,336	36,286	36,286	61,262	61,262	72,275	72,275	70,265	70,265
Contaminated soils	0	0	0	0	0	31,712	0	8,451	0	43,910	0	2,585	0
Municipal incinerator ash	0	0	0	58,269	0	34,087	0	30,029	0	94,350	0	101,262	0
Biomass and fossil fuel combustion ash	0	20,880	0	0	0	52,385	0	61,968	0	64,809	0	29,870	0
C&D process fines (used as daily cover)	30	0	0	7,931	2,379	42,320	12,696	41,109	12,333	45,148	13,544	46,744	14,023
Construction and demolition debris	30	0	0	76,088	22,826	163,581	49,074	143,453	43,036	125,790	37,737	104,309	31,293
Oversized bulky waste	100	0	0	12,271	12,271	29,225	29,225	9,649	9,649	21,405	21,405	51,438	51,438
Miscellaneous Waste	100	5,453	5,453	14,740	14,740	19,868	19,868	34,295	34,295	11,551	11,551	13,871	13,871
MSW bypass and soft layer material	100	0	0	2,035	2,035	11,155	11,155	7,620	7,620	21,426	21,426	39,524	39,524
Front-end process residue	100	393	393	45,644	45,644	105,139	105,139	74,763	74,763	117,118	117,118	84,727	84,727
Total		**53,412**	**32,532**	**252,314**	**135,232**	**525,758**	**263,443**	**472,599**	**242,958**	**617,782**	**295,056**	**544,595**	**305,141**

Waste Categoy	Assumed % Degradable	2010 (tons)	2010 (degradable tons)	2011 (tons)	2011 (degradable tons)	2012 (tons)	2012 (degradable tons)	2013 (tons)	2013 (degradable tons)	2014 (tons)	2014 (degradable tons)	Future Tonnages based on 700,000 tons/year		Degradable Tons (2015 to closure)
WWTP and miscellaneous biosolids/sludge material	100	58,558	58,558	51,053	51,053	49,270	49,270	64,559	64,559	46,004	46,004	70,000	10.0%	70,000
Contaminated soils	0	6,407	0	17,526	0	2,615	0	11,017	0	16,075	0	30,000	4.3%	0
Municipal incinerator ash	0	104,865	0	105,526	0	101,276	0	57,435	0	54,131	0	58,000	8.3%	0
Biomass and fossil fuel combustion ash	0	26,322	0	12,855	0	7,785	0	8,715	0	24,771	0	35,000	5.0%	0
C&D process fines (used as daily cover)	30	87,449	26,235	125,301	37,590	152,171	45,651	152,915	45,875	126,152	37,846	138,000	19.7%	41,400
Construction and demolition debris	30	145,488	43,646	149,744	44,923	150,706	45,212	167,418	50,225	199,451	59,835	195,000	27.9%	58,500
Oversized bulky waste	100	96,520	96,520	98,888	98,888	64,689	64,689	54,353	54,353	48,219	48,219	60,000	8.6%	60,000
Miscellaneous Waste	100	17,815	17,815	17,326	17,326	13,884	13,884	28,862	28,862	18,910	18,910	35,000	5.0%	35,000
MSW bypass and soft layer material	100	39,524	39,524	22,355	22,355	729	729	7,326	7,326	38,516	38,516	25,000	3.6%	25,000
Front-end process residue	100	125,250	125,250	103,306	103,306	94,178	94,178	53,654	53,654	57,048	57,048	54,000	7.7%	54,000
Total		**708,198**	**407,548**	**703,880**	**375,442**	**637,303**	**313,613**	**606,254**	**304,854**	**629,277**	**306,378**	**700,000**	**100.00%**	**343,900**

EPA Categories
- Sewage Sludge
- Inert Waste
- Wood Waste / C&D
- Bulk MSW

Note:

1. Waste reports provided by NEWSME and degradable percentages provided by USEPA in the Federal Mandatory Greenhouse Gas Reporting Rule Subpart HH.

Annual Waste Acceptance Rates Summary With Proposed Expansion

Juniper Ridge Landfill
Old Town, Maine

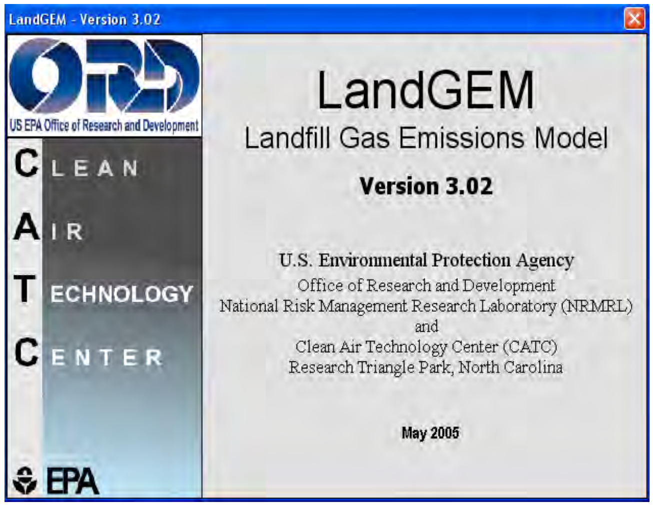
Year	Waste Accepted (tons)	Degradable Waste Accepted (tons)
1997	26,369	22,299
1998	32,525	26,339
1999	34,486	29,168
2000	41,549	32,286
2001	41,569	30,532
2002	47,690	38,846
2003	59,772	44,126
2004	53,412	32,532
2005	252,314	135,232
2006	525,758	263,443
2007	472,599	242,958
2008	617,782	295,056
2009	544,595	305,141
2010	708,198	407,548
2011	703,880	375,442
2012	637,303	313,613
2013	606,254	304,854
2014	629,277	306,378
2015	700,000	343,900
2016	700,000	343,900
2017	700,000	343,900
2018	700,000	343,900
2019	700,000	343,900
2020	700,000	343,900
2021	700,000	343,900
2022	700,000	343,900
2023	700,000	343,900
2024	700,000	343,900
2025	700,000	343,900
2026	700,000	343,900
2027	700,000	343,900
2028	700,000	343,900
2029	700,000	343,900
2030	700,000	343,900
2031	195,000	95,801
Total	**17,430,332**	**8,803,993**

Notes:

1. Megagrams = 0.907 x tons.

2. JRL's permitted capacity is approximately 10,280,000 cubic yards (cy). Near the end of 2014, the site had approximately 3,900,000 cy of remaining air space. A proposed expansion would increase the landfill volume by 9,350,000 cy. Based on an estimated waste placement density of 0.86 tons per cubic yard, the additional waste to be accepted at JRL from 2015 through closure, including the expansion, is approximately 11,395,000 tons.

3. Waste considered nondegradable includes ash, contaminated soil, and a portion of the construction and demolition debris (C&D).



Summary Report

Landfill Name or Identifier: Juniper Ridge Landfill

About LandGEM:

First-Order Decomposition Rate Equation:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_o \left(\frac{M_i}{10}\right) e^{-kt_{ij}}$$

Where,

Q_{CH4} = annual methane generation in the year of the calculation (*m^3/year*)

i = 1-year time increment

n = (year of the calculation) - (initial year of waste acceptance)

j = 0.1-year time increment

k = methane generation rate (*$year^{-1}$*)

L_o = potential methane generation capacity (*m^3/Mg*)

M_i = mass of waste accepted in the i^{th} year (*Mg*)

t_{ij} = age of the j^{th} section of waste mass M_i accepted in the i^{th} year (*decimal years*, e.g., 3.2 years)

LandGEM is based on a first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste in municipal solid waste (MSW) landfills. The software provides a relatively simple approach to estimating landfill gas emissions. Model defaults are based on empirical data from U.S. landfills. Field test data can also be used in place of model defaults when available. Further guidance on EPA test methods, Clean Air Act (CAA) regulations, and other guidance regarding landfill gas emissions and control technology requirements can be found at http://www.epa.gov/ttnatw01/landfill/landflpg.html.

LandGEM is considered a screening tool — the better the input data, the better the estimates. Often, there are limitations with the available data regarding waste quantity and composition, variation in design and operating practices over time, and changes occurring over time that impact the emissions potential. Changes to landfill operation, such as operating under wet conditions through leachate recirculation or other liquid additions, will result in generating more gas at a faster rate. Defaults for estimating emissions for this type of operation are being developed to include in LandGEM along with defaults for convential landfills (no leachate or liquid additions) for developing emission inventories and determining CAA applicability. Refer to the Web site identified above for future updates.

Input Review

LANDFILL CHARACTERISTICS

Landfill Open Year	**1997**	
Landfill Closure Year (with 80-year limit)	**2031**	
Actual Closure Year (without limit)	***2031***	
Have Model Calculate Closure Year?	**Yes**	
Waste Design Capacity	**8,803,993**	*short tons*

MODEL PARAMETERS

Methane Generation Rate, k	**0.100**	*$year^{-1}$*
Potential Methane Generation Capacity, L_o	**110**	*m^3/Mg*
NMOC Concentration	**873**	*ppmv as hexane*
Methane Content	**50**	*% by volume*

WASTE ACCEPTANCE RATES

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	*(short tons/year)*	*(Mg)*	*(short tons)*
1997	20,272	22,299	0	0
1998	23,945	26,339	20,272	22,299
1999	26,516	29,168	44,217	48,639
2000	29,350	32,286	70,733	77,807

2001	27,756	30,532	100,084	110,092
2002	35,315	38,846	127,840	140,624
2003	40,114	44,126	163,154	179,470
2004	29,575	32,532	203,269	223,595
2005	122,938	135,232	232,843	256,127
2006	239,494	263,443	355,781	391,359
2007	220,871	242,958	595,275	654,802
2008	268,233	295,056	816,145	897,760
2009	277,401	305,141	1,084,379	1,192,816
2010	370,498	407,548	1,361,779	1,497,957
2011	341,310	375,442	1,732,278	1,905,505
2012	285,103	313,613	2,073,588	2,280,947
2013	277,140	304,854	2,358,691	2,594,560
2014	278,525	306,378	2,635,831	2,899,414
2015	312,636	343,900	2,914,356	3,205,792
2016	312,636	343,900	3,226,993	3,549,692
2017	312,636	343,900	3,539,629	3,893,592
2018	312,636	343,900	3,852,265	4,237,492
2019	312,636	343,900	4,164,902	4,581,392
2020	312,636	343,900	4,477,538	4,925,292
2021	312,636	343,900	4,790,174	5,269,192
2022	312,636	343,900	5,102,811	5,613,092
2023	312,636	343,900	5,415,447	5,956,992
2024	312,636	343,900	5,728,084	6,300,892
2025	312,636	343,900	6,040,720	6,644,792
2026	312,636	343,900	6,353,356	6,988,692
2027	312,636	343,900	6,665,993	7,332,592
2028	312,636	343,900	6,978,629	7,676,492
2029	312,636	343,900	7,291,265	8,020,392
2030	312,637	343,900	7,603,902	8,364,292
2031	87,092	95,801	7,916,538	8,708,192

Results

Year	Total landfill gas		
	(Mg/year)	***(m^3/year)***	***(av ft^3/min)***
1997	0	0	0
1998	5.327E+02	4.265E+05	2.866E+01
1999	1.111E+03	8.898E+05	5.978E+01
2000	1.702E+03	1.363E+06	9.158E+01
2001	2.311E+03	1.851E+06	1.244E+02
2002	2.821E+03	2.259E+06	1.518E+02
2003	3.480E+03	2.787E+06	1.872E+02
2004	4.203E+03	3.366E+06	2.261E+02
2005	4.580E+03	3.668E+06	2.464E+02
2006	7.375E+03	5.905E+06	3.968E+02
2007	1.297E+04	1.038E+07	6.976E+02
2008	1.754E+04	1.404E+07	9.435E+02
2009	2.291E+04	1.835E+07	1.233E+03
2010	2.802E+04	2.244E+07	1.508E+03
2011	3.509E+04	2.810E+07	1.888E+03
2012	4.072E+04	3.261E+07	2.191E+03
2013	4.434E+04	3.550E+07	2.385E+03
2014	4.740E+04	3.796E+07	2.550E+03
2015	5.021E+04	4.020E+07	2.701E+03
2016	5.364E+04	4.296E+07	2.886E+03
2017	5.675E+04	4.545E+07	3.054E+03
2018	5.957E+04	4.770E+07	3.205E+03
2019	6.211E+04	4.974E+07	3.342E+03
2020	6.442E+04	5.158E+07	3.466E+03
2021	6.650E+04	5.325E+07	3.578E+03
2022	6.839E+04	5.476E+07	3.680E+03
2023	7.010E+04	5.613E+07	3.771E+03
2024	7.164E+04	5.737E+07	3.854E+03
2025	7.304E+04	5.849E+07	3.930E+03
2026	7.430E+04	5.950E+07	3.998E+03
2027	7.545E+04	6.041E+07	4.059E+03
2028	7.648E+04	6.124E+07	4.115E+03
2029	7.742E+04	6.199E+07	4.165E+03
2030	7.827E+04	6.267E+07	4.211E+03
2031	**7.903E+04**	**6.329E+07**	**4.252E+03**

2032	7.380E+04	5.910E+07	3.971E+03
2033	6.678E+04	5.347E+07	3.593E+03
2034	6.042E+04	4.838E+07	3.251E+03
2035	5.467E+04	4.378E+07	2.942E+03
2036	4.947E+04	3.961E+07	2.662E+03
2037	4.476E+04	3.584E+07	2.408E+03
2038	4.050E+04	3.243E+07	2.179E+03
2039	3.665E+04	2.935E+07	1.972E+03
2040	3.316E+04	2.655E+07	1.784E+03
2041	3.000E+04	2.403E+07	1.614E+03
2042	2.715E+04	2.174E+07	1.461E+03
2043	2.457E+04	1.967E+07	1.322E+03
2044	2.223E+04	1.780E+07	1.196E+03
2045	2.011E+04	1.611E+07	1.082E+03
2046	1.820E+04	1.457E+07	9.791E+02
2047	1.647E+04	1.319E+07	8.860E+02
2048	1.490E+04	1.193E+07	8.017E+02
2049	1.348E+04	1.080E+07	7.254E+02
2050	1.220E+04	9.768E+06	6.563E+02
2051	1.104E+04	8.839E+06	5.939E+02
2052	9.988E+03	7.998E+06	5.374E+02
2053	9.037E+03	7.237E+06	4.862E+02
2054	8.177E+03	6.548E+06	4.400E+02
2055	7.399E+03	5.925E+06	3.981E+02
2056	6.695E+03	5.361E+06	3.602E+02
2057	6.058E+03	4.851E+06	3.259E+02
2058	5.481E+03	4.389E+06	2.949E+02
2059	4.960E+03	3.972E+06	2.668E+02
2060	4.488E+03	3.594E+06	2.415E+02
2061	4.061E+03	3.252E+06	2.185E+02
2062	3.674E+03	2.942E+06	1.977E+02
2063	3.325E+03	2.662E+06	1.789E+02
2064	3.008E+03	2.409E+06	1.619E+02
2065	2.722E+03	2.180E+06	1.464E+02
2066	2.463E+03	1.972E+06	1.325E+02
2067	2.229E+03	1.785E+06	1.199E+02
2068	2.016E+03	1.615E+06	1.085E+02
2069	1.825E+03	1.461E+06	9.817E+01
2070	1.651E+03	1.322E+06	8.883E+01
2071	1.494E+03	1.196E+06	8.037E+01
2072	1.352E+03	1.082E+06	7.272E+01
2073	1.223E+03	9.794E+05	6.580E+01
2074	1.107E+03	8.862E+05	5.954E+01
2075	1.001E+03	8.018E+05	5.388E+01

Landfill Gas Generation Rate Estimates
Including the Proposed Expansion

Juniper Ridge Landfill
Old Town, Maine

Flows at 40% CH4

Year	LFG Generation Estimates (scfm at 50% CH_4) k=0.1, Lo=110	Collection Efficiency	LFG Collection Estimates (scfm at 50% CH_4) k=0.1, Lo=110	LFG Generation Estimates (scfm at 40% CH_4)	LFG Collection Estimates (scfm at 40% CH_4)
1997	0	85%	0	0	0
1998	29	85%	24	36	30
1999	60	85%	51	75	64
2000	92	85%	78	114	97
2001	124	85%	106	155	132
2002	152	85%	129	190	161
2003	187	85%	159	234	199
2004	226	85%	192	283	240
2005	246	85%	209	308	262
2006	397	85%	337	496	422
2007	698	85%	593	872	741
2008	943	85%	802	1,179	1,002
2009	1,233	85%	1,048	1,541	1,310
2010	1,508	85%	1,282	1,885	1,602
2011	1,888	85%	1,605	2,360	2,006
2012	2,191	85%	1,862	2,739	2,328
2013	2,385	85%	2,028	2,982	2,535
2014	2,550	85%	2,168	3,188	2,710
2015	2,701	85%	2,296	3,377	2,870
2016	2,886	85%	2,453	3,608	3,067
2017	3,054	85%	2,596	3,817	3,244
2018	3,205	85%	2,724	4,006	3,405
2019	3,342	85%	2,841	4,177	3,551
2020	3,466	85%	2,946	4,332	3,682
2021	3,578	85%	3,041	4,473	3,802
2022	3,680	85%	3,128	4,599	3,909
2023	3,771	85%	3,206	4,714	4,007
2024	3,854	85%	3,276	4,818	4,095
2025	3,930	85%	3,340	4,912	4,175
2026	3,998	85%	3,398	4,997	4,247
2027	4,059	85%	3,450	5,074	4,313
2028	4,115	85%	3,498	5,144	4,372
2029	4,165	85%	3,540	5,207	4,426
2030	4,211	85%	3,579	5,264	4,474
2031	**4,252**	**85%**	**3,614**	**5,315**	**4,518**
2032	3,971	85%	3,375	4,963	4,219
2033	3,593	85%	3,054	4,491	3,817
2034	3,251	85%	2,763	4,064	3,454
2035	2,942	85%	2,500	3,677	3,125
2036	2,662	85%	2,262	3,327	2,828
2037	2,408	85%	2,047	3,010	2,559
2038	2,179	85%	1,852	2,724	2,315
2039	1,972	85%	1,676	2,465	2,095

Landfill Gas Generation Rate Estimates
Including the Proposed Expansion

Juniper Ridge Landfill
Old Town, Maine

Year	LFG Generation Estimates (scfm at 50% CH_4) k=0.1, Lo=110	Collection Efficiency	LFG Collection Estimates (scfm at 50% CH_4) k=0.1, Lo=110	LFG Generation Estimates (scfm at 40% CH_4)	LFG Collection Estimates (scfm at 40% CH_4)
2040	1,784	85%	1,516	2,230	1,896
2041	1,614	85%	1,372	2,018	1,715
2042	1,461	85%	1,242	1,826	1,552
2043	1,322	85%	1,123	1,652	1,404
2044	1,196	85%	1,017	1,495	1,271
2045	1,082	85%	920	1,353	1,150
2046	979	85%	832	1,224	1,040
2047	886	85%	753	1,107	941
2048	802	85%	681	1,002	852
2049	725	85%	617	907	771
2050	656	85%	558	820	697
2051	594	85%	505	742	631
2052	537	85%	457	672	571
2053	486	85%	413	608	517
2054	440	85%	374	550	467
2055	398	85%	338	498	423
2056	360	85%	306	450	383
2057	326	85%	277	407	346
2058	295	85%	251	369	313
2059	267	85%	227	334	284
2060	241	85%	205	302	257
2061	218	85%	186	273	232
2062	198	85%	168	247	210
2063	179	85%	152	224	190
2064	162	85%	138	202	172
2065	146	85%	124	183	156
2066	133	85%	113	166	141
2067	120	85%	102	150	127
2068	108	85%	92	136	115
2069	98	85%	83	123	104
2070	89	85%	76	111	94
2071	80	85%	68	100	85
2072	73	85%	62	91	77
2073	66	85%	56	82	70
2074	60	85%	51	74	63
2075	54	85%	46	67	57

PURPOSE: Estimate the internal gas velocity and pressure loss that can be expected for a 24-inch diameter landfill gas (LFG) header pipe proposed as part of the expansion to the LFG system at the Juniper Ridge Landfill (JRL) in Old Town, Maine. Compare these values with industry accepted values to justify pipe sizing.

METHOD: LFG generation modeling (performed separately using LandGEM) suggests that a future total LFG flow rate of 4,500 scfm can be expected in the proposed 24-inch perimeter header pipe located in the proposed east perimeter berm. Check to see if the velocity of LFG, V, is no greater than 20 ft/s for counter-current gas and condensate flow or 40 ft/s for concurrent gas and condensate flow [REF. 1] for the total LFG flow rate estimated by LandGEM. Next, use the Low-Pressure Mueller Equation to estimate pipe pressure losses. Check to see if Pressure Loss, ΔP, is less than 1 inch per 100 feet of pipe or 0.01 in/ft.

GIVEN:

- Total LFG flow rate from LandGEM = 4,500 scfm
- Internal diameter of 24-inch diameter SDR-17 HDPE pipe = 21.007 in.
- Cross-sectional area of 24-inch diameter SDR-17 HDPE pipe = 2.407 ft^2
- Approximate length of proposed header pipe = 3,330 feet

CALCULATION:

Velocity of the gas inside pipe, V:

$$V = \frac{Q}{A}$$

where V = LFG Velocity, feet per second
Q = LFG flow rate, cubic feet per second
A= Cross sectional area of the pipe, square feet
where $A = \pi r^2$ and r = radius of the pipe, feet

$$V = \left((4{,}500 \text{ scfm})\left(\frac{1 \text{ min}}{60 \text{ sec}}\right)\right) \div 2.407 \text{ ft}^2 = 31.2 \text{ ft/s}$$

Check: $31.2 \text{ ft/s} < 40 \text{ft/s}$ OKAY

Friction Losses in Pipe: Low-Pressure Mueller Equation [REF 1]:

$$\Delta P = L\left[\frac{60 \cdot Q \cdot G^{0.425}}{2971 \cdot d^{2.725}}\right]^{1.739}$$

Where: ΔP = pressure loss, inches of water column

L = length of pipe, ft.
Q = gas flow rate, ft^3/min.
G = specific gravity of the gas, use 0.81 for landfill gas
d = internal pipe diameter, in.

$$\Delta P = 3{,}330 \text{ ft} \times \left[\frac{60 \cdot (4{,}500 \text{ scfm}) \cdot (0.81)^{0.425}}{2971 \cdot (21.007 \text{ in})^{2.725}}\right]^{1.739}$$

$$\Delta P = 3.93 \text{ in W.C.}$$

$$\text{Check:} \quad \frac{\Delta P}{L} < \frac{0.01 \text{ in}}{\text{ft}}$$

$$\frac{3.93 \text{ in}}{3{,}330 \text{ ft}} = \frac{0.00118 \text{ in}}{1 \text{ ft}} < \frac{0.01 \text{ in}}{1 \text{ ft}} \qquad \text{OKAY}$$

RESULTS:

The 24-inch diameter pipe meets the above criteria for velocity (concurrent flow) and pressure loss. A section of the pipe also experiences counter-current flow. Say this section of pipe conveys half of the total 4,500 scfm (2250 scfm) then it would meet the velocity criteria of less than 20 ft/s.

Spreadsheet calculations using the methods detailed in this sample calculation were performed for each of the primary LFG header pipes (numbered 1 thru 8) designed as part of the LFG system expansion. The calculations are included as Attachment A and the results of which are shown in Table 1.

Table 1

Header #	Projected LFG Flow (scfm)*	Pipe Diameter (in)**	Pipe Length (ft)	LFG Velocity (ft/s)	Pressure Loss (in W.C.)	Pressure Loss less than 1in/100ft?	Comments
1	1,175	12	2,130	28.8	4.87	Yes	None
2	969	12	970	23.8	1.59	Yes	None
3	1,410	12	2,400	34.6	7.53	Yes	None
4	426	12	1,070	10.5	0.42	Yes	Pipe has capacity to handle more flow.
5	2,062	12	2,750	50.6	16.72	Yes	Exceeds velocity criteria for condition when gas flow is in one direction.***
6	1,785	12	2,350	43.8	11.12	Yes	Exceeds velocity criteria for condition when gas flow is in one direction.***
7	955	12	1,870	23.4	2.98	Yes	None
8	333	12	760	8.2	0.19	Yes	Pipe has capacity to handle more flow.

*Estimated LFG flow rate projections for each header were calculated using LandGEM and are based on waste volumes calculated using AutoCAD (Attachment B).
**12-inch diameter LFG conveyance pipe is the largest pipe size used inside the limit of waste and was selected for convenience of construction, operation, and maintenance.
***Gas flow in header pipes 1 thru 8 is expected to be pulled in one of two directions for normal operating conditions. Therefore velocity is not expected to exceed 40 ft/s under normal operating conditions.

REFERENCES:

1. *Geotechnical Aspects of Landfill Design and Construction*, Xuede Qian, Robert M. Koerner, Donald H. Gray, Prentice Hall, Upper Saddle River, NJ, 2002, pp. 370-373.

Attachment A

File Number: 2536.27
Project: JRL LFG Master Plan
Location: Juniper Ridge Landfill, Old Town, Maine
Subject: Pipe Sizing Calculations
Calculated By: R. Clay   Date: 4/3/2015
Checked By: E. Steinhauser   Date: 4/20/2015
Header: **24-inch (from Sample Calc)**

Header Information

Nominal Diameter	24	in
SDR-	17	
Condensate Flow	Concurrent	
Approximate Pipe Length	3,330	ft
Inside Diameter	21.007	in
Flow Area	2.407	ft^2

Flow Parameters

Spec. Gravity of Gas	0.81	0.81 is typical for LFG		
Total Flow	4,500	cfm		
Velocity	31.2	ft/s	ACCEPTABLE	V = Q/A
Pressure Loss	3.93	in WC	ACCEPTABLE	$\Delta P = L*[(60*Q*G^{0.425})/(2971*d^{2.725})]^{(1/0.575)}$

Condensate

Temp. Initial	110	deg. F
Temp. Reduced	50	deg. F
Generation Rate	1.72	gal/min.
	2,472	gal/day
	902,390	gal/year

Attachment A

File Number: 2536.27
Project: JRL LFG Master Plan
Location: Juniper Ridge Landfill, Old Town, Maine
Subject: Pipe Sizing Calculations
Calculated By: R. Clay Date: 4/3/2015
Checked By: E. Steinhauser Date: 4/20/2015
Header: **Header 1**

Header Information

Nominal Diameter	12	in		
SDR-	17			
Condensate Flow	Concurrent			
Approximate Pipe Length	2,130	ft		
Inside Diameter	11.160	in		
Flow Area	0.679	ft^2		

Flow Parameters

Spec. Gravity of Gas	0.81	0.81 is typical for LFG		
Total Flow	1,175	cfm		
Velocity	28.8	ft/s	ACCEPTABLE	V = Q/A
Pressure Loss	4.87	in WC	ACCEPTABLE	$\Delta P = L*[(60*Q*G^{0.425})/(2971*d^{2.725})]^{(1/0.575)}$

Condensate

Temp. Initial	110	deg. F
Temp. Reduced	50	deg. F
Generation Rate	0.45	gal/min.
	646	gal/day
	235,624	gal/year

Attachment A

File Number: 2536.27
Project: JRL LFG Master Plan
Location: Juniper Ridge Landfill, Old Town, Maine
Subject: Pipe Sizing Calculations
Calculated By: R. Clay — Date: 4/3/2015
Checked By: E. Steinhauser — Date: 4/20/2015
Header: **Header 2**

Header Information

Nominal Diameter	12	in
SDR-	17	
Condensate Flow	Concurrent	
Approximate Pipe Length	970	ft
Inside Diameter	11.160	in
Flow Area	0.679	ft^2

Flow Parameters

Spec. Gravity of Gas	0.81	0.81 is typical for LFG		
Total Flow	969	cfm		
Velocity	23.8	ft/s	ACCEPTABLE	V = Q/A
Pressure Loss	1.59	in WC	ACCEPTABLE	$\Delta P = L*[(60*Q*G^{0.425})/(2971*d^{2.725})]^{(1/0.575)}$

Condensate

Temp. Initial	110	deg. F
Temp. Reduced	50	deg. F
Generation Rate	0.37	gal/min.
	532	gal/day
	194,315	gal/year

Attachment A

File Number: 2536.27
Project: JRL LFG Master Plan
Location: Juniper Ridge Landfill, Old Town, Maine
Subject: Pipe Sizing Calculations
Calculated By: R. Clay   Date: 4/3/2015
Checked By: E. Steinhauser   Date: 4/20/2015
Header: **Header 3**

Header Information

Nominal Diameter	12	in
SDR-	17	
Condensate Flow	Concurrent	
Approximate Pipe Length	2,400	ft
Inside Diameter	11.160	in
Flow Area	0.679	ft^2

Flow Parameters

Spec. Gravity of Gas	0.81	0.81 is typical for LFG		
Total Flow	1,410	cfm		
Velocity	34.6	ft/s	ACCEPTABLE	$V = Q/A$
Pressure Loss	7.53	in WC	ACCEPTABLE	$\Delta P = L*[(60*Q*G^{0.425})/(2971*d^{2.725})]^{(1/0.575)}$

Condensate

Temp. Initial	110	deg. F
Temp. Reduced	50	deg. F
Generation Rate	0.54	gal/min.
	775	gal/day
	282,749	gal/year

Attachment A

File Number: 2536.27
Project: JRL LFG Master Plan
Location: Juniper Ridge Landfill, Old Town, Maine
Subject: Pipe Sizing Calculations
Calculated By: R. Clay — Date: 4/3/2015
Checked By: E. Steinhauser — Date: 4/20/2015
Header: **Header 4**

Header Information

Nominal Diameter	12	in
SDR-	17	
Condensate Flow	Concurrent	
Approximate Pipe Length	1,070	ft
Inside Diameter	11.160	in
Flow Area	0.679	ft^2

Flow Parameters

Spec. Gravity of Gas	0.81	0.81 is typical for LFG		
Total Flow	426	cfm		
Velocity	10.5	ft/s	ACCEPTABLE	V = Q/A
Pressure Loss	0.42	in WC	ACCEPTABLE	$\Delta P = L*[(60*Q*G^{0.425})/(2971*d^{2.725})]^{(1/0.575)}$

Condensate

Temp. Initial	110	deg. F
Temp. Reduced	50	deg. F
Generation Rate	0.16	gal/min.
	234	gal/day
	85,426	gal/year

Attachment A

File Number: 2536.27
Project: JRL LFG Master Plan
Location: Juniper Ridge Landfill, Old Town, Maine
Subject: Pipe Sizing Calculations
Calculated By: R. Clay   Date: 4/3/2015
Checked By: E. Steinhauser   Date: 4/20/2015
Header: **Header 5**

Header Information

Nominal Diameter	12	in		
SDR-	17			
Condensate Flow	Concurrent			
Approximate Pipe Length	2,750	ft		
Inside Diameter	11.160	in		
Flow Area	0.679	ft^2		

Flow Parameters

Spec. Gravity of Gas	0.81	0.81 is typical for LFG		
Total Flow	2,062	cfm		
Velocity	50.6	ft/s	OUTSIDE RANGE	V = Q/A
Pressure Loss	16.72	in WC	ACCEPTABLE	$\Delta P = L*[(60*Q*G^{0.425})/(2971*d^{2.725})]^{(1/0.575)}$

Condensate

Temp. Initial	110	deg. F
Temp. Reduced	50	deg. F
Generation Rate	0.79	gal/min.
	1,133	gal/day
	413,495	gal/year

Attachment A

File Number:	2536.27
Project:	JRL LFG Master Plan
Location:	Juniper Ridge Landfill, Old Town, Maine
Subject:	Pipe Sizing Calculations
Calculated By:	R. Clay — Date: 4/3/2015
Checked By:	E. Steinhauser — Date: 4/20/2015
Header:	**Header 6**

Header Information

Nominal Diameter	12	in
SDR-	17	
Condensate Flow	Concurrent	
Approximate Pipe Length	2,350	ft
Inside Diameter	11.160	in
Flow Area	0.679	ft^2

Flow Parameters

Spec. Gravity of Gas	0.81	0.81 is typical for LFG		
Total Flow	1,785	cfm		
Velocity	43.8	ft/s	OUTSIDE RANGE	V = Q/A
Pressure Loss	11.12	in WC	ACCEPTABLE	$\Delta P = L*[(60*Q*G^{0.425})/(2971*d^{2.725})]^{(1/0.575)}$

Condensate

Temp. Initial	110	deg. F
Temp. Reduced	50	deg. F
Generation Rate	0.68	gal/min.
	981	gal/day
	357,948	gal/year

Attachment A

File Number: 2536.27
Project: JRL LFG Master Plan
Location: Juniper Ridge Landfill, Old Town, Maine
Subject: Pipe Sizing Calculations
Calculated By: R. Clay Date: 4/3/2015
Checked By: E. Steinhauser Date: 4/20/2015
Header: **Header 7**

Header Information

Nominal Diameter	12	in
SDR-	17	
Condensate Flow	Concurrent	
Approximate Pipe Length	1,870	ft
Inside Diameter	11.160	in
Flow Area	0.679	ft^2

Flow Parameters

Spec. Gravity of Gas	0.81	0.81 is typical for LFG		
Total Flow	955	cfm		
Velocity	23.4	ft/s	ACCEPTABLE	V = Q/A
Pressure Loss	2.98	in WC	ACCEPTABLE	$\Delta P = L*[(60*Q*G^{0.425})/(2971*d^{2.725})]^{(1/0.575)}$

Condensate

Temp. Initial	110	deg. F
Temp. Reduced	50	deg. F
Generation Rate	0.36	gal/min.
	525	gal/day
	191,507	gal/year

Attachment A

File Number: 2536.27
Project: JRL LFG Master Plan
Location: Juniper Ridge Landfill, Old Town, Maine
Subject: Pipe Sizing Calculations
Calculated By: R. Clay   Date: 4/3/2015
Checked By: E. Steinhauser   Date: 4/20/2015
Header: **Header 8**

Header Information

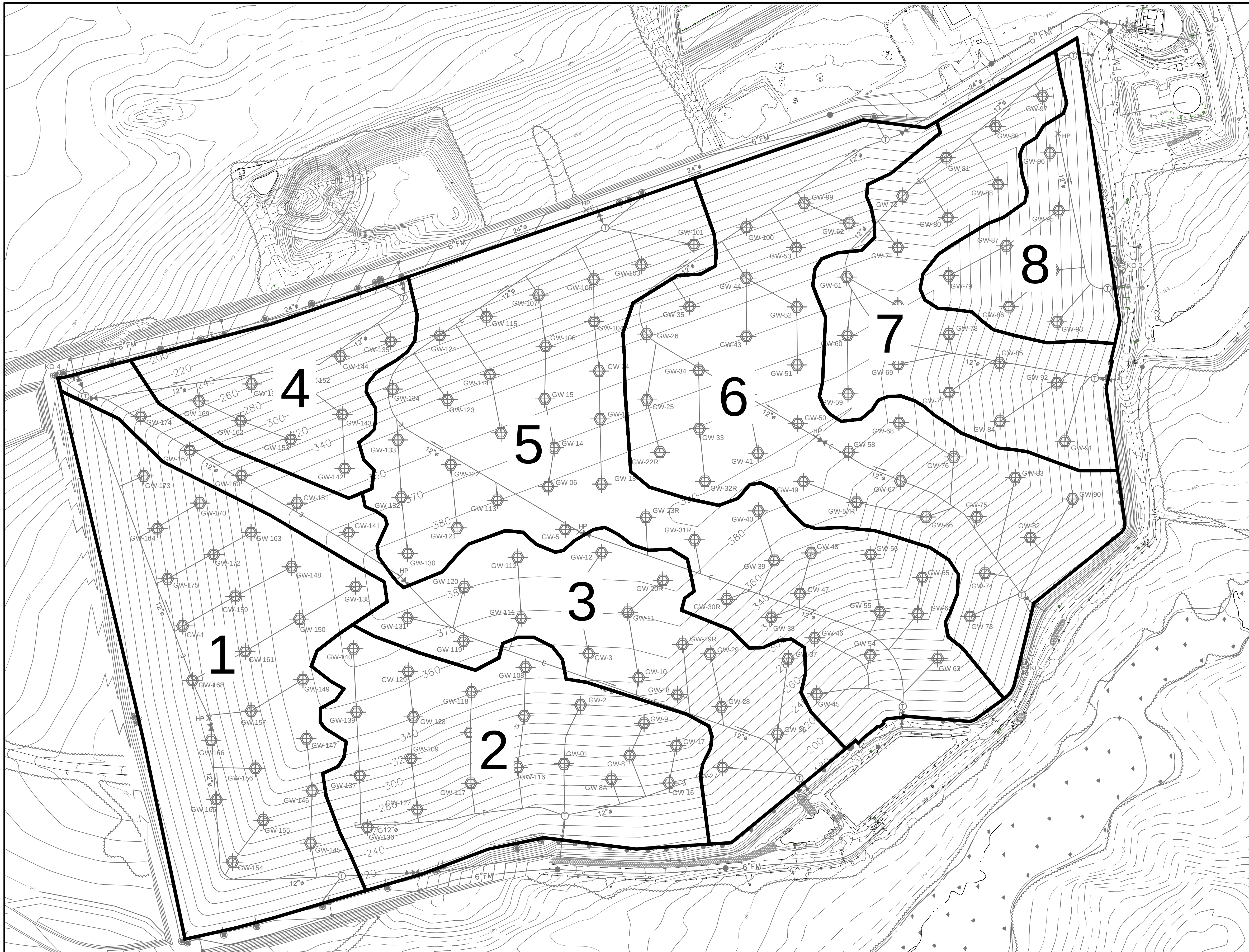
Nominal Diameter	12	in
SDR-	17	
Condensate Flow	Concurrent	
Approximate Pipe Length	760	ft
Inside Diameter	11.160	in
Flow Area	0.679	ft^2

Flow Parameters

Spec. Gravity of Gas	0.81	0.81 is typical for LFG		
Total Flow	333	cfm		
Velocity	8.2	ft/s	ACCEPTABLE	V = Q/A
Pressure Loss	0.19	in WC	ACCEPTABLE	$\Delta P = L*[(60*Q*G^{0.425})/(2971*d^{2.725})]^{(1/0.575)}$

Condensate

Temp. Initial	110	deg. F
Temp. Reduced	50	deg. F
Generation Rate	0.13	gal/min.
	183	gal/day
	66,777	gal/year



NOTES:

1. BASE MAP WAS PREPARED BY AERIAL SURVEY & PHOTO INC., OF NORRIDGEWOCK, MAINE. PHOTO DATE JULY 31, 2014. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE.
2. PROPOSED EXPANSION GRADES WERE PROVIDED TO SANBORN HEAD BY SEVEE & MAHER, (SME) INC. OF CUMBERLAND, MAINE.
3. LOCATIONS OF LANDFILL COMPONENTS SHOWN ON THIS PLAN, SUCH AS LEACHATE CLEANOUTS, ARE BASED ON DESIGN LOCATIONS PROVIDED TO SHA BY SEVEE & MAHER ENGINEERS, INC. OF CUMBERLAND, MAINE.

PIPE SIZING LEGEND:

- LFG HEADER PIPE
- GW-35 VERTICAL LFG WELL
- CONDENSATE TRAP
- CONTROL VALVE
- KO-1 CONDENSATE KNOCKOUT
- CLEANOUT LOCATION
- VERTICAL RISER

Volume Summary

Name	2d Area	Approximate Volume of Waste
Volume 1	797608.91 Sq. Ft.	2351587.97 Cu. Yd.<Fill>
Volume 2	612117.49 Sq. Ft.	1979317.58 Cu. Yd.<Fill>
Volume 3	658782.80 Sq. Ft.	2987541.75 Cu. Yd.<Fill>
Volume 4	286832.42 Sq. Ft.	770057.11 Cu. Yd.<Fill>
Volume 5	1149697.11 Sq. Ft.	4755219.43 Cu. Yd.<Fill>
Volume 6	936511.60 Sq. Ft.	3934417.80 Cu. Yd.<Fill>
Volume 7	512148.42 Sq. Ft.	1952651.12 Cu. Yd.<Fill>
Volume 8	243286.41 Sq. Ft.	603030.01 Cu. Yd.<Fill>

ATTACHMENT B

SANBORN HEAD

GRAPHICAL SCALE
150' 75' 0' 150' 301'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: FEBRUARY 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

HEADER SIZING WORKSHEET

PROJECT NUMBER: 2536.27

SHEET NUMBER: 1 OF 1

PURPOSE: Estimate the condensate generation expected north of the high point of the proposed 24-inch diameter perimeter header pipe to be installed as part of the future expansion to the Juniper Ridge Landfill. The condensate in the pipe will drain by gravity to a condensate knockout structure. A pump inside the structure will then discharge the liquid into a primary leachate collection cleanout.

GIVEN:

- Total LFG flow rate from LandGEM modeling = 4,500 scfm

ASSUME:

- Conservatively assume a condensate generation rate of 5 gallons per hour per 100 scfm of LFG, based on the attached graph titled Appendix A.13 Determining Condensate Generation [Ref. 1] (e.g., assume wellhead temperature of 131 °F [Ref. 2] and ambient temperature of approximately 32 °F).
- By inspection and for simplicity, assume that the LFG flow rate north of the high point in the perimeter header is about ¼ of the total projected flow rate = 4,500 scfm

$$\frac{4{,}500\text{ scfm}}{4} = 1{,}125\text{ scfm}$$

CALCULATION

The condensate collection rate was calculated as follows:

$$Q_{Condensate} = Q_{Potential\ LFG\ collection} \times P_{Condensate}$$

where:

$Q_{Condensate}$	=	Condensate Collection rate (gal/hr)
$Q_{Potential\ LFG\ Collection}$	=	Potential LFG Generation Rate = 1,400 scfm
$P_{Condensate}$	=	Condensate Generation Rate = 5 gal/hr per 100 scfm

Therefore:

$$Q_{Condensate} = (1{,}125\text{ scfm}) \text{x} \left(\frac{5\text{ gal}}{\text{hr x 100scfm}}\right) \text{x} \left(\frac{\text{hr}}{60\text{ min}}\right) = 0.938\text{ gal/min, say 1 gal/min}$$

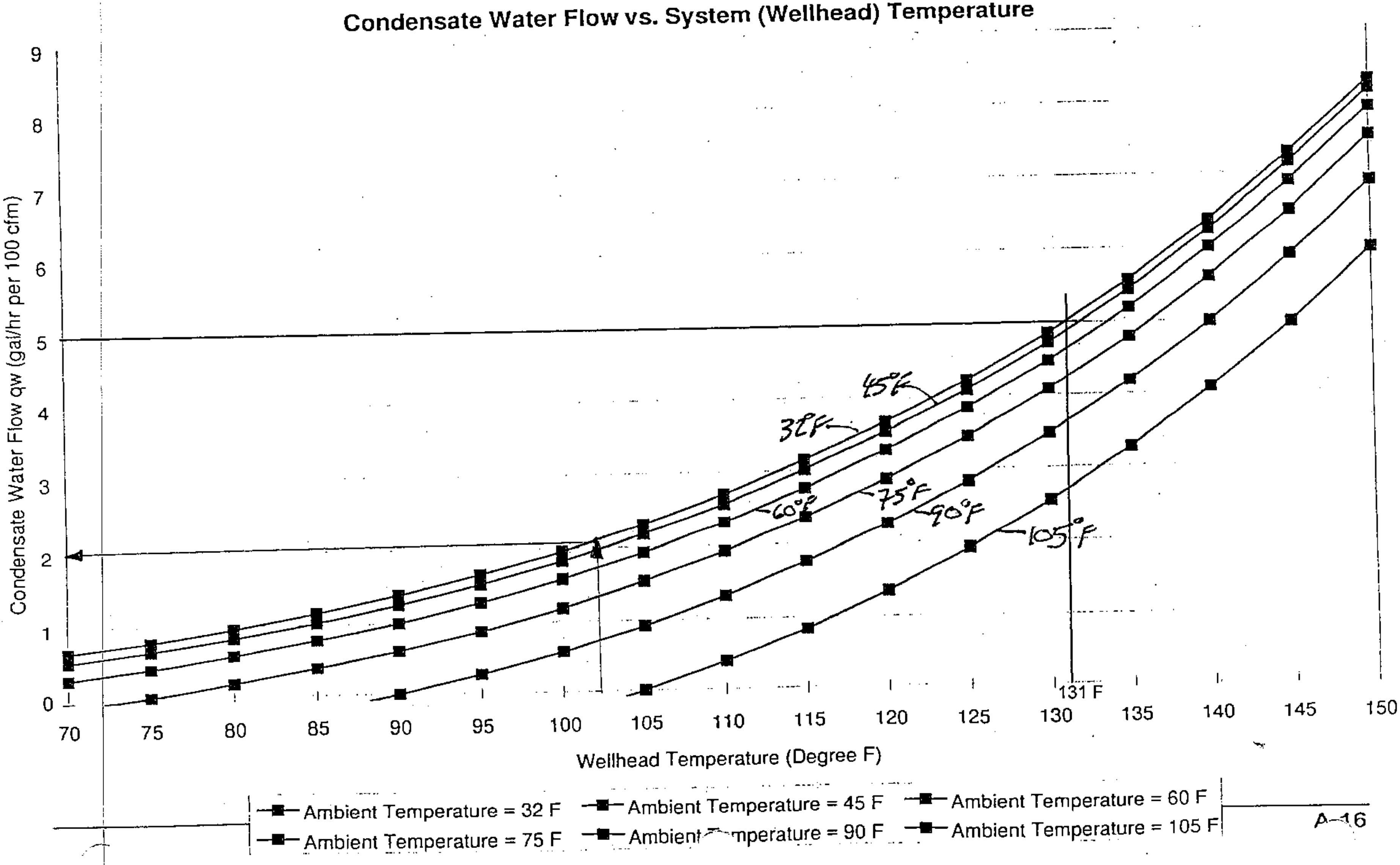
REFERENCES

1. Solid Waste Association of North America (SWANA), "*Landfill Gas Operation & Maintenance Manual of Practice*", 1998.
2. ADEM Rule 335-3-19-.03 (2)(c) requires gas at wellheads to be less than 55 C (131 F).

REF: SWANA, "Landfill G Operation & Maintenance, Manual of Practices," 1998

APPENDIX A.13

Determining Condensate Generation



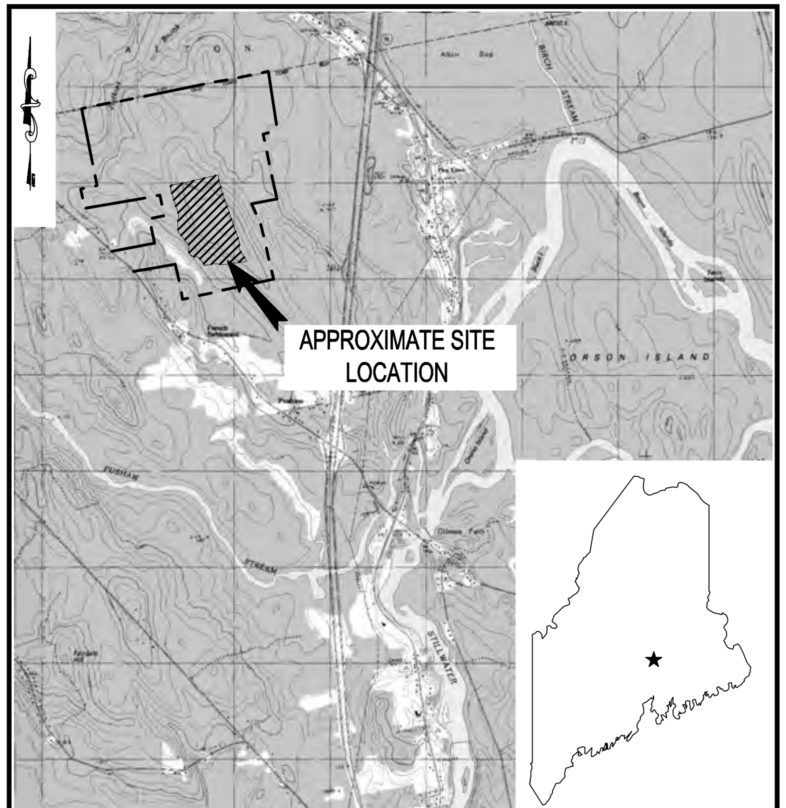
ATTACHMENT A

APPENDIX B

ENGINEERING DRAWINGS

LANDFILL GAS SYSTEM EXPANSION DRAWINGS

JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE
JUNE 2015



FROM: USGS TOPOGRAPHIC MAP- OLD TOWN, MAINE (1988)

LOCUS PLAN
SCALE: 1"=1000'

SHEET INDEX

STATE OF MAINE
Eric S. Steinhauser
10609
PROFESSIONAL ENGINEER

ISSUED FOR
MAINE DEP APPROVAL
6/05/15

PREPARED FOR:

new england
NEW ENGLAND WASTE SERVICES

NEWSME LANDFILL OPERATIONS, LLC

JUNIPER RIDGE LANDFILL

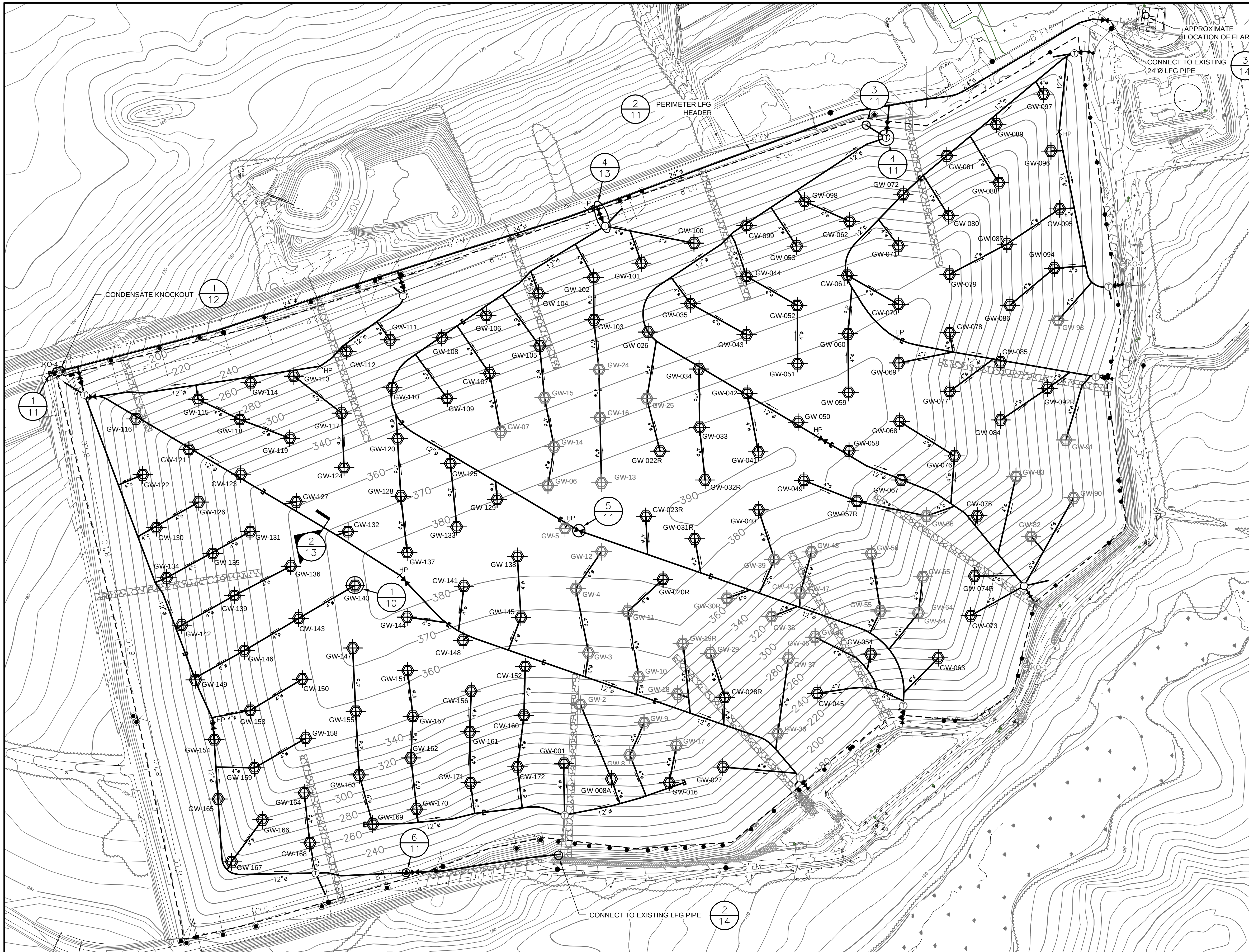
OLD TOWN, MAINE

PREPARED BY:

SANBORN HEAD

20 FOUNDRY STREET, CONCORD, NEW HAMPSHIRE 03301
(603) 229-1900 FAX (603) 229-1919

PROJ.#: 2536.27 "LANDFILL GAS SYSTEM EXPANSION DRAWINGS, JUNIPER RIDGE LANDFILL, OLD TOWN, MAINE" JUNE 2015.



NOTES:

1. THE BASE MAP SHOWN WAS PREPARED BY AERIAL SURVEY & PHOTO INC., OF NORRIDGEWOCK, MAINE. PHOTO DATE JULY 31, 2014. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE.
2. PROPOSED EXPANSION GRADES SHOWN WERE PROVIDED TO SANBORN HEAD BY SEVEE & MAHER, (SME) INC. OF CUMBERLAND, MAINE.
3. ACTUAL GRADES MAY DIFFER FROM GRADES SHOWN ON DRAWINGS AT THE TIME OF CONSTRUCTION.
4. THE EXISTING LANDFILL GAS EXTRACTION SYSTEM INFRASTRUCTURE FEATURES SHOWN ARE BASED ON A COMBINATION OF DESIGN AND AS-BUILT DOCUMENTATION AVAILABLE TO SANBORN, HEAD & ASSOCIATES, INC. (SANBORN HEAD). ACTUAL LOCATIONS OF INDIVIDUAL FEATURES MAY BE DIFFERENT THAN SHOWN.
5. THE LOCATIONS OF MANY OF THE LANDFILL DESIGN COMPONENTS SHOWN ON THIS PLAN, SUCH AS LEACHATE CLEANOUTS, STORMWATER MANAGEMENT FEATURES, AND UTILITIES, ARE BASED ON PROPOSED LOCATIONS PROVIDED TO SANBORN HEAD BY SEVEE & MAHER ENGINEERS, INC. OF CUMBERLAND, MAINE.
6. THIS PLAN IS INTENDED TO ILLUSTRATE THE PROPOSED LAYOUT OF THE LANDFILL GAS (LFG) EXTRACTION SYSTEM. ACTUAL LOCATION OF WELLS, PIPE, AND VALVES MAY CHANGE DEPENDING ON SITE CONDITIONS AND CONSTRAINTS DURING CONSTRUCTION.
7. SOLID LANDFILL GAS CONVEYANCE PIPE AND COLLECTION TRENCHES SHALL BE INSTALLED AT A MINIMUM SLOPE OF 6 PERCENT. PERFORATED LANDFILL GAS COLLECTION TRENCHES SHALL BE INSTALLED AT A MINIMUM SLOPE OF 2 PERCENT.
8. HDPE PIPE AND FITTINGS SHALL BE SDR-17.
9. EXISTING WELLS SHALL BE EXTENDED OR REPLACED AS FILLING PROGRESSES.

LEGEND:

EXISTING		PROPOSED
180	10 FOOT CONTOUR	370
	2 FOOT CONTOUR	
GW-11	VERTICAL LFG WELL	GW-35
12"Ø	LFG CONVEYANCE PIPE (SIZE AND SLOPE DIRECTION)	12"Ø
T	CONDENSATE TRAP	T
	CONTROL VALVE	
KO-1	CONDENSATE KNOCKOUT	KO-4
	LEACHATE COLLECTION CLEANOUT	
	VERTICAL RISER	
	LIMIT OF WASTE CONTAINMENT	
	CELL LIMIT	
	EDGE OF ROAD	
HP	HIGH POINT	HP
	RIPRAP-LINED DOWNCHUTE	
	TEMPORARY PIPE TERMINATION	

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN HEAD

GRAPHICAL SCALE 150' 75' 0' 150' 300'

STATE OF MAINE Eric S. Steinhauser 10809 PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

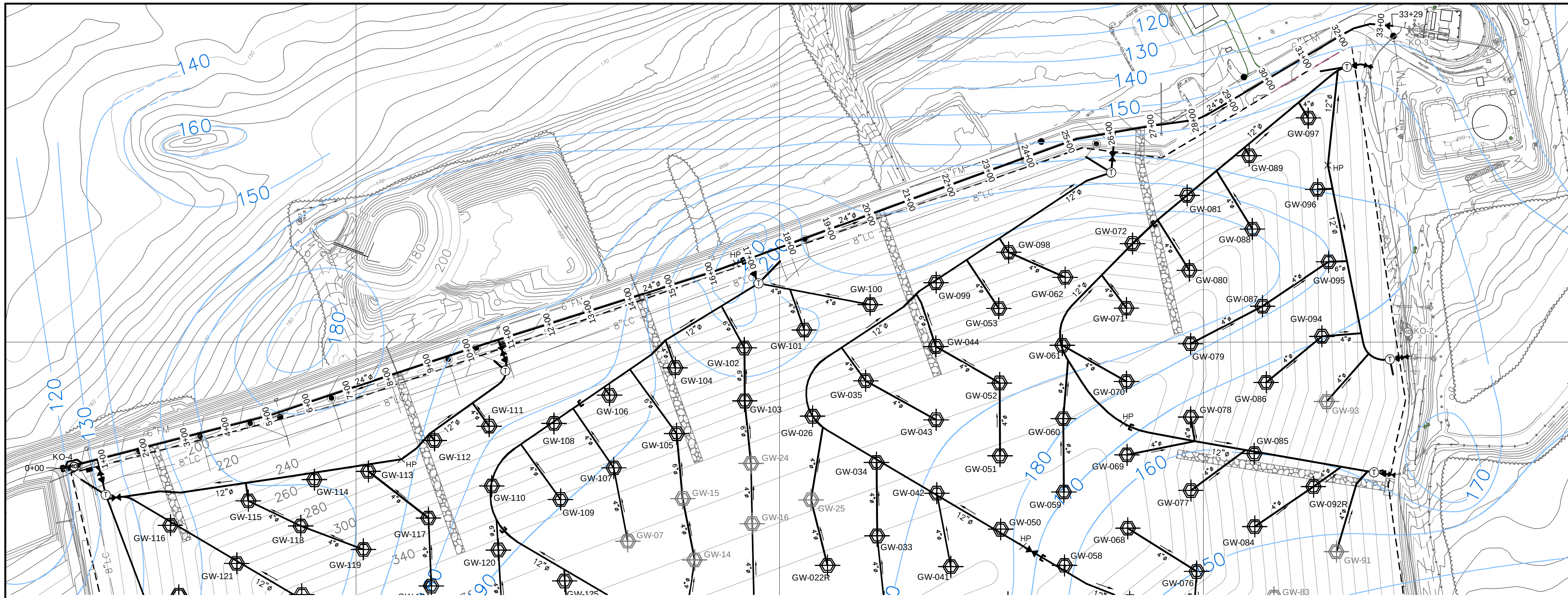
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LANDFILL GAS EXTRACTION SYSTEM PLAN

PROJECT NUMBER: 2536.27

SHEET NUMBER: 2 OF 14



PLAN

NOT TO SCALE

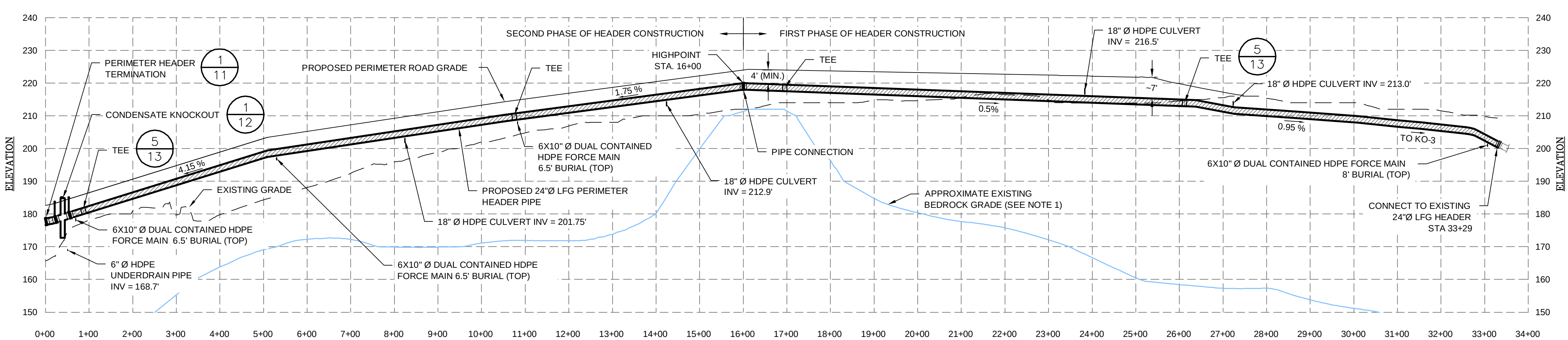
GRAPHICAL SCALE

150' 75' 0' 150' 300'

NOTE:

1. EXISTING BEDROCK CONTOURS WERE PROVIDED TO SANBORN HEAD BY SME ON NOVEMBER 14, 2014. THESE GRADES ARE PRELIMINARY AND SHOULD BE CONSIDERED APPROXIMATE.
2. FORCE MAIN AND CULVERT CROSSINGS SHOWN ON PROFILE WERE PROVIDED BY SME ON APRIL 6, 2015.

210 BEDROCK CONTOUR



PROFILE

NOT TO SCALE

VERTICAL SCALE

20' 10' 0' 20' 40'

150' 75' 0' 150' 300'

HORIZONTAL SCALE

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN HEAD

SCALE AS NOTED

STATE OF MAINE Eric S. Steinhauser 10809 PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN

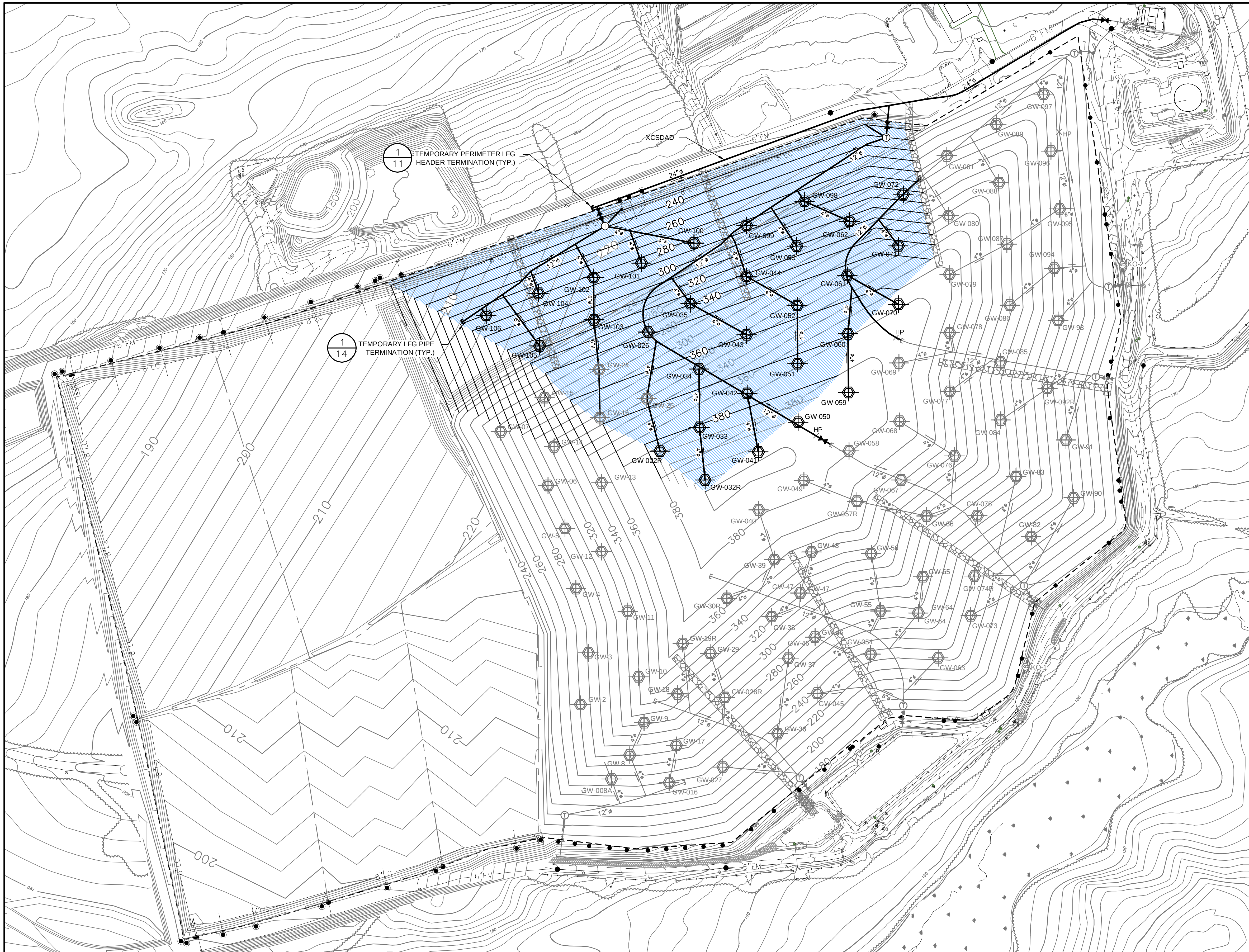
JUNIPER RIDGE LANDFILL

OLD TOWN, MAINE

PERIMETER LFG HEADER PIPE PROFILE

PROJECT NUMBER: 2536.27

SHEET NUMBER: 3 OF 14



NOTES:

1. SHEETS 4 THRU 9 OF THIS DRAWING SET SHOW THE SEQUENTIAL CONSTRUCTION OF THE LANDFILL GAS SYSTEM FOR CELLS 11-16. ACTUAL LOCATIONS OF INDIVIDUAL FEATURES AND TIMING OF INSTALLATION MAY CHANGE DUE TO FUTURE PLANNING OR CONSTRAINTS DURING CONSTRUCTION.
2. GAS COLLECTION TRENCHES WILL BE INSTALLED AS FILLING PROGRESSES IN EACH CELL AND ARE NOT SHOWN FOR CLARITY. GAS COLLECTION TRENCHES ARE INTENDED TO BE A TEMPORARY MEASURE OF GAS COLLECTION UNTIL FINAL GRADES ARE REACHED AND VERTICAL WELLS ARE INSTALLED.
3. SEE SHEET 2 FOR NOTES AND LEGEND INFORMATION.

= AREA EXPECTED TO REACH FINAL GRADE

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN HEAD

GRAPHICAL SCALE
150' 75' 0' 150' 300'

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

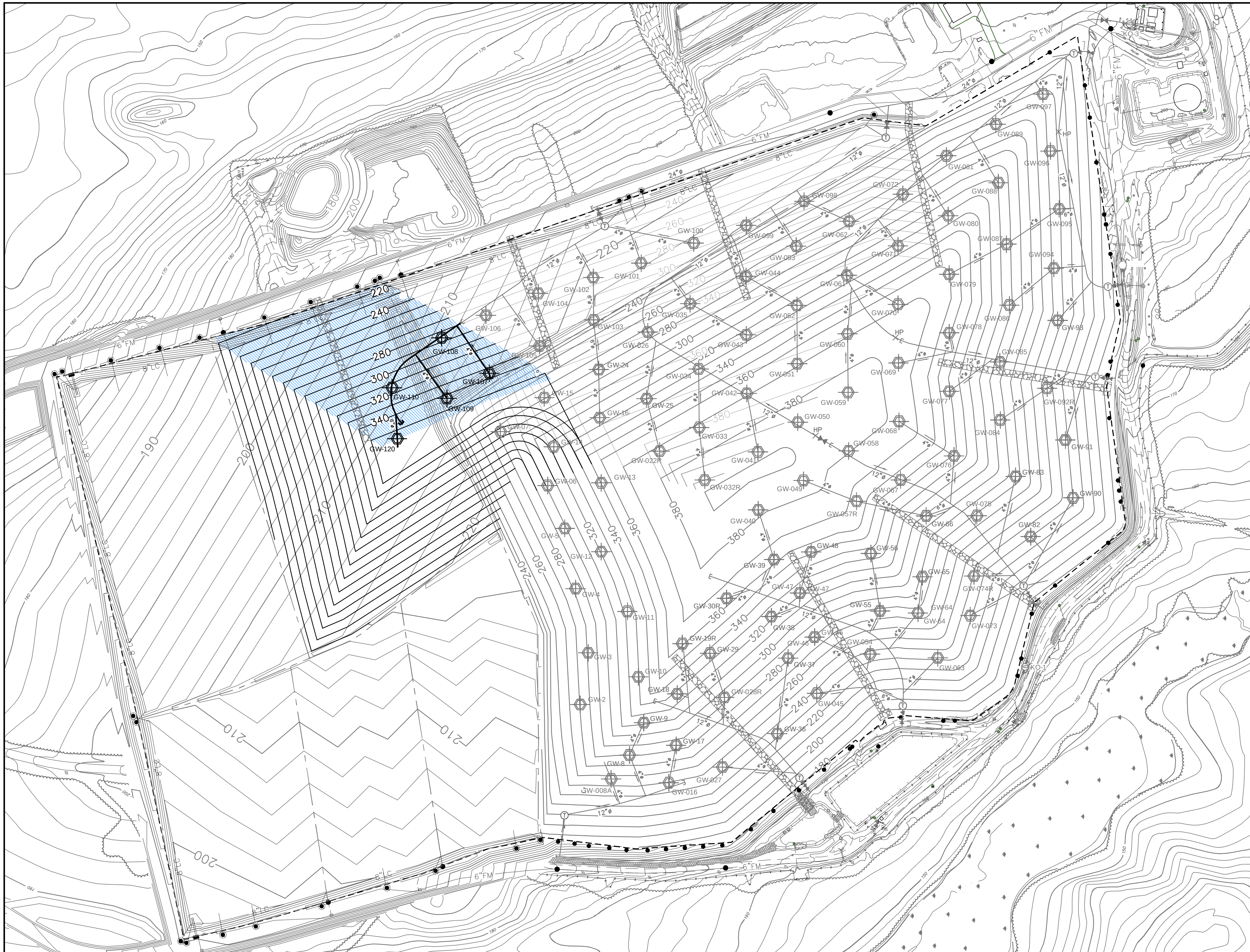
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

CELL 11 LFG INFRASTRUCTURE DEVELOPMENT PLAN

PROJECT NUMBER: 2536.27

SHEET NUMBER: 4 OF 14



NOTES:

1. SHEETS 4 THRU 9 OF THIS DRAWING SET SHOW THE SEQUENTIAL CONSTRUCTION OF THE LANDFILL GAS SYSTEM FOR CELLS 11-16. ACTUAL LOCATIONS OF INDIVIDUAL FEATURES AND TIMING OF INSTALLATION MAY CHANGE DUE TO FUTURE PLANNING OR CONSTRAINTS DURING CONSTRUCTION.
2. GAS COLLECTION TRENCHES WILL BE INSTALLED AS FILLING PROGRESSES IN EACH CELL AND ARE NOT SHOWN FOR CLARITY. GAS COLLECTION TRENCHES ARE INTENDED TO BE A TEMPORARY MEASURE OF GAS COLLECTION UNTIL FINAL GRADES ARE REACHED AND VERTICAL WELLS ARE INSTALLED.
3. SEE SHEET 2 FOR NOTES AND LEGEND INFORMATION.

= AREA EXPECTED TO REACH FINAL GRADE

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN HEAD

GRAPHICAL SCALE

150' 75' 0' 150' 300'

STATE OF MAINE Eric S. Steinhauser 10809 PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN

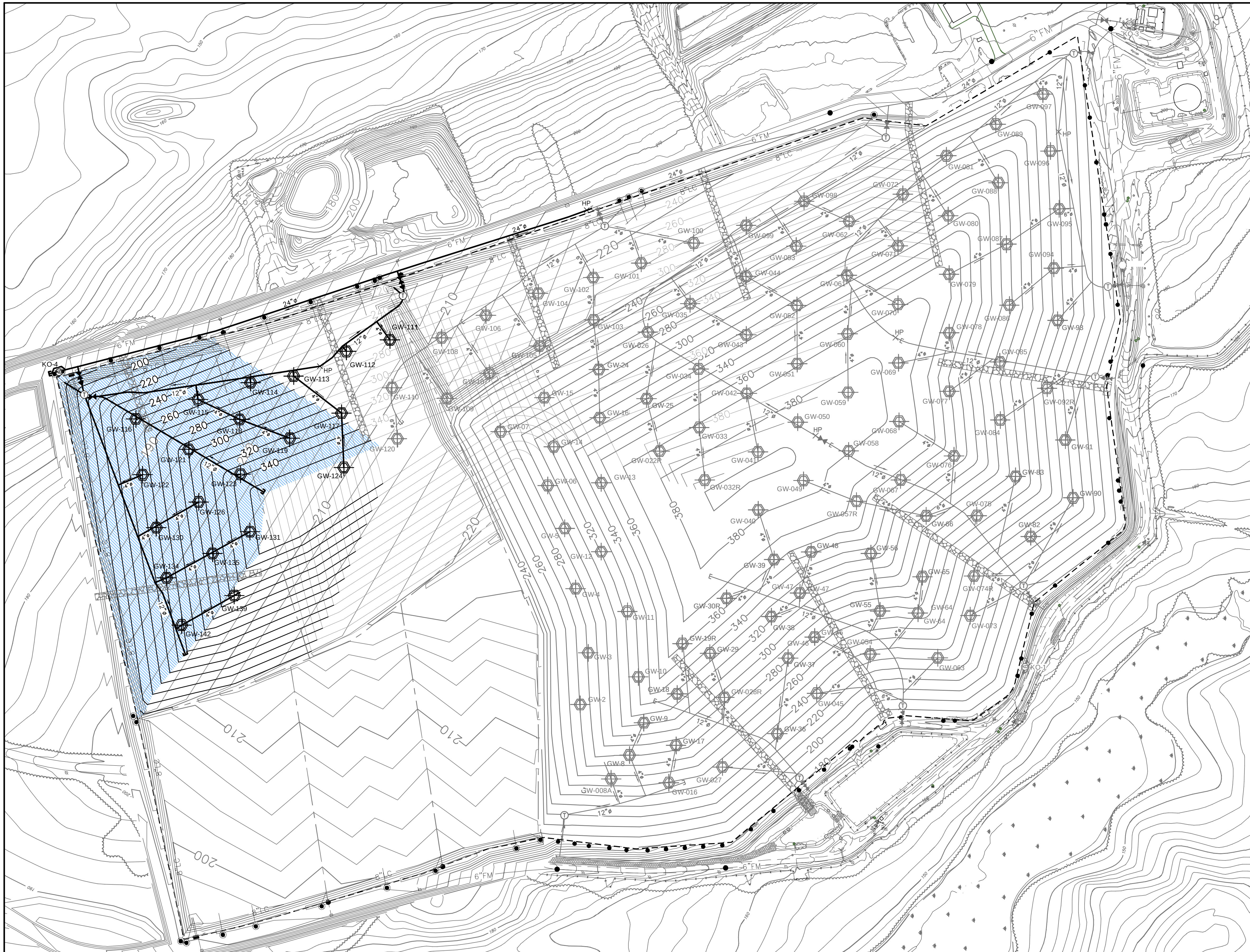
JUNIPER RIDGE LANDFILL

OLD TOWN, MAINE

CELL 12 LFG INFRASTRUCTURE DEVELOPMENT PLAN

PROJECT NUMBER: 2536.27

SHEET NUMBER: 5 OF 14



NOTES:

1. SHEETS 4 THRU 9 OF THIS DRAWING SET SHOW THE SEQUENTIAL CONSTRUCTION OF THE LANDFILL GAS SYSTEM FOR CELLS 11-16. ACTUAL LOCATIONS OF INDIVIDUAL FEATURES AND TIMING OF INSTALLATION MAY CHANGE DUE TO FUTURE PLANNING OR CONSTRAINTS DURING CONSTRUCTION.
2. GAS COLLECTION TRENCHES WILL BE INSTALLED AS FILLING PROGRESSES IN EACH CELL AND ARE NOT SHOWN FOR CLARITY. GAS COLLECTION TRENCHES ARE INTENDED TO BE A TEMPORARY MEASURE OF GAS COLLECTION UNTIL FINAL GRADES ARE REACHED AND VERTICAL WELLS ARE INSTALLED.
3. SEE SHEET 2 FOR NOTES AND LEGEND INFORMATION.

(hatched area) = AREA EXPECTED TO REACH FINAL GRADE

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN | HEAD

GRAPHICAL SCALE
150' 75' 0' 150' 300'

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

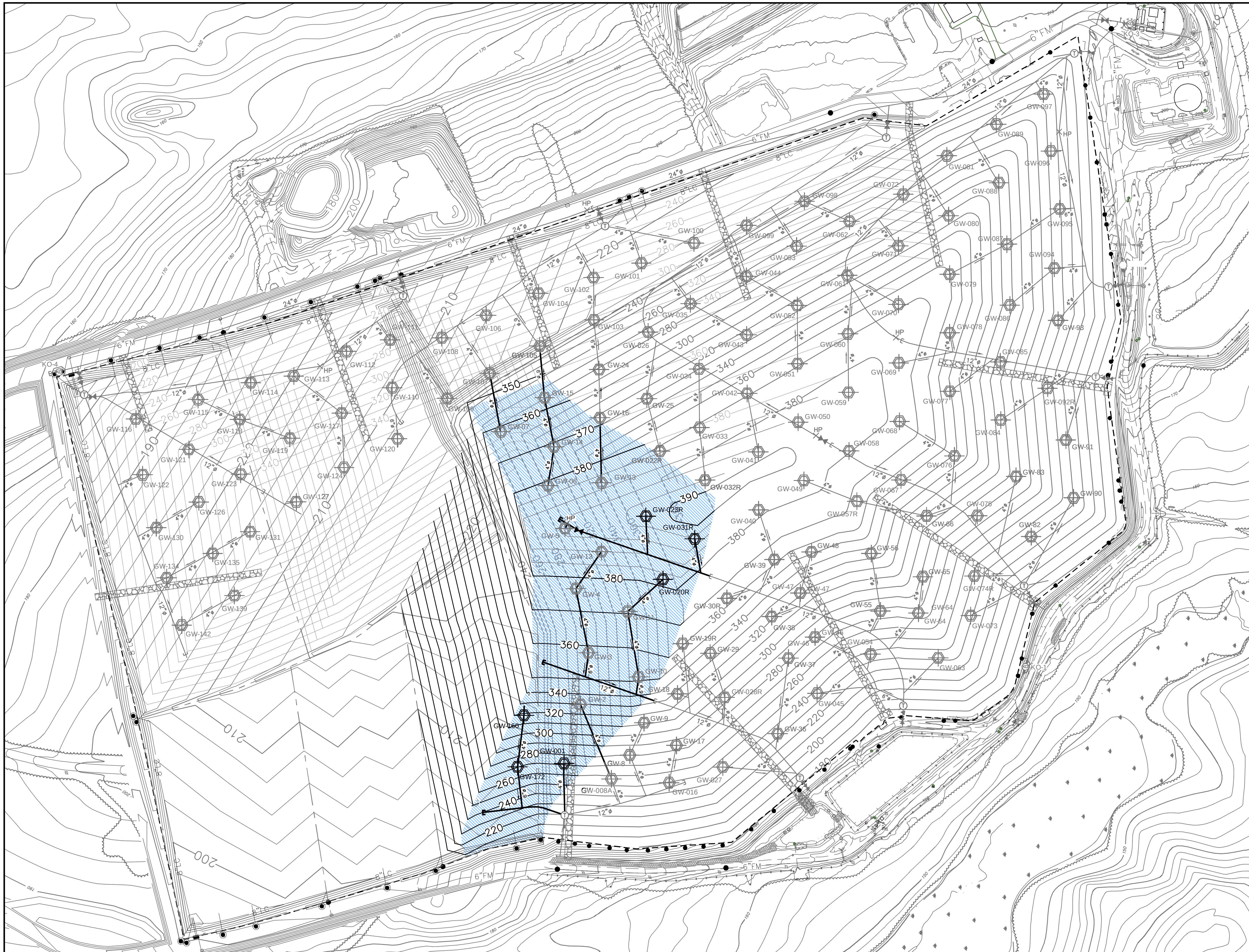
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

CELL 13 LFG INFRASTRUCTURE DEVELOPMENT PLAN

PROJECT NUMBER: 2536.27

SHEET NUMBER: 6 OF 14



NOTES:

1. SHEETS 4 THRU 9 OF THIS DRAWING SET SHOW THE SEQUENTIAL CONSTRUCTION OF THE LANDFILL GAS SYSTEM FOR CELLS 11-16. ACTUAL LOCATIONS OF INDIVIDUAL FEATURES AND TIMING OF INSTALLATION MAY CHANGE DUE TO FUTURE PLANNING OR CONSTRAINTS DURING CONSTRUCTION.
2. GAS COLLECTION TRENCHES WILL BE INSTALLED AS FILLING PROGRESSES IN EACH CELL AND ARE NOT SHOWN FOR CLARITY. GAS COLLECTION TRENCHES ARE INTENDED TO BE A TEMPORARY MEASURE OF GAS COLLECTION UNTIL FINAL GRADES ARE REACHED AND VERTICAL WELLS ARE INSTALLED.
3. SEE SHEET 2 FOR NOTES AND LEGEND INFORMATION.

= AREA EXPECTED TO REACH FINAL GRADE

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN | HEAD

GRAPHICAL SCALE

150' 75' 0' 150' 300'

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

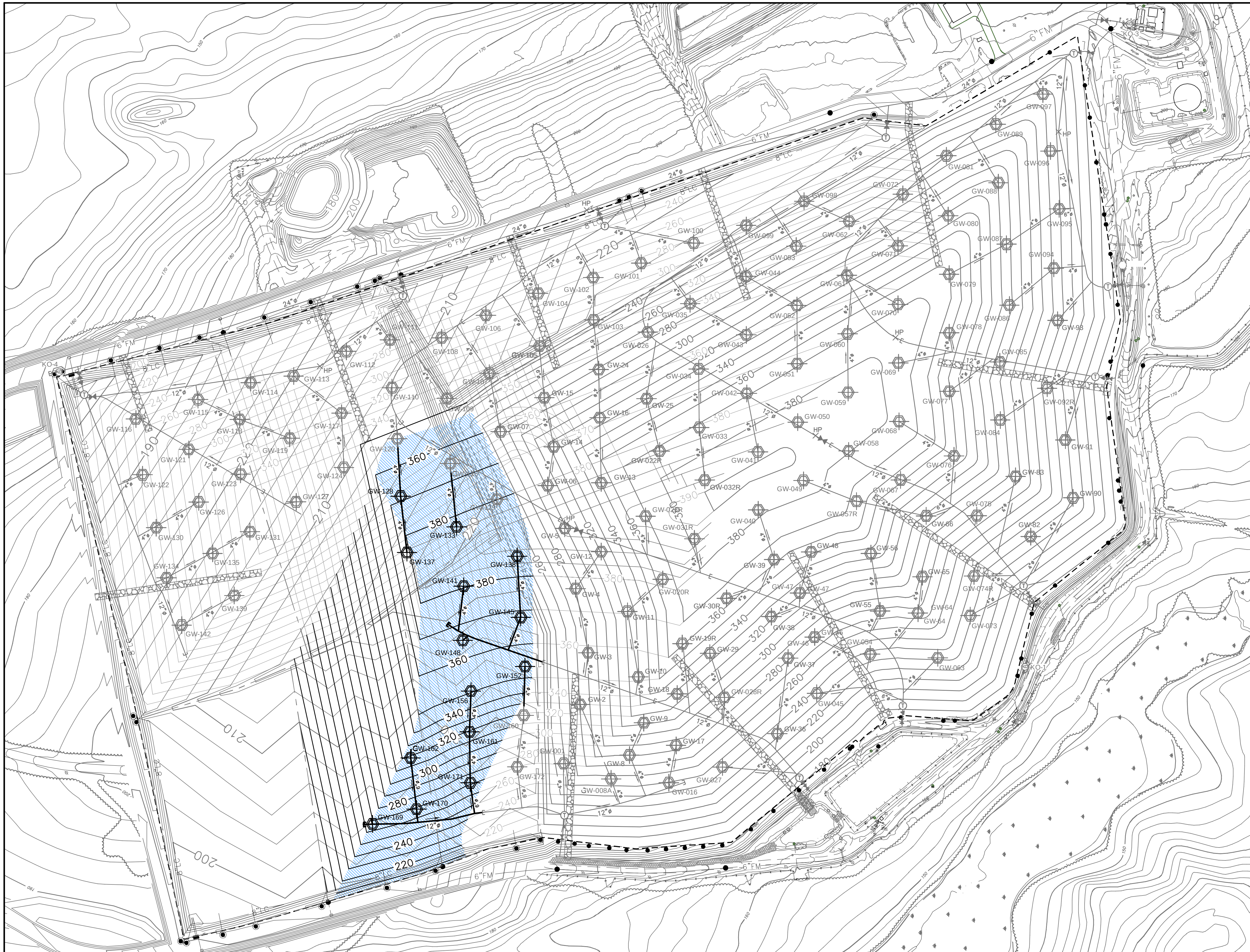
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

CELL 14 LFG INFRASTRUCTURE DEVELOPMENT PLAN

PROJECT NUMBER: 2536.27

SHEET NUMBER: 7 OF 14



NOTES:

1. SHEETS 4 THRU 9 OF THIS DRAWING SET SHOW THE SEQUENTIAL CONSTRUCTION OF THE LANDFILL GAS SYSTEM FOR CELLS 11-16. ACTUAL LOCATIONS OF INDIVIDUAL FEATURES AND TIMING OF INSTALLATION MAY CHANGE DUE TO FUTURE PLANNING OR CONSTRAINTS DURING CONSTRUCTION.
2. GAS COLLECTION TRENCHES WILL BE INSTALLED AS FILLING PROGRESSES IN EACH CELL AND ARE NOT SHOWN FOR CLARITY. GAS COLLECTION TRENCHES ARE INTENDED TO BE A TEMPORARY MEASURE OF GAS COLLECTION UNTIL FINAL GRADES ARE REACHED AND VERTICAL WELLS ARE INSTALLED.
3. SEE SHEET 2 FOR NOTES AND LEGEND INFORMATION.

= AREA EXPECTED TO REACH FINAL GRADE

ISSUED FOR
MAINE DEP APPROVAL
6/05/15

SANBORN HEAD

GRAPHICAL SCALE
150' 75' 0' 150' 300'

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

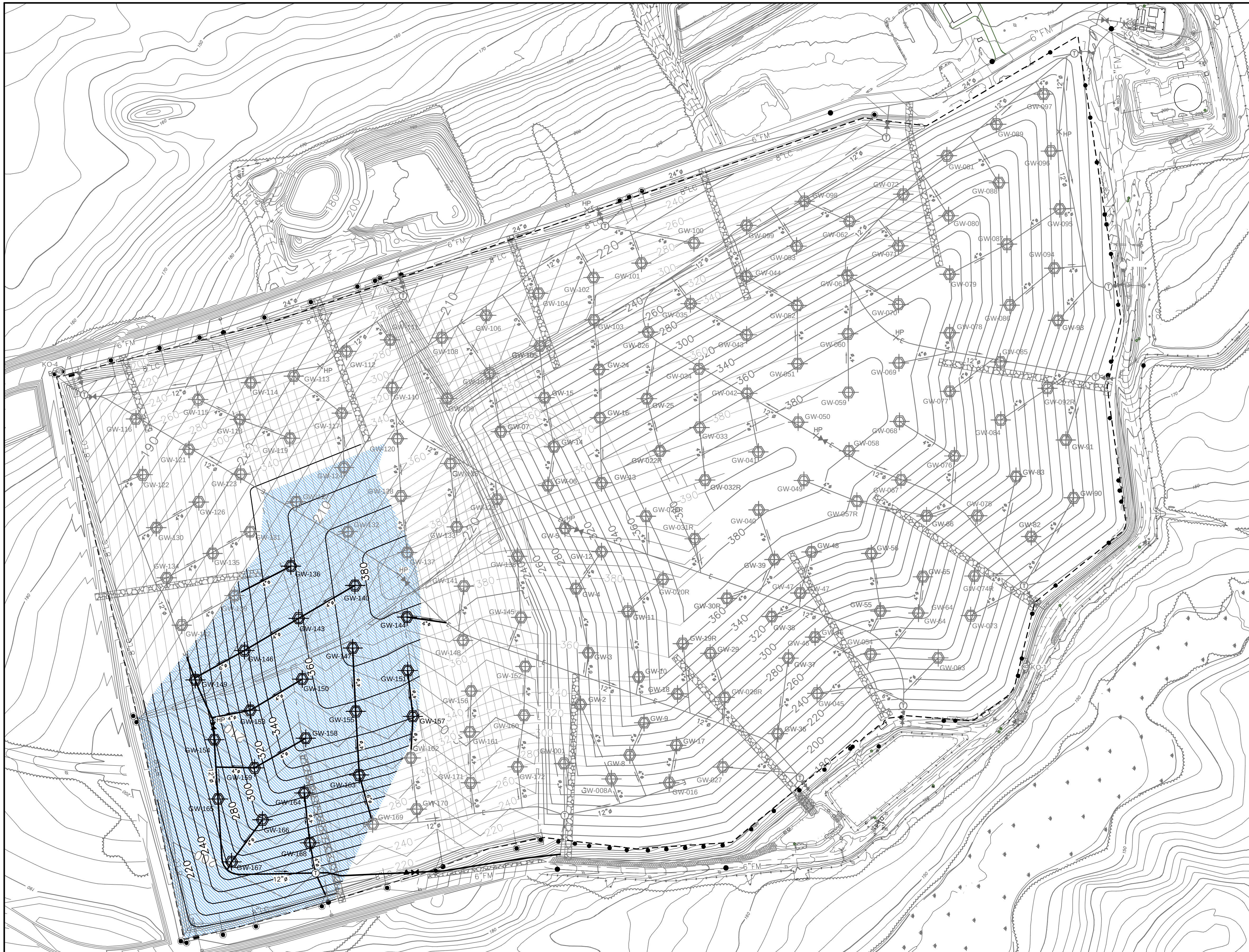
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

CELL 15 LFG INFRASTRUCTURE DEVELOPMENT PLAN

PROJECT NUMBER: 2536.27

SHEET NUMBER: 8 OF 14



NOTES:

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3. SEE SHEET 2 FOR NOTES AND LEGEND INFORMATION.

= AREA EXPECTED TO REACH FINAL GRADE

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN HEAD

GRAPHICAL SCALE 150' 75' 0' 150' 300'

STATE OF MAINE Eric S. Steinhauser 10809 PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

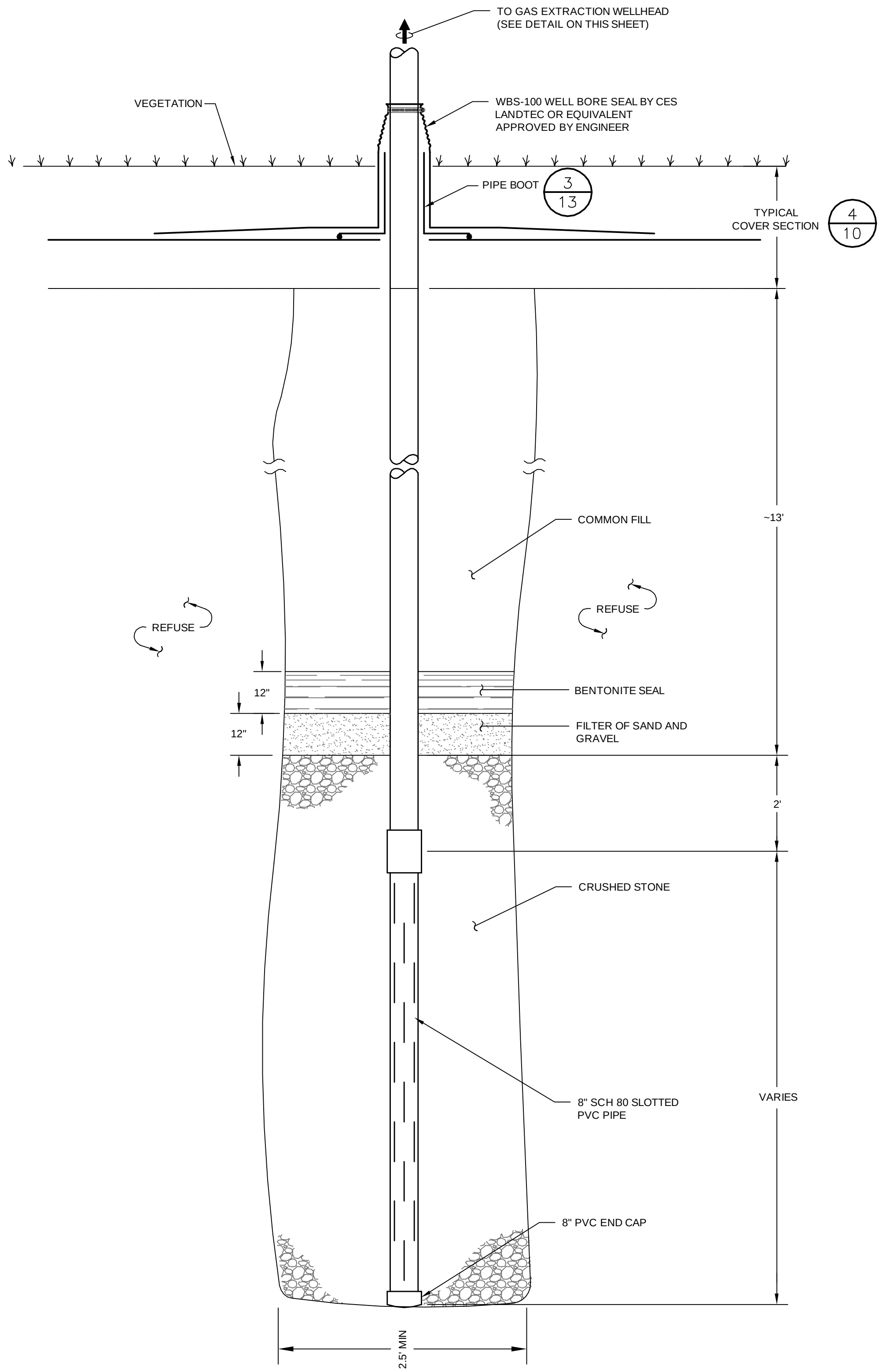
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

CELL 16 LFG INFRASTRUCTURE DEVELOPMENT PLAN

PROJECT NUMBER: 2536.27

SHEET NUMBER: 9 OF 14

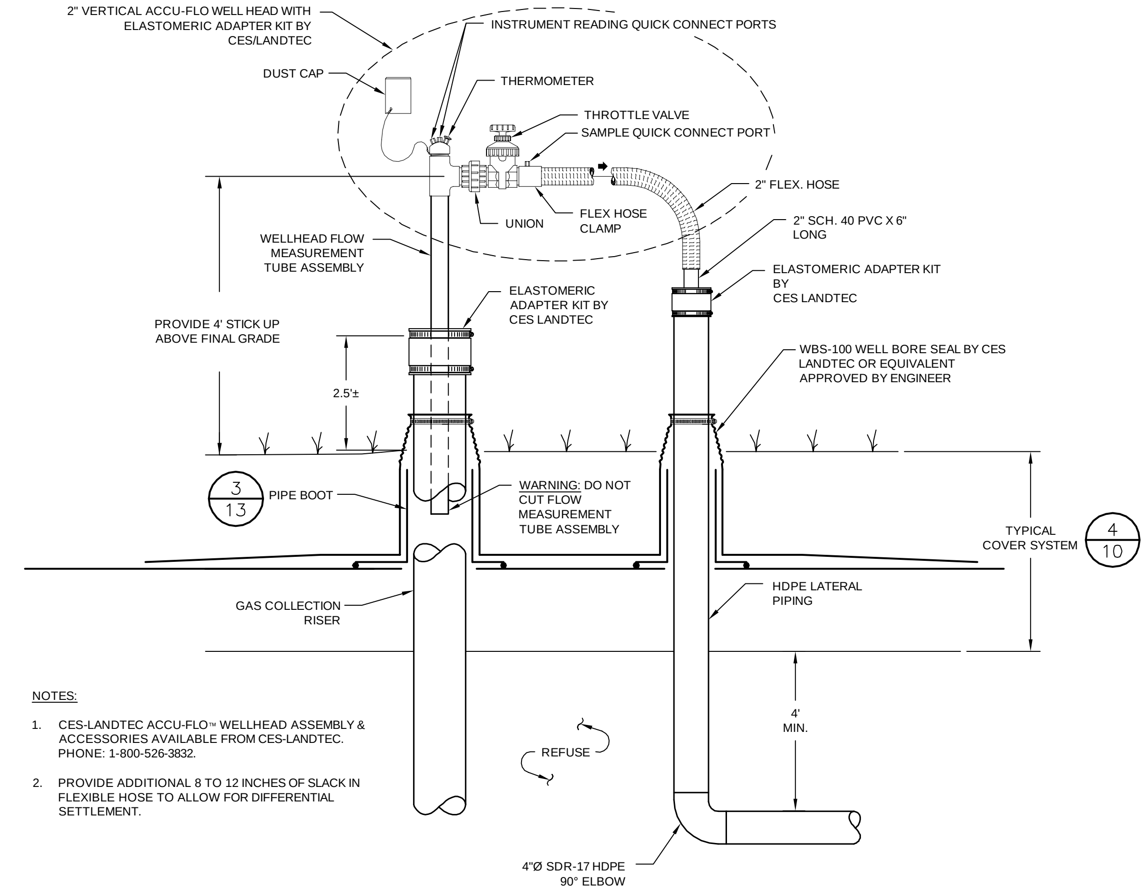


NOTES:

1. PIPE PERFORATED WITH SLOTS 1/8" TO 1/4" WIDE BY 8" LONG. FOUR SLOTS PER ROW SPACED 90° APART, WITH ADJACENT ROWS OFFSET BY 45°.
2. BOTTOM OF WELL IS DESIGNED TO BE 15 FEET ABOVE PRIMARY LINER SAND. REFER TO WELL SCHEDULE FOR ELEVATIONS.

1 TYPICAL GAS EXTRACTION WELL DETAIL

NOT TO SCALE

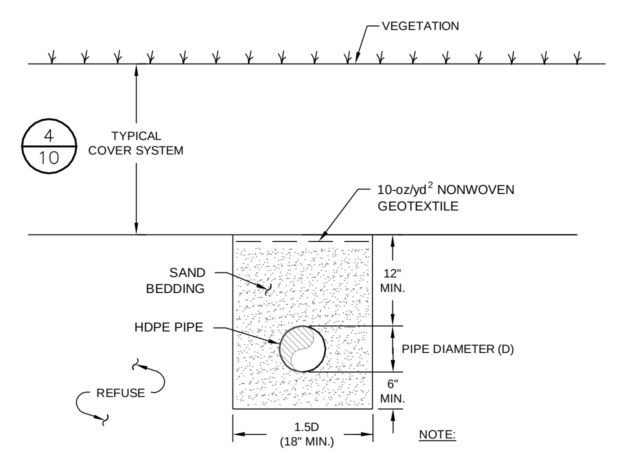


NOTES:

1. CES-LANDTEC ACCU-FLO™ WELLHEAD ASSEMBLY & ACCESSORIES AVAILABLE FROM CES-LANDTEC. PHONE: 1-800-526-3832.
2. PROVIDE ADDITIONAL 8 TO 12 INCHES OF SLACK IN FLEXIBLE HOSE TO ALLOW FOR DIFFERENTIAL SETTLEMENT.

2 TYPICAL GAS EXTRACTION WELLHEAD DETAIL

NOT TO SCALE

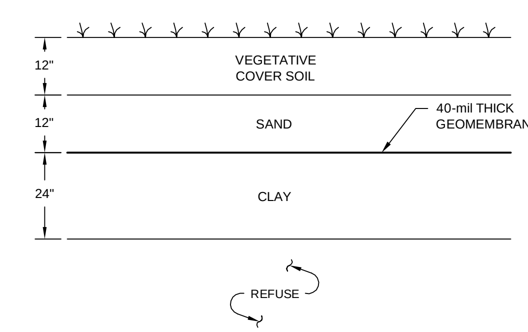


NOTE:

1. PROVIDE MINIMUM 6% PIPE SLOPE.

3 TYPICAL GAS PIPE TRENCH WITHIN LIMIT OF WASTE CONTAINMENT

NOT TO SCALE



4 TYPICAL COVER SYSTEM

NOT TO SCALE

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN HEAD

SCALE AS NOTED

STATE OF MAINE Eric S. Steinhauser 10809 PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

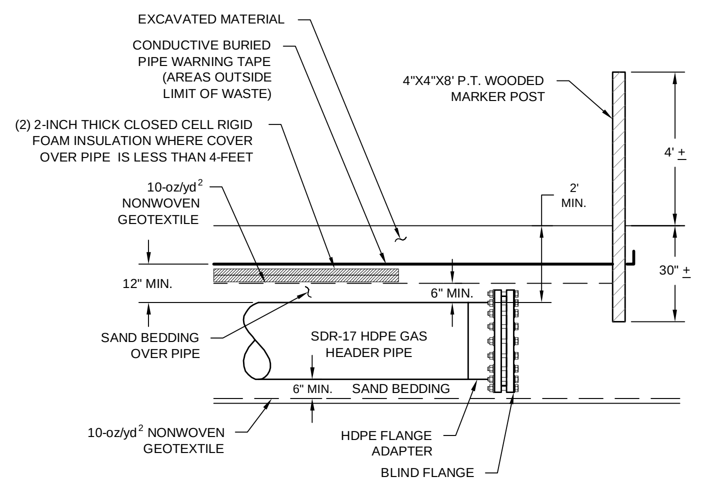
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LANDFILL GAS EXTRACTION SYSTEM DETAILS

PROJECT NUMBER: 2536.27

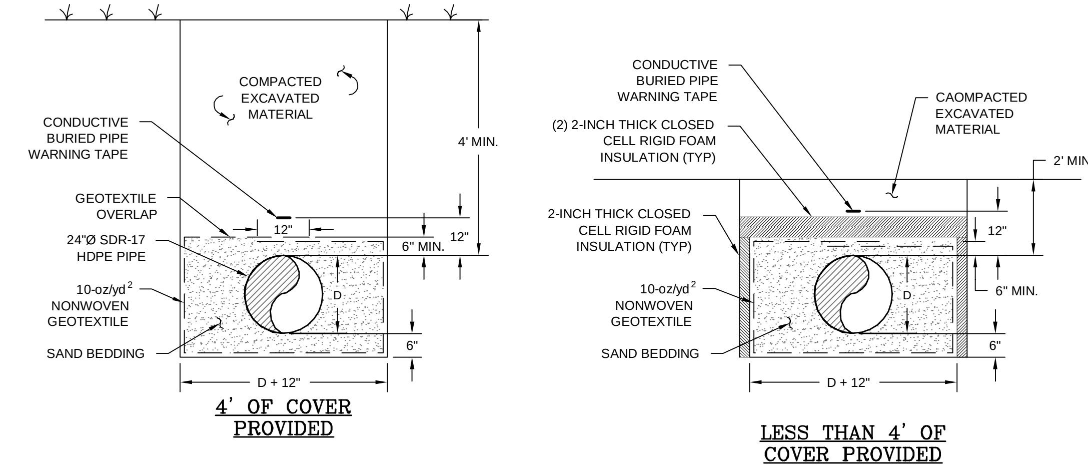
SHEET NUMBER: 10 OF 14



TEMPORARY PERIMETER LFG HEADER TERMINATION

1

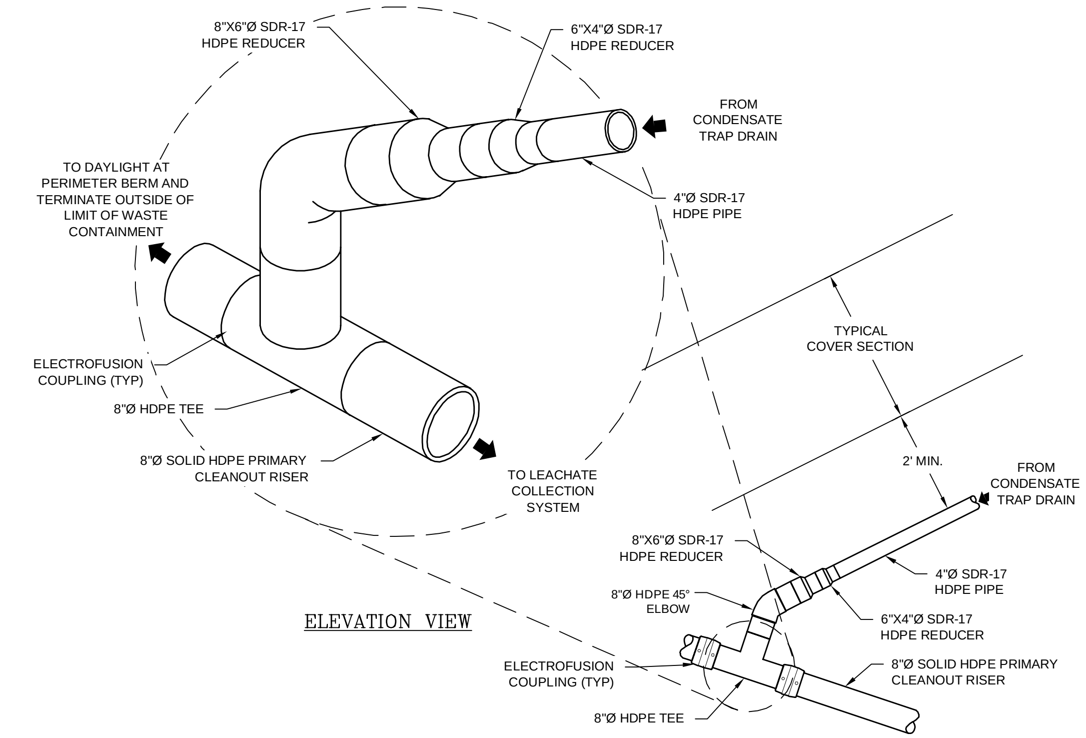
NOT TO SCALE



TYPICAL GAS HEADER PIPE TRENCH OUTSIDE LIMIT OF WASTE

2

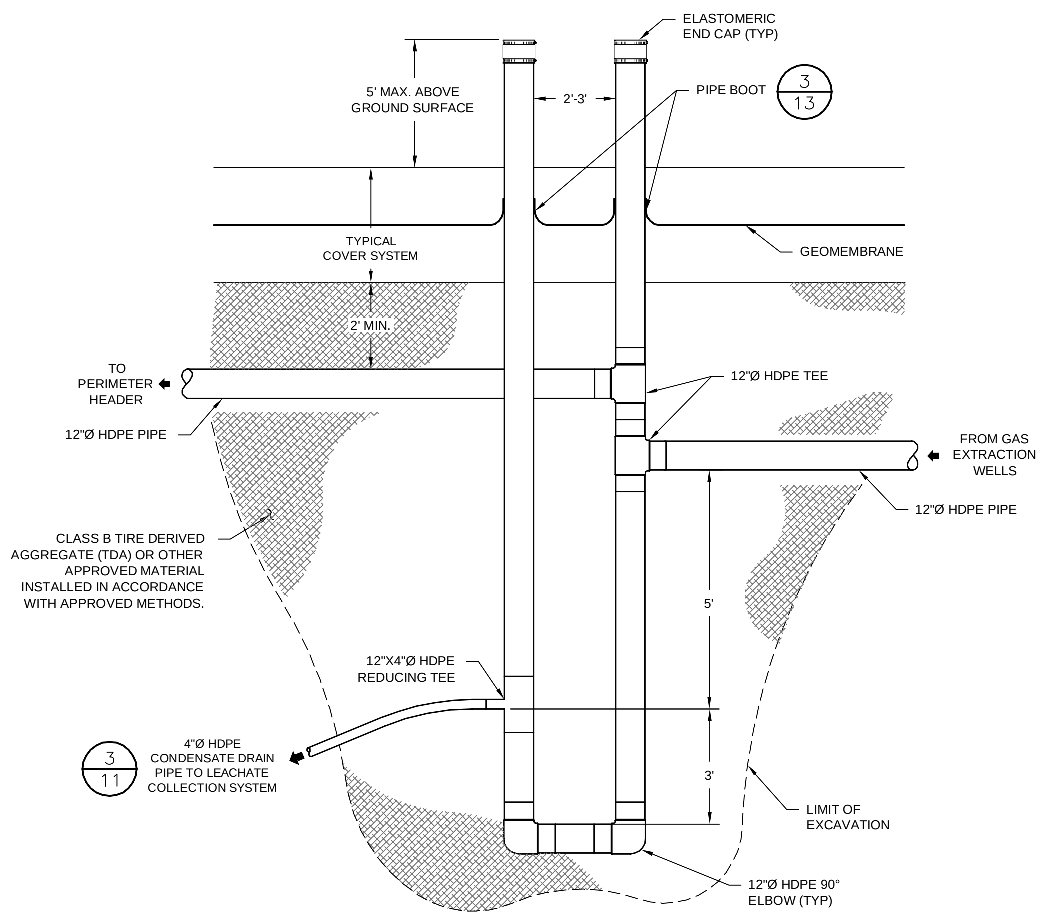
NOT TO SCALE



TYPICAL CLEANOUT TIE-IN DETAIL

3

NOT TO SCALE



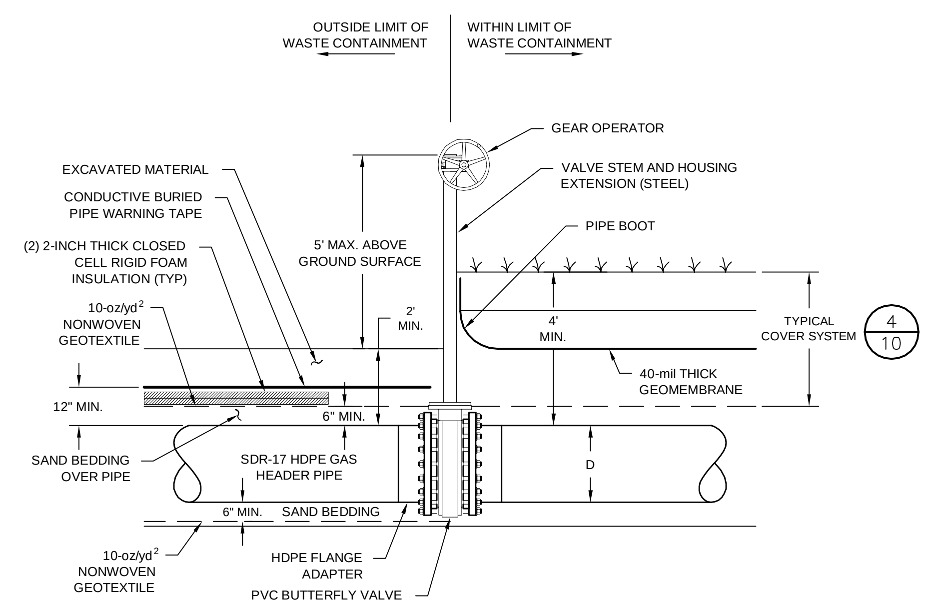
NOTES:

1. TIRE DERIVED AGGREGATE SHALL CONFORM TO THE REQUIREMENTS OF ASTM D 6270.

TYPICAL CONDENSATE TRAP

4

NOT TO SCALE



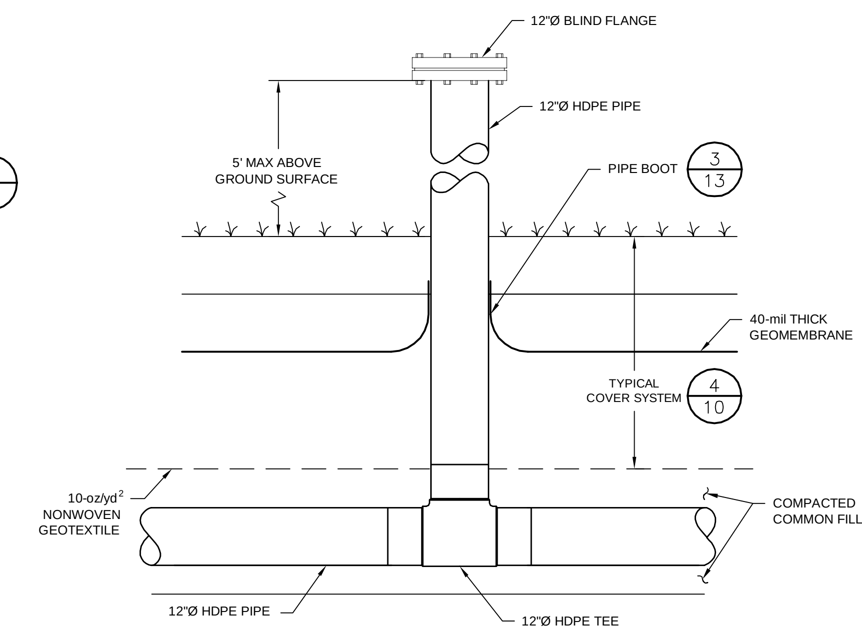
NOTE:

1. FLANGE BACKUP RINGS AND FASTENERS SHALL BE TYPE 316 STAINLESS STEEL.
2. PROTECT BELOW GRADE BOLTS AND FLANGES BY COVERING WITH A 6-MIL THICK POLYETHYLENE WRAP. DUCT TAPE WRAP TO HDPE PIPE.

CONTROL VALVE DETAIL (TYP)

5

NOT TO SCALE



VERTICAL RISER DETAIL (TYP)

6

NOT TO SCALE

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN HEAD

SCALE AS NOTED

STATE OF MAINE Eric S. Steinhauser 10809 LICENSED PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

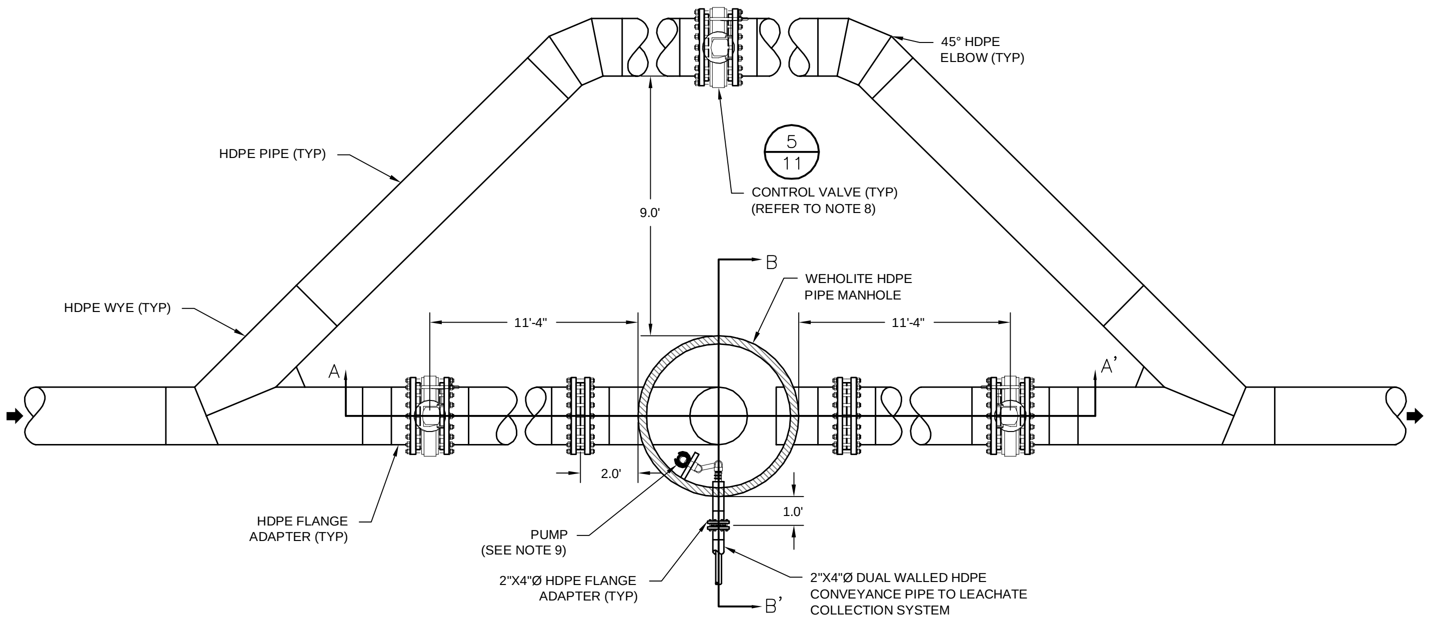
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

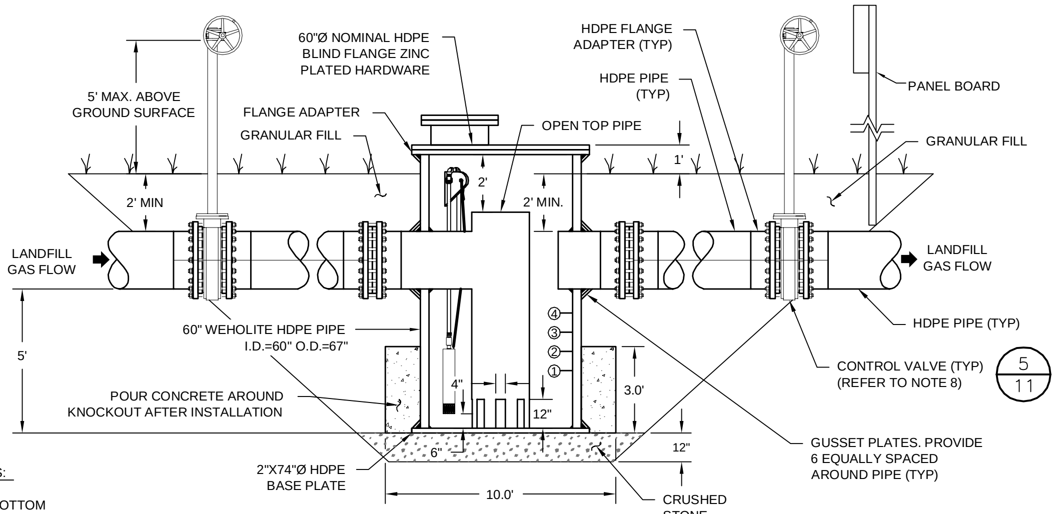
LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LANDFILL GAS EXTRACTION SYSTEM DETAILS

PROJECT NUMBER: 2536.27

SHEET NUMBER: 11 OF 14

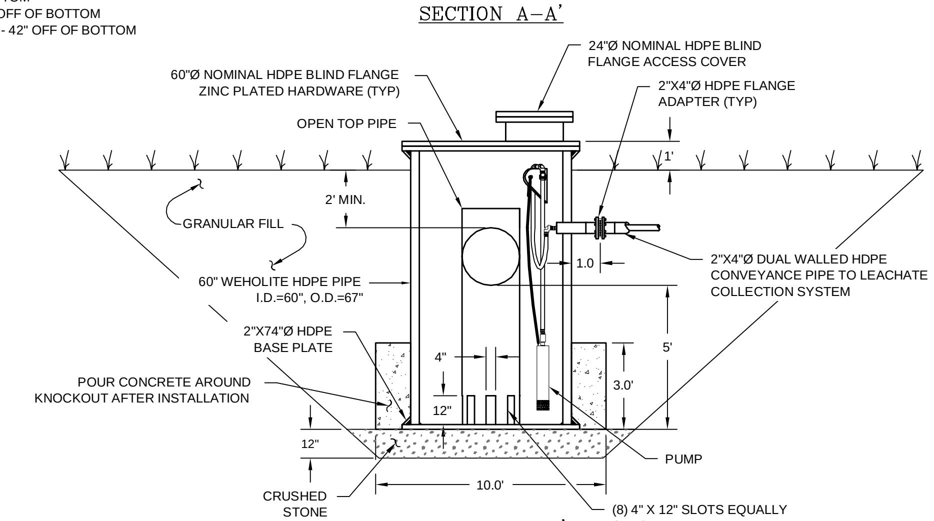




LIQUID LEVEL CONTROL NOTES:

① PUMP OFF - 18" OFF OF BOTTOM
② PUMP ON - 30" OFF OF BOTTOM
③ HIGH WATER ALARM - 36" OFF OF BOTTOM
④ HIGH HIGH WATER ALARM - 42" OFF OF BOTTOM

SECTION A–A'



SECTION B–B'

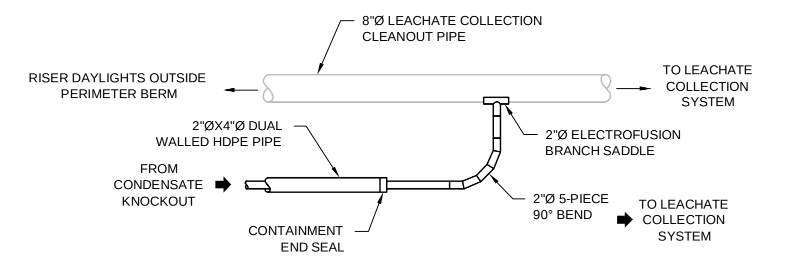
CONDENSATE KNOCKOUT DETAIL

1

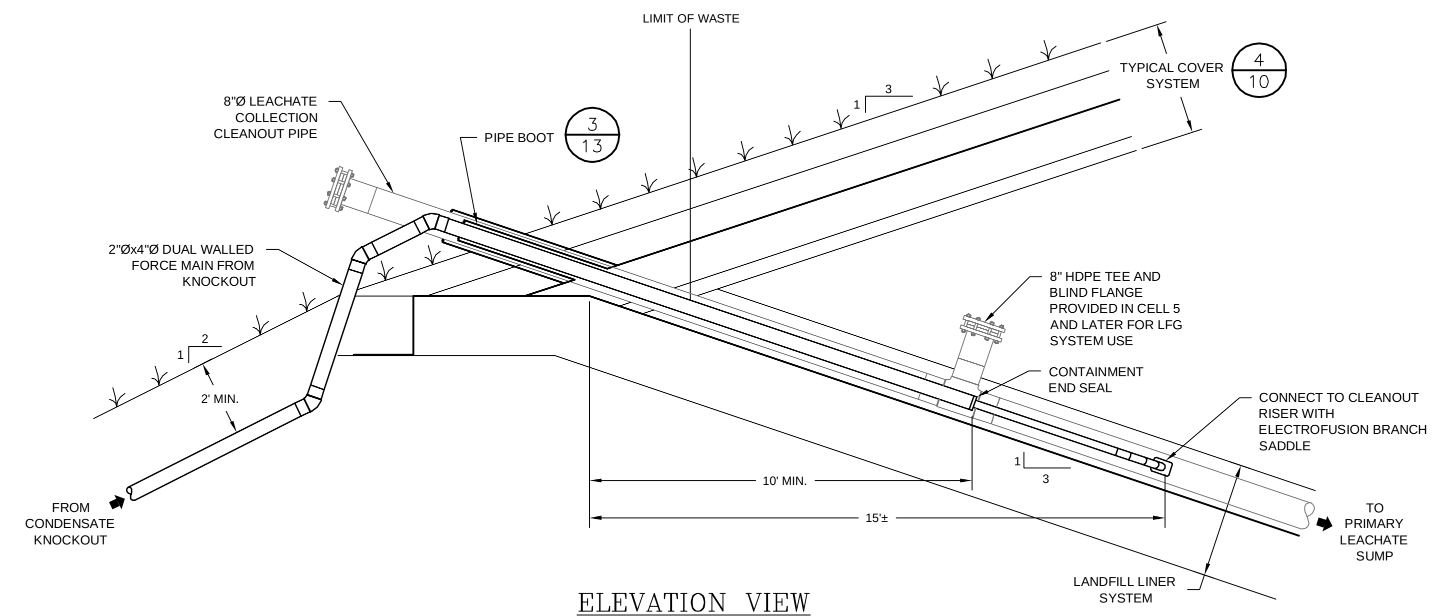
NOT TO SCALE

NOTES:

1. REFER TO PREVIOUS SHEETS FOR ADDITIONAL NOTES.
2. ALL HDPE PIPE AND FITTINGS SHALL BE SDR-17 UNLESS OTHERWISE NOTED.
3. CONTRACTOR SHALL FOLLOW EXCAVATION PRACTICES AND REGULATIONS APPROVED BY OSHA REQUIREMENTS FOR PROTECTIVE SYSTEMS. - 1926.652.
4. CONDENSATE KNOCKOUT SHALL HAVE AN OSHA APPROVED CONFINED SPACE SIGN ATTACHED TO THE TOP OF THE COVER. SIGN SHALL BE 14" WIDE BY 10" HIGH, AND SHALL HAVE UV-RESISTANT PAINT ON AN ALUMINUM BASE. SIGN SHALL READ "DANGER CONFINED SPACE, HAZARDOUS ATMOSPHERE, ENTER BY PERMIT ONLY."
5. CONDENSATE PUMP SHALL BE GOULDS PUMP MODEL 1SC51C-1, AS SPECIFIED BY NEWSME LANDFILL OPERATIONS, LLC.
6. CONTRACTOR SHALL INSTALL PUMP CONTROLS, ASSOCIATED CONTROL WIRING, AND ELECTRICAL POWER AS NEEDED TO OPERATE THE PUMP AND PROVIDE NECESSARY ALARMS.
7. CONDENSATE KNOCKOUT IS A CLASS 1 DIVISION 1 GROUP D CLASSIFIED SPACE. PROVIDE EXPLOSION-PROOF OR INTRINSICALLY-SAFE ELECTRICAL EQUIPMENT. PROVIDE CONDUIT SEALS ON ALL ELECTRICAL CONDUIT.
8. PROTECT BELOW GRADE BOLTS AND FLANGES BY COVERING WITH A 6-MIL THICK POLYETHYLENE WRAP. DUCT TAPE WRAP TO HDPE PIPE.
9. PUMP IN CONDENSATE KNOCKOUT SHALL BE ABLE TO PUMP MORE THAN 1 GPM.



PLAN VIEW



ELEVATION VIEW

KNOCKOUT FORCE MAIN CONNECTION DETAIL

2

NOT TO SCALE

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN ||| HEAD

SCALE AS NOTED

STATE OF MAINE Eric S. Steinhauser 10809 PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

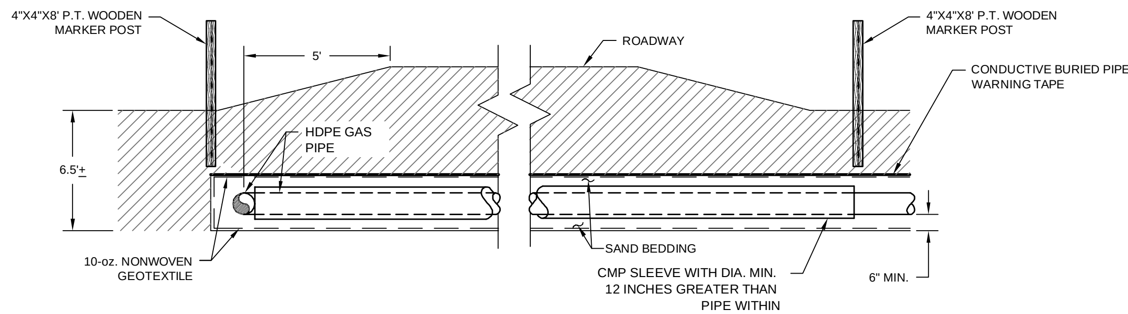
LANDFILL GAS EXTRACTION SYSTEM DETAILS

PROJECT NUMBER: 2536.27

SHEET NUMBER: 12 OF 14

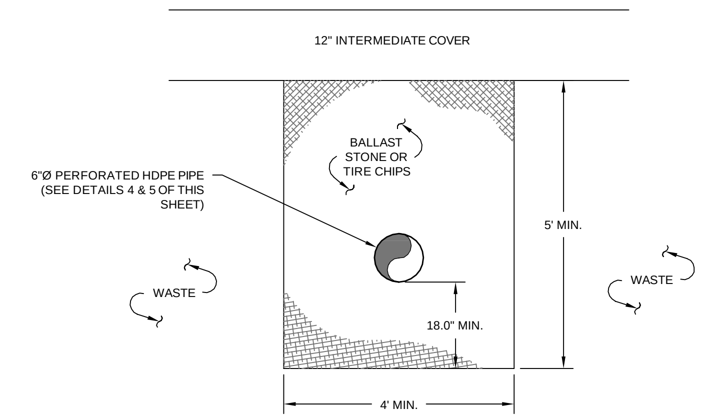
NOTE:

1. THESE DRAWINGS DO NOT SHOW ALL INTERIM LANDFILL ACCESS ROADS WHICH MAY BE CONSTRUCTED DURING FILLING OPERATIONS. THIS DETAIL APPLIES WHEN ROAD CROSSING CONDITIONS ARE PRESENT.



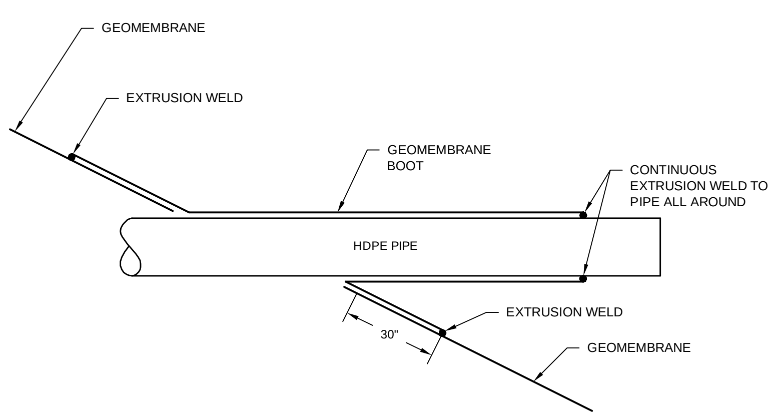
GAS PIPE ROAD CROSSING SLEEVE DETAIL

1 NOT TO SCALE



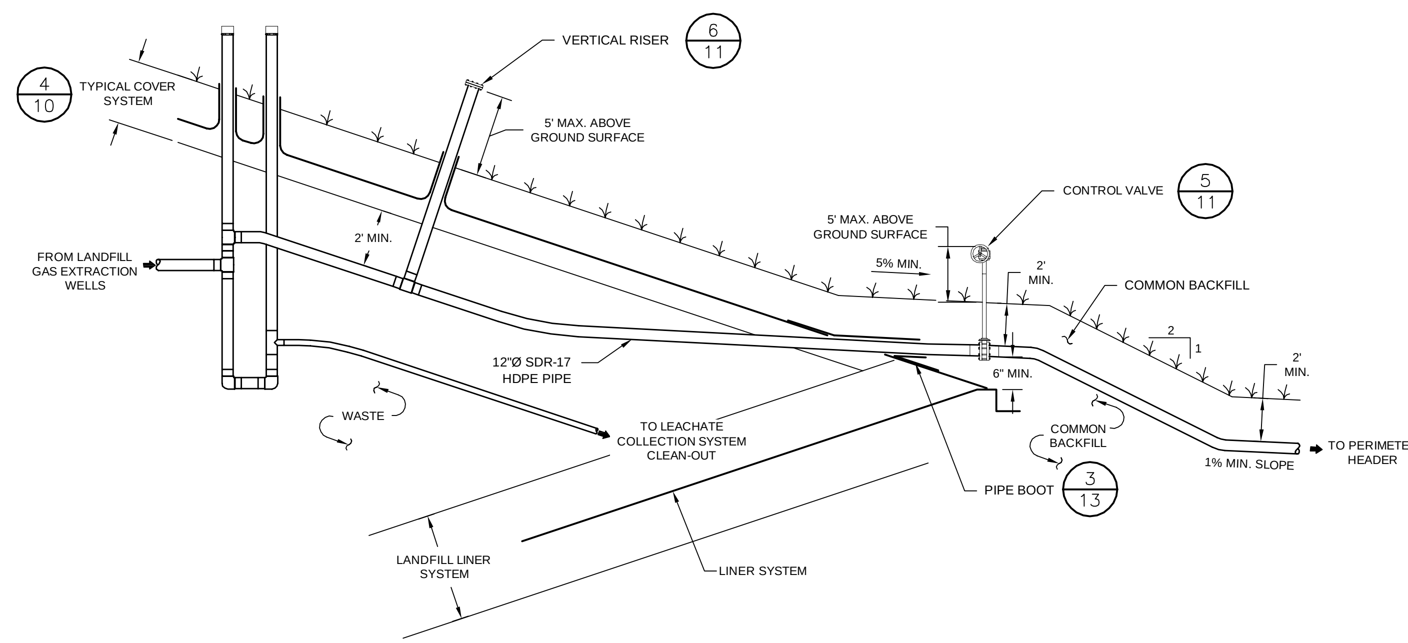
TYPICAL GAS COLLECTION TRENCH SECTION

2 NOT TO SCALE



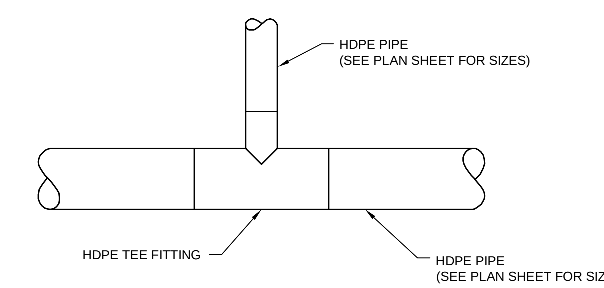
TYPICAL PIPE BOOT DETAIL

3 NOT TO SCALE



CAP PENETRATION DETAIL

4 NOT TO SCALE



"TEE" CONNECTION DETAIL

5 NOT TO SCALE

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN HEAD

SCALE AS NOTED

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

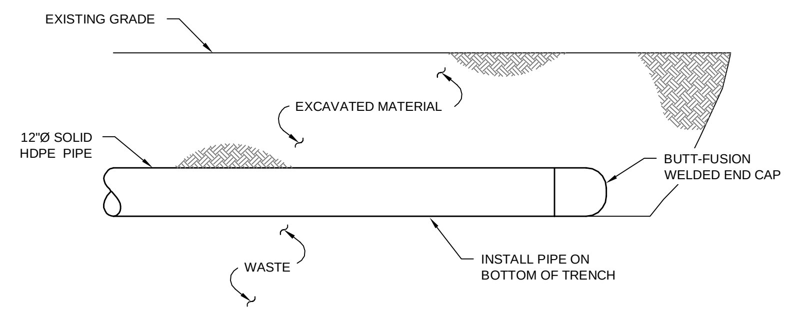
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LANDFILL GAS EXTRACTION SYSTEM DETAILS

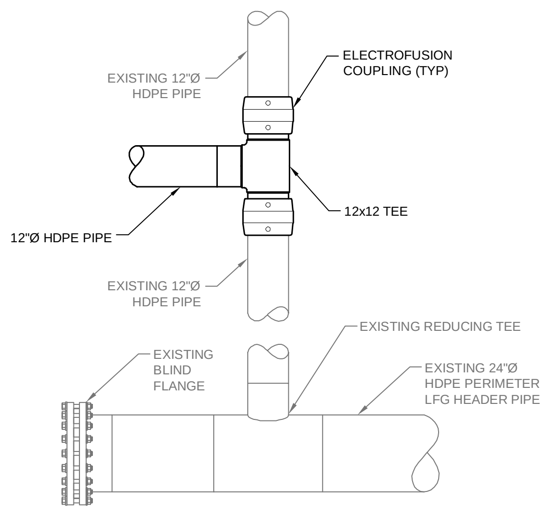
PROJECT NUMBER: 2536.27

SHEET NUMBER: 13 OF 14



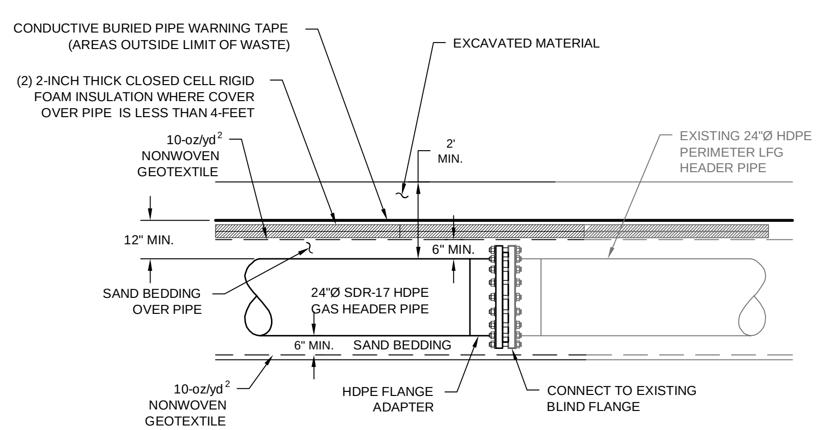
1 TEMPORARY LFG PIPE TERMINATION

NOT TO SCALE



2 WEST LFG CONVEYANCE PIPE CONNECTION DETAIL

NOT TO SCALE



3 PERIMETER LFG CONVEYANCE PIPE CONNECTION DETAIL

NOT TO SCALE

LANDFILL GAS EXTRACTION WELL SCHEDULE

WELL DESIGNATION	NORTHING	EASTING	BOTTOM OF WASTE (FT)	TOP OF EXISTING WASTE (FT)	TOTAL WELL DEPTH (FT)	BOTTOM OF WELL SCREEN (FT)	TOP OF WELL SCREEN (FT)	SCREEN LENGTH (FT)	TOP OF CASING ELEV. (FT)
GW-001	479171.1	925548.7	203.1	271.3	53.2	218.1	256.3	38.2	274.3
GW-008A	479030.7	925503.0	196.1	256.9	45.7	211.1	241.9	30.7	259.9
GW-016	478859.9	925491.7	188.5	249.4	45.9	203.5	234.4	30.9	252.4
GW-020R	478878.2	926093.3	209.3	381.1	156.8	224.3	366.1	141.8	384.1
GW-022R	478887.0	926473.0	213.6	381.7	153.1	228.6	366.7	138.1	384.7
GW-023R	478928.7	926280.1	212.5	388.2	160.6	227.5	373.2	145.6	391.2
GW-026	478922.2	926825.3	217.1	349.1	116.9	232.1	334.1	101.9	352.1
GW-027	478701.0	925538.0	183.2	243.4	45.3	198.2	228.4	30.3	246.4
GW-028R	478695.3	925744.2	194.6	294.2	84.6	209.6	279.2	69.6	297.2
GW-031R	478784.3	926213.2	208.6	387.7	164.1	223.6	372.7	149.1	390.7
GW-032R	478753.5	926387.1	210.9	388.0	162.1	225.9	373.0	147.1	391.0
GW-033	478769.9	926542.9	214.8	380.4	150.6	229.8	365.4	135.6	383.4
GW-034	478771.5	926716.1	214.3	364.4	135.1	229.3	349.4	120.1	367.4
GW-035	478796.8	926909.2	217.6	339.1	106.6	232.6	324.1	91.6	342.1
GW-040	478595.2	926299.0	205.3	381.9	161.6	220.3	366.9	146.6	384.9
GW-041	478596.0	926470.3	209.4	387.5	163.2	224.4	372.5	148.2	390.5
GW-042	478629.0	926643.7	212.0	376.0	149.0	227.0	361.0	134.0	379.0
GW-043	478630.6	926816.9	213.5	359.6	131.1	228.5	344.6	116.1	362.6
GW-044	478631.1	926990.1	215.3	332.2	101.8	230.3	317.2	86.8	335.2
GW-045	478421.8	925756.4	177.0	237.0	45.0	192.0	222.0	30.0	240.0
GW-049	478461.3	926386.1	205.7	384.7	164.0	220.7	369.7	149.0	387.7
GW-050	478478.2	926558.5	214.0	385.7	156.7	229.0	370.7	141.7	388.7
GW-051	478479.8	926731.7	210.8	372.7	146.8	225.8	357.7	131.8	375.7
GW-052	478480.9	926903.9	214.7	356.4	126.7	229.7	341.4	111.7	359.4
GW-053	478482.6	927079.8	214.5	320.6	91.1	229.5	305.6	76.1	323.6
GW-054	478263.7	925872.0	176.7	237.0	45.2	191.7	222.0	30.2	240.0
GW-057R	478304.0	926324.8	196.4	365.8	154.4	211.4	350.8	139.4	368.8
GW-058	478327.4	926473.3	202.0	380.5	163.5	217.0	365.5	148.5	383.5
GW-059	478329.1	926646.5	209.0	385.9	161.9	224.0	370.9	146.9	388.9
GW-060	478330.7	926819.7	209.7	369.4	144.7	224.7	354.4	129.7	372.4
GW-061	478332.7	926992.9	211.8	353.0	126.1	226.8	338.0	111.1	356.0
GW-062	478326.0	927153.1	213.2	315.0	86.8	228.2	300.0	71.8	318.0
GW-063	478063.7	925861.2	170.3	231.9	46.6	185.3	216.9	31.6	234.9
GW-067	478173.5	926387.8	195.8	352.2	141.4	210.8	337.2	126.4	355.2
GW-068	478178.0	926560.9	201.2	376.7	160.5	216.2	361.7	145.5	379.7
GW-069	478180.1	926734.1	203.8	375.9	157.2	218.8	360.9	142.2	378.9
GW-070	478181.3	926907.3	207.5	367.6	145.1	222.5	352.6	130.1	370.6
GW-071	478181.5	927080.5	210.5	345.0	119.4	225.5	330.0	104.4	348.0
GW-072	478167.1	927233.0	212.3	293.9	66.6	227.3	278.9	51.6	296.9
GW-073	477967.4	925985.9	171.0	231.8	45.8	186.0	216.8	30.8	234.8
GW-074R	477956.4	926103.4	173.9	239.0	50.1	188.9	224.0	35.1	242.0
GW-075	477947.9	926282.0	180.2	278.1	82.9	195.2	263.1	67.9	281.1
GW-076	478015.5	926458.8	189.9	338.9	134.0	204.9	323.9	119.0	341.9
GW-077	478029.5	926650.0	196.6	340.9	129.3	211.6	325.9	114.3	343.9
GW-078	478029.8	926823.2	201.3	351.6	135.2	216.3	336.6	120.2	354.6
GW-079	478030.1	926996.4	205.9	360.8	139.9	220.9	345.8	124.9	363.8
GW-080	478033.0	927169.6	209.4	322.7	98.2	224.4	307.7	83.2	325.7
GW-081	478038.0	927346.9	216.1	271.7	40.6	231.1	256.7	25.6	274.7
GW-084	477878.6	926564.9	186.9	294.4	92.5	201.9	279.4	77.5	297.4
GW-085	477879.7	926736.9	193.1	295.4	87.2	208.1	280.4	72.2	298.4
GW-086	477851.7	926905.1	197.1	303.0	91.0	212.1	288.0	76.0	306.0
GW-087	477860.0	927085.1	202.7	304.0	86.4	217.7	289.0	71.4	307.0
GW-088	477884.2	927267.3	208.5	309.8	86.3	223.5	294.8	71.3	312.8
GW-089	477891.8	927440.3	211.8	262.8	36.0	226.8	247.8	21.0	265.8
GW-092R	477740.0	926659.1	184.4	245.0	45.7	199.4	230.0	30.7	248.0
GW-094	477720.1	927014.1	196.6	257.9	46.3	211.6	242.9	31.3	260.9
GW-095	477704.4	927189.8	201.7	251.1	34.4	216.7	236.1	19.4	254.1
GW-096	477730.2	927361.0	207.7	257.0	34.2	222.7	242.0	19.2	260.0
GW-097	477752.2	927529.6	211.3	254.1	27.8	226.3	239.1	12.8	257.1
GW-098	478459.4	927212.4	220.9	281.5	45.6	235.9	266.5	30.6	284.5
GW-099	478630.8	927140.8	223.9	284.9	46.0	238.9	269.9	31.0	287.9
GW-100	478786.2	927088.7	222.6	283.9	46.3	237.6	268.9	31.3	286.9
GW-101	478941.9	927028.9	221.8	285.4	48.6	236.8	270.4	33.6	288.4
GW-102	479083.5	926986.5	221.0	282.9	46.8	236.0	267.9	31.8	285.9
GW-103	479082.4	926861.4	225.4	322.1	81.7	240.4	307.1	66.7	325.1
GW-104	479246.4	926939.8	217.0	278.4	46.4	232.0	263.4	31.4	281.4
GW-105	479243.1	926784.1	222.7	327.4	89.7	237.7	312.4	74.7	330.4
GW-106	479401.5	926874.9	213.8	280.5	51.7	228.8	265.5	36.7	283.5
GW-107	479391.3	926703.4	221.5	335.2	98.7	236.5	320.2	83.7	338.2
GW-108	479532.6	926808.3	211.0	285.9	59.9	226.0	270.9	44.9	288.9
GW-109	479517.1	926628.7	221.8	343.8	107.0	236.8	328.8	92.0	346.8
GW-110	479679.4	926660.7	209.0	314.1	90.0	224.0	299.1	75.0	317.1
GW-111	479685.6	926802.0	206.1	269.6	48.4	221.1	254.6	33.4	272.6

LANDFILL GAS EXTRACTION WELL SCHEDULE

WELL DESIGNATION	NORTHING	EASTING	BOTTOM OF WASTE (FT)	TOP OF EXISTING WASTE (FT)	TOTAL WELL DEPTH (FT)	BOTTOM OF WELL SCREEN (FT)	TOP OF WELL SCREEN (FT)	SCREEN LENGTH (FT)	TOP OF CASING ELEV. (FT)
GW-112	479814.8	926768.1	203.2	264.1	45.9	218.2	249.1	30.9	267.1
GW-113	479970.9	926695.1	200.0	267.4	52.4	215.0	252.4	37.4	270.4
GW-114	480098.0	926675.4	196.5	257.8	46.3	211.5	242.8	31.3	260.8
GW-115	480253.9	926625.6	192.2	254.1	46.9	207.2	239.1	31.9	257.1
GW-116	480438.0	926567.9	186.2	249.0	47.8	201.2	234.0	32.8	252.0
GW-117	479829.0	926585.2	206.0	319.0	98.0	221.0	304.0	83.0	322.0
GW-118	480130.3	926566.5	197.6	287.5	75.0	212.6	272.5	60.0	290.5
GW-119	479982.2	926510.9	203.0	323.0	105.1	218.0	308.0	90.1	326.0
GW-120	479663.7	926509.6	212.5	352.4	124.9	227.5	337.4	109.9	355.4
GW-121	480281.2	926478.0	194.3	295.9	86.6	209.3	280.9	71.6	298.9
GW-122	480417.9	926402.8	191.2	252.4	46.1	206.2	237.4	31.1	255.4
GW-123	480127.8	926404.4	200.6	338.1	122.5	215.6	323.1	107.5	341.1
GW-124	479822.2	926424.4	209.3	354.5	130.2	224.3	339.5	115.2	357.5
GW-125	479507.4	926436.3	217.6	365.0	132.5	232.6	350.0	117.5	368.0
GW-126	480251.9	926322.4	198.4	303.1	89.8	213.4	288.1	74.8	306.1
GW-127	479963.3	926322.7	206.8	358.7	136.9	221.8	343.7	121.9	361.7
GW-128	479654.0	926339.8	214.8	368.6	138.7	229.8	353.6	123.7	371.6
GW-129	479368.9	926330.6	219.7	379.9	145.1	234.7	364.9	130.1	382.9
GW-130	480377.6	926246.4	195.9	258.0	47.0	210.9	243.0	32.0	261.0
GW-131	480099.9	926234.5	204.5	348.3	128.8	219.5	333.3	113.8	351.3
GW-132	479810.3	926234.3	213.1	372.5	144.4	228.1	357.5	129.4	375.5
GW-133	479488.4	926248.7	219.1	381.6	147.5	234.1	366.6	132.5	384.6
GW-134	480347.0	926098.0	199.7	260.8	46.1	214.7	245.8	31.1	263.8
GW-135	480210.8	926170.1	202.5	309.2	91.8	217.5	294.2	76.8	312.2
GW-136	479979.6	926132.6	210.3	358.7	133.3	225.3	343.7	118.3	361.7
GW-137	479635.0	926172.9	217.0	382.0	150.0	232.0	367.0	135.0	385.0
GW-138	479308.9	926161.6	219.6	383.0	148.5	234.6	368.0	133.5	386.0
GW-139	480146.5	926045.6	206.6	324.4	102.8	221.6	309.4	87.8	327.4
GW-140	479789.5	926075.3	215.2	376.7	146.4	230.2	361.7	131.4	379.7
GW-141	479467.3	926073.2	221.0	380.3	144.3	236.0	365.3	129.3	383.3
GW-142	480302.2	925958.1	203.6	268.7	50.0	218.6	253.7	35.0	271.7
GW-143	479956.4	925978.3	213.4	358.7	130.3	228.4	343.7	115.3	361.7
GW-144	479635.4	925981.6	219.6	377.6	143.0	234.6	362.6	128.0	380.6
GW-145	479298.3	925980.7	218.8	368.0	134.2	233.8	353.0	119.2	371.0
GW-146	480116.8	925882.5	211.1	326.2	100.1	226.1	311.2	85.1	329.2
GW-147	479796.3	925890.5	217.1	372.0	140.0	232.1	357.0	125.0	375.0
GW-148	479469.9	925913.1	217.2	365.4	133.2	232.2	350.4	118.2	368.4
GW-149	480261.9	925796.2	207.7	273.9	51.2	222.7	258.9	36.2	276.9
GW-150	479945.9	925798.4	213.4	356.9	128.5	228.4	341.9	113.5	359.9
GW-151	479633.7	925823.4	212.9	363.1	135.2	227.9	348.1	120.2	366.1
GW-152	479285.6	925835.4	215.1	353.4	123.3	230.1	338.4	108.3	356.4
GW-153	480099.6	925705.7	212.2	320.9	93.6	227.2	305.9	78.6	323.9
GW-154	480205.6	925618.7	208.3	279.4	56.1	223.3	264.4	41.1	282.4
GW-155	479787.3	925702.6	211.1	357.1	131.0	226.1	342.1	116.0	360.1
GW-156	479445.8	925762.8	212.9	350.5	122.6	227.9	335.5	107.6	353.5
GW-157	479618.4	925688.2	209.9	350.4	125.5	224.9	335.4	110.5	353.4
GW-158	479935.4	925623.3	209.1	350.9	126.9	224.1	335.9	111.9	353.9
GW-159	480086.8	925535.4	208.4	310.8	87.3	223.4	295.8	72.3	313.8
GW-160	479289.6	925691.2	211.1	318.4	92.3	226.1	303.4	77.3	321.4
GW-161	479449.9	925642.2	210.6	319.0	93.4	225.6	304.0	78.4	322.0
GW-162	479624.3	925565.0	207.6	317.9	95.3	222.6	302.9	80.3	320.9
GW-163	479777.3	925514.4	207.2	316.8	94.5	222.2	301.8	79.5	319.8
GW-164	479939.8	925461.4	205.7	313.8	93.2	220.7	298.8	78.2	316.8
GW-165	480194.7	925443.5	204.6	268.2	48.6	219.6	253.2	33.6	271.2
GW-166	480063.5	925381.7	205.2	298.4	78.2	220.2	283.4	63.2	301.4
GW-167	480154.6	925257.7	200.8	262.9	47.1	215.8	247.9	32.1	265.9
GW-168	479923.1	925313.5	202.2	264.8	47.6	217.2	249.8	32.6	267.8
GW-169	479737.1	925369.4	203.7	266.6	47.9	218.7	251.6	32.9	269.6
GW-170	479606.9	925413.5	204.4	268.4	49.0	219.4	253.4	34.0	271.4
GW-171	479447.5	925491.2	207.5	271.6	49.1	222.5	256.6	34.1	274.6
GW-172	479308.8	925538.8	207.2	270.5	48.3	222.2	255.5	33.3	273.5

NOTES:

1. LFG WELLS GW-001 THROUGH GW-097 WERE TAKEN FROM PREVIOUS LFG DESIGN DRAWINGS PREPARED BY SANBORN HEAD IN OCTOBER 2003 AND REVISED IN SEPTEMBER 2010. WELLS ALREADY INSTALLED AT THE SITE ACCOUNT FOR GAPS IN NUMBERING.
2. LFG EXTRACTION WELLS SHALL BE INSTALLED WITHIN ONE FOOT OF LISTED LOCATIONS.
3. A TEMPORARY BENCHMARK WITH ELEVATION SHALL BE ESTABLISHED AT EACH WELL PRIOR TO DRILLING.
4. 15 FEET OF SOLID RISER IS TO BE PROVIDED BELOW INTERMEDIATE COVER GRADES. THE INTENT IS TO PROVIDE 3 FEET OF STICK UP ABOVE FILL GRADES.
5. ELEVATIONS SHALL BE CONFIRMED AGAINST AS-BUILT TOP OF PRIMARY SAND GRADES AND FILL GRADES PRIOR TO CONSTRUCTION.

ISSUED FOR MAINE DEP APPROVAL 6/05/15

SANBORN HEAD

SCALE AS NOTED

STATE OF MAINE — Eric S. Steinhauser — 10809 — PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: JUNE 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LANDFILL GAS EXTRACTION SYSTEM DETAILS

PROJECT NUMBER: 2536.27

SHEET NUMBER: 14 OF 14

APPENDIX C

TECHNICAL SPECIFICATIONS

CONTENTS

DIVISION 2 - SITE WORK

SECTION 02560

LANDFILL GAS EXTRACTION WELLS

PART 1 - GENERAL

1.1 SCOPE OF APPLICATION

A. Supply all equipment, materials, and labor needed to install landfill gas extraction wells as specified herein and as indicated on the Drawings.

1.2 SUBMITTALS

A. Submit to ENGINEER Certificates of Compliance on materials furnished, and manufacturer's brochures containing complete information and instructions pertaining to the storage, handling, installation, and inspection of pipe and appurtenances furnished.

B. Submit to ENGINEER well logs within 7 days of the completion of well installations.

C. The well logs shall depict a construction diagram for each well drilled, including the total depth of the well, the temperature of spoils, depth, thickness, and description of soil or waste strata, and the occurrence of any water bearing zones.

1.3 SITE CONDITIONS

A. Obstructions and saturated conditions such as sludges, and foundry sands are sometimes encountered when drilling in landfills, many of which can be drilled through. CONTRACTOR is expected to make reasonable effort to drill through obstructions and saturated conditions and will be paid for offset redrilling and boring abandonment only with prior written approval from OWNER.

B. Well drilling shall be performed on a level surface. CONTRACTOR shall provide a level surface at each drilling location as required. The size of the level area shall be acceptable to the drilling subcontractor. Any soil placed to level the drilling location shall be removed following well installation.

PART 2 - PRODUCTS

2.1 BALLAST STONE

A. Ballast Stone shall be hard, durable, and resistant to weathering and to water action, free from overburden, spoil, and organic materials. Ballast Stone shall be washed, and uniformly blended according to the particle size distribution requirements shown below.

Sieve Size	Percent Passing by Weight
2-inch	100
1½-inch	90 - 100
1-inch	30 - 40
¾-inch	10 - 15
½-inch	0 - 5
⅜-inch	0 - 5

2.2 BENTONITE SEAL

A. Bentonite Seal shall be constructed using dry bentonite chips or pellets.

2.3 SAND/GRAVEL FILTER

A. Sand/Gravel Filter should conform to the following particle size distribution.

Sieve Size	Percent Passing by Weight
1½-inch	100
No. 4	70 - 100
No. 40	30 - 80
No. 200	0 - 15

2.4 COMMON FILL

A. Common Fill should be soil containing no stone larger than 4 inches, and shall have a maximum of 75 percent passing the No. 40 sieve and a minimum of 35 percent passing the No. 200 sieve.

2.5 PVC PIPE

A. Refer to Specification Section 15212.

2.6 WELLHEAD

A. Wellheads should be nominal 2-inch size CES/LANDTEC Accu-Flo wellhead, Model 200, with elastomer adapter kits, or equivalent approved by OWNER. The wellhead components are indicated on the Drawings.

B. Wellhead and flow measurement tube shall be compatible with the CES/LANDTEC GEM-2000™ Landfill Gas Monitor.

PART 3 - EXECUTION

3.1 DRILLING

A. ENGINEER shall observe all drilling operations.

B. Wells shall be drilled to the minimum diameter and the specific depths shown on the Drawings. CONTRACTOR shall drill the wells using bucket-type augers and dry drilling equipment; wet rotary drilling equipment may not be used.

C. Well depths shown on the Drawings are estimated based on projected top of waste elevations and may be adjusted in the field by ENGINEER. At no time shall the drilling extend deeper than the bottom of well screen elevation.

D. If water is encountered in a borehole, then CONTRACTOR may be directed to drill beyond the point that it was encountered. If wet conditions remain, then drilling may be terminated and the length of perforated pipe adjusted by ENGINEER, or the well may be relocated. If wet conditions cease (e.g., due to trapped water layer), then drilling will continue to the design depth.

E. As soon as drilling is completed, a safety screen shall be placed over the top of the borehole. This screen shall stay in place until backfilling is within 4 feet of the surface. Safety screen size should be large enough to accommodate all backfill materials and any tools used during backfill yet not large enough for any human to accidentally fall through.

F. Wells shall be drilled straight and plumb and the well pipe shall be installed in the center of the borehole. CONTRACTOR will take all compression off of the pipe by mechanical means and center the pipe in the middle of the borehole before starting to backfill.

G. PVC well pipe shall be solvent cemented and mechanically fastened with stainless steel fasteners.

3.2 BACKFILLING

A. Backfilling the borehole shall commence immediately after drilling is completed and the PVC pipe has been installed. Backfill materials shall be installed as indicated on the Drawings and as approved by ENGINEER.

B. Ballast Stone shall be poured or scooped through the safety screen at a rate that will not endanger the integrity of the well casing and limits the potential for bridging.

C. The Sand/Gravel Filter shall be poured through the safety screen until a layer at least 1-foot thick above the Ballast Stone is formed.

D. The Bentonite Seal will be formed by evenly distributing bentonite around the annulus of the well until a minimum plug thickness of 1 foot has been achieved.

E. Common Fill shall be rodded in the boring to provide even distribution and compaction.

3.3 DISPOSAL

A. Refuse from well drilling operations shall be hauled to the active face of the landfill operation the same day it is excavated.

[END OF SECTION 02560]

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SECTION 02565

LANDFILL GAS TRENCHES

PART 1 - GENERAL

1.1 SCOPE OF WORK

A. CONTRACTOR shall provide all labor, materials, equipment, and incidentals necessary to excavate and backfill trenches for the landfill gas management system as shown on the Drawings and specified herein, including, but not limited to: excavation of waste; placement of soil, aggregate, and pipe; compaction of soil; and grading.

PART 2 – PRODUCTS

2.1 GENERAL

A. All soil, unless otherwise specified, shall consist of clean soil substantially free from organic materials, wood, trash, and other objectionable materials that may be compressible or that cannot be properly compacted. Soil shall not contain stone blocks, broken concrete, masonry rubble, or other similar materials. Soil shall have physical properties such that it can be readily spread and compacted to the specified density. Snow, ice, and frozen soil shall not be permitted.

B. Unless otherwise specified, the maximum soil particle size shall be no larger than two-thirds the loose lift thickness.

2.2 MATERIALS

A. Tire Chips shall be provided by the OWNER and shall be placed in accordance with ASTM D 6270.

B. HDPE pipe and fittings refer to Specification Section 15210.

PART 3 - EXECUTION

3.1 GENERAL EXCAVATION BELOW GRADE

A. CONTRACTOR shall plan and perform earthwork activities to prevent damage to existing structures, safeguard people and property, minimize disruptions to site traffic, protect the structures to be installed, and provide safe working conditions in compliance with local safety regulations and provisions of the Occupational Safety and Health Act (OSHA).

B. Excavation shall be made to the elevations and dimensions shown on the Drawings. Excavate sufficient material to provide suitable room for construction providing bracing and support as required.

3.2 EXCAVATION IN WASTE

A. CONTRACTOR shall take safety precautions during construction activities that conform to all OSHA regulations and the safety requirements of OWNER and the Specifications.

B. Trenches shall be excavated to the depths, widths, and alignments shown on the Drawings.

C. CONTRACTOR shall separate cover soil from excavated refuse to the extent possible. Cover soil may be used to backfill trenches. Excavated material not suitable for use as soil shall be transported to the working face as directed by OWNER.

D. Pockets of perched leachate may be encountered during waste excavation activities. CONTRACTOR shall immediately notify OWNER and ENGINEER when leachate is encountered. ENGINEER will provide CONTRACTOR with directions on how to manage the leachate in narrative and/or drawing form. Potential leachate management techniques may include one or a combination of the following.
   1. Backfilling the affected area.
   2. Realigning the trench.
   3. Installing a French drain.

E. To the extent possible, the trench invert shall slope uniformly as indicated on the Drawings.

F. CONTRACTOR shall not excavate more trench than can be backfilled in one day after placement of the pipe. Excavations shall not be left open overnight.

3.3 BACKFILL

A. Excavated material shall be placed in loose layers and compacted to the extent possible with the goal of establishing a firm, even surface. The loose lift thickness shall not exceed 12 inches.

B. ENGINEER does not have to be present, and does not supervise or direct the actual Work by CONTRACTOR, his/her employees, or agents. Neither the presence of ENGINEER nor any observations and testing performed by ENGINEER shall excuse CONTRACTOR from defects discovered in their Work.

[END OF SECTION 02565]

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CONTENTS

DIVISION 15 - MECHANICAL

SECTION 15210

HIGH DENSITY POLYETHYLENE (HDPE) PIPE, FITTINGS, AND APPURTENANCES

PART 1 - GENERAL

1.1 SCOPE OF WORK

A. Furnish and install HDPE pipe and fittings for the landfill gas extraction system.

B. Pressure test HDPE pipe.

1.2 DELIVERY, STORAGE, AND HANDLING

A. The pipe and fitting manufacturer shall package products for shipment in a manner suitable for safe transport by commercial carrier. When delivered, CONTRACTOR shall inspect the shipment and report any damage to the pipe and fittings manufacturer. Pipe and fittings shall be handled, installed, and tested in accordance with manufacturer's recommendations, and the requirements of this Section.

B. Pipe Storage:
   1. Store or stack pipe to prevent damage from marring, crushing or puncture. Limit maximum stacking height to 6 feet or manufacturer's recommended maximum height, whichever is less.
   2. Store in accordance with manufacturer's recommendations.

C. Pipe Handling:

   1. Protect pipe from excessive heat or harmful chemicals.
   2. Handle pipe and use equipment needed to avoid gouging of the pipe surfaces.

PART 2 - PRODUCTS

2.1 PHYSICAL PROPERTIES:

A. Materials used for the manufacture of PE pipe and fittings shall meet the following physical property requirements:

Property	Unit	Test Procedure	Value
Material Designation	-	PPI/ASTM	-
PPI Material Listing	-	PPI TR-4	PE 3608
Cell Classification	-	ASTM D 3350	345464C
Density	g/cm3	ASTM D 1505	>0.940
Melt Index [E]	g/10 min	ASTM D 1238	<0.15
Flexural Modulus	psi	ASTM D 790	110,000 and <160,000
Tensile Strength	psi	ASTM D 638	3000 to 3500
PENT	hours	ASTM F 1473	>100
HDB	psi	ASTM D 2837	1600 at 23^{0} C
UV Stabilizer [C]	% Carbon Black	ASTM D 1603	2 to 3
Elastic Modulus	psi	ASTM D 638	110,000
Brittleness Temperature	^{o}F	ASTM D 746	<-180
Vicat Softening Temperature	^{o}F	ASTM D 1525	255
Thermal Expansion	in/in/ ^{o}F	ASTM D 696	1 x 10E-4
Hardness	Shore D	ASTM D 2240	64
Molecular Weight Category	-	-	Extra High

B. There shall be no evidence of splitting, cracking, or breaking when the pipe is tested.

C. Ring Stiffness Constant (RSC) values for the pipe shall be 90 percent of the nominal.

D. The pipe and fittings shall be homogenous throughout and free from visible cracks, holes, foreign inclusions, or other injurious defects. The pipe shall be as uniform as commercially practical in color, opacity, density, and other physical properties.

E. Clean rework or recycled material generated by the manufacturer's own production may be used so long as the pipe or fittings produced meet all the requirements of this Section.

2.2 PIPE AND FITTINGS

A. Dimensions:
1. Pipe Dimensions: The nominal inside diameter of the pipe shall be true to the specified pipe size in accordance with ASTM D 2513. Standard laying lengths shall be 40 feet ± 2 inches.
2. Fitting Dimensions: Fittings such as couplings, wyes, tees, adaptors, etc. for use in laying pipe shall have standard dimensions that conform to ASTM D 3261.
3. Pipe and fittings shall be SDR-17 unless otherwise noted.

B. Pipe and fittings shall be produced from identical materials meeting the requirements of this Section. Special or custom fittings may be exempted from this requirement.

C. Pipe and fittings shall be pressure rated to meet the service pressure requirements specified. Fittings shall be fully pressure rated to at least the same service pressure rating as the joining pipe.

D. Molded fittings shall meet the requirements of ASTM D 3261 and this Section. At the point of fusion, the outside diameter and minimum wall thickness of fitting butt fusion outlets shall meet the diameter and wall thickness specifications of the mating system pipe. Fitting markings shall include a production code that identifies the location and date of manufacture. Upon request, the manufacturer shall provide an explanation of his production code.

E. Marking:

1. Each standard and random length of pipe and fitting shall be clearly marked with the following information:
    a. Manufacturer's Name or Trademark;
    b. ASTM Standard Designation;
    c. Nominal Pipe Size;
    d. Class & Profile Number;
    e. Production Code, including Extrusion Date, and Lot or Batch Number; and
    f. Standard Dimension Ratio.

F. The pipe and fitting manufacturer shall certify that samples of production pipe have undergone stress regression testing, evaluation, and validation in accordance with ASTM D 2837 and PPI TR-3. Under these procedures, the minimum hydrostatic design basis shall be certified by the pipe and fitting manufacturer to be 1600 psi at 73.4° F and 800 psi at 140° F.

G. Material shall be listed in the name of the pipe and fitting manufacturer by the Plastics Pipe Institute (PPI) in PPI TR-4 with the following Standard Grade ratings:

	73.4° F	140° F
1. Hydrostatic Design Basis (HDB)	1,600 psi	800 psi
2. Hydrostatic Design Stress (HDS)	800 psi	400 psi

H. PPI material listing in the name of the resin supplier is not acceptable in meeting this requirement.

I. Certification:

1. As the basis of the acceptance of the material, the manufacturer shall furnish a certificate of conformance of this Section upon request. When prior agreement is being made in writing between CONTRACTOR and the

manufacturer, the manufacturer shall furnish other conformance certification in the form of affidavit of conformance, test results, or copies of test reports.

2.3 GASKETS AND HARDWARE

A. All gaskets shall be Viton or other similar materials approved by OWNER. Joint hardware shall be Type 304 stainless steel.

2.4 FITTINGS

A. Fittings shall be manufactured from polyethylene compound having cell classification equal to or exceeding compound used in pipe to ensure compatibility of polyethylene resins.

B. Dimensions of fittings conforming to standard dimensions and tolerances in accordance with ASTM D 3261.

C. Fittings shall have the same or higher pressure rating as pipe.

D. Markings:
   1. Manufacturer's name or trademark.
   2. Nominal size.
   3. Type of plastic pipe (i.e., PE 3408).
   4. Standard dimension ratio.
   5. Extrusion date, lot number or batch number.

E. The Drawings do not show all fittings that may be required. Provide all fittings required for a complete installation.

PART 3 – EXECUTION

3.1 FIELD QUALITY CONTROL

A. Pipe may be rejected for failure to conform to any of the following:
   1. Fractures or cracks passing through pipe wall, except single crack not exceeding 2 inches in length at either end of pipe, which may be cut off and discarded. All pipes within one shipment shall be rejected if defects exist in more than five percent of shipment or delivery.
   2. Cracks sufficient to impair strength, durability, or service ability of pipe.
   3. Defects indicating improper proportioning, mixing, and molding.
   4. Damaged ends, where such damage prevents making satisfactory joint.
   5. Damage due to handling or installation. Scratches and gouges exceeding five percent of the wall thickness shall be considered excessive, and may be rejected by ENGINEER or OWNER.

B. Acceptance of fittings, stubs, or other specially fabricated pipe sections shall be based on visual inspection by ENGINEER and documentation of conformance to this Section.

C. Prior to backfilling trench CONTRACTOR shall obtain as-built top of pipe coordinates and elevations at grade changes, terminations, fittings, and at least every 50 feet along the pipe.

3.2 INSTALLATION

A. Trench, backfill, and compact in accordance with Specification Section 02565.

B. Heat Fusion of Pipe:

1. Weld pipe in accordance with manufacturer's recommendation for butt fusion methods. The pipe manufacturer shall certify fusion machine operators.
2. Butt fusion equipment for joining procedures shall be capable of meeting conditions recommended by pipe manufacturer including, but not limited to, temperature, alignment, and fusion pressures.
3. Branch saddle fusions shall be joined in accordance with manufacturer's recommendations and procedures. Branch saddle fusion equipment shall be of a size to facilitate saddle fusion within the trench.
4. For cleaning pipe ends, solutions such as detergents and solvents, when required, shall be used in accordance with manufacturer's recommendations. Solvents shall not be used unless approved by OWNER.
5. Do not bend pipe to greater degree than minimum radius recommended by manufacturer for type and grade.
6. Do not subject pipe to strains that will overstress or buckle pipe or impose excessive stress on joints.
7. Before butt fusing pipe, observe inside of each pipe length for presence of dirt, sand, mud, shavings, and other debris or animals. Remove debris from pipe prior to fusing.
8. Cap open ends of fused pipe at end of each working day to prevent entry by animals, debris, or stormwater.
9. Use compatible fusion techniques when polyethylenes of different melt indexes are fused together. Refer to manufacturer's specifications for compatible fusion.

C. Flange Jointing:

1. Use on flanged pipe connection sections.
2. At a minimum convoluted stainless steel backup rings shall be used for joining HDPE pipes below grade, and epoxy-coated carbon steel backup flanges shall be used above grade, unless stainless steel is specified by OWNER.
3. Butt fuse fabricated flange adapters to pipe or use electrofusion couplings.
4. Observe the following precautions in connection of flange joints:

a. Use full-face gaskets only.
b. All fasteners and back-up rings shall be Type 18-8 or Type 304 stainless steel below grade, and zinc-plated steel above grade.
c. Align flanges or flange/valve connections to provide tight seal.
d. U.S. Standard round washers may be used on some flanges when in accordance with manufacturer's recommendations. Bolts shall be lubricated prior to installation.

5. Protect below grade bolts and flanges by covering with a 6-mil thick PE wrap. Duct tape wrap to HDPE pipe.
6. Electrofusion couplers, where used, shall be installed per manufacturer's specifications. The outside diameter of the HDPE pipe and face shall be prepared in accordance with manufacturer's recommendations prior to installing the coupler.

D. Pipe Placement:

1. Grade control equipment shall be of the type to accurately maintain design grades and slopes during installation of pipe.
2. Unless otherwise specifically stated, install pipe in accordance with manufacturer's recommendations.
3. Maximum lengths of fused pipe to be handled as one section shall not exceed 400 feet and shall be placed according to the manufacturer's recommendations as to pipe size, pipe SDR, and topography so as not to cause excessive gouging or surface abrasion. Pipe wall gouges deeper than 3/16-inch may be cause for rejection of the pipe.
4. Cap pipe sections longer than single joint (usually 40 feet) on both ends during placement except during fusing operations.
5. Remove dirt or debris from inside of pipe before backfilling.
6. Notify ENGINEER prior to installing pipe into trench and allow time for observation. CONTRACTOR shall correct irregularities identified during observation.
7. Complete connections within trench whenever possible to prevent overstressed connections.
8. Allow pipe sufficient time to adjust to trench temperature prior to testing, fusion welding, making segment connections, or backfilling activity.
9. To reduce branch saddle stress, install saddles at slope equal to and continuous with connecting pipe.
10. Install reducers adjacent to laterals and tees unless directed otherwise.
11. Place pipe system in trench allowing at least 12 in./100 ft. for thermal contraction and expansion.

3.2 PIPE TESTING

A. CONTRACTOR shall perform a pneumatic test of the non-perforated pipe and fittings, with the exception of the 50-feet of solid pipe installed in the horizontal collection trenches, after placement in the trench, in accordance with manufacturer's recommendations.

B. Pipes shall be pressure tested in presence of ENGINEER. Provide adequate notice to ENGINEER before performing test.

C. Pneumatic testing shall be performed as follows:
   1. The test period at the test pressure shall last no more than 10 minutes.
   2. Provide all necessary connections, bulkheads, flanges, bracing, and blocking, as well as all required test equipment.
   3. Test pressure gauge shall have a recommended range of 20 psig, with minor gradations no greater than 0.1 psig.
   4. Pipe to be tested shall be exposed in the trench, except bends, reduced pressure rated fittings and components, which shall be buried or restrained. Flange connections shall be visible to check for leaks.
   5. Test pressure shall be 10 psig.
   6. Acceptance
      a. Test shall be accepted if the pressure drop over 10 minutes is less than 5 percent of the pressure at the beginning of the test period.

D. Test Report
   1. ENGINEER shall prepare and submit to OWNER a test report using the attached forms for each pipe system tested. Include following information in test report.
      a. Date of test.
      b. Description and identification of pipe system tested.
      c. Type of test performed.
      d. Test fluid.
      e. Test pressure.
      f. Results of test.
      g. Type and location of leaks detected.
      h. Corrective action taken to repair leaks.
      i. Results of retesting.
      j. Name of person performing test.

[END OF SECTION 15210]

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ATTACHMENT 1 TO SECTION 15210
PIPE PRESSURE AIR TEST LOG

SANBORN HEAD	Project No.:
	Project Name:
	Project Location:
	Weather:
Contractor:	Test No.:
SHA Personnel:	Person/Company Performing the Test:
Date of Test:	Time of Test: Finish:
Pipe Length: ~ ft. Pipe Diameter: in.	Pipe Material: Pipe SDR/Sch.:
Rated Working Pressure:	Test Pressure: psi
Location/designation of pipe tested:	

t Time (min.)	T Pipe Temperature (ºC)	P_t Pressure Gauge Reading (psig)	P_c Pressure Drop (%)
0			
5			
10			
15			
30			
60			

Pass Fail	Retest? Yes No
Description of leaks and repairs of retested pipe segments:	

P_c = Percent Pressure Drop $\frac{P_o - P_t}{P_o} \times 100$

P_o = Initial Pressure Gauge Reading

P_t = Pressure Gauge Reading at Time t

Comments:

Signature:

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SECTION 15212

POLYVINYL CHLORIDE (PVC) PIPE AND FITTINGS

PART 1 - GENERAL

1.1 SCOPE OF WORK

A. Supply polyvinyl chloride (PVC) Schedule 80 pipe and fittings as shown on the Drawings.

1.2 SUBMITTALS

A. Submit to ENGINEER manufacturer's technical product data and installation instructions for PVC pipe and fittings.

PART 2 - PRODUCTS

2.1 PIPE AND FITTINGS

A. Pipe and fittings shall be manufactured from a PVC compound which meets the requirements of Cell Classification 12454-B PVC as outlined in ASTM D 1784.

B. PVC pipe used in the construction of landfill gas extraction system shall meet the requirements of ASTM D 1784 and ASTM D 1785 for Schedule 80 PVC pipe.

C. PVC fittings used in the construction of landfill gas extraction system shall meet the requirements of ASTM D 2464 and ASTM D 2467.

D. All PVC cements shall meet the requirements of ASTM D 2564 for solvent cemented PVC joints.

E. Clean rework or recycle material generated by the manufacturer's own production may be used so long as the pipe or fittings produced meet all the requirements of this Section.

F. Fittings shall be industrial, heavy duty, hub style.

G. Socket fittings shall be pressure rated the same as the corresponding size pipe prescribed by ASTM D 1785. Threaded fittings shall be pressure rated to at least 50 percent of the rating for socket fittings.

2.2 FLANGES

A. Flanges shall be one piece solid design or two-part Van Stone type that use the tapered, serrated face and full face gasket technique for joining and are compatible with ANSI B16.5 Class 150 metal flanges.

B. Flanges shall be pressure rated at 150 psi for water service at 73°F, non-shock and have a minimum burst requirement of 3.3 times the rated pressure.

C. Bolts shall be zinc-plated ASTM A193, Grade B8M hex head, and nuts shall be zinc-plated ASTM A194, Grade 8M hex head.

D. Gaskets shall be ⅛-inch thick, full face Viton or other similar materials approved by OWNER.

PART 3 - EXECUTION

3.1 PVC PIPE HANDLING

A. PVC pipe and pipe fittings shall be handled carefully in loading and unloading. They shall be lifted by hoists and lowered on skidways in such a manner as to avoid shock. Derricks, ropes, or other suitable equipment shall be used for lowering the pipe into well borings. Pipe and pipe fittings shall not be dropped or dumped.

3.2 PVC PIPE INSTALLATION

A. PVC pipe installation shall conform to the requirements of this Section, the manufacturer's recommendations, and as outlined in ASTM D 2774V.

3.3 JOINING OF PVC PIPES

A. Pipes shall be joined in accordance with ASTM D 2855.

B. Pipe shall be inspected for cuts, scratches, or other damages prior to installation. Pipe with imperfections shall not be used.

C. Burrs, chips, etc., shall be removed from pipe interior and exterior.

D. Loose dirt and moisture shall be wiped from the interior and exterior of the pipe end and the interior of the fitting.

E. Pipe cuts shall be square and perpendicular to the center line of pipe.

F. A coating of CPS primer, as recommended by pipe supplier, shall be applied to the entire interior surface of the fitting socket, and to an equivalent area on the exterior of the pipe prior to applying solvent cement.

G. The solvent cement shall comply with the requirements of ASTM D 2564 and shall be applied in strict accordance with manufacturer's specifications.

H. Pipe and pipe fittings shall be selected so that there will be as small a deviation as possible at the joints, and so that inverts present a smooth surface. Pipe and fittings that do not fit together to form a tight fitting shall be rejected.

[END OF SECTION 15212]

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APPENDIX D

CONSTRUCTION QUALITY ASSURANCE PLAN

SANBORN HEAD

Building Trust. Engineering Success.

Construction Quality Assurance Plan
Landfill Gas Extraction System Expansion
Juniper Ridge Landfill
Old Town, Maine

Prepared for
NEWSME Landfill Operations, LLC
Old Town, Maine

Prepared by
Sanborn, Head & Associates, Inc.
20 Foundry Street
Concord, New Hampshire

File 2536.27
June 2015

TABLE OF CONTENTS

1.0 INTRODUCTION

This Construction Quality Assurance (CQA) Plan addresses the quality assurance activities specific to the installation of landfill gas (LFG) extraction systems components at the Juniper Ridge Landfill. In the context of this Plan, quality assurance refers to means and actions employed to assure that the components of the LFG extraction system are installed in accordance with the drawings and specifications. Quality assurance is provided by a party independent from the Contractor. Quality control refers to those actions taken by the contractor and the manufacturers to ensure that materials and workmanship meet the requirements of the drawings and specifications.

The scope of this CQA Plan applies to manufacturing, shipment, handling, and installation of LFG extraction system components. The CQA Plan does not address design guidelines, installation specifications, or selection of the components. The specifications define the quality of materials and workmanship to be used and employed. The CQA Plan defines the means to assure that the level of material and workmanship used in the construction meets or exceeds the requirements of the drawings and specifications.

2.0 PARTIES

2.1 Project Manager

The Project Manager is an official representative of NEWSME Landfill Operations LLC (NEWSME) and is responsible for the construction project. The Project Manager coordinates the project meetings as defined in Section 3.0, and serves as a liaison between all parties involved in the project. The Project Manager is also responsible for proper resolution of quality assurance issues that arise during construction.

2.2 Design Engineer

The Design Engineer is the individual and/or firms responsible for the preparation of the design, including drawings and specifications. The Engineer is responsible for approving all changes to the drawings and specifications, and for making design clarifications during construction. The Engineer may attend the pre-construction meeting and progress meetings as requested by the Project Manager. At the completion of the construction, the Design Engineer will prepare record drawings based on as-built information provided by the CQA Engineer.

2.3 CQA Engineer

The CQA Engineer is either a qualified representative of NEWSME, or a representative of an engineering firm, independent of NEWSME, that is experienced in observing and documenting construction. The number of CQA Engineer personnel needed on site at a given time will be decided by the Contractor's schedule.

The CQA Engineer is responsible for observing and documenting the construction activities as defined in this CQA Plan. Specific duties of the CQA Engineer personnel include:

- Reviewing the drawings and specifications, and all modifications thereto;
- Reviewing other project-specific documentation, including proposed layouts, and manufacturer and Contractor literature;
- Documenting construction operations using field reports, logs, and/or photographs;
- Attending project meetings;
- Noting on-site activities that could result in damage and/or delays;
- Reporting unapproved construction deviations to the Project Manager;
- Verifying that the contractor is obtaining as-built survey information as required by this plan, the drawings, and specifications; and
- Preparing a construction documentation report.

3.0 COMMUNICATION

3.1 Pre-Construction Meeting

A pre-construction meeting should be held at the site prior to the start of construction. Typically, the meeting is to be attended by the Project Manager and representatives of the Design Engineer, CQA Engineer, and Contractor. Specific agenda topics for meeting include:

- Review of the project team members, and their roles and responsibilities;
- Review of the site-specific safety and security requirements;
- Review of the project design components and goals; and
- Review of construction schedule.

The meeting shall be documented by the Project Manager or his designee.

3.2 Progress Meetings

Progress meetings should be held with the Project Manager and representatives of the Contractor, CQA Engineer, and other parties invited by the Project Manager. The agenda for the progress meetings should include a discussion of:

- Current progress;
- Planned activities for the next week;
- Issues requiring resolution; and
- New business.

The Project Manager, or his designee, should document the meetings, specifically noting problems and decisions. If any matter remains unresolved at the end of this meeting, then the Project Manager is responsible for assuring that the matter is resolved and the resolution is communicated to the appropriate parties.

4.0 DOCUMENTATION

The CQA Engineer is responsible for providing the Project Manager with documentation that clearly and succinctly describes the construction activities and the locations of the constructed components. A complete file of the construction documentation should be maintained on site. Documentation consists of daily reports, test reports, as-built survey, and the Construction Documentation Report.

4.1 Daily Reports

A report and/or log should be prepared for each day construction is performed. The report and/or log should document the construction and monitoring activities performed that day, identifying problems encountered and remedial action taken. Documentation should include the equipment used, the work force provided including subcontractors. The report and/or log should be completed at the end of the work day, prior to the CQA Engineer leaving the site.

4.2 Testing Reports

On-site pneumatic pressure testing of pipe shall be reported on an appropriate Test Report Log. Test reports shall be submitted along with the daily report.

4.3 As-Built Survey

The CQA Engineer is responsible for verifying that the Contractor as-built survey is correct and accurate. In addition, the CQA Engineer is responsible for documenting changes to the construction details. As-built survey drawings are to include horizontal and vertical locations of trench end points, landfill gas extraction wells, and well heads. The Contractor is responsible for recording changes to pertinent details and supplying this information to the CQA Engineer. The CQA Engineer will forward the as-built survey and changes to the construction details to the Design Engineer, who will prepare the record drawings to be included in the CQA Engineer's Construction Documentation Report.

4.4 Construction Documentation Report

The CQA Engineer is responsible for preparing a report that documents the construction activities and includes the record drawings prepared by the Design Engineer. The report should include the following:

- Parties and personnel involved with the project;
- Seal and signature of a professional engineer licensed in the State of Maine;
- Record drawings, sealed and signed by a professional engineer licensed in the State of Maine;

- Written clarifications and interpretations of the specifications;
- Change Orders to the design;
- Minutes from pertinent meetings;
- Copies of the pertinent CQA records (e.g., contractor submittals; pipe test logs; and daily reports); and
- Photographs.

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APPENDIX E

OPERATIONS AND MAINTENANCE MANUAL

Operations and Maintenance Manual

Landfill Gas Management System
Juniper Ridge Landfill
Old Town, Maine

Prepared for
New England Waste Services of ME, Inc.

Prepared by
Sanborn, Head & Associates, Inc.

File 2536.27
June 2015

STATE OF MAINE
Eric
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TABLE OF CONTENTS

TABLES

FIGURES

1.0 INTRODUCTION

This manual describes operations and maintenance procedures related to the landfill gas management system at the Juniper Ridge Landfill (JRL) in Old Town, Maine. The landfill is owned by the State of Maine; however, the facility, and landfill gas, is managed by NEWSME Landfill Operations, LLC (NEWSME). The objectives of the landfill gas management system are to: (i) control odors emanating from the landfill; and (ii) to comply with the federal and state requirements regarding landfill gas emissions.

Currently, JRL has an active landfill gas management system installed in all constructed landfill cells that have reached the necessary grade to initiate installation.

Individuals designated to operate and maintain the landfill gas management system are properly trained with respect to the potential hazards of landfill gas and the proper operating procedures for the site-specific equipment. This manual is a general guide and is not intended to be a substitute for proper hands-on training in operations, regulatory requirements, and site-specific safety activities that may be required by various local, state, and/or federal agencies.

Landfill operations staff should become familiar with the properties of landfill gas and related hazards discussed below, and should receive proper training, which may include lockout/tag out procedures as well as electrical and pneumatic safety procedures.

2.0 CHARACTERISTICS OF LANDFILL GAS AND POTENTIAL HAZARDS

2.1 Landfill Gas Characteristics

Landfill gas is generated when anaerobic bacteria consume organic matter in waste. Landfill gas is chiefly composed of methane and carbon dioxide with lesser amounts of oxygen, nitrogen, and water vapor and trace amounts of hydrogen, ethane, hydrogen sulfide, and volatile organic compounds (VOCs). Oxygen and nitrogen are typically present because of air entrained in the landfill (air is approximately 21 percent oxygen and 79 percent nitrogen). Air entrainment in landfills occurs either during placement of waste, from atmospheric weather effects, because of landfill gas management system operations, or diffusion into the landfill. Typical ranges of constituent concentrations in landfill gas are presented in Table 1.

Important landfill gas characteristics are provided below.

- Landfill gas is primarily comprised of methane (typically about 55 percent) and carbon dioxide (typically about 45 percent).

- Landfill gas has relatively high moisture content; cooling generally results in the formation of condensate.

- Landfill gas is flammable and explosive in the range of 5 to 15 percent in air.

- Landfill gas may migrate through surrounding soils, within open conduits, and trench backfill.

- Landfill gas may accumulate in confined spaces.
- Landfill gas has a specific gravity that is usually close to that of air.
- Within the landfill, the typical temperature range for landfill gas is 16 degrees (°) to 58° Celsius (C) (60° to 120° Fahrenheit (F)).
- Component gases (methane, carbon dioxide, water vapor and others) tend to stay together, but may separate through soil and liquid contact.
- Secondary constituents (trace gases) may cause nuisance odors, environmental pollution, and may create a health risk.

The flammable range of methane is approximately 5 to 15 percent (by volume) in air. The lower limit of 5 percent is referred to as the Lower Explosive Limit (LEL); the upper limit of 15 percent is referred to as the Upper Explosive Limit (UEL). The specific gravity of methane and carbon dioxide are 0.55 and 1.52, respectively. However, the specific gravity of landfill gas is close to that of air, and it should not be assumed that methane gas would rise. The landfill gas mixture may be lighter or heavier than air and its behavior will be dictated by its overall composition.

Methane and carbon dioxide are odorless gasses. However, landfill gas has its own characteristic odor due to the presence of trace compounds in the gas. Some of the most significant examples of the classes of odor causing trace constituents include esters, phenols, organic acids, solvents, and sulfur compounds (including mercaptans). However, landfill gas may not always exhibit an identifiable odor because the odor carrying trace components may be stripped off because of movement through cover or adjacent soil.

Landfill gas levels can be monitored using various meters. At a minimum, LEL, percent methane, percent oxygen, and percent hydrogen sulfide should be measured at any location where there is potential for landfill gas to be present and where personnel could be exposed to landfill gas.

Personnel should take immediate action to evacuate the area, if monitoring results indicate:

- The LEL is 50 percent or higher (2.5 percent methane by volume);
- The concentration of oxygen is lower than 19.5 percent; or
- The concentration of hydrogen sulfide is more than 5 parts per million (ppm).

2.2 Potential Hazards to Personnel

Landfill operations staff should be familiar with the following types of hazards related to the presence of landfill gas and landfill gas condensate, and the appropriate and safe procedures to identify and avoid them.

Methane is a colorless, odorless, flammable, and potentially explosive gas that may be emitted into the atmosphere as landfill gas together with other volatile trace gases. Landfill gas, which may contain other gases, may migrate through soil and bedrock into surrounding areas or contact groundwater where it may adversely affect the environment. Landfill gas may travel long distances underground and accumulate underneath and in structures and confined or enclosed spaces creating a potential explosion hazard. Carbon dioxide, the other major component of landfill gas, is colorless, odorless, and non-combustible.

2.2.1 Respiratory Hazards

Methane and carbon dioxide are asphyxiates. A potential hazard posed by landfill gas is oxygen deficiency, which may cause asphyxiation. As landfill gas builds up it displaces air, hence reducing the amount of oxygen that can be inhaled by a person. An oxygen deficient atmosphere exists when the oxygen comprises 19.5 percent or less of the air. It is imperative that confined space regulations and procedures be followed before personnel enter confined spaces or locations where an oxygen deficient atmosphere could exist. Under certain circumstances, special "permitted entry" requirements apply.

Potentially lethal concentrations of hydrogen sulfide (H_2S) may be present at landfills, particularly at landfills that receive a significant quantity of construction and demolition (C&D) debris. Personnel must always be alert for the hazards presented by H_2S. H_2S is a colorless, toxic flammable gas, which at low concentrations has an offensive odor similar to that of rotten eggs. Sense of smell can be lost within 2 to 15 minutes of exposure to H_2S.

Other volatile organic components of landfill gas may also create respiratory hazards.

2.2.2 Explosive Atmosphere

Landfill gas tends to migrate and may accumulate in confined spaces. The occurrence and accumulation of methane is sometimes transient. The presence of slight amounts of methane, less than the LEL, is an indication that more may accumulate under other conditions if corrective action is not taken. If methane is detected at concentrations greater than 15 percent (100 percent of the UEL) by volume, then there is always the potential for an explosive methane-air "front" that could be formed nearby by dilution.

Personnel should take the following precautions.

- Avoid any possible source of ignition when working on the landfill gas management system. Sources of ignition may include cell phones (on or off), battery-powered watches, flashlights, non-intrinsically safe equipment, etc. **Smoking is prohibited when working on or near the landfill gas system components**.

- Avoid wearing synthetic clothing, such as polyester, as these materials are extremely flammable. **Wearing synthetic clothing can be fatal in a methane gas flash fire.**

2.2.3 Potential for Landfill Fire

If large quantities of air are introduced into the landfill in a localized area, through either natural occurrence or overly aggressive operation of the landfill gas extraction system, then poorly supported combustion of the buried waste may occur and carbon monoxide may be detected. Subsurface fires produce temperatures of several hundred degrees Fahrenheit within the landfill and typically results from short-circuiting air intrusion into:

- The landfill/cover soil interface;
- Cracks, breaks or buried imperfections in the cover/cap;
- Breaks in buried collection piping and extraction wells; or
- Backfill surrounding collection system components (e.g., from the filter or gravel pack of an extraction well or the gravel backfill around a sump).

Preventing the introduction of air into the landfill by proper operation of the landfill gas extraction system and maintenance of the landfill cover is the best course of action.

2.2.4 Landfill Gas Condensate

Landfill gas condensate may contain trace chemicals and may be biologically active. Appropriate protective gloves and splash protection equipment should be used when working with landfill gas condensate. Operating personnel should avoid direct skin contact.

Condensate is odorous, and may release VOCs. Careful control during condensate handling and disposal is necessary to limit release of odors.

The vapors emanating from condensate storage tanks may be flammable.

3.0 SYSTEM COMPONENTS AND MONITORING PROGRAM

3.1 Introduction

The primary objectives of the landfill gas management system are to: (i) control odors emanating from the landfill; and (ii) comply with the federal, state, and local requirements regarding landfill gas emissions. Further, the landfill gas management system should be operated to maintain anaerobic conditions within the landfill, thereby limiting the intrusion of air into the waste. To meet these objectives, the system components should be monitored on a routine basis.

The landfill gas management systems at JRL are installed in phases as each landfill cell is developed and filled. Due to the waste stream mix at JRL (comprising of pulp/paper sludge, wastewater sludge, CDD residuals, FEPR, and other special wastes) Hydrogen Sulfide (H_2S) tends to be generated rather quickly (within three-months of initial waste placement within a cell). Due to the odor issues associated with rapid LFG generation, LFG is managed using horizontal collection trenches constructed in the waste as the cell is developed. Landfill gas extracted from the landfill is conveyed to a blower/flare station for landfill gas treatment. As the outer slopes of the cells are filled to final grades, vertical extraction wells are installed in accordance with the final landfill gas plan approved by the Maine Department of Environmental Protection (MDEP). The active landfill gas extraction system will continue to operate at the landfill, extracting landfill gas from the horizontal trenches and vertical extraction wells installed in areas where final grades are achieved.

Included with this manual are figures that illustrate the landfill gas infrastructure associated with the constructed cells at the facility.

A description of the various components of the landfill gas management system is provided below. Where applicable, the monitoring requirements for the various components are also discussed below and summarized in Table 2.

3.2 Gas Collection Trenches

Gas collection trenches are installed at discrete locations in the waste mass, and have been designed to manage landfill gas during landfill operations. The first series of trenches in an area of new waste fill will be excavated into the waste mass after approximately 20 feet of waste has been placed in the cell. Additional trenches are constructed at about 40-foot vertical increments thereafter. The trenches are spaced horizontally about 100 feet apart with typically 3-4 trenches per 40-foot lift (dependent upon overall cell width). The constructed trench will consist of a stone or tire chip-filled excavation with a perforated 6-inch diameter SDR-17 HDPE conveyance pipe. The trench will be installed at a minimum 2 percent slope and will drain away from the gas collection wellhead and back into the landfill via the perforations in the pipe.

3.3 Condensate Trap

Landfill gas condensate will be managed using traps constructed at low points along the conveyance pipe. The traps are designed to allow the condensate to drain into the waste mass or to discharge to the primary leachate collection system. Each trap consists of a U-shaped tube filled with liquid to provide a seal against the vacuum in the system. To maintain a seal, the liquid column in the trap must be at least as high as the maximum vacuum obtainable in that portion of the system.

3.4 Wellhead Assemblies

The wellhead assemblies are generally installed at each horizontal collection trench and on the vertical extraction wells. The wellheads provide a means to control landfill gas flow and a means to collect monitoring data. The wellhead assemblies include a gate valve, flexible hose, fittings, and taps that are designed to allow for:

- Differential settlement between the landfill gas transmission pipe and the wellhead assembly;
- Sampling of the gas in the wellhead;
- Measurement of the gas flow rate;
- Measurement of the gas temperature;
- Control of the gas flow rate; and
- Access to the well from the top for equipment or measurements.

Wellheads are monitored on a weekly basis (as part of the LFG monitoring program) to observe their general condition, with particular attention to the condition of the flexible hose between the wellhead and the transmission pipe. Additional data to be gathered includes:

- Valve position (percent open);
- Gas flow rate;
- Static pressure;
- Percent methane;
- Percent carbon dioxide;
- Percent oxygen; and
- Gas temperature.

3.5 Blower/Flare Station

Currently, there is one 3,500 cubic feet per minute (cfm) flare station with dual blowers that extracts landfill gas from the entire landfill.

The blower/flare station is checked at least weekly to evaluate: (i) the condition of pipe and connections; (ii) the consistency of the flare operation; and (iii) the condition of the automatic sparking ignition system.

3.6 Ancillary Observations

In the course of monitoring system components, the condition of the landfill cover systems should also be observed for indications of settlement, tears and rips in the exposed synthetic cover, stressed vegetation, improper drainage, and condition of cover soils. Further, the presence of odors should also be noted.

3.7 Monitoring and Reporting

NEWSME monitors the LFG system components on a weekly basis. A trained NEWSME employee (or intern) performs the landfill gas monitoring described above and listed in Table 2. Results of the weekly monitoring events are reported to MDEP within one week of the monitoring date.

NEWSME reserves the right to request a reduction in the monitoring frequency, if the landfill gas readings remain relatively consistent overall. Justification to reduce the monitoring frequency will be submitted to MDEP for approval.

4.0 OPERATION AND ADJUSTMENT

4.1 Well System Tuning

The adjustment or "tuning" of the landfill gas management system involves monitoring various parameters and making adjustments to optimize the extraction of landfill gas from each extraction point in the system. The objective of the tuning is to provide negative pressure at each extraction point without causing intrusion of air into the landfill. Tuning is an iterative process, as adjustments to any portion of the system have the potential to affect the entire system. A discussion of the monitoring and tuning procedures is provided below. A summary of the steps to be taken and data to be gathered is presented in Table 3.

4.2 Equipment

Equipment required for monitoring the landfill gas management system includes a device or devices to measure landfill gas flow rates and landfill gas composition, and a volt-ohm meter and amp meter probe to evaluate components of the electrical and control systems. The instrumentation used to monitor landfill gas flow rates, pressures, and composition is a GEM-2000 Portable Gas Analyzer manufactured by CES Landtec of Colton, California.

Like most analytical instrumentation, it is important to field calibrate the GEM-2000 prior to using it to collect landfill gas data. The instrument requires calibration with methane, carbon dioxide, and oxygen span gases. The GEM-2000 should be field-checked with calibration gas, and if necessary, calibrated in accordance with the manufacturer's recommendations at least once each day that it is used. A log of the calibration should be kept with the instrument. Vibration, shock, and large temperature changes can affect the calibration of the instrument.

CES Landtec certifies that this instrument is intrinsically safe. However, it is generally good practice to avoid operating this instrument in an explosive atmosphere. On an annual basis, the GEM-2000 should be sent to the manufacturer for a factory calibration.

4.3 Indicator Parameters

Typical ranges in concentrations of the various constituents found in landfill gas are presented in Table 1. Normal values for the landfill are established using data collected during operation. System tuning should be performed based on the methane, carbon dioxide, and oxygen concentrations in the landfill gas. Typically, as the methane and carbon dioxide concentrations decrease, the concentrations of oxygen and nitrogen will increase. Such a trend indicates air intrusion into the system and adjustments should be made to reduce the landfill gas extraction (vacuum) rate. Alternatively, the landfill gas extraction rate could be increased if the methane and carbon dioxide concentrations are consistently in the middle to upper end of the typical ranges and/or indicate the development of an upward trend.

The composition of the landfill gas with respect to methane, carbon dioxide, and oxygen content is read using the "Read Gas Levels" option on the GEM-2000 instrument. The gas sample is obtained through the static pressure port on the instrument. The instrument provides a readout in percent of each of the three gases, methane, carbon dioxide, and oxygen, and percent of the remaining gas, which is designated the "balance gas."

4.4 Flow Rates

The landfill gas extraction flow rates will be different at each monitoring point and will vary with barometric pressure changes as well as landfill cover condition (i.e., whether geomembrane has been constructed over the extraction location or the condition of the intermediate cover). Likewise, the cumulative landfill gas flow rate at the flare will vary with time. The flow rates can be adjusted, if needed, based on the concentrations of the various constituents as described above. As the operating record of the system becomes established over time, "normal" flow ranges for the individual extraction points as well as the system may be established.

The landfill gas flow rate is calculated from differential pressure readings obtained at the wellheads. The GEM-2000 can be programmed to directly correlate differential pressure to flow rate.

4.5 Pressures

Landfill gas pressure will vary throughout the system at any given time, and will vary with varying extraction rates. The pressures at the extraction points should be negative (vacuum) to provide active extraction from that point. If the pressure is positive, then adjustments should be made to increase the flow rate, providing that gas constituent concentrations are within the normal ranges as discussed above.

The static pressure at the landfill gas extraction points and along the conveyance pipe is obtained using the “Read Gas Levels” option on the GEM-2000 instrument. The striped tube with the external filter/water trap assembly is used to connect between the static pressure port on the GEM-2000 and the static pressure ports at the monitoring locations.

4.6 Temperature

Landfill gas temperature at the extraction points is obtained directly from thermometers installed on the wellhead assemblies or from the GEM-2000 using a thermocouple inserted in the wellhead thermometer port.

5.0 MAINTENANCE AND TROUBLESHOOTING

5.1 Collection System Maintenance

LFG system maintenance involves the following:

- Repairs to the conveyance pipes due to damage caused by accident, settlement, environmental factors, and aging;
- Repair or replacement of system components (e.g., wellheads, access ports, flex hoses, valves, condensate traps, etc.);
- Excavation for repair of damaged pipe and components; and
- Repairing and re-adjusting pipe supports and anchors.

In many instances, repairing the system may require shutting down the flare or certain sections of the LFG collection system. The duration of the shutdown should be kept to a minimum; where possible, the work should be scheduled to coincide with scheduled flare shutdowns.

5.2 Landfill Surface

The landfill cover is an integral part of the landfill gas management system. Proper landfill cover maintenance practices are important for effective operation and performance of the landfill gas management system. Experience has shown that in most cases, proper cover maintenance in conjunction with timely installation of active landfill gas management system components will address most landfill odor problems. A visual inspection is helpful in identifying rips, tears, pinholes, cracks, fissures, or bare spots in the synthetic and soil cover systems. Damaged areas should be evaluated and repaired as soon as practical.

5.3 Conveyance Pipe

Over time, the conveyance pipe may develop air leaks. Air leakage should be limited to the degree practicable and it is recommended that oxygen not exceed 3.5 percent by volume in landfill gas in the conveyance pipe. (Under normal operations, the landfill gas should contain no more than one percent oxygen.)

Leaks can occur in above-grade pipe systems due to pipe separations caused by thermal contraction resulting from cooling at night and during a system shutdown. Separations or damage can occur to below-grade pipe due to differential settlement. Buried pipe is also subject to expansion and contraction, but to a lesser degree because of a more uniform temperature and the anchoring effect of the soil support within the trench.

The conveyance pipe is generally installed at a minimum slope of 5 percent within the landfill to limit the potential for liquid ponding in the pipe because of differential settlement. However, condensate blockages along the conveyance pipe may occur. These blockages can be evaluated by installing access ports for monitoring. With buried systems, it may be necessary to "pot hole" (i.e., perform exploratory excavation) with a backhoe to install access ports for monitoring. If the main conveyance pipe becomes blocked or restricted with condensate, then either re-establishing the slope of the pipe or installing an additional condensate trap and drain should rectify the condition.

5.4 Blower(s)/Flare Station Maintenance

A brief discussion of general maintenance requirements for specific equipment follows. For more detailed information refer to the applicable manufacturer's information. Table 4 describes the monitoring checklist for the blower(s)/flare station.

5.4.1 Pipe and Fittings

Process plant pipe and fittings commonly consist of both steel and thermoplastic. Both are durable long-lived materials. However, thermoplastic pipe can be subject to damage from shock, strain, or heat. Thermoplastic pipe should not be used near sources of extreme heat such as the flare. Carbon steel piping can erode and corrode. Stainless steel, cast iron, and aluminum piping have all been successfully used in landfill gas applications.

Landfill gas and condensate exhibit corrosive properties. The presence of oxygen, carbon dioxide, and organic acids common to landfill gas can be present in landfill gas condensate. The combination of these constituents can promote corrosion of steel pipe that carries landfill gas condensate. The most common point of wear due to erosion or corrosion in steel pipe in landfill applications is typically at pipe elbows and other fittings that are subject to erosion and where liquid condensate accumulates. The pipe should be inspected for evidence of corrosion (leakage, particularly at fittings). Where questions of pipe integrity exist, ultrasonic thickness testing may be performed, if necessary.

5.4.2 Valves

Valve seats and stem seals may wear and eventually require replacement. Butterfly valves with elastometer seals, such as Buna-N or EPDM, may be affected by landfill gas. In such cases, it may be necessary to try other elastometer types to find a material more suitable to the service. Viton or TeflonTM valve seats in butterfly and ball valves, respectively, have demonstrated reasonably good performance.

5.4.3 Blower Maintenance

Routine maintenance for blowers and motors consists of listening for signs of abnormal operating conditions, monitoring for excessive vibration or temperature, and draining condensate from the blower housing periodically and before startup (if not automatically drained). The blower drive belt tension and wear should be checked on a monthly basis. If belts are glazed or cracked, then they should be replaced. At least one spare set of matched belts should always be on hand. On direct drive machines, flexible coupling alignment should be checked on initial setup and periodically as recommended by the manufacturer (typically quarterly to annually). Bearings should be greased or repacked according to the manufacturers' recommendations, (typically quarterly to annually). The electric drive motor, if not equipped with sealed bearings, should also be greased. Blower seals and packing should be checked periodically for leakage. If blower seals continually leak or will not last, then consult the manufacturer or try another type of seal or seal material. Consult the manufacturer's literature for detailed information on the maintenance of the blower.

5.4.4 Gas Inlet Automatic Block Valve

An automatic block valve shuts off the flow of landfill gas to the blower(s)/flare station when the flare is not operating or when a fault or shutdown is initiated. This is a butterfly type valve and should be serviced only when a need is indicated. The automatic block valve seat should maintain a gas tight seal whenever the valve is in the closed position. Refer to the manufacturer's literature for information on service.

5.4.5 Flame Arrester

A flame arrester is designed to prevent the migration of burning landfill gas from the flare backwards into the process pipe and the flare station. This condition can cause what is known as "detonation" (an explosion) or "flashback" within the pipe network. A flame arrester will only work properly if the velocity and pressure of the flashback in the pipe is within the allowable range and the flame arrester is properly assembled.

The differential pressure across the flame arrester should be checked during monthly monitoring. The normal differential pressure is typically less than 0.5 inches water column (w.c.). The differential pressure across the flame arrester should not exceed 1.0-inch w.c. If excessive differential pressure is observed, then the flame arrester should be serviced. To service the flame arrester, shut down the blower/flare station and block in the flame arrester upstream using the manual and automatic block valves (**verify the valves do not leak**). Closely follow the directions in the manufacturer's literature for maintenance and re-assembly of the flame arrester element. It is important to note that a flame arrester's effectiveness is based upon a design spacing or gap in the flame arrester element. During maintenance and re-assembly, this spacing must be maintained according to the manufacturer's original specifications if the flame arrester is to function as designed. Ensure that all parts are returned and in the proper orientation when re-assembling the flame arrester.

5.4.6 Flare

Operation and maintenance of the flare is straightforward and consists of maintaining proper fuel pressure, maintaining the igniter system, and keeping the flare drained of condensate. Proper fuel velocity, quality, mixing, and flame condition are key to performance. Also, to operate consistently, the flare burner assembly must be adequately shielded from excessive wind. Problems with flame stability in an open flare are usually caused by poor landfill gas quality.

The primary wear on flares is due to thermal stress. If the flare is operated in an imbalanced condition or at excessively high temperature, then it will exhibit signs of accelerated thermal stress. This may be indicated by wear and deformation of the burner.

The flare may require burner adjustment or modification to achieve and maintain proper combustion performance. Adjustment of the flare may involve changing an orifice or burner ring, or moving or changing a plate. Consult the manufacturer or seek qualified assistance.

Landfill gas velocity to the flare is adjusted at the blower/flare station inlet. This is accomplished by balancing the distribution of the blower's total pressure, so that there is sufficient fuel pressure at the flare. In severe cases where adjustment will not work, the flare burner or the blowers may need to be modified or replaced. **Never modify the flame arrester to increase gas velocity.**

The flame safeguard sensor system consists of an electronic controller mounted in the control panel and a thermocouple mounted near the tip of the flare. At least one spare thermocouple should be kept on the site.

A thermocouple can be checked independently with a voltmeter and thermocouple tables or with a digital thermocouple test meter or digital thermometer. Proper polarity must be observed when installing and monitoring a thermocouple. If the thermocouple is subjected to flame impingement, then its life may be shortened considerably. Thermocouples can be mounted in protective sheathing; however, this will cause some delay in response to temperature changes.

See the flare manufacturer's literature for specific component operation, maintenance, and troubleshooting information.

5.4.7 Electrical Equipment Controls and Instrumentation

Dust may accumulate in electrical cabinets and absorb moisture from the air. Over sufficient time, a conductive path can be created that can cause a failure. Connections may also become loose due to thermal expansion and contraction. Electrical service and control cabinets should be cleaned on an annual basis. Wire connections should be checked and tightened throughout the cabinets annually. Calibration and verification of instrumentation gages and thermocouples should be performed annually. Shutdown alarms and devices should be tested and the results recorded in a log. Thermocouples for sensing flare stack temperature should be maintained, and replaced when they no longer perform properly. This is normally evident by failure of the temperature controller to properly read or control the flare stack temperature (usually due to an open junction) or by loose or corroded connection terminals at the temperature transmitter, connector block, or temperature controller.

Test and recalibrate instruments, fault protection, and shutdown devices. Large breakers or fused disconnects should be disconnected under load. Ensure high voltage breakers or disconnects are "locked out" in accordance with 29 CFR 1910.147 and 1910.333 Subpart S before working on equipment associated with them. Fuses should be physically pulled to isolate equipment. When the blower/flare station will be down for major maintenance or stand down, large breakers should be locked out (i.e., physically separated and disconnected) and the fuses should be pulled.

5.4.8 Lubrication - General

Follow the manufacturer's recommendations for specific types and brands of lubricants. It is important to use the recommended type of grease and not to mix types or brands of grease. Do not over lubricate. Personnel who perform lubrication services should be knowledgeable in lubrication practices and should follow the manufacturer's instructions for lubrication requirements.

Establish an initial lubrication frequency based upon the equipment manufacturer's recommendation. It may be necessary to adjust the lubrication frequency interval based upon experience with the equipment.

5.4.9 Other Equipment Maintenance and Operating Tips

The system operator should be proactive, remain alert, and develop a habit of observing equipment.

Equipment noises (such as bearings) may be monitored using an equipment stethoscope or using a wrench or similar tool by placing it on the equipment and placing the opposite end of the tool against the bone in front of the ear to listen. It is important to develop a sense of what baseline conditions are for comparison. The smell of leaking landfill gas or burned lubricant can indicate a seal, component, or lubricant failure.

When checking motors or other electrical devices for temperature by feel, the back of the hand should be used. Approach the equipment slowly and feel for radiant heat, which would indicate a very high temperature. If the equipment is too hot to maintain hand contact, then it is at or above a threshold of about 60 to 63°C (140 to 145°F) and may be considered excessive in many cases depending upon the equipment and service. The reason for using the back of the hand is that it is more heat sensitive and in the case of electrical fault to the casing, the natural reaction will be for the muscles of the arm to contract away from the device. This can prevent electrocution.

Operating personnel should wear all cotton clothing that provides some degree of protection in gas flash fires. Some synthetics such as polyester blends will melt readily, which can be fatal. Ties or loose items (e.g., identification badges hanging around the neck, etc.) should never be worn around rotating or belt-driven equipment. All watches, rings, identification bracelets, etc., should be removed when performing electrical testing or troubleshooting.

It is important that maintenance supplies, lubricants, and spare parts be inventoried on a frequent basis to ensure that adequate stocks are maintained for when they will be needed. Supplies should be reordered and restocked as used.

5.4.10 Condensate Handling Systems

Condensate is managed using traps constructed inside the limit of waste, and condensate knockout structures constructed outside the limit of waste. The condensate knockout structures collect condensate in perimeter landfill gas conveyance pipes located outside the limit of waste and discharge the condensate into primary leachate collection system cleanouts. The condensate traps inside the limit of waste drain by gravity into primary leachate collection system cleanouts or in some cases drain back into the waste mass. The blower/flare station is fitted with various traps, drains, valves, and pumps for handling condensate. Condensate can be corrosive and the equipment should be checked carefully and frequently for the effects of corrosion. Seals, o-rings, and valves are usually high maintenance items. Refer to the manufacturer's information for maintenance of individual equipment or components.

6.0 COLD WEATHER OPERATIONAL CONSIDERATIONS

Condensate in exposed pipes and equipment or in below-grade pipes without adequate soil cover may freeze during winter operations. Care must be taken to limit the amount of condensate allowed to collect in the landfill gas system at any time. The landfill gas is a source of heat for the system. If the system shuts down for a short period during winter months, then condensate in the exposed portions of the system may freeze.

If freezing of condensate under normal operating conditions becomes a regular problem, then heat trace and insulate the affected areas.

7.0 DATA COLLECTION

Data will be collected routinely using the data logger feature of the GEM-2000 for the flare, the well field, structures, etc. These "readings" are transferred to a computer and then uploaded to a secure database website. The database can be accessed by approved landfill personnel.

7.1 Data Assessment

During the initial start-up and operation of the landfill gas management system, baseline data should be acquired. The data should be representative of normal (not unusual, imbalanced, or irregular) conditions. These baseline data may be used in the future for comparison with current data. Parameters to be monitored include pressure, differential pressure, temperature, and flow, at various locations within the landfill gas management system.

Pressure will change with changes in landfill gas flow. Similarly, the landfill gas temperature will change as more waste is disposed and as the in-place waste ages.

With the above caveat in mind, equipment performance may be compared with past or baseline performance under similar operating conditions. Persons assessing the data should be aware of the normal operating range for each parameter and note any changes and assess the reasons for that change. Equipment deterioration that can be either sudden or very gradual may be indicated by an abnormal monitoring result. Such indications should be promptly investigated. Data should fall within established parameters for normal operating ranges for that equipment based upon service conditions. Manufacturer's information and equipment operating experience along with judgment are required to assess the data and determine these ranges.

Over the years, a number of data assessment techniques for landfill gas management systems have been developed. Relevant techniques are listed below.

1. Comparing current performance data with baseline data.

2. Comparing data with tables of acceptable ranges and conditions cross-referenced with recommended adjustments.

3. Directly comparing monitoring data with target criteria (e.g., methane, oxygen, nitrogen residual, wellhead vacuum, flow, etc.).

4. Assessing individual extraction point data parameters with subjective judgment (no specific analytical or mathematical method used).

5. Performing a summation of total landfill gas flow from all the extraction points and comparing with predicted or prior demonstrated acceptable well field flow. This may be used to develop a compensation factor to calculate individual extraction point targets and readjust portions of the landfill gas system infrastructure as needed.

6. Differentiating between air intrusion through the landfill cover and waste mass, and collection pipe leakage, and compensating accordingly (see No. 8 below).

7. Evaluating nitrogen residual by measuring nitrogen with a gas chromatograph or calculate nitrogen as a balance gas.

8. Comparing a summation of individual extraction point data with total composite flow, while accounting for pipe leakage and flow measurement error.

These techniques should be used in conjunction with target criteria and established acceptable performance ranges for each extraction location.

7.2 Landfill Daily Log Book

Whenever the system is monitored for any reason, staff should make appropriate entries in the Daily Log Book stored in the landfill office.

- Name of person making the entry;
- Date and time;
- Reason for the monitoring (e.g., routine, shutdown, specific monitoring or maintenance activity, etc.);
- Reason for any shutdown;

- Actions taken or adjustments made;
- Equipment status upon leaving; and
- Unusual observations made.

The daily log is used as a record of events regarding the landfill and to communicate between operating personnel. The log entry also becomes part of the daily landfill readings.

7.3 Data Collection Routine

Data are collected manually at the individual data points (i.e., at wells on the landfill, at migration monitoring probes surrounding the landfills, etc.).

Equipment used for data collection includes:

- GEM-2000 Portable Gas Analyzer;
- Calibration gases (use before going into the field);
- Data reading sheets;
- Clipboard and writing implement;
- Pocket calculator;
- Site map of the data points;
- Carrying tray, toolbox, or backpack, etc.;
- Tools needed to access the system components; and
- Spare parts for maintenance such as access ports, plugs, etc.

8.0 APPROVAL PROCEDURES FOR LANDFILL MANAGEMENT SYSTEM INSTALLATION

Prior to the installation of new landfill gas management system infrastructure within the landfill, various procedures must be followed to assure that the proposed system modification is properly designed and approved. This section defines the procedures to be followed prior to the modifying the landfill gas management system.

8.1 System Design

The landfill gas management system structures, conveyance pipes, and condensate management structures at JRL are designed by Sanborn, Head & Associates, Inc. (SHA) using sound engineering principles that follow industry standard procedures. The blower/flare station is sized according to projected landfill gas flow rates.

NEWSME routinely retains SHA to prepare detailed design packages for the expansion of the landfill gas management system associated with each new operational cell to comply with Condition 15.B of Solid Waste Order #S-020700-WD-N-A. The detailed design package typically includes the following:

- A description of the basis for the design;
- Drawings;
- Specifications; and
- Quality assurance and quality control information.

The landfill gas system expansion design for each cell is based on the projected development plans as prepared by Sevee & Maher Engineers, Inc. and a yearly review of landfill gas generation rates performed by SHA. The landfill gas expansion design is then submitted to the MDEP for review and approval.

Required changes to the existing LFG infrastructure are occasionally identified and proposed by NEWSME as the landfill gas generation rate and the disposal capacity needs are reviewed. In addition, NEWSME may propose changes to the approved landfill gas management system design to address observed conditions that may require modifications or additions to the system.

8.2 Approval Procedures

Procedures to modify approved landfill gas management system designs fall into two categories referred to as Major and Minor Revisions. A discussion of these revisions are discussed in Sections 8.3 and 8.4 below and depicted in the flow chart provided as Figure 3.

8.3 Approval of Major Revisions to Approved Design

Major revisions are defined as a modification that affects the design or operation of the gas management system and can include such projects as:

- The addition of vertical extraction wells;
- The installation or rerouting of conveyance pipes;
- Changes to the condensate management design; and
- The addition of gas collection trenches.

Major revisions to approved design projects will be handled as a Change Order pursuant to 06-096 CMR 401-3.D of the Maine Solid Waste Regulations. Prior to submitting a formal change order request, NEWSME will contact the MDEP and describe the issue (orally) and the proposed remedy (i.e., construct additional wells). Appropriate sketches will be provided as necessary. NEWSME will identify the anticipated time frame for construction and the name of the qualifying person who will oversee the construction. Following this step, the proposed (MDEP agreed upon) changes will be provided to SHA, who will revise the drawings to include the location of additional wells and associated conveyance pipe, to include well depth information, etc. NEWSME will submit a written change order request to the MDEP for review and approval at least five business days prior to the planned construction, unless an alternate deadline has been agreed upon with the MDEP. The MDEP will issue a response to the change order request within five business days or approval of the Change Order is automatically granted.

8.4 Approval of Minor Revisions to Approved Design

Minor revisions to the design are defined as modifications that do not significantly affect the design or operation of the landfill gas management system and can include projects such as:

- Minor shifting of a previously approved trench;

- The addition of a pipe intended to bypass a "water-out" or non-functioning section of an existing trench; and
- The addition of a short stub to an existing gas collection trench.

These modifications do not typically require the installation of an additional wellhead and are often a means of addressing a concern in a section of the operational landfill area.

Prior to construction of these changes to the landfill gas management system, NEWSME will notify the MDEP and describe the need for the change, the location, and how the structure will be connected to the existing infrastructure. A hand sketch will be provided as necessary.

9.0 INFRASTRUCTURE CONSTRUCTION AND DOCUMENTATION

Construction of landfill gas infrastructure will be peformed by qualified NEWSME staff and specialty contractors when needed. This section describes the components of the landfill gas management system that can be installed by NEWSME staff and the system components that require specialty contractors.

9.1 Construction Projects by NEWSME Staff

Qualified NEWSME staff is authorized to install the below listed infrastructure:

- Gas collection trenches;
- Conveyance pipe within the solid waste boundary;
- Condensate structures located within the solid waste boundary; and
- Wellheads on new wells and trenches and replacement wellhead fixtures.

NEWSME staff will follow an approved set of technical specifications for each project and qualified personnel will document the construction using field survey techniques. Following construction, field survey data will be provided to SHA so that the as-built drawings may be updated. Updated as-built drawings will be provided to the MDEP as part of the annual report. As-built drawings pertaining to new wellhead installations will be provided to the MDEP within 45 days of completion of work.

9.2 Construction Projects by Specialty Contractors

Specialty contractors will be retained to perform the following installations:

- Vertical extraction wells;
- Conveyance pipes outside of the solid waste boundaries; and
- Condensate pipe and structures outside of the solid waste boundary.

Following the construction of the above infrastructure, updated information will be provided to SHA and as-built plans provide to the MDEP within 45 days of completion of work.

9.3 Construction Quality Assurance and Quality Control

Construction activities by NEWSME staff as listed in Section 9.1 above (with the exception of LFG conveyance pipe installations) will be overseen and documented by qualified NEWSME staff.

Construction of vertical extraction wells, conveyance pipes of 12-inches diameter or greater, and condensate pipe and structures outside of the solid waste boundary will be overseen by qualified construction quality assurance personnel separate from NEWSME and the installation contractor following an approved CQA plan. The construction will be documented and the information will be submitted to the MDEP within 45 days of completion of work.

9.4 Licensing of LFG Infrastructure Installations

Proposals for new gas related projects will be submitted to the MDEP in the form of a minor revision application pursuant to 06-096 CMR 400.3.B(2)(b) of the Maine Solid Waste Management Regulations, except that if a major redesign of the gas extraction system is being proposed, the MDEP may require an amendment application be submitted. For projects related to new cell construction, including the layout for proposed gas collection trenches, the landfill gas management system design will be included with the application for the new cell construction. The MDEP may include comments on the proposed landfill gas management system design as part of its review of the new cell design. MDEP's review will be completed prior to the construction of the new cell.

9.5 Emergency Situations

In an after-hours emergency, such as vandalism or a catastrophic failure, that causes damage and/or shuts down the landfill gas management system, NEWSME will immediately notify the MDEP staff by all means (office, home, DEP spill response line) to notify them of any proposed activities associated with abating the condition. However, it is understood by MDEP staff that any work required to get the landfill gas management system operating again will proceed as needed.

TABLE 1

TYPICAL LANDFILL GAS CONSTITUENTS

Operations and Maintenance Manual
Juniper Ridge Landfill
Old Town, Maine

COMPONENT	PERCENT VOLUME (All are stated on a dry basis except moisture.)
Methane (CH_4)	45 to 58%.
Carbon Dioxide (CO_2)	32 to 45%.
Oxygen (O_2)	Less than 1%.
Nitrogen (N_2)	0 to 3%.
Hydrogen (H_2)	Trace to 5% plus; generally less than 1%.
Carbon Monoxide (CO)	Trace; CO is an indicator of the possible presence of a subsurface fire.
Hydrogen Sulfide (H_2S) & Other Sulfur Components	Varies by landfill (nominally 10-200 ppm).
Moisture	Up to 14% (increases with gas temperature).
Volatile Organic Compounds (VOCs)	Less than 2%; typically ¼ to ½%.

Note: This table represents typical characteristics of landfill gas. A difference between characteristics in the gas from the facility and the values tabulated above does not necessarily indicate a problem. However, a large disparity should be reviewed to evaluate the cause.

TABLE 2

RECOMMENDED MONITORING SCHEDULE

Operations and Maintenance Manual
Juniper Ridge Landfill
Old Town, Maine

ITEM	FREQUENCY	PARAMETER
Wellheads	Weekly	• Condition of flex hose; • Valve position; • Gas flow rate; • Static Pressure; • Percent methane; • Percent carbon dioxide; • Percent oxygen; and • Temperature of gas.
Blower/Flare Station	Weekly	• Condition of pipe and connections; • Consistency of flame; and • Functioning of ignition sparker.
Conveyance Pipe	Bi-Annual	• General condition of exposed pipe.

Notes:

1. The monitoring frequency may be reduced with approval from the Maine Department of Environmental Protection.

2. In addition to the monitoring schedule outlined above mechanical components of the blower/flare station should also be monitored and serviced in accordance with the manufacturer's instructions.

TABLE 3

GAS EXTRACTION SYSTEM MONITORING CHECKLIST

Operations and Maintenance Manual
Juniper Ridge Landfill
Old Town, Maine

A. <u>Prior to going out onto the landfill.</u>

1. Calibrate the GEM-2000 Portable Gas Analyzer (meter) using methane, carbon dioxide, and oxygen.
2. Calibrate the pressure transducers by performing the "Zero Pressure" function.
3. Record the ambient weather conditions including:
   - Temperature;
   - Barometric pressure;
   - Wind speed and direction;
   - Precipitation amounts; and
   - Current observations (i.e., drizzling, raining, snowing).

B. <u>At each wellhead assembly.</u>

1. Connect the striped tubing with the external filter/water trap assembly from the static pressure/sampling port on the meter to the static pressure port on the wellhead assembly.
2. Connect the clear tubing between the impact pressure port on the meter and the impact pressure port on the wellhead assembly.
3. Perform the "Read Gas Levels" function on the meter. Follow instructions on the meter.
4. Record the following data on the data sheets or in the meter memory:
   - Station identification;
   - Percent methane;
   - Percent carbon dioxide;
   - Percent oxygen;
   - Percent balance;
   - Percent LEL;
   - Temperature of the gas stream;
   - Static pressure;
   - Differential pressure;
   - Gas flow rate; and
   - Control valve percent open.

5. Make adjustments to the flow rate by adjusting the wellhead control valve, if required.

NOTES:

1. THE BASE MAP SHOWN WAS PREPARED BY AERIAL SURVEY & PHOTO INC., OF NORRIDGEWOCK, MAINE. PHOTO DATE JULY 31, 2014. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE.
2. PROPOSED EXPANSION GRADES SHOWN WERE PROVIDED TO SANBORN HEAD BY SEVEE & MAHER, (SME) INC. OF CUMBERLAND, MAINE.
3. ACTUAL GRADES MAY DIFFER FROM GRADES SHOWN ON DRAWINGS AT THE TIME OF CONSTRUCTION.
4. THE EXISTING LANDFILL GAS EXTRACTION SYSTEM INFRASTRUCTURE FEATURES SHOWN ARE BASED ON A COMBINATION OF DESIGN AND AS-BUILT DOCUMENTATION AVAILABLE TO SANBORN, HEAD & ASSOCIATES, INC. (SANBORN HEAD). ACTUAL LOCATIONS OF INDIVIDUAL FEATURES MAY BE DIFFERENT THAN SHOWN.
5. THE LOCATIONS OF MANY OF THE LANDFILL DESIGN COMPONENTS SHOWN ON THIS PLAN, SUCH AS LEACHATE CLEANOUTS, STORMWATER MANAGEMENT FEATURES, AND UTILITIES, ARE BASED ON PROPOSED LOCATIONS PROVIDED TO SANBORN HEAD BY SEVEE & MAHER ENGINEERS, INC. OF CUMBERLAND, MAINE.
6. THIS PLAN IS INTENDED TO ILLUSTRATE THE PROPOSED LAYOUT OF THE LANDFILL GAS (LFG) EXTRACTION SYSTEM. ACTUAL LOCATION OF WELLS, PIPE, AND VALVES MAY CHANGE DEPENDING ON SITE CONDITIONS AND CONSTRAINTS DURING CONSTRUCTION.
7. SOLID LANDFILL GAS CONVEYANCE PIPE AND COLLECTION TRENCHES SHALL BE INSTALLED AT A MINIMUM SLOPE OF 6 PERCENT. PERFORATED LANDFILL GAS COLLECTION TRENCHES SHALL BE INSTALLED AT A MINIMUM SLOPE OF 2 PERCENT.
8. HDPE PIPE AND FITTINGS SHALL BE SDR-17.
9. HDPE FITTINGS SHALL BE MOLDED; FABRICATED FITTINGS SHALL NOT BE USED.

LEGEND:

EXISTING		PROPOSED
180	10 FOOT CONTOUR	370
	2 FOOT CONTOUR	
GW-11	VERTICAL LFG WELL	GW-35
12"ø	LFG CONVEYANCE PIPE (SIZE AND SLOPE DIRECTION)	12"ø
T	CONDENSATE TRAP	T
	CONTROL VALVE	
KO-1	CONDENSATE KNOCKOUT	KO-4
	LEACHATE COLLECTION CLEANOUT	
	VERTICAL RISER	
	LIMIT OF WASTE CONTAINMENT	
	CELL LIMIT	
	EDGE OF ROAD	
HP	HIGH POINT	HP
	RIPRAP-LINED DOWNCHUTE	
	TEMPORARY PIPE TERMINATION	

SANBORN | HEAD

GRAPHICAL SCALE

150' 75' 0' 150' 300'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: June 2015

LFG SYSTEM EXPANSION MASTER PLAN
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

JRL LFG INFRASTRUCTURE PLAN (FULL BUILD-OUT)

PROJECT NUMBER: 2536.27

FIGURE NUMBER: 1

MAINE STATE PLANE

CURRENT ACTIVE LFG COLLECTION SOURCES:

VERTICAL WELLS	HORIZONTAL COLLECTION TRENCHES	OTHER
GW-02	GCT-01	3W-01
GW-03	GCT-17	3W-02
GW-04	GCT-18	7SOUTH
GW-05	GCT-201	L7WEST
GW-06	GCT-2A1	LC--5
GW-09	GCT-2A2	LC--6
GW-10	GCT-3A1	LGV401
GW-11	GCT-3A2	LGV402
GW-12	GCT-3A3	LGV403
GW-13	GCT-3A4	LGV404
GW-14	GCT-3A5	LPC-1
GW-15	GCT-3B1	LPC-3
GW-16	GCT-3B2	LPC-4
GW-18	GCT-3B3	LPC4A
GW-19R	GCT-3B4	LPC-2
GW-20R	GCT-401	
GW-21	GCT-401A	
GW-22R	GCT-402	
GW-23R	GCT-402A	
GW-24	GCT-403	
GW-25	GCT-404	
GW-28	GCT-404A	
GW-29	GCT-405A	
GW-30R	GCT-406	
GW-31R	GCT-406A	
GW-32	GCT-501	
GW-36	GCT-502	
GW-37	GCT-503	
GW-38	GCT-504	
GW-39	GCT-505	
GW-46	GCT-506	
GW-47	GCT-507	
GW-48	GCT-508	
GW-54	GCT-509	
GW-55	GCT-510	
GW-56	GCT-511	
GW-57	GCT-512	
GW-64	GCT-513	
GW-65	GCT-514	
GW-66	GCT-601	
GW--7	GCT-602	
GW-74	GCT-603	
GW-75	GCT-604	
GW-82	GCT-605	
GW-83	GCT-606	
GW-90	GCT-607	
GW-91	GCT-608	
GW--A	GCT-609	
GW--D	GCT-610	
GW--E	GCT-701	
GW--F	GCT-702	
GW-G2	GCT-703	
GW-H2	GCT-704	
GW--I	GCT-705	
GW--J	GCT-706	
GW--K	GCT-707	
GW--L	GCT-708	
GW--M	GCT-709	
GW--N	GCT-710	
GW--O	GCT-711	
GW--P	GCT-801	
GW--S	GCT-802	
GW--T	GCT-803	
	GCT-804	
	GCT-805	
	GCT-806	
	GCT-807	
	GCT-808	
	GCT-809	
	GCT-810	
	GCT-811	
	GCT-812	
	GCT-813	
	GCT-814	
	GCT-815	
	GCT-816	
	GCT-817	
	GCT-818	
	GCT-819	

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P:\2500s\2536.27\Graphics Files\CAD\LFG Master Plan\XRefs\20111026 PERIMETER HEADER AB.dwg

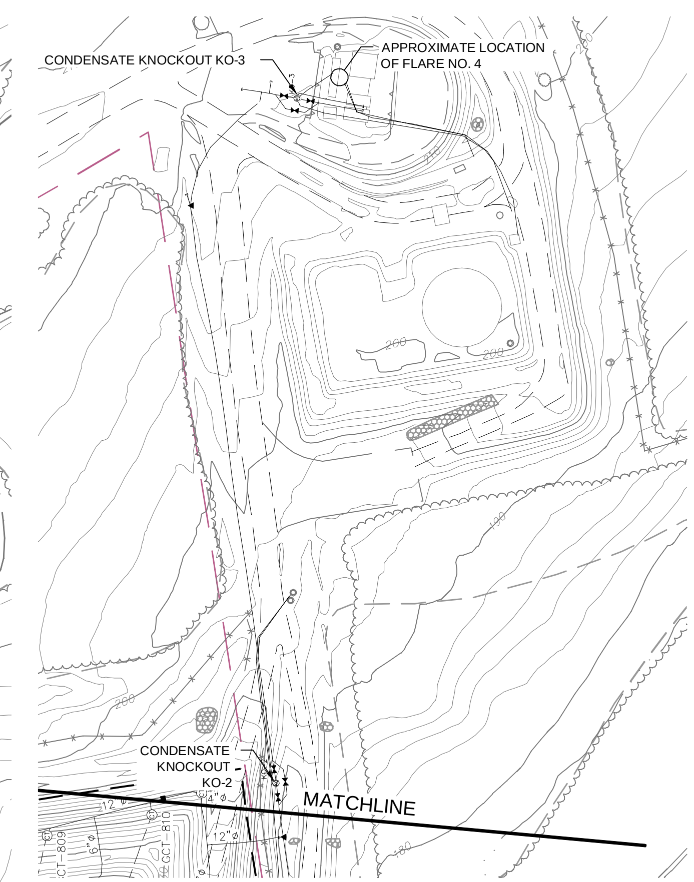
NOTES:

1. THE EXISTING LANDFILL GAS EXTRACTION SYSTEM INFRASTRUCTURE FEATURES SHOWN ARE BASED ON A COMBINATION OF DESIGN AND AS-BUILT DOCUMENTATION AVAILABLE TO SANBORN, HEAD & ASSOCIATES, INC. (SANBORN HEAD). ACTUAL LOCATIONS OF INDIVIDUAL FEATURES MAY BE DIFFERENT THAN SHOWN.
2. BASE MAP WAS PREPARED BY AERIAL SURVEY & PHOTO INC., OF NORRIDGEWOCK, MAINE. PHOTO DATE JULY 31, 2014. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE.

LEGEND:

EXISTING

- 190 — 10-FOOT CONTOUR
- 2-FOOT CONTOUR
- LIMIT OF WASTE CONTAINMENT
- CELL LIMIT
- EDGE OF ROAD
- LANDFILL GAS CONVEYANCE PIPE
- LANDFILL GAS COLLECTION TRENCH (PERFORATED PIPE)
- LIMIT OF MARSH
- FENCE LINE
- GW-9 — LANDFILL GAS EXTRACTION WELL
- GCT-21 — COLLECTION TRENCH WELLHEAD
- COLLECTION TRENCH TERMINATION
- PIPE END CAP
- LEACHATE COLLECTION PIPE CLEANOUT
- LEACHATE COLLECTION INLET
- LANDFILL GAS EXTRACTION WELLHEAD
- RIPRAP AREAS



SANBORN | HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: E. STEINHAUSER
PIC: E. STEINHAUSER
DATE: June 2015

LFG SYSTEM EXPANSION MASTER PLAN

JUNIPER RIDGE LANDFILL

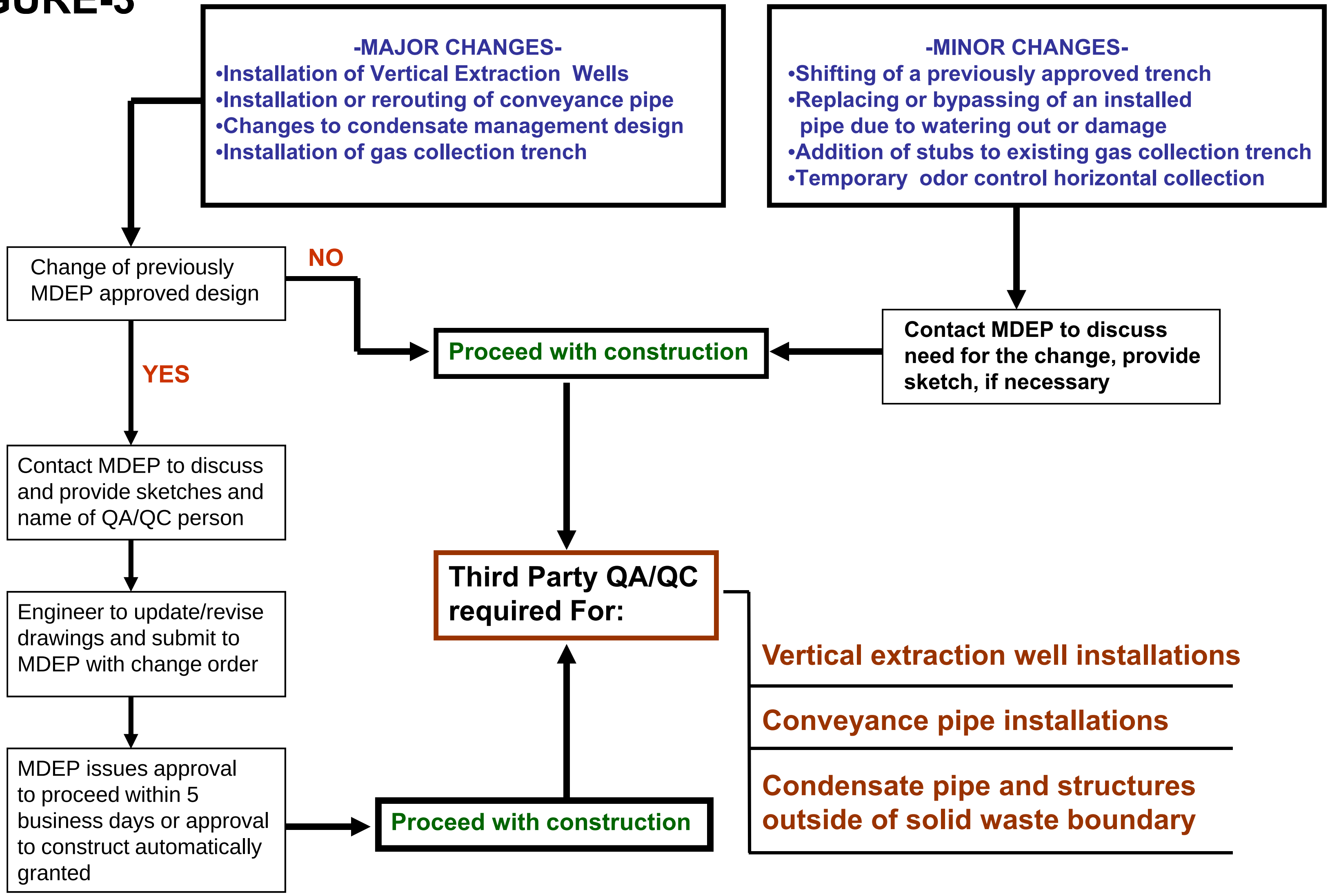
OLD TOWN, MAINE

JRL LFG INFRASTRUCTURE PLAN (AS-BUILT - CELLS 1-8)

PROJECT NUMBER: 2536.27

FIGURE NUMBER: 2

FIGURE-3



-PROTOCOL FOR LFG SYSTEMS INSTALLATION-

APPENDIX J

CONTAMINANT TRANSPORT CALCULATIONS

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill (Cell 11). Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor A.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1600ft$ Southeast - Northwest

$Length_1 := 255ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 9.366 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Imported Soil Layer	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 865.149 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 0.601 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_11} := 200.6ft$ $Head_A := 173ft$

$i_2 := \frac{Head_{Cell\_11} - Head_A}{540ft}$ $i_2 = 0.051$ $v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $v_{gw} = 5.448 \times 10^{-3} \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$$i_2 := \frac{Q_2}{(k_2)\cdot Area_1} \qquad i_2 = 0.011$$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cell 11):

Sens. Rec	X_2 (ft)	Z_2 (ft)
A	540	300
B	770	300

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_2 := 540ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 300ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1\cdot n_2\cdot v_2} \qquad a_2 = 18.142\cdot ft$$

Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 540 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 81 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 81 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 5.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 5.4 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 5.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 5.4 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 127.5 \cdot ft$ Northeast - Southwest

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 800 \cdot ft$ Southeast - Northwest

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$ Northeast - Southwest

Lateral distance of interest (z): $z_1 := 0ft$ Southeast - Northwest

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \text{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \text{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \text{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \text{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

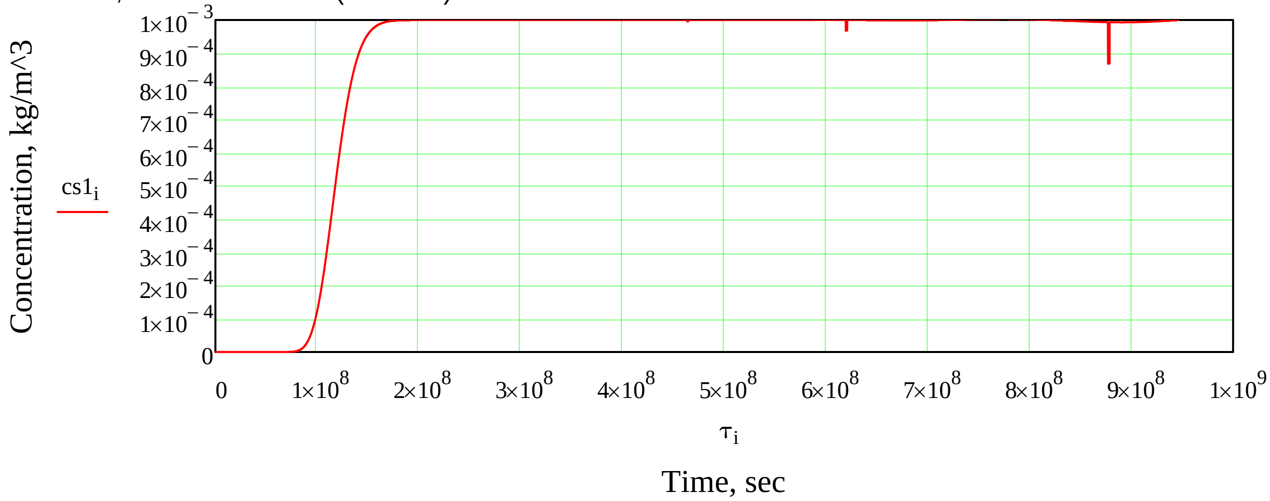
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0, 1 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

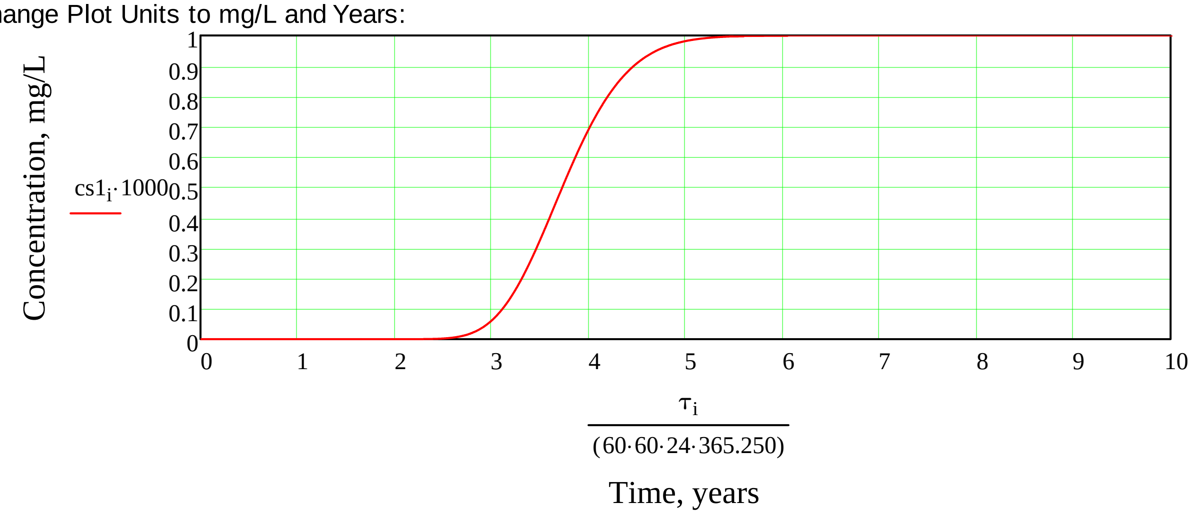
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

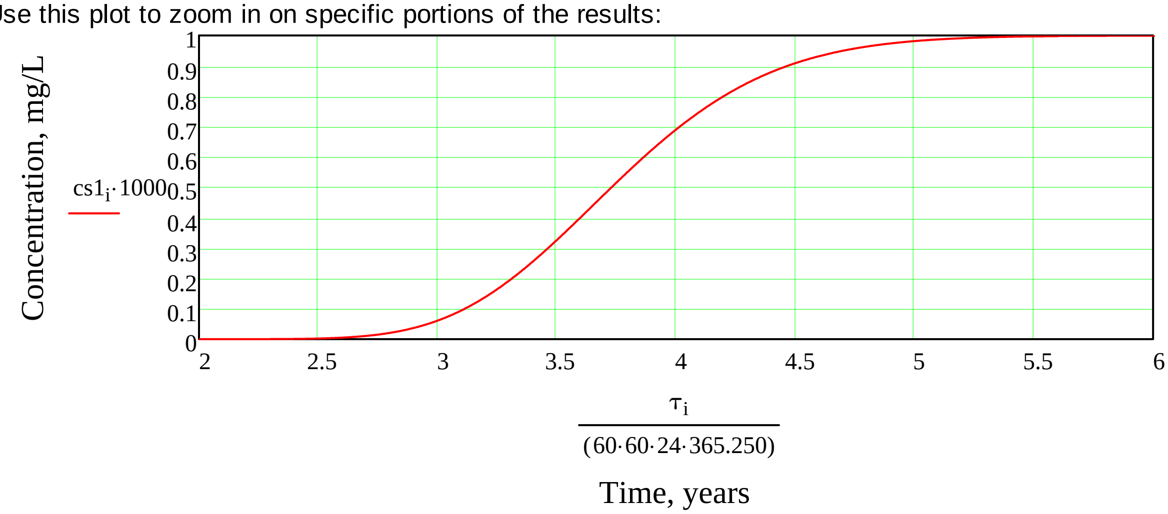
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1 yr$ $t_{2\_90\%} := 4.5 yr$ $t_{2\_100\%} := 5.5 yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^3 \cdot day$ $t_{2\_90\%} = 1.644 \times 10^3 \cdot day$ $t_{2\_100\%} = 2.009 \times 10^3 \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 18.142 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 800 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 81 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 81 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 5.4 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 5.4 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 5.4 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 5.4 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 8.1 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.54 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.54 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \text{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \text{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \text{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \text{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

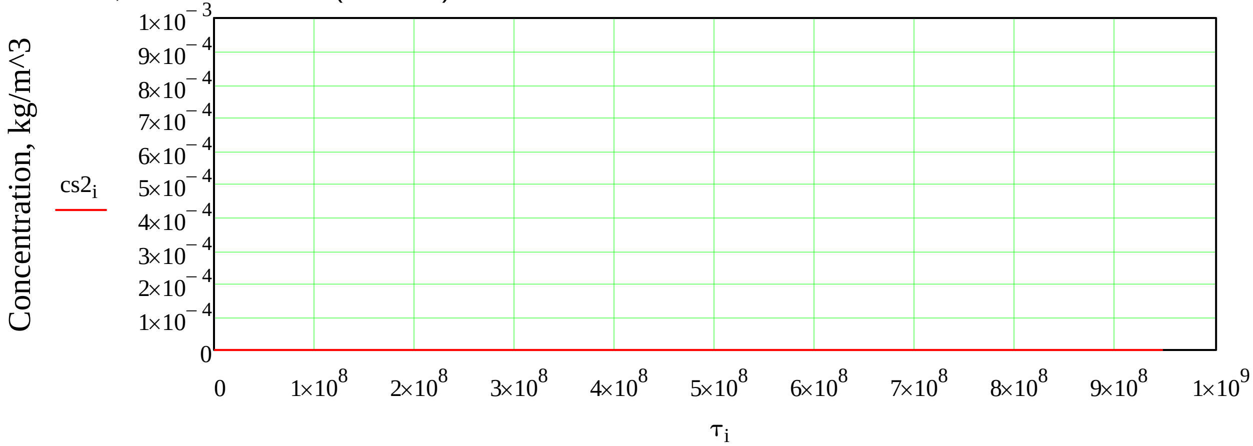
$i := 0,1..10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{day}$$

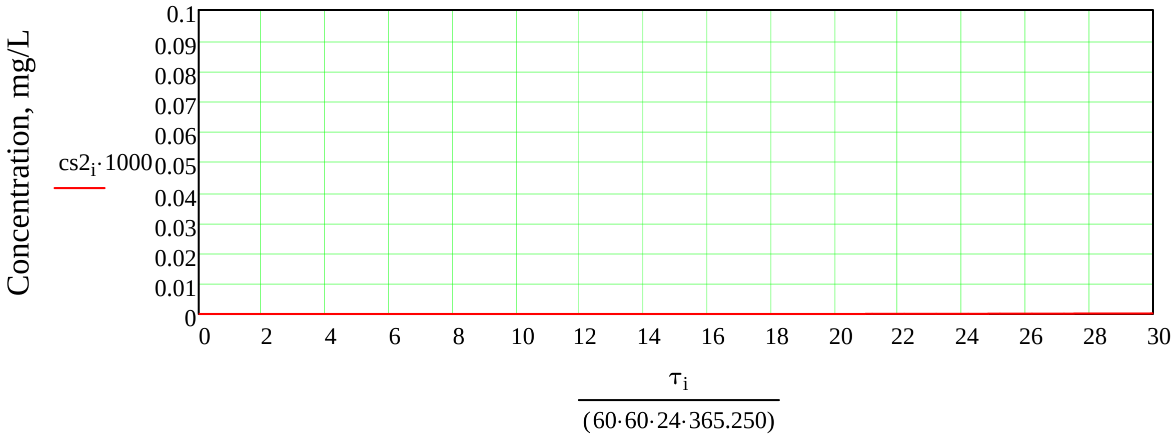
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)

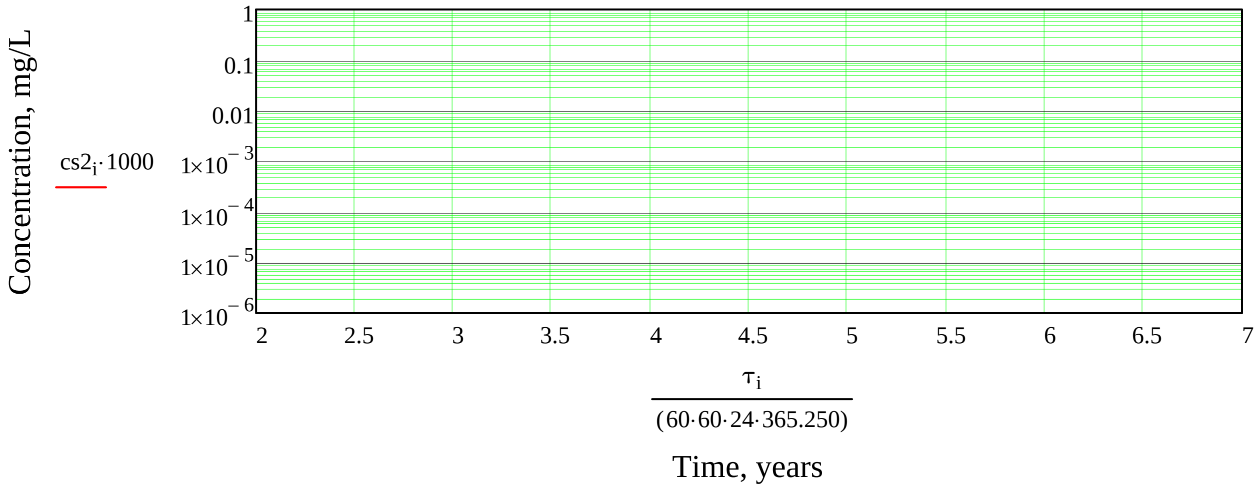


B. Change Plot Units to mg/L and Years:

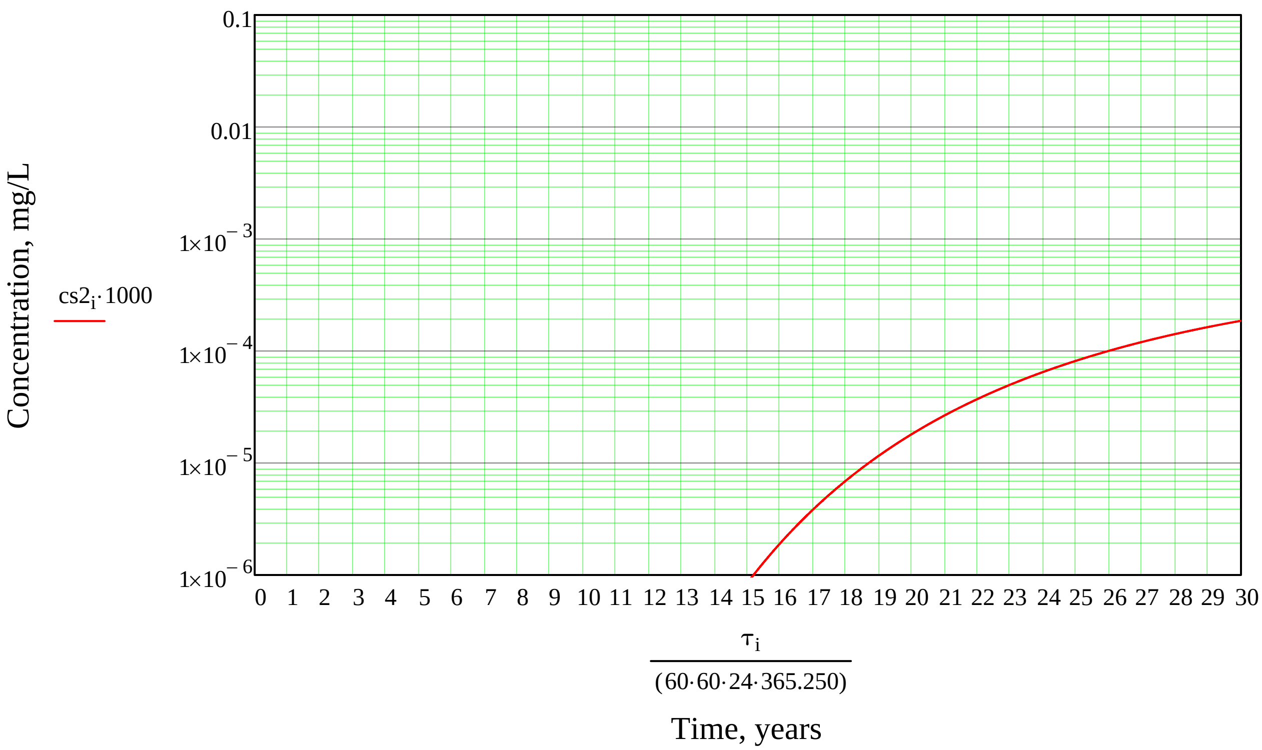


$x_2 = 540 \cdot ft$ $y_2 = 0$ $z_2 = 300 \cdot ft$

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 540 \cdot ft$ $y_2 = 0$ $z_2 = 300 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
Complete Failure of the engineered systems of the landfill. Flow is vertically down through Layer 1 (Imported Soil layer); then through Layer 2 (Till); and horizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor B.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1600ft$ Southeast - Northwest

$Length_1 := 255ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 9.366 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Imported Soil Layer	Native Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 1ft$	$x_2 := 4.ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 865.149 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 0.601 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

$LQ := \frac{Q_1}{Area_1}$ $LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

LQ was Used to determine the value of a_3

$v_3 := 5 \frac{ft}{day}$

Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day..

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{Q_2}{(k_2) \cdot Area_1}$ $i_2 = 0.011$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the east side of the Imported Soil Layer in Cell 11):

Sens. Rec	X_3 (ft)	Z_3 (ft)
A	540	300
B	770	300

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_3 := 540ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 300ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 90.709 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 4 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.04 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.04 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 0.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 0.4 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 0.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 0.4 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

These Calcs

Lateral dispersivity $\alpha_{y\_BR} := \dfrac{20ft}{Y_3}$ $\alpha_{y\_BR} = 0.4$ Z axis

Downgradient dispersivity: $\alpha_{x\_BR} := \dfrac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$ $\alpha_{x\_BR} = 1.2$ X axis

Vertical dispersivity $\alpha_{z\_BR} := \dfrac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$ $\alpha_{z\_BR} = 0.02$ Y axis

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2000 \\ 5000 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 127.5 \cdot ft$ Northeast - Southwest

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 800 \cdot ft$ Southeast - Northwest

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$ Northeast - Southwest

Lateral distance of interest (z): $z_1 := 0ft$ Southeast - Northwest

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

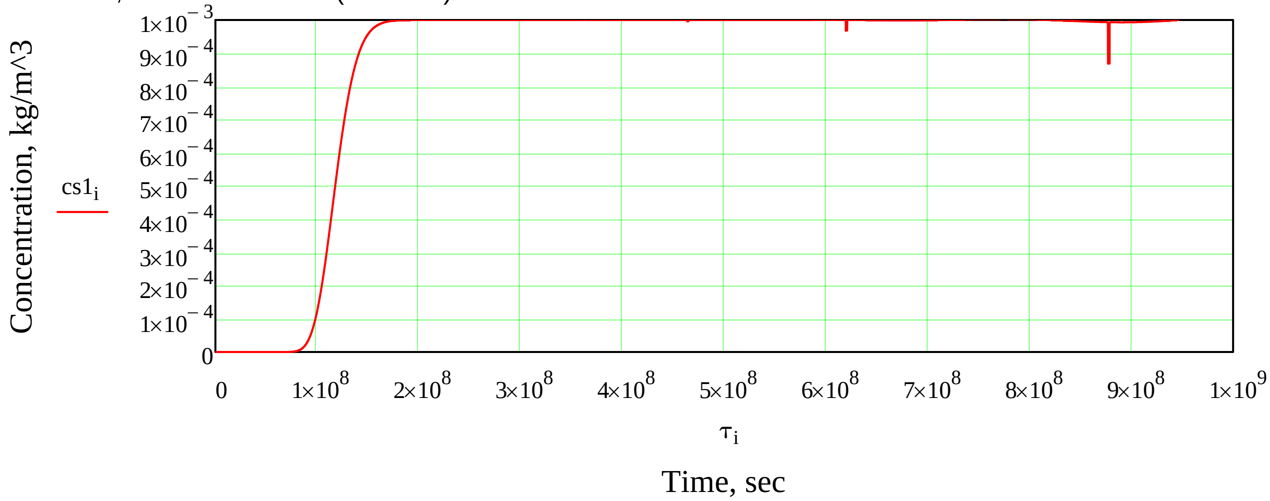
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0, 1 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

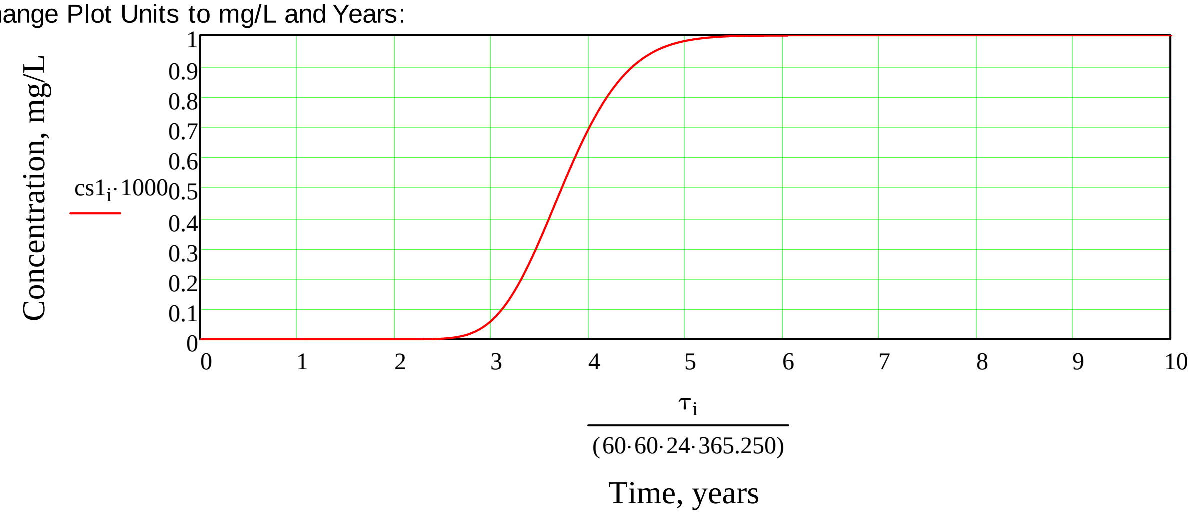
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

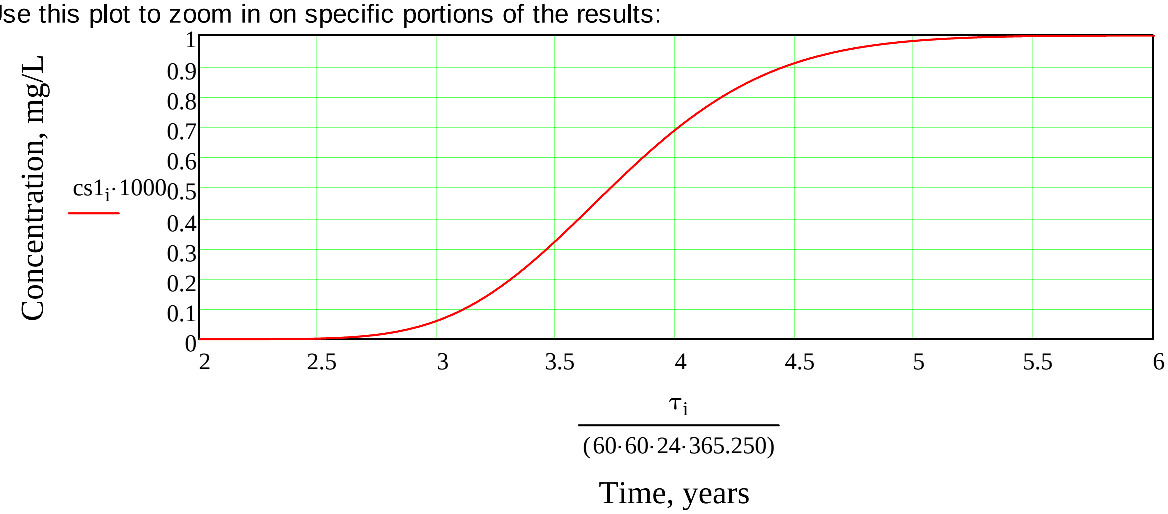
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $\quad t_{2\_10\%} := 3.1yr$ $\quad t_{2\_90\%} := 4.5yr$ $\quad t_{2\_100\%} := 5.5yr$

$t_{2\_1\%} = 913.105 \cdot day$ $\quad t_{2\_10\%} = 1.132 \times 10^{3} \cdot day$ $\quad t_{2\_90\%} = 1.644 \times 10^{3} \cdot day$ $\quad t_{2\_100\%} = 2.009 \times 10^{3} \cdot day$

Use the values above for time steps 3, 4, 5, and 6 below

A. Source to Layer 2:

number of concentration steps $\quad j_2 := 7$

Iteration intervals $\quad i := 1, 2 .. 10950$

Concentration (mg/l) $\quad$ Source Term (days)

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $\quad a_2 := a_1 \quad a_2 = 127.5 \cdot ft$

Half-Width of Source in Z-direction $\quad b_2 := b_1 \quad b_2 = 800 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $\quad v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

Distance of interest (x): $\quad x_2 = 4 \cdot ft$ $\quad$ Vertical (down) $\quad$ to Top of Layer 3

Lateral distance of interest (y): $\quad y_2 := 0ft$

Lateal distance of interest (z): $\quad z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $\quad Dx_2 := \alpha x_2 \cdot v_2 \quad Dx_2 = 4.535 \times 10^{-5} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $\quad Dy_2 := \alpha y_2 \cdot v_2 \quad Dy_2 = 4.535 \times 10^{-4} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $\quad Dz_2 := \alpha z_2 \cdot v_2 \quad Dz_2 = 4.535 \times 10^{-4} \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

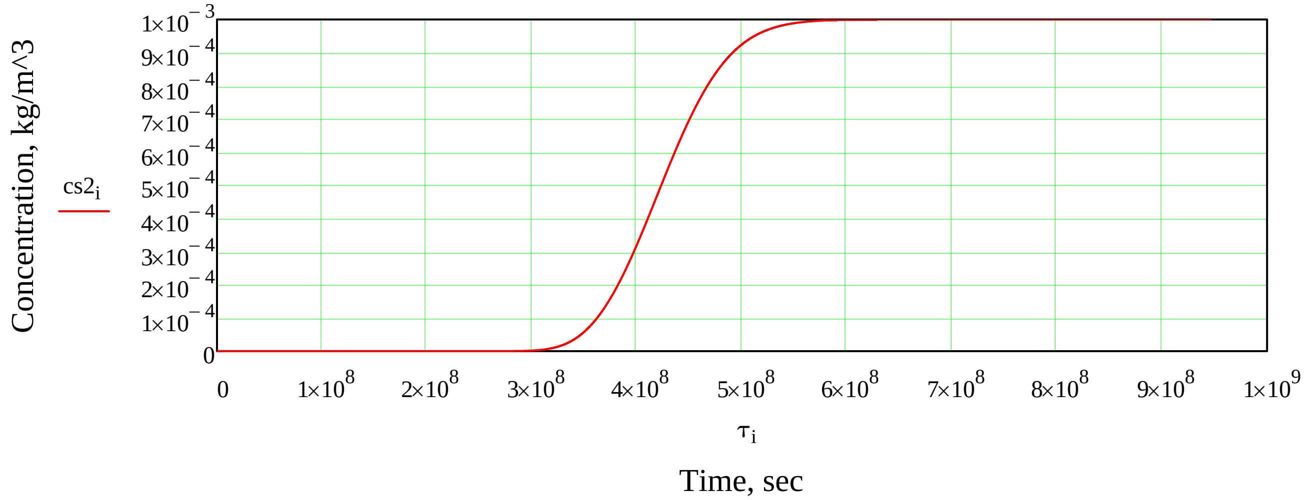
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 0,1..10950$ $\qquad$ $\tau_i := i\cdot day$

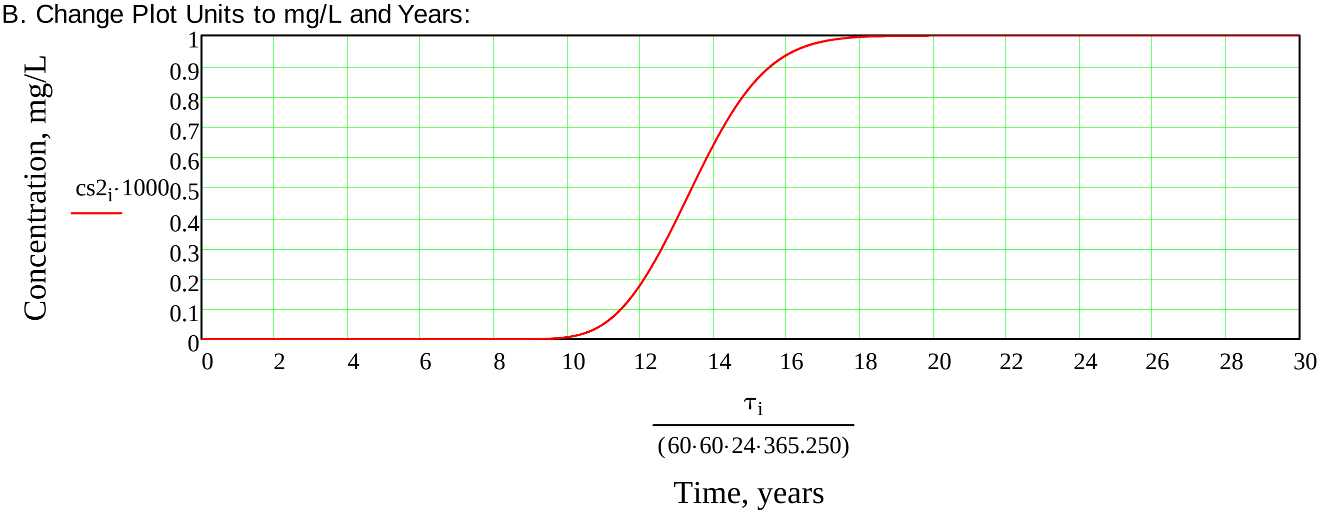
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

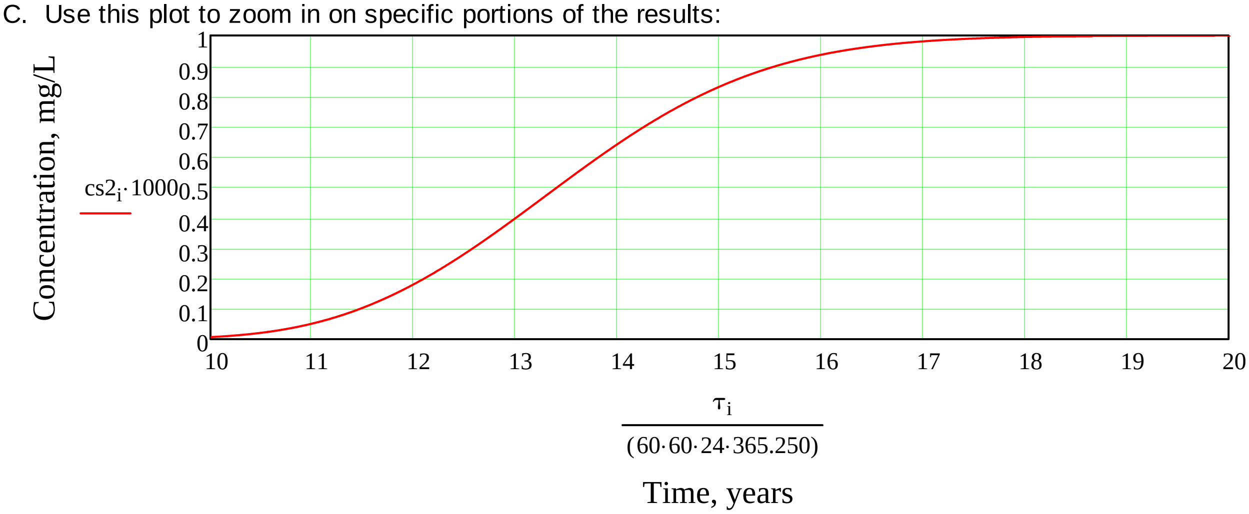
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

$t_{3\_1\%} := 10 \cdot yr$ $t_{3\_10\%} := 11.5yr$ $t_{3\_90\%} := 15.5yr$ $t_{3\_100\%} := 18yr$

$t_{3\_1\%} = 3.156 \times 10^{8} s$ $t_{3\_10\%} = 4.2 \times 10^{3} \cdot day$ $t_{3\_90\%} = 5.661 \times 10^{3} \cdot day$ $t_{3\_100\%} = 6.574 \times 10^{3} \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 3155 \\ 3156 \\ 4200 \\ 5661 \\ 6574 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 3

This source sub-divides the results from Layer 2.

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 90.709 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 800 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 648 \cdot ft$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 648 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 216 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 216 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 10.8 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 10.8 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 3.24 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.08 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 54 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \operatorname{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \operatorname{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \operatorname{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \operatorname{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

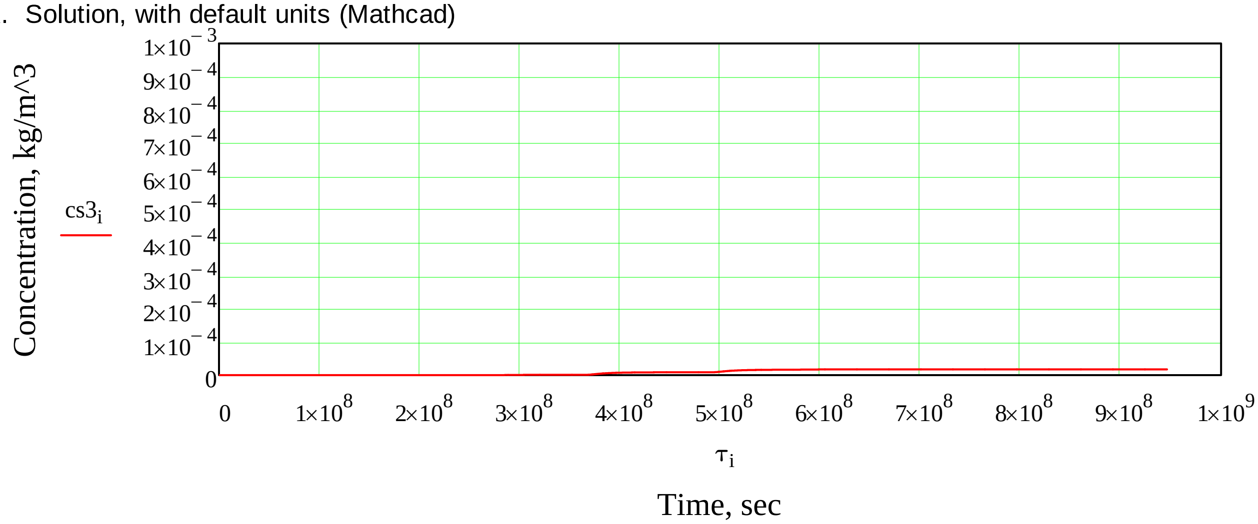
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 0, 1 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

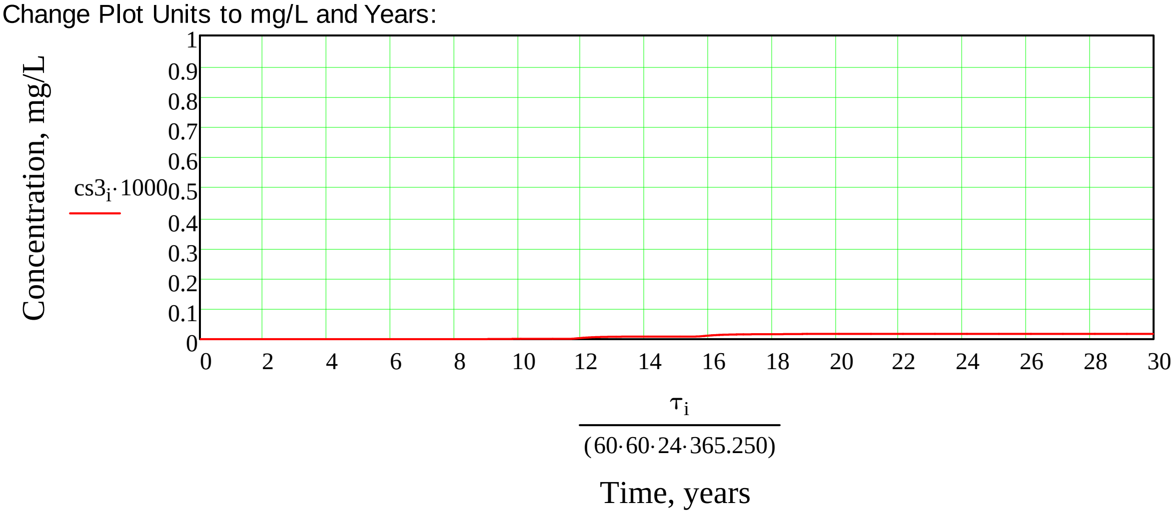
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

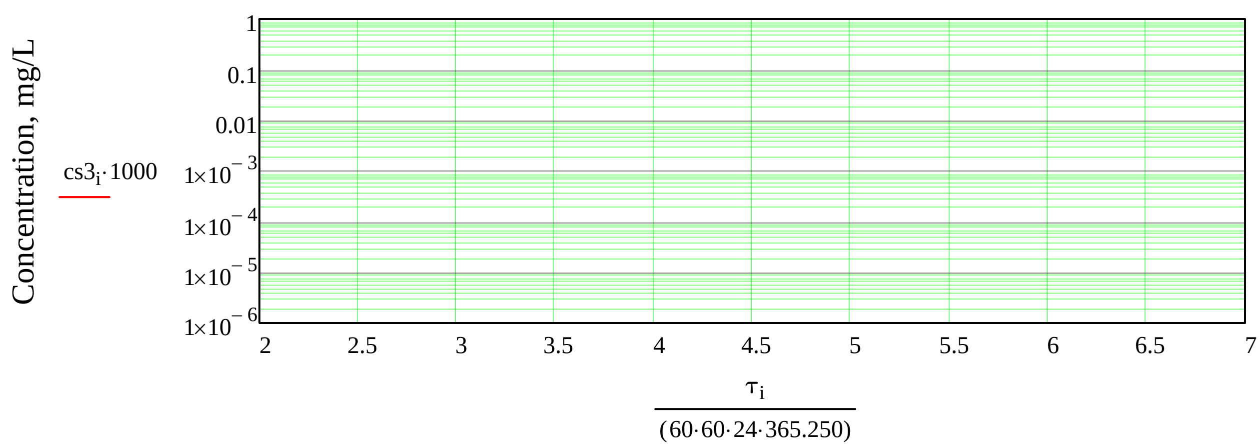
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

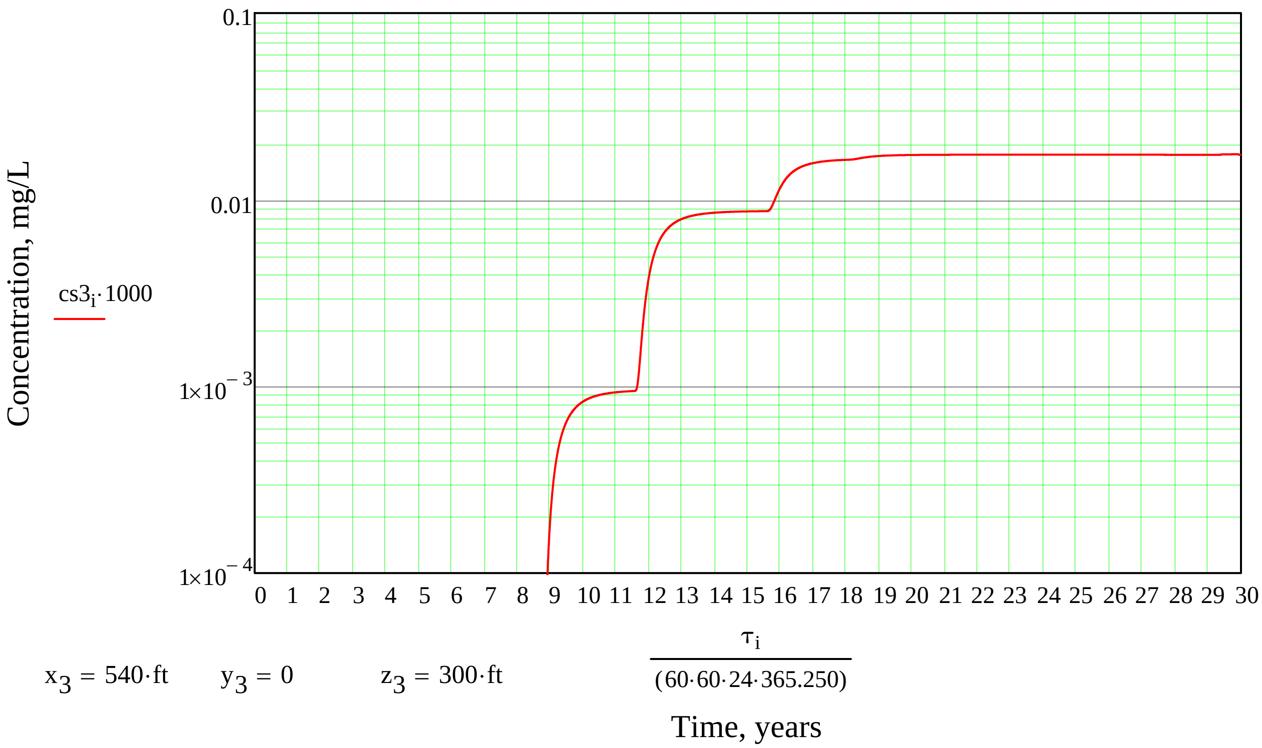


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 540 \cdot ft$ $y_3 = 0$ $z_3 = 300 \cdot ft$ Time, years

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 540 \cdot ft$ $y_3 = 0$ $z_3 = 300 \cdot ft$

JRL - Expansion Contaminant Transport Evaluation - Complete Failure of Engineered Systems - Eastern Flow

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill (Cell 11). Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor B.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1600ft$ Southeast - Northwest

Flow is generally Northeasterly

$Length_1 := 255ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 9.366 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	
	Imported Soil Layer	Till (Horizontal)	
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2	From Shallow Bedrock Area east side of Cell 11 to NE , Point A on Figure 7-1 in Vol. II of Application.

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 865.149 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 0.601 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_11} := 200.6ft$ $Head_A := 173ft$

$i_2 := \frac{Head_{Cell\_11} - Head_A}{540ft}$ $i_2 = 0.051$ $v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $v_{gw} = 5.448 \times 10^{-3} \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$$i_2 := \frac{Q_2}{(k_2) \cdot Area_1} \qquad i_2 = 0.011$$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cell 11):

Sens. Rec	X_2 (ft)	Z_2 (ft)
A	540	300
B	770	300

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_2 := 770ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 300ft$ Northwest - Southeast

F. Determine the thickness that the leak travels into the Till (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2} \qquad a_2 = 18.142 \cdot ft$$

Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 770 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 115.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 115.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 7.7 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 7.7 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 7.7 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 7.7 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 127.5 \cdot ft$ Northeast - Southwest

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 800 \cdot ft$ Southeast - Northwest

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$ Northeast - Southwest

Lateral distance of interest (z): $z_1 := 0ft$ Southeast - Northwest

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

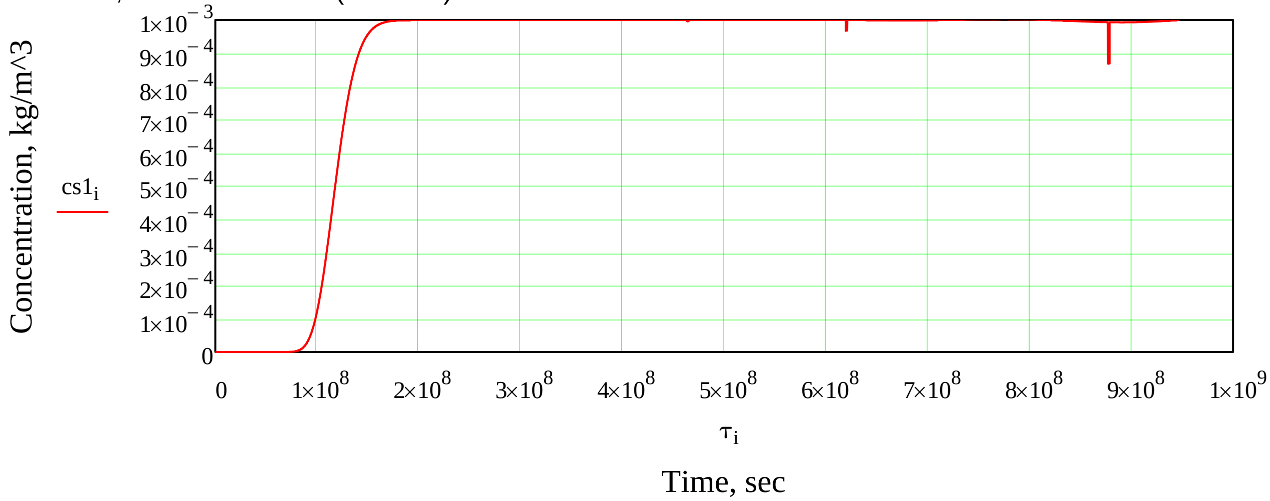
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0, 1 .. 10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

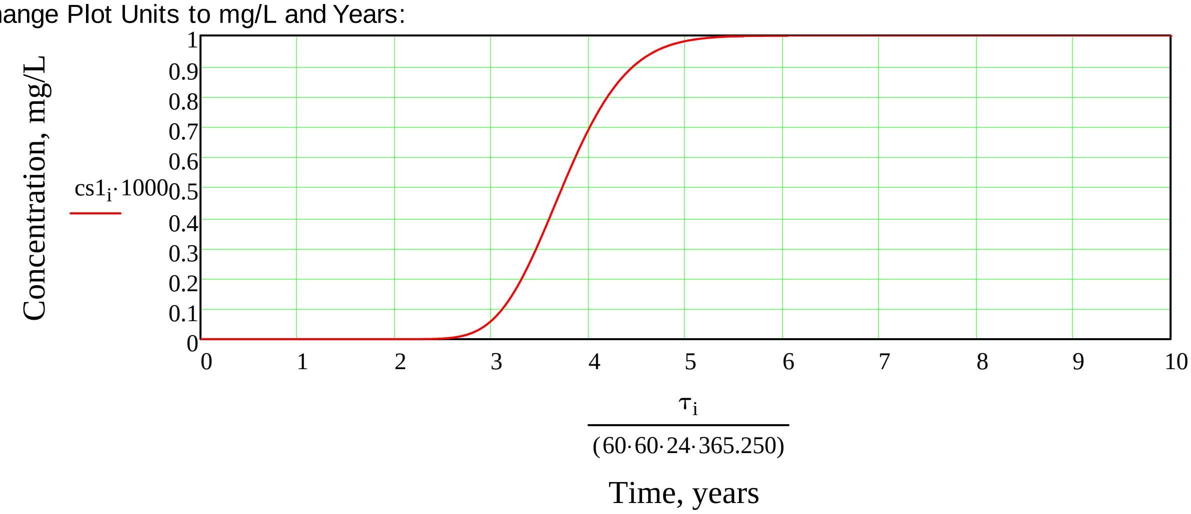
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

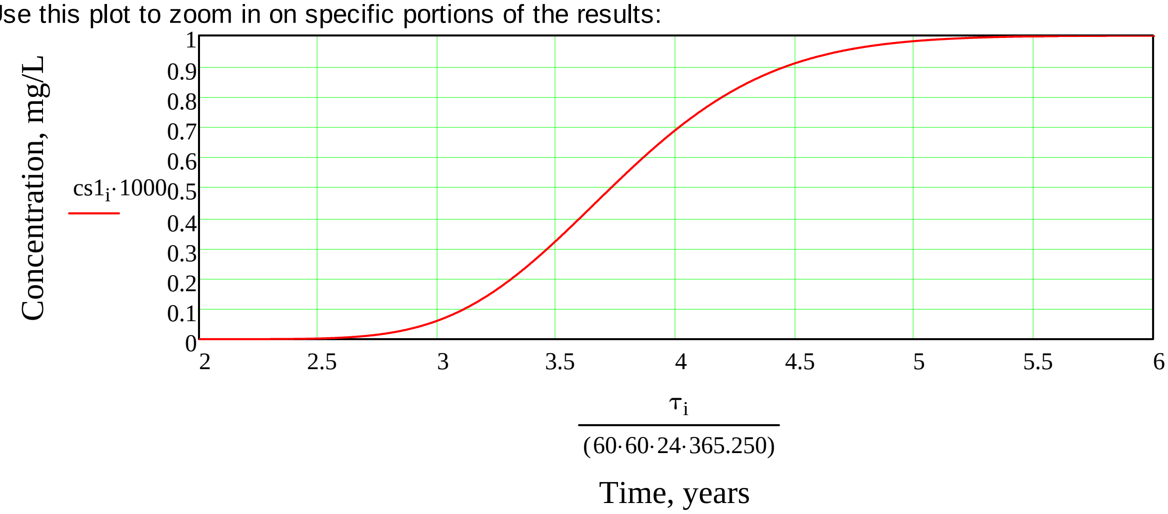
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1yr$ $t_{2\_90\%} := 4.5yr$ $t_{2\_100\%} := 5.5yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^3 \cdot day$ $t_{2\_90\%} = 1.644 \times 10^3 \cdot day$ $t_{2\_100\%} = 2.009 \times 10^3 \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 18.142 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 800 \cdot ft$ Southeast - Northwest

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 115.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 115.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 7.7 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 7.7 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 7.7 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 7.7 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 11.55 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.77 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.77 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

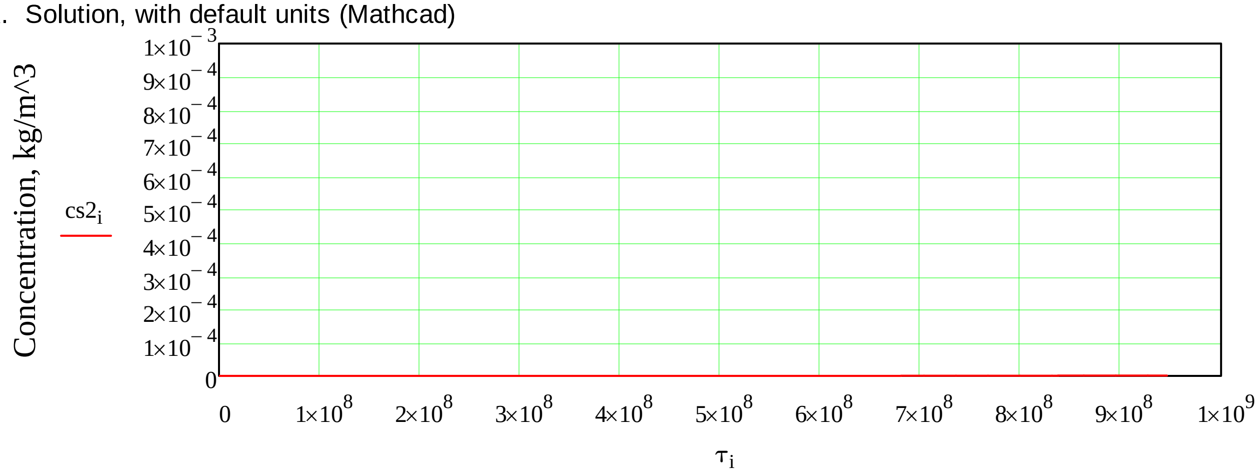
$i := 0,1..10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{day}$$

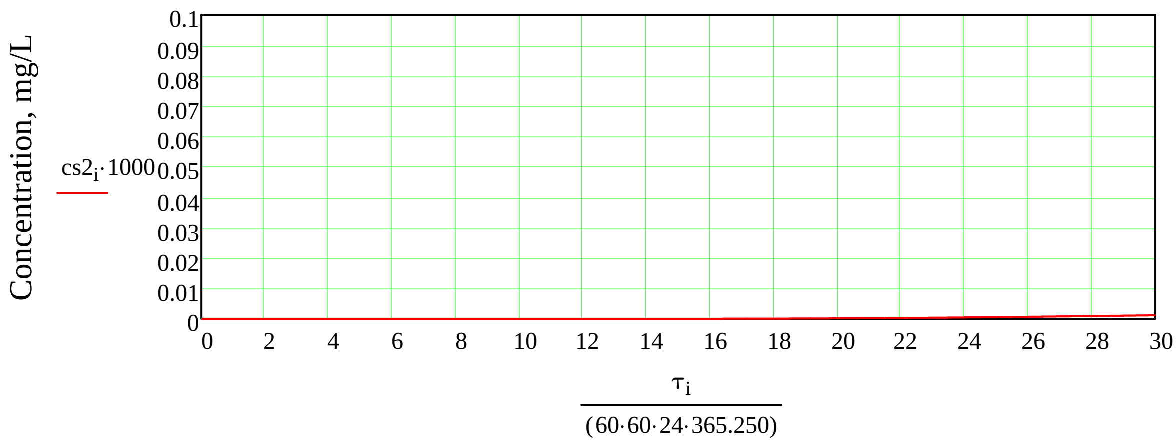
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)

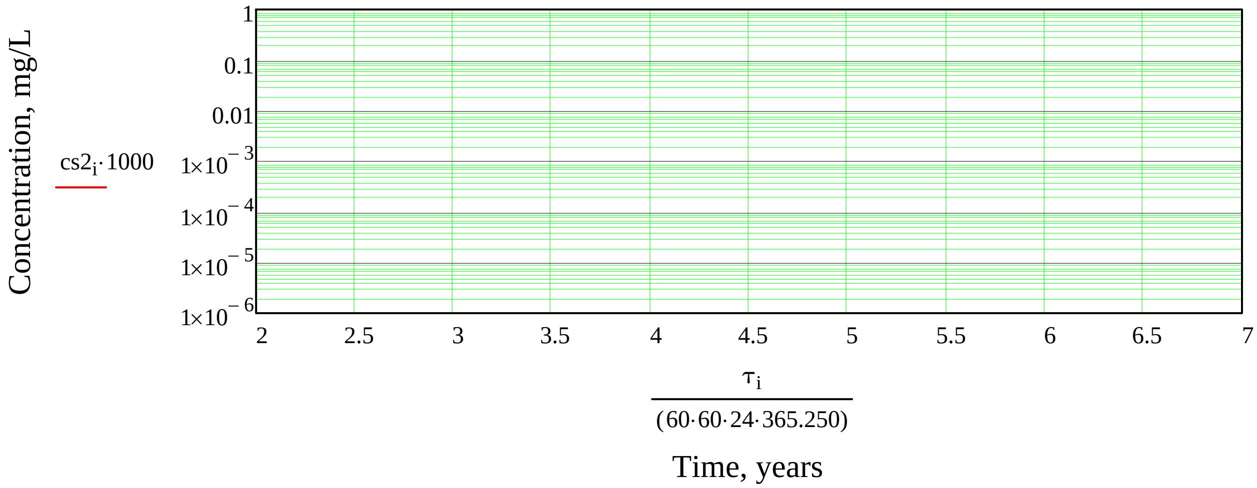


B. Change Plot Units to mg/L and Years:

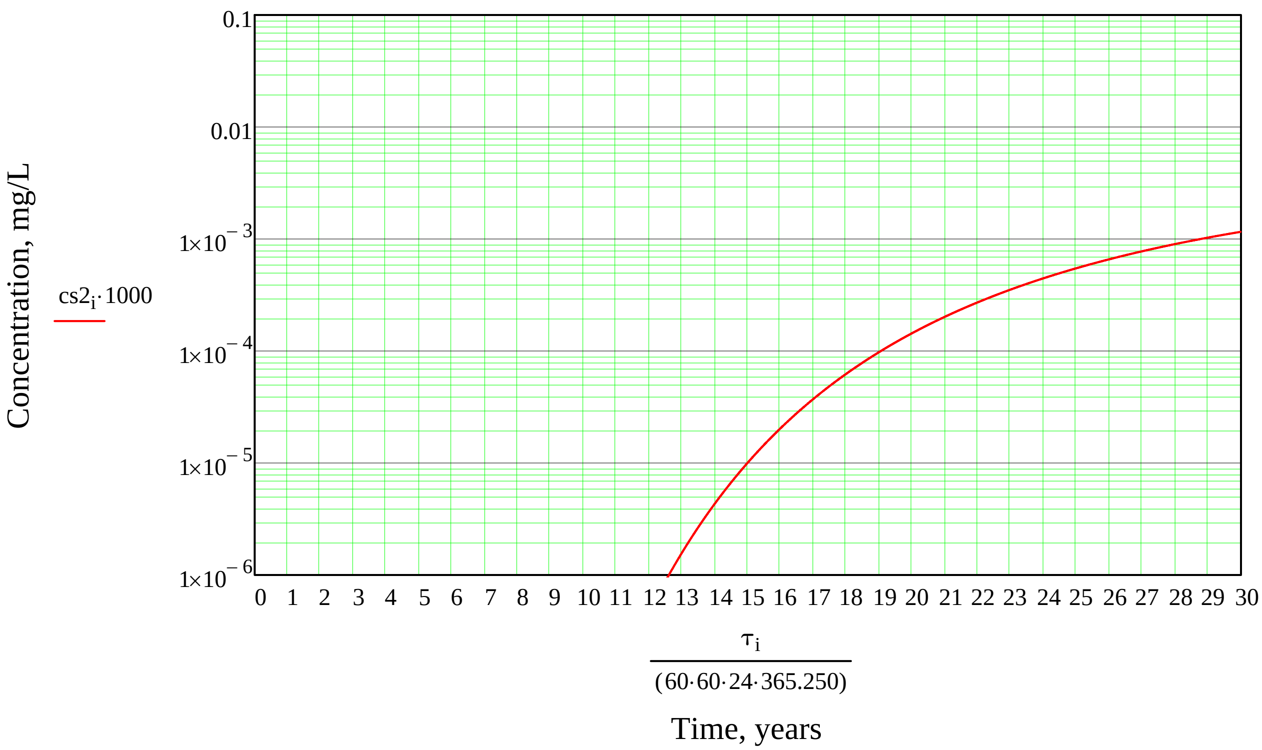


$x_2 = 770 \cdot ft$ $y_2 = 0$ $z_2 = 300 \cdot ft$

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 770 \cdot ft$ $y_2 = 0$ $z_2 = 300 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
Complete Failure of the engineered systems of the landfill. Flow is vertically down through Layer 1 (Imported Soil layer); then through Layer 2 (Till); and horizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor B.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1600ft$ Southeast - Northwest

$Length_1 := 255ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 9.366 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Imported Soil Layer	Native Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 1ft$	$x_2 := 4.ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 865.149 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 0.601 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

$LQ := \frac{Q_1}{Area_1}$ $LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

LQ was Used to determine the value of a_3

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day..

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{Q_2}{(k_2) \cdot Area_1}$ $i_2 = 0.011$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the east side of the Imported Soil Layer in Cell 11):

Sens. Rec	X_3 (ft)	Z_3 (ft)
A	540	300
B	770	300

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_3 := 770ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 300ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 90.709 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 4 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.04 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.04 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 0.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 0.4 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 0.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 0.4 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

These Calcs

Downgradient distances: $X_3 := 50ft$ $\quad Y_3 := 50ft$ $\quad Z_3 := 50ft$

Lateral dispersivity $\quad \alpha_{y\_BR} := \frac{20ft}{Y_3} \quad \alpha_{y\_BR} = 0.4$ $\quad$ Z axis

Downgradient dispersivity: $\quad \alpha_{x\_BR} := \frac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3} \quad \alpha_{x\_BR} = 1.2$ $\quad$ X axis

Vertical dispersivity $\quad \alpha_{z\_BR} := \frac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3} \quad \alpha_{z\_BR} = 0.02$ $\quad$ Y axis

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2000 \\ 5000 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 127.5 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 800 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

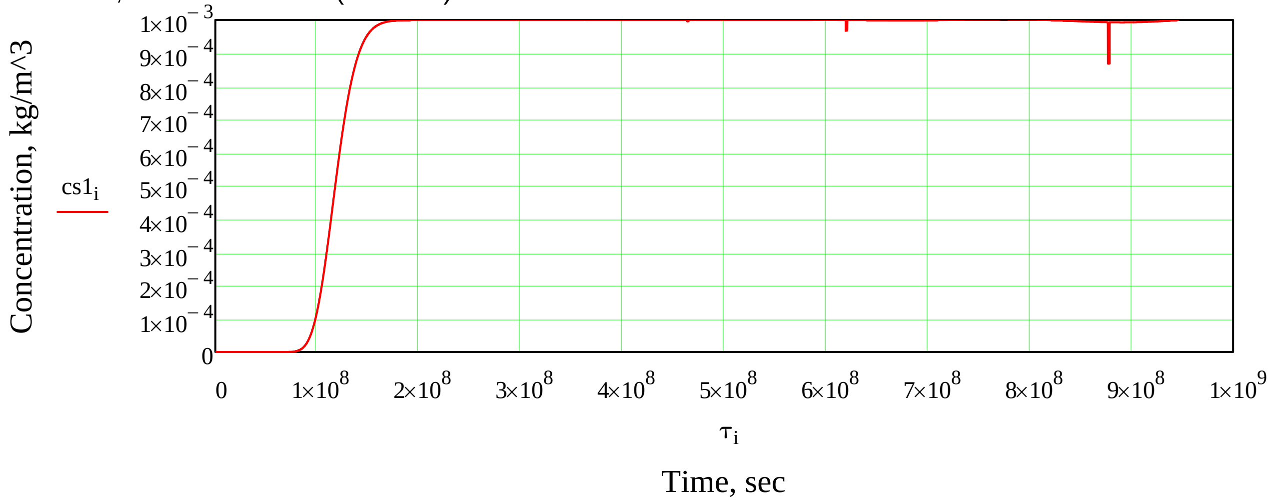
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0,1..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

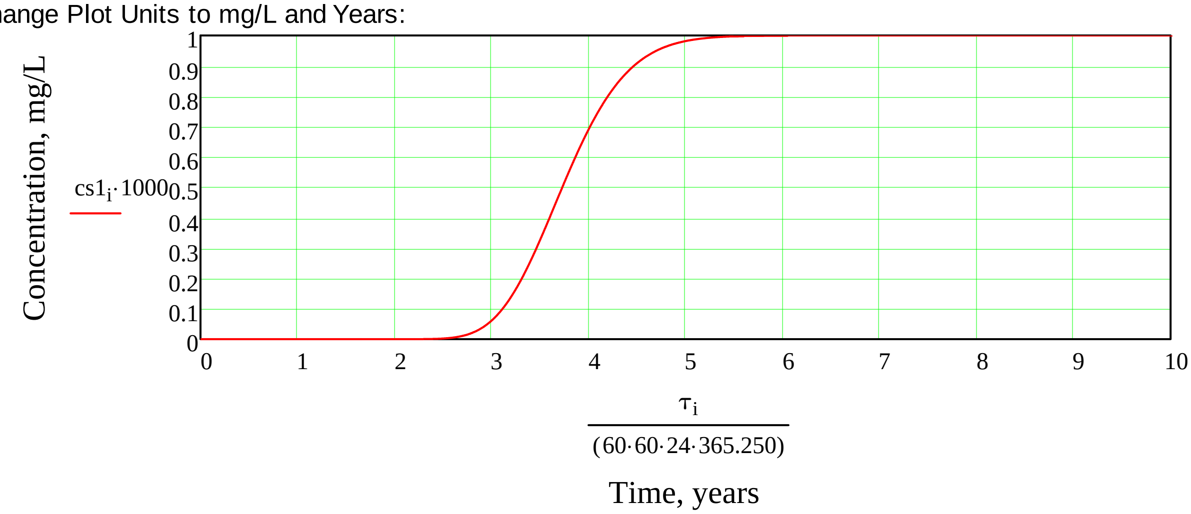
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

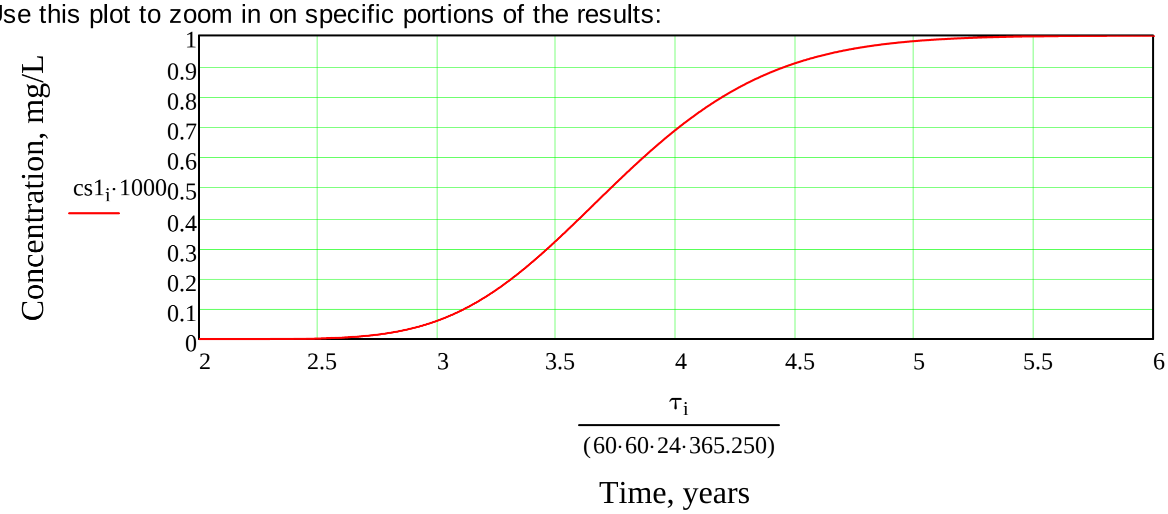
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $\quad t_{2\_10\%} := 3.1yr$ $\quad t_{2\_90\%} := 4.5yr$ $\quad t_{2\_100\%} := 5.5yr$

$t_{2\_1\%} = 913.105 \cdot day$ $\quad t_{2\_10\%} = 1.132 \times 10^3 \cdot day$ $\quad t_{2\_90\%} = 1.644 \times 10^3 \cdot day$ $\quad t_{2\_100\%} = 2.009 \times 10^3 \cdot day$

Use the values above for time steps 3, 4, 5, and 6 below

A. Source to Layer 2:

number of concentration steps $\quad j_2 := 7$

Iteration intervals $\quad i := 1, 2 .. 10950$

Concentration (mg/l) $\quad$ Source Term (days)

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $\quad a_2 := a_1 \quad a_2 = 127.5 \cdot ft$

Half-Width of Source in Z-direction $\quad b_2 := b_1 \quad b_2 = 800 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $\quad v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

Distance of interest (x): $\quad x_2 = 4 \cdot ft \quad$ Vertical (down) $\quad$ to Top of Layer 3

Lateral distance of interest (y): $\quad y_2 := 0ft$

Lateal distance of interest (z): $\quad z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $\quad Dx_2 := \alpha x_2 \cdot v_2 \quad Dx_2 = 4.535 \times 10^{-5} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $\quad Dy_2 := \alpha y_2 \cdot v_2 \quad Dy_2 = 4.535 \times 10^{-4} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $\quad Dz_2 := \alpha z_2 \cdot v_2 \quad Dz_2 = 4.535 \times 10^{-4} \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \text{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \text{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \text{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \text{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

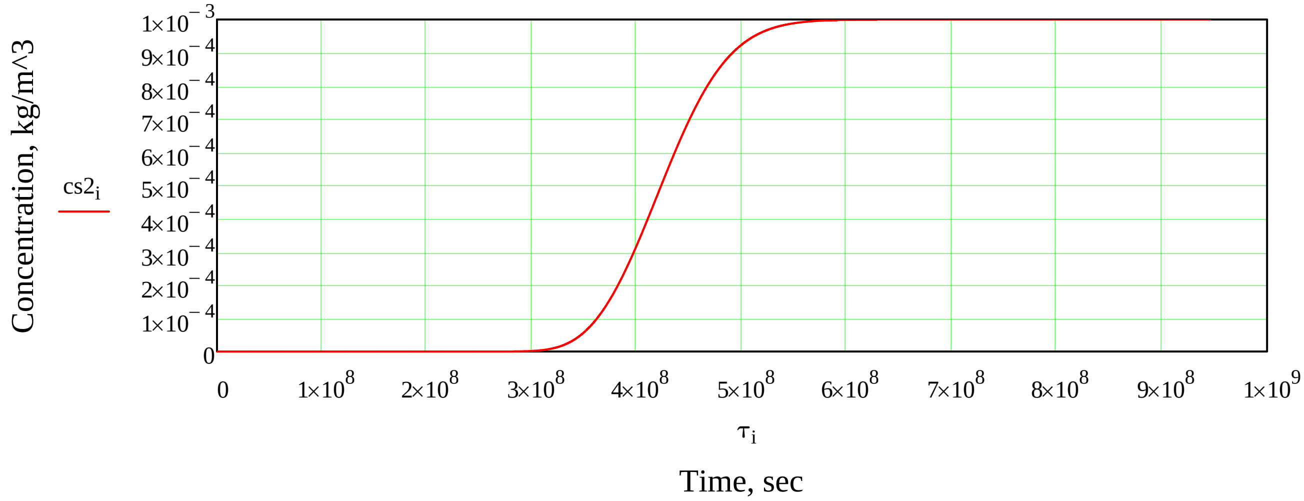
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 0, 1 .. 10950$ $\tau_i := i\cdot day$

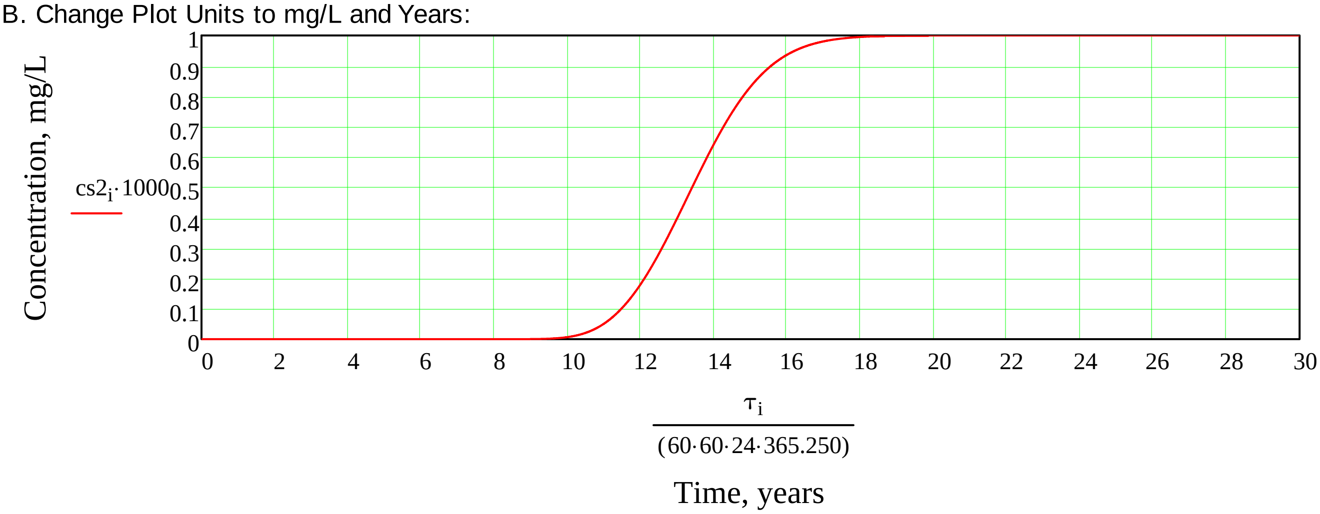
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

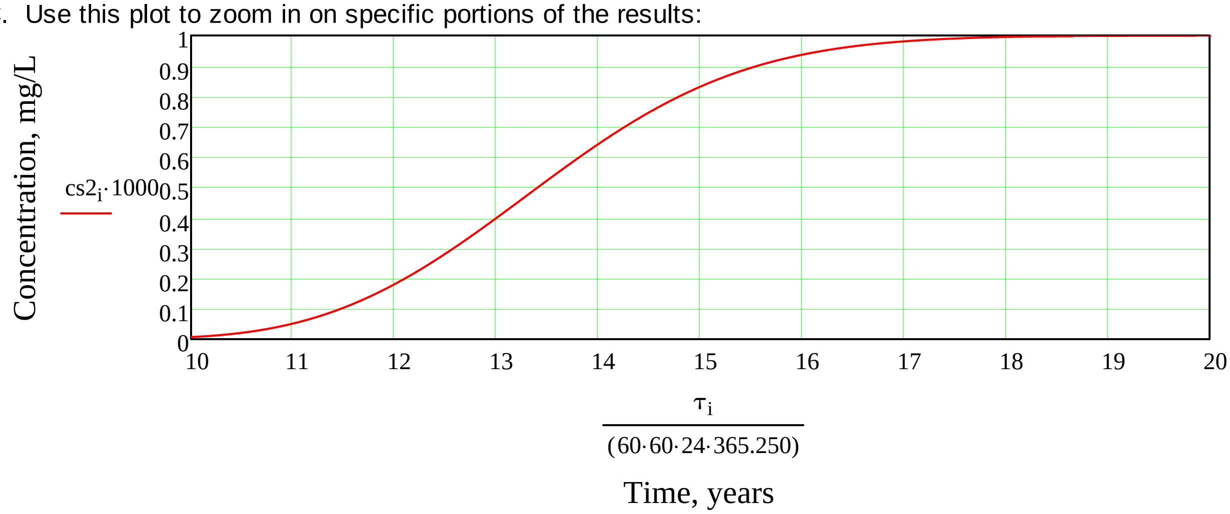
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

$t_{3\_1\%} := 10 \cdot yr$ $t_{3\_10\%} := 11.5yr$ $t_{3\_90\%} := 15.5yr$ $t_{3\_100\%} := 18yr$

$t_{3\_1\%} = 3.156 \times 10^{8} s$ $t_{3\_10\%} = 4.2 \times 10^{3} \cdot day$ $t_{3\_90\%} = 5.661 \times 10^{3} \cdot day$ $t_{3\_100\%} = 6.574 \times 10^{3} \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 3155 \\ 3156 \\ 4200 \\ 5661 \\ 6574 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 3

This source sub-divides the results from Layer 2.

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 90.709 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 800 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 924 \cdot ft$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 924 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 308 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 308 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 15.4 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 15.4 \cdot ft$ Lateral (northwest-southeast)

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 4.62 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.54 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 77 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{v_3^{\,2}}{4\cdot Dx_3}\cdot t - \frac{x_3^{\,2}}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \operatorname{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \operatorname{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \operatorname{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \operatorname{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

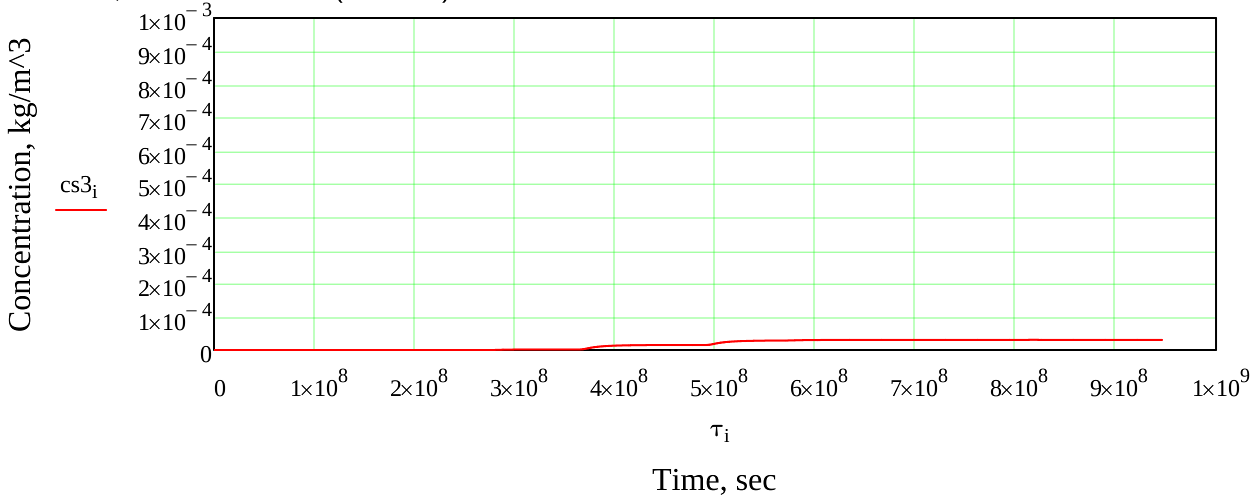
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 0,1\,..\,10950$ $\qquad \tau_i := i\cdot day$

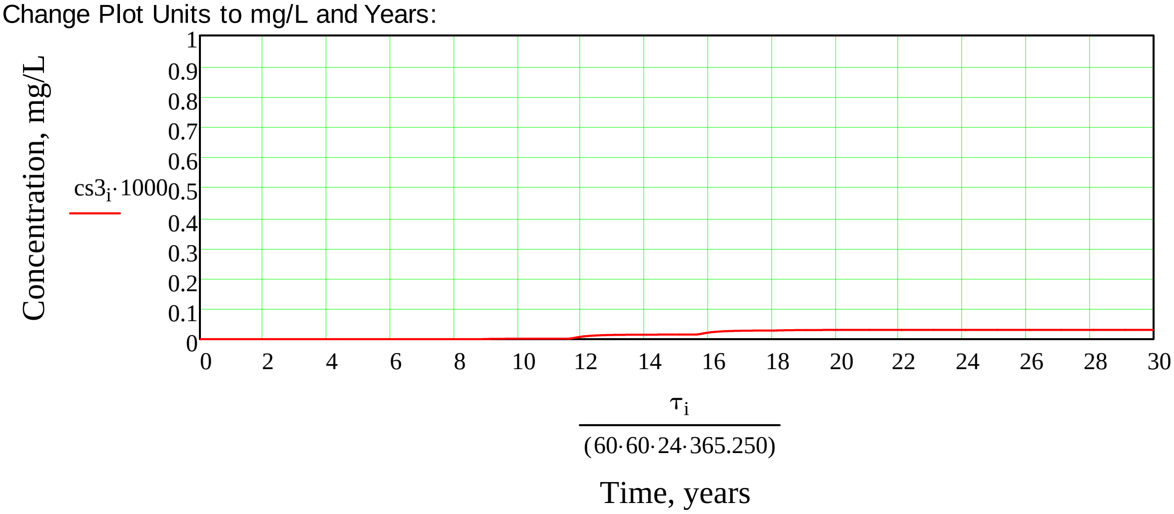
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

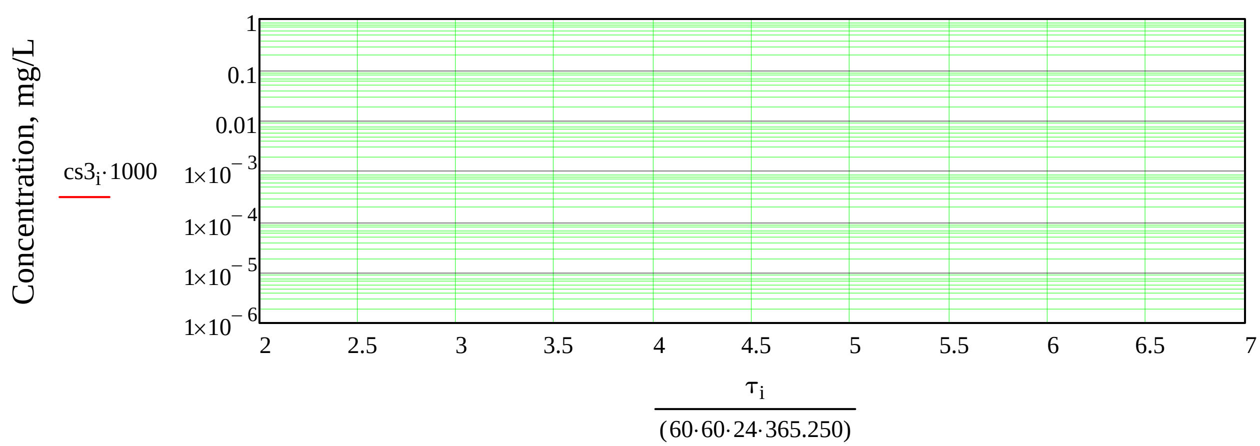
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

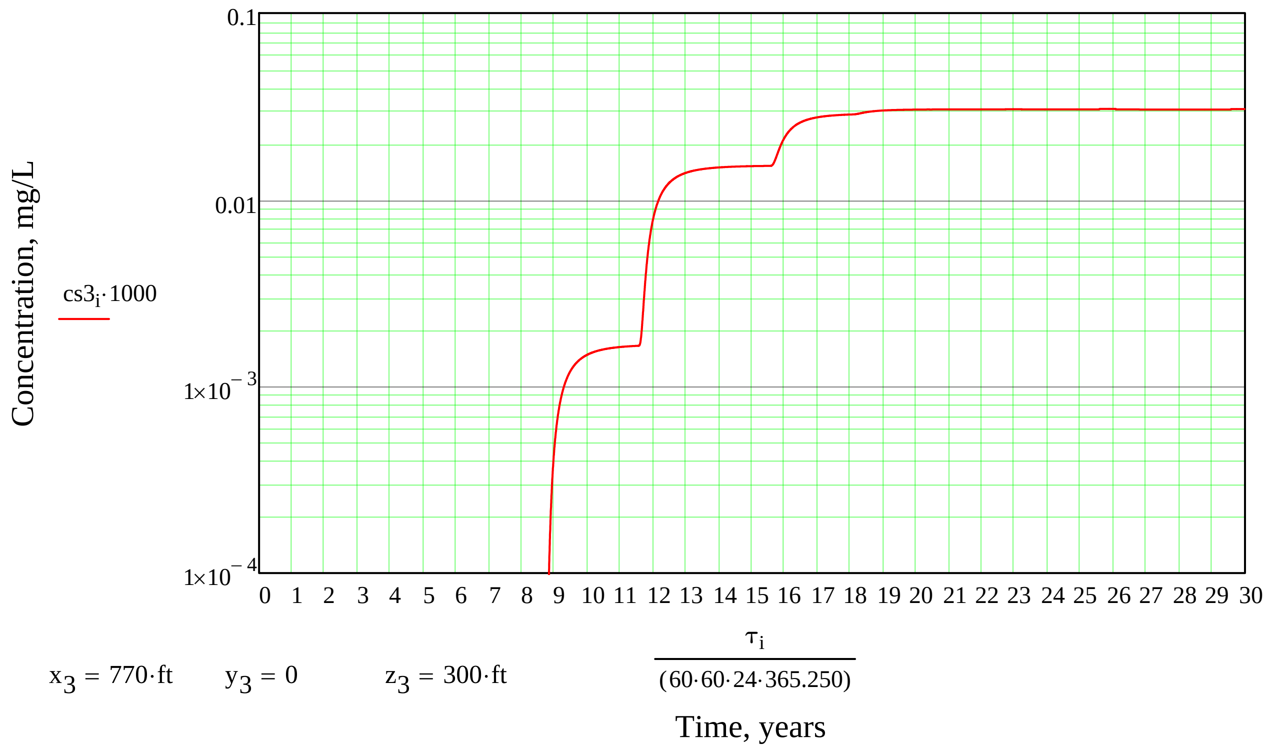


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 770 \cdot ft$ $y_3 = 0$ $z_3 = 300 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 770 \cdot ft$ $y_3 = 0$ $z_3 = 300 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill (Cells 12 and 13). Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor C.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1600ft$ Southeast - Northwest

$Length_1 := 255ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\quad Area_1 = 9.366 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Imported Soil Layer	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 865.149 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.601 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_11} := 201.95ft$ $\quad Head_A := 60ft$

$i_2 := \frac{Head_{Cell\_11} - Head_A}{540ft}$ $\quad i_2 = 0.263$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 0.028 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$$i_2 := \frac{Q_2}{(k_2)\cdot Area_1} \qquad i_2 = 0.011$$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cell 14):

distance of interest (x): $x_2 := 930ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 340ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2} \qquad a_2 = 18.142 \cdot ft$$

Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

				Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1 \quad \alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1 \quad \alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1 \quad \alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

				Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 930 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 139.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2 \quad \alpha x_2 = 139.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 9.3 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2 \quad \alpha y_2 = 9.3 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 9.3 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2 \quad \alpha z_2 = 9.3 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 127.5 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 800 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

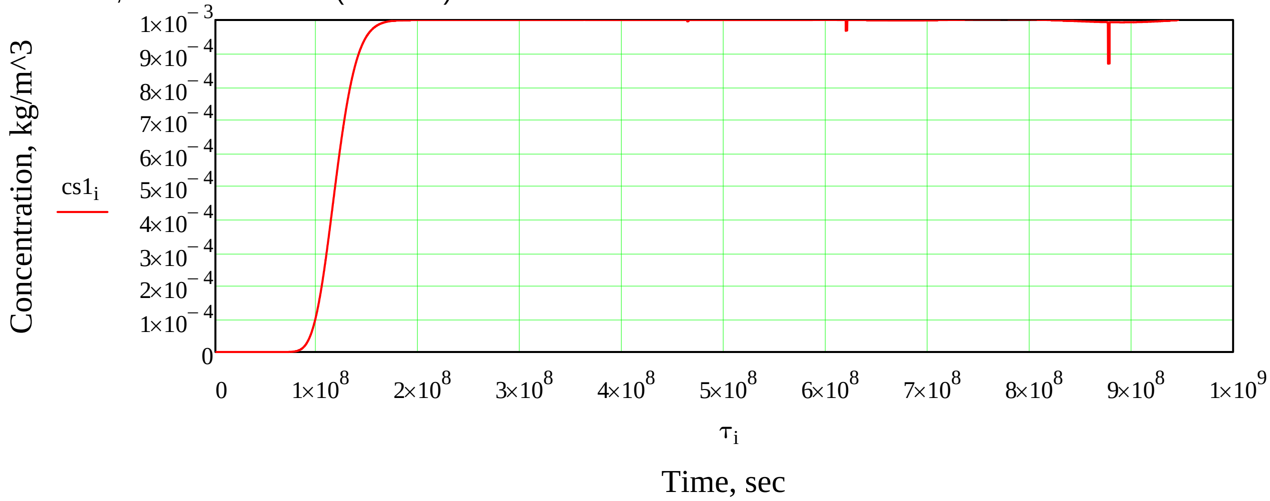
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0,1..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

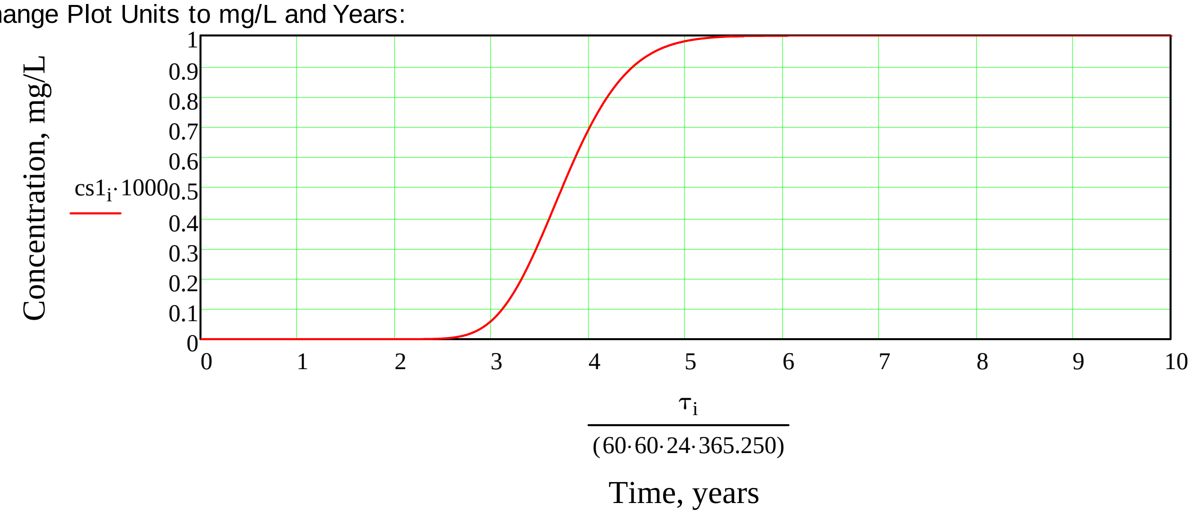
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1(x_1,y_1,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1(x_1,y_1,|\tau_i - ti_n|)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

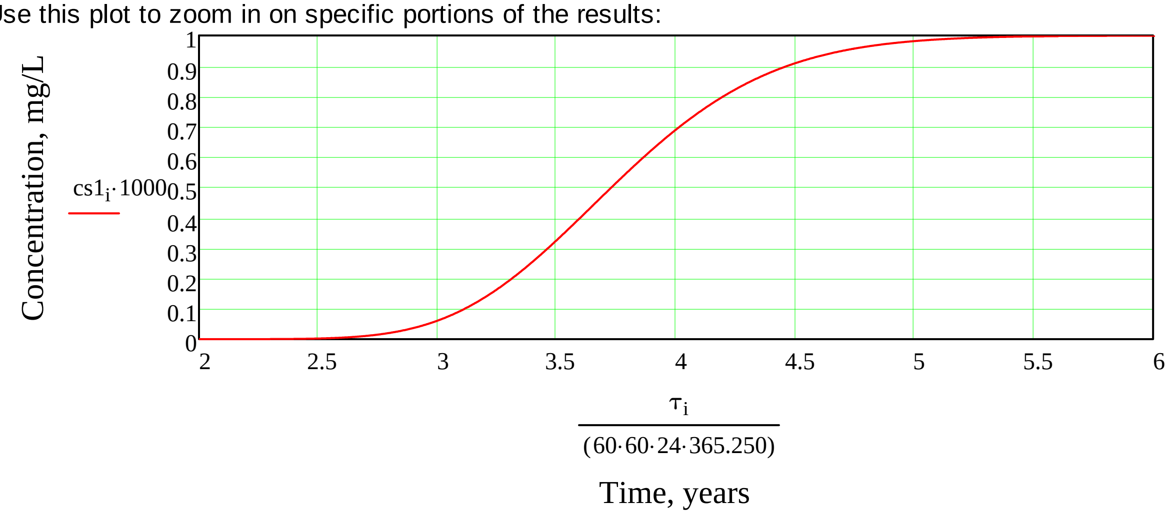
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1yr$ $t_{2\_90\%} := 4.5yr$ $t_{2\_100\%} := 5.5yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^3 \cdot day$ $t_{2\_90\%} = 1.644 \times 10^3 \cdot day$ $t_{2\_100\%} = 2.009 \times 10^3 \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 18.142 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 800 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 139.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 139.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 9.3 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 9.3 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 9.3 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 9.3 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 13.95 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.93 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.93 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

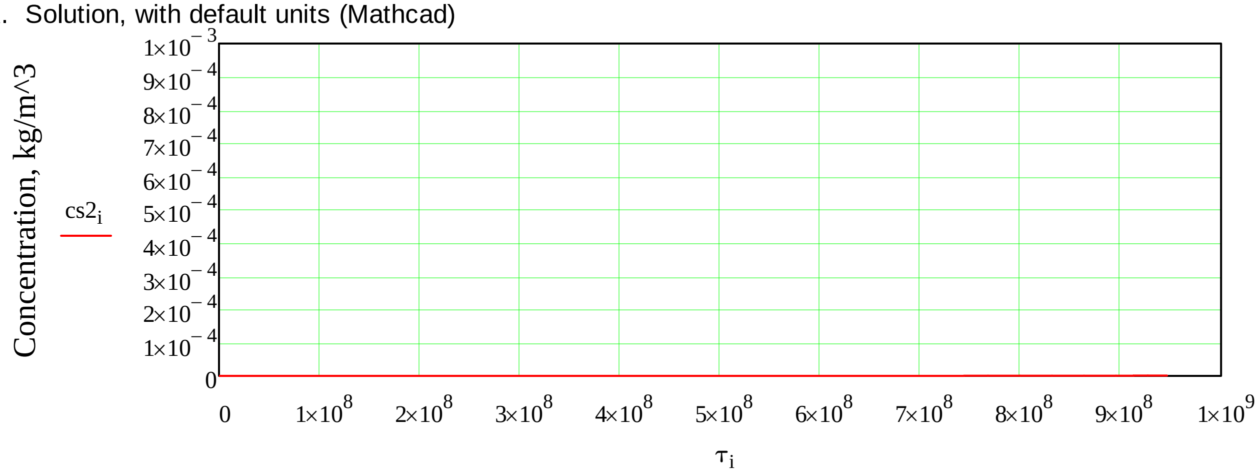
$i := 0,1..10950$ $\qquad \tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2(x_2,y_2,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2(x_2,y_2,|\tau_i - ti_n|)\right)\right]\right]$$

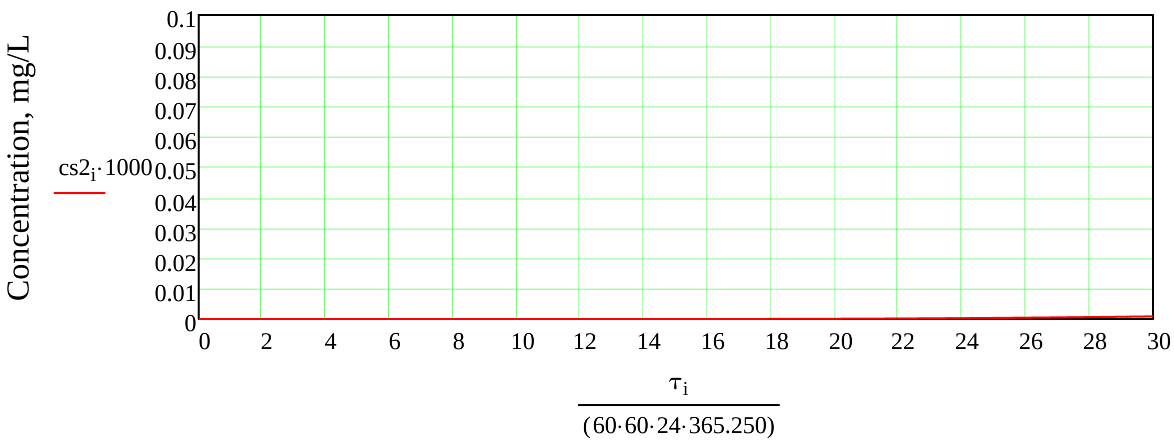
5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

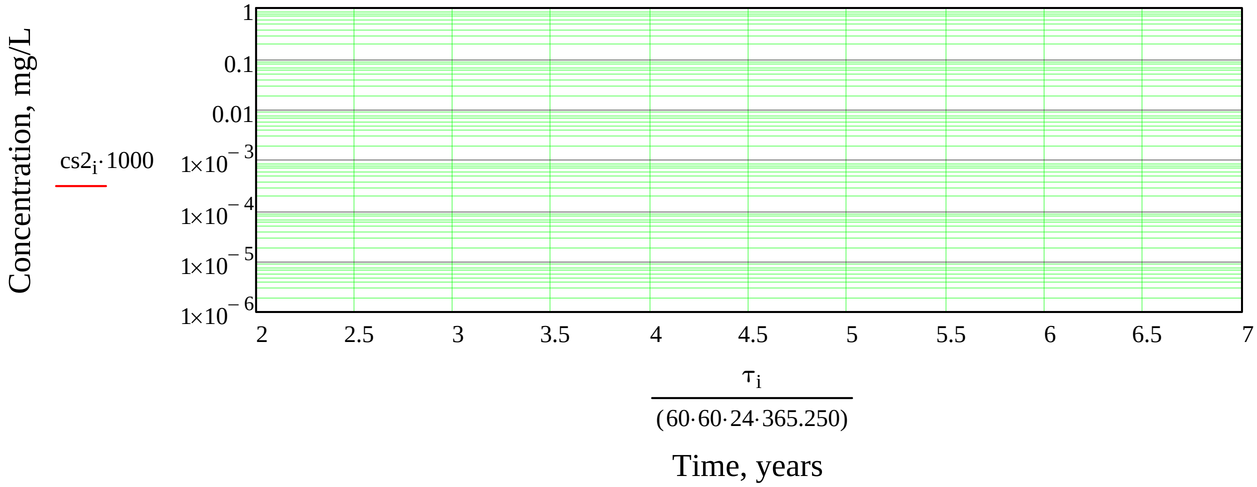
Time, sec



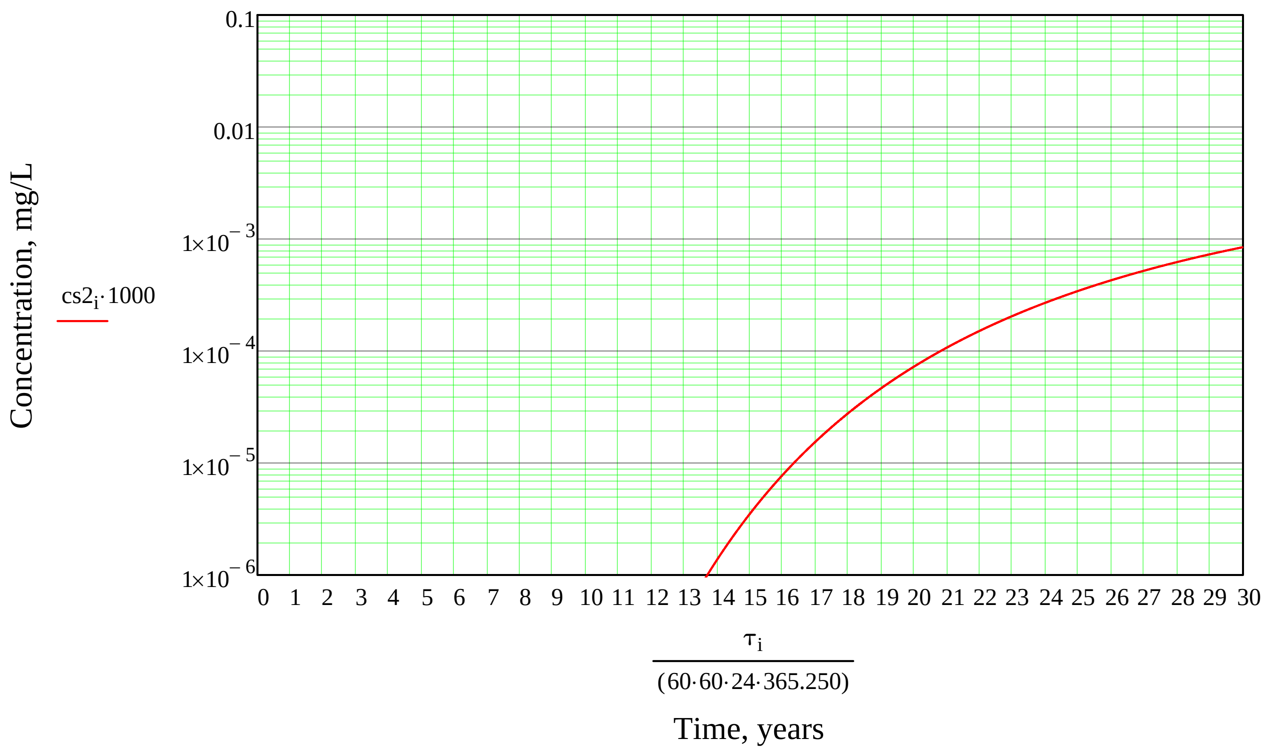
$x_2 = 930 \cdot ft$ $y_2 = 0$ $z_2 = 340 \cdot ft$

Time, years

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 930 \cdot ft$ $y_2 = 0$ $z_2 = 340 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
Complete Failure of the engineered systems of the landfill. Flow is from Cell 12 &13; then vertically down through Layer 1 (Imported Soil layer); then through Layer 2 (Till); and horizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor C.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1100ft$ Southeast - Northwest

$Length_1 := 970ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\qquad Area_1 = 24.495 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Imported Soil Layer	Native Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 1ft$	$x_2 := 20.ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\qquad Q_1 = 2.263 \times 10^3 \cdot \frac{gal}{day}$ $\qquad Q_2 := Q_1$ $\qquad Q_1 = 1.571 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\qquad v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

$LQ := \frac{Q_1}{Area_1}$ $\qquad LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

LQ was Used to determine the value of a_3

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $\qquad v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day..

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{Q_2}{(k_2) \cdot Area_1}$ $\qquad i_2 = 0.011$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the east side of the Imported Soil Layer in Cell 11):

distance of interest (x): $x_3 := 930ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 340ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3} \qquad a_3 = 62.362 \cdot ft$$

Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 20 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.2 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.2 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 2 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 2 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 2 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 2 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

These Calcs

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

Lateral dispersivity $\alpha_{y\_BR} := \dfrac{20ft}{Y_3}$ $\alpha_{y\_BR} = 0.4$ Z axis

Downgradient dispersivity: $\alpha_{x\_BR} := \dfrac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$ $\alpha_{x\_BR} = 1.2$ X axis

Vertical dispersivity $\alpha_{z\_BR} := \dfrac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$ $\alpha_{z\_BR} = 0.02$ Y axis

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 2000 \\ 5000 \\ 10950 \end{pmatrix} \cdot day$ This is a continuous source.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 485 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 550 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

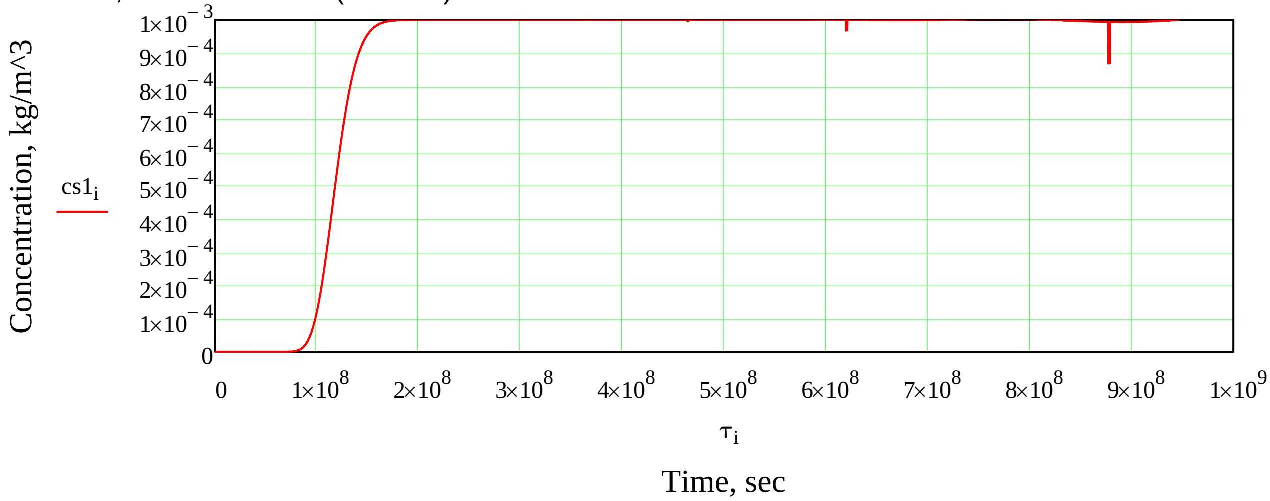
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0,1..10950$ $\qquad$ $\tau_i := i\cdot day$

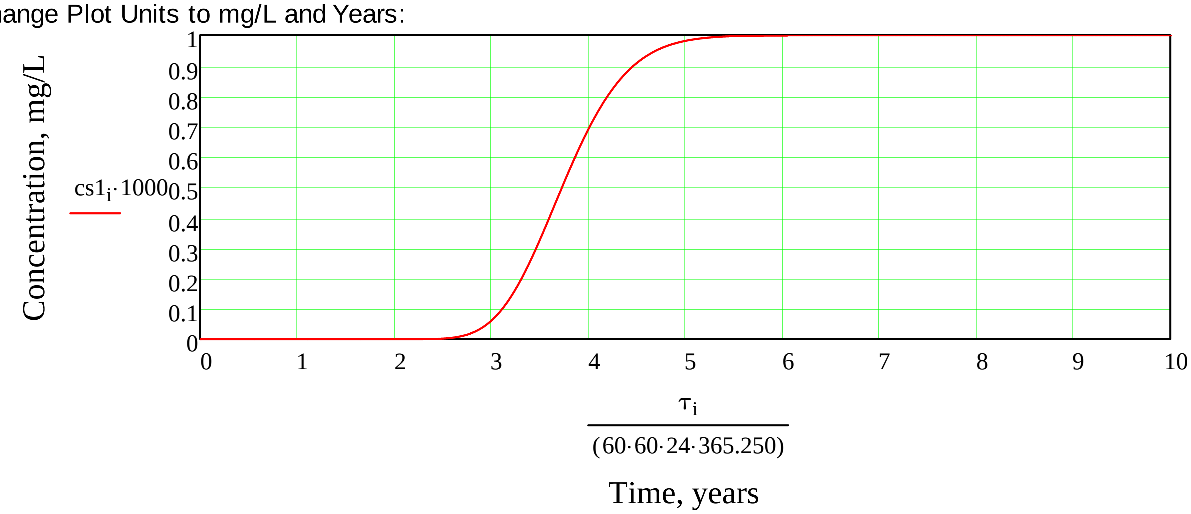
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

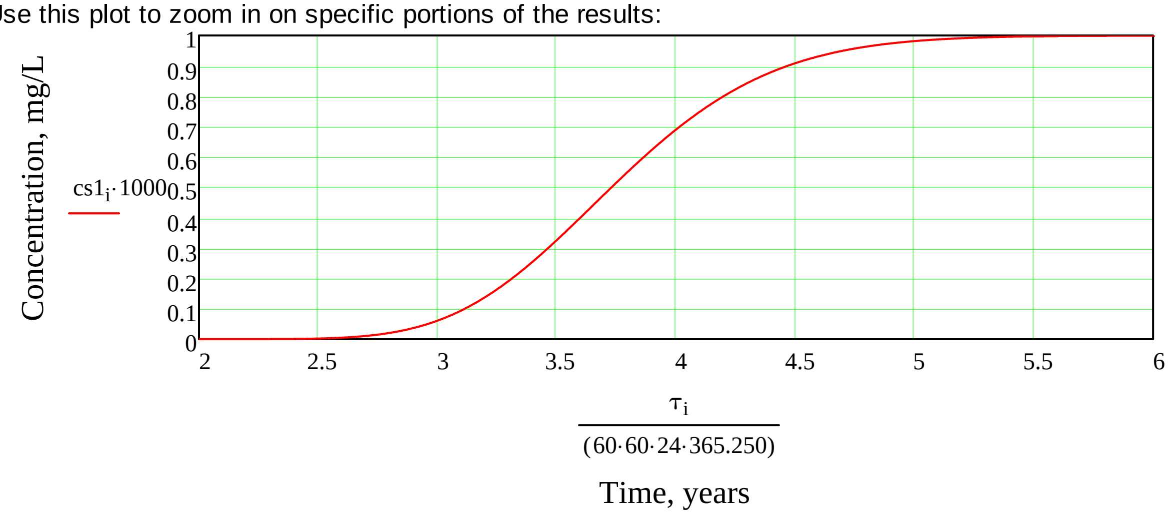
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1yr$ $t_{2\_90\%} := 4.5yr$ $t_{2\_100\%} := 5.5yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^3 \cdot day$ $t_{2\_90\%} = 1.644 \times 10^3 \cdot day$ $t_{2\_100\%} = 2.009 \times 10^3 \cdot day$

Use the values above for time steps 3, 4, 5, and 6 below

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 485 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 550 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 20 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$

Lateal distance of interest (z): $z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 2.268 \times 10^{-4} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 2.268 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 2.268 \times 10^{-3} \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

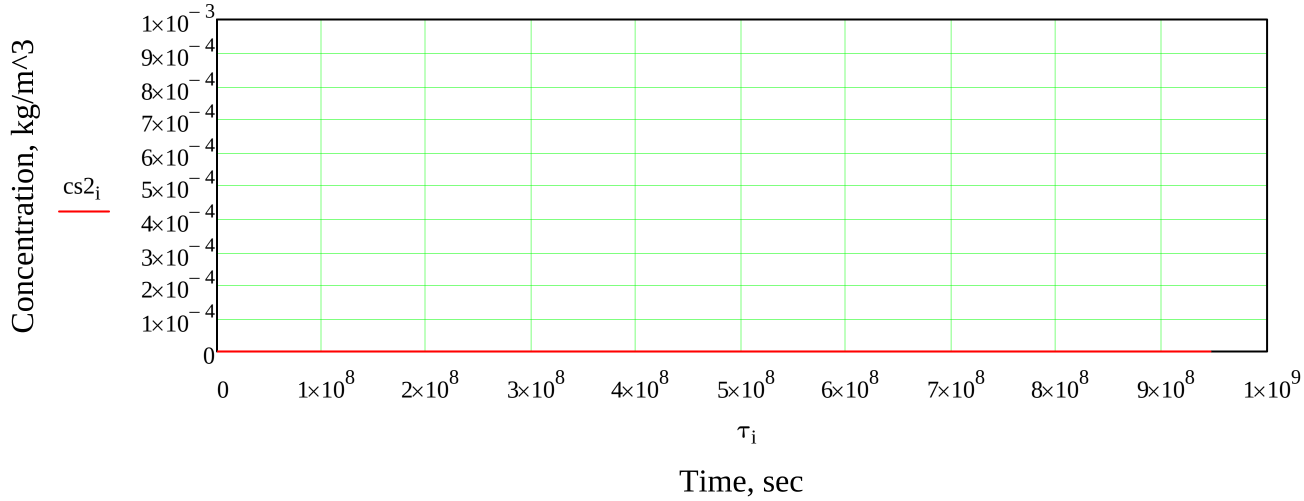
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 0,1..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

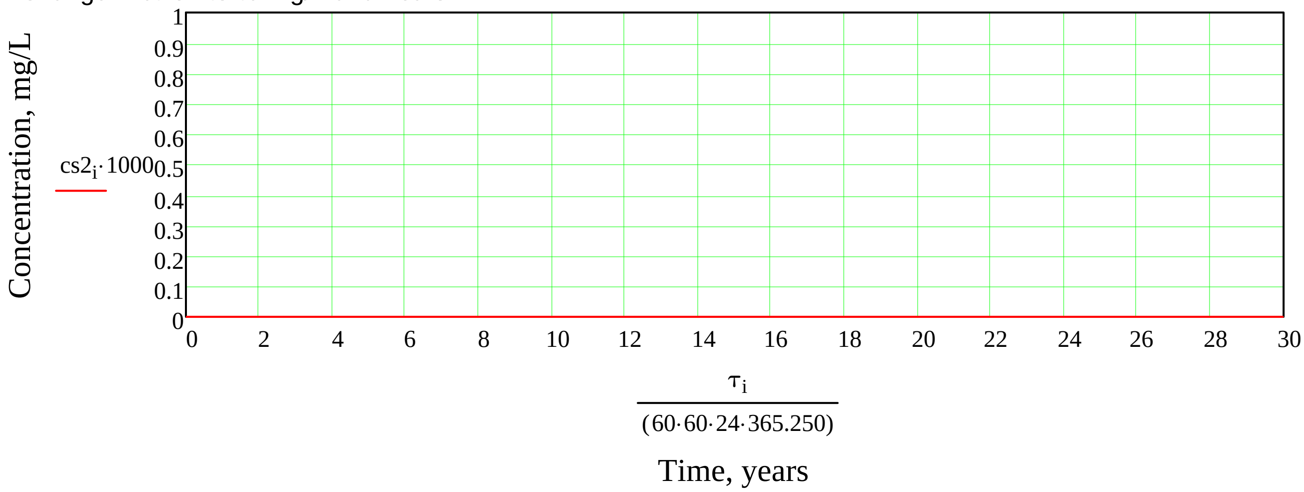
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

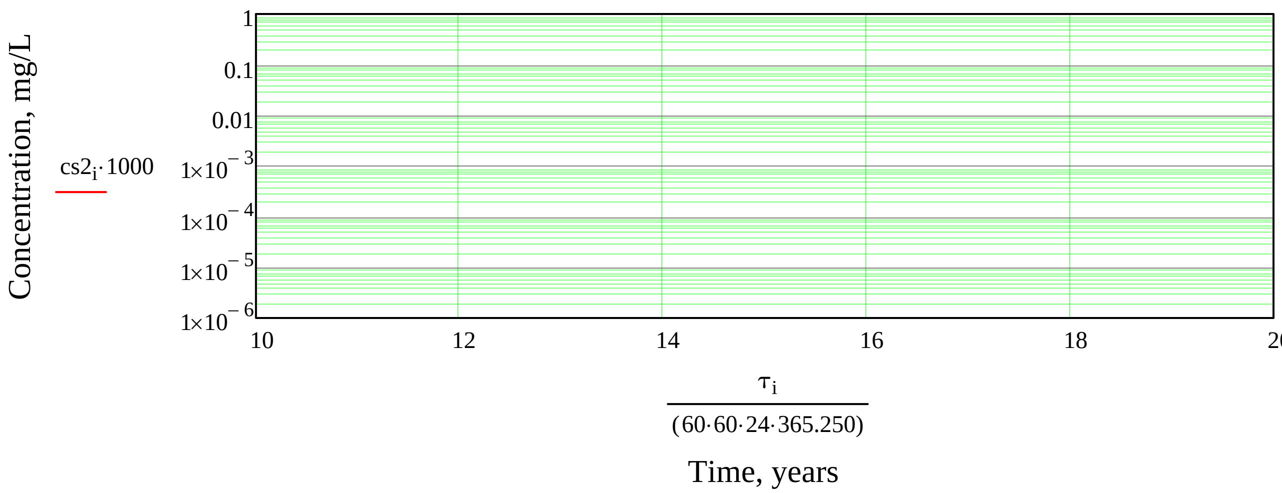
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

Concentration leaving the base of Layer 2 (Till) is <1 x 10-6 mg/L; therefore, the analysis stops here

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 3155 \\ 3156 \\ 4200 \\ 5661 \\ 6574 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 3

This source sub-divides the results from Layer 2.

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 62.362 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 550 \cdot ft$ Southeast - Northwest

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 1.116 \times 10^3$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 1.116 \times 10^3 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 372 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 372 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 18.6 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 18.6 \cdot ft$ Lateral

Note: This was rotated to use correct orientation from Tracer Test.

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 5.58 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.86 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 93 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \text{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \text{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \text{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \text{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

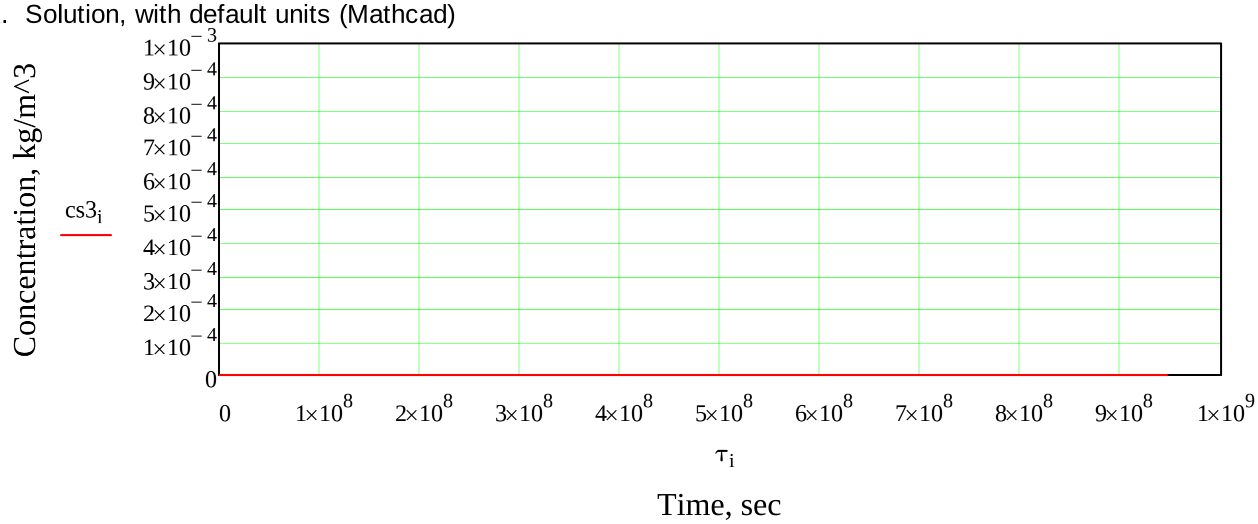
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 0,1..10950$ $\qquad$ $\tau_i := i\cdot day$

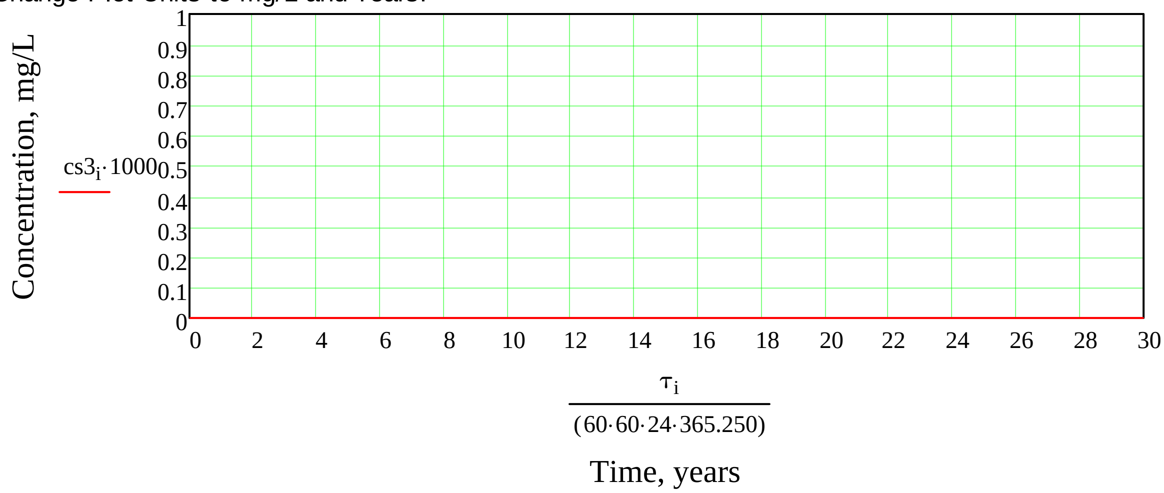
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

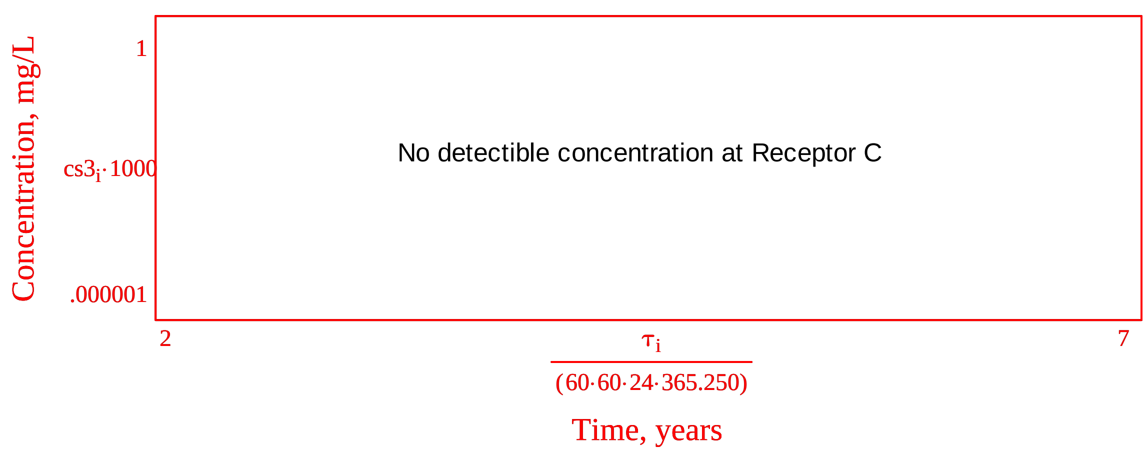
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

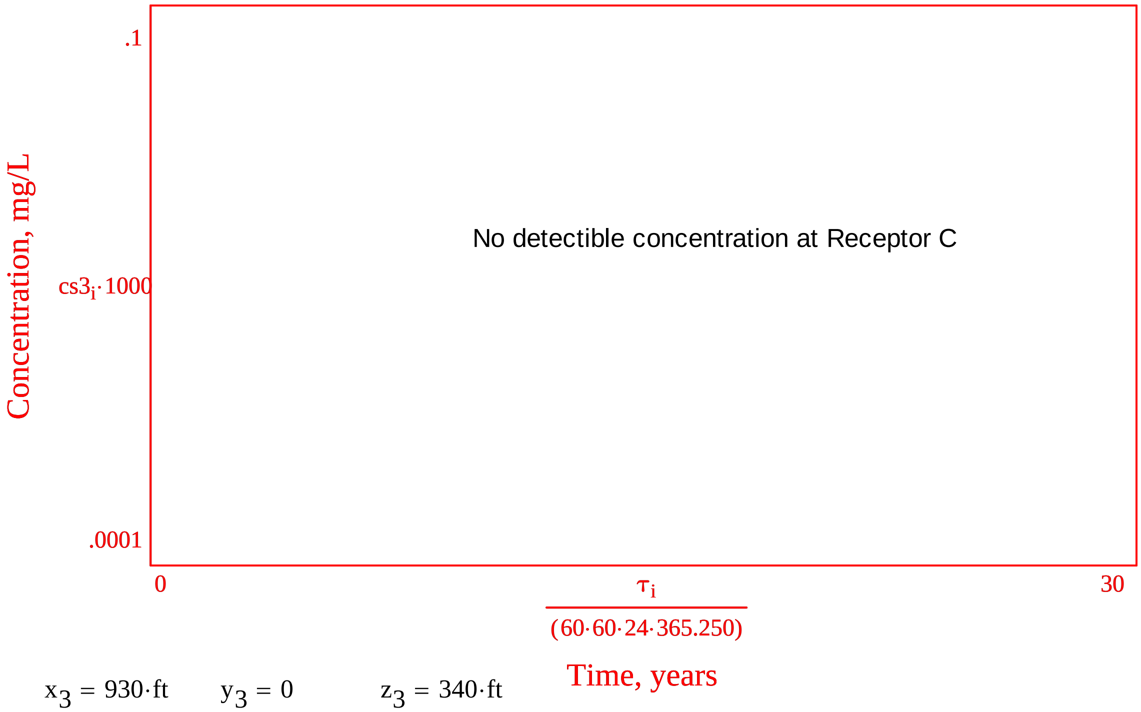


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 930 \cdot ft$ $y_3 = 0$ $z_3 = 340 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 930 \cdot ft$ $y_3 = 0$ $z_3 = 340 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill (Cell 14-16). Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor E.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1200ft$ North - South

Flow is generally Northeasterly

$Length_1 := 720ft$ Layers 1,2 = East - West (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 19.835 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Imported Soil Layer	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2

From Shallow Bedrock Area east side of Cell 11 to NE , Point A on Figure 7-1 in Vol. II of Application.

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 1.832 \times 10^3 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 1.272 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_15} := 200.44ft$ $Head_D := 149ft$

$i_2 := \frac{Head_{Cell\_15} - Head_D}{540ft}$ $i_2 = 0.095$ $v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $v_{gw} = 0.01 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$$i_2 := \frac{Q_2}{(k_2) \cdot Area_1} \qquad i_2 = 0.011$$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cell 11):

Sens. Rec	X_3 (ft)	Z_3 (ft)
D	810	600
E	450	200
F	450	340
G	870	600

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_2 := 810ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 600ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2} \qquad a_2 = 13.606 \cdot ft$$

Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 810 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 121.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 121.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 8.1 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 8.1 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 8.1 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 8.1 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 360 \cdot ft$ Northeast - Southwest

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 600 \cdot ft$ Southeast - Northwest

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$ Northeast - Southwest

Lateral distance of interest (z): $z_1 := 0ft$ Southeast - Northwest

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot \exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

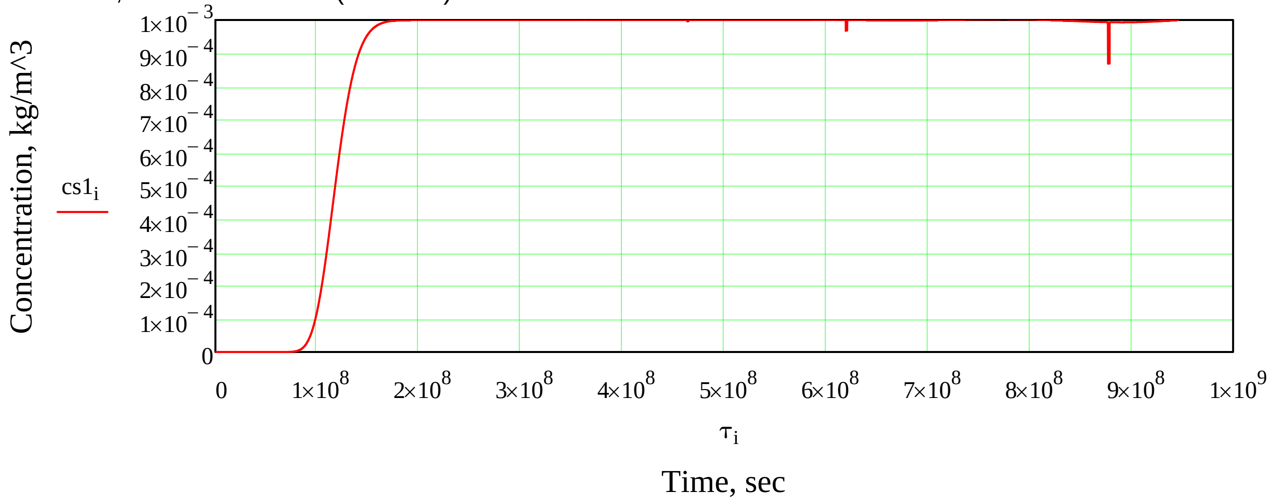
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0, 1 .. 10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

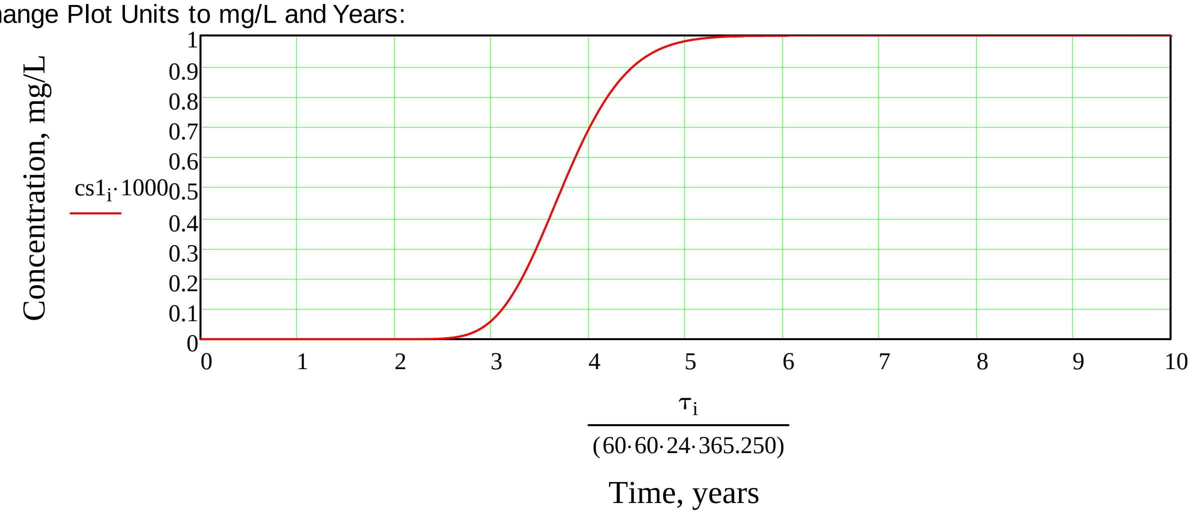
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

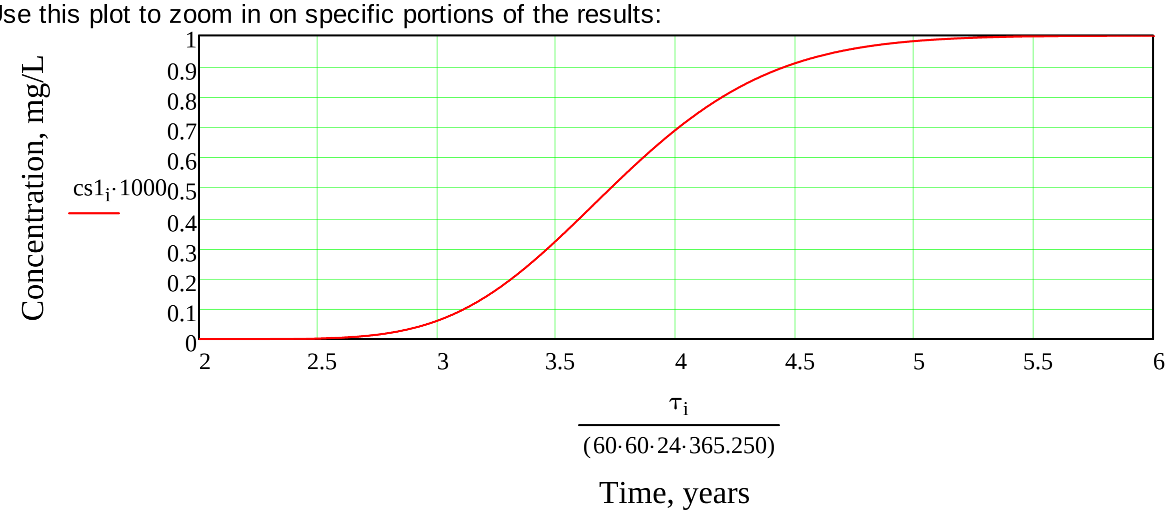
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1 \cdot yr$ $t_{2\_90\%} := 4.5 \cdot yr$ $t_{2\_100\%} := 5.5 \cdot yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^{3} \cdot day$ $t_{2\_90\%} = 1.644 \times 10^{3} \cdot day$ $t_{2\_100\%} = 2.009 \times 10^{3} \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 13.606 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 600 \cdot ft$ Southeast - Northwest

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 121.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 121.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 8.1 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 8.1 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 8.1 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 8.1 \cdot ft$ Lateral (northwest-southeast)

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 12.15 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.81 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.81 \cdot \frac{ft^2}{day}$

<u>4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):</u>

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

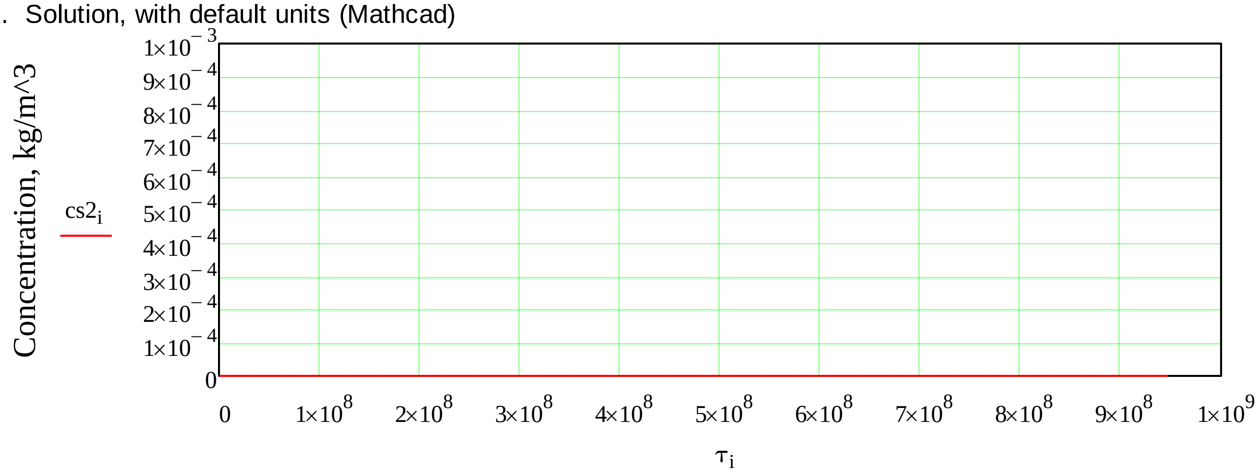
$i := 0,1..10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{day}$$

$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

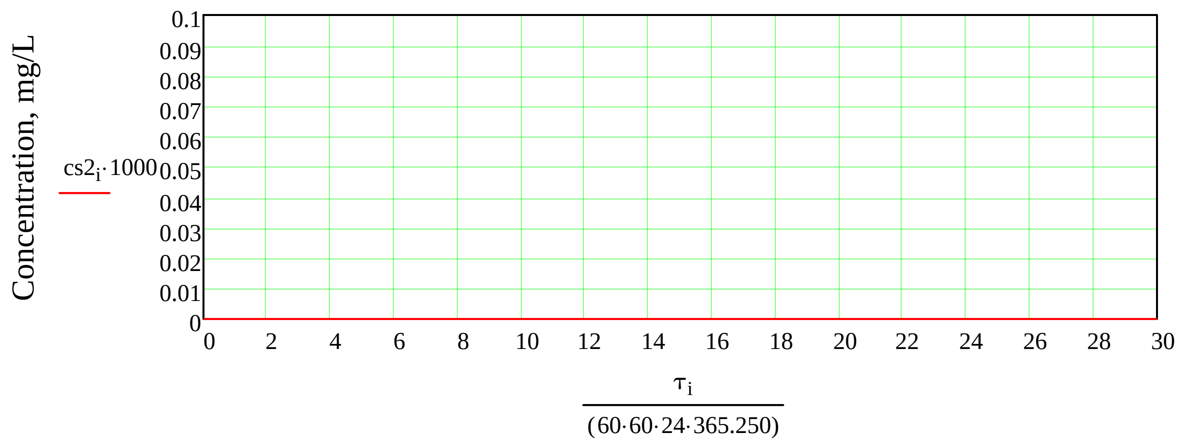
5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

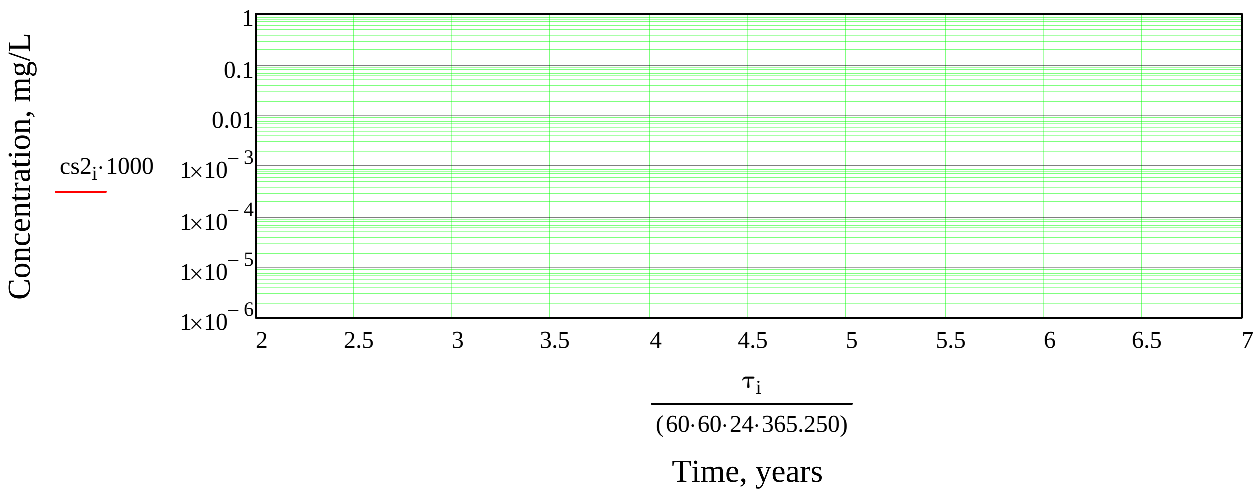
Time, sec



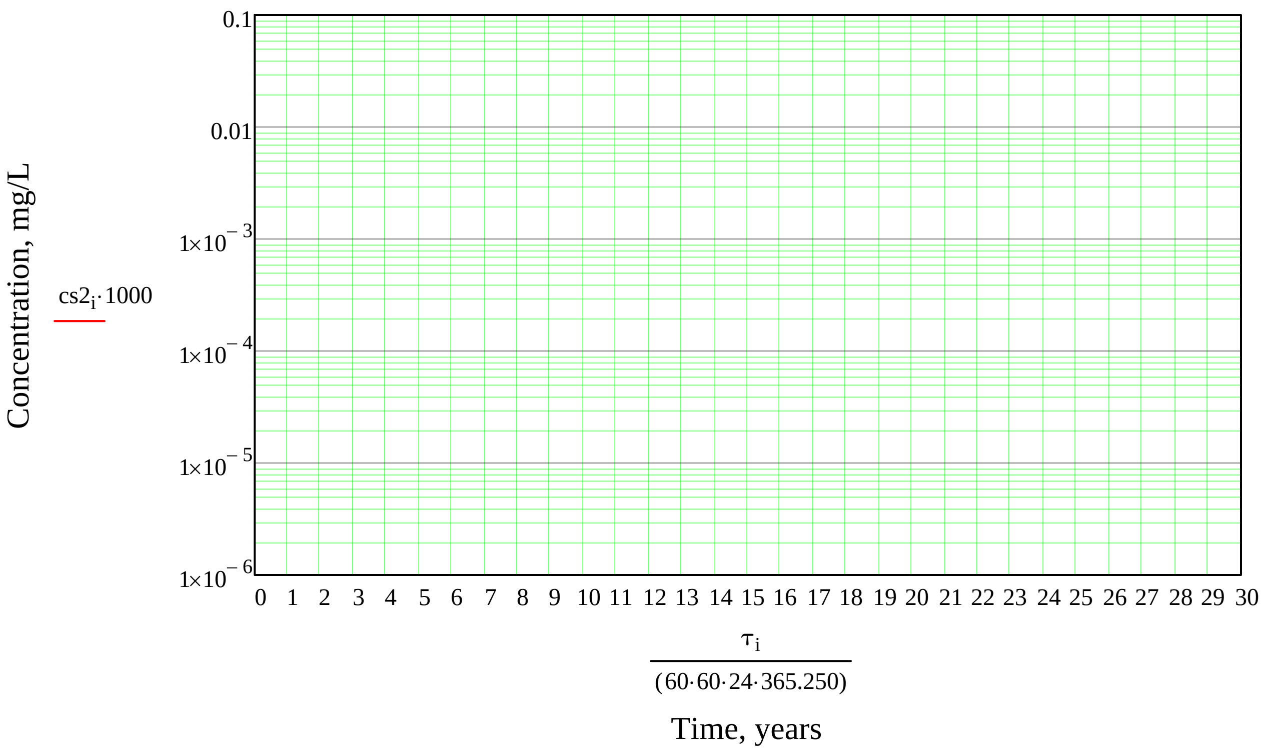
$x_2 = 810 \cdot ft$ $y_2 = 0$ $z_2 = 600 \cdot ft$

Time, years

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 810 \cdot ft$ $y_2 = 0$ $z_2 = 600 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill. Flow is vertically down through Layer 1 (Imported Soil layer); then through Layer 2 (Till); and horizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor D.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction- to the west):

Z axis (all layers) $Width_1 := 1200ft$ North - South

$Length_1 := 720ft$ Layers 1,2 = East - West (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\qquad Area_1 = 19.835 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Imported Soil Layer	Native Till	Bedrock
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 1ft$	$x_2 := 5ft$	X3 defined in Section 3.3

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $\qquad i_1 := 1$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\qquad Q_1 = 1.832 \times 10^3 \cdot \frac{gal}{day}$ $\qquad Q_2 := Q_1$ $\qquad Q_1 = 1.272 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\qquad v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $\qquad LQ := \frac{Q_1}{Area_1}$ $\qquad LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $\qquad v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

$v_3 := 5 \frac{ft}{day}$ $\qquad$ Velocity in bedrock is from the Bedrock Tracer Test.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{Q_2}{(k_2) \cdot Area_1}$ $\qquad i_2 = 0.011$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Sensitive Receptor (from Center of Western Side of Expansion):

Sens. Rec	X_3 (ft)	Z_3 (ft)
D	810	600
E	450	200
F	450	340
G	870	600

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_3 := 810ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth)

Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 600ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 68.031 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

				Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1\cdot ft$	$\alpha_{x\_1}\cdot x_1 = 0.01\cdot ft$	$\alpha x_1 := \alpha_{x\_1}\cdot x_1$ $\alpha x_1 = 0.01\cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1}\cdot x_1 = 0.01\cdot ft$	$\alpha y_1 := \alpha_{y\_1}\cdot x_1$ $\alpha y_1 = 0.01\cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1}\cdot x_1 = 0.01\cdot ft$	$\alpha z_1 := \alpha_{z\_1}\cdot x_1$ $\alpha z_1 = 0.01\cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till):

				Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 5\cdot ft$	$\alpha_{x\_2}\cdot x_2 = 0.05\cdot ft$	$\alpha x_2 := \alpha_{x\_2}\cdot x_2$ $\alpha x_2 = 0.05\cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2}\cdot x_2 = 0.5\cdot ft$	$\alpha y_2 := \alpha_{y\_2}\cdot x_2$ $\alpha y_2 = 0.5\cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2}\cdot x_2 = 0.5\cdot ft$	$\alpha z_2 := \alpha_{z\_2}\cdot x_2$ $\alpha z_2 = 0.5\cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

These Calcs

Lateral dispersivity $\alpha_{y\_BR} := \frac{20ft}{Y_3}$ $\alpha_{y\_BR} = 0.4$ Z axis

Downgradient dispersivity: $\alpha_{x\_BR} := \frac{(3\cdot\alpha_{y\_BR}\cdot X_3)}{X_3}$ $\alpha_{x\_BR} = 1.2$ X axis

Vertical dispersivity $\alpha_{z\_BR} := \frac{(0.05\cdot\alpha_{y\_BR}\cdot Y_3)}{Z_3}$ $\alpha_{z\_BR} = 0.02$ Y axis

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2000 \\ 5000 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 600 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

X, Y = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

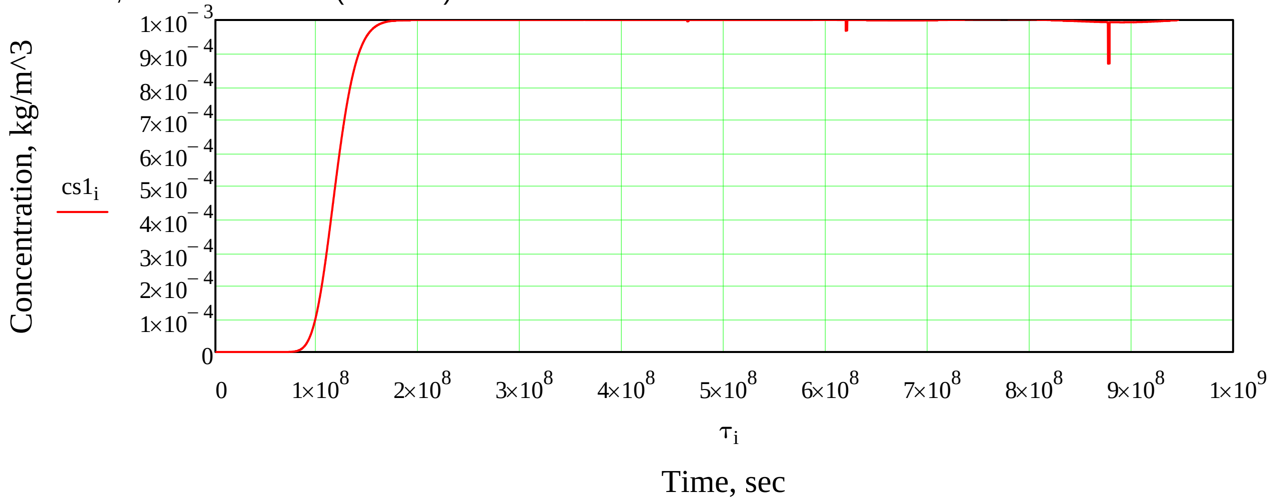
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..10950$ $\qquad$ $\tau_i := i\cdot day$

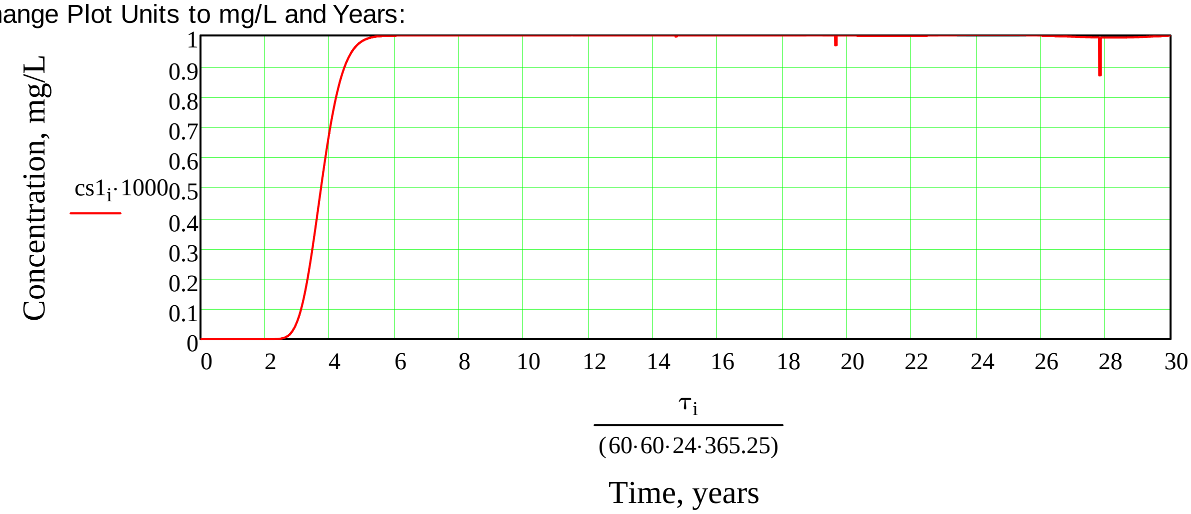
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

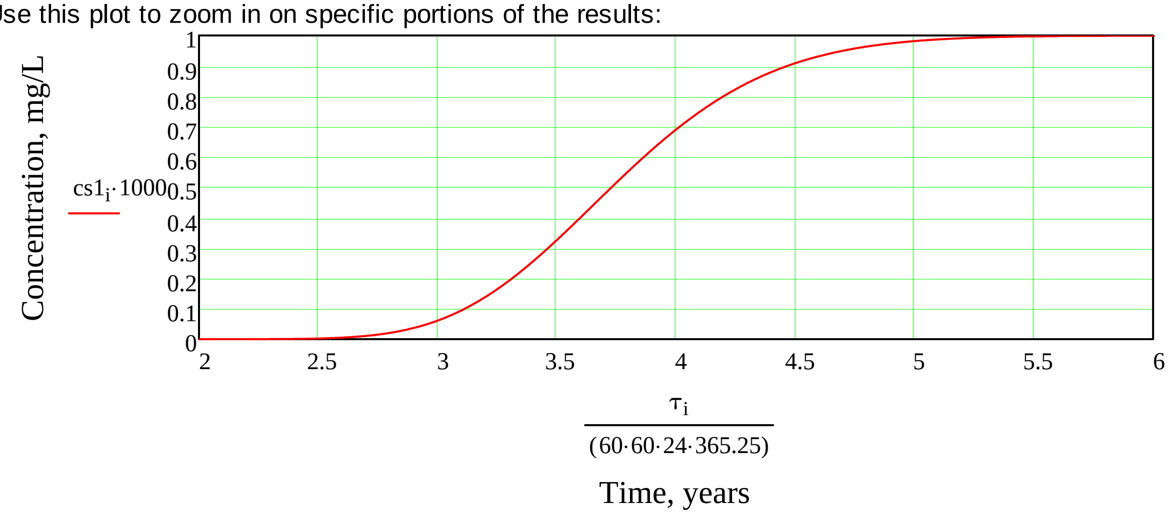
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $\quad t_{2\_10\%} := 3.1yr$ $\quad t_{2\_90\%} := 4.5yr$ $\quad t_{2\_100\%} := 5.5yr$

$t_{2\_1\%} = 913.105 \cdot day$ $\quad t_{2\_10\%} = 1.132 \times 10^{3} \cdot day$ $\quad t_{2\_90\%} = 1.644 \times 10^{3} \cdot day$ $\quad t_{2\_100\%} = 2.009 \times 10^{3} \cdot day$

Use the values above for time steps 3, 4, 5, and 6 below

A. Source to Layer 2:

number of concentration steps $\quad j_2 := 7$

Iteration intervals $\quad i := 1, 2 .. 10950$

Concentration (mg/l)	Source Term (days)
0.00	0
0.00	912
0.01	913
0.10	1132
0.9	1644
1.0	2009
1.0	10950

$co2 := (0.00, 0.00, 0.01, 0.10, 0.9, 1.0, 1.0)^T \cdot \frac{mg}{L}$ $\quad ti := (0, 912, 913, 1132, 1644, 2009, 10950)^T \cdot day$

Input parameters (Layer 2): This assumes no increase in the width of the plume as it moves through Layer 1 and enters Layer 2.

Half-Length of Source in Y-direction $\quad a_2 := a_1 \quad a_2 = 360 \cdot ft$

Half-Width of Source in Z-direction $\quad b_2 := b_1 \quad b_2 = 600 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $\quad v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

Distance of interest (x): $\quad x_2 = 5 \cdot ft \quad$ Vertical (down) $\quad$ to Top of Layer 3

Lateral distance of interest (y): $\quad y_2 := 0ft$

Lateal distance of interest (z): $\quad z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $\quad Dx_2 := \alpha x_2 \cdot v_2 \quad Dx_2 = 5.669 \times 10^{-5} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $\quad Dy_2 := \alpha y_2 \cdot v_2 \quad Dy_2 = 5.669 \times 10^{-4} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $\quad Dz_2 := \alpha z_2 \cdot v_2 \quad Dz_2 = 5.669 \times 10^{-4} \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

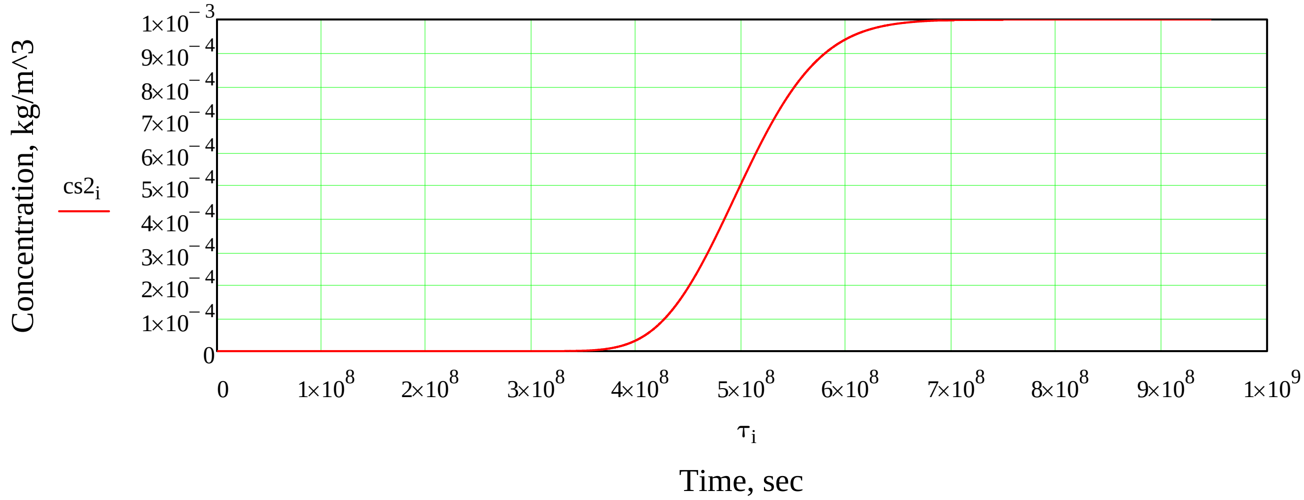
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1,2..10950$ $\qquad \tau_i := i\cdot day$

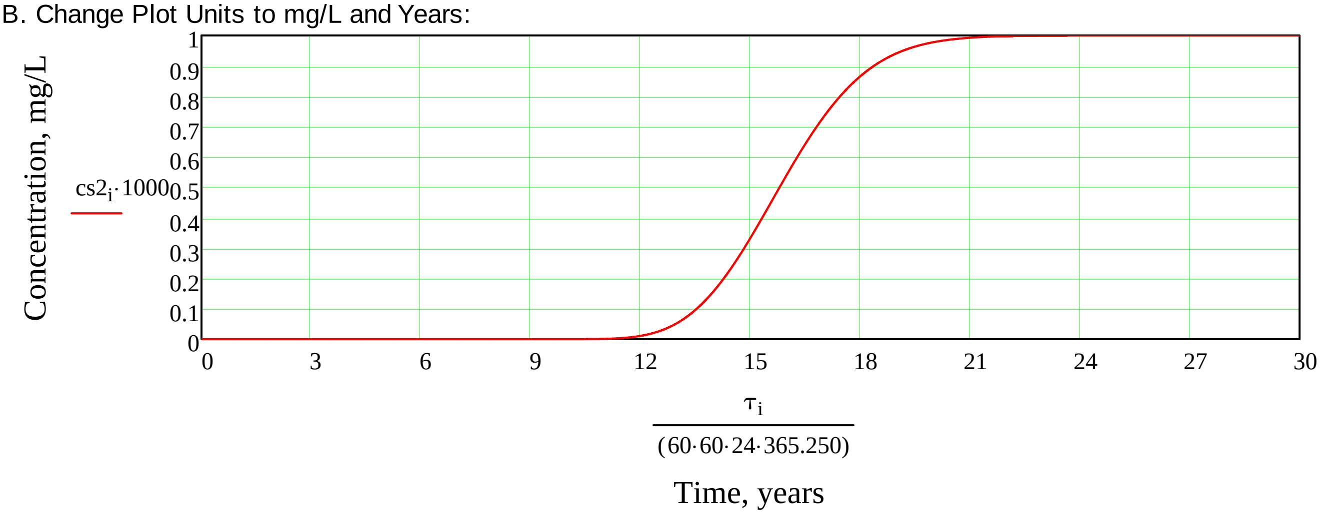
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

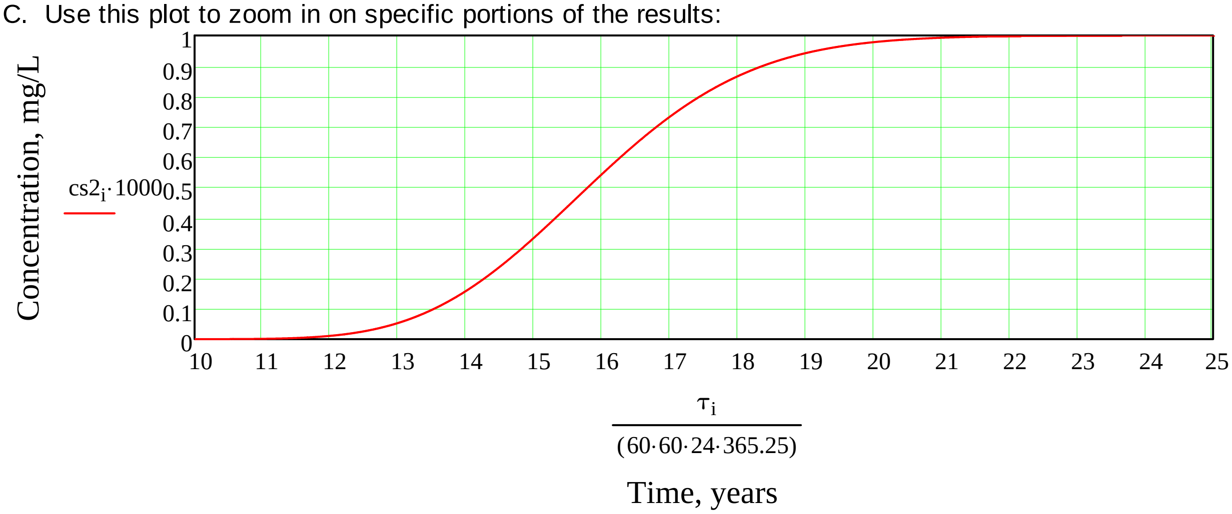
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

$t_{3\_0\%} := 12 \cdot yr$ $t_{3\_10\%} := 13.5yr$ $t_{3\_90\%} := 18.5yr$ $t_{3\_100\%} := 21yr$

$t_{3\_0\%} = 4.383 \times 10^{3} \cdot day$ $t_{3\_10\%} = 4.931 \times 10^{3} \cdot day$ $t_{3\_90\%} = 6.757 \times 10^{3} \cdot day$ $t_{3\_100\%} = 7.67 \times 10^{3} \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 4382 \\ 4383 \\ 4931 \\ 6757 \\ 7670 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 68.031 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 600 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 972 \cdot ft$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 972 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 324 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 324 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 16.2 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 16.2 \cdot ft$ Lateral

Note: This was rotated to use correct orientation from Tracer Test.

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 4.86 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.62 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 81 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \mathrm{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \mathrm{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \mathrm{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \mathrm{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

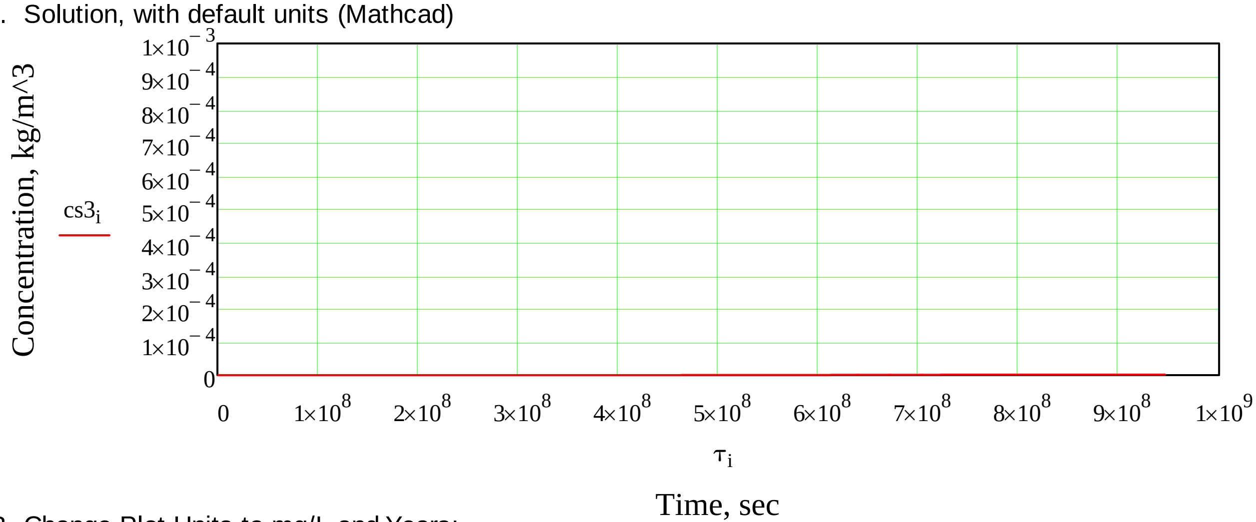
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2..10950$ $\qquad \tau_i := i\cdot day$

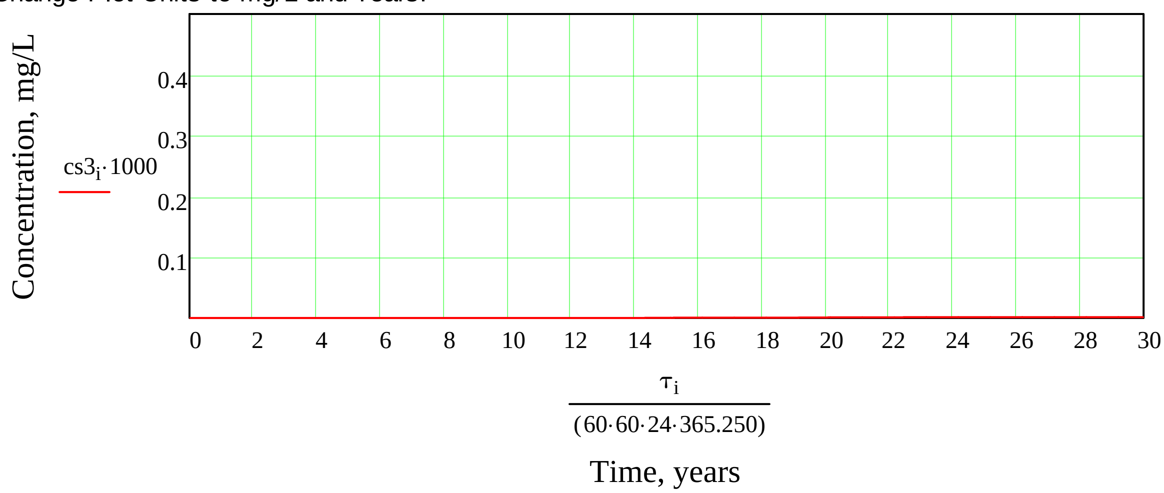
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_3(x_3,y_3,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_3(x_3,y_3,|\tau_i - ti_n|)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

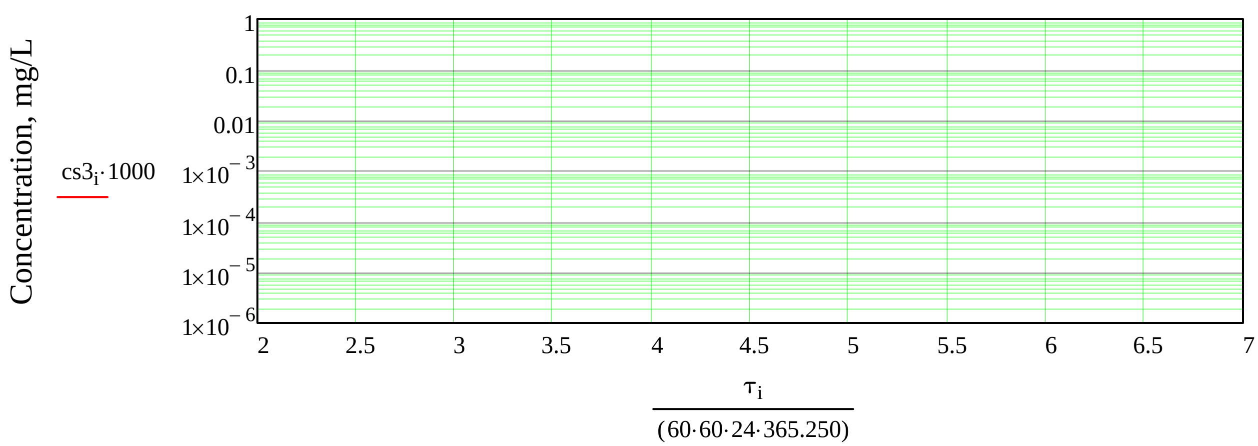
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

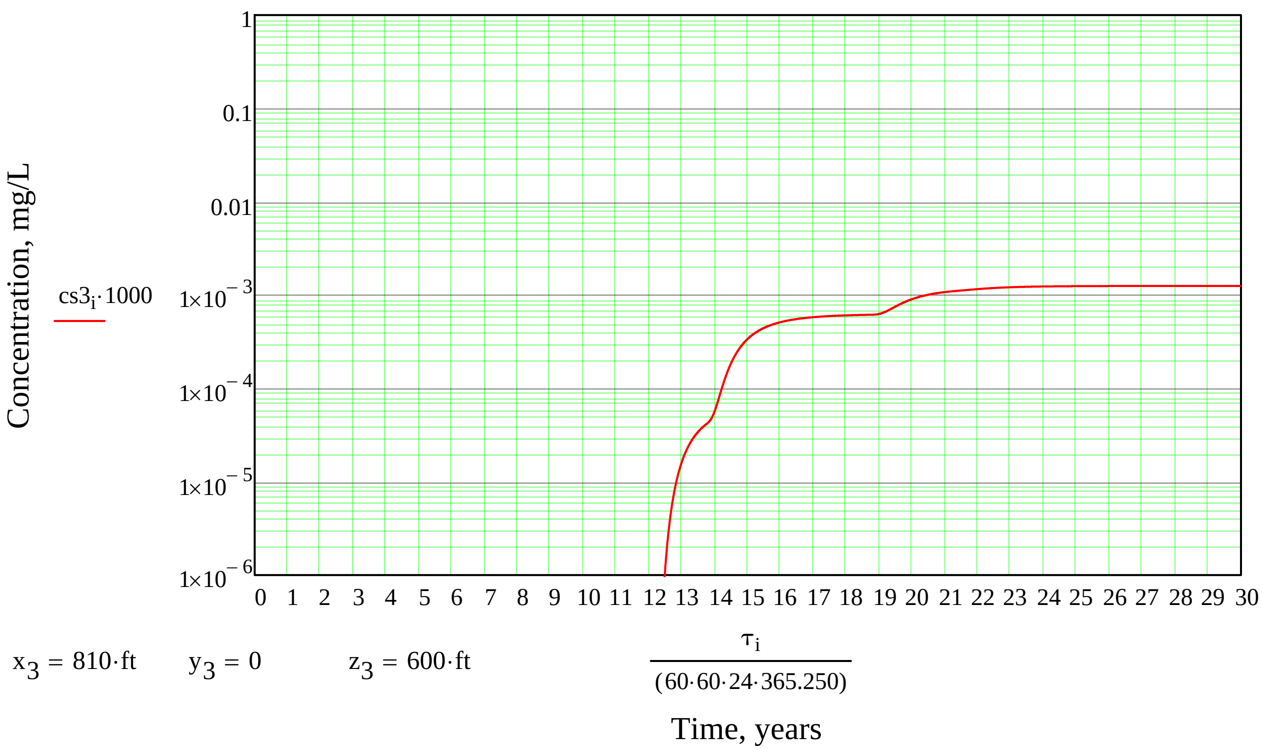


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 810 \cdot ft$ $y_3 = 0$ $z_3 = 600 \cdot ft$ Time, years

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 810 \cdot ft$ $y_3 = 0$ $z_3 = 600 \cdot ft$

JRL - Expansion Contaminant Transport Evaluation - Complete Failure of Engineered Systems - Western Flow

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill (Cell 14-16). Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor E.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1200ft$ North - South

$Length_1 := 720ft$ Layers 1,2 = East - West (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 19.835 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Imported Soil Layer	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 1.832 \times 10^3 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 1.272 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_15} := 200.44ft$ $Head_E := 72ft$

$i_2 := \frac{Head_{Cell\_15} - Head_E}{540ft}$ $i_2 = 0.238$ $v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $v_{gw} = 0.025 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$$i_2 := \frac{Q_2}{(k_2) \cdot Area_1} \qquad i_2 = 0.011$$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cell 14):

Sens. Rec	X_3 (ft)	Z_3 (ft)
D	810	600
E	450	200
F	450	340
G	870	600

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_2 := 450ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 200ft$ Lateral

F. Determine the thickness that the leak travels into the Till (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2} \qquad a_2 = 13.606 \cdot ft$$

Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 450 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 67.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 67.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 4.5 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 4.5 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 4.5 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 4.5 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 600 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \text{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \text{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \text{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \text{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

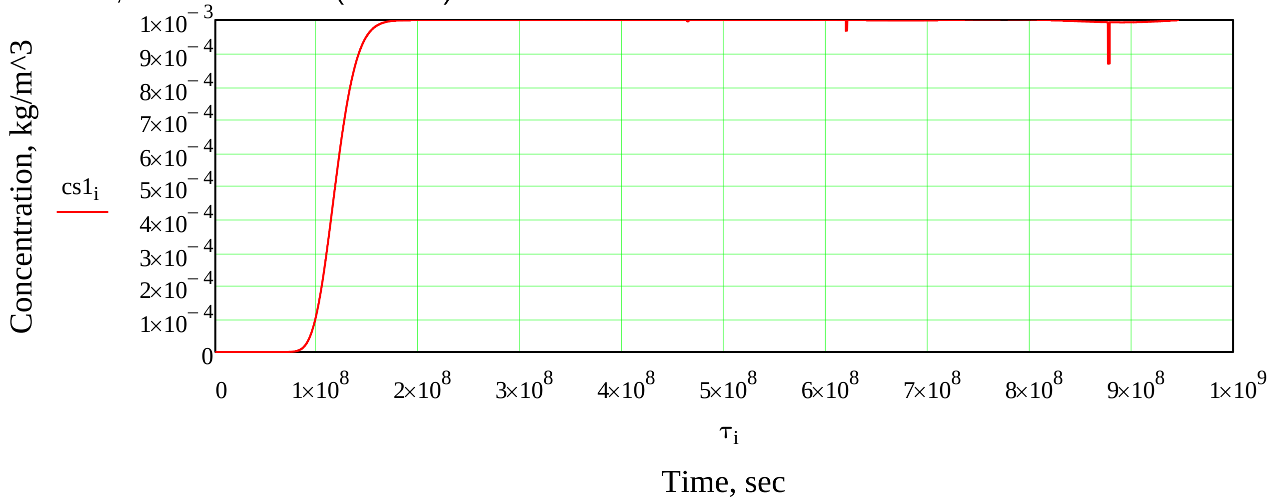
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0, 1 .. 10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

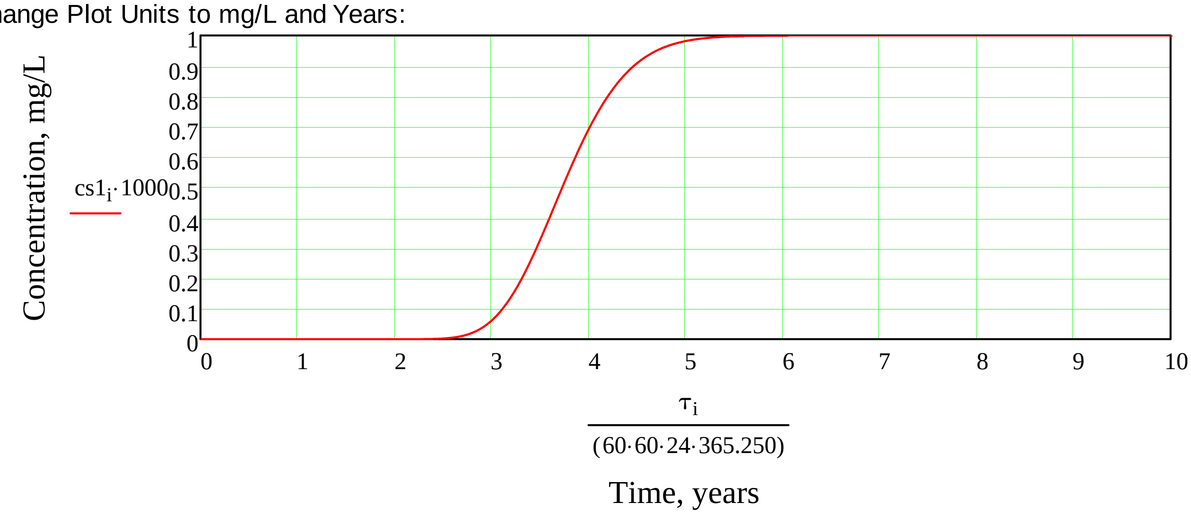
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

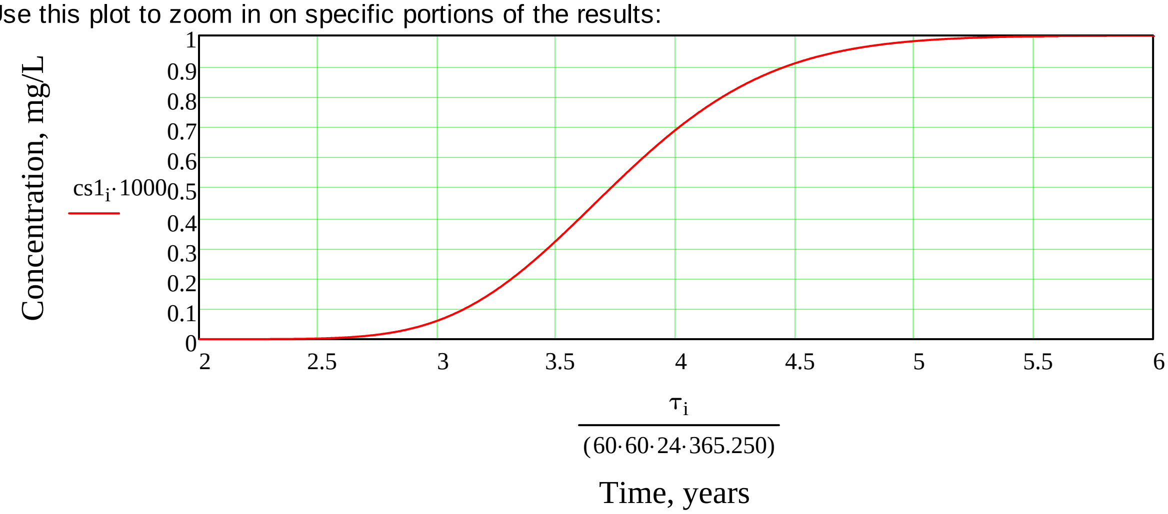
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1yr$ $t_{2\_90\%} := 4.5yr$ $t_{2\_100\%} := 5.5yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^3 \cdot day$ $t_{2\_90\%} = 1.644 \times 10^3 \cdot day$ $t_{2\_100\%} = 2.009 \times 10^3 \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 13.606 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 600 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 67.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 67.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 4.5 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 4.5 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 4.5 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 4.5 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 6.75 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.45 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.45 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \text{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \text{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \text{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \text{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

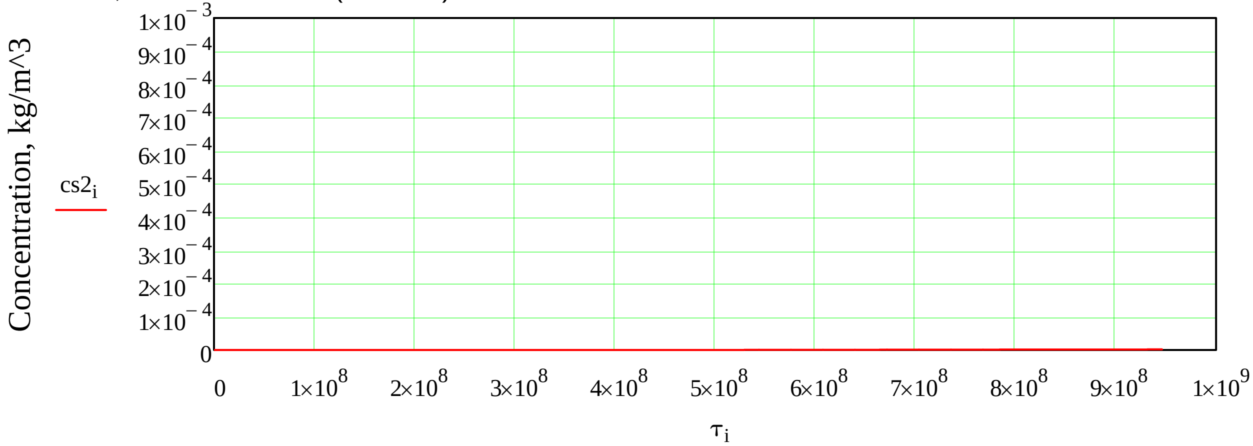
$i := 0, 1 .. 10950$ $\quad\quad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

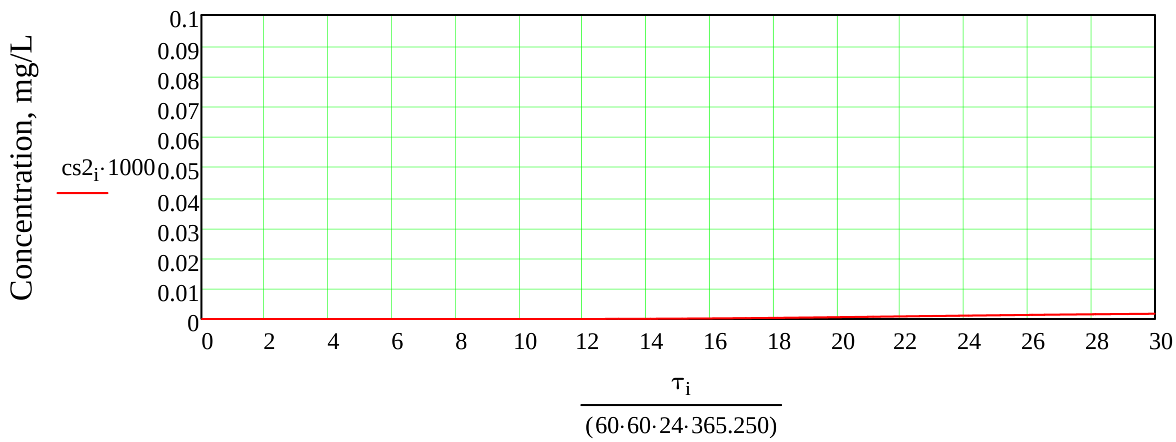
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)

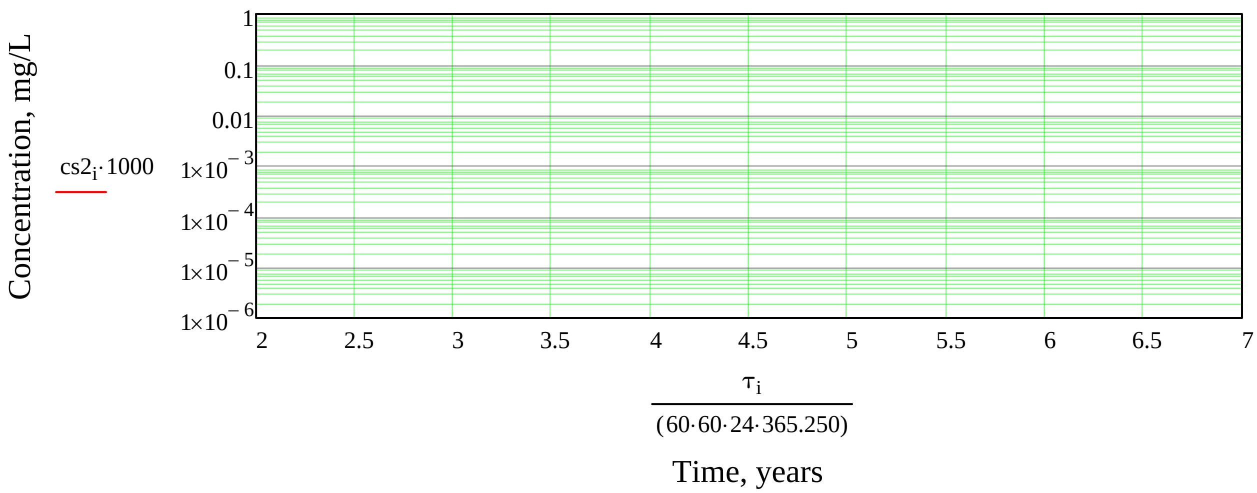


B. Change Plot Units to mg/L and Years:

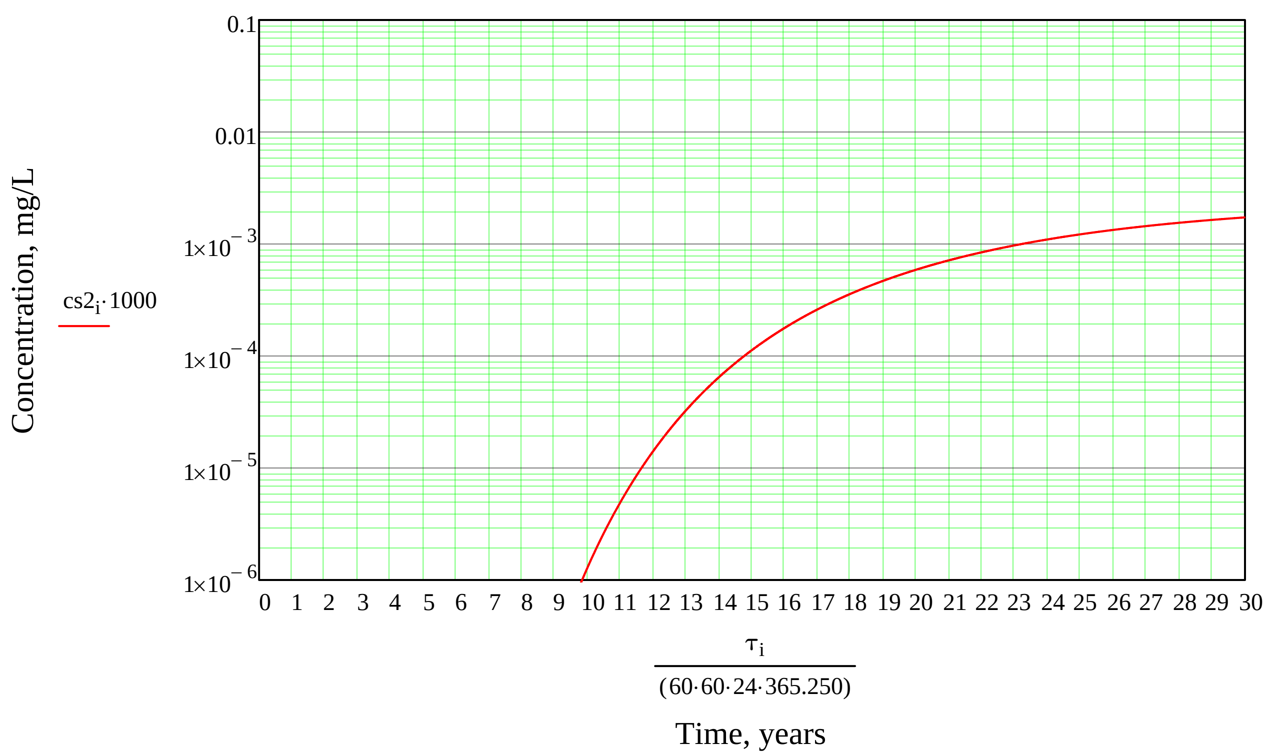


$x_2 = 450 \cdot ft$ $\quad y_2 = 0$ $\quad z_2 = 200 \cdot ft$

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 450 \cdot ft$ $y_2 = 0$ $z_2 = 200 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill. Flow is vertically down through Layer 1 (Imported Soil layer); then through Layer 2 (Till); and horizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor E.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction- to the west):

Z axis (all layers) $Width_1 := 1200ft$ North - South

$Length_1 := 720ft$ Layers 1,2 = East - West (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 19.835 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Imported Soil Layer	Native Till	Bedrock
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 1ft$	$x_2 := 5ft$	X3 defined in Section 3.3

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 1.832 \times 10^3 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 1.272 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock is from the Bedrock Tracer Test.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{Q_2}{(k_2) \cdot Area_1}$ $i_2 = 0.011$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Sensitive Receptor (from Center of Western Side of Cells 15 and 16 Expansion):

Sens. Rec	X_3 (ft)	Z_3 (ft)
D	810	600
E	450	200
F	450	340
G	870	600

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_3 := 450ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 200ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 68.031 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 5 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.05 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.05 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 0.5 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 0.5 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 0.5 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 0.5 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

These Calcs

Lateral dispersivity	$\alpha_{y\_BR} := \frac{20ft}{Y_3}$	$\alpha_{y\_BR} = 0.4$	Z axis
Downgradient dispersivity:	$\alpha_{x\_BR} := \frac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$	$\alpha_{x\_BR} = 1.2$	X axis
Vertical dispersivity	$\alpha_{z\_BR} := \frac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$	$\alpha_{z\_BR} = 0.02$	Y axis

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2000 \\ 5000 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 600 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

X, Y = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

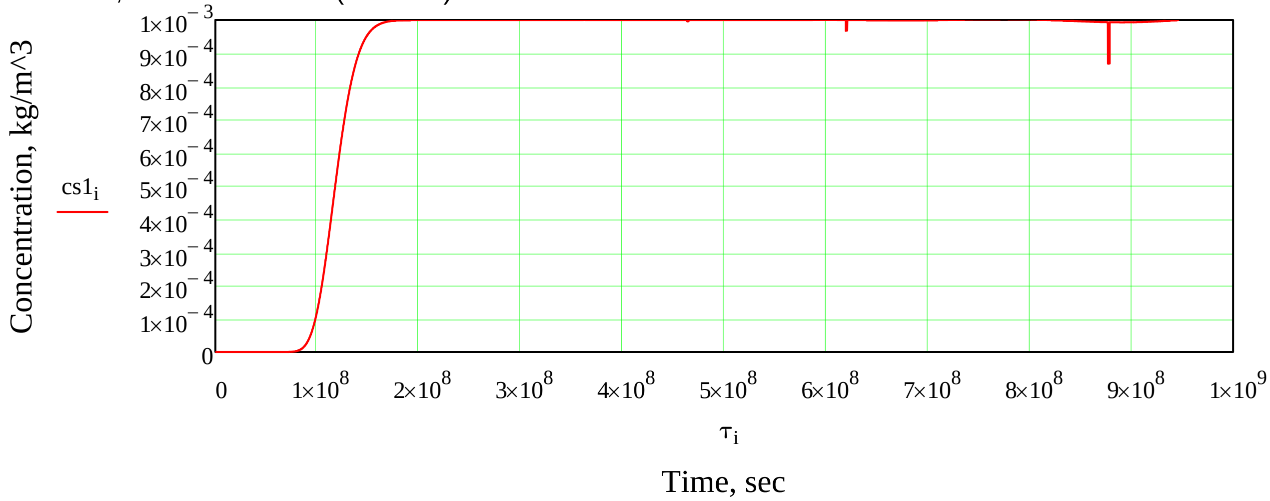
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

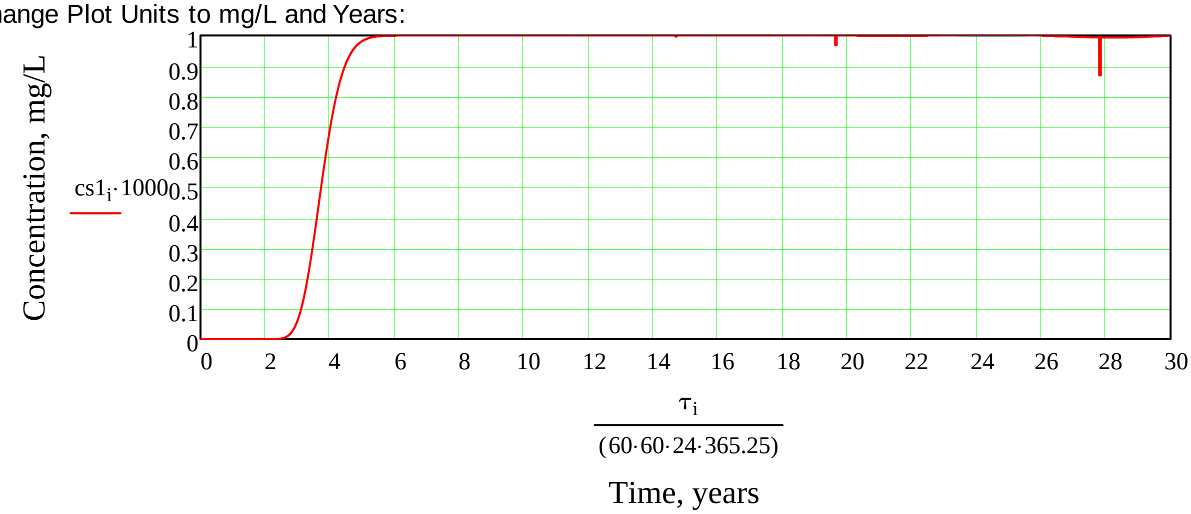
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

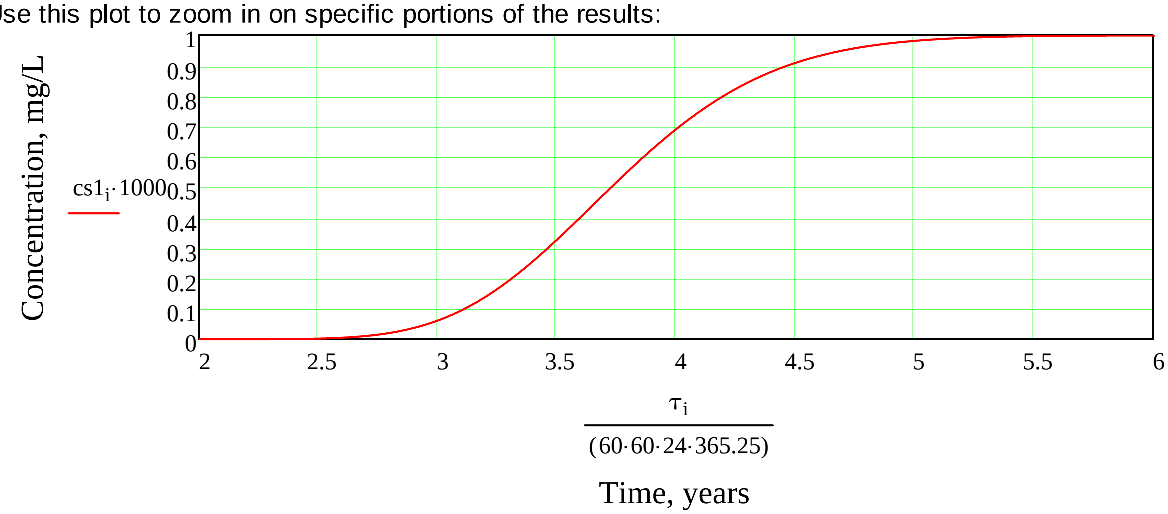
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5\cdot yr$ $t_{2\_10\%} := 3.1yr$ $t_{2\_90\%} := 4.5yr$ $t_{2\_100\%} := 5.5yr$

$t_{2\_1\%} = 913.105\cdot day$ $t_{2\_10\%} = 1.132\times10^{3}\cdot day$ $t_{2\_90\%} = 1.644\times10^{3}\cdot day$ $t_{2\_100\%} = 2.009\times10^{3}\cdot day$

Use the values above for time steps 3, 4, 5, and 6 below

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1,2..10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.9 \\ 1.0 \\ 1.0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 2): This assumes no increase in the width of the plume as it moves through Layer 1 and enters Layer 2.

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 360\cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 600\cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 1.134\times10^{-3}\cdot\frac{ft}{day}$

Distance of interest (x): $x_2 = 5\cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$ East - West

Lateal distance of interest (z): $z_2 := 0ft$ Nort - South

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2\cdot v_2$ $Dx_2 = 5.669\times10^{-5}\cdot\frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2\cdot v_2$ $Dy_2 = 5.669\times10^{-4}\cdot\frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2\cdot v_2$ $Dz_2 = 5.669\times10^{-4}\cdot\frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

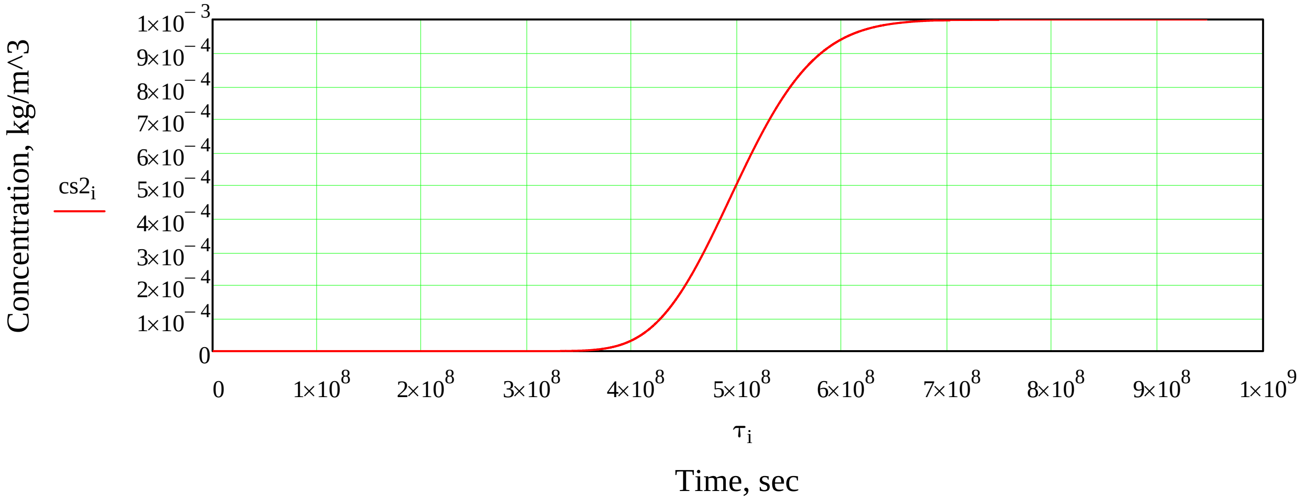
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

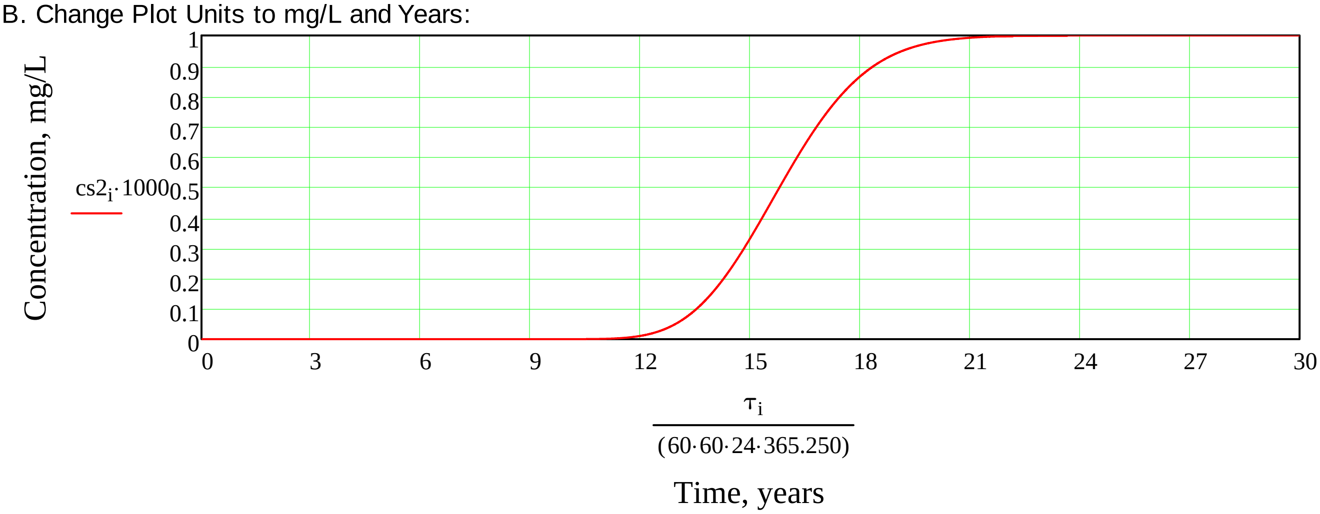
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

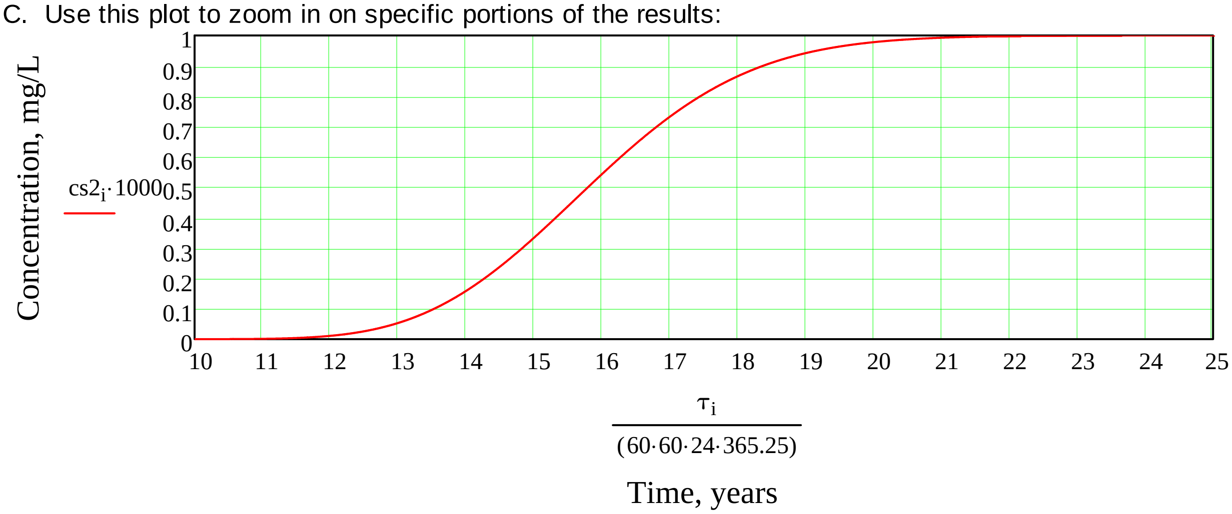
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

$t_{3\_0\%} := 12 \cdot yr$ $t_{3\_10\%} := 13.5yr$ $t_{3\_90\%} := 18.5yr$ $t_{3\_100\%} := 21yr$

$t_{3\_0\%} = 4.383 \times 10^{3} \cdot day$ $t_{3\_10\%} = 4.931 \times 10^{3} \cdot day$ $t_{3\_90\%} = 6.757 \times 10^{3} \cdot day$ $t_{3\_100\%} = 7.67 \times 10^{3} \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 4382 \\ 4383 \\ 4931 \\ 6757 \\ 7670 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 68.031 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 600 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 540 \cdot ft$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 540 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 180 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 180 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 9 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 9 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 2.7 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 900 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 45 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \text{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \text{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \text{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \text{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

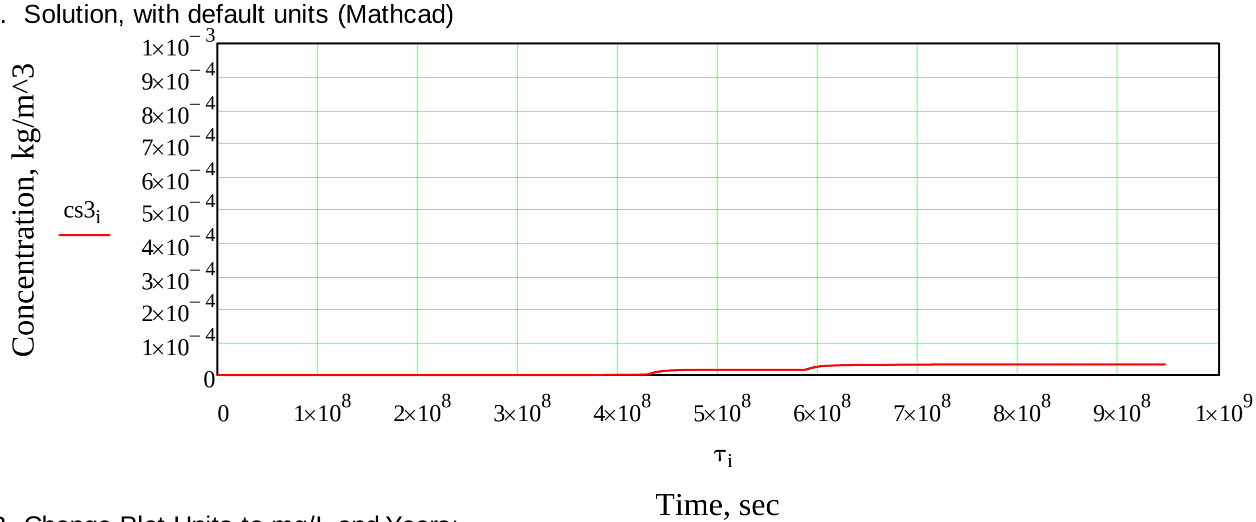
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2..10950$ $\qquad$ $\tau_i := i\cdot day$

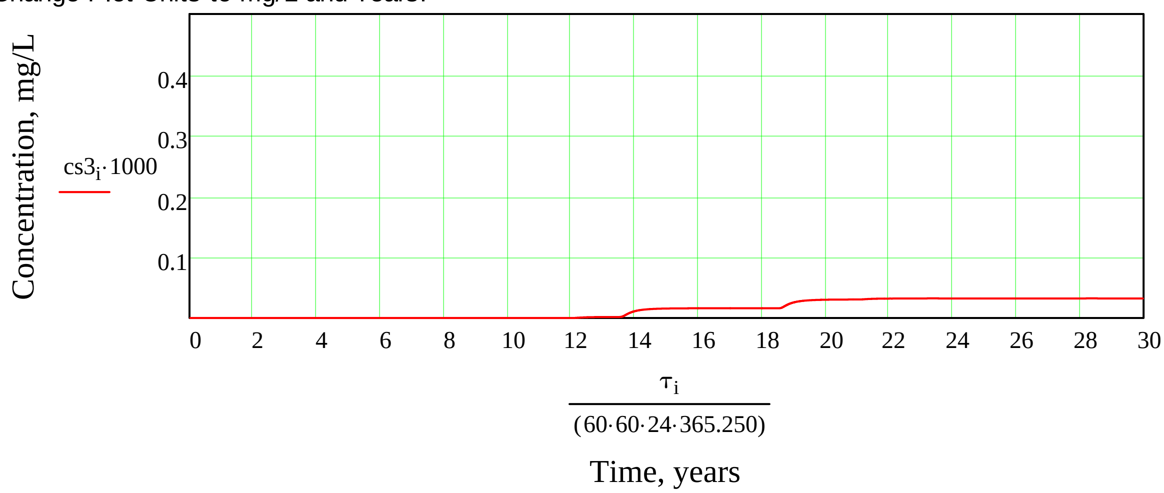
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

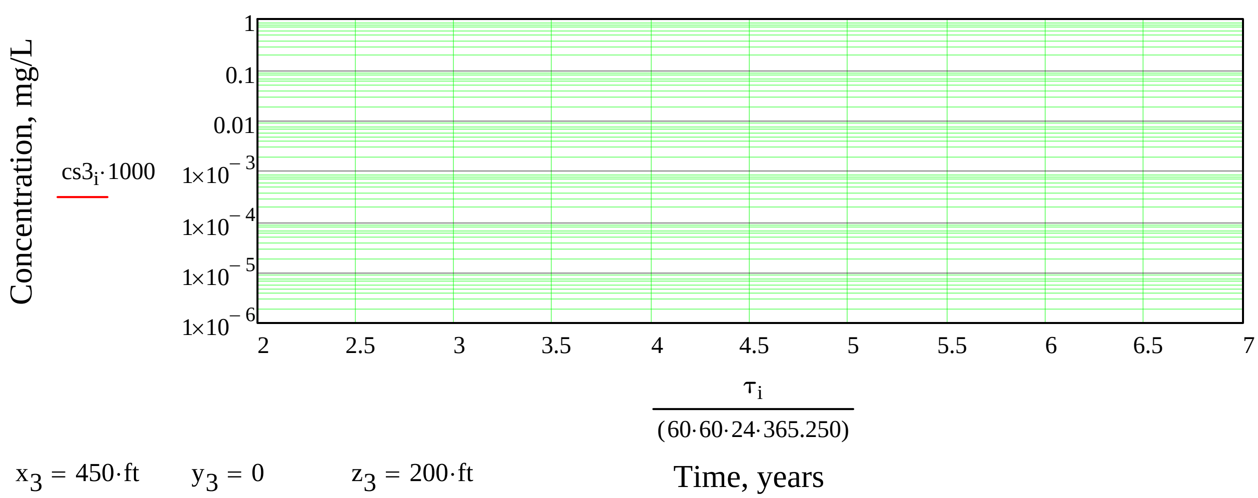
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

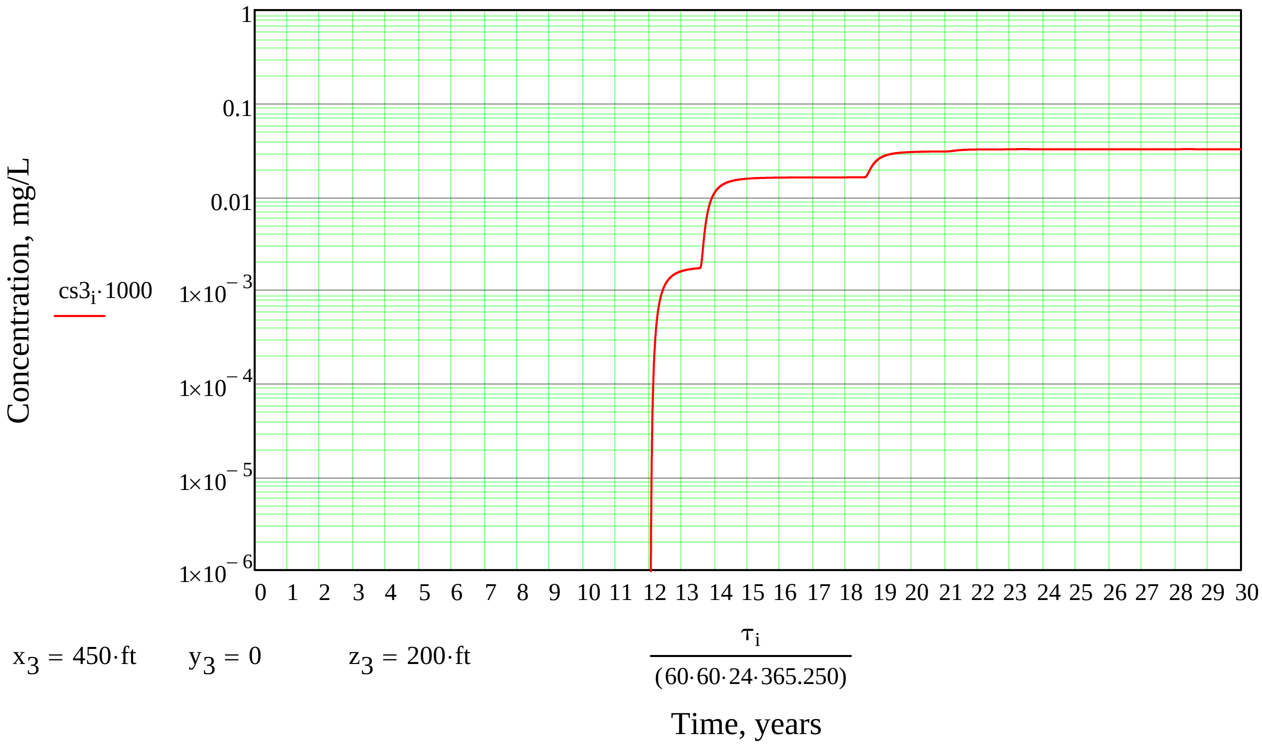


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 450 \cdot ft$ $y_3 = 0$ $z_3 = 200 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 450 \cdot ft$ $y_3 = 0$ $z_3 = 200 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill (Cell 14-16). Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor F.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1200ft$ North - South

$Length_1 := 720ft$ Layers 1,2 = East - West (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\quad Area_1 = 19.835 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Imported Soil Layer	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 1.832 \times 10^3 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 1.272 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_15} := 200.44ft$ $\quad Head_F := 77ft$

$i_2 := \frac{Head_{Cell\_15} - Head_F}{540ft}$ $\quad i_2 = 0.229$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 0.024 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$$i_2 := \frac{Q_2}{(k_2) \cdot Area_1} \qquad i_2 = 0.011$$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cell 11):

Sens. Rec	X_3 (ft)	Z_3 (ft)
D	810	600
E	450	200
F	450	340
G	870	600

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_2 := 450ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 340ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2} \qquad a_2 = 13.606 \cdot ft$$

Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 450 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 67.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 67.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 4.5 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 4.5 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 4.5 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 4.5 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 600 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

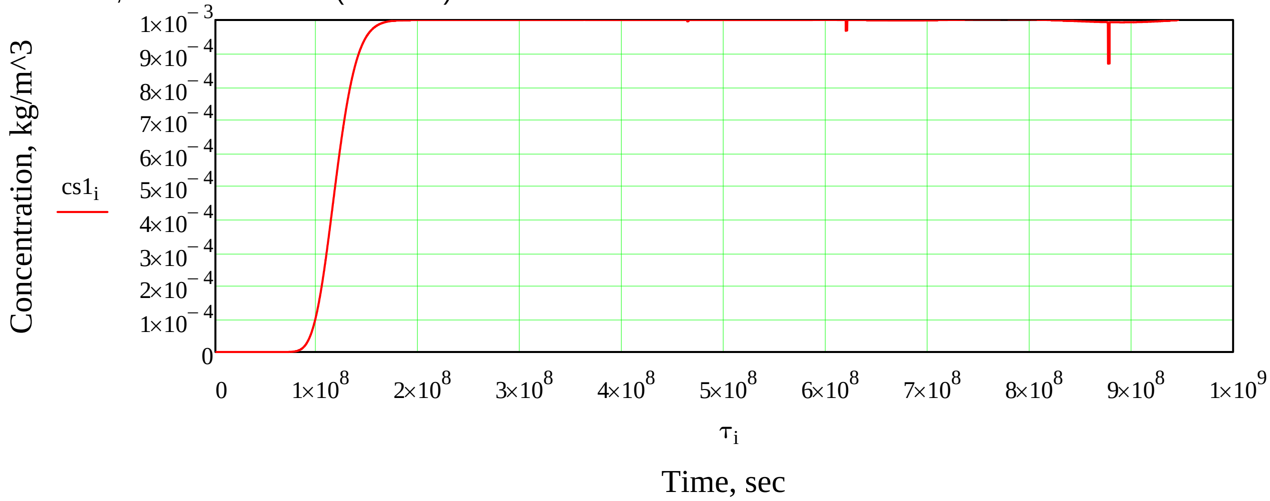
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0, 1 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

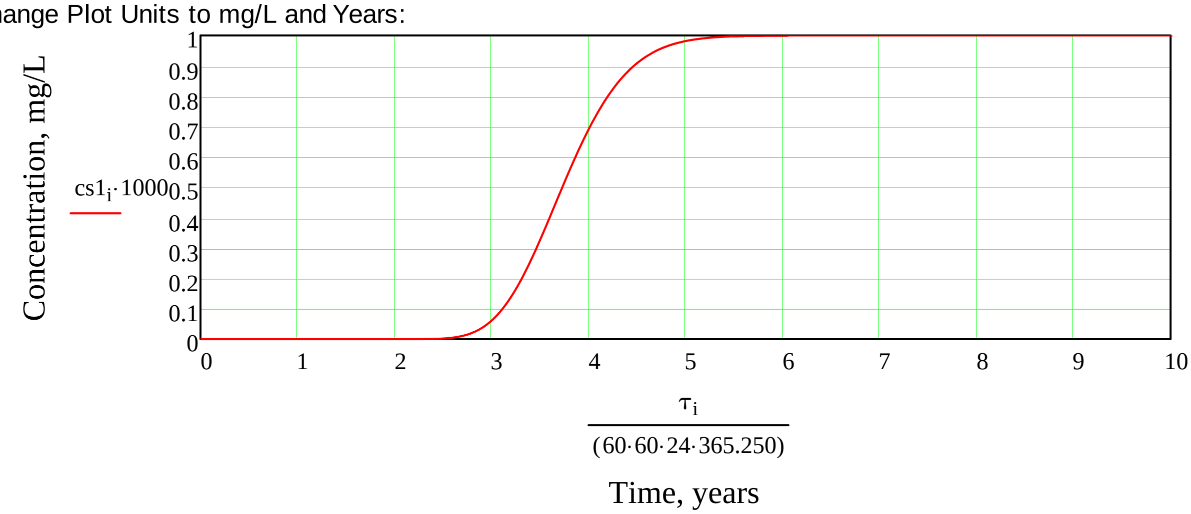
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

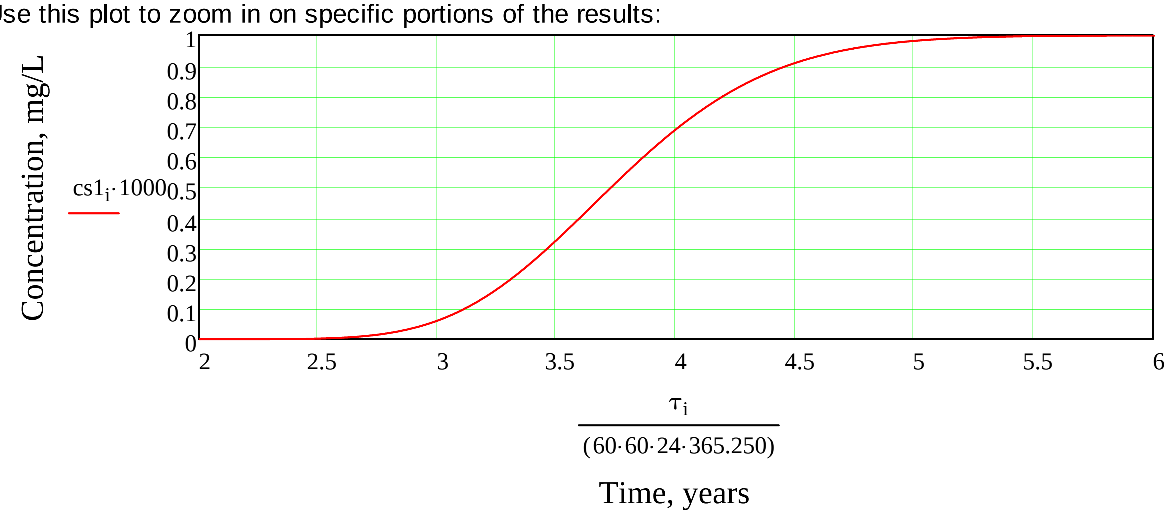
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1 yr$ $t_{2\_90\%} := 4.5 yr$ $t_{2\_100\%} := 5.5 yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^3 \cdot day$ $t_{2\_90\%} = 1.644 \times 10^3 \cdot day$ $t_{2\_100\%} = 2.009 \times 10^3 \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 13.606 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 600 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 67.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 67.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 4.5 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 4.5 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 4.5 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 4.5 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 6.75 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.45 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.45 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

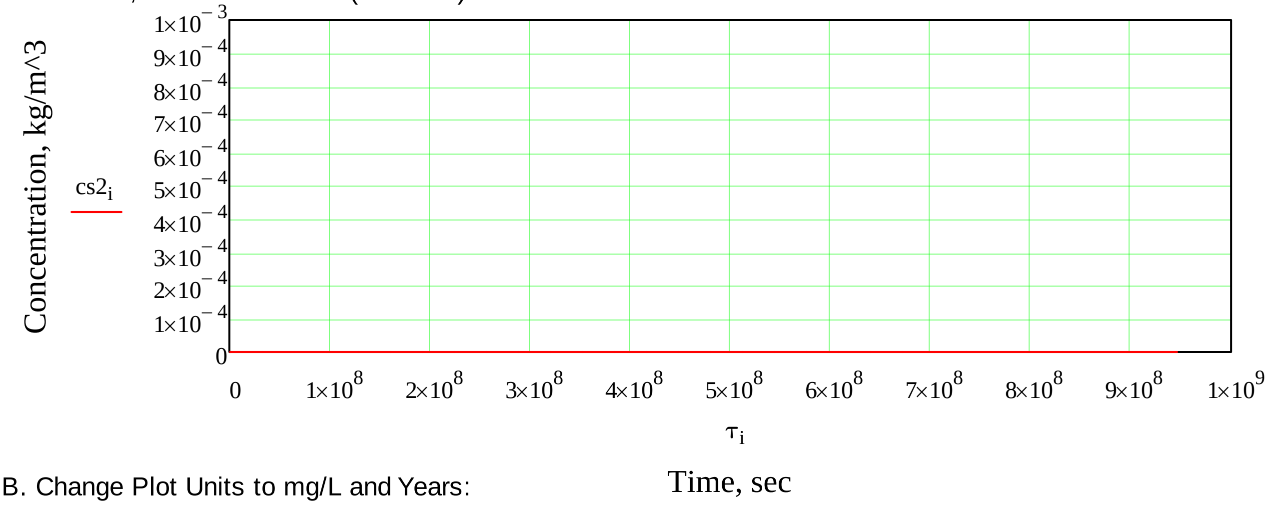
$i := 0, 1 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

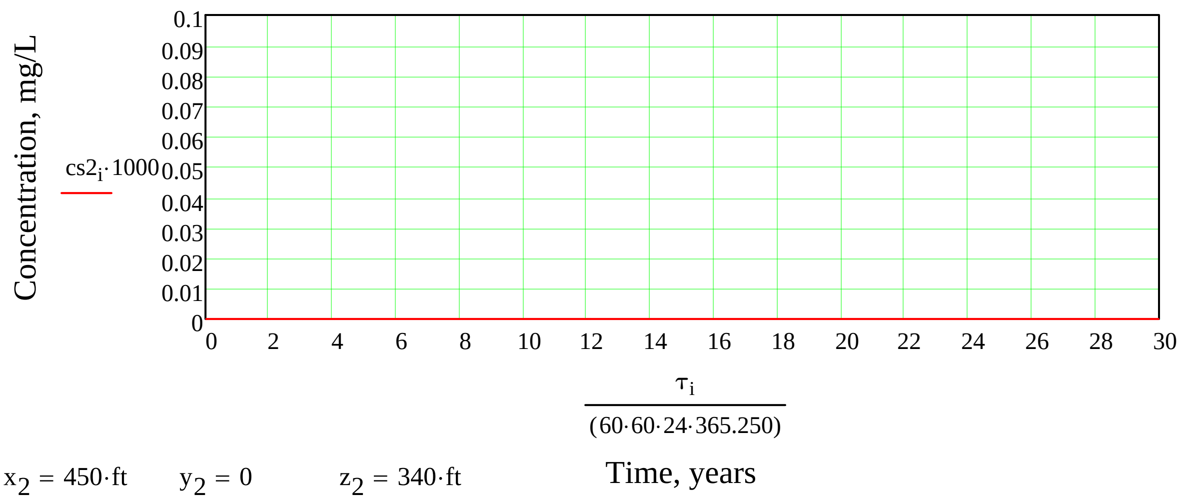
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)

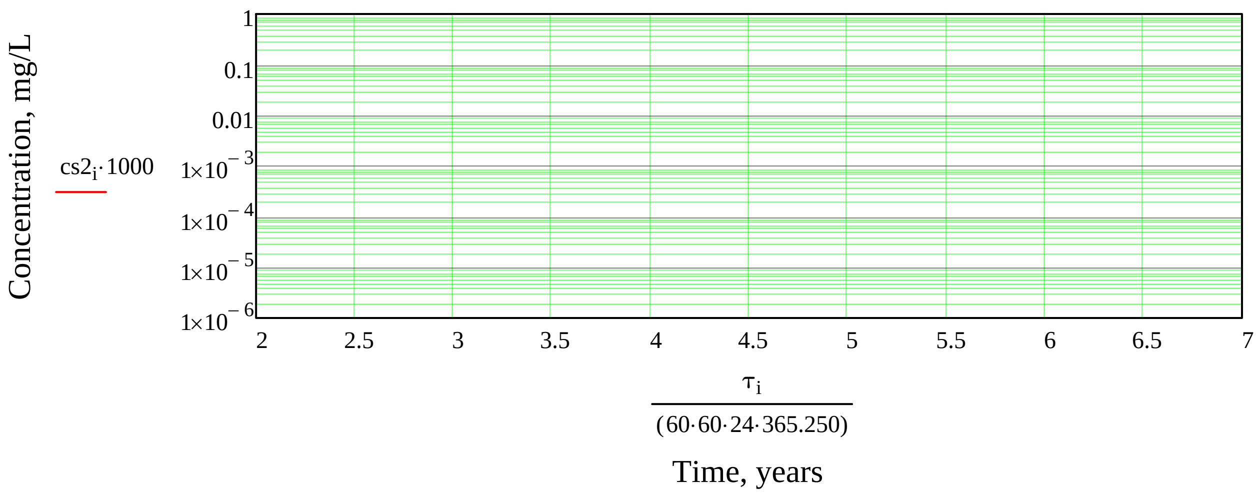


B. Change Plot Units to mg/L and Years:

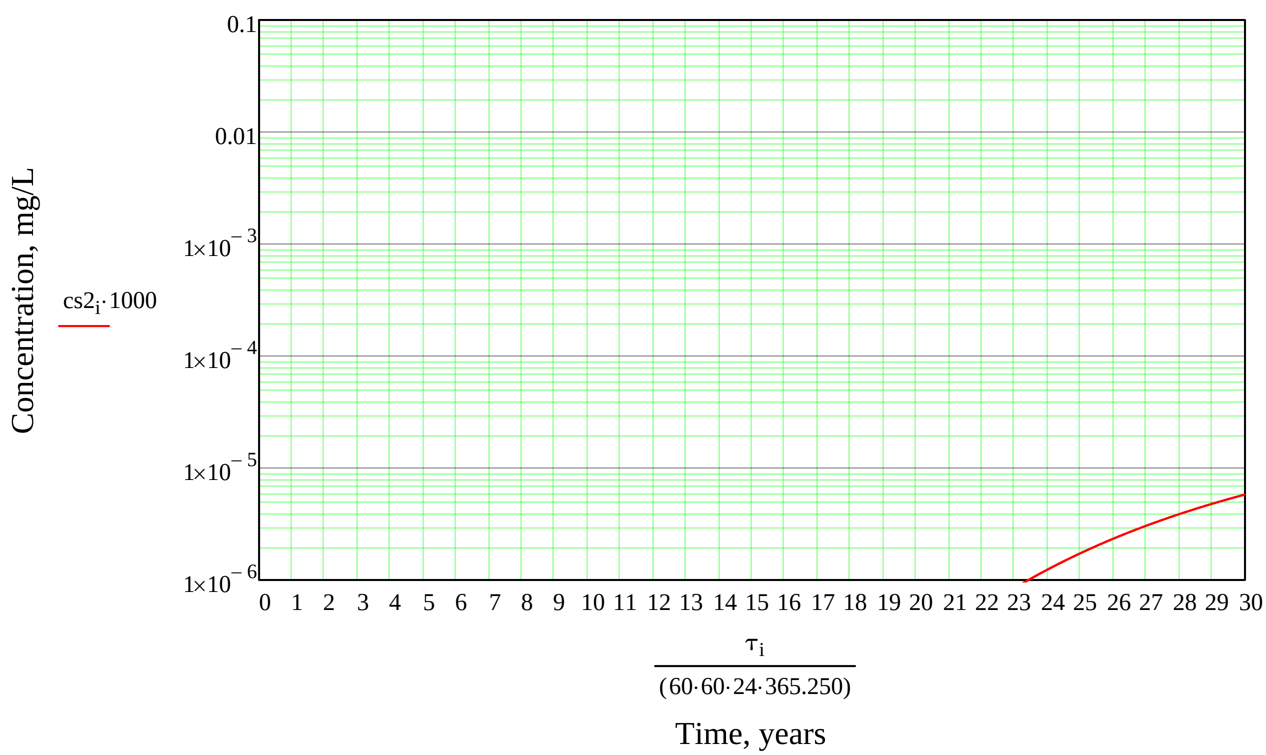


$x_2 = 450 \cdot ft$ $\quad y_2 = 0$ $\quad z_2 = 340 \cdot ft$

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 450 \cdot ft$ $\quad y_2 = 0$ $\quad z_2 = 340 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill. Flow is vertically down through Layer 1 (Imported Soil layer); then through Layer 2 (Till); and horizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor F.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction- to the west):

Z axis (all layers) $Width_1 := 1200ft$ North - South

$Length_1 := 720ft$ Layers 1,2 = East - West (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 19.835 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Imported Soil Layer	Native Till	Bedrock
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 1ft$	$x_2 := 5ft$	X3 defined in Section 3.3

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 1.832 \times 10^3 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 1.272 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock is from the Bedrock Tracer Test.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{Q_2}{(k_2) \cdot Area_1}$ $i_2 = 0.011$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Sensitive Receptor (from Center of Western Side of Expansion):

Sens. Rec	X_3 (ft)	Z_3 (ft)
D	810	600
E	450	200
F	450	340
G	870	600

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_3 := 450ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 340ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3} \qquad a_3 = 68.031 \cdot ft$$

Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 5 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.05 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.05 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 0.5 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 0.5 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 0.5 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 0.5 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

These Calcs

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

Lateral dispersivity $\alpha_{y\_BR} := \frac{20ft}{Y_3}$ $\alpha_{y\_BR} = 0.4$ Z axis

Downgradient dispersivity: $\alpha_{x\_BR} := \frac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$ $\alpha_{x\_BR} = 1.2$ X axis

Vertical dispersivity $\alpha_{z\_BR} := \frac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$ $\alpha_{z\_BR} = 0.02$ Y axis

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 2000 \\ 5000 \\ 10950 \end{pmatrix} \cdot day$

This is a continuous source.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 600 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

X, Y = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

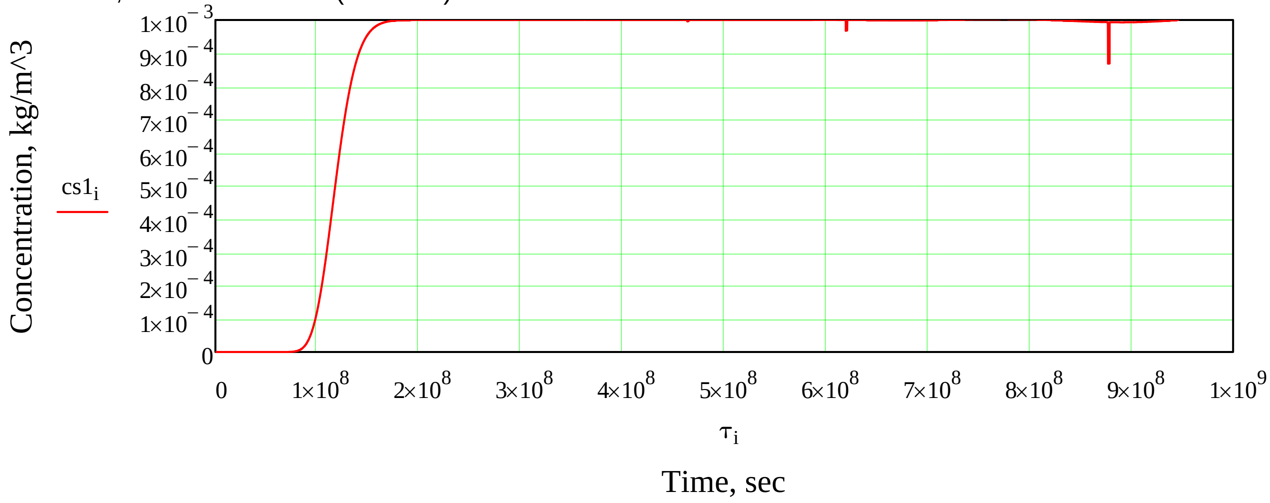
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1, 2 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

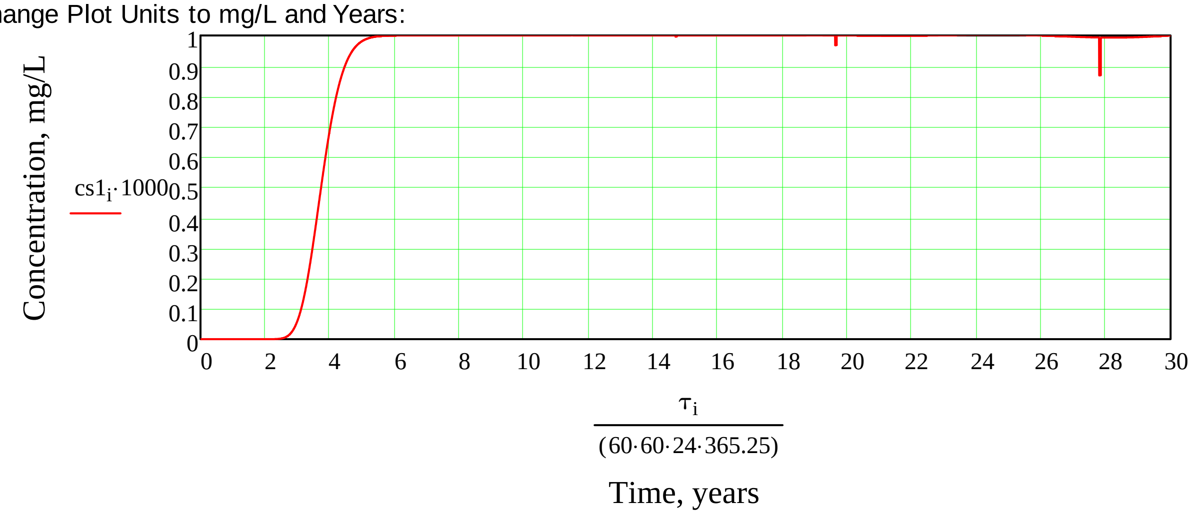
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

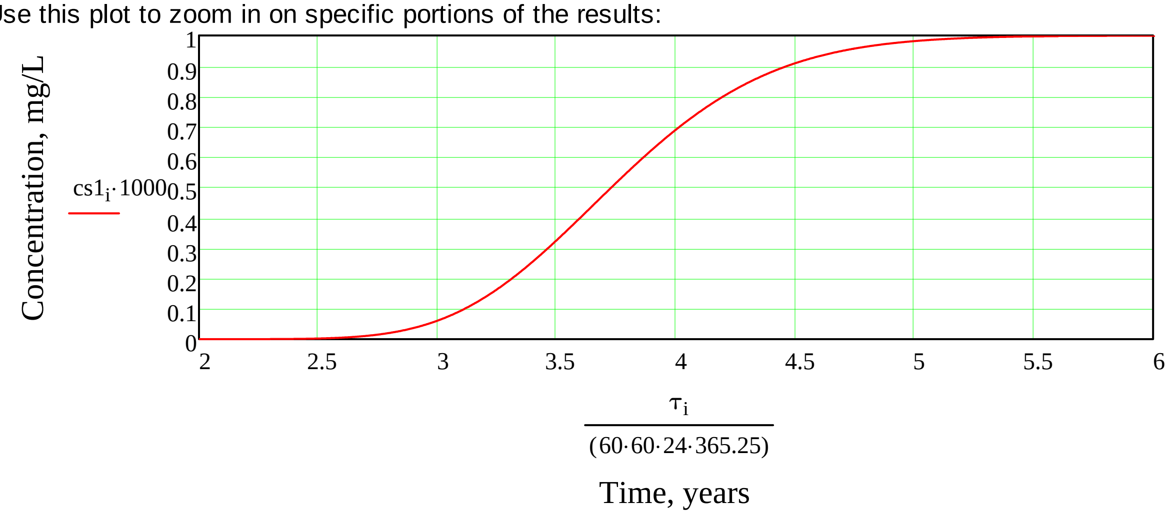
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1yr$ $t_{2\_90\%} := 4.5yr$ $t_{2\_100\%} := 5.5yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^{3} \cdot day$ $t_{2\_90\%} = 1.644 \times 10^{3} \cdot day$ $t_{2\_100\%} = 2.009 \times 10^{3} \cdot day$

Use the values above for time steps 3, 4, 5, and 6 below

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.9 \\ 1.0 \\ 1.0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 2): This assumes no increase in the width of the plume as it moves through Layer 1 and enters Layer 2.

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 600 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 5 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$

Lateal distance of interest (z): $z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 5.669 \times 10^{-5} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 5.669 \times 10^{-4} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 5.669 \times 10^{-4} \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

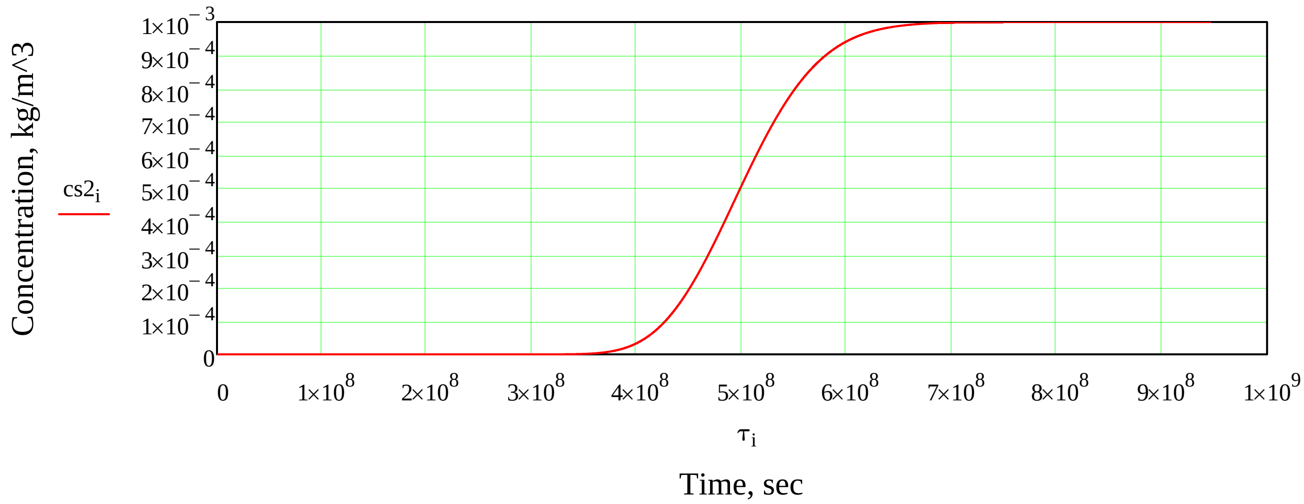
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1,2\,..\,10950$ $\qquad$ $\tau_i := i\cdot day$

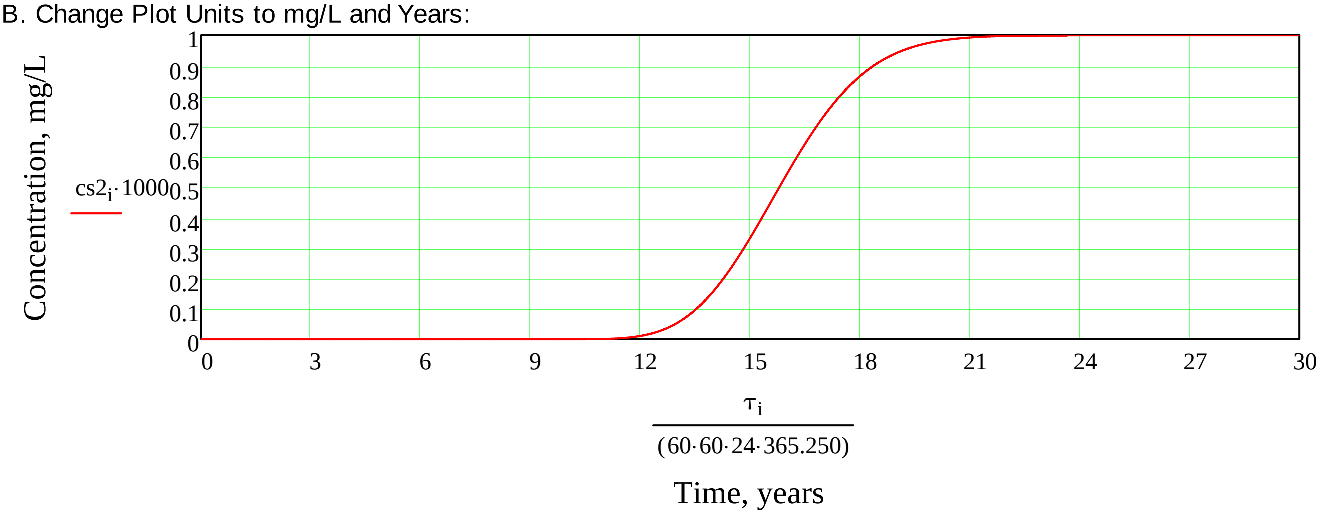
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

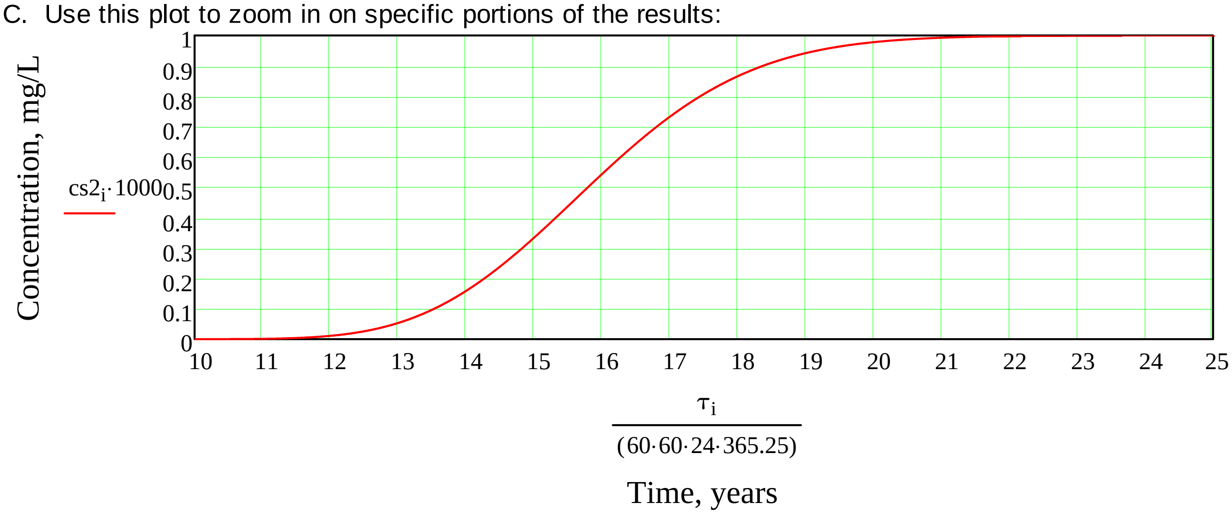
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

$t_{3\_0\%} := 12 \cdot yr$ $t_{3\_10\%} := 13.5yr$ $t_{3\_90\%} := 18.5yr$ $t_{3\_100\%} := 21yr$

$t_{3\_0\%} = 4.383 \times 10^{3} \cdot day$ $t_{3\_10\%} = 4.931 \times 10^{3} \cdot day$ $t_{3\_90\%} = 6.757 \times 10^{3} \cdot day$ $t_{3\_100\%} = 7.67 \times 10^{3} \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 4382 \\ 4383 \\ 4931 \\ 6757 \\ 7670 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is East-West; Z is Nort - South; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 68.031 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 600 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 540 \cdot ft$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 540 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 180 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 180 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 9 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 9 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 2.7 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 900 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 45 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \text{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \text{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \text{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \text{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

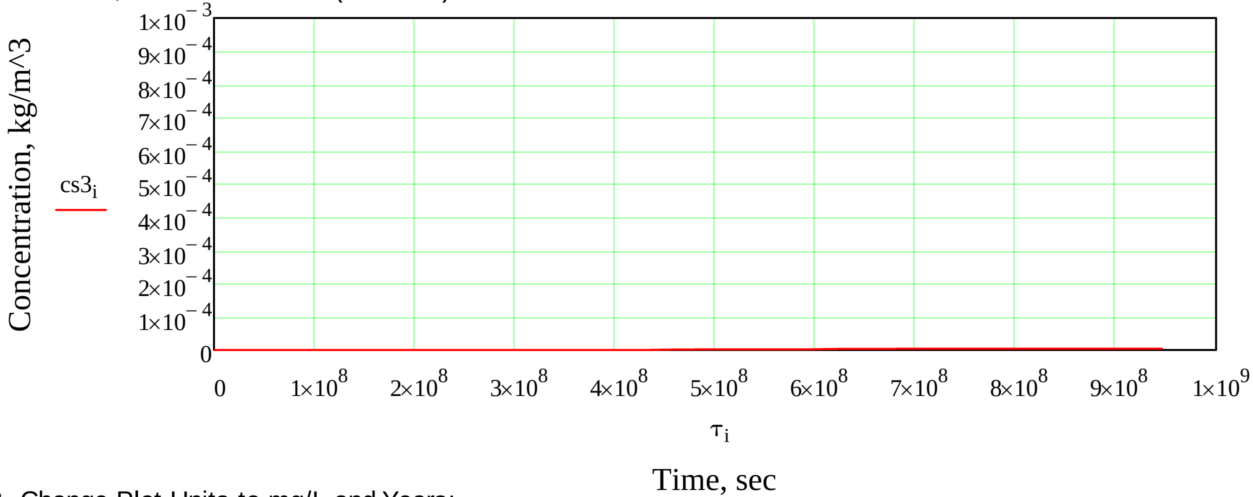
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

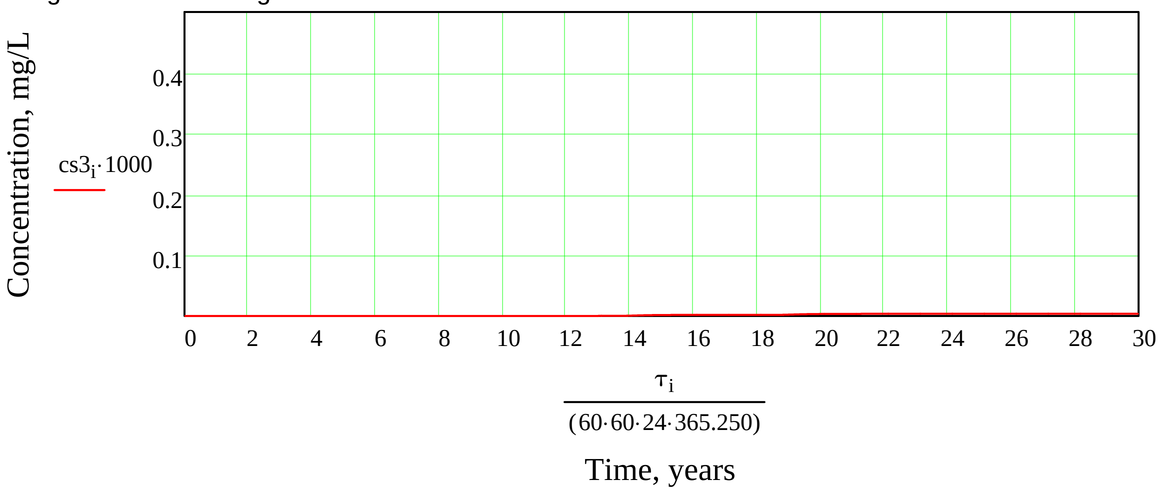
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_3(x_3,y_3,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_3(x_3,y_3,|\tau_i - ti_n|)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

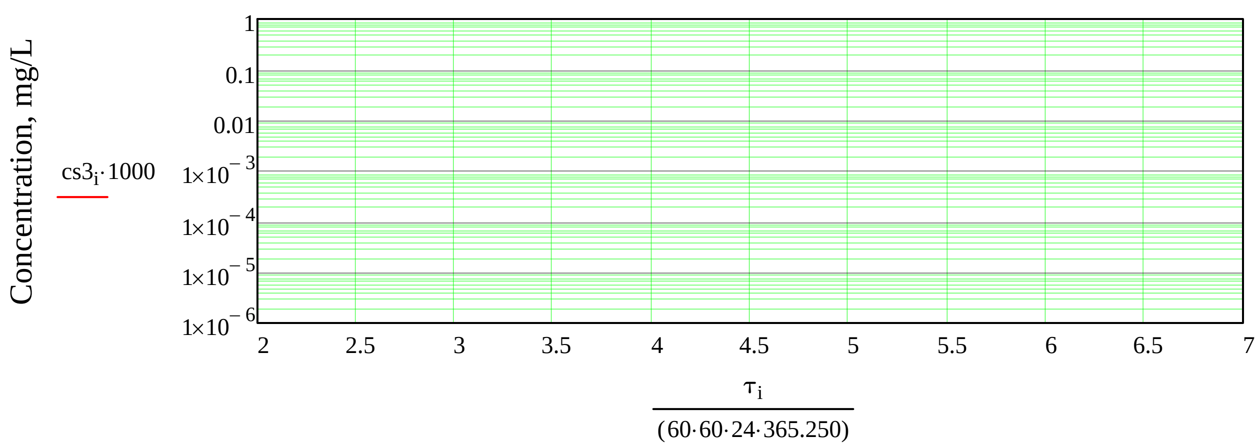
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



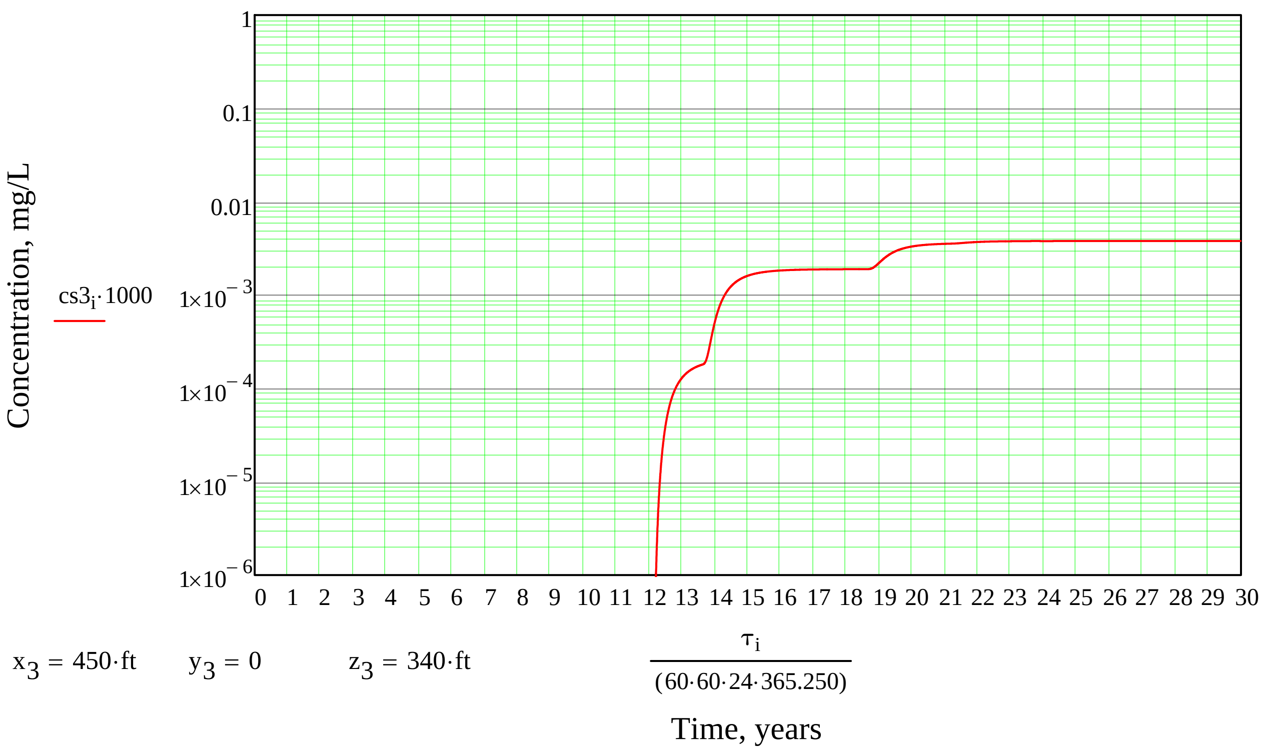
C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 450 \cdot ft$ $y_3 = 0$ $z_3 = 340 \cdot ft$ Time, years

D. Time to reach Criteria; Steady State; and Maximum.

Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 450 \cdot ft$ $y_3 = 0$ $z_3 = 340 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill (Cell 15 &16). Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor G.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1200ft$ North - South

$Length_1 := 720ft$ Layers 1,2 = East - West (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 19.835 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Imported Soil Layer	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 1.832 \times 10^3 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 1.272 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_15} := 200.44ft$ $Head_G := 165ft$

$i_2 := \frac{Head_{Cell\_15} - Head_G}{540ft}$ $i_2 = 0.066$ $v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $v_{gw} = 6.995 \times 10^{-3} \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$$i_2 := \frac{Q_2}{(k_2) \cdot Area_1} \qquad i_2 = 0.011$$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cell 16):

Sens. Rec	X_3 (ft)	Z_3 (ft)
D	810	600
E	450	200
F	450	340
G	870	600

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_2 := 870ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical

Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 600ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2} \qquad a_2 = 13.606 \cdot ft$$

Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 870 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 130.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 130.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 8.7 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 8.7 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 8.7 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 8.7 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 600 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Y&Z = 0 yields the maximum concentration

Lateral distance of interest (z): $z_1 := 0ft$

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

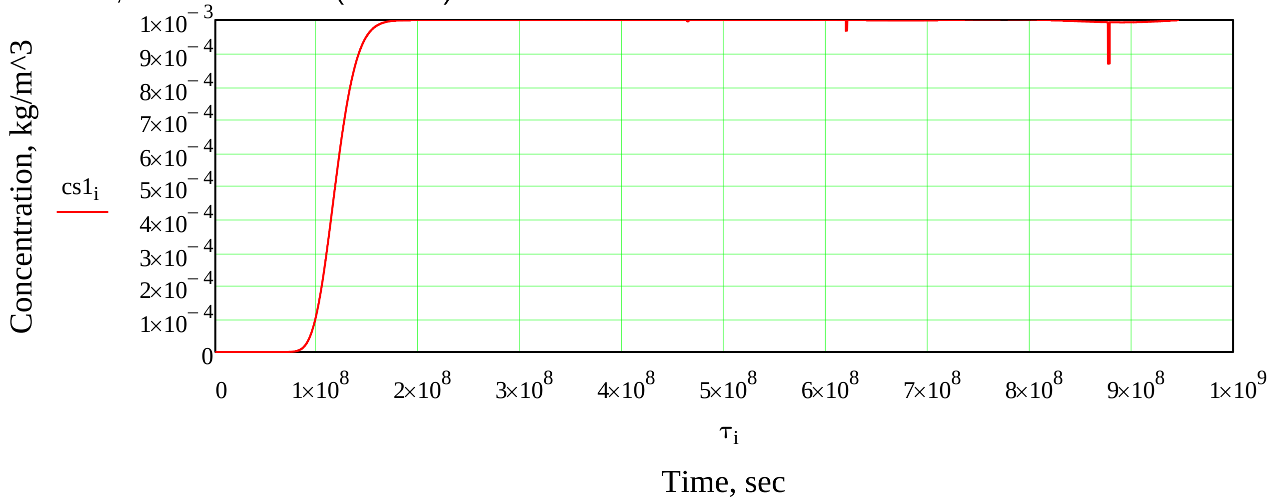
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0, 1 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

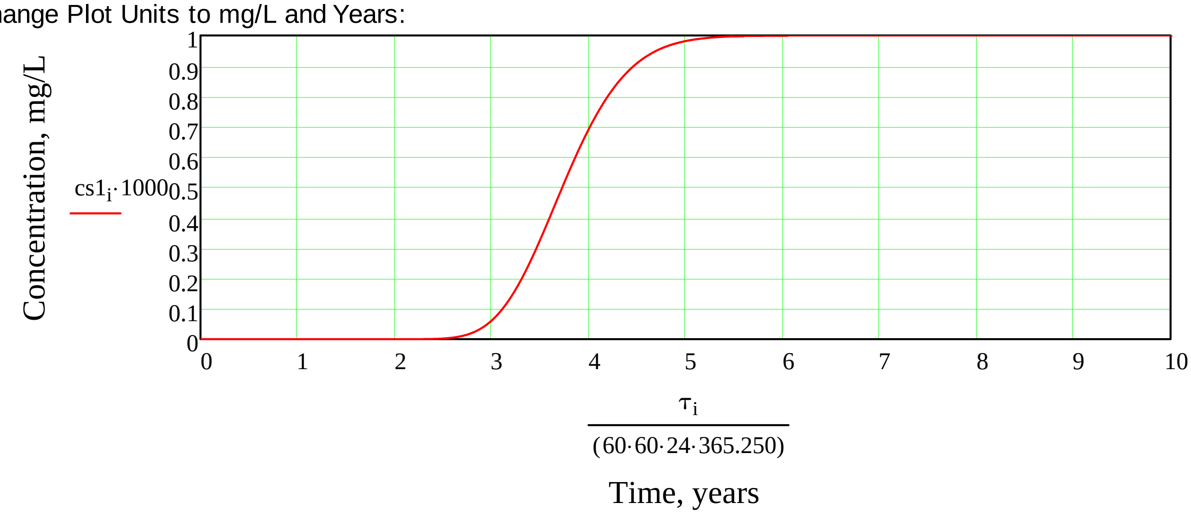
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1(x_1,y_1,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1(x_1,y_1,|\tau_i - ti_n|)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

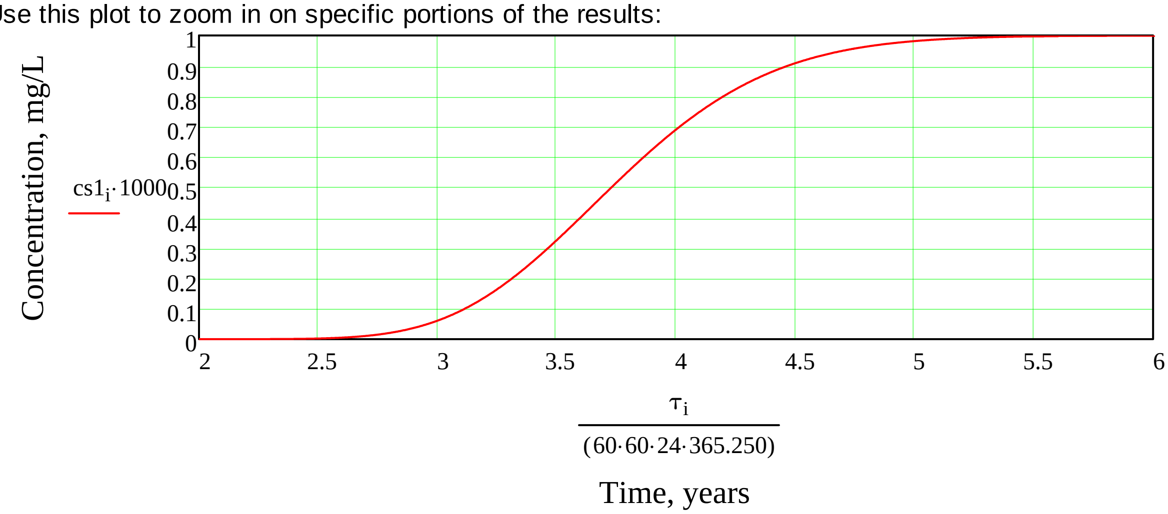
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1 \cdot yr$ $t_{2\_90\%} := 4.5 \cdot yr$ $t_{2\_100\%} := 5.5 \cdot yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^3 \cdot day$ $t_{2\_90\%} = 1.644 \times 10^3 \cdot day$ $t_{2\_100\%} = 2.009 \times 10^3 \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 13.606 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 600 \cdot ft$ Southeast - Northwest

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 130.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 130.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 8.7 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 8.7 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 8.7 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 8.7 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 13.05 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.87 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.87 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

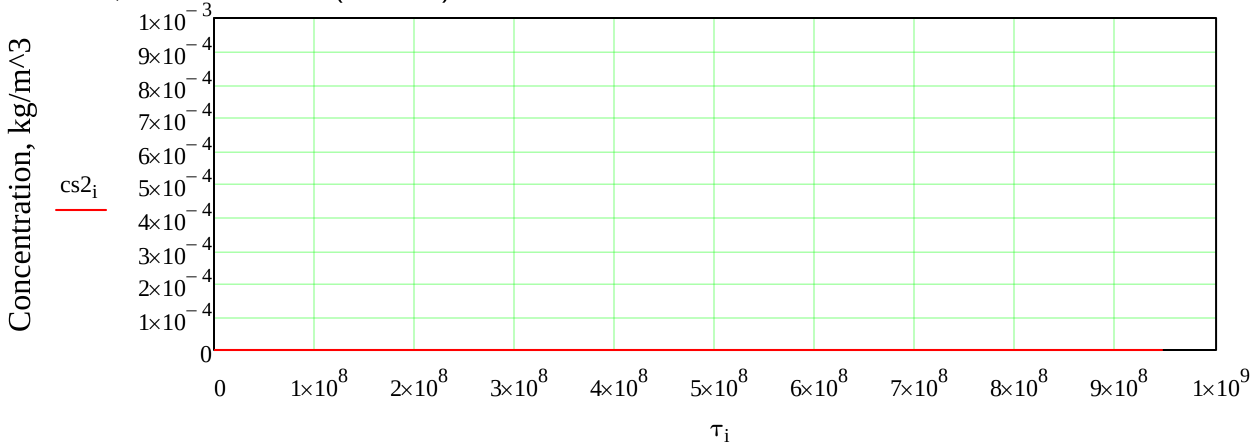
$i := 0,1..10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{day}$$

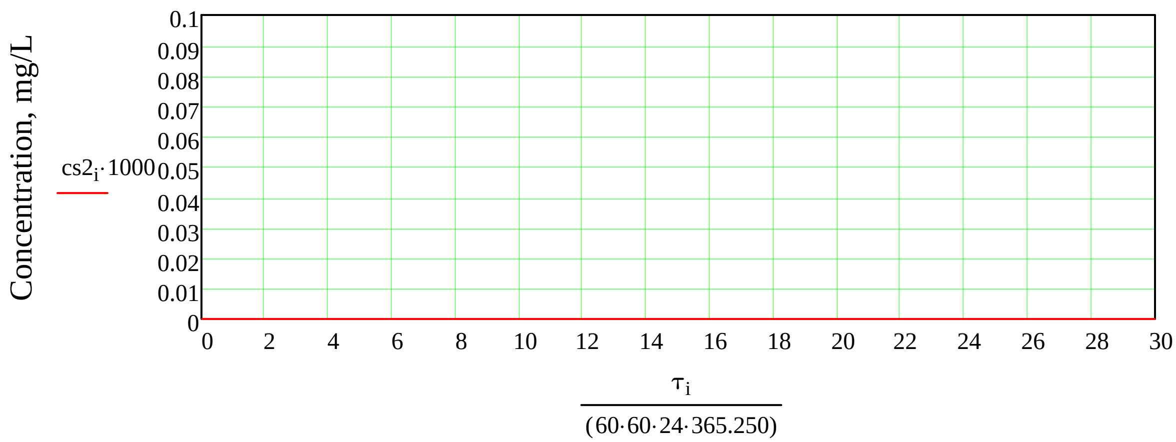
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)

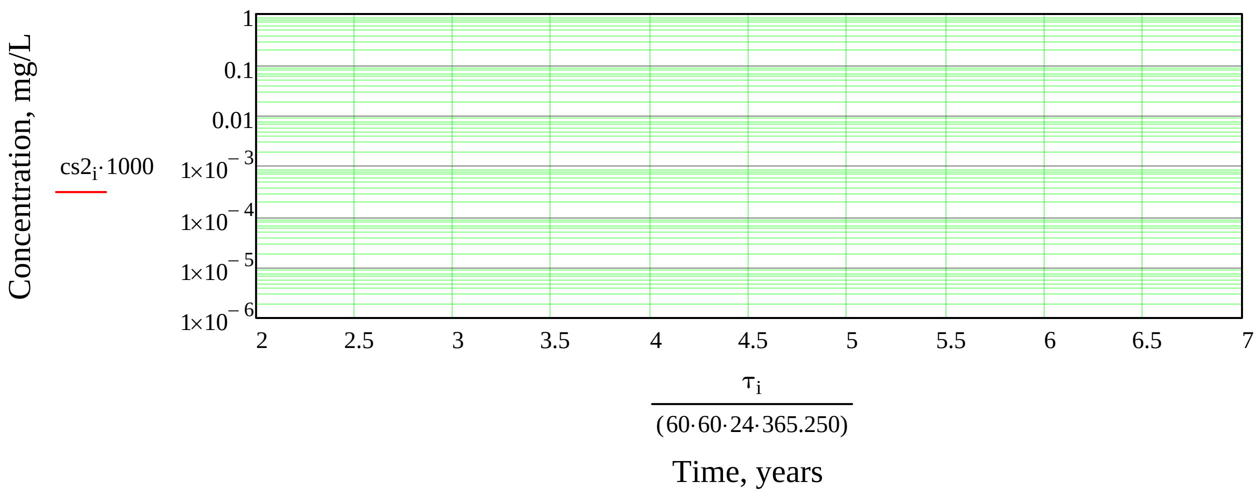


B. Change Plot Units to mg/L and Years:

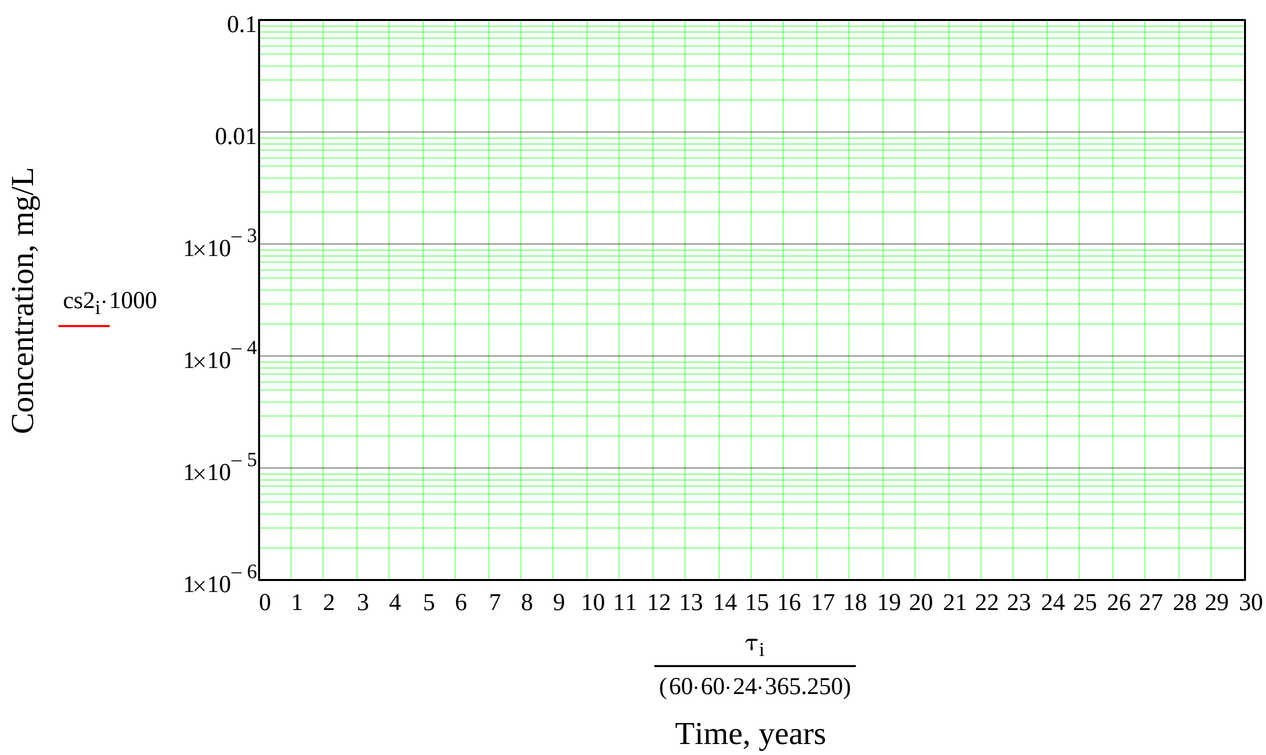


$x_2 = 870 \cdot ft$ $y_2 = 0$ $z_2 = 600 \cdot ft$

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 870 \cdot ft$ $y_2 = 0$ $z_2 = 600 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of Cells 15 and 16 of the landfill. Flow is vertically down through Layer 1 (Imported Soil layer); then through Layer 2 (Till); and horizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor G.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction- to the west):

Z axis (all layers) $Width_1 := 1200ft$ North - South

$Length_1 := 720ft$ Layers 1,2 = East - West (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\quad Area_1 = 19.835 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Imported Soil Layer	Native Till	Bedrock
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 1ft$	$x_2 := 5ft$	X3 defined in Section 3.3

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $\quad i_1 := 1$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 1.832 \times 10^3 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 1.272 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $\quad v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock is from the Bedrock Tracer Test.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{Q_2}{(k_2) \cdot Area_1}$ $\quad i_2 = 0.011$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Sensitive Receptor (from Center of Western Side of Expansion):

Sens. Rec	X_3 (ft)	Z_3 (ft)
D	810	600
E	450	200
F	450	340
G	870	600

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_3 := 870ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 600ft$ North - South

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 68.031 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Vertical

2.2 Dispersion in Layer 2 (Native Till):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 5 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.05 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.05 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 0.5 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 0.5 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 0.5 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 0.5 \cdot ft$	Vertical

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

Downgradient distances: $X_3 := 50ft$ $\quad Y_3 := 50ft$ $\quad Z_3 := 50ft$ — These Calcs

Lateral dispersivity $\quad \alpha_{y\_BR} := \frac{20ft}{Y_3} \quad \alpha_{y\_BR} = 0.4$ — Z axis

Downgradient dispersivity: $\quad \alpha_{x\_BR} := \frac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3} \quad \alpha_{x\_BR} = 1.2$ — X axis

Vertical dispersivity $\quad \alpha_{z\_BR} := \frac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3} \quad \alpha_{z\_BR} = 0.02$ — Y axis

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 2000 \\ 5000 \\ 10950 \end{pmatrix} \cdot day$ This is a continuous source.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 360 \cdot ft$ East - West

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 600 \cdot ft$ North - South

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$ East - West

Lateral distance of interest (z): $z_1 := 0ft$ North - South

X, Y = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

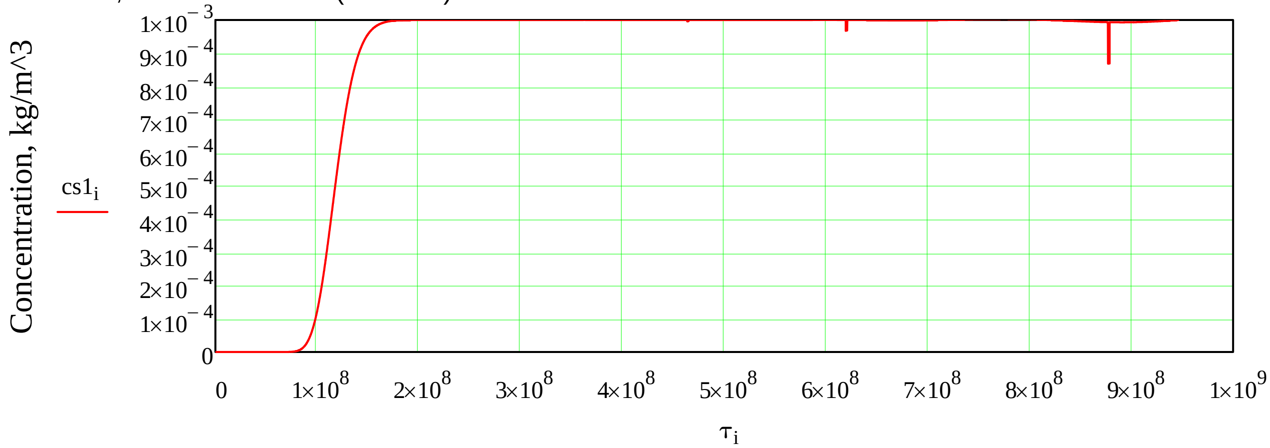
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

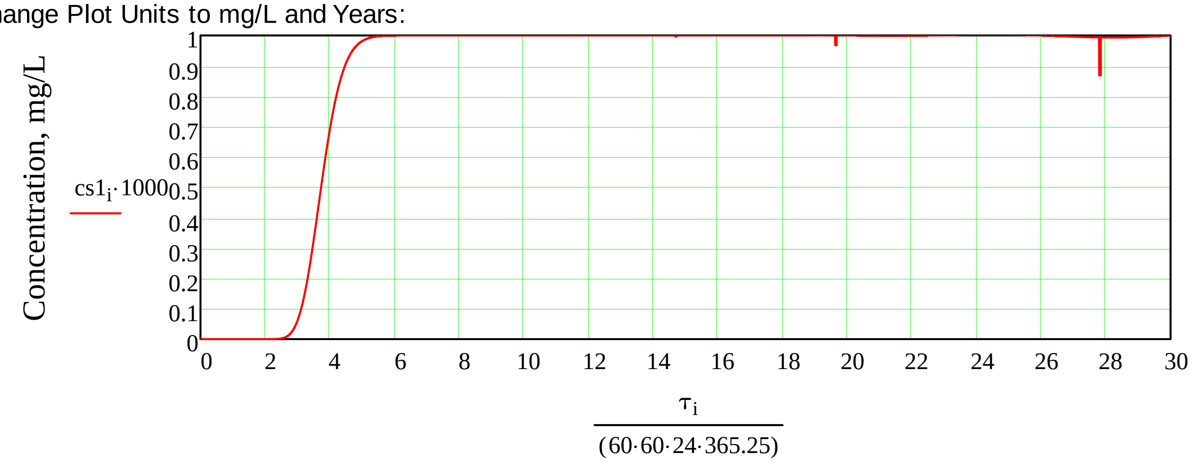
5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

A. Solution, with default units (Mathcad)



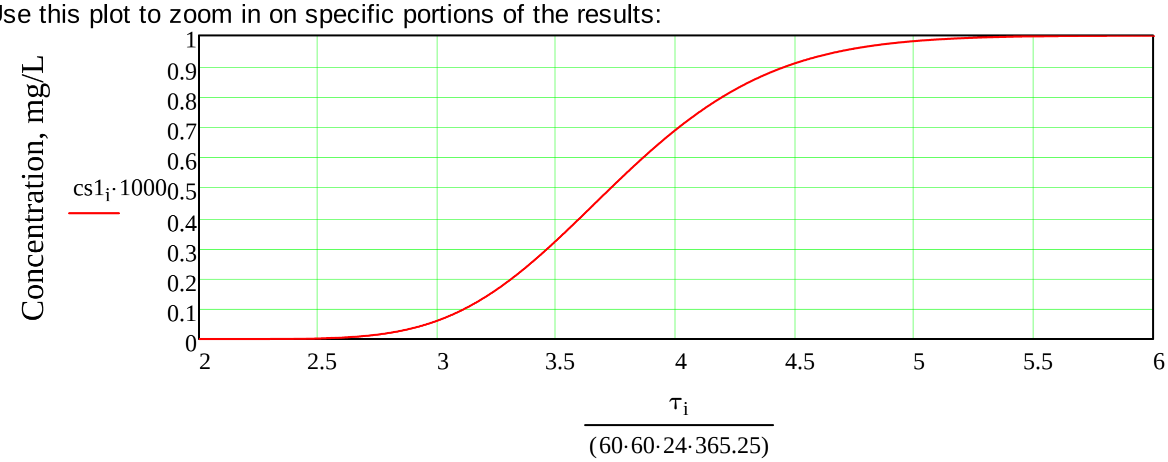
Time, sec

B. Change Plot Units to mg/L and Years:



Time, years

C. Use this plot to zoom in on specific portions of the results:



Time, years

3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1yr$ $t_{2\_90\%} := 4.5yr$ $t_{2\_100\%} := 5.5yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^{3} \cdot day$ $t_{2\_90\%} = 1.644 \times 10^{3} \cdot day$ $t_{2\_100\%} = 2.009 \times 10^{3} \cdot day$

Use the values above for time steps 3, 4, 5, and 6 below

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.9 \\ 1.0 \\ 1.0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 2): This assumes no increase in the width of the plume as it moves through Layer 1 and enters Layer 2.

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 600 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 1.134 \times 10^{-3} \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 5 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$ East - West

Lateal distance of interest (z): $z_2 := 0ft$ Nort - South

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 5.669 \times 10^{-5} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 5.669 \times 10^{-4} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 5.669 \times 10^{-4} \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

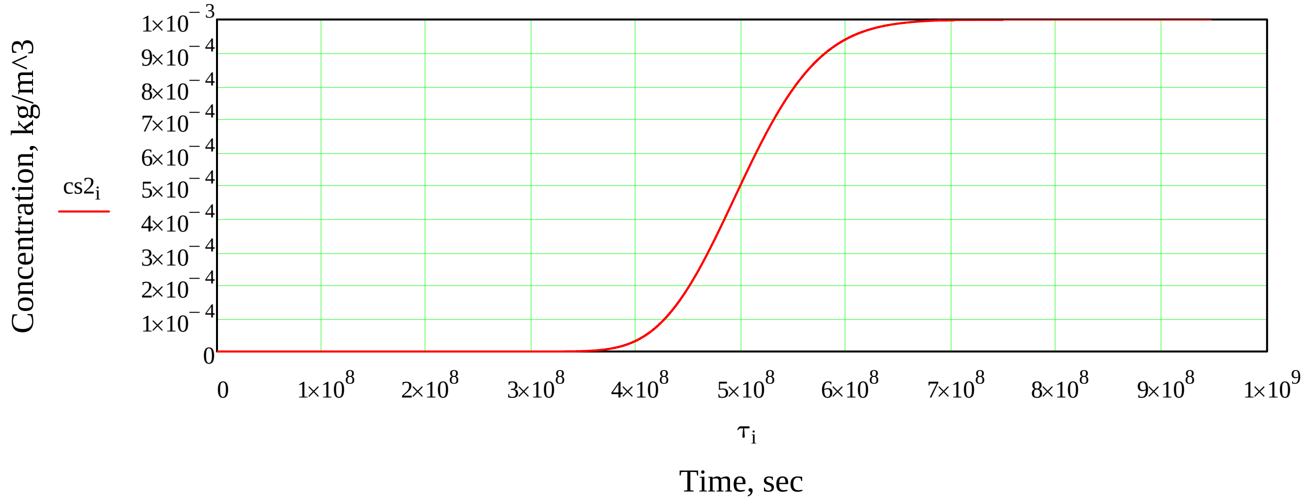
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1,2\,..\,10950$ $\qquad$ $\tau_i := i\cdot day$

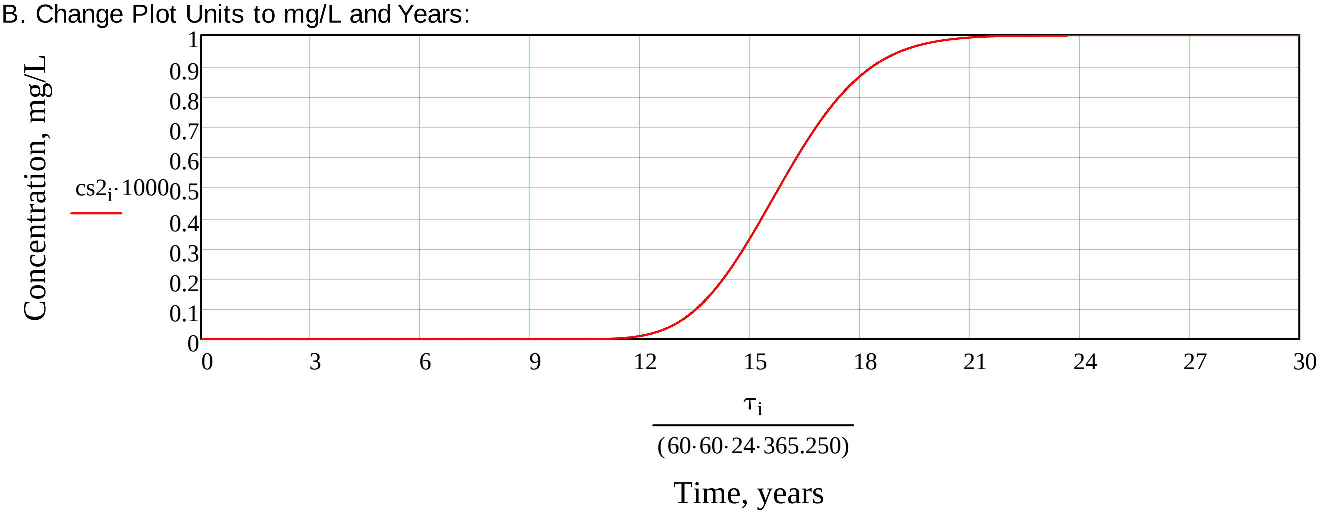
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

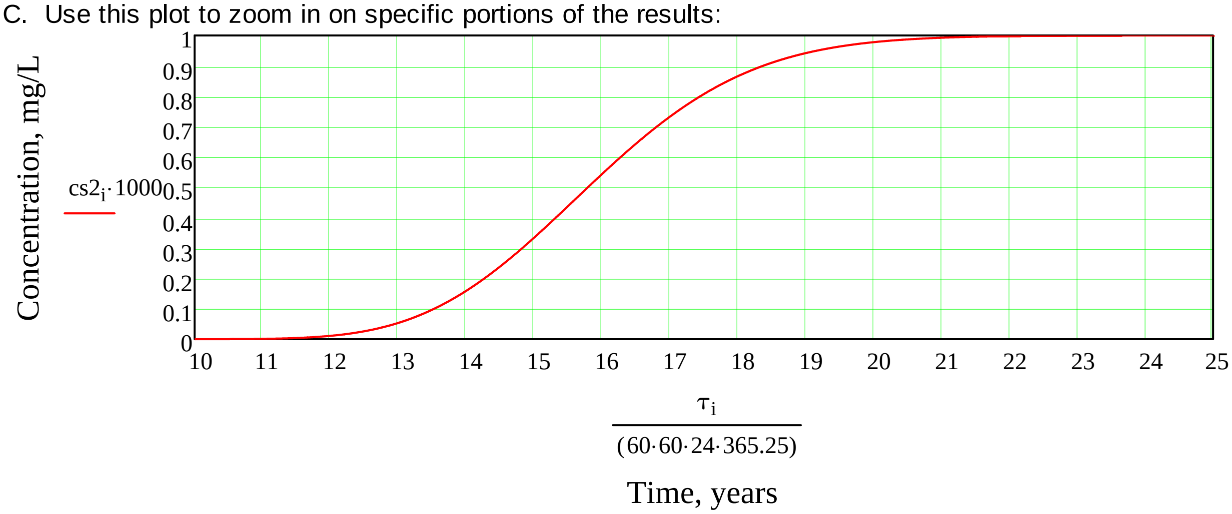
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

$t_{3\_0\%} := 12 \cdot yr$ $t_{3\_10\%} := 13.5yr$ $t_{3\_90\%} := 18.5yr$ $t_{3\_100\%} := 21yr$

$t_{3\_0\%} = 4.383 \times 10^{3} \cdot day$ $t_{3\_10\%} = 4.931 \times 10^{3} \cdot day$ $t_{3\_90\%} = 6.757 \times 10^{3} \cdot day$ $t_{3\_100\%} = 7.67 \times 10^{3} \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 4382 \\ 4383 \\ 4931 \\ 6757 \\ 7670 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is East-West; Z is Nort - South; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 68.031 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 600 \cdot ft$ North - South

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 1.044 \times$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 1.044 \times 10^3 \cdot ft$ Flow

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 348 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 348 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 17.4 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 17.4 \cdot ft$ Lateral (north-south)

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 5.22 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.74 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 87 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \operatorname{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \operatorname{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \operatorname{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \operatorname{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

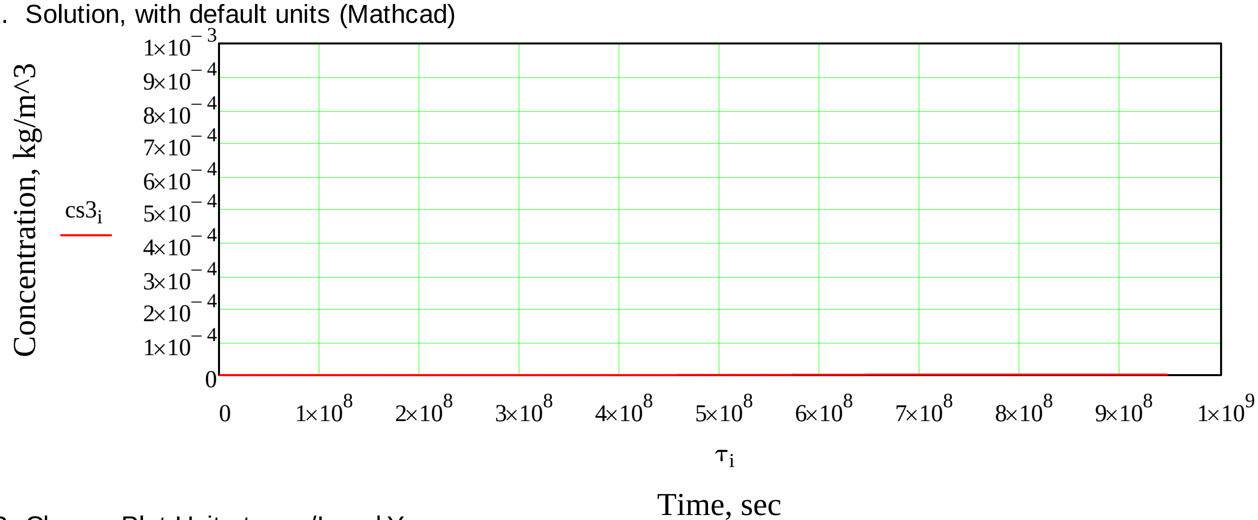
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

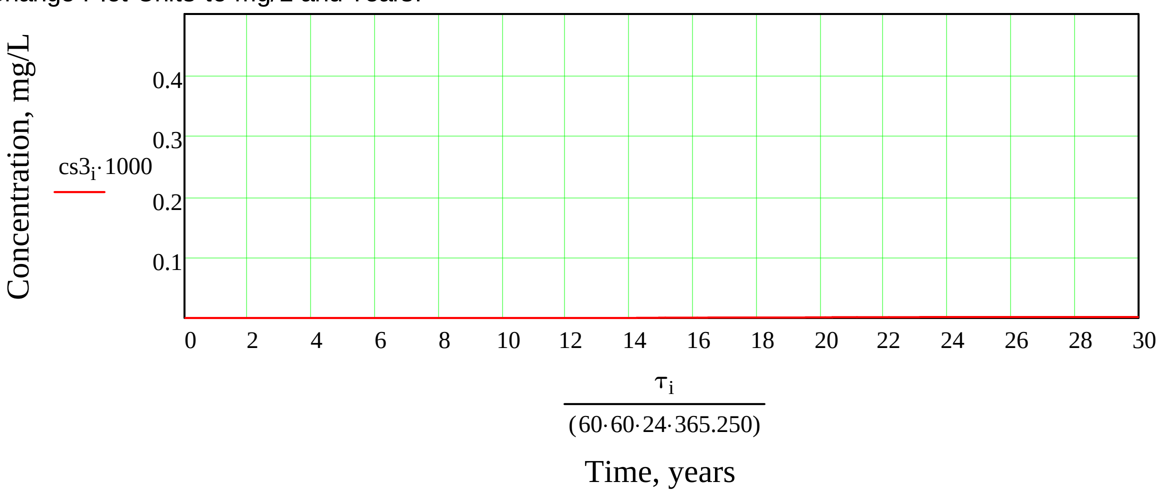
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

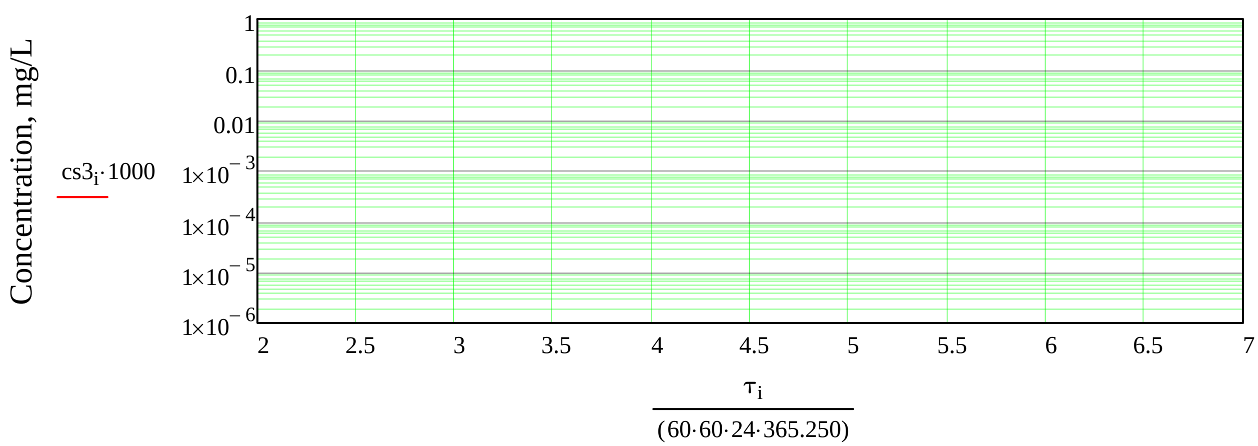
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

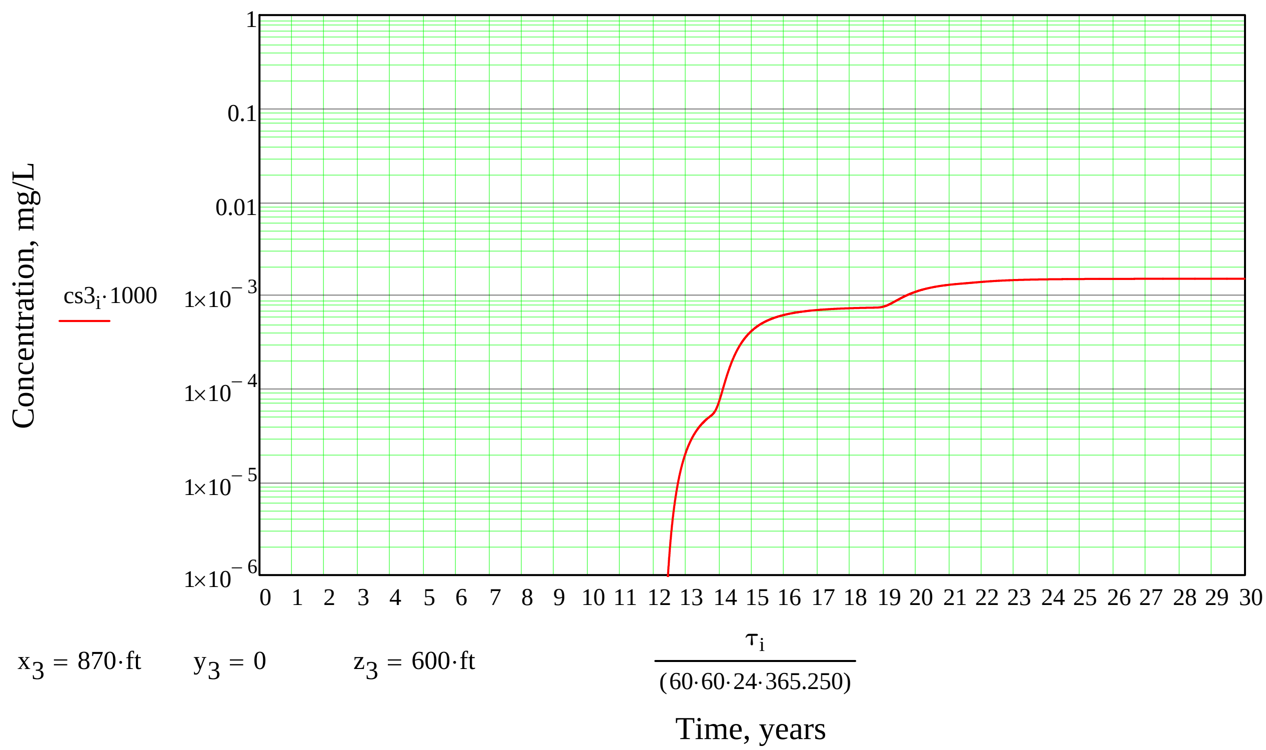


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 870 \cdot ft$ $y_3 = 0$ $z_3 = 600 \cdot ft$ Time, years

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 870 \cdot ft$ $y_3 = 0$ $z_3 = 600 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

A leaky Liner scenario, with Q = 4.6 gallons per acre per day: Cell 11. Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor A or B.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1600ft$ Southeast - Northwest

$Length_1 := 255ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 9.366 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Imported Soil Layer	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

$Q_1 := 4.6 \frac{gal}{day}$ $i_1 := \frac{Q_1}{k_1 \cdot (Area_1)}$ $i_1 = 5.317 \times 10^{-3}$

C. Calculate flow rate through Layer 1 & 2:

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 3.865 \times 10^{-6} \cdot \frac{ft}{day}$ $LQ := \frac{Q_1 \cdot \frac{Area_1}{acre}}{Area_1}$ $LQ = 4.6 \cdot \frac{\frac{gal}{acre}}{day}$

$Q_2 := Q_1$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_11} := 200.6ft$ $Head_A := 173ft$

$i_2 := \frac{Head_{Cell\_11} - Head_A}{540ft}$ $i_2 = 0.051$ $v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $v_{gw} = 5.448 \times 10^{-3} \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 = 0.051$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cell 11):

Sens. Rec	X_2 (ft)	Z_2 (ft)
A	540	300
B	770	300

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_2 := 540ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 300ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2} \qquad a_2 = 0.096 \cdot ft$$

Y Direction in Layer 3 (Vertical)

Note that leachate does not actually travel into bedrock. This equasion only applies where leachate does exit Layer 1.

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 540 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 81 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 81 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 5.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 5.4 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 5.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 5.4 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 127.5 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 800 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 3.865 \times 10^{-6} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 3.865 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 3.865 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 3.865 \times 10^{-8} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

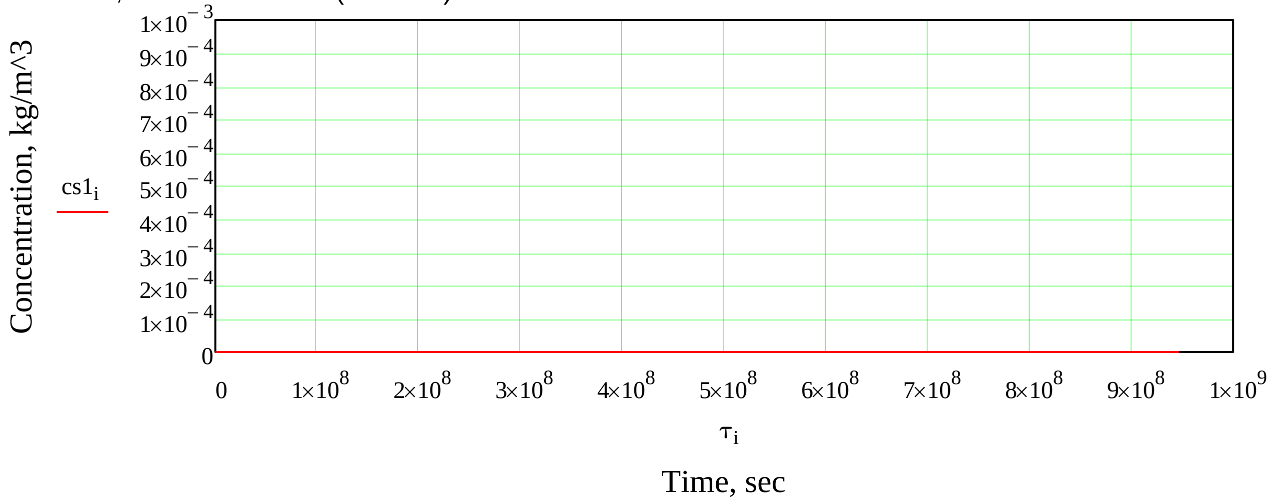
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0,1..10950$ $\qquad \tau_i := i\cdot day$

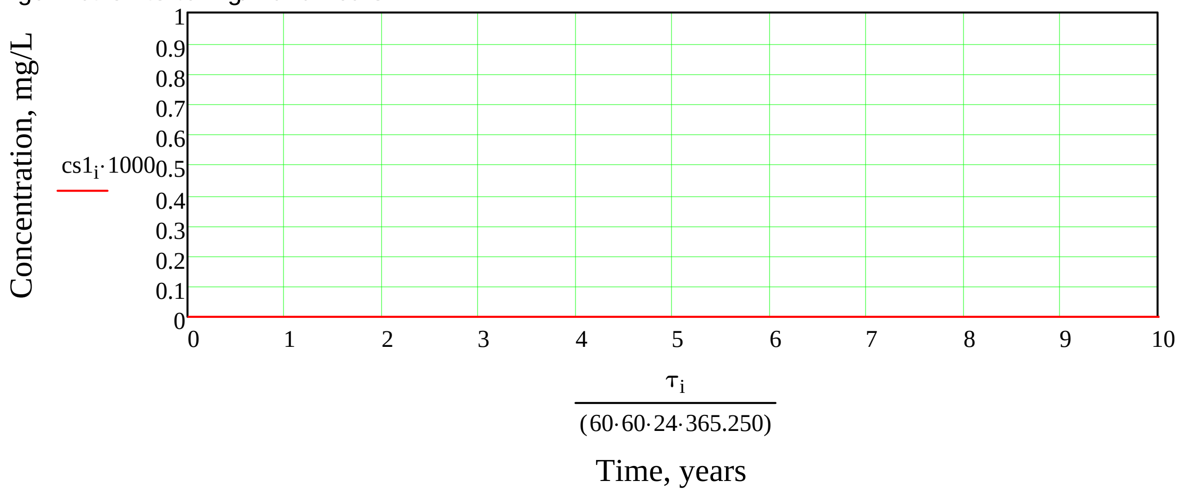
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

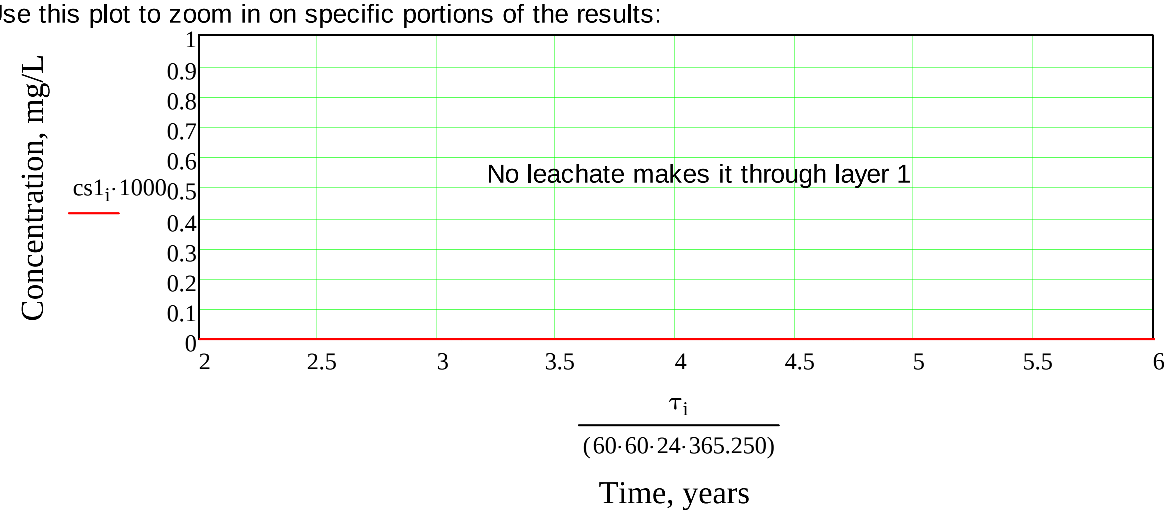
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

No Leachate makes it through the Imported Soil Layer in 30 years at the rate of 4.6 g/a/d.

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration | Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.0 \\ 0.0 \\ 0.0 \\ 0.0 \\ 0.0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 0.096 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 800 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 81 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 81 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 5.4 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 5.4 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 5.4 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 5.4 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 8.1 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.54 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.54 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

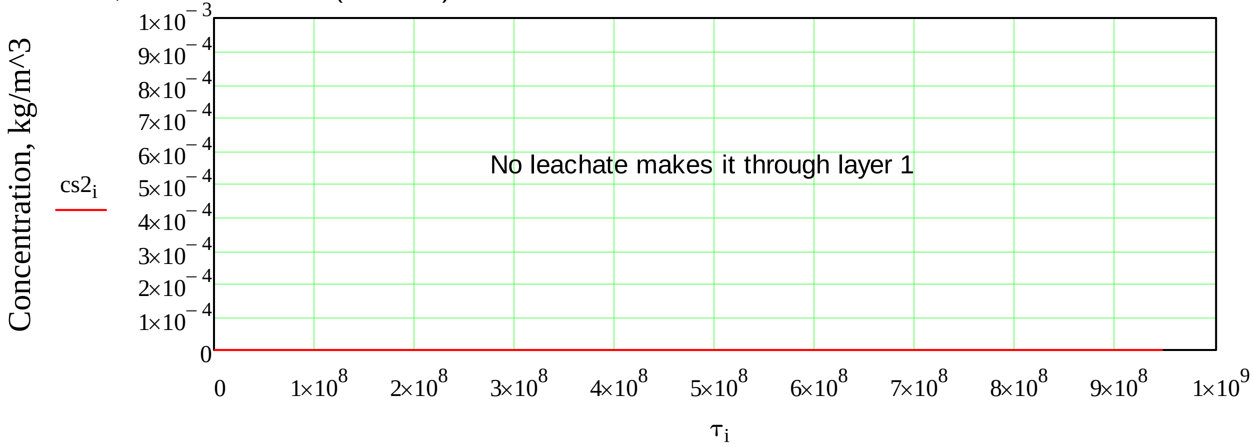
$i := 0,1..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

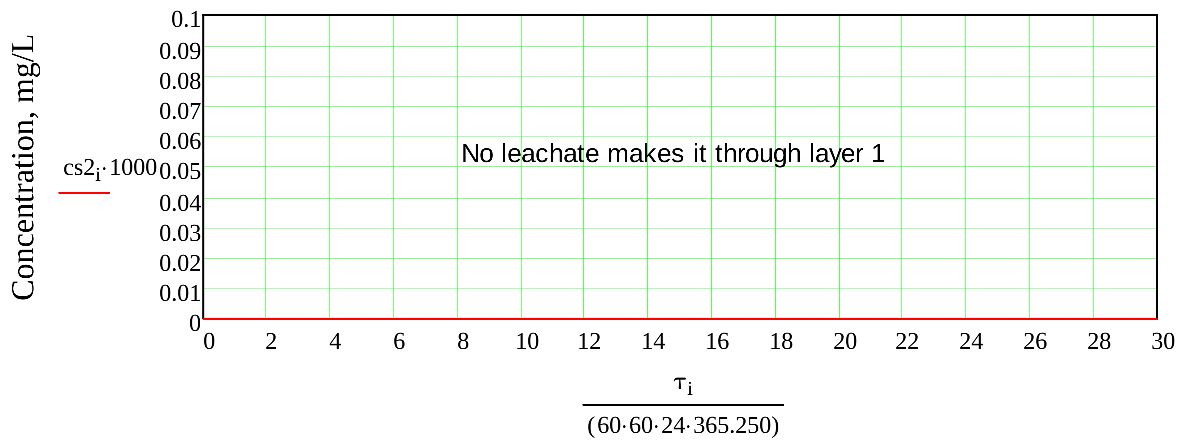
5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

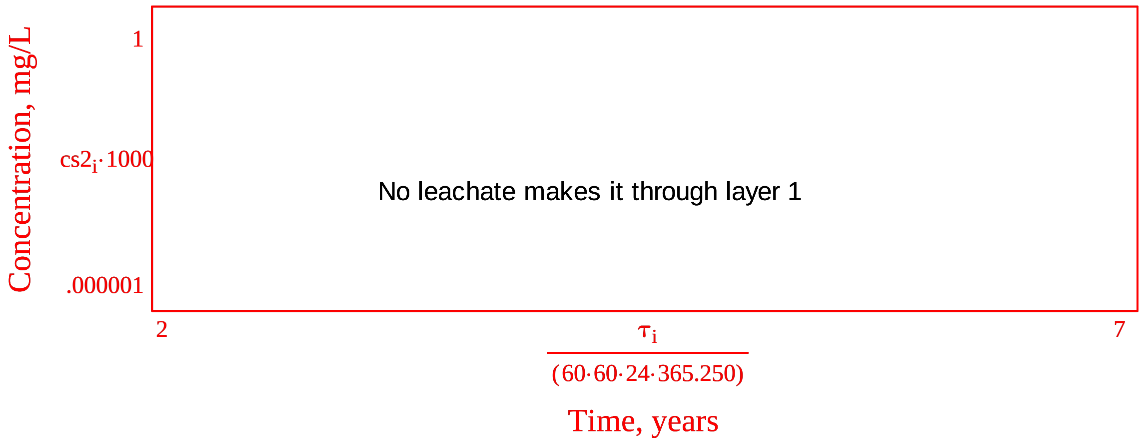
Time, sec



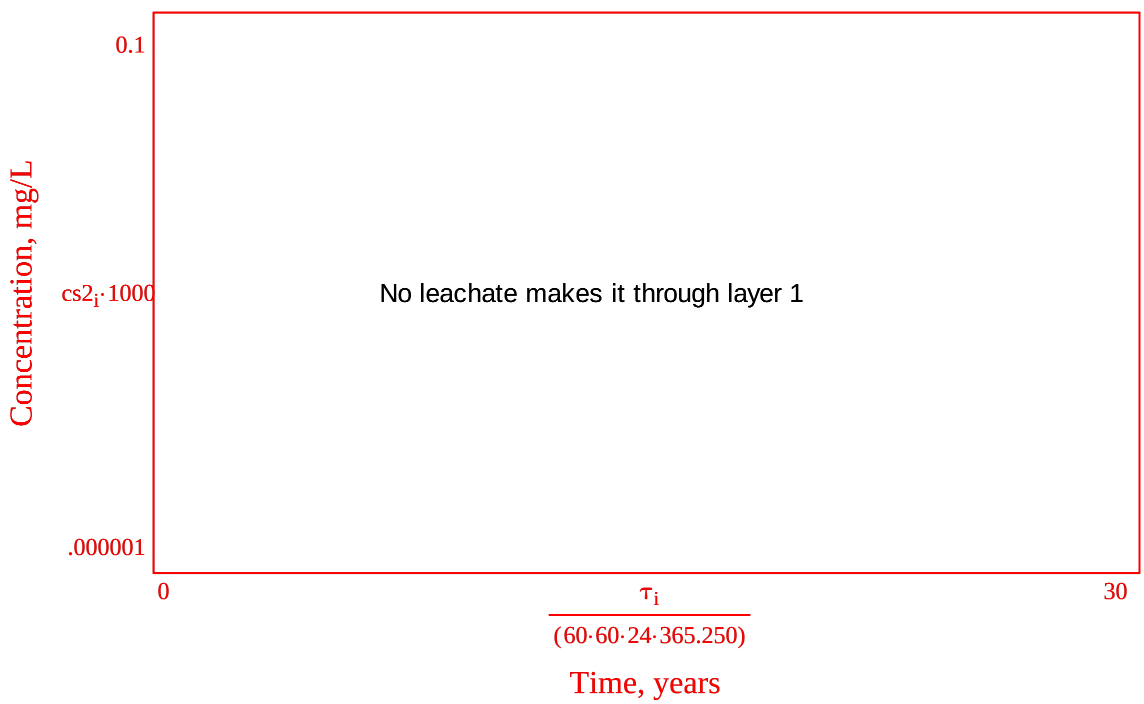
$x_2 = 540 \cdot ft$ $y_2 = 0$ $z_2 = 300 \cdot ft$

Time, years

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 540 \cdot ft$ $\quad y_2 = 0$ $\quad z_2 = 300 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
A leaky Liner scenario: Cell 11. Flow is vertically down through Layer 1 (Imported Soil layer); then through Layer 2 (Till); and horizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptors A and B.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1600ft$ Southeast - Northwest

$Length_1 := 255ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 9.366 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Imported Soil Layer	Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 1ft$	$x_2 := 4ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are: Three holes/acre.

$Q_1 := 4.6 \frac{gal}{day}$ $i_1 := \frac{Q_1}{k_1 \cdot (Area_1)}$ $i_1 = 5.317 \times 10^{-3}$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 3.865 \times 10^{-6} \cdot \frac{ft}{day}$

$LQ := \frac{Q_1 \cdot \frac{Area_1}{acre}}{Area_1}$ $LQ = 4.6 \cdot \frac{\frac{gal}{acre}}{day}$

LQ was Used to determine the value of a_3

$Q_2 := Q_1$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 6.029 \times 10^{-6} \cdot \frac{ft}{day}$

$v_3 := 5 \frac{ft}{day}$

Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{Q_2}{(k_2) \cdot Area_1}$ $i_2 = 5.656 \times 10^{-5}$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the east side of the Imported Soil Limits in Cell 11):

Sens. Rec	X_3 (ft)	Z_3 (ft)
A	540	300
B	770	300

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_3 := 540ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 300ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 0.482 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 4 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.04 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.04 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 0.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 0.4 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 0.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 0.4 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

			These Calcs
Lateral dispersivity	$\alpha_{y\_BR} := \frac{20ft}{Y_3}$	$\alpha_{y\_BR} = 0.4$	Z axis
Downgradient dispersivity:	$\alpha_{x\_BR} := \frac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$	$\alpha_{x\_BR} = 1.2$	X axis
Vertical dispersivity	$\alpha_{z\_BR} := \frac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$	$\alpha_{z\_BR} = 0.02$	Y axis

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 1000 \\ 5000 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 127.5 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 800 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 3.865 \times 10^{-6} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 3.865 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 3.865 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 3.865 \times 10^{-8} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

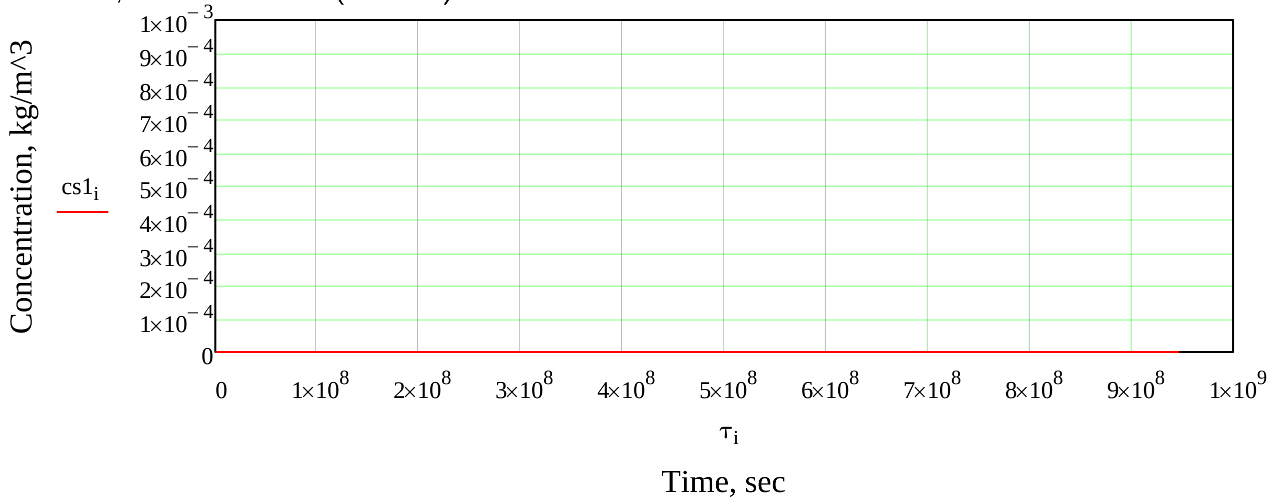
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

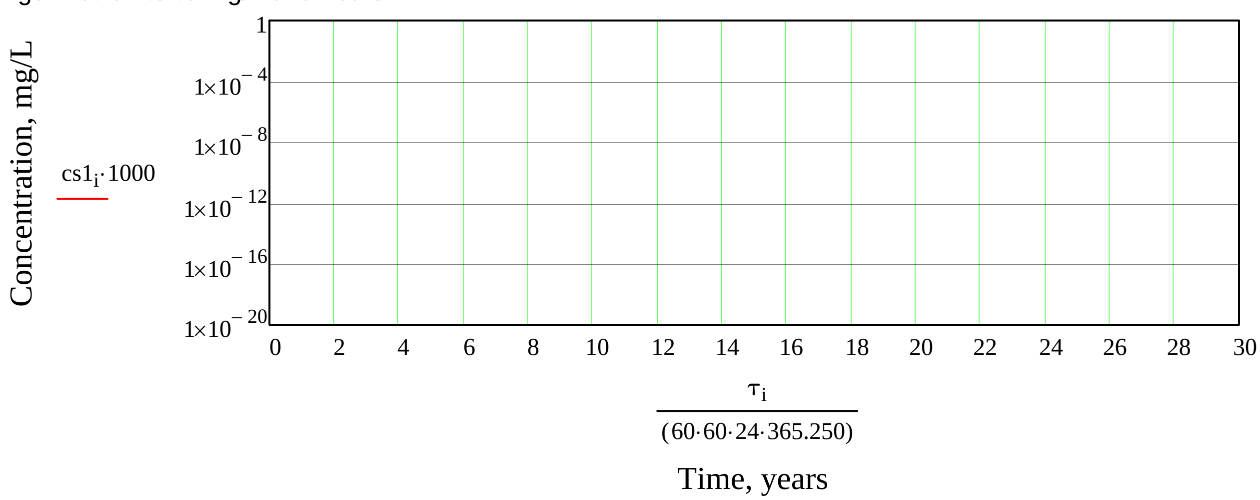
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

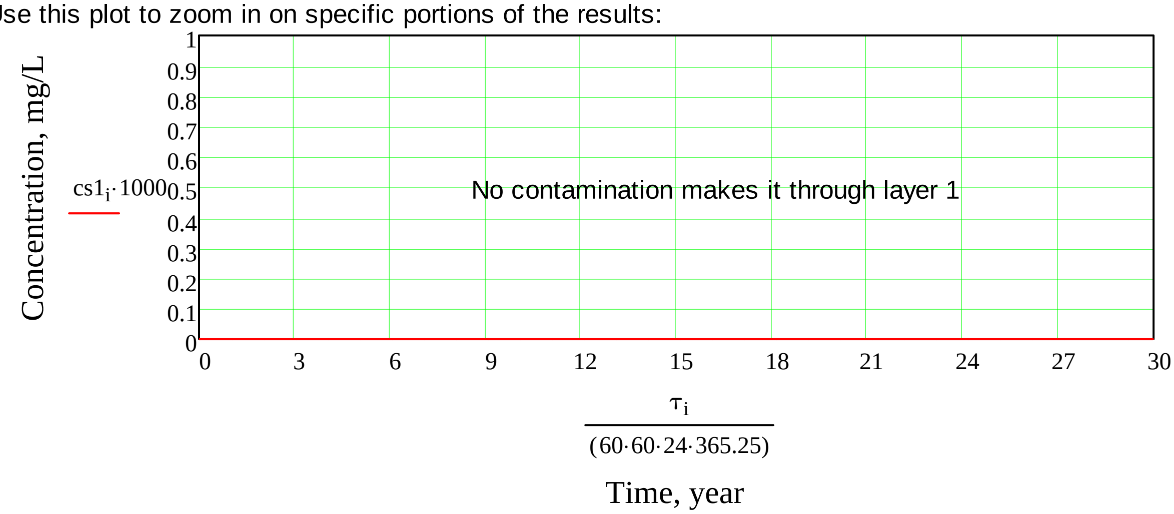
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

No Leachate makes it through the Imported Soil Layer in 30 years at the rate of 4.6 g/a/d.

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 54 \\ 55 \\ 65 \\ 95 \\ 110 \\ 10950 \end{pmatrix} day$$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 127.5 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 800 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 6.029 \times 10^{-6} \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 4 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$

Lateal distance of interest (z): $z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 2.411 \times 10^{-7} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 2.411 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 2.411 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \text{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \text{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \text{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \text{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

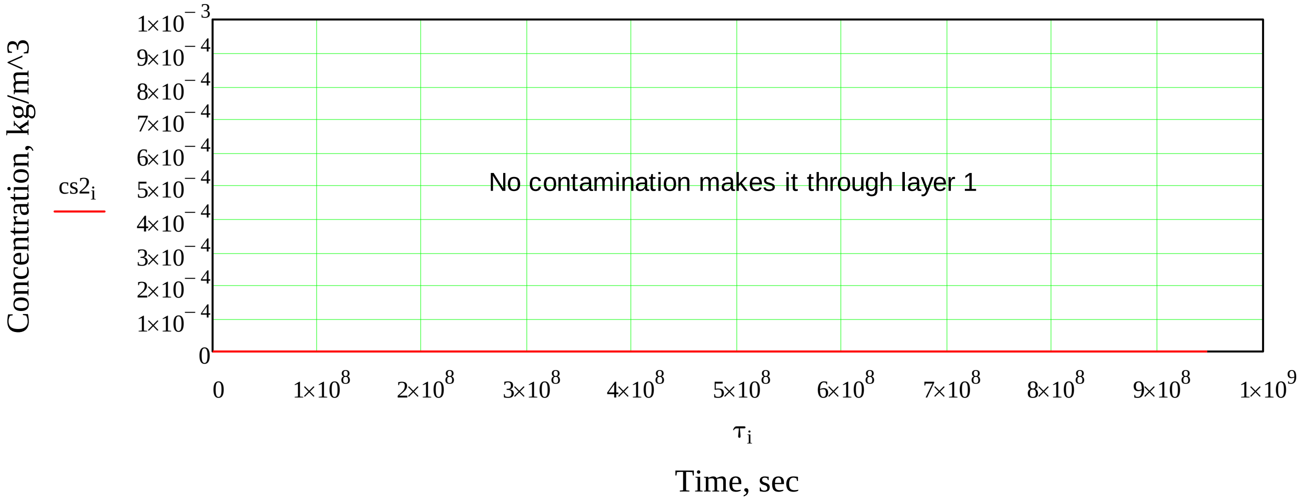
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

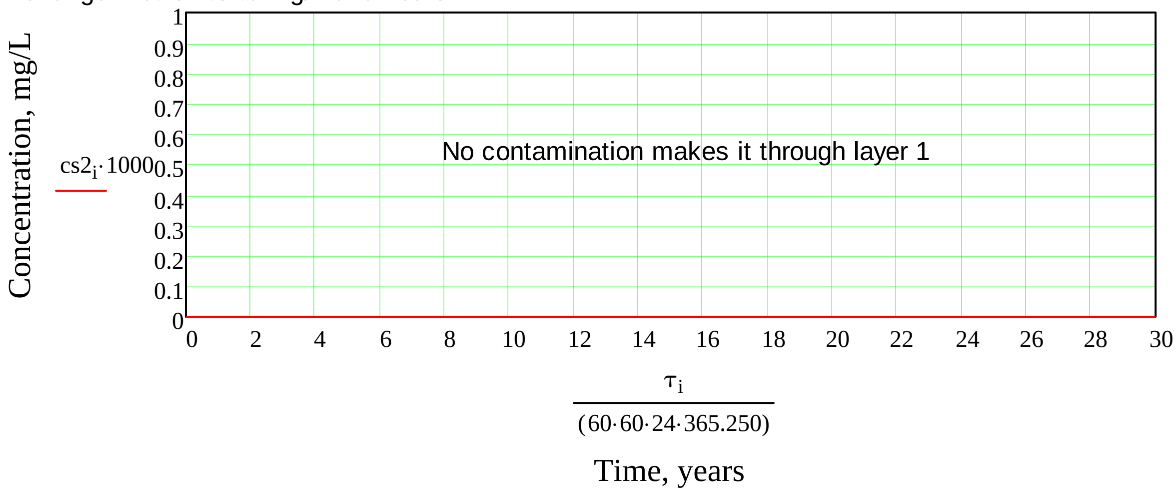
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

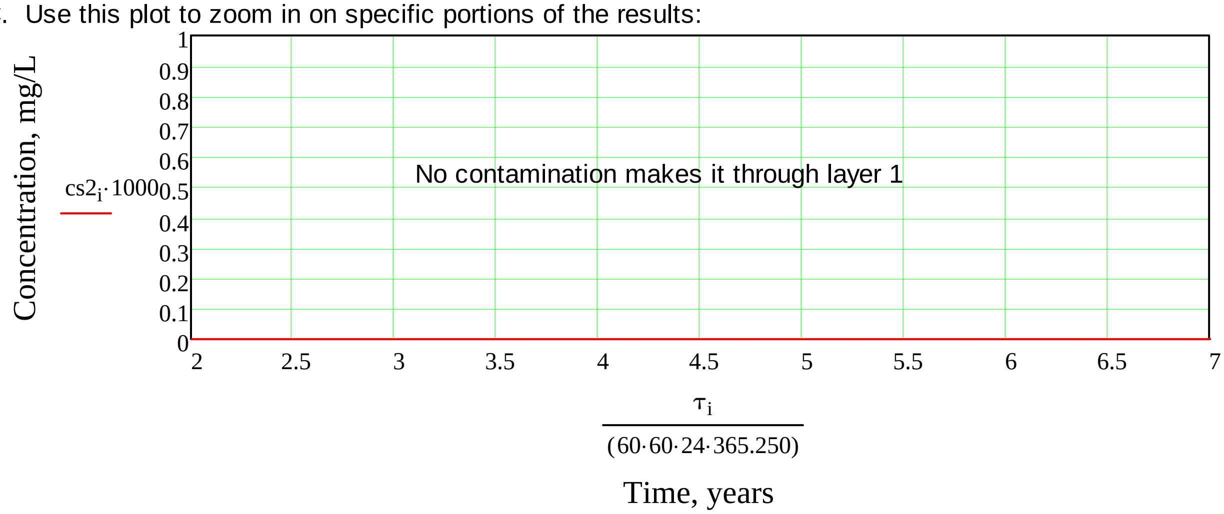
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

$t_{3\_1\%} := 0 \cdot yr$ $t_{3\_10\%} := 0yr$ $t_{3\_90\%} := 0yr$ $t_{3\_100\%} := 0yr$

$t_{3\_1\%} = 0 \cdot day$ $t_{3\_10\%} = 0 \cdot day$ $t_{3\_90\%} = 0 \cdot day$ $t_{3\_100\%} = 0 \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 1095 \\ 1096 \\ 1315 \\ 1826 \\ 2191 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 3

This source sub-divides the results from Layer 2.

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Northeast-Southwest; Z is Southeast - Northwest; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 0.482 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 800 \cdot ft$ Southeast - Northwest

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 648 \cdot ft$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 648 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 216 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 216 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 10.8 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 10.8 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 3.24 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.08 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 54 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \text{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \text{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \text{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \text{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

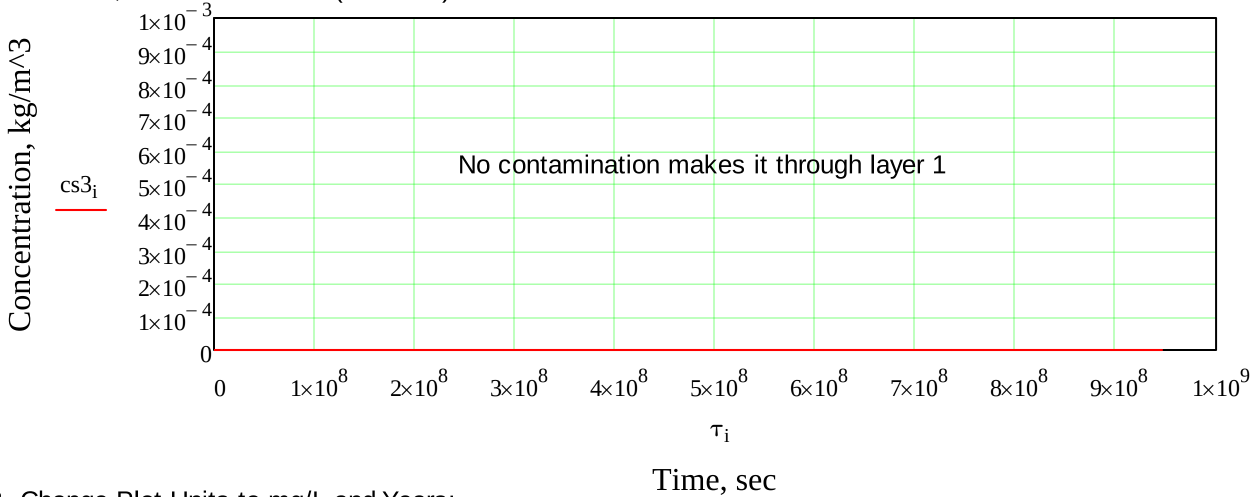
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

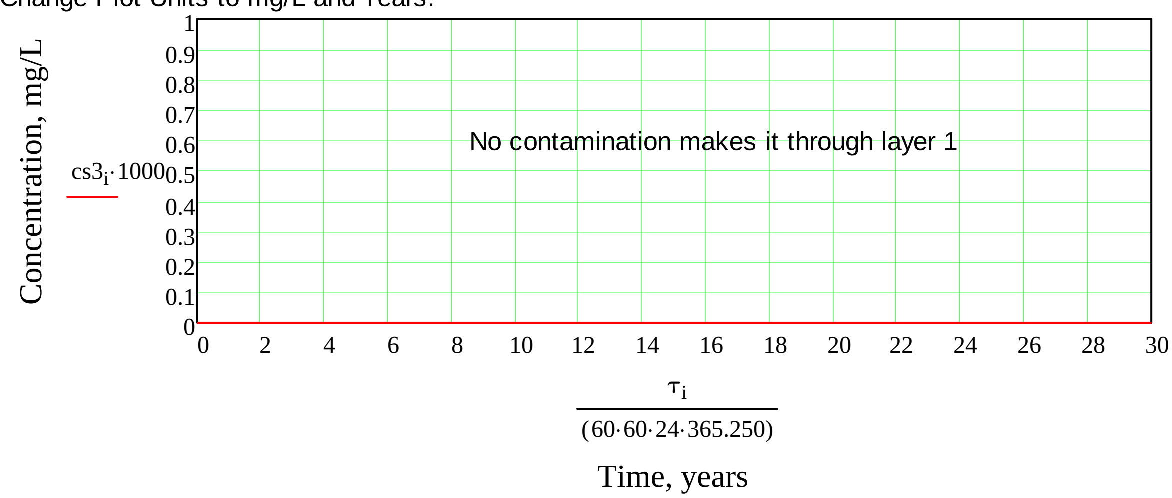
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

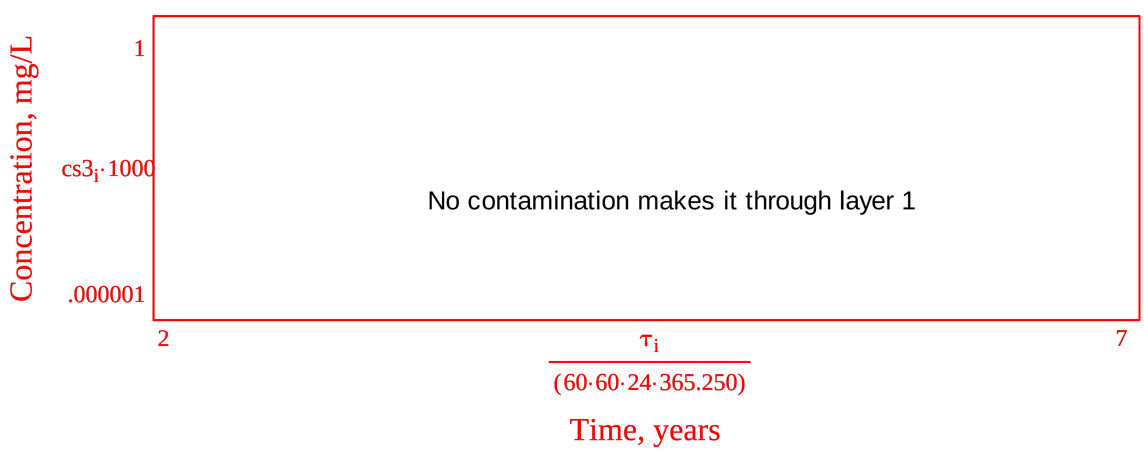
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

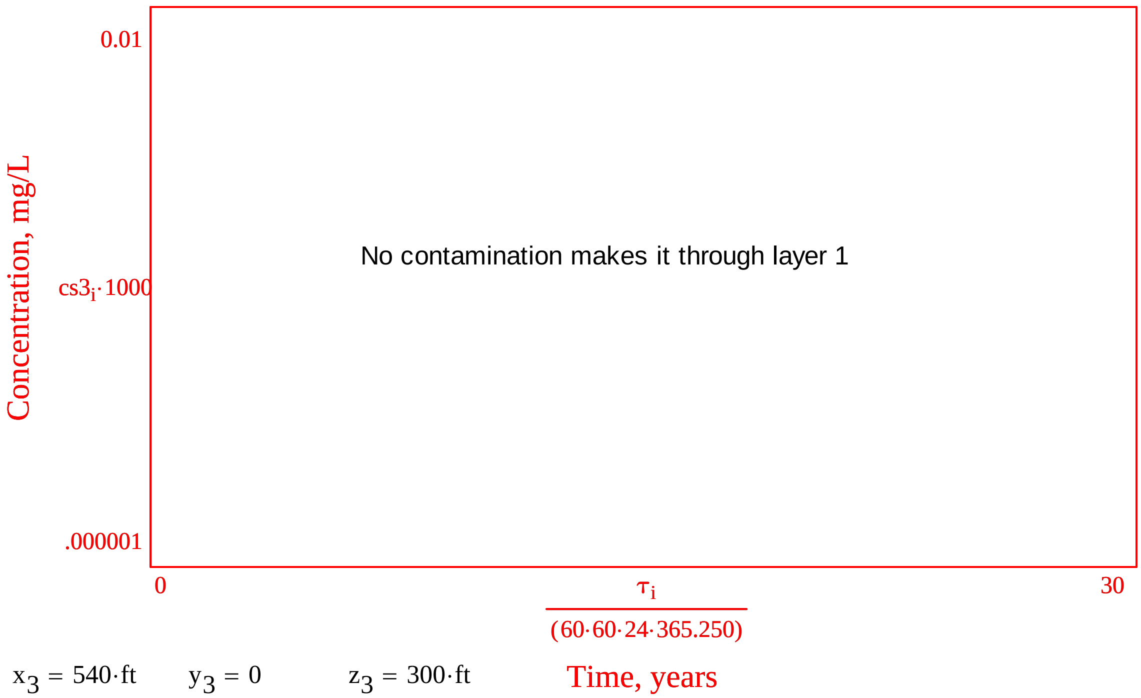


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 540 \cdot ft$ $y_3 = 0$ $z_3 = 300 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 540 \cdot ft$ $\quad y_3 = 0$ $\quad z_3 = 300 \cdot ft$

JRL - Expansion Contaminant Transport Evaluation - Failure of Engineered Systems - Eastern Flow

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

A leaky Liner scenario, with Q = 4.6 gallons per acre per day: Cell 12 and 13. Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor C.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1100ft$ Southeast - Northwest

$Length_1 := 970ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 24.495 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Imported Soil Layer	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

$Q_1 := 4.6 \frac{gal}{day}$ $i_1 := \frac{Q_1}{k_1 \cdot (Area_1)}$ $i_1 = 2.033 \times 10^{-3}$

C. Calculate flow rate through Layer 1 & 2:

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 1.478 \times 10^{-6} \cdot \frac{ft}{day}$ $LQ := \frac{Q_1 \cdot \frac{Area_1}{acre}}{Area_1}$ $LQ = 4.6 \cdot \frac{\frac{gal}{acre}}{day}$

$Q_2 := Q_1$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_12} := 201.95ft$ $Head_C := 145ft$

$i_2 := \frac{Head_{Cell\_12} - Head_C}{540ft}$ $i_2 = 0.105$ $v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $v_{gw} = 0.011 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$$i_2 = 0.105$$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cells 12 and 13):

distance of interest (x): $x_2 := 930ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 340ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2} \qquad a_2 = 0.025 \cdot ft$$

Y Direction in Layer 2 (Vertical)

Note that leachate does not actually travel into bedrock. This equasion only applies where leachate does exit Layer 1.

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 930 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 139.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 139.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 9.3 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 9.3 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 9.3 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 9.3 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 485 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 550 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 1.478 \times 10^{-6} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 1.478 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 1.478 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 1.478 \times 10^{-8} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

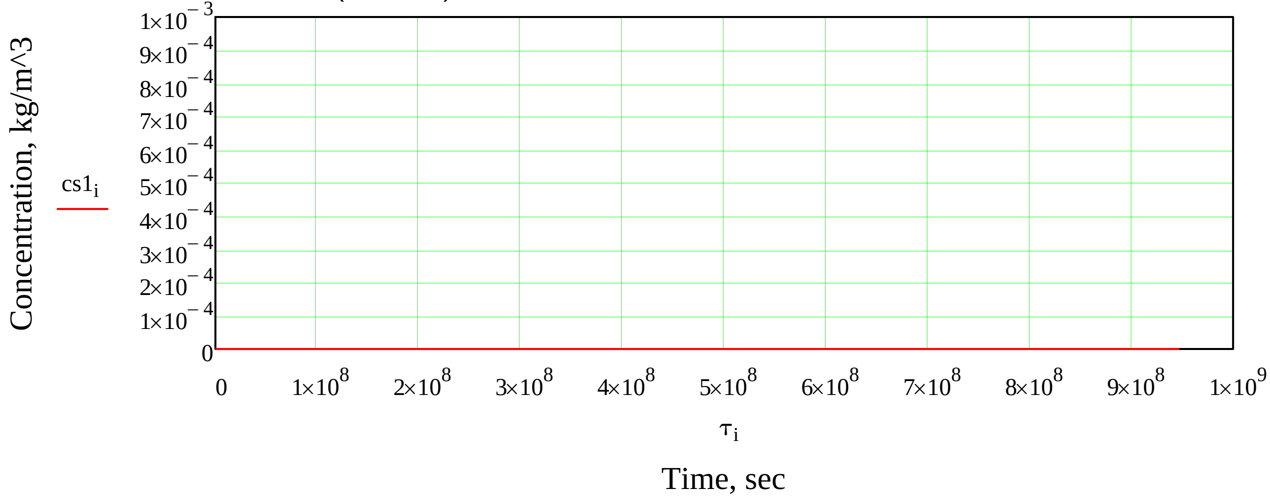
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0, 1 .. 10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

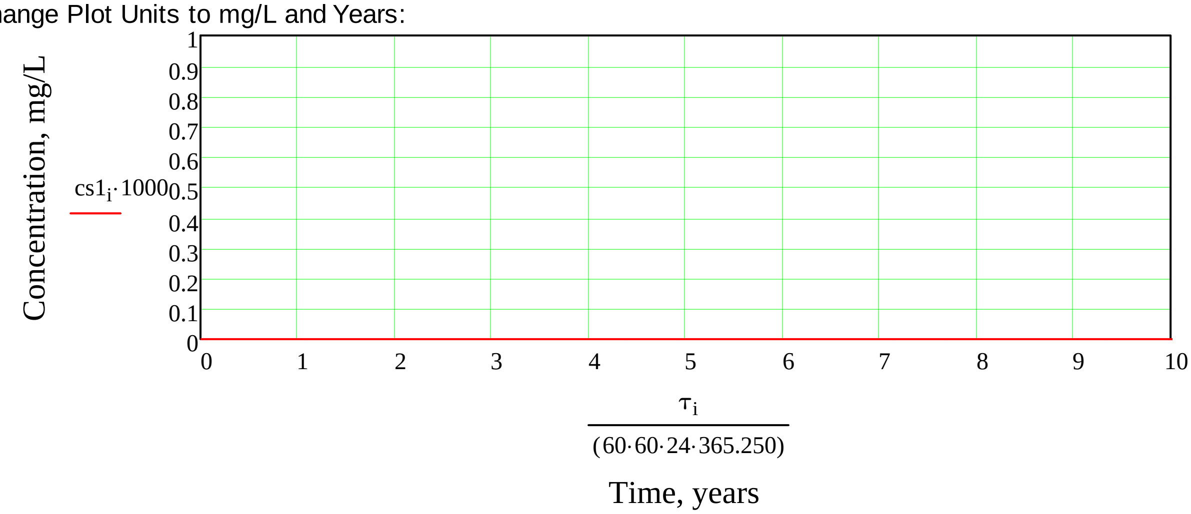
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

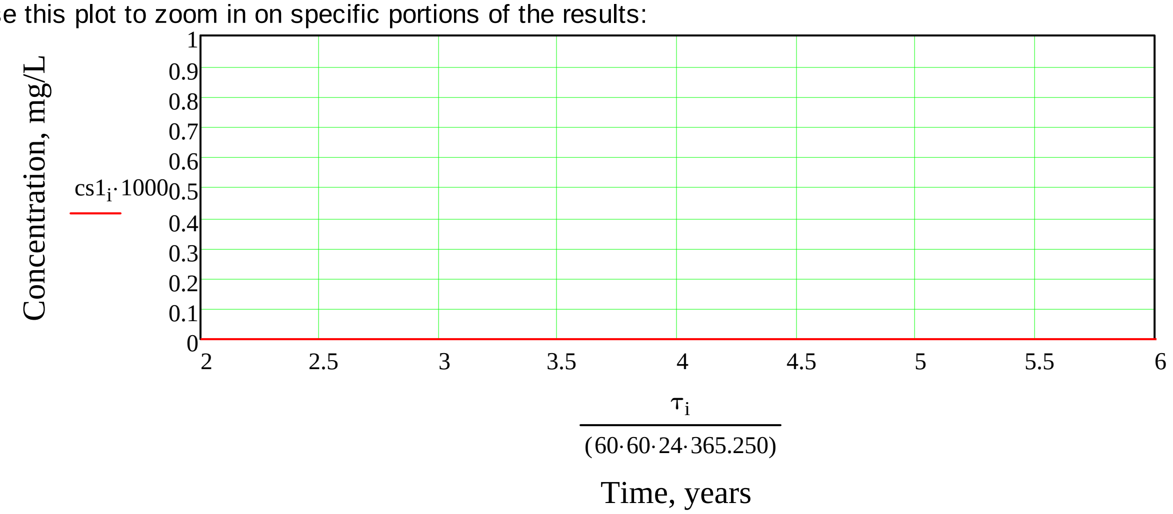
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

No Leachate makes it through the Imported Soil Layer in 30 years at the rate of 4.6 g/a/d.

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.0 \\ 0.0 \\ 0.0 \\ 0.0 \\ 0.0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2):

This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 0.025 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 550 \cdot ft$ Southeast - Northwest

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 139.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 139.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 9.3 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 9.3 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 9.3 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 9.3 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 13.95 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.93 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.93 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \text{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \text{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \text{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \text{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

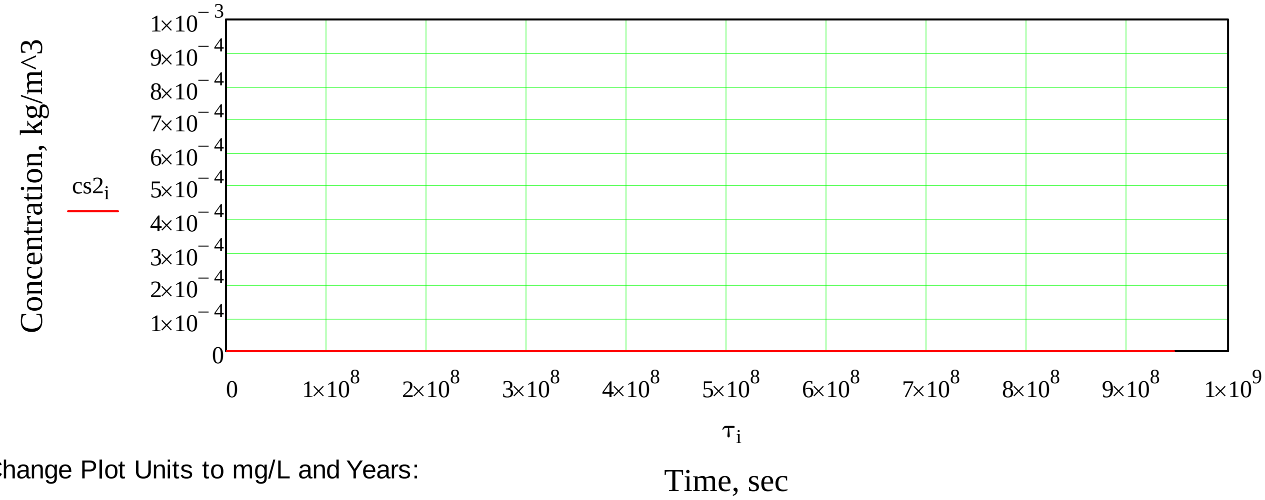
$i := 0, 1 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

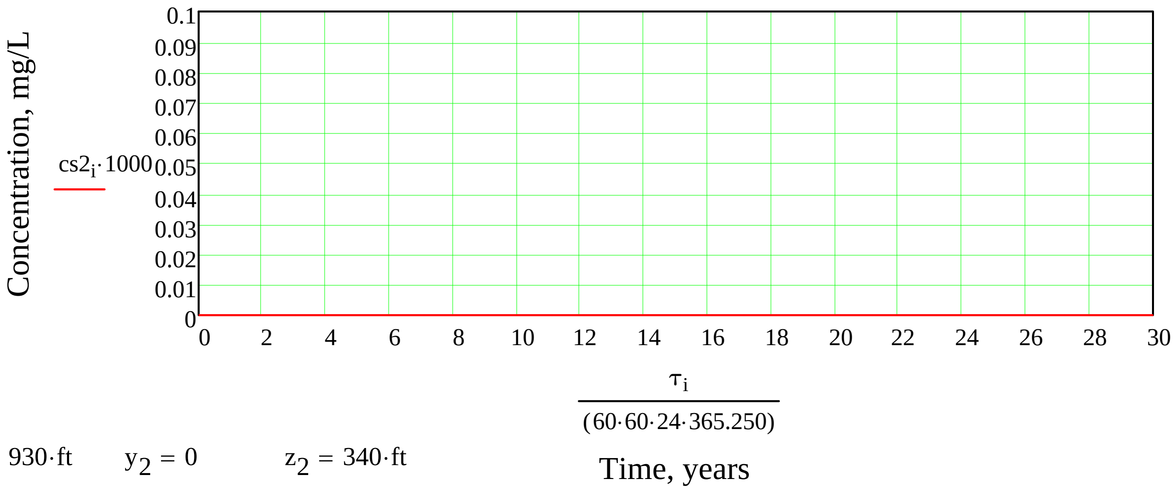
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2(x_2,y_2,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2(x_2,y_2,|\tau_i - ti_n|)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)

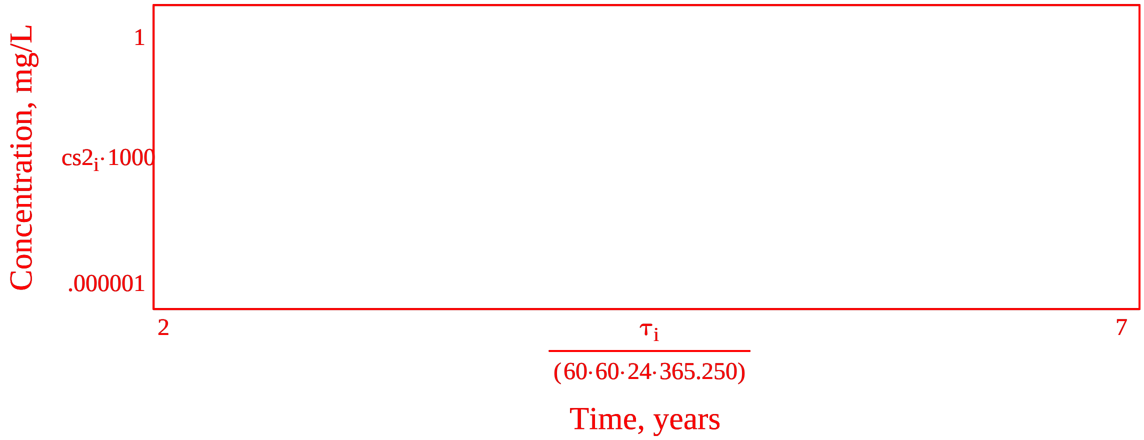


B. Change Plot Units to mg/L and Years:

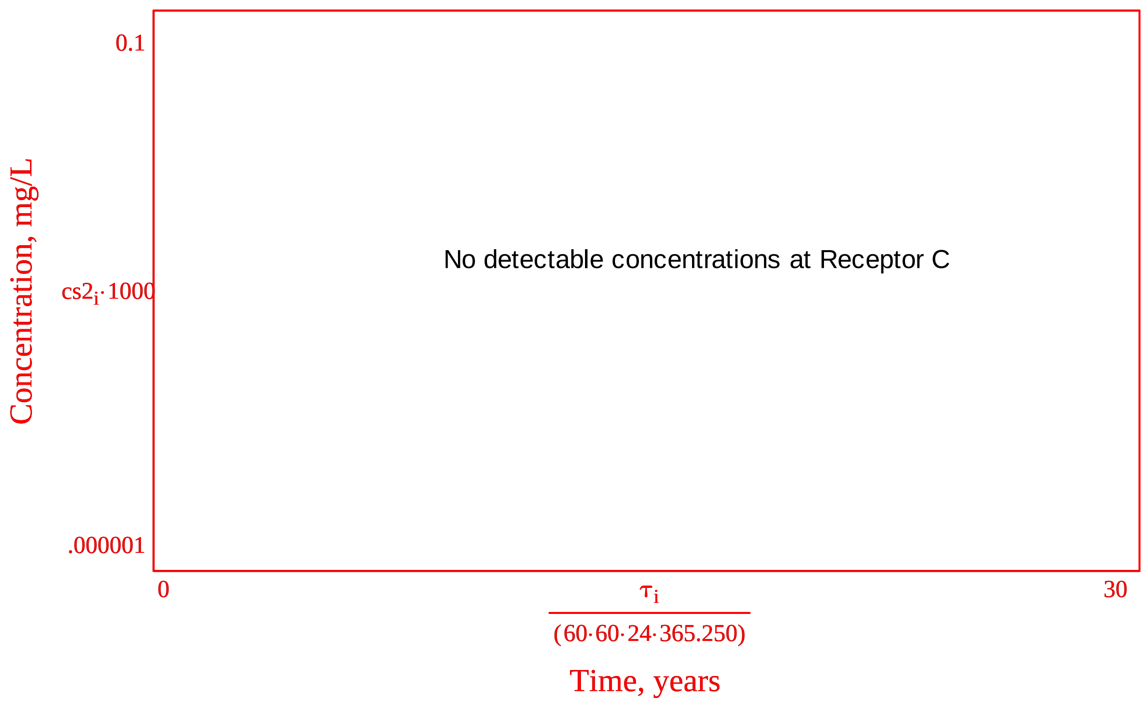


$x_2 = 930 \cdot ft$ $y_2 = 0$ $z_2 = 340 \cdot ft$

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 930 \cdot ft$ $y_2 = 0$ $z_2 = 340 \cdot ft$

JRL - Expansion Contaminant Transport Evaluation - Failure of Engineered Systems - Western Flow

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
A leaky Liner scenario: Cell 12 and 13. Flow is vertically down through Layer 1 (Imported Soil layer); then through Layer 2 (Till); and horizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptors C.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1100ft$ Southeast - Northwest

$Length_1 := 970ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 24.495 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Imported Soil Layer	Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 1ft$	$x_2 := 20ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are: Three holes/acre.

$Q_1 := 4.6 \frac{gal}{day}$ $i_1 := \frac{Q_1}{k_1 \cdot (Area_1)}$ $i_1 = 2.033 \times 10^{-3}$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 1.478 \times 10^{-6} \cdot \frac{ft}{day}$

$LQ := \frac{Q_1 \cdot \frac{Area_1}{acre}}{Area_1}$ $LQ = 4.6 \cdot \frac{\frac{gal}{acre}}{day}$

LQ was Used to determine the value of a_3

$Q_2 := Q_1$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 2.305 \times 10^{-6} \cdot \frac{ft}{day}$

$v_3 := 5 \frac{ft}{day}$

Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day..

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{Q_2}{(k_2) \cdot Area_1}$ $i_2 = 2.163 \times 10^{-5}$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the east side of the Imported Soil Limits in Cell 12 & 13):

distance of interest (x): $x_3 := 930ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 340ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 0.127 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 20 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.2 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.2 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 2 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 2 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 2 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 2 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

These Calcs

Lateral dispersivity	$\alpha_{y\_BR} := \frac{20ft}{Y_3}$	$\alpha_{y\_BR} = 0.4$	Z axis
Downgradient dispersivity:	$\alpha_{x\_BR} := \frac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$	$\alpha_{x\_BR} = 1.2$	X axis
Vertical dispersivity	$\alpha_{z\_BR} := \frac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$	$\alpha_{z\_BR} = 0.02$	Y axis

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 1000 \\ 5000 \\ 10950 \end{pmatrix} \cdot day$ This is a continuous source.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 485 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 550 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 1.478 \times 10^{-6} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 1.478 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 1.478 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 1.478 \times 10^{-8} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

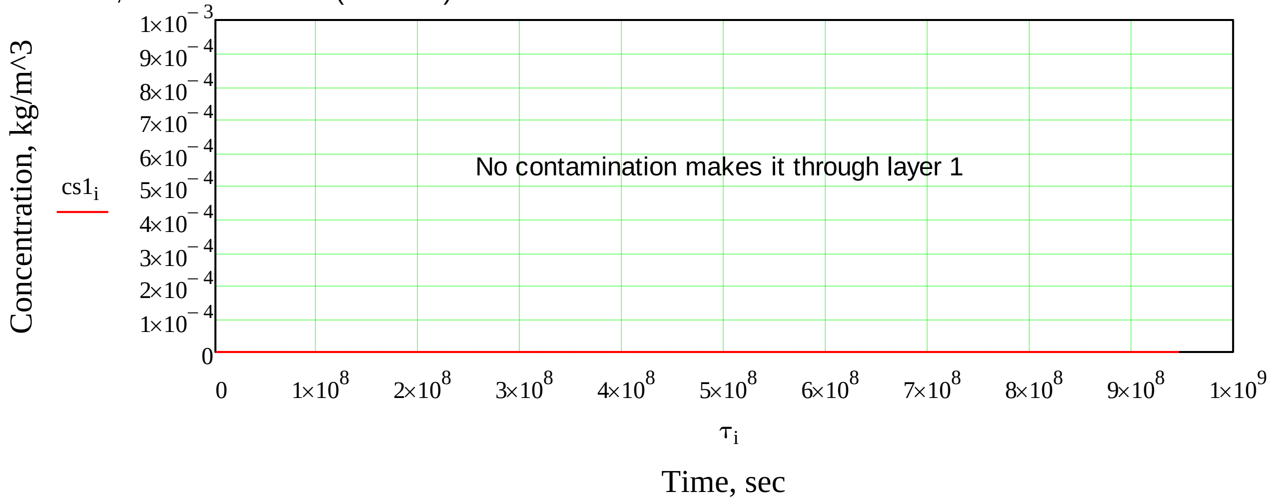
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..10950$ $\tau_i := i\cdot day$

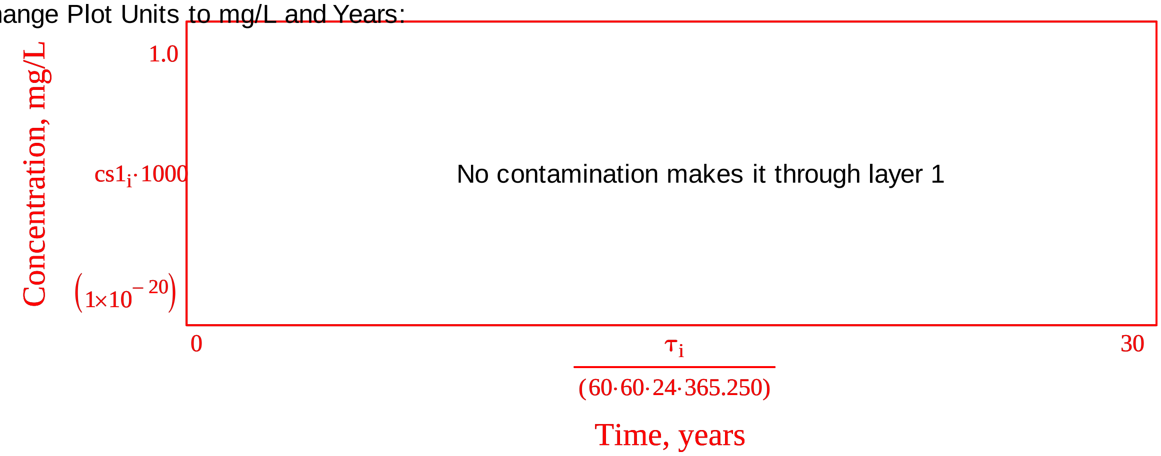
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

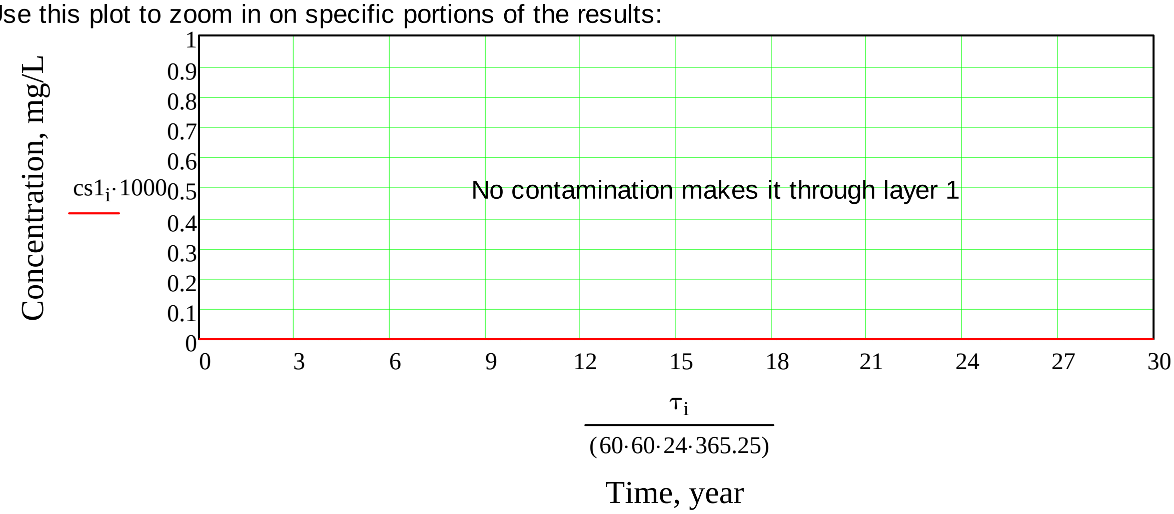
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

No Leachate makes it through the Imported Soil Layer in 30 years at the rate of 4.6 g/a/d.

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 54 \\ 55 \\ 65 \\ 95 \\ 110 \\ 10950 \end{pmatrix} day$$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 485 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 550 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 2.305 \times 10^{-6} \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 20 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$

Lateal distance of interest (z): $z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 4.611 \times 10^{-7} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 4.611 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 4.611 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \text{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \text{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \text{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \text{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

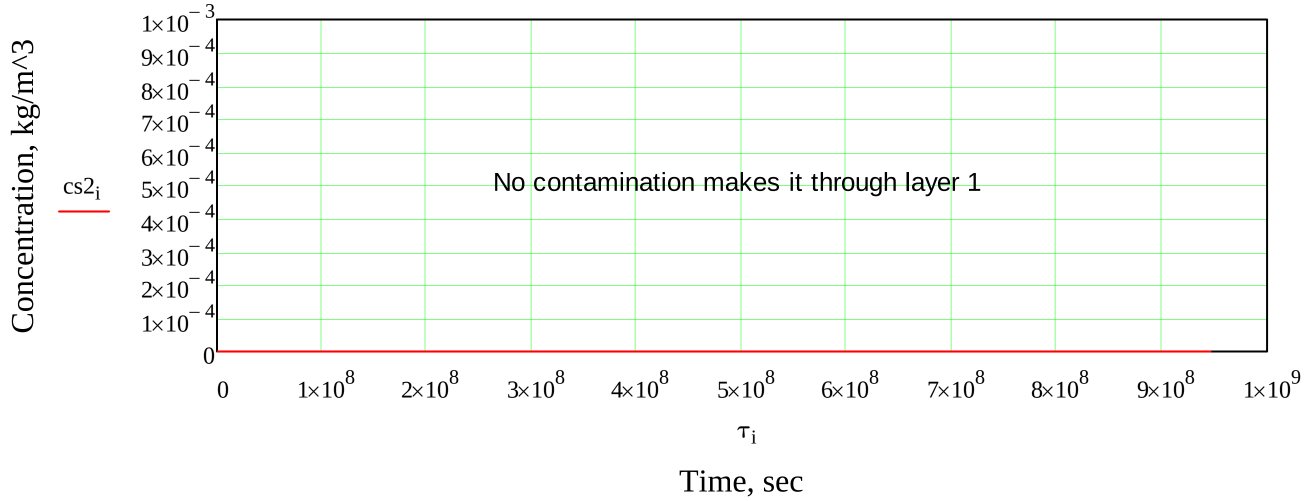
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1, 2 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

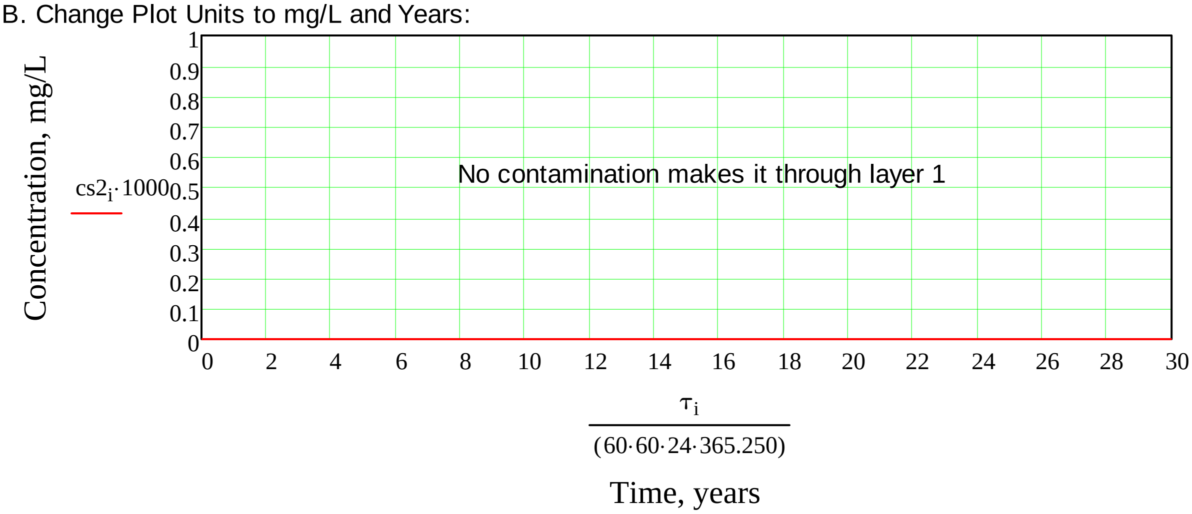
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

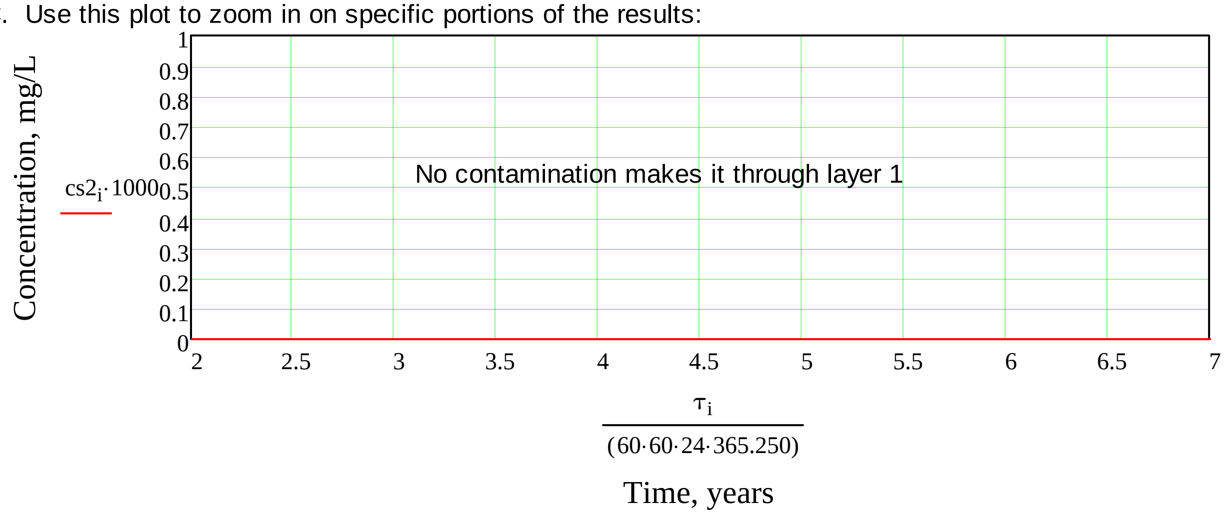
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

$t_{3\_1\%} := 0\cdot yr$ $t_{3\_10\%} := 0yr$ $t_{3\_90\%} := 0yr$ $t_{3\_100\%} := 0yr$

$t_{3\_1\%} = 0\cdot day$ $t_{3\_10\%} = 0\cdot day$ $t_{3\_90\%} = 0\cdot day$ $t_{3\_100\%} = 0\cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 1095 \\ 1096 \\ 1315 \\ 1826 \\ 2191 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 3

This source sub-divides the results from Layer 2.

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Northeast-Southwest; Z is Southeast - Northwest; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 0.127\cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 550\cdot ft$ Southeast - Northwest

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 1.116 \times 10^3$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 1.116 \times 10^3 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 372 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 372 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 18.6 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 18.6 \cdot ft$ Lateral (northwest-southeast)

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 5.58 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.86 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 93 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \text{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \text{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \text{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \text{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

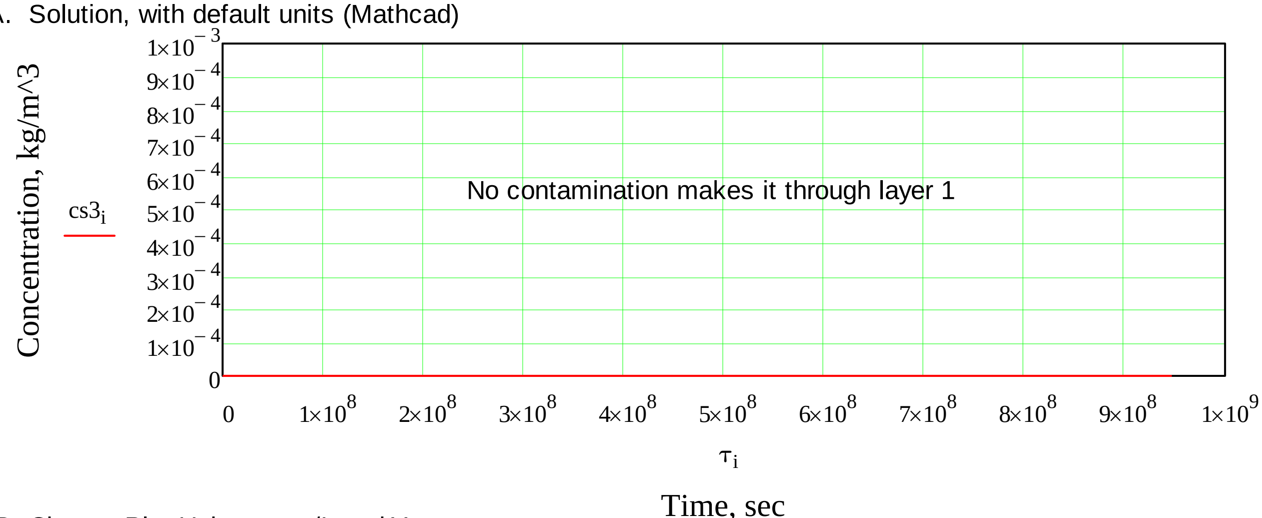
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2..10950$ $\qquad \tau_i := i\cdot day$

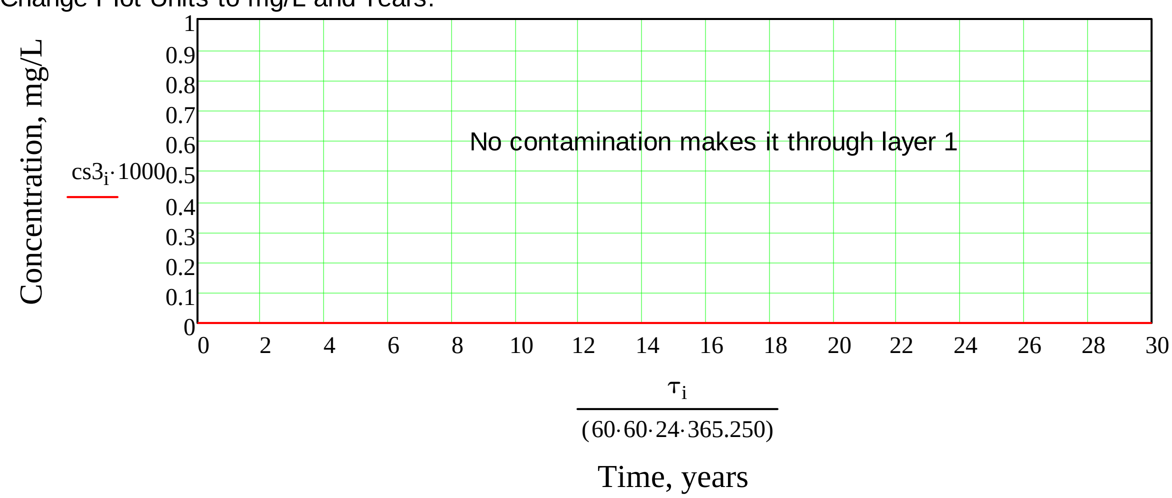
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

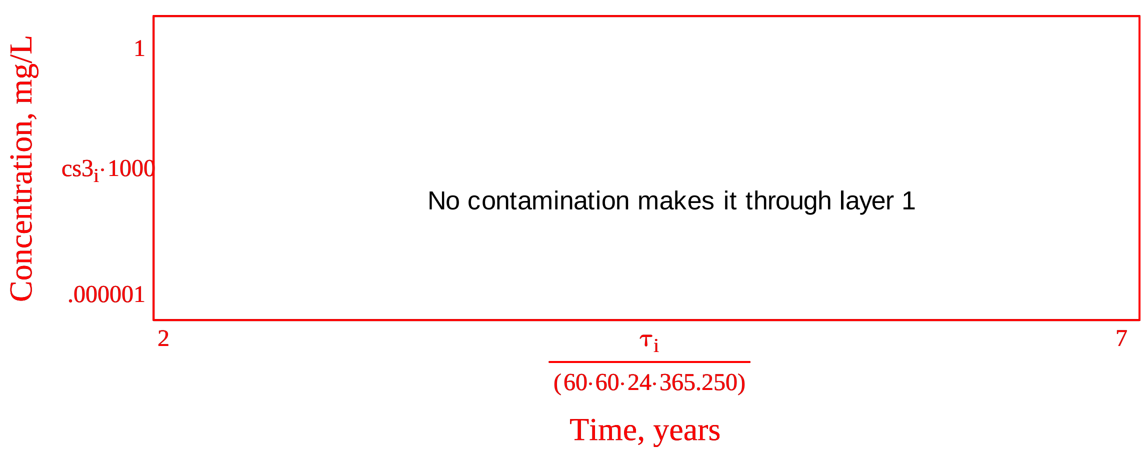
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

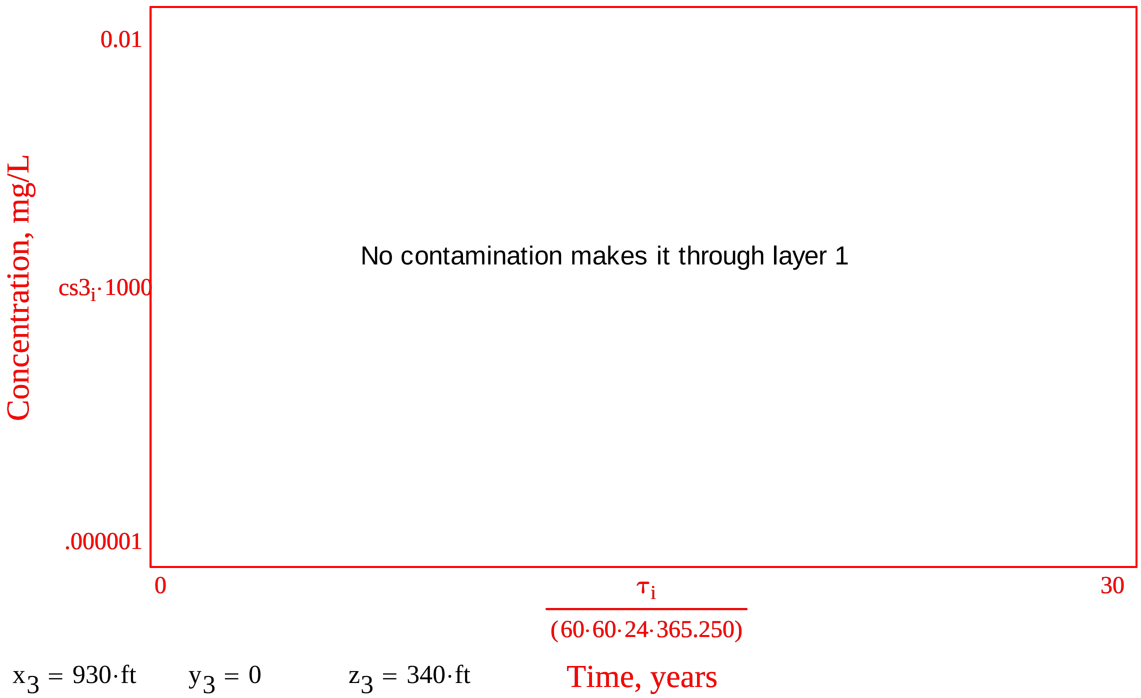


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 930 \cdot ft$ $\quad y_3 = 0$ $\quad z_3 = 340 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 930 \cdot ft$ $y_3 = 0$ $z_3 = 340 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

A leaky Liner scenario, with Q = 4.6 gallons per acre per day: Cells 14, 15 and 16. Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptors D, E, F and G.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1200ft$ North - South

$Length_1 := 720ft$ Layers 1,2 = East - West (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\qquad Area_1 = 19.835 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Imported Soil Layer	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

$Q_1 := 4.6 \frac{gal}{day}$ $\qquad i_1 := \frac{Q_1}{k_1 \cdot (Area_1)}$ $\qquad i_1 = 2.511 \times 10^{-3}$

C. Calculate flow rate through Layer 1 & 2:

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\qquad v_1 = 1.825 \times 10^{-6} \cdot \frac{ft}{day}$ $\qquad LQ := \frac{Q_1 \cdot \frac{Area_1}{acre}}{Area_1}$ $\qquad LQ = 4.6 \cdot \frac{\frac{gal}{acre}}{day}$

$Q_2 := Q_1$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_15} := 200.44ft$ $\qquad Head_E := 72ft$ $\qquad$ Worst Case is Receptor E

$i_2 := \frac{Head_{Cell\_15} - Head_E}{540ft}$ $\qquad i_2 = 0.238$ $\qquad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\qquad v_{gw} = 0.025 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\qquad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$$i_2 = 0.238$$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cells 14, 15 and 16):

Sens. Rec	X_3 (ft)	Z_3 (ft)
D	810	600
E	450	200
F	450	340
G	870	600

See Figure 7-1 in Volume II of the application.

Since leachate does not make it through the Imported Soil Layer, only Receptor E need be evaluated.

distance of interest (x): $x_2 := 450ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 200ft$

F. Determine the thickness that the leak travels into the bedrock (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2} \qquad a_2 = 0.034 \cdot ft$$

Y Direction in Layer 3 (Vertical)

Note that leachate does not actually travel into bedrock. This equasion only applies where leachate does exit Layer 1.

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Vertical

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 450 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 67.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 67.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 4.5 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 4.5 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 4.5 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 4.5 \cdot ft$	Vertical

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 600 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 1.825 \times 10^{-6} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Y&Z = 0 yields the maximum concentration

Lateral distance of interest (z): $z_1 := 0ft$

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 1.825 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 1.825 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 1.825 \times 10^{-8} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \text{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \text{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \text{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \text{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

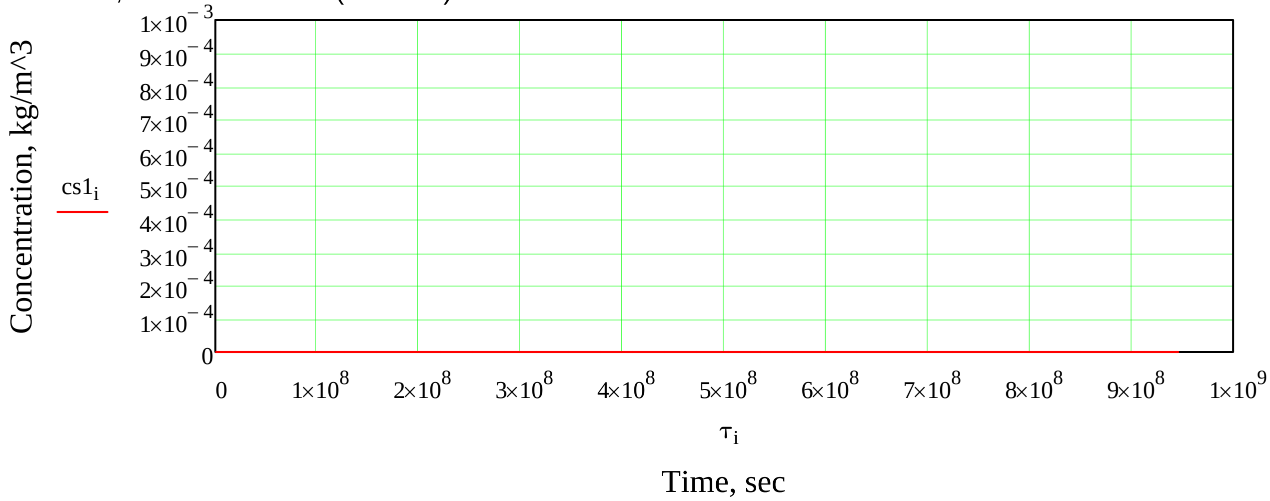
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0, 1 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

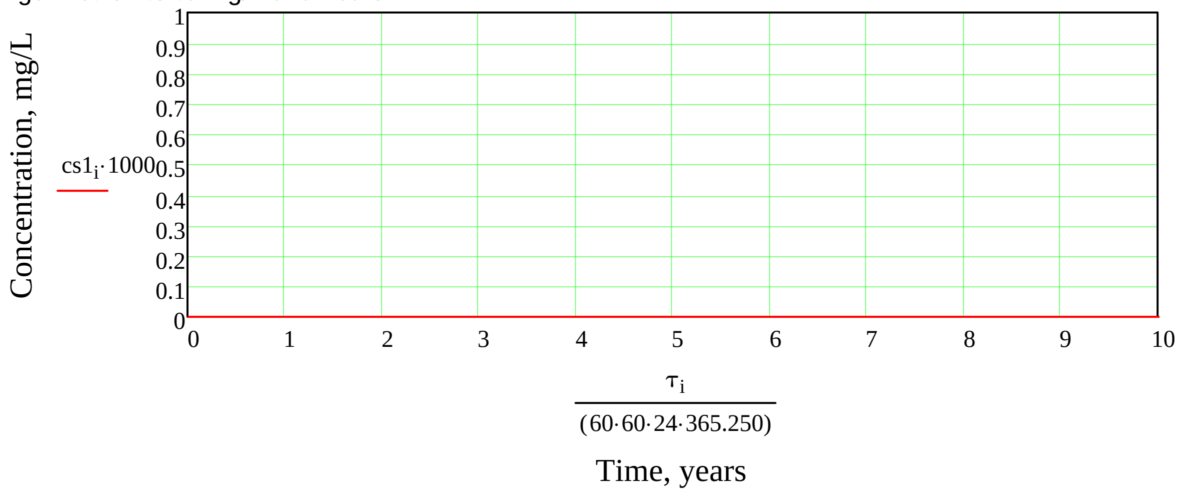
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1(x_1,y_1,\left|\tau_i - ti_{n-1}\right|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1(x_1,y_1,\left|\tau_i - ti_n\right|)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

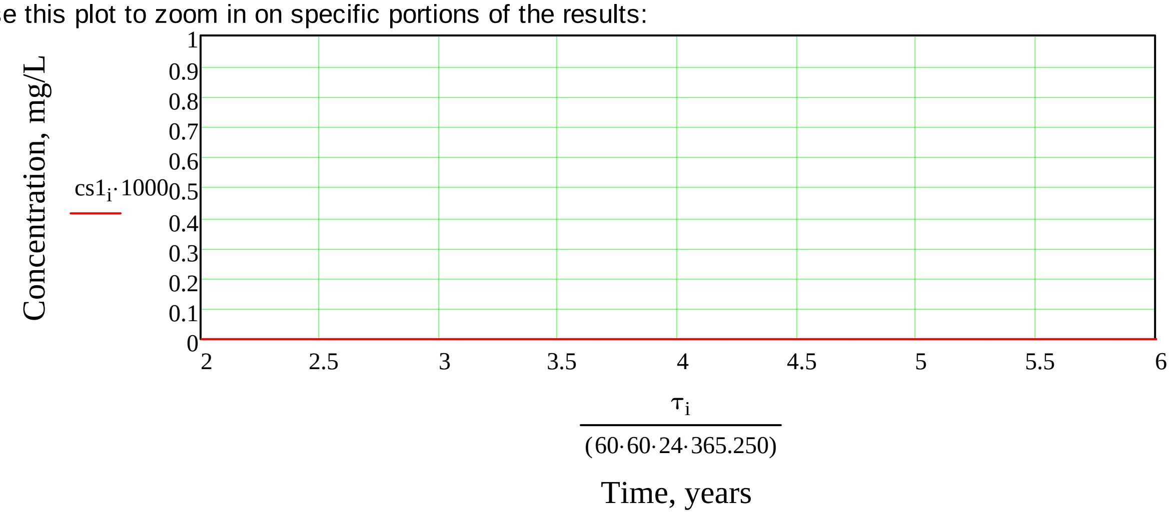
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



<u>3.2 Source Definition, to Layer 2 (Till)</u>

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

No Leachate makes it through the Imported Soil Layer in 30 years at the rate of 4.6 g/a/d.

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration / Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.0 \\ 0.0 \\ 0.0 \\ 0.0 \\ 0.0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1 and 2. X now is Northeast-Southwest; Z is Southeast - Northwest; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 0.034 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 600 \cdot ft$ Southeast - Northwest

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

> Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 67.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 67.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 4.5 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 4.5 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 4.5 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 4.5 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 6.75 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.45 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.45 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \text{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \text{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \text{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \text{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

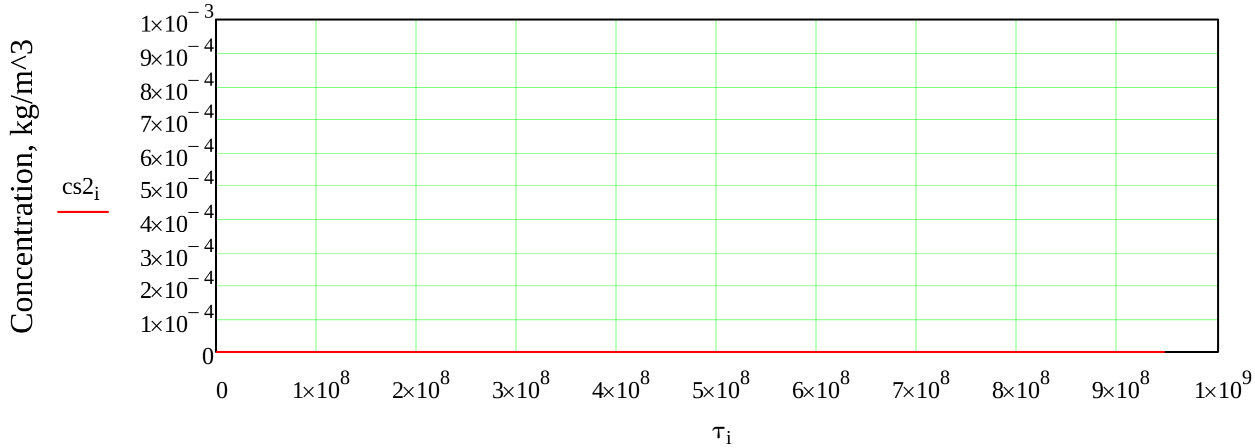
$i := 0,1..10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

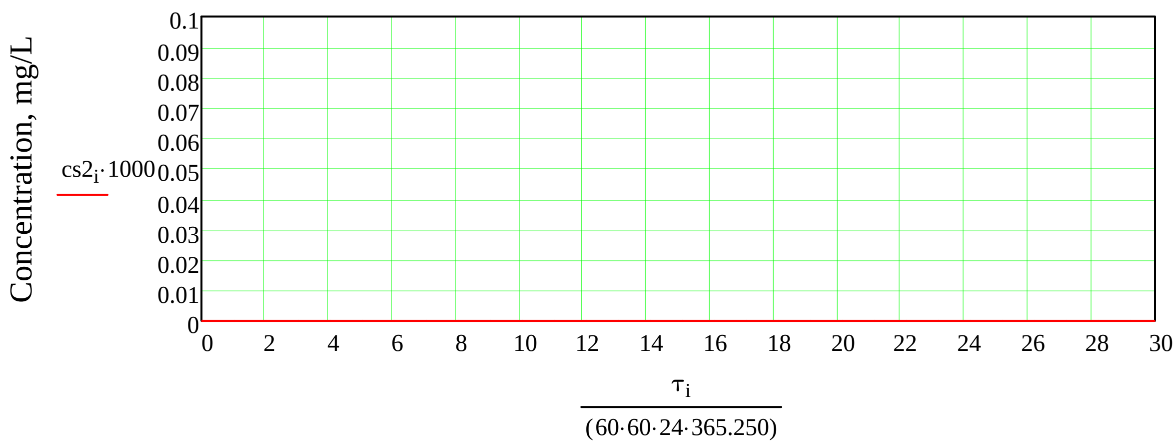
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)

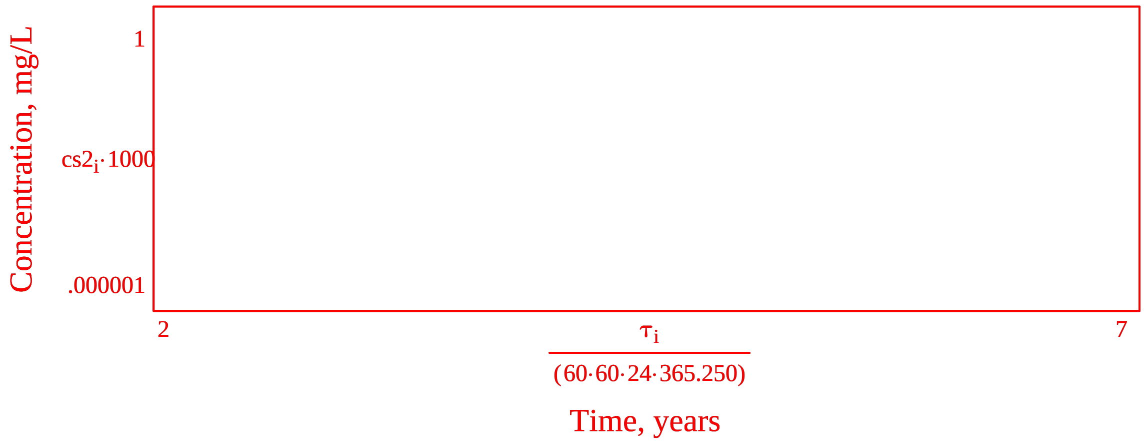


B. Change Plot Units to mg/L and Years:

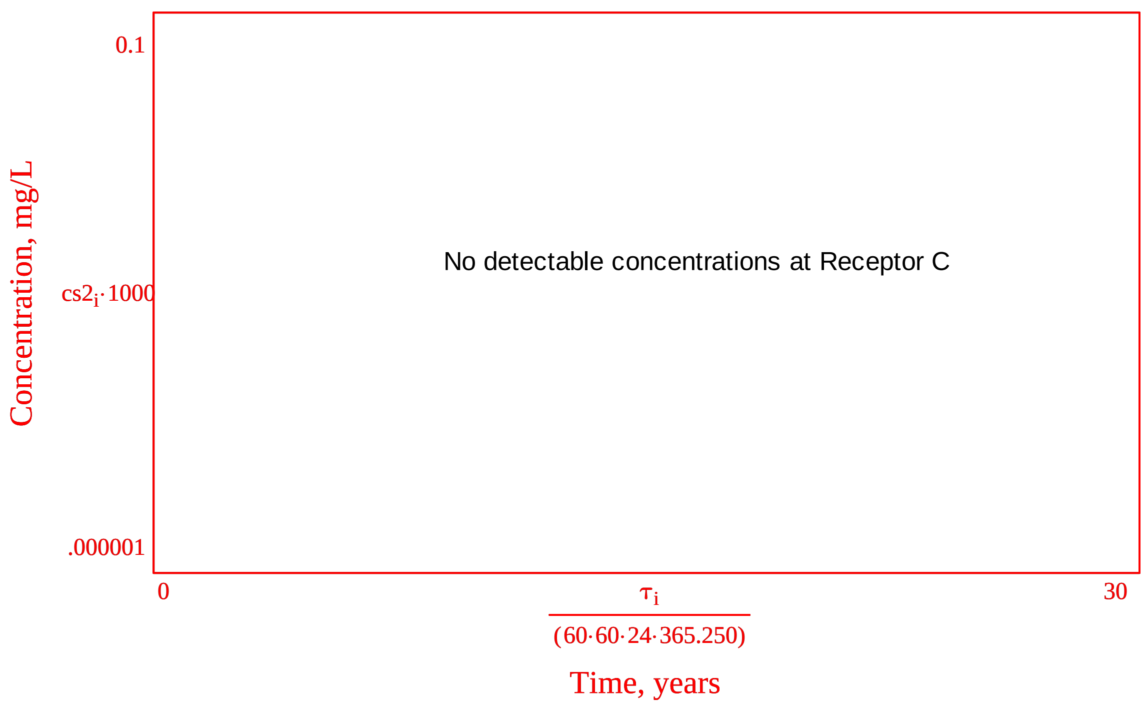


$x_2 = 450 \cdot ft$ $y_2 = 0$ $z_2 = 200 \cdot ft$

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 450 \cdot ft$ $y_2 = 0$ $z_2 = 200 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
A leaky Liner scenario: Cells 14, 15 and 16. Flow is vertically down through Layer 1 (Imported Soil layer); then through Layer 2 (Till); and horizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptors D through G.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1200ft$ North - South

$Length_1 := 720ft$ Layers 1,2 = East - West (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 19.835 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Imported Soil Layer	Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 1ft$	$x_2 := 5ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are: Three holes/acre.

$Q_1 := 4.6 \frac{gal}{day}$ $i_1 := \frac{Q_1}{k_1 \cdot (Area_1)}$ $i_1 = 2.511 \times 10^{-3}$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 1.825 \times 10^{-6} \cdot \frac{ft}{day}$

$LQ := \frac{Q_1 \cdot \frac{Area_1}{acre}}{Area_1}$ $LQ = 4.6 \cdot \frac{\frac{gal}{acre}}{day}$

LQ was Used to determine the value of a_3

$Q_2 := Q_1$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 2.847 \times 10^{-6} \cdot \frac{ft}{day}$

$v_3 := 5 \frac{ft}{day}$

Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day..

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{Q_2}{(k_2) \cdot Area_1}$ $i_2 = 2.671 \times 10^{-5}$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the east side of the Imported Soil Limits in Cells 14, 15 and 16):

Sens. Rec	X_3 (ft)	Z_3 (ft)
D	810	600
E	450	200
F	450	340
G	870	600

See Figure 7-1 in Volume II of the application.

Since leachate does not make it through the Imported Soil Layer, only Receptor E need be evaluated.

distance of interest (x): $x_3 := 450ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 200ft$

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$ $a_3 = 0.171 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Vertical

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 5 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.05 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.05 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 0.5 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 0.5 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 0.5 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 0.5 \cdot ft$	Vertical

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

These Calcs

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

Lateral dispersivity $\alpha_{y\_BR} := \frac{20ft}{Y_3}$ $\alpha_{y\_BR} = 0.4$ Z axis

Downgradient dispersivity: $\alpha_{x\_BR} := \frac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$ $\alpha_{x\_BR} = 1.2$ X axis

Vertical dispersivity $\alpha_{z\_BR} := \frac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$ $\alpha_{z\_BR} = 0.02$ Y axis

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 1000 \\ 5000 \\ 10950 \end{pmatrix} \cdot day$ This is a continuous source.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 600 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 1.825 \times 10^{-6} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 1.825 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 1.825 \times 10^{-8} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 1.825 \times 10^{-8} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \text{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \text{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \text{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \text{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

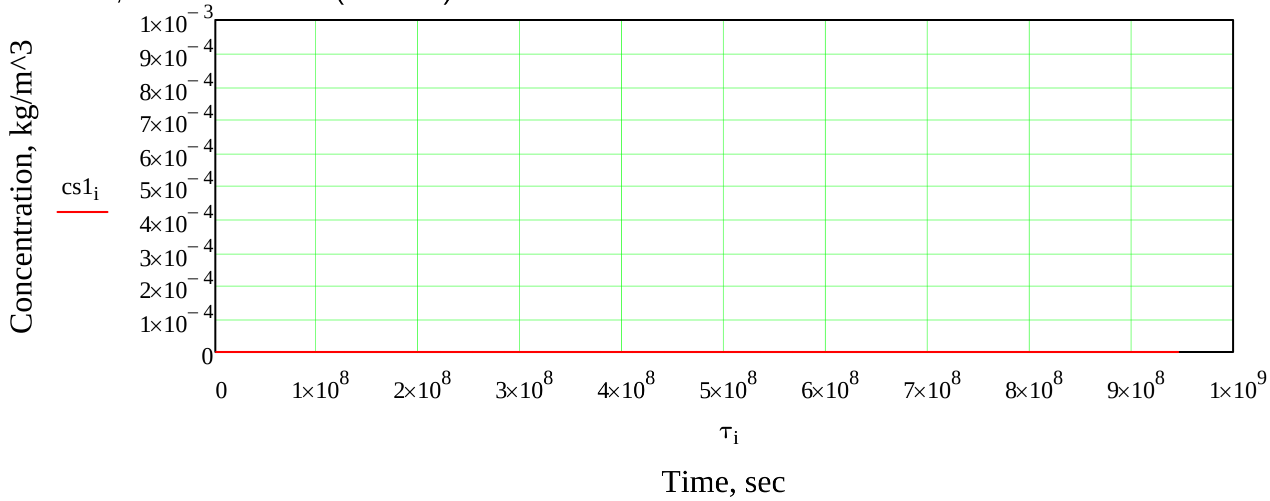
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1, 2 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

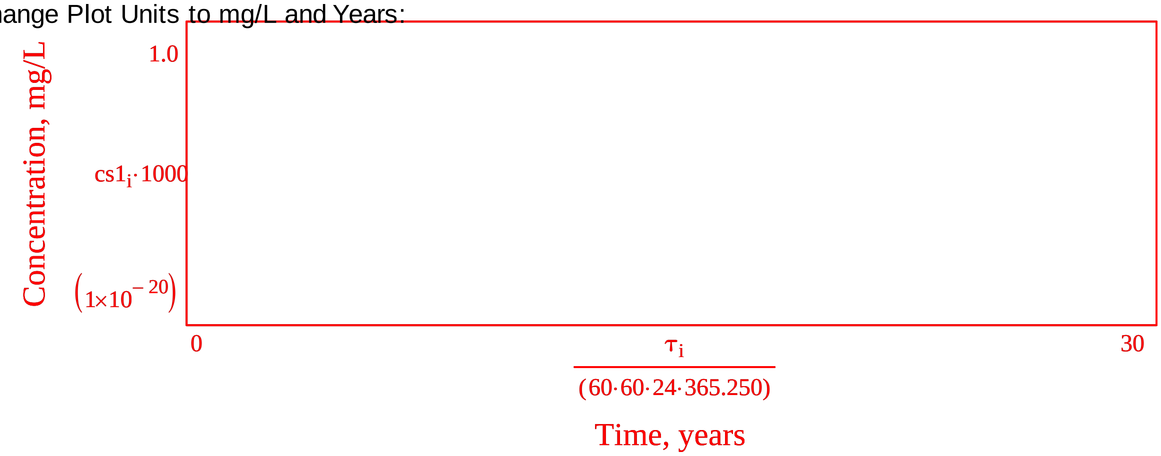
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

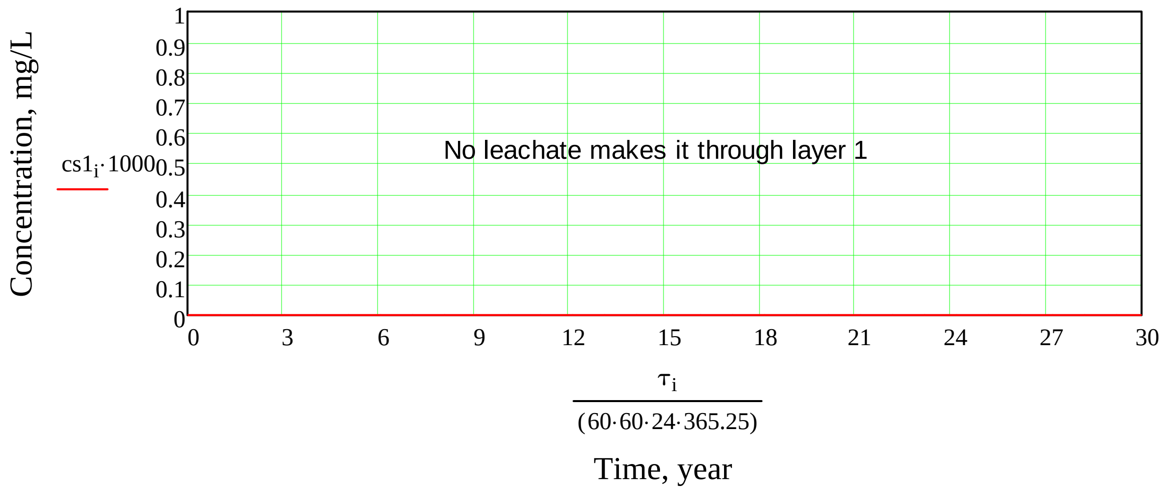
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



<u>3.2 Source Definition, to Layer 2 (Till):</u>

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

No Leachate makes it through the Imported Soil Layer in 30 years at the rate of 4.6 g/a/d.

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l)	Source Term (days)
0.00	0
0.00	54
0.00	55
0.00	65
0.00	95
0.00	110
0.00	10950

$co2 := (0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00)^T \cdot \frac{mg}{L}$ $\quad ti := (0, 54, 55, 65, 95, 110, 10950)^T \cdot day$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $a_2 := a_1$ $\quad a_2 = 360 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $\quad b_2 = 600 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

<u>Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):</u>

Velocity (from above) $v_2 = 2.847 \times 10^{-6} \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 5 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$

Y&Z = 0 yields the maximum

concentration

Lateal distance of interest (z): $z_2 := 0ft$

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 1.423 \times 10^{-7} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 1.423 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 1.423 \times 10^{-6} \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

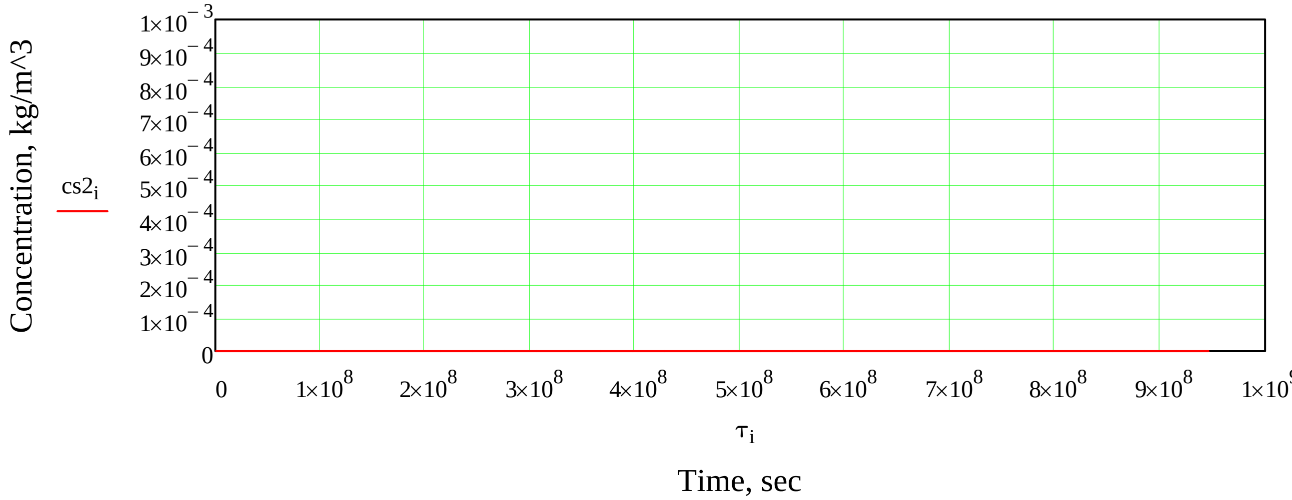
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1,2..10950$ $\tau_i := i\cdot day$

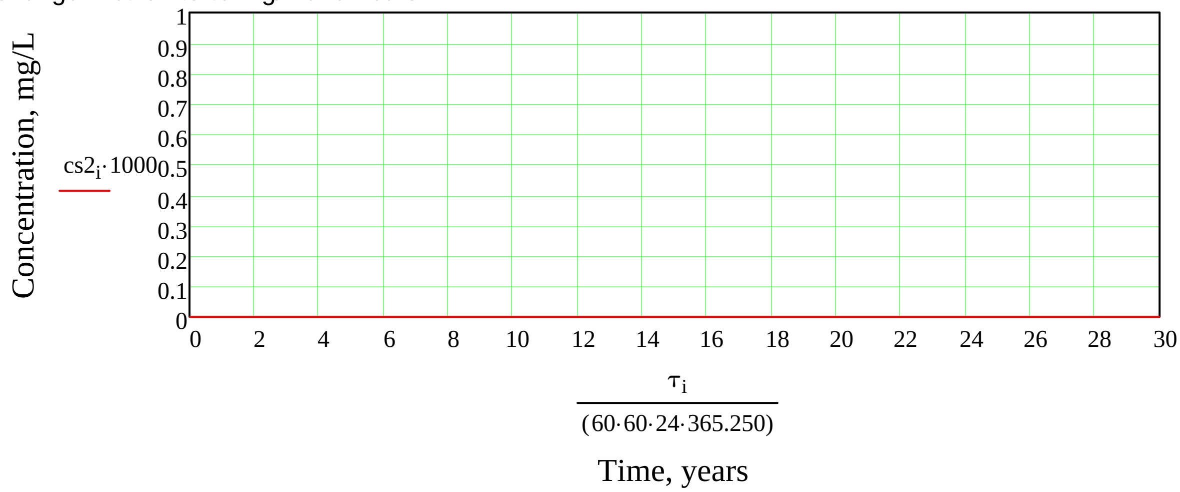
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

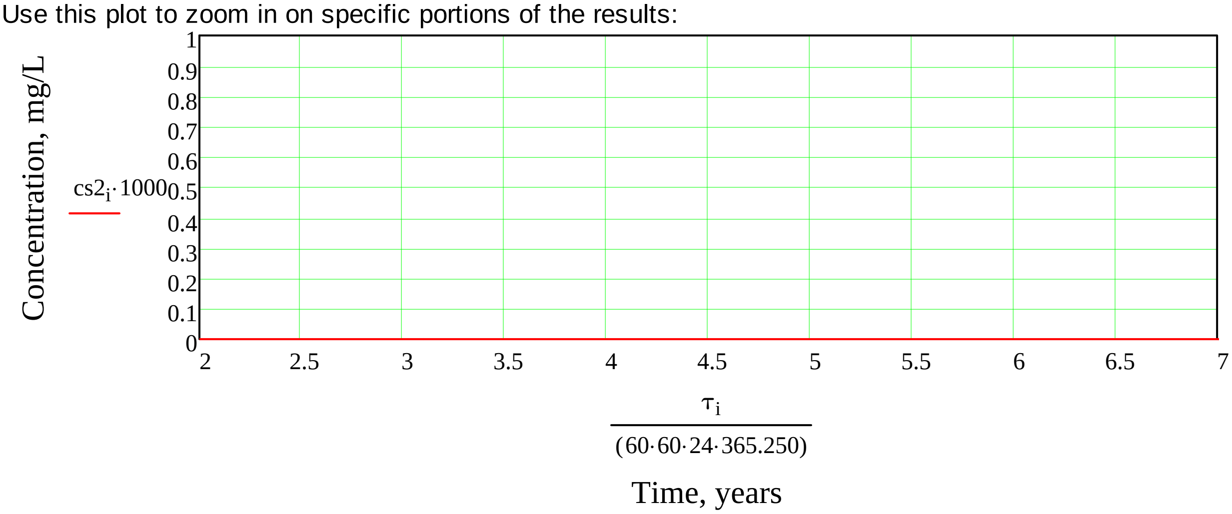
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

$t_{3\_1\%} := 0 \cdot yr$ $t_{3\_10\%} := 0yr$ $t_{3\_90\%} := 0yr$ $t_{3\_100\%} := 0yr$

$t_{3\_1\%} = 0 \cdot day$ $t_{3\_10\%} = 0 \cdot day$ $t_{3\_90\%} = 0 \cdot day$ $t_{3\_100\%} = 0 \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 1095 \\ 1096 \\ 1315 \\ 1826 \\ 2191 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 3

This source sub-divides the results from Layer 2.

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 0.171 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 600 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 540 \cdot ft$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 540 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 180 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 180 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 9 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 9 \cdot ft$ Lateral (northwest-southeast)

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 2.7 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 900 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 45 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{v_3^{\,2}}{4\cdot Dx_3}\cdot t - \frac{x_3^{\,2}}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \operatorname{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \operatorname{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \operatorname{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \operatorname{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

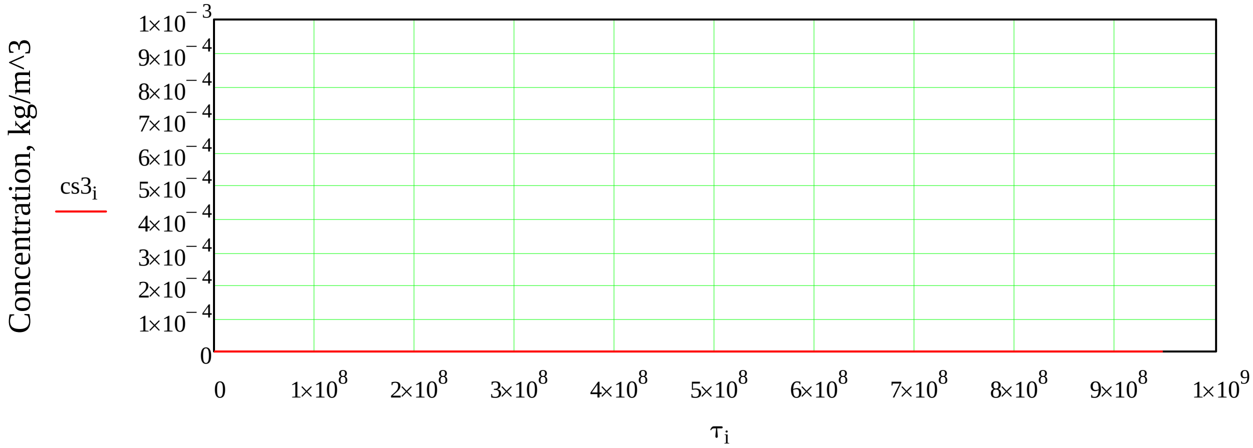
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1, 2 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

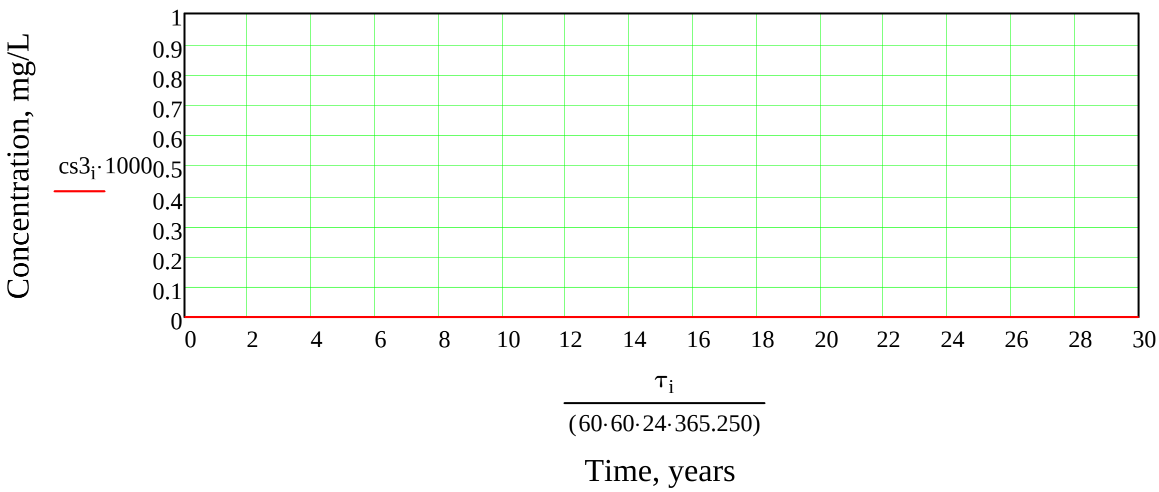
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

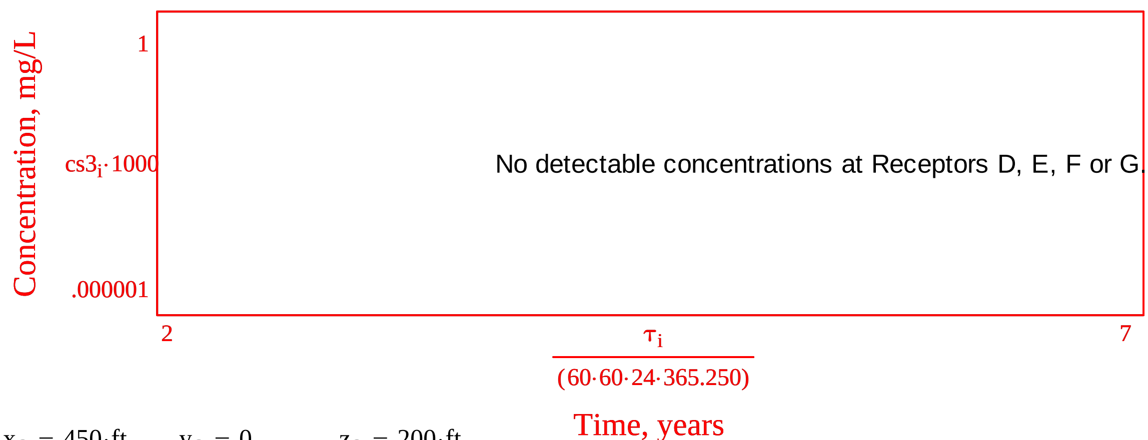
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

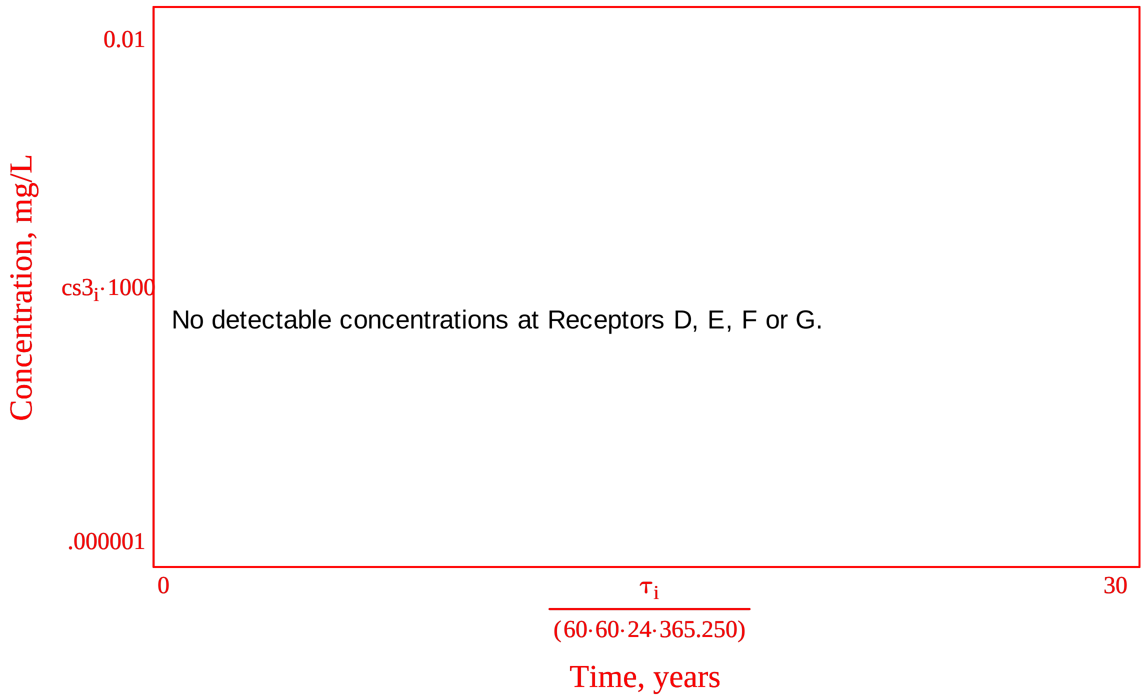


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 450 \cdot ft$ $y_3 = 0$ $z_3 = 200 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 450 \cdot ft$ $y_3 = 0$ $z_3 = 200 \cdot ft$

JRL - Expansion Contaminant Transport Evaluation - Complete Failure of Engineered Systems - Eastern Flow

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Complete Failure of the engineered systems of the landfill (Cell 11). Flow is vertically down through Layer 1 (Imported Soil layer); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor B.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 1600ft$ Southeast - Northwest

Flow is generally Northeasterly

$Length_1 := 255ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 9.366 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Imported Soil Layer	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1 \cdot 10^{-7} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.39$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 1ft$	X3 defined in Section 3.2

From Shallow Bedrock Area east side of Cell 11 to NE , Point A on Figure 7-1 in Vol. II of Application.

B. Hydraulic conditions applied are:

Assume Layer 1 is free draining and sets the system flow rate.

Hydraulic gradient (i) $i_1 := 1$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 865.149 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 0.601 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 92.367 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwatyer contours, from Fig 5-1:

$Head_{Cell\_11} := 200.6ft$ $Head_A := 173ft$

$i_2 := \frac{Head_{Cell\_11} - Head_A}{540ft}$ $i_2 = 0.051$ $v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $v_{gw} = 5.448 \times 10^{-3} \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$$i_2 := \frac{Q_2}{(k_2) \cdot Area_1} \qquad i_2 = 0.011$$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Imported Soil Limits in Cell 11):

Sens. Rec	X_2 (ft)	Z_2 (ft)
A	540	300
B	770	300

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_2 := 770ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 300ft$ Northwest - Southeast

F. Determine the thickness that the leak travels into the Till (a_2), this is the source size in Till.

$$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2} \qquad a_2 = 18.142 \cdot ft$$

Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Imported Soil Layer):

Assume that the Imported Soil Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.01 \cdot ft$	Flow
$\alpha_{y\_1} := 0.1$		$\alpha_{y\_1} \cdot x_1 = 0.1 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.1 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.1$		$\alpha_{z\_1} \cdot x_1 = 0.1 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.1 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 770 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 115.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 115.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 7.7 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 7.7 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 7.7 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 7.7 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Imported Soil Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 2190 \\ 2191 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 127.5 \cdot ft$ Northeast - Southwest

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 800 \cdot ft$ Southeast - Northwest

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 7.268 \times 10^{-4} \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$ Northeast - Southwest

Lateral distance of interest (z): $z_1 := 0ft$ Southeast - Northwest

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 7.268 \times 10^{-6} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 7.268 \times 10^{-5} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 7.268 \times 10^{-5} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \text{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \text{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \text{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \text{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

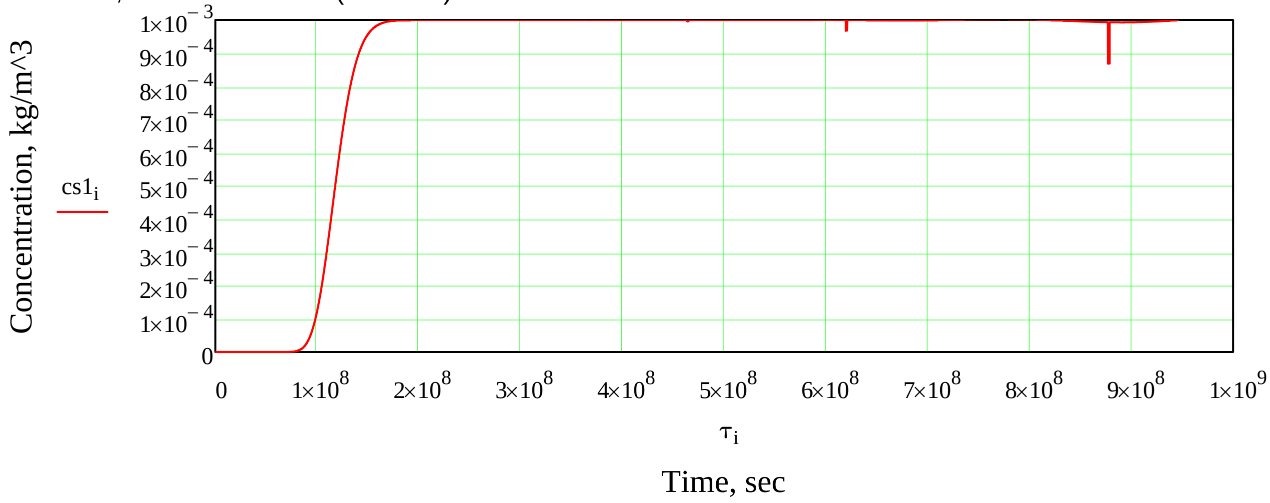
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 0,1..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

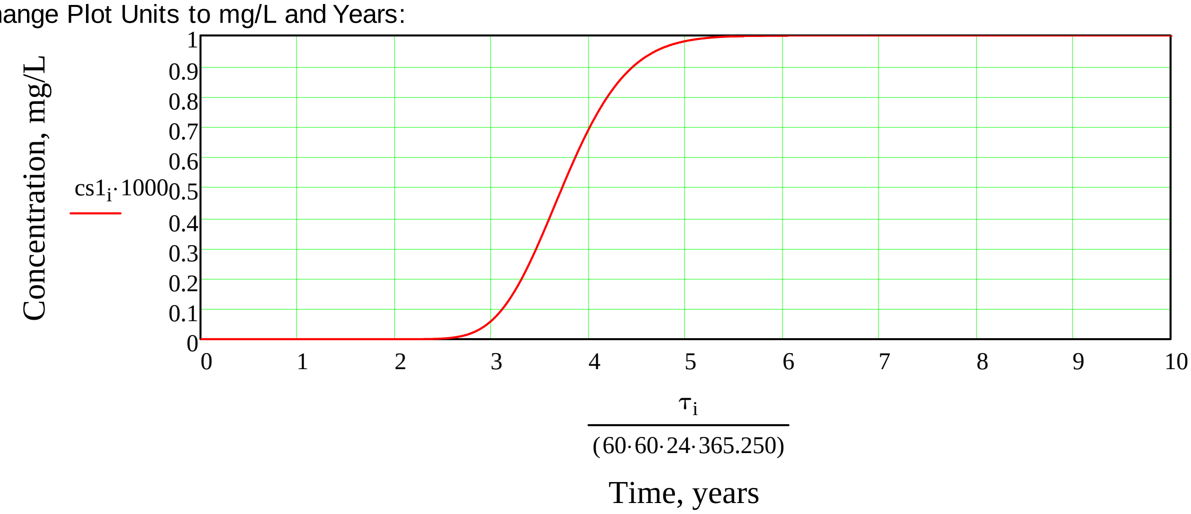
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

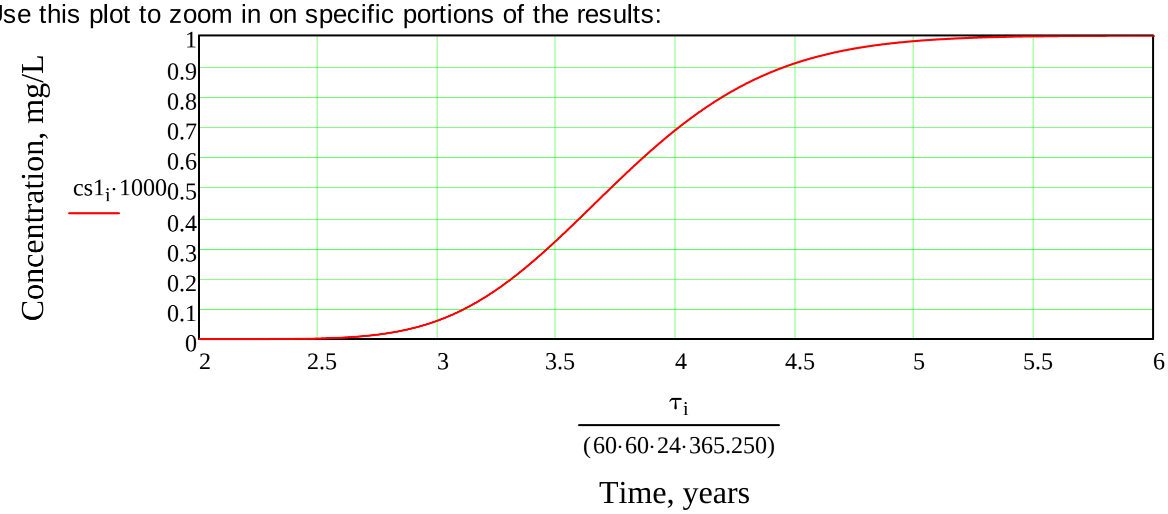
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

$t_{2\_1\%} := 2.5 \cdot yr$ $t_{2\_10\%} := 3.1 \cdot yr$ $t_{2\_90\%} := 4.5 \cdot yr$ $t_{2\_100\%} := 5.5 \cdot yr$

$t_{2\_1\%} = 913.105 \cdot day$ $t_{2\_10\%} = 1.132 \times 10^3 \cdot day$ $t_{2\_90\%} = 1.644 \times 10^3 \cdot day$ $t_{2\_100\%} = 2.009 \times 10^3 \cdot day$

Use these values below for time steps 3, 4, 5, 6 below.

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.01 \\ 0.10 \\ 0.90 \\ 1.00 \\ 1.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 912 \\ 913 \\ 1132 \\ 1644 \\ 2009 \\ 10950 \end{pmatrix} day$$

C = 0 up to 1 day prior to plume entering Layer 2

This source sub-divides the results from Layer 2.

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 18.142 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 800 \cdot ft$ Southeast - Northwest

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 115.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 115.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 7.7 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 7.7 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 7.7 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 7.7 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 11.55 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.77 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.77 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot \exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

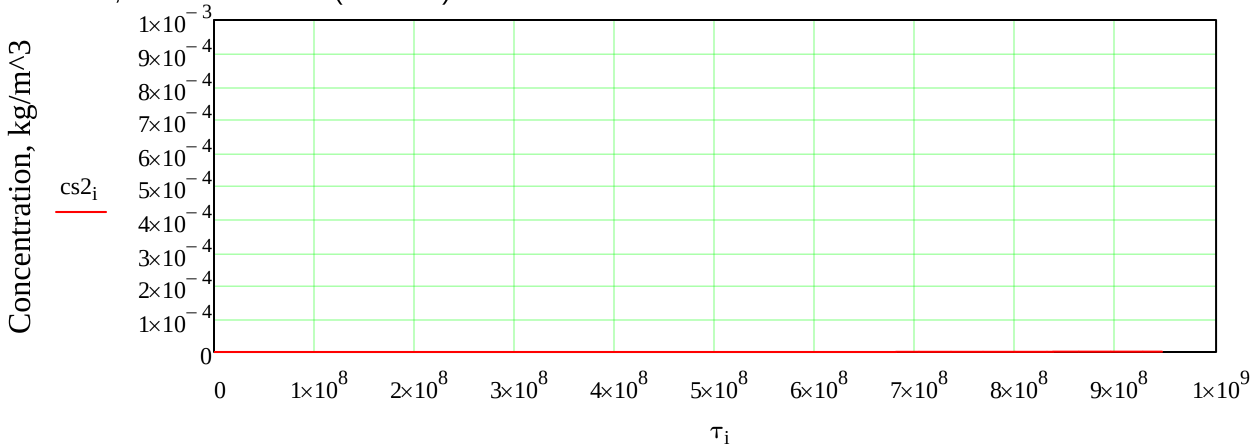
$i := 0,1..10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

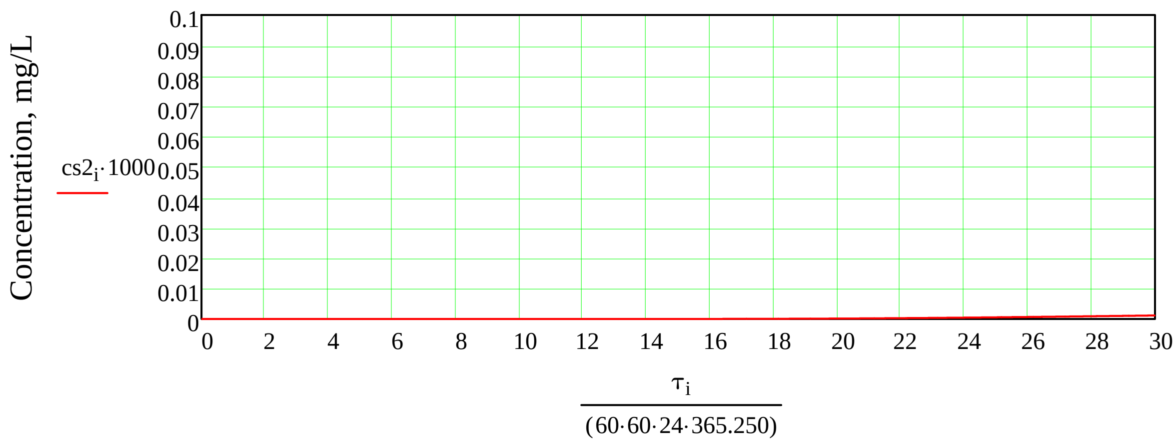
5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

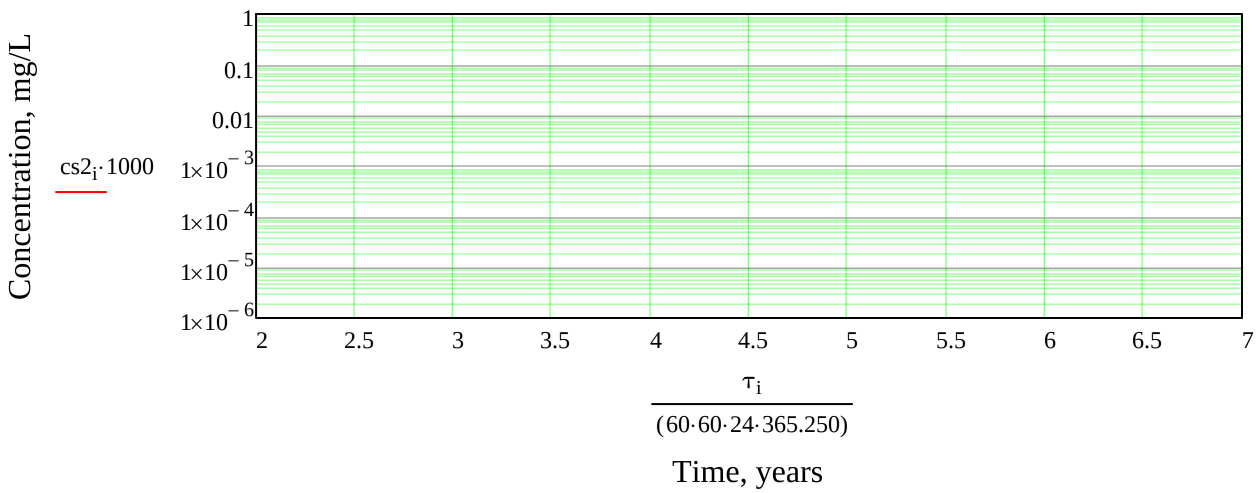
Time, sec



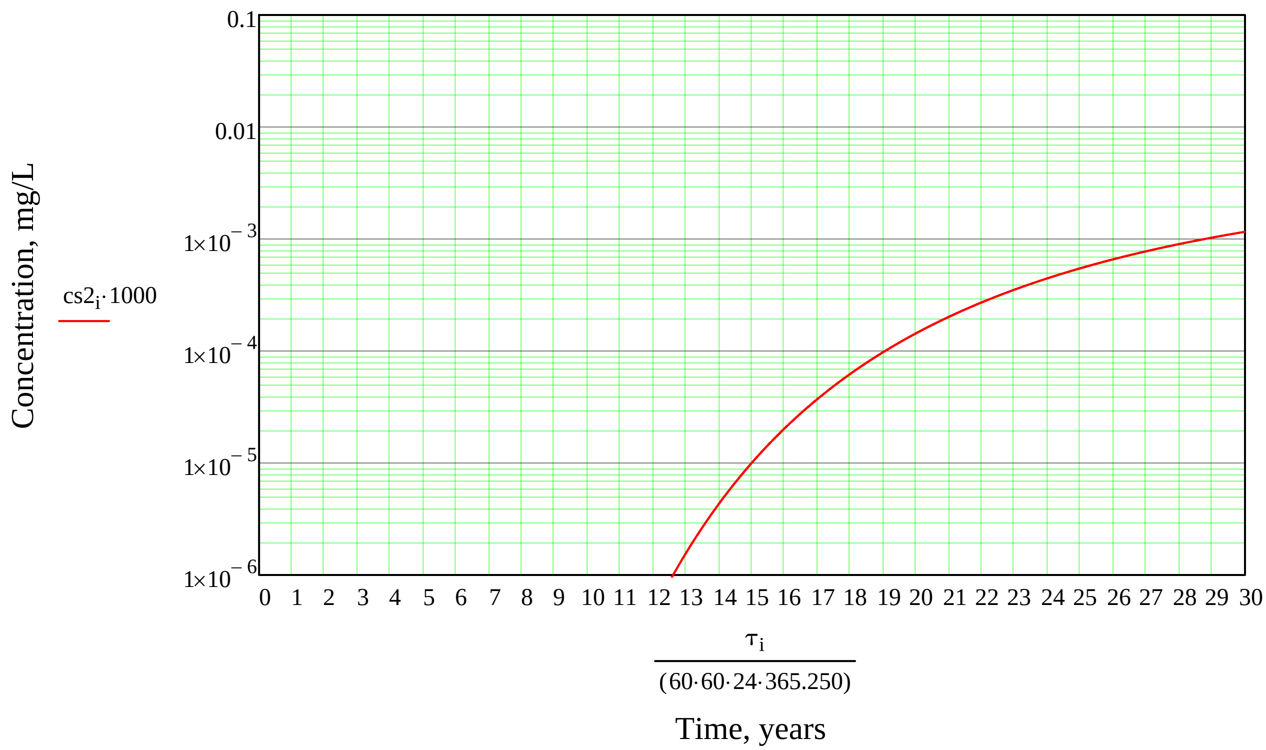
$x_2 = 770 \cdot ft$ $\quad y_2 = 0$ $\quad z_2 = 300 \cdot ft$

Time, years

C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot B



D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 770 \cdot ft$ $y_2 = 0$ $z_2 = 300 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on East Side of Cell 11. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor A.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\quad Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Common Borrow	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 2ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\quad \Delta H_1 := x_1 + H_1$ $\quad \Delta H_1 = 8 \cdot ft$

Hydraulic gradient (i) $\quad i_1 := \frac{\Delta H_1}{x_1}$ $\quad i_1 = 4$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 558.106 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.388 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.426 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 3.473 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_11} := 200.6ft$ $\quad Head_A := 173ft$

$i_2 := \frac{(Head_{Cell\_11} + \Delta H_1) - Head_A}{700ft}$ $\quad i_2 = 0.051$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 5.42 \times 10^{-3} \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.938$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe East of Cell 11):

Sens. Rec	X_2 (ft)	Z_2 (ft)
A	510	0
B	760	0

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_2 := 510ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the Till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 9.948 \cdot ft$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

				Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 2 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.02 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$ $\alpha x_1 = 0.02 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.02 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$ $\alpha y_1 = 0.02 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.02 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$ $\alpha z_1 = 0.02 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

				Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 510 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 76.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 76.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 5.1 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 5.1 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 5.1 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 5.1 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.426 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 2 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Y&Z = 0 yields the maximum concentration

Lateral distance of interest (z): $z_1 := 0ft$

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 8.527 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 8.527 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 8.527 \times 10^{-3} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

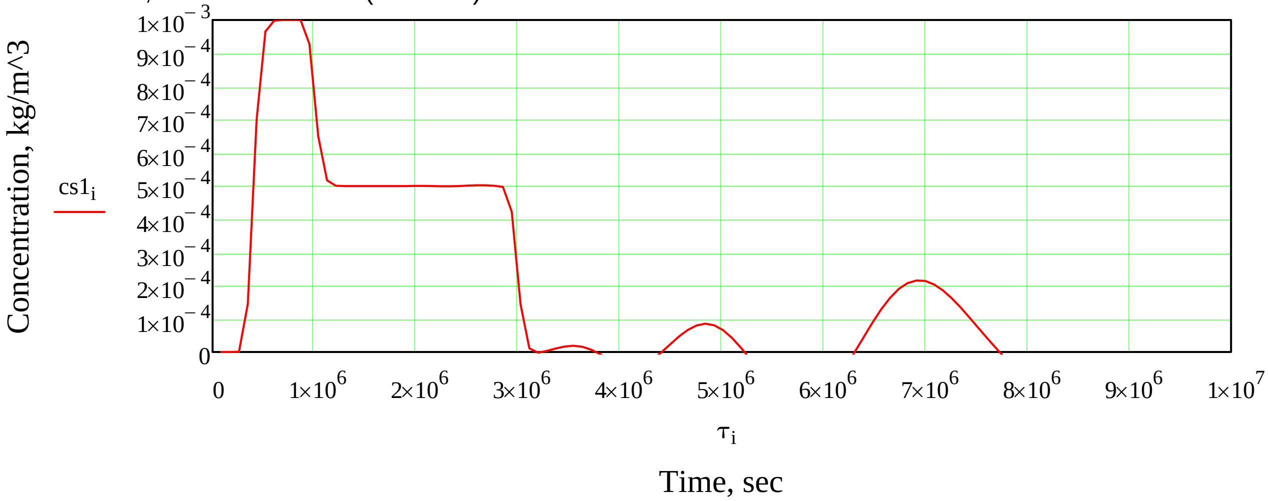
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\qquad\qquad$ $\tau_i := i\cdot day$

$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

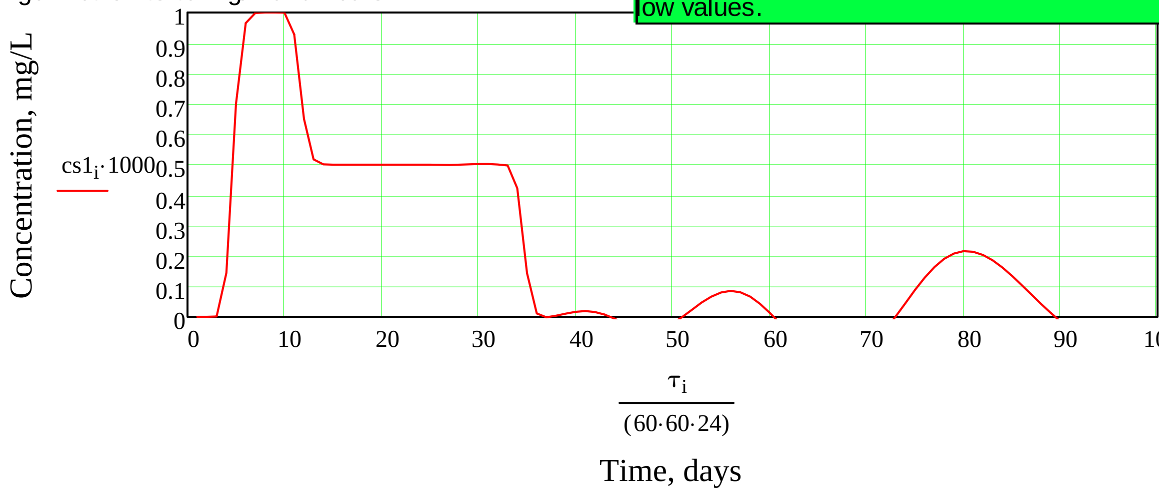
5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

A. Solution, with default units (Mathcad)

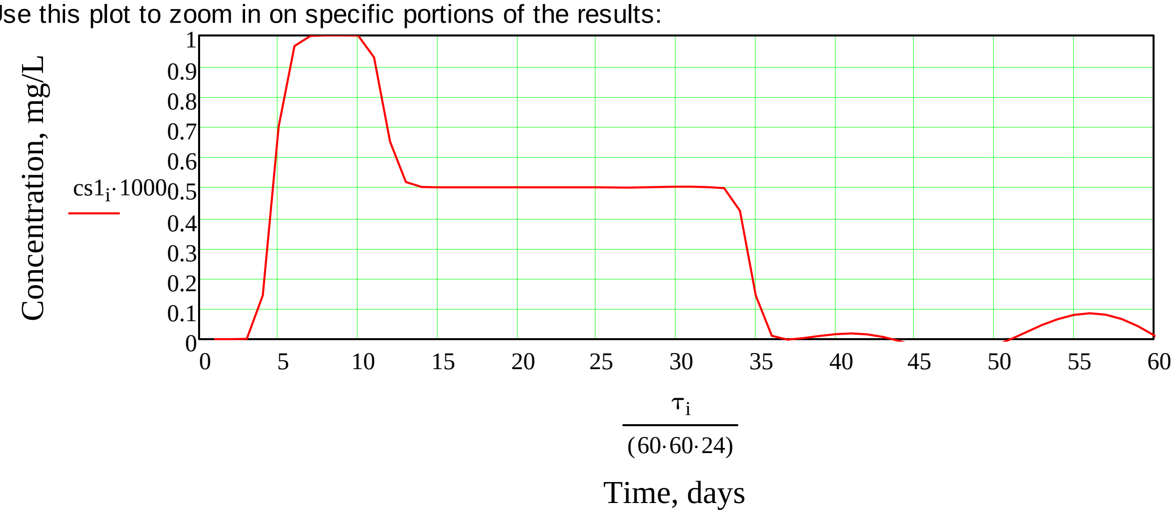


NOTE : After approximately 35 days, concentration is 0. Bounce is result of numerical instability at very low values.

B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 1.00 \\ 1.00 \\ 0.50 \\ 0.50 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 3 \\ 7 \\ 10 \\ 14 \\ 35 \\ 37 \end{pmatrix} day$$

B. Input parameters (Layer 2):

This ordinate system is rotated from Layer 1. X now is Direction of Dlowt-Southwest; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 9.948 \cdot ft$

Exceeds till thickness

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\quad \alpha_{x\_2} \cdot x_2 = 76.5 \cdot ft$ $\quad \alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\quad \alpha x_2 = 76.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\quad \alpha_{y\_2} \cdot x_2 = 5.1 \cdot ft$ $\quad \alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\quad \alpha y_2 = 5.1 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\quad \alpha_{z\_2} \cdot x_2 = 5.1 \cdot ft$ $\quad \alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\quad \alpha z_2 = 5.1 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $\quad Dx_2 := \alpha x_2 \cdot v_2$ $\quad Dx_2 = 7.65 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $\quad Dy_2 := \alpha y_2 \cdot v_2$ $\quad Dy_2 = 0.51 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $\quad Dz_2 := \alpha z_2 \cdot v_2$ $\quad Dz_2 = 0.51 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

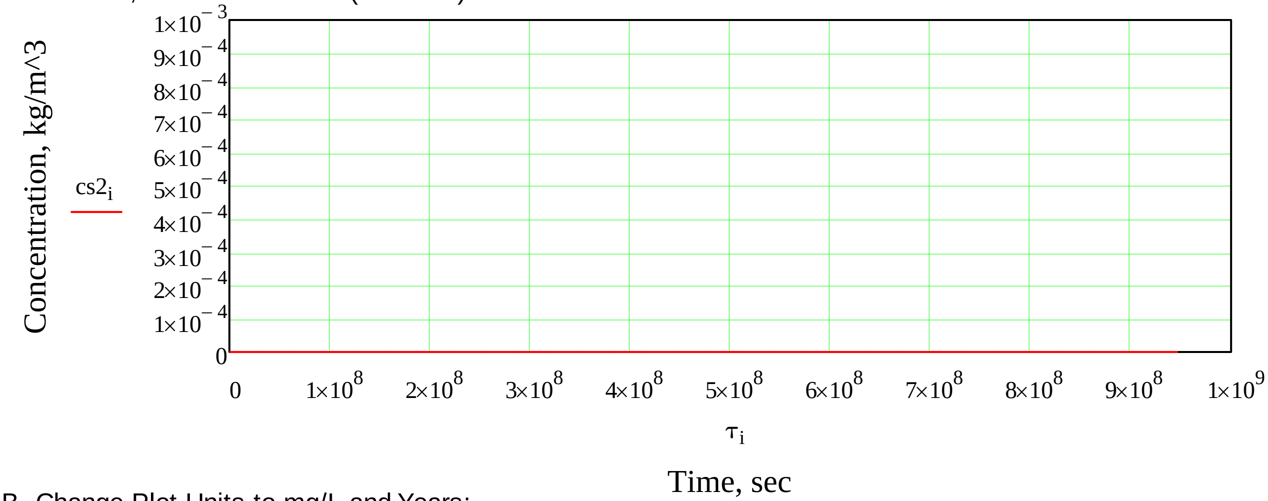
$i := 1,2..10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{day}$$

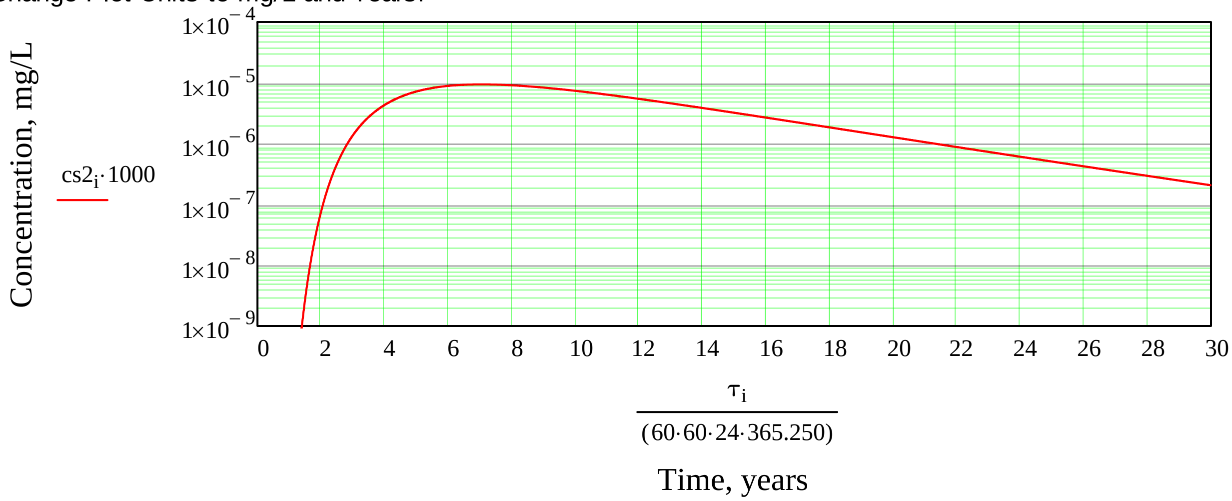
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

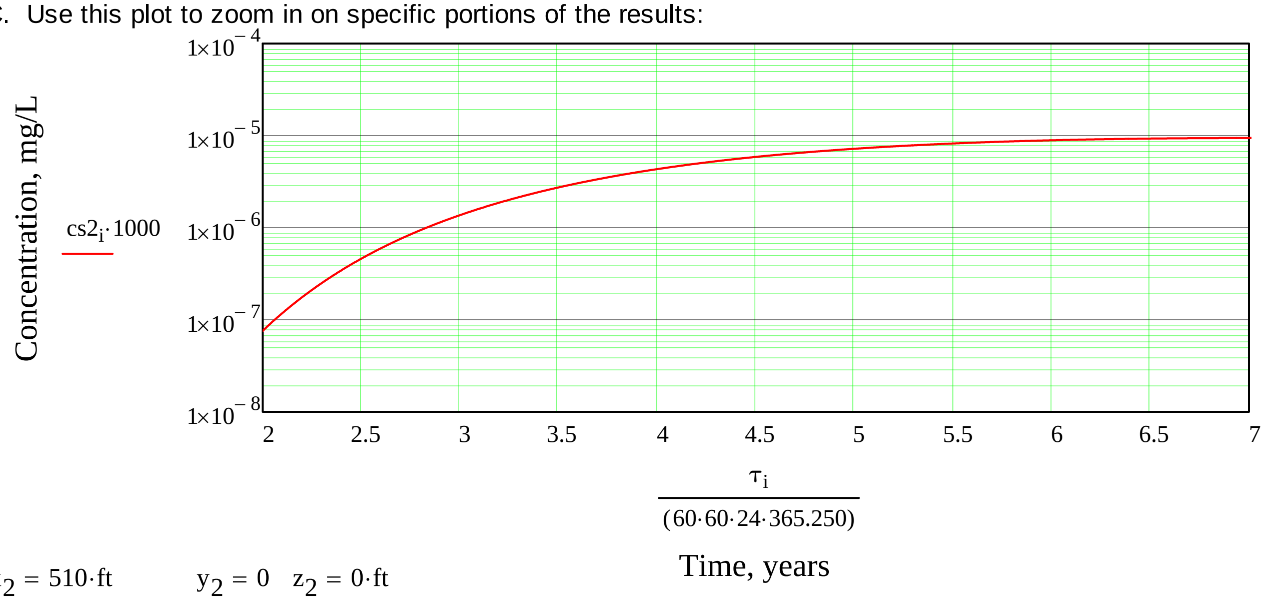
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

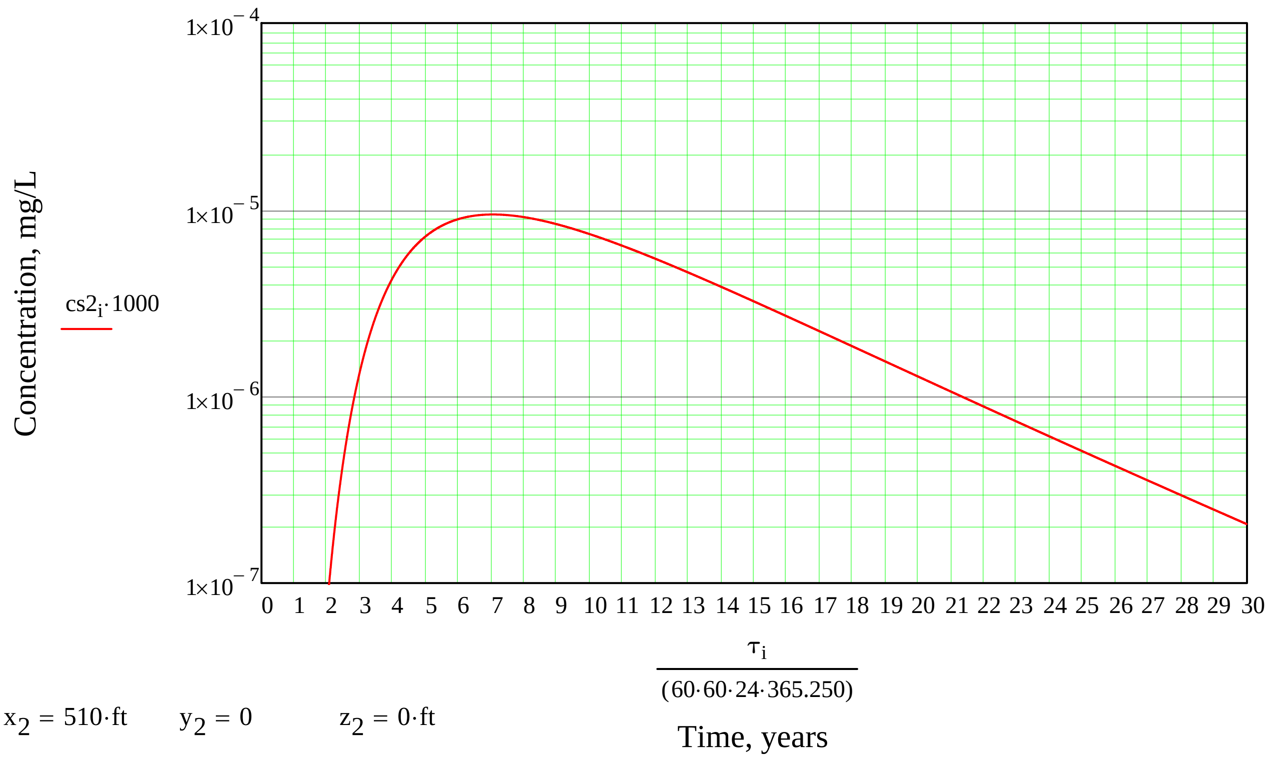


C. Use this plot to zoom in on specific portions of the results:



$x_2 = 510 \cdot ft$ $\quad y_2 = 0 \quad z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 510 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
Leakey Force Main on East Side of Cell 11. Flow is vertically down through Layer 1 (Common Borrow); then vertically through Layer 2 (Till); and thenhorizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor A.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Common Borrow	Native Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 2ft$	$x_2 := 30ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 8 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 4$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 558.106 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 0.388 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 0.426 \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 3.473 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 0.426 \cdot \frac{ft}{day}$

LQ was Used to determine the value of a_3

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $i_2 = 4$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the east side of the Importes Soil Limits in Cell 11):

distance of interest (x): $x_3 := 510ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3} \qquad a_3 = 49.739 \cdot ft$$

Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 2 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.02 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.02 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.02 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.02 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.02 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.02 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 30 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.3 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.3 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 3 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 3 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 3 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 3 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

These Calcs

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

Lateral dispersivity $\alpha_{y\_BR} := \frac{20ft}{Y_3}$ $\alpha_{y\_BR} = 0.4$ Z axis

Downgradient dispersivity: $\alpha_{x\_BR} := \frac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$ $\alpha_{x\_BR} = 1.2$ X axis

Vertical dispersivity $\alpha_{z\_BR} := \frac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$ $\alpha_{z\_BR} = 0.02$ Y axis

3.1 Source Definition, to Layer 1 (Common Borrow Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.426 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 2 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 8.527 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 8.527 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 8.527 \times 10^{-3} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

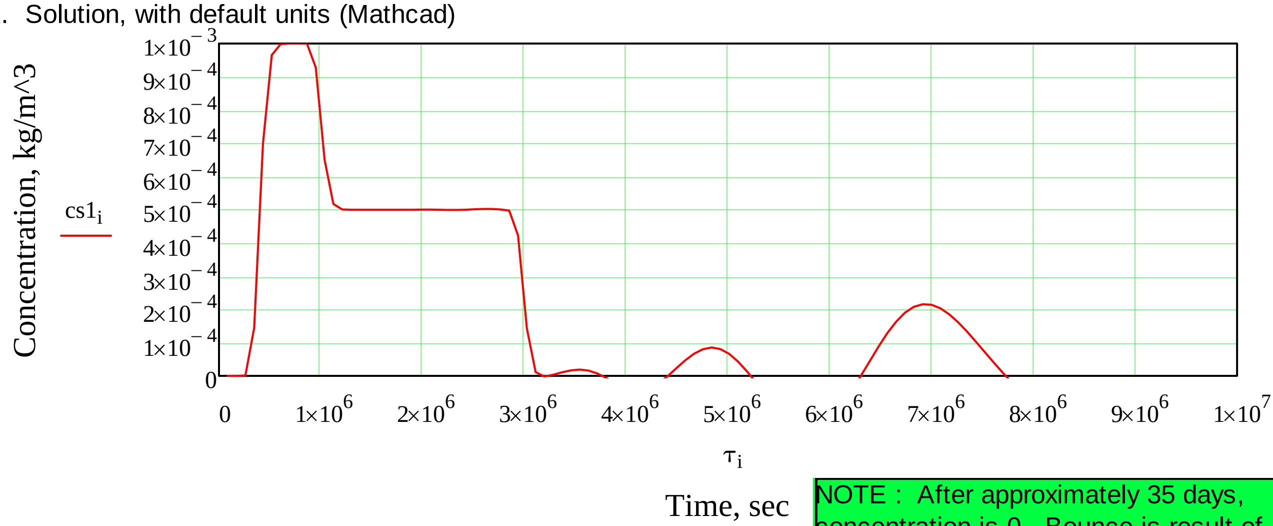
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2\,..\,100$ $\qquad\qquad$ $\tau_i := i\cdot day$

$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

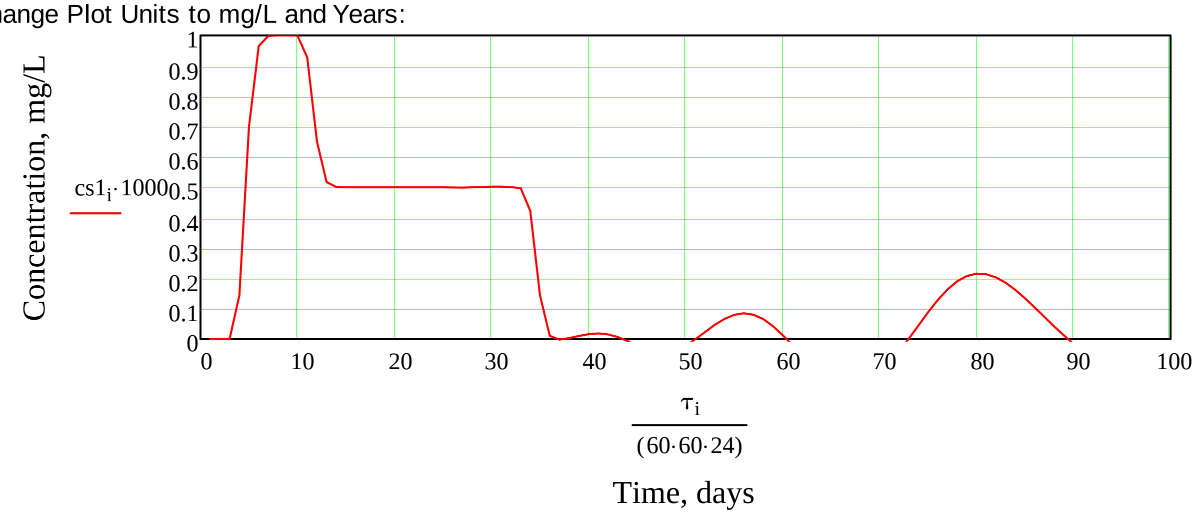
5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

A. Solution, with default units (Mathcad)

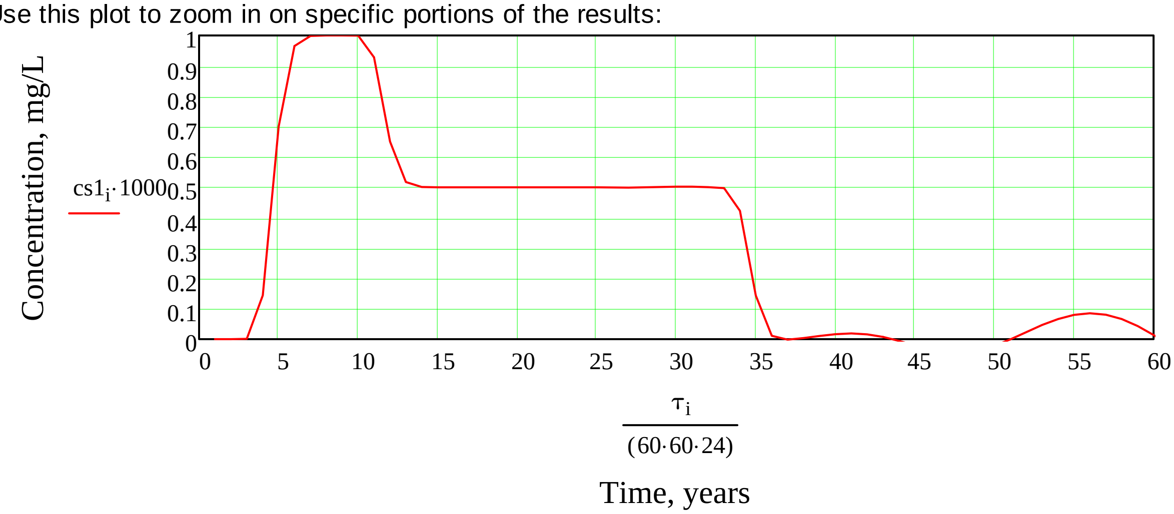


NOTE : After approximately 35 days, concentration is 0. Bounce is result of numerical instability at very low values.

B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 1.00 \\ 1.00 \\ 0.50 \\ 0.50 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 3 \\ 7 \\ 10 \\ 14 \\ 35 \\ 37 \end{pmatrix} day$$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 0.426 \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 30 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$ Northeast - Southwest

Lateal distance of interest (z): $z_2 := 0ft$ Southeast - Northwest

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 0.128 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 1.279 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 1.279 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

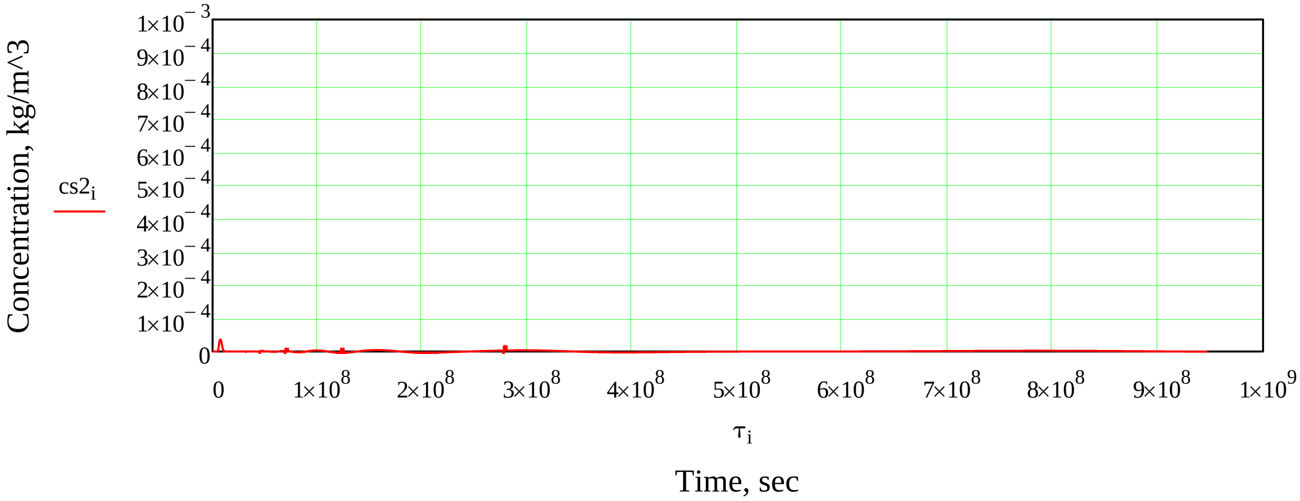
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1,2..10950$ $\qquad$ $\tau_i := i\cdot day$

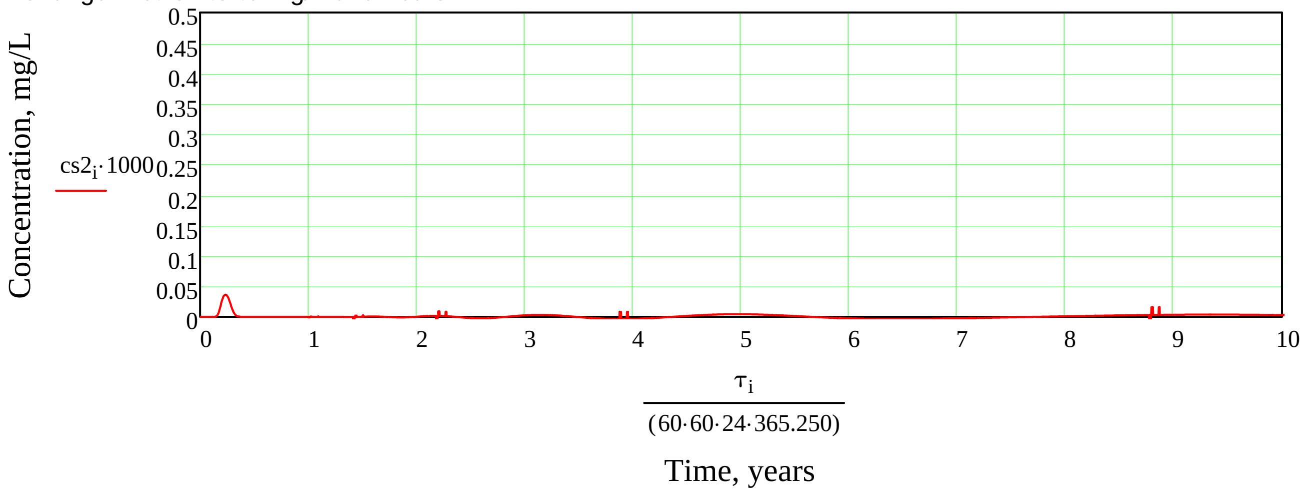
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

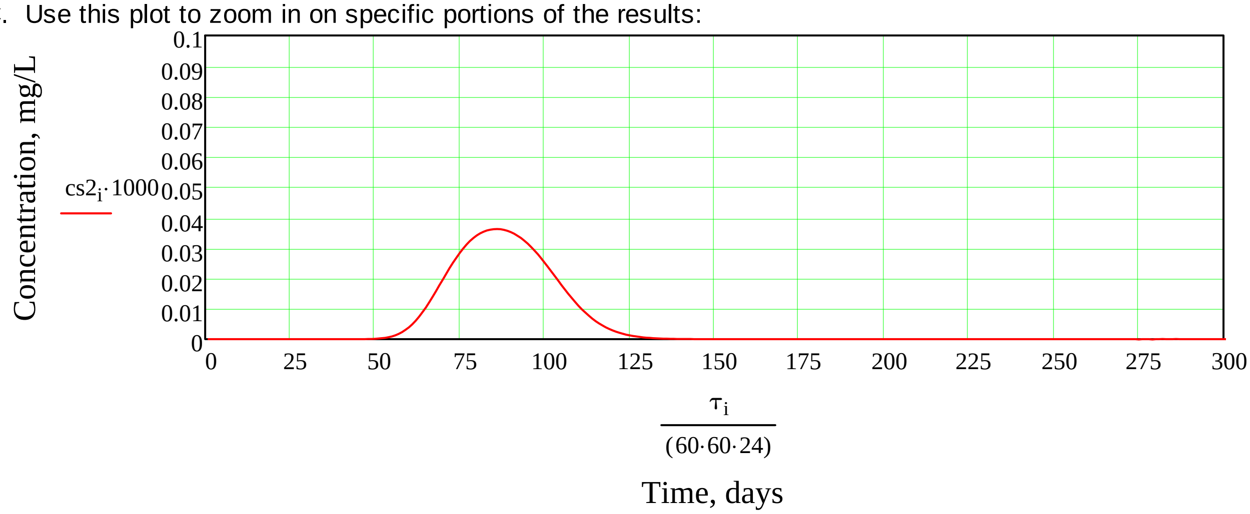
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.04 \\ 0.04 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 0 \\ 50 \\ 75 \\ 100 \\ 125 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 49.739 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 1.167 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 612 \cdot ft$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 612 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 204 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 204 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 10.2 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 10.2 \cdot ft$ Lateral

Note: This was rotated to use correct orientation from Tracer Test.

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 3.06 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.02 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 51 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \operatorname{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \operatorname{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \operatorname{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \operatorname{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

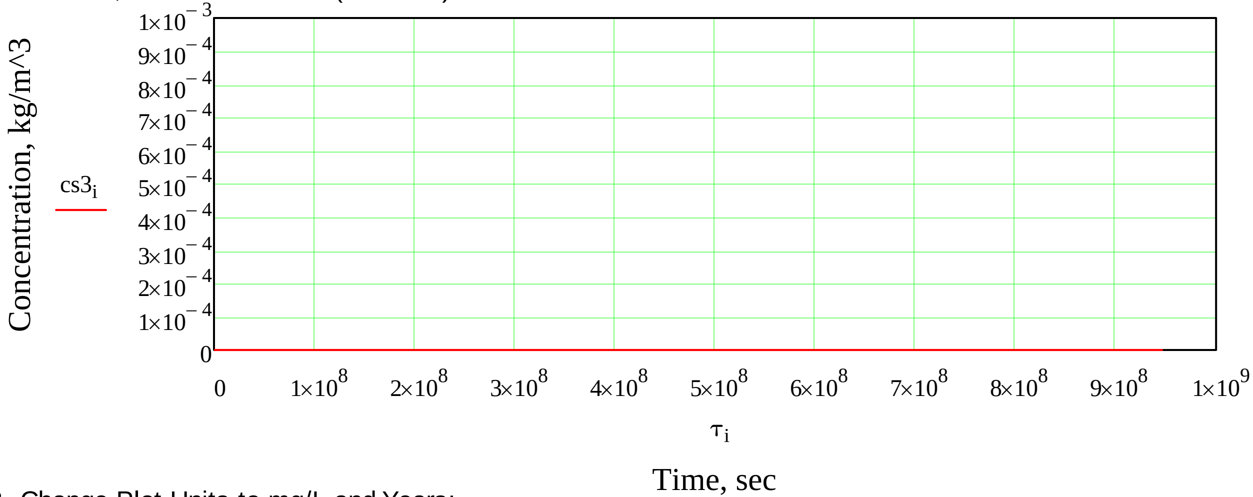
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

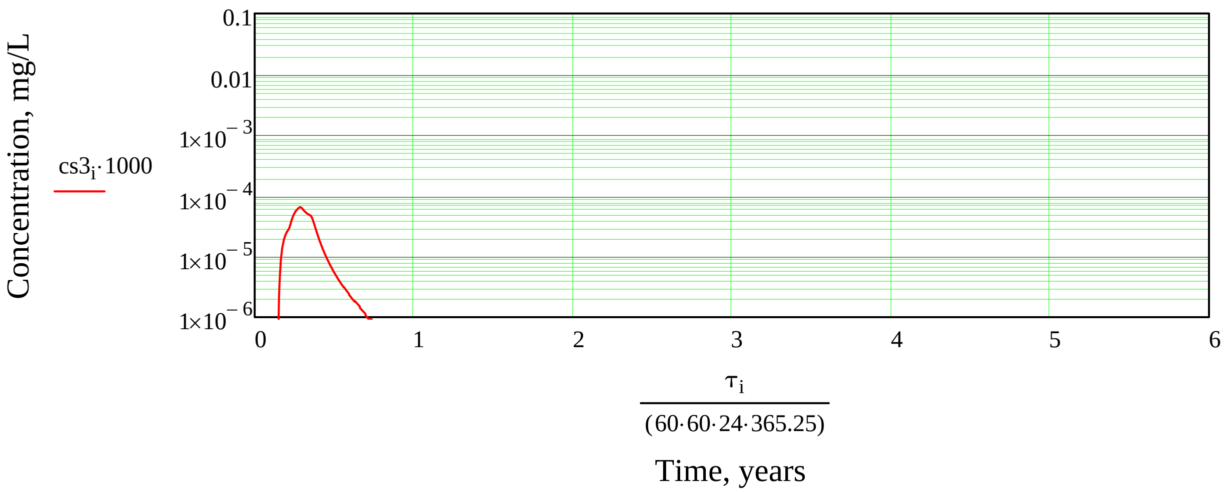
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

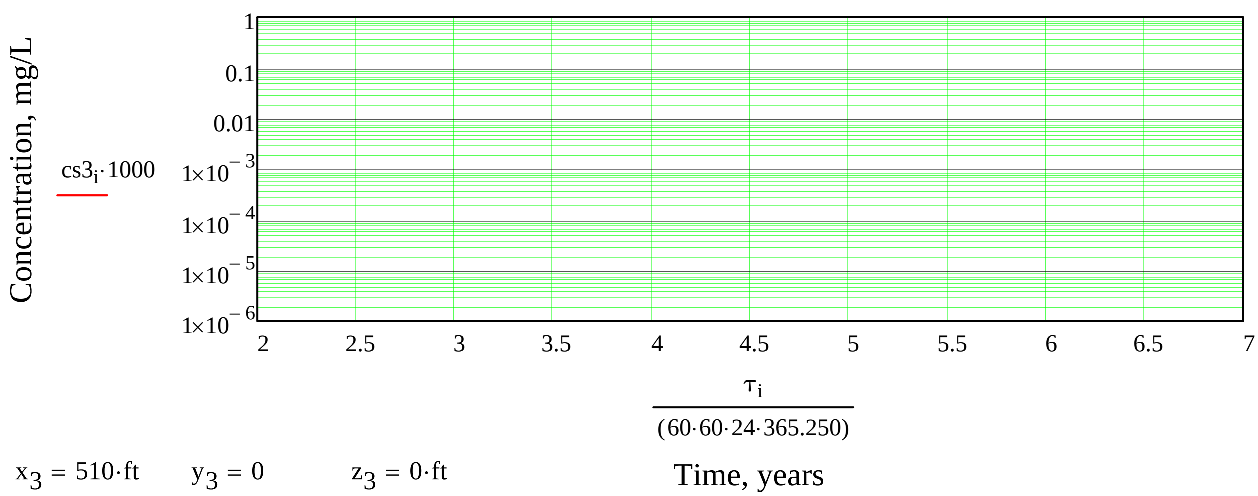
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

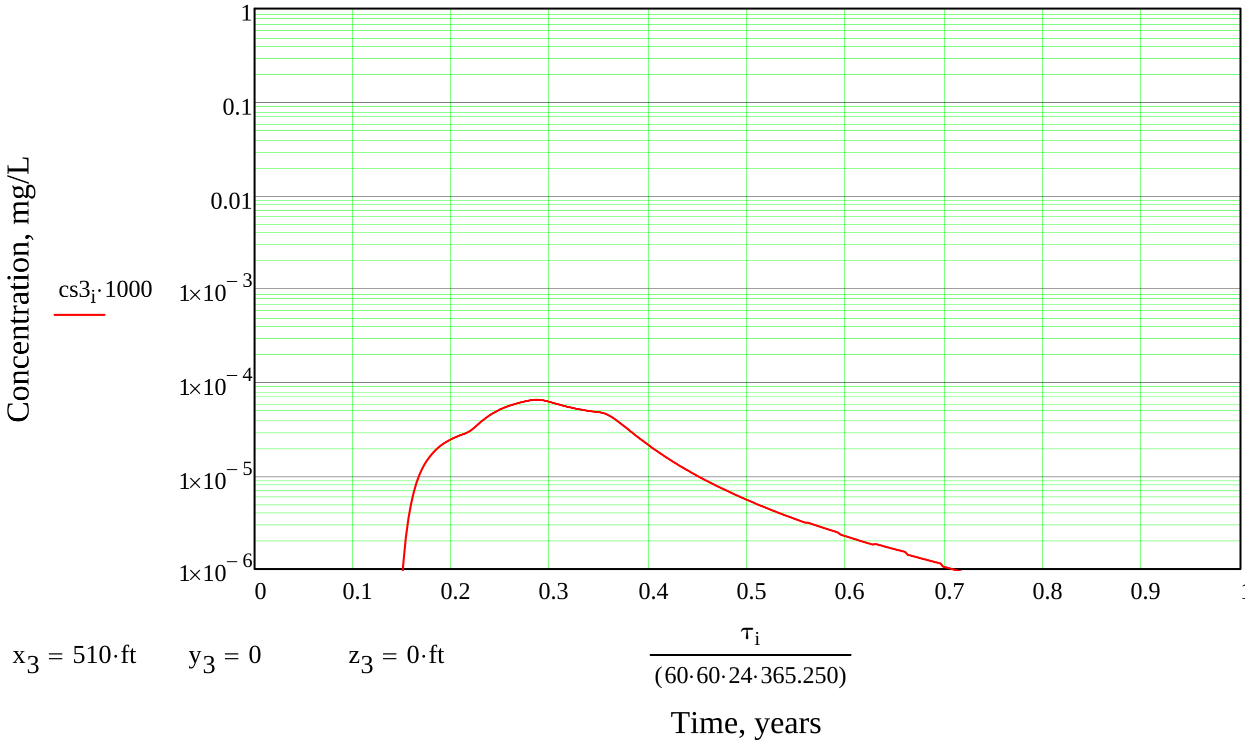


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot A shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 510 \cdot ft$ $\quad y_3 = 0$ $\quad z_3 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 510 \cdot ft$ $y_3 = 0$ $z_3 = 0 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on East Side of Cell 11. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor A.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1 Common Borrow	LAYER 2 Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 2ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 8 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 4$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\qquad Q_1 = 558.106 \cdot \frac{gal}{day}$ $\qquad Q_2 := Q_1$ $\qquad Q_1 = 0.388 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\qquad v_1 = 0.426 \cdot \frac{ft}{day}$ $\qquad LQ := \frac{Q_1}{Area_1}$ $\qquad LQ = 3.473 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_11} := 200.6ft$ $\qquad Head_A := 173ft$

$i_2 := \frac{(Head_{Cell\_11} + \Delta H_1) - Head_A}{700ft}$ $\qquad i_2 = 0.051$ $\qquad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\qquad v_{gw} = 5.42 \times 10^{-3} \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\qquad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\qquad i_2 = 0.938$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe East of Cell 11):

Sens. Rec	X_2 (ft)	Z_2 (ft)
A	510	0
B	760	0

See Figure 7-1 in Volume II of the application.

distance of interest (x): $x_2 := 510ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the Till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\qquad a_2 = 9.948 \cdot ft$ $\qquad$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 2 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.02 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.02 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.02 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.02 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.02 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.02 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 510 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 76.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 76.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 5.1 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 5.1 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 5.1 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 5.1 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.426 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 2 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 8.527 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 8.527 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 8.527 \times 10^{-3} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

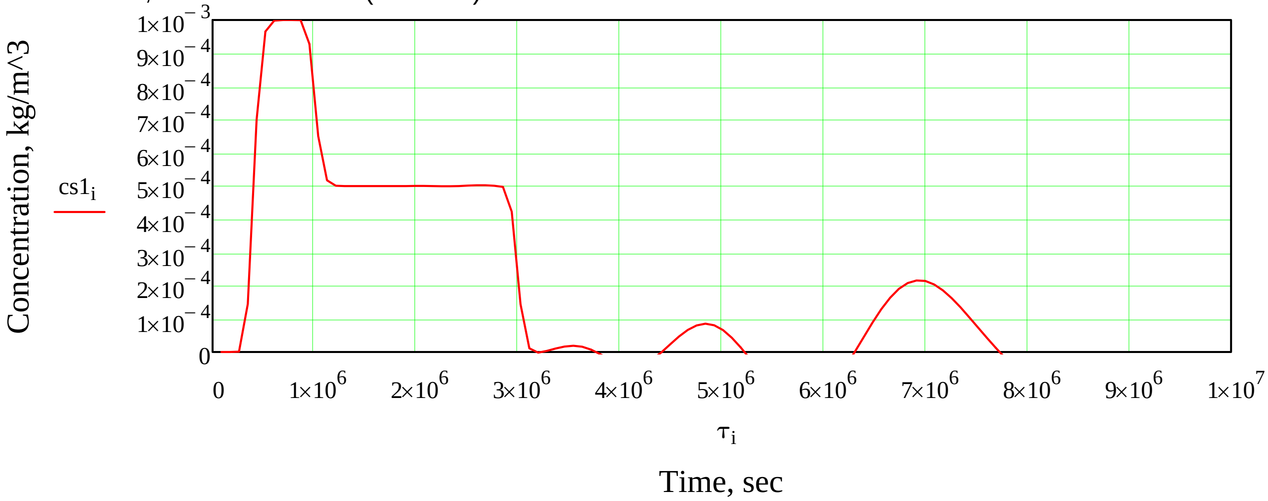
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1, 2 .. 100$ $\tau_i := i\cdot day$

$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

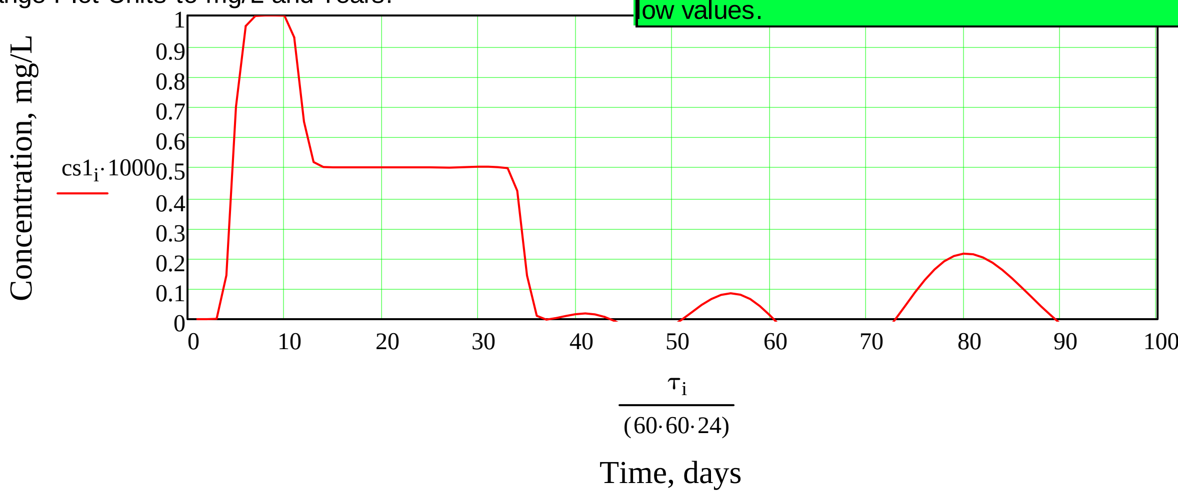
5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

A. Solution, with default units (Mathcad)

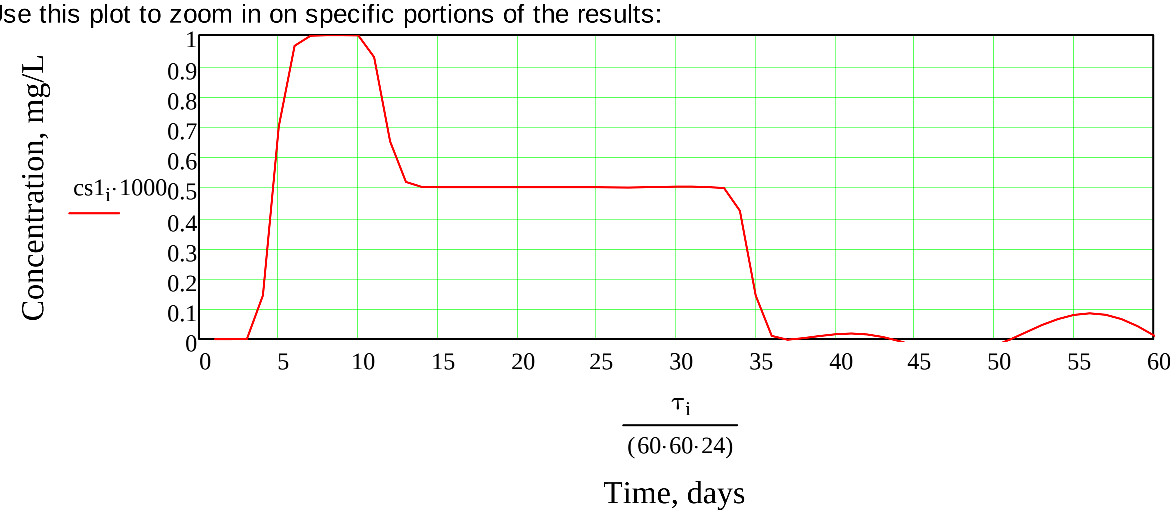


NOTE : After approximately 35 days, concentration is 0. Bounce is result of numerical instability at very low values.

B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 1.00 \\ 1.00 \\ 0.50 \\ 0.50 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 3 \\ 7 \\ 10 \\ 14 \\ 35 \\ 37 \end{pmatrix} day$$

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 9.948 \cdot ft$

Exceeds till thickness

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 76.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 76.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 5.1 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 5.1 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 5.1 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 5.1 \cdot ft$ Lateral

Note: This was rotated to use correct orientation from Tracer Test.

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 7.65 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.51 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.51 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

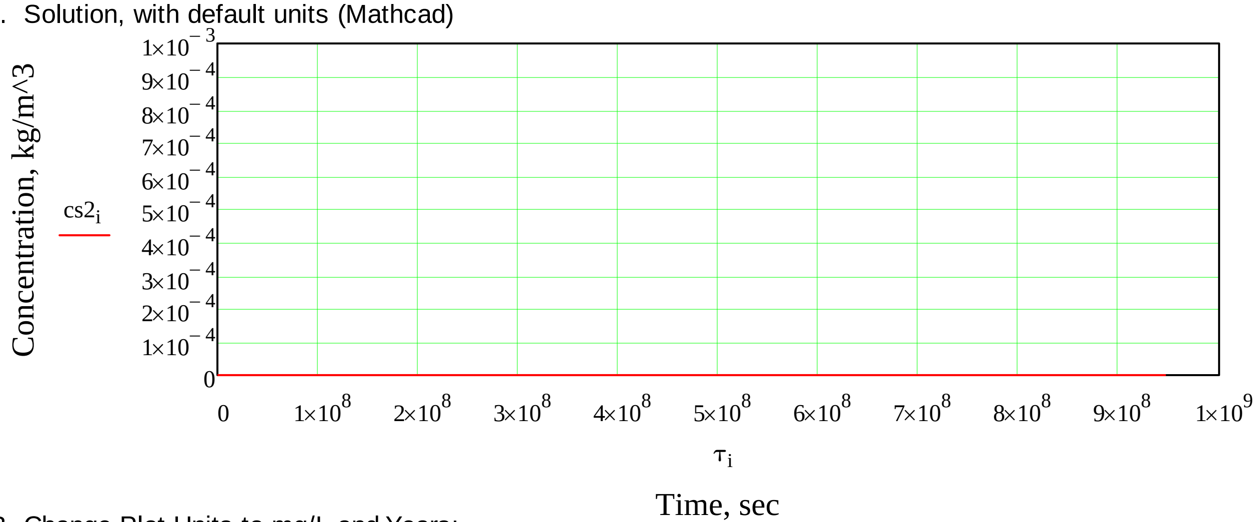
$i := 1,2 \,..\, 10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

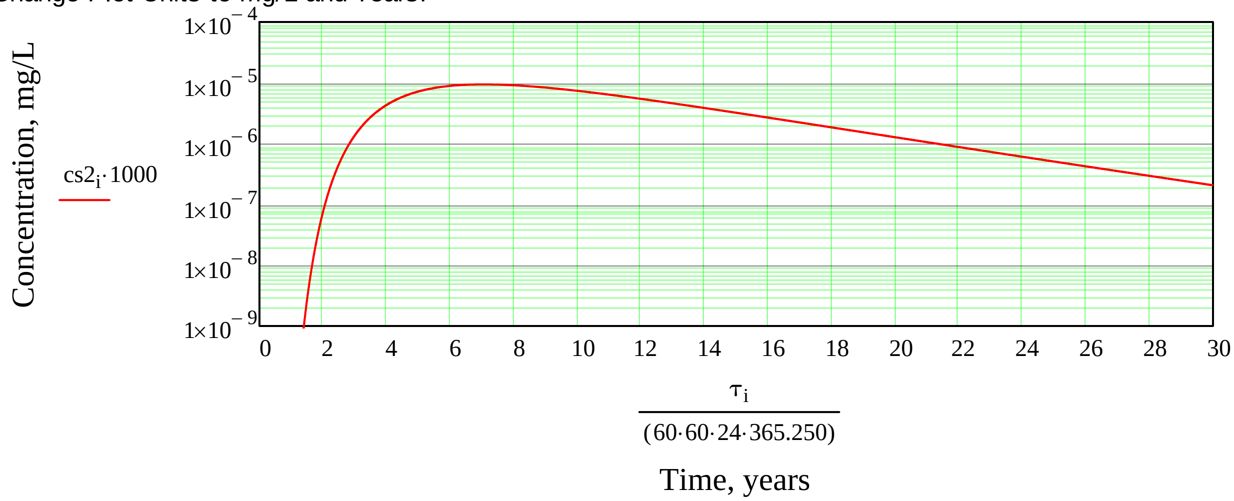
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

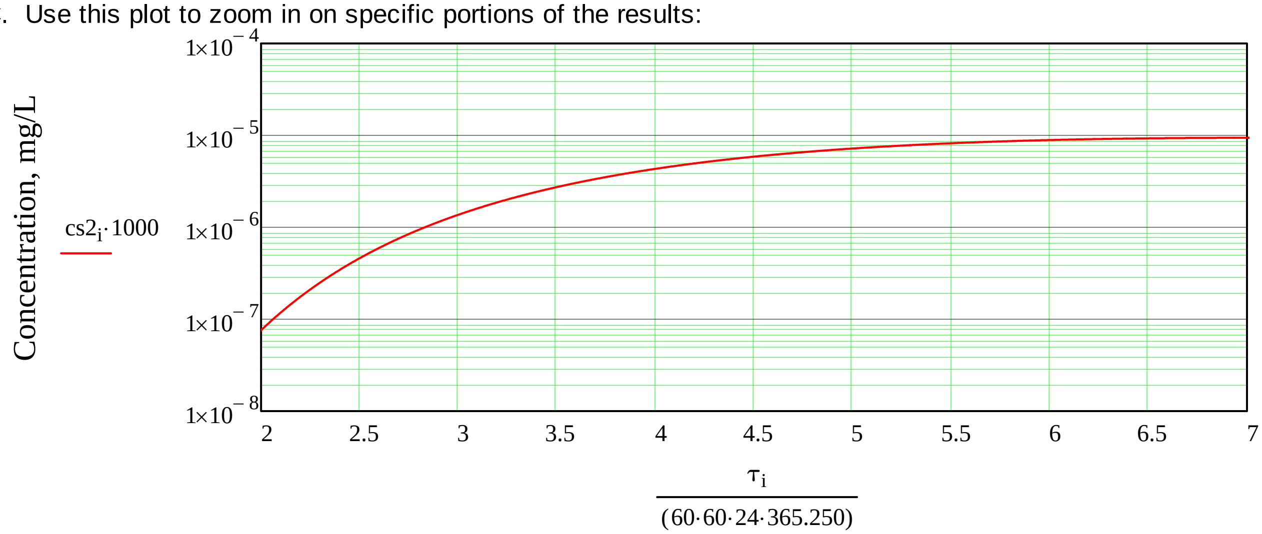
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



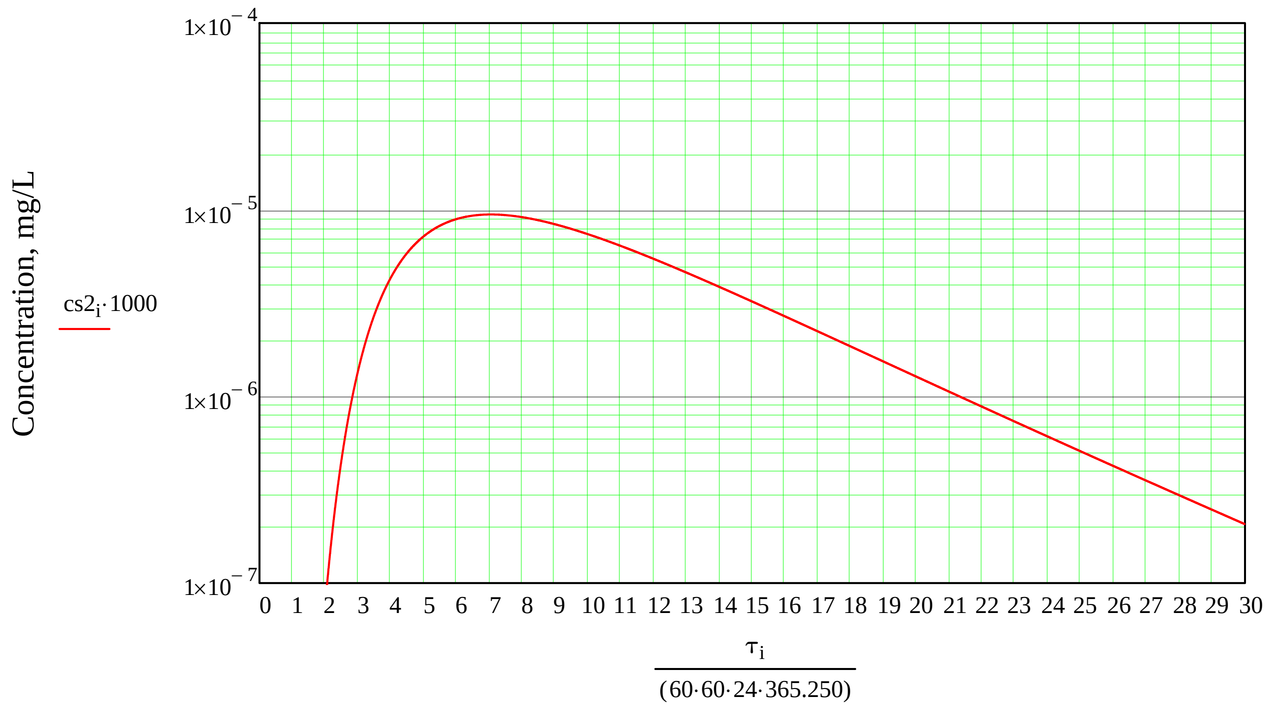
C. Use this plot to zoom in on specific portions of the results:



Time, years

$x_2 = 510 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 510 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
Leakey Force Main on East Side of Cell 11. Flow is vertically down through Layer 1 (Common Borrow); then vertically through Layer 2 (Till); and thenhorizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor B.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Common Borrow	Native Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 2ft$	$x_2 := 4ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 8 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 4$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 558.106 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 0.388 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 0.426 \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 3.473 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 0.426 \cdot \frac{ft}{day}$

LQ was Used to determine the value of a_3

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $i_2 = 4$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the east side of the Importes Soil Limits in Cell 11):

distance of interest (x): $x_3 := 760ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 49.739 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 2 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.02 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.02 \cdot ft$	Flow
$\alpha_{y\_1} := 0.1$		$\alpha_{y\_1} \cdot x_1 = 0.2 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.2 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.1$		$\alpha_{z\_1} \cdot x_1 = 0.2 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.2 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 4 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.04 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.04 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 0.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 0.4 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 0.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 0.4 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

These Calcs

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

Lateral dispersivity $\alpha_{y\_BR} := \dfrac{20ft}{Y_3}$ $\alpha_{y\_BR} = 0.4$ Z axis

Downgradient dispersivity: $\alpha_{x\_BR} := \dfrac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$ $\alpha_{x\_BR} = 1.2$ X axis

Vertical dispersivity $\alpha_{z\_BR} := \dfrac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$ $\alpha_{z\_BR} = 0.02$ Y axis

3.1 Source Definition, to Layer 1 (Common Borrow Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.426 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 2 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Y&Z = 0 yields the maximum concentration

Lateral distance of interest (z): $z_1 := 0ft$

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 8.527 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.085 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.085 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

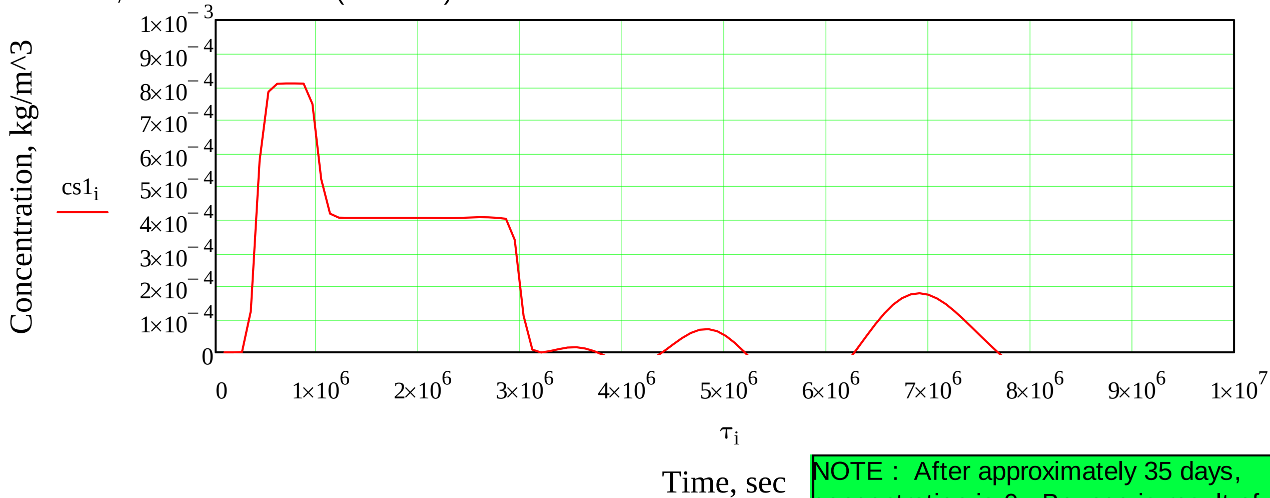
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\qquad\qquad$ $\tau_i := i\cdot day$

$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1(x_1,y_1,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1(x_1,y_1,|\tau_i - ti_n|)\right)\right]\right]$$

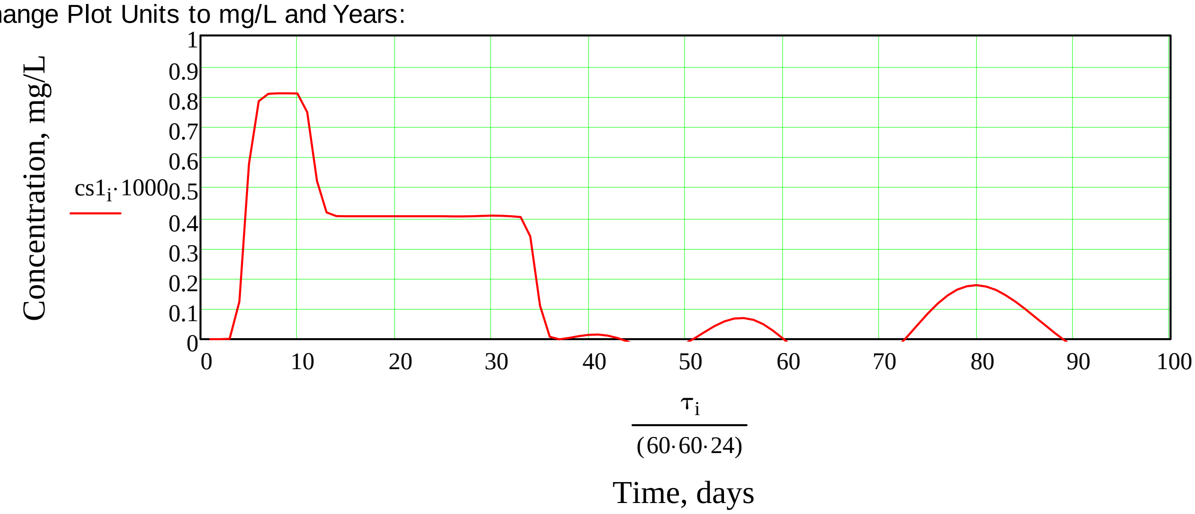
5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

A. Solution, with default units (Mathcad)

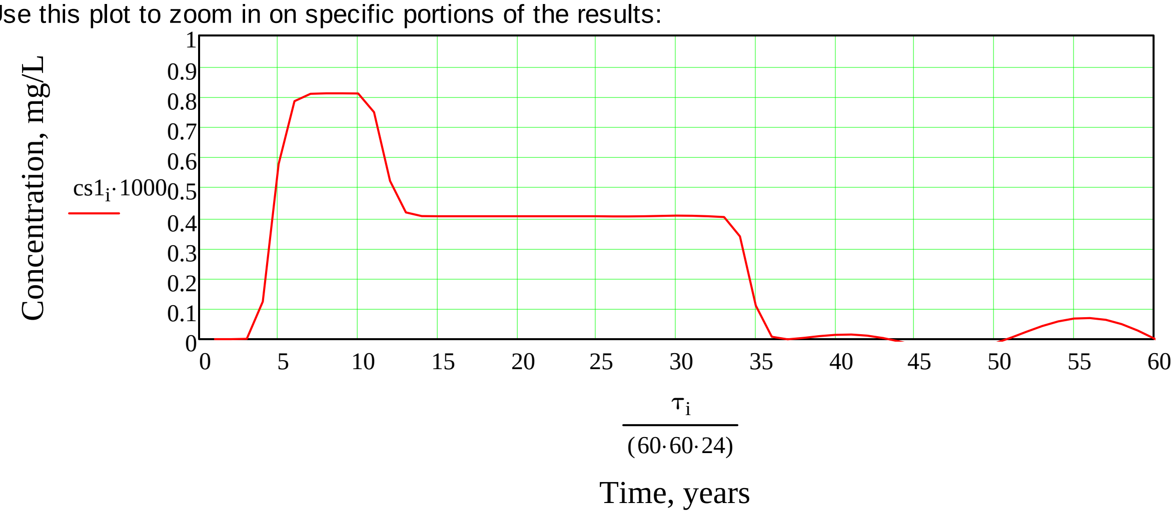


NOTE : After approximately 35 days, concentration is 0. Bounce is result of numerical instability at very low values.

B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 8$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0 \\ 0 \\ 1 \\ 1 \\ .5 \\ .5 \\ 0 \\ 0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 3 \\ 7 \\ 10 \\ 14 \\ 35 \\ 37 \\ 100 \end{pmatrix} day$$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 0.426 \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 4 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$

Lateal distance of interest (z): $z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 0.017 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.171 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.171 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

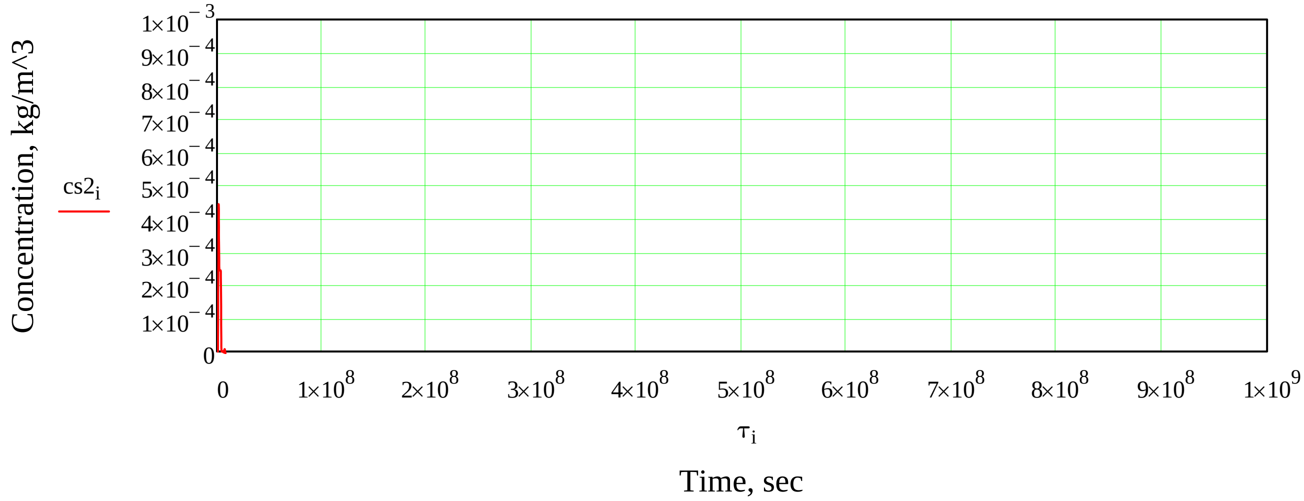
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1,2..100$ $\tau_i := i\cdot day$

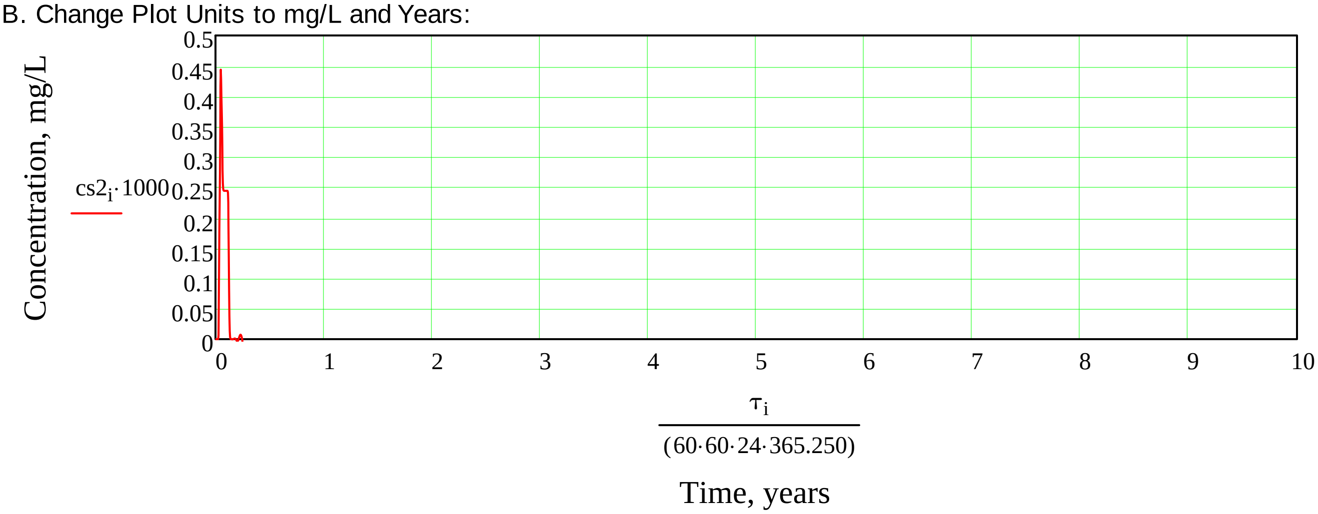
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

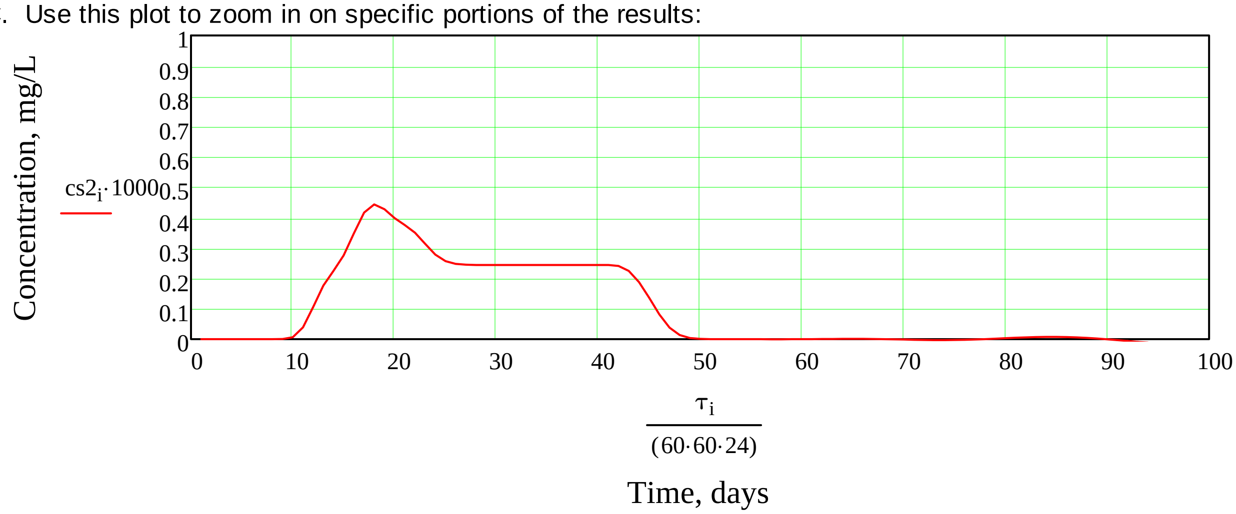
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.50 \\ 0.25 \\ 0.25 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 10 \\ 18 \\ 25 \\ 40 \\ 50 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Northeast-Southwest; Z is Southeast - Northwest; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 49.739 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 1.167 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\quad \alpha_{x\_3} \cdot x_3 = 912 \cdot ft$ $\quad \alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\quad \alpha x_3 = 912 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\quad \alpha_{y\_3} \cdot x_3 = 304 \cdot ft$ $\quad \alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\quad \alpha y_3 = 304 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\quad \alpha_{z\_3} \cdot x_3 = 15.2 \cdot ft$ $\quad \alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\quad \alpha z_3 = 15.2 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $\quad Dx_3 := \alpha x_3 \cdot v_3 \quad Dx_3 = 4.56 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $\quad Dy_3 := \alpha y_3 \cdot v_3 \quad Dy_3 = 1.52 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $\quad Dz_3 := \alpha z_3 \cdot v_3 \quad Dz_3 = 76 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \operatorname{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \operatorname{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \operatorname{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \operatorname{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

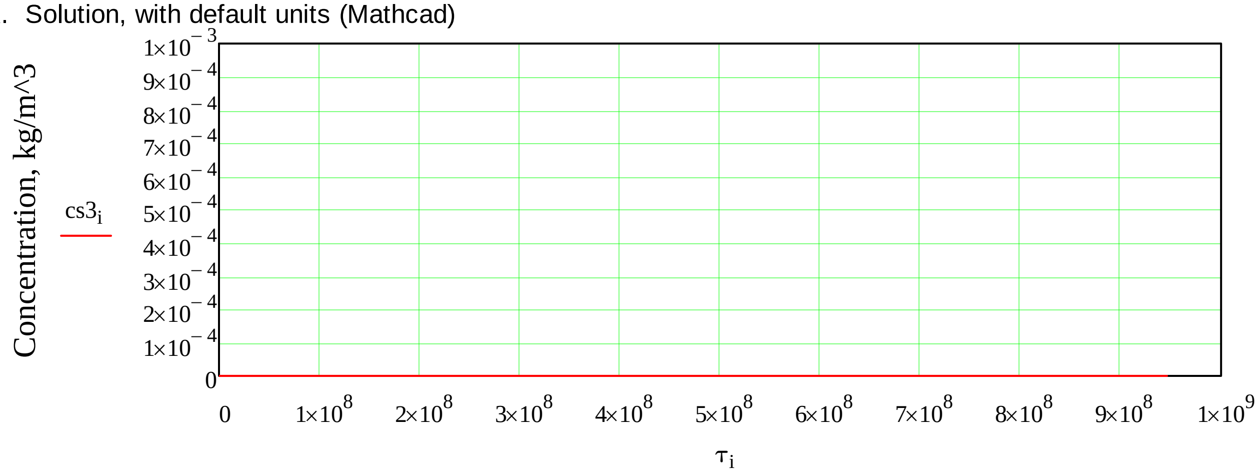
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2\,..\,10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

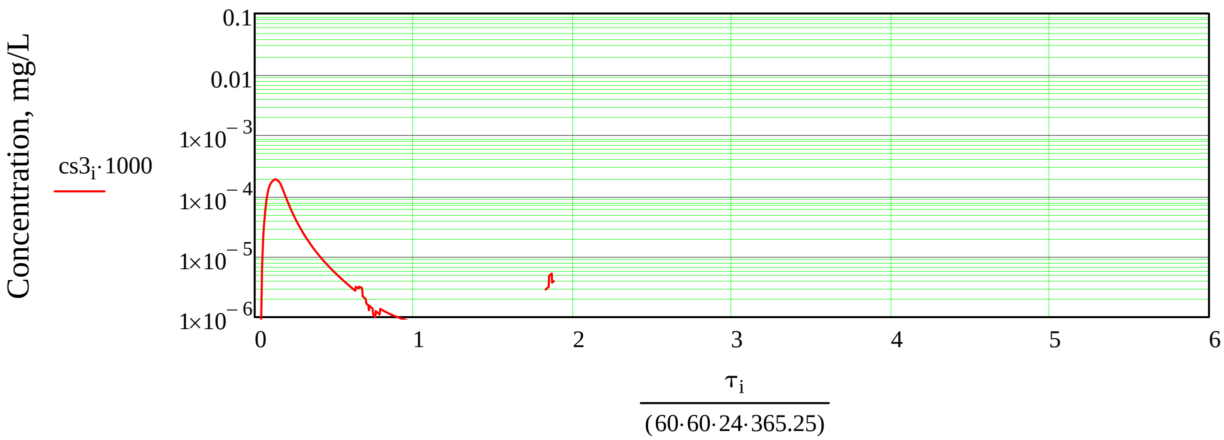
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

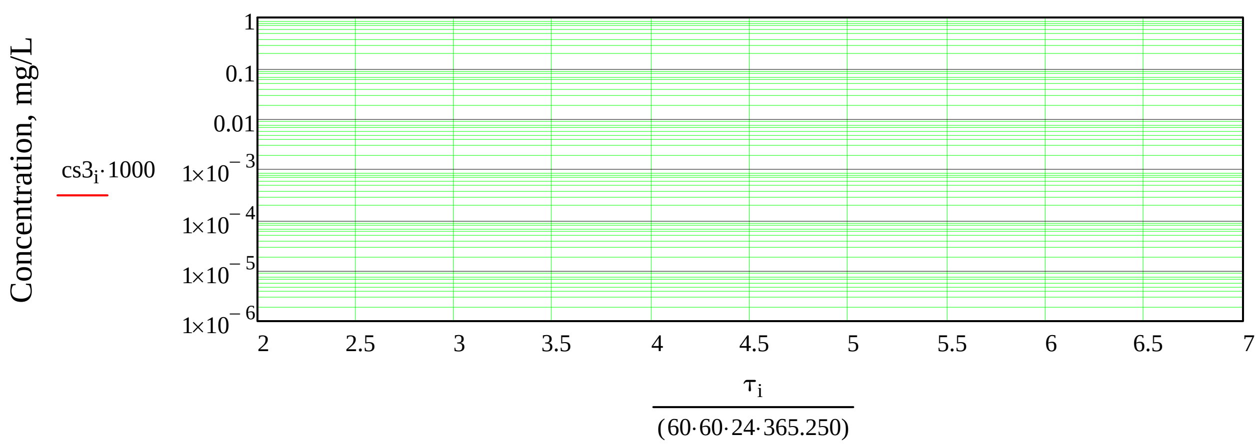
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

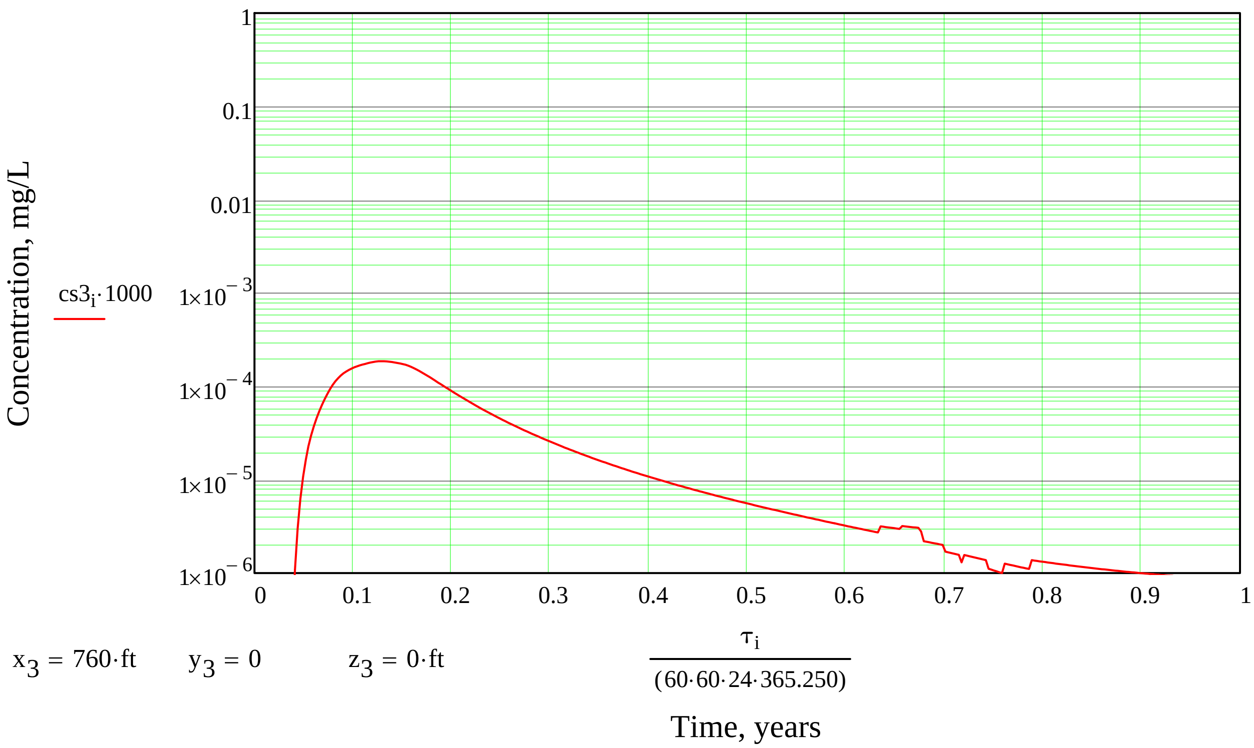


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot A shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 760 \cdot ft$ $y_3 = 0$ $z_3 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 760 \cdot ft$ $y_3 = 0$ $z_3 = 0 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on Northeast Corner of Cell 13. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor C.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Common Borrow	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 6ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 12 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 2$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 279.053 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.194 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.213 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 1.737 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_12} := 201.95ft$ $\quad Head_C := 145ft$

$i_2 := \frac{(Head_{Cell\_12} + \Delta H_1) - Head_C}{700ft}$ $\quad i_2 = 0.098$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 0.01 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.938$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe at Northeast corner of Cell 13):

distance of interest (x): $x_2 := 900ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 4.974 \cdot ft$ $\quad$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 6 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.06 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.06 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.06 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.06 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.06 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.06 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 900 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 135 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 135 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 9 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 9 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 9 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 9 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.213 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 6 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.013 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.013 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.013 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

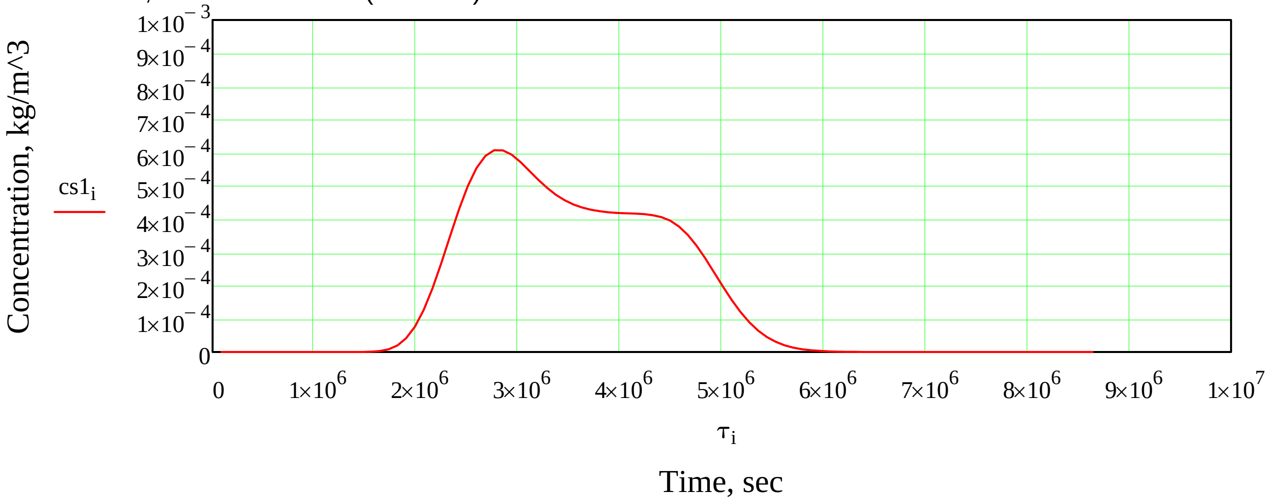
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\tau_i := i\cdot day$

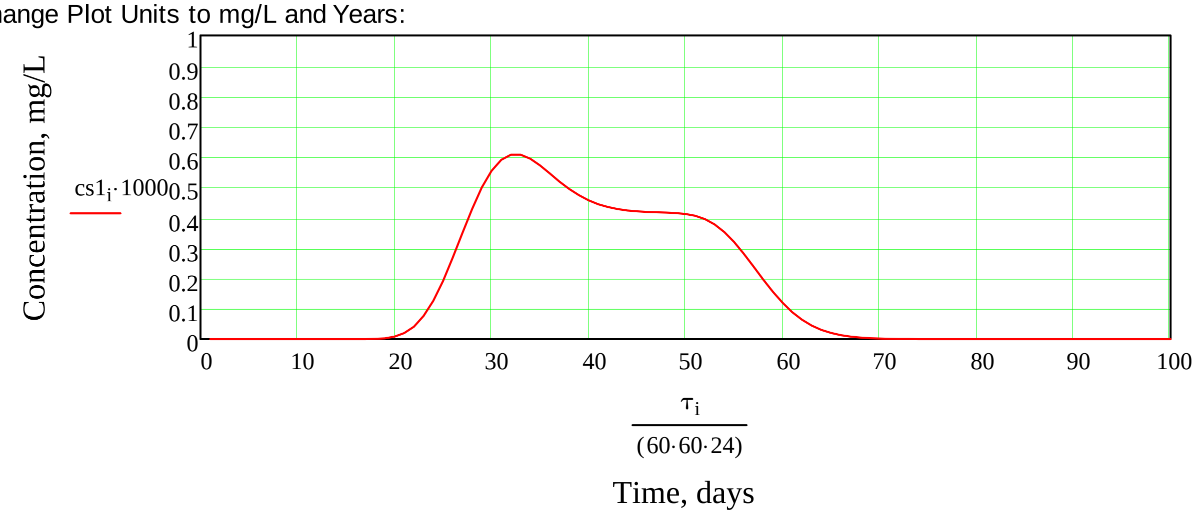
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

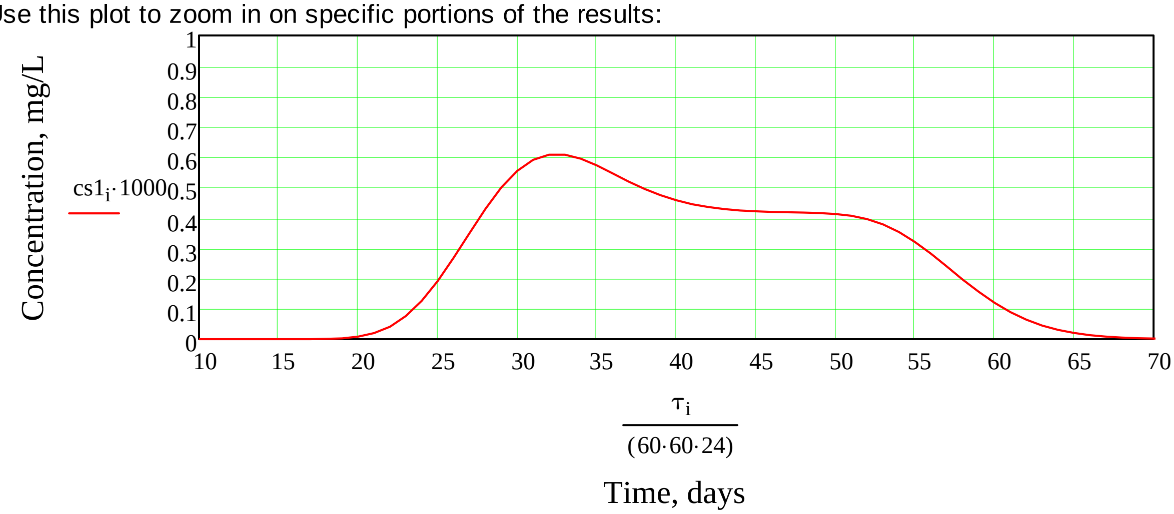
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration — Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 1.00 \\ 1.00 \\ 0.45 \\ 0.45 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 20 \\ 31 \\ 35 \\ 45 \\ 53 \\ 68 \end{pmatrix} day$$

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 4.974 \cdot ft$

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 135 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 135 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 9 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 9 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 9 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 9 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 13.5 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.9 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.9 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

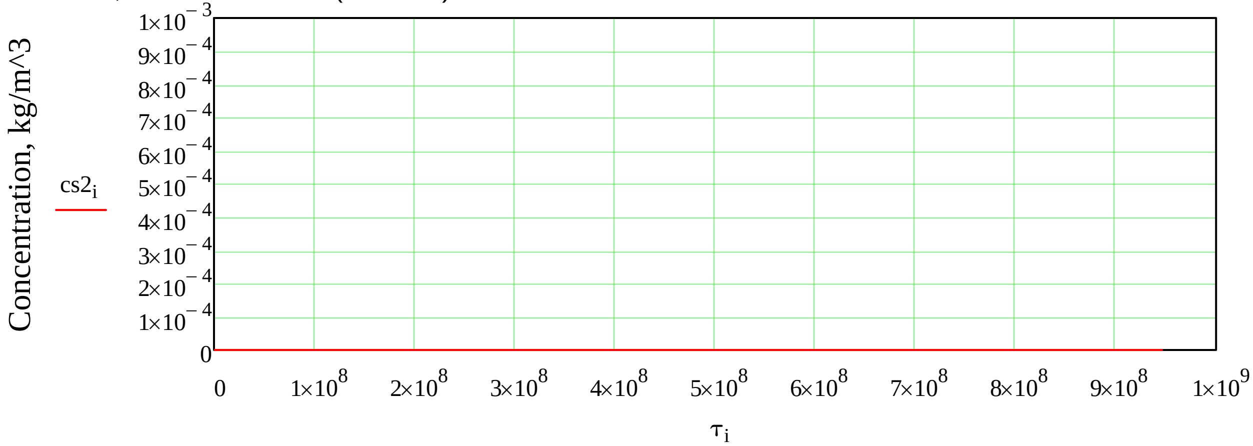
$i := 1, 2 .. 10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

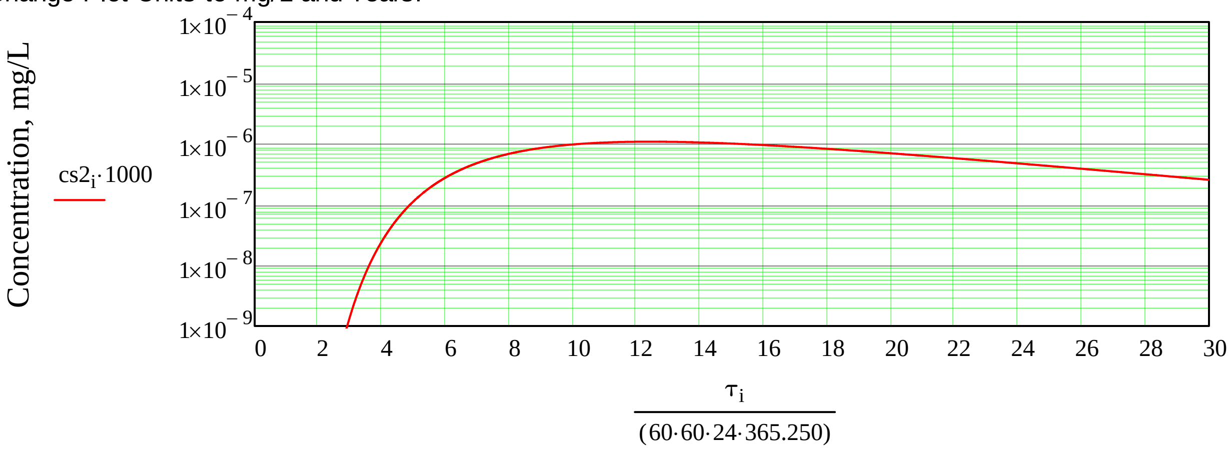
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

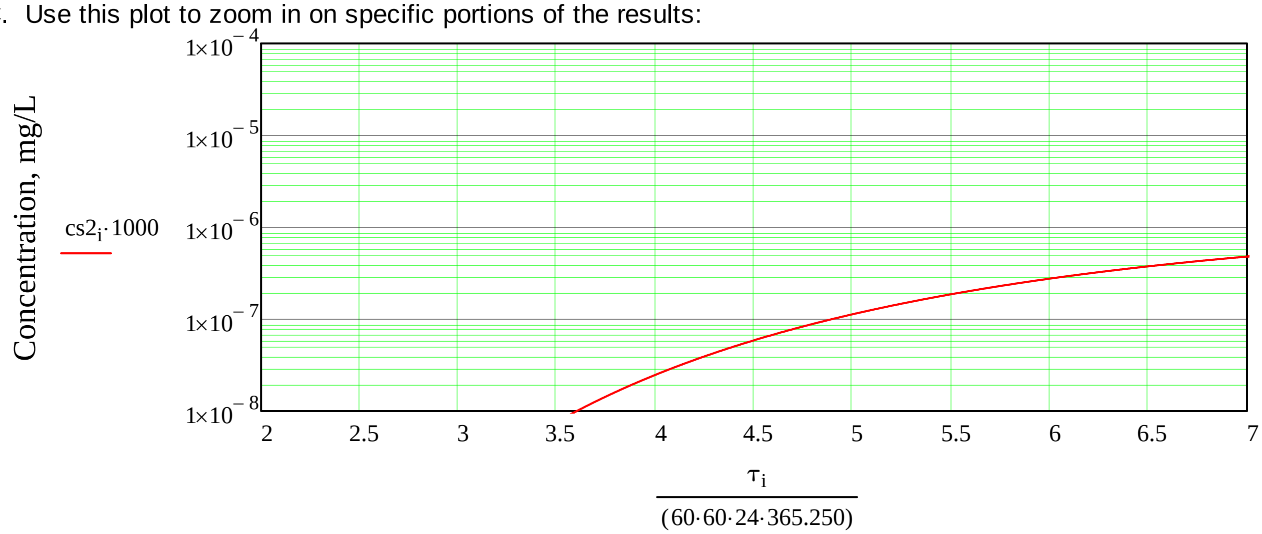
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

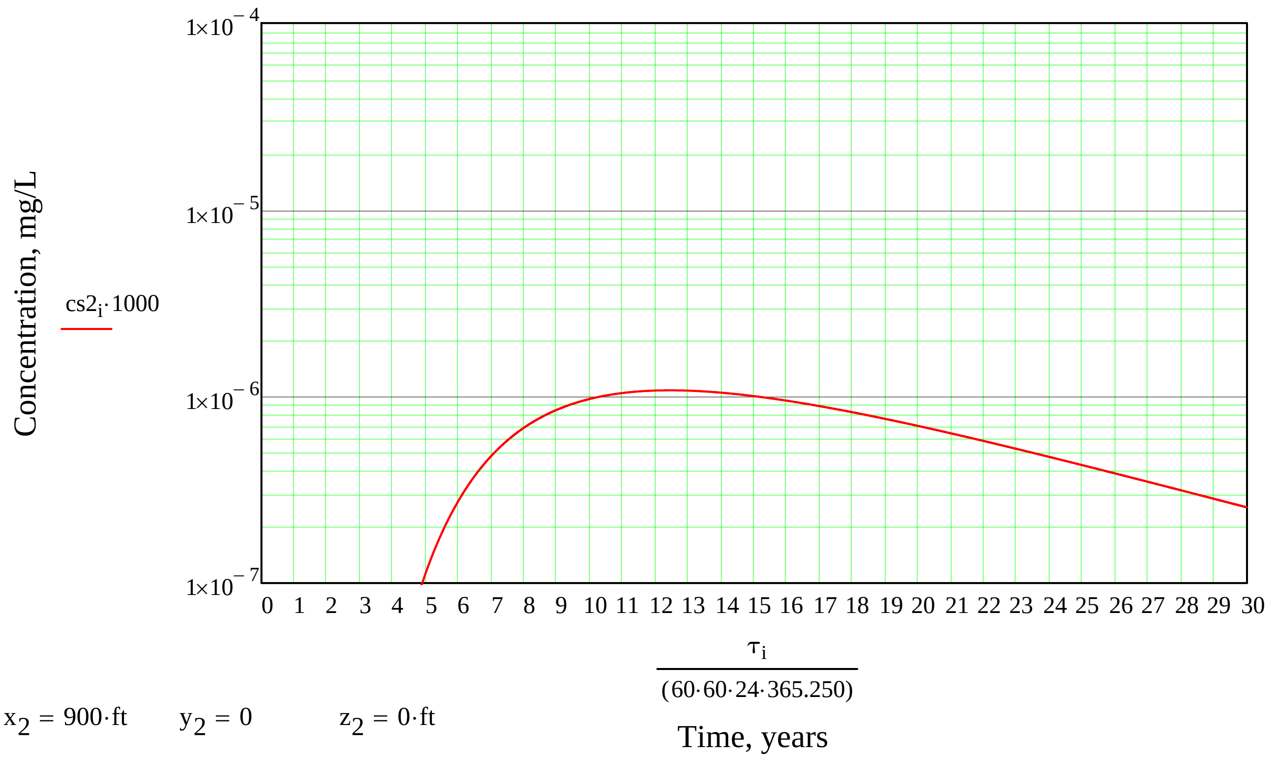


C. Use this plot to zoom in on specific portions of the results:



$x_2 = 900 \cdot ft$ $\quad y_2 = 0 \quad z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 900 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
Leakey Force Main on Northeast Corner of Cells 12 & 13. Flow is vertically down through Layer 1 (Common Borrow); then vertically through Layer 2 (Till); and thenhorizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor C.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Common Borrow	Native Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 6ft$	$x_2 := 20ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 12 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 2$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 279.053 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 0.194 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 0.213 \cdot \frac{ft}{day}$

$LQ := \frac{Q_1}{Area_1}$ $LQ = 1.737 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 0.213 \cdot \frac{ft}{day}$

LQ was Used to determine the value of a_3

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $i_2 = 2$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the northeast corner of Cell 13):

distance of interest (x): $x_3 := 900ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 24.869 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 6 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.06 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.06 \cdot ft$	Flow
$\alpha_{y\_1} := 0.1$		$\alpha_{y\_1} \cdot x_1 = 0.6 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.6 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.1$		$\alpha_{z\_1} \cdot x_1 = 0.6 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.6 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 20 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.2 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.2 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 2 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 2 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 2 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 2 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

These Calcs

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

Lateral dispersivity	$\alpha_{y\_BR} := \dfrac{20ft}{Y_3}$	$\alpha_{y\_BR} = 0.4$	Z axis
Downgradient dispersivity:	$\alpha_{x\_BR} := \dfrac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$	$\alpha_{x\_BR} = 1.2$	X axis
Vertical dispersivity	$\alpha_{z\_BR} := \dfrac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$	$\alpha_{z\_BR} = 0.02$	Y axis

3.1 Source Definition, to Layer 1 (Common Borrow Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.213 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 6 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.013 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.128 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.128 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

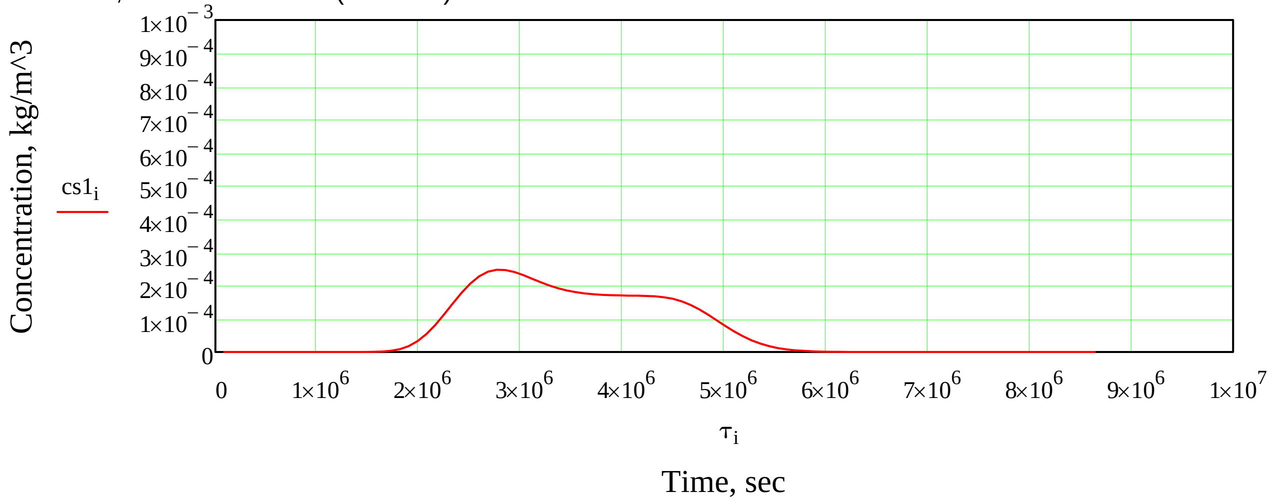
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\qquad\qquad$ $\tau_i := i\cdot day$

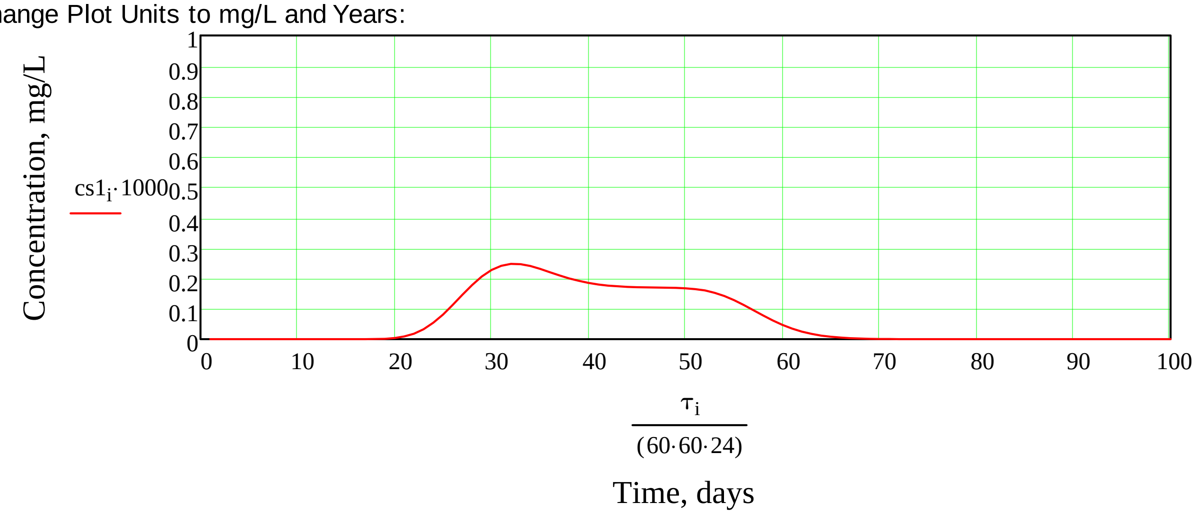
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

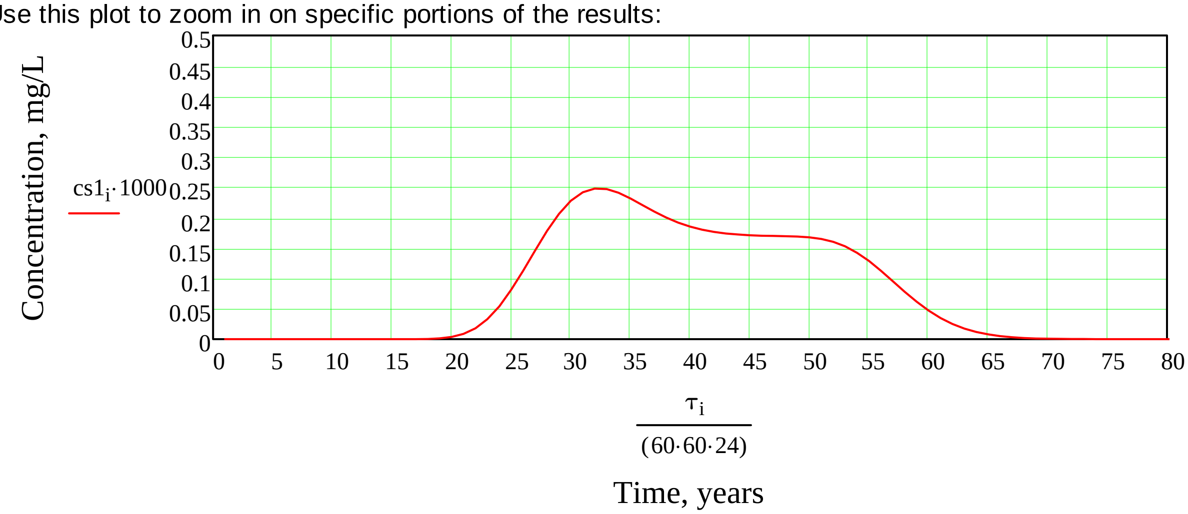
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 8$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0 \\ 0 \\ 0.25 \\ 0.25 \\ 0.18 \\ 0.18 \\ 0 \\ 0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 20 \\ 30 \\ 35 \\ 43 \\ 53 \\ 68 \\ 100 \end{pmatrix} day$$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 0.213 \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 20 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$

Lateal distance of interest (z): $z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 0.043 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.426 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.426 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

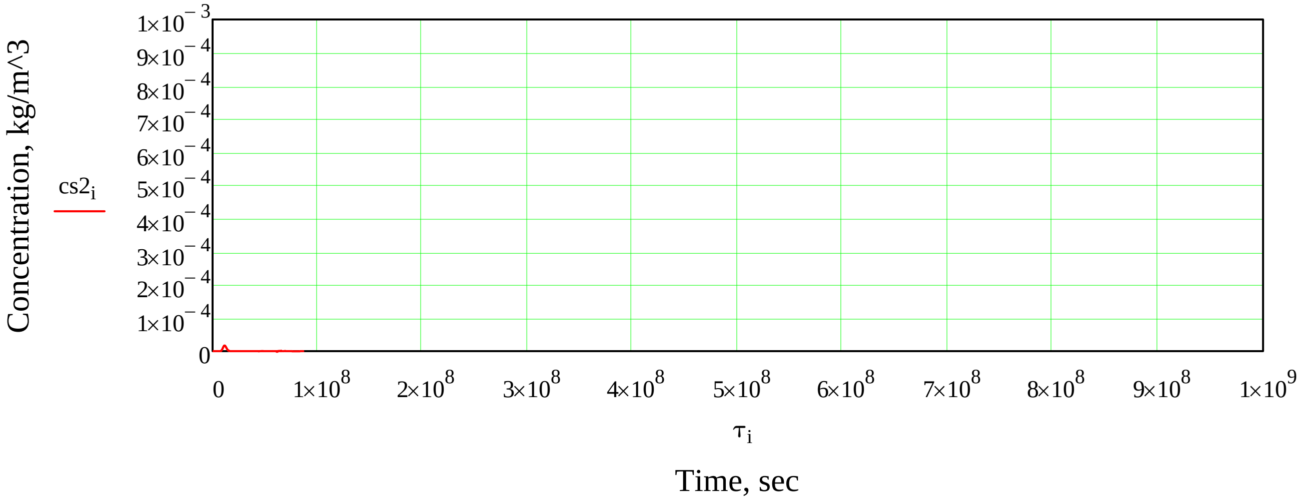
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1,2..1000$ $\qquad$ $\tau_i := i\cdot day$

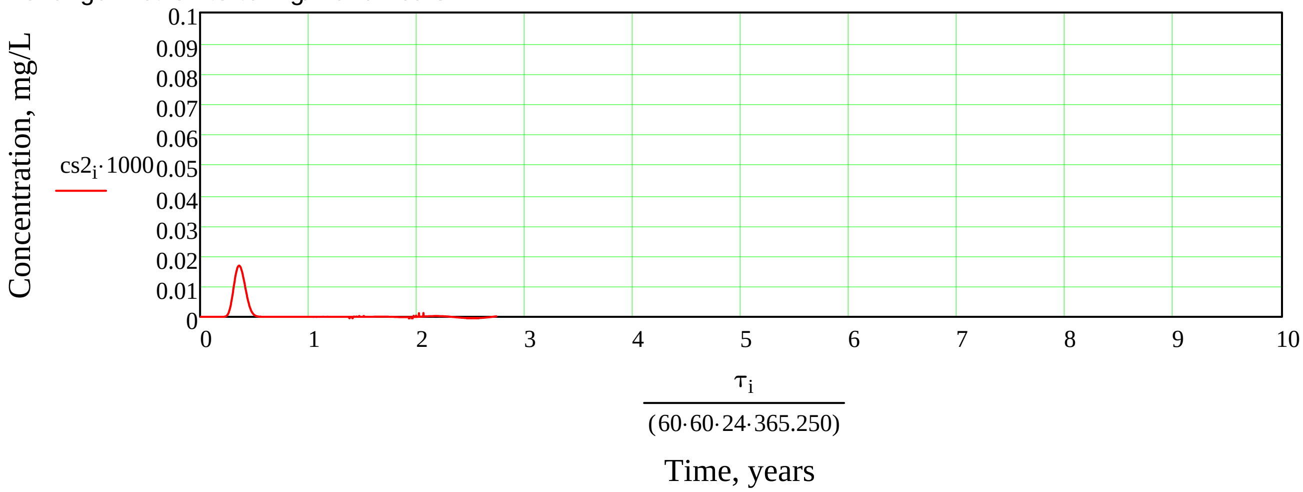
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

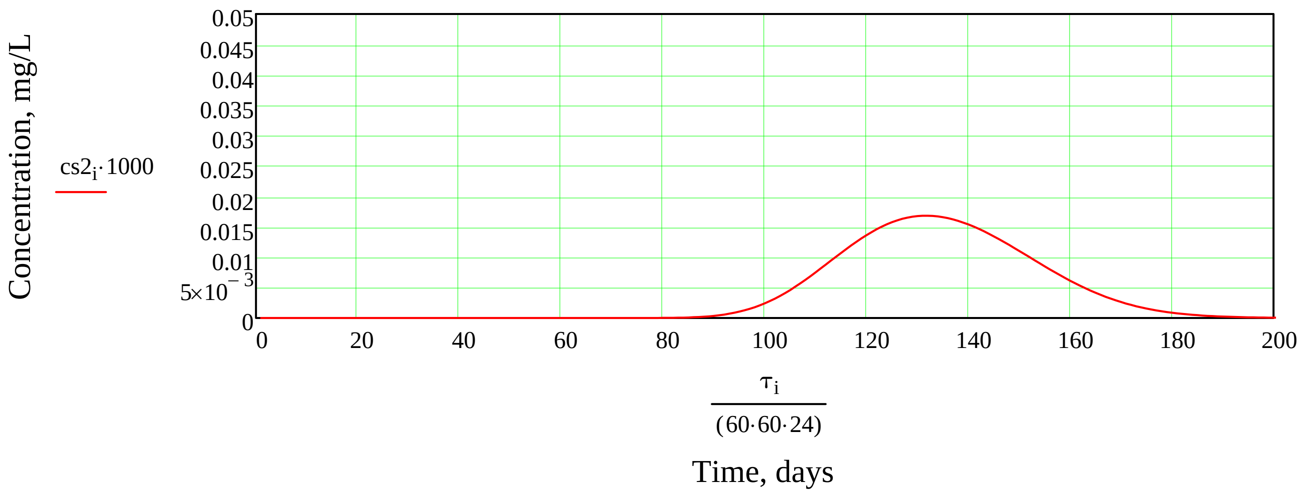
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l)   Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.02 \\ 0.02 \\ 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 90 \\ 120 \\ 140 \\ 190 \\ 1000 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Northeast-Southwest; Z is Southeast - Northwest; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 24.869 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 1.167 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 1.08 \times$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 1.08 \times 10^3 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 360 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 360 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 18 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 18 \cdot ft$ Lateral

Note: This was rotated to use correct orientation from Tracer Test.

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 5.4 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.8 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 90 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{v_3^{\;2}}{4\cdot Dx_3}\cdot t - \frac{x_3^{\;2}}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \operatorname{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \operatorname{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \operatorname{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \operatorname{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

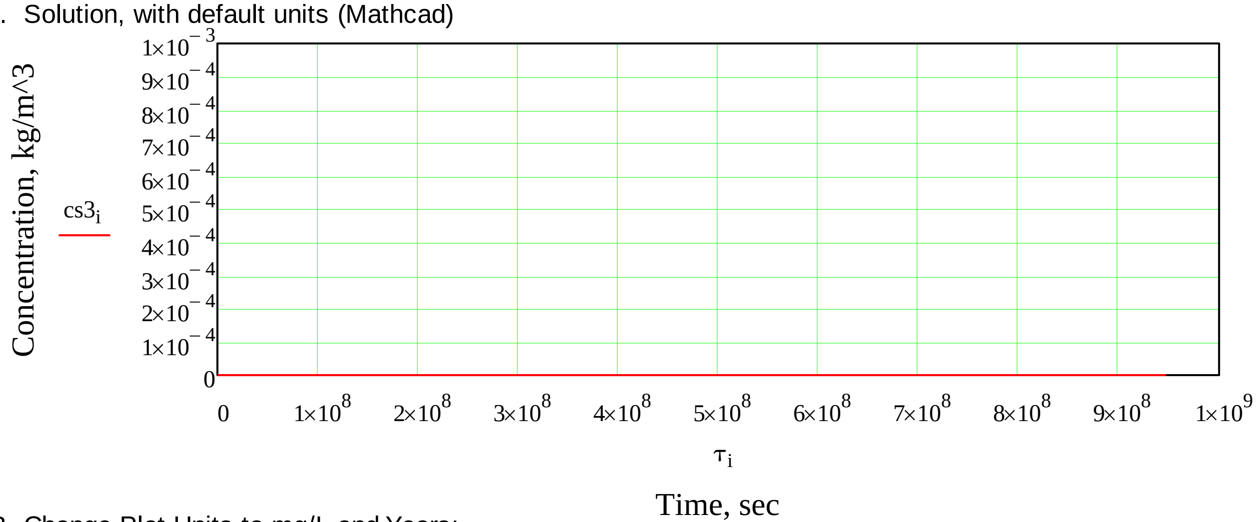
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

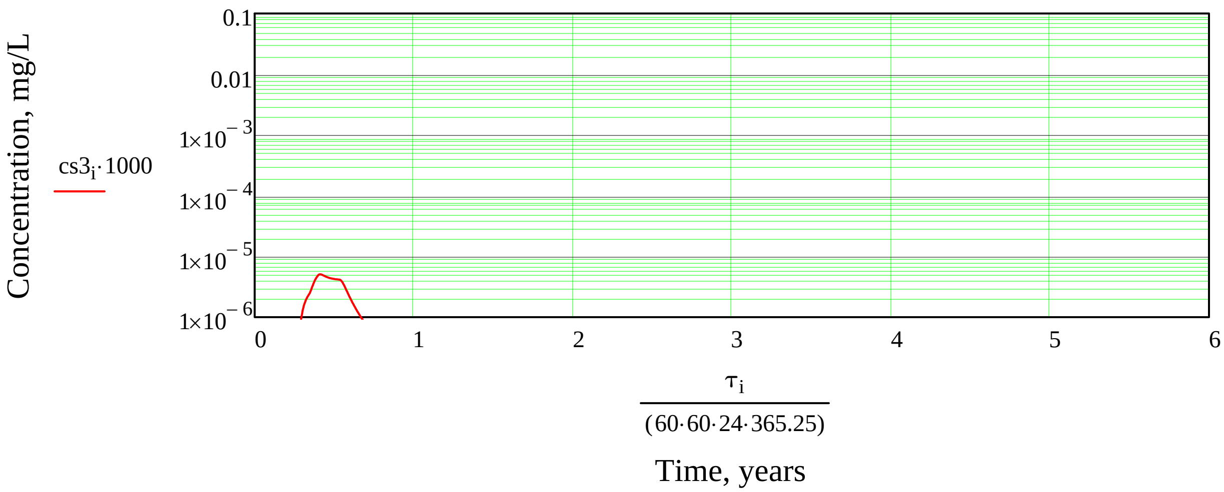
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

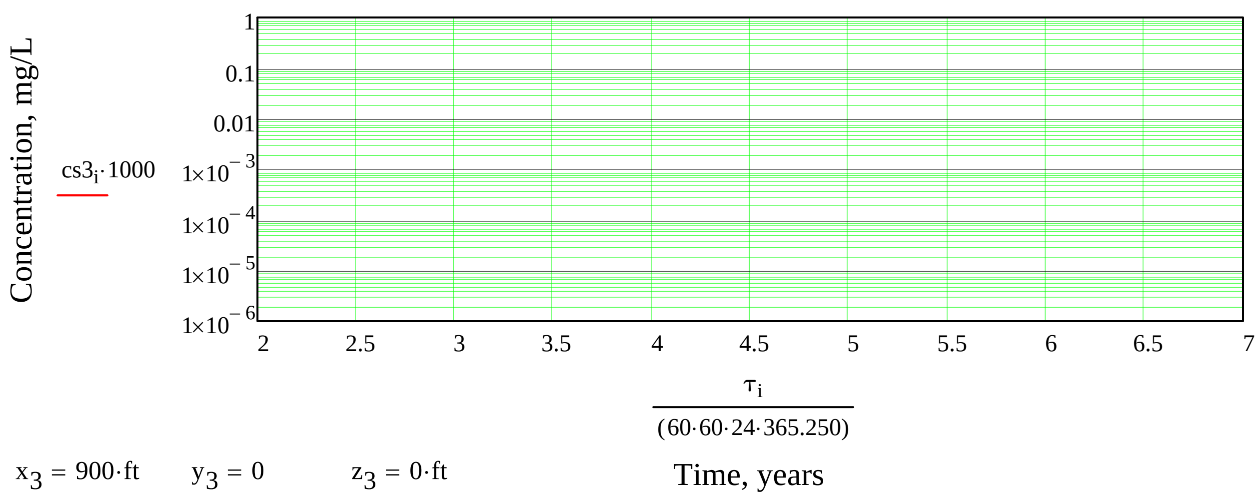
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

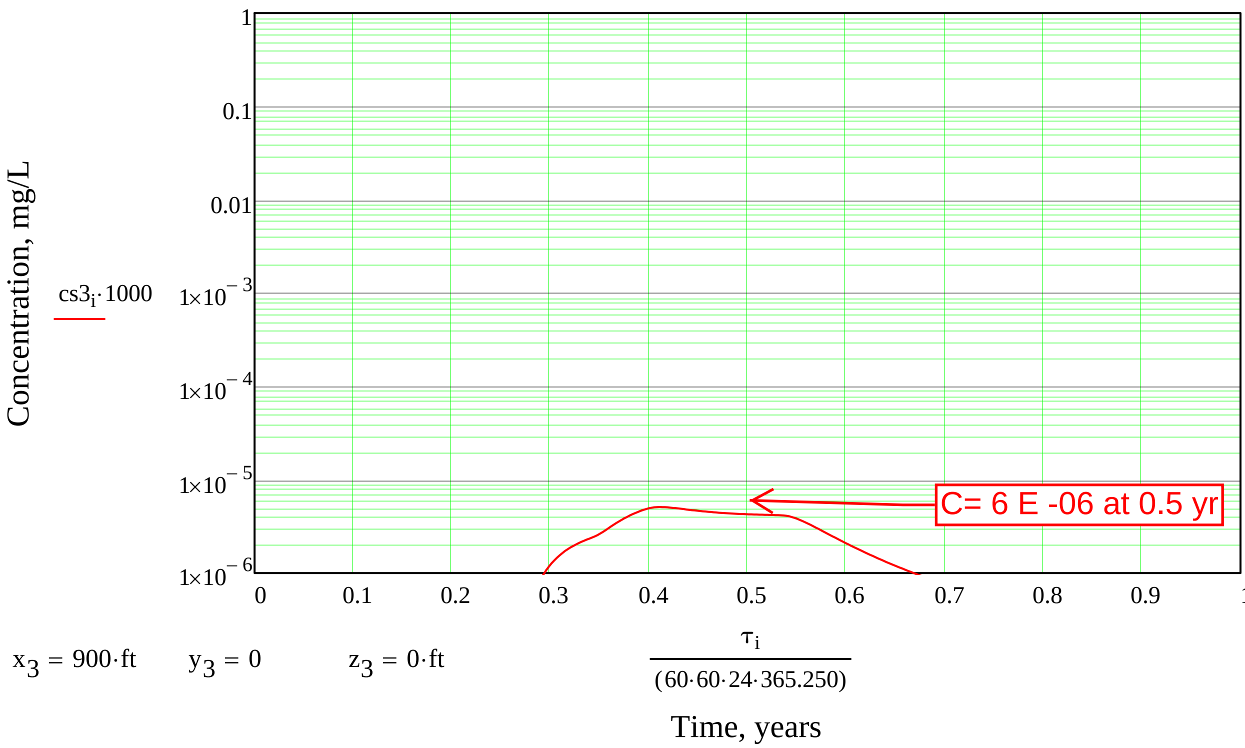


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot A shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 900 \cdot ft$ $y_3 = 0$ $z_3 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 900 \cdot ft$ $y_3 = 0$ $z_3 = 0 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on Northeast Corner of Cell 13. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor C.**
Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Common Borrow	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 0.1ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 6.1 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 61$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 8.511 \times 10^3 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 5.91 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 6.502 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 5.296 \times 10^5 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_12} := 201.95ft$ $\quad Head_C := 145ft$

$i_2 := \frac{(Head_{Cell\_12} + \Delta H_1) - Head_C}{700ft}$ $\quad i_2 = 0.09$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 9.6 \times 10^{-3} \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $\quad V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $\quad v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.938$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe at Northeast corner of Cell 13):

distance of interest (x): $\quad x_2 := 750ft$ $\quad$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $\quad y_2 := 0ft$ $\quad$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $\quad z_2 := 0ft$ $\quad$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 151.703 \cdot ft$ $\quad$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 0.1 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 1 \times 10^{-3} \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 1 \times 10^{-3} \cdot ft$	Flow
$\alpha_{y\_1} := 0.1$		$\alpha_{y\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.01 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.1$		$\alpha_{z\_1} \cdot x_1 = 0.01 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.01 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 750 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 112.5 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 112.5 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 7.5 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 7.5 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 7.5 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 7.5 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$$

Since there is no common borrow, the leak freely enters The till and travels toward Receptor D.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 6.502 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 0.1 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 6.502 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.065 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.065 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

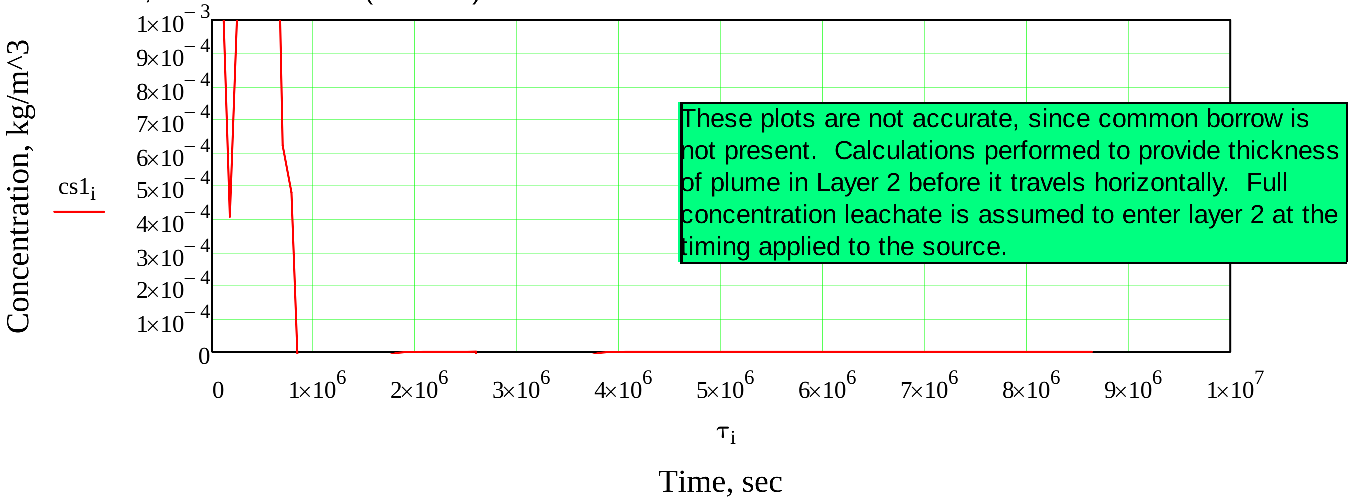
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\qquad\qquad$ $\tau_i := i\cdot day$

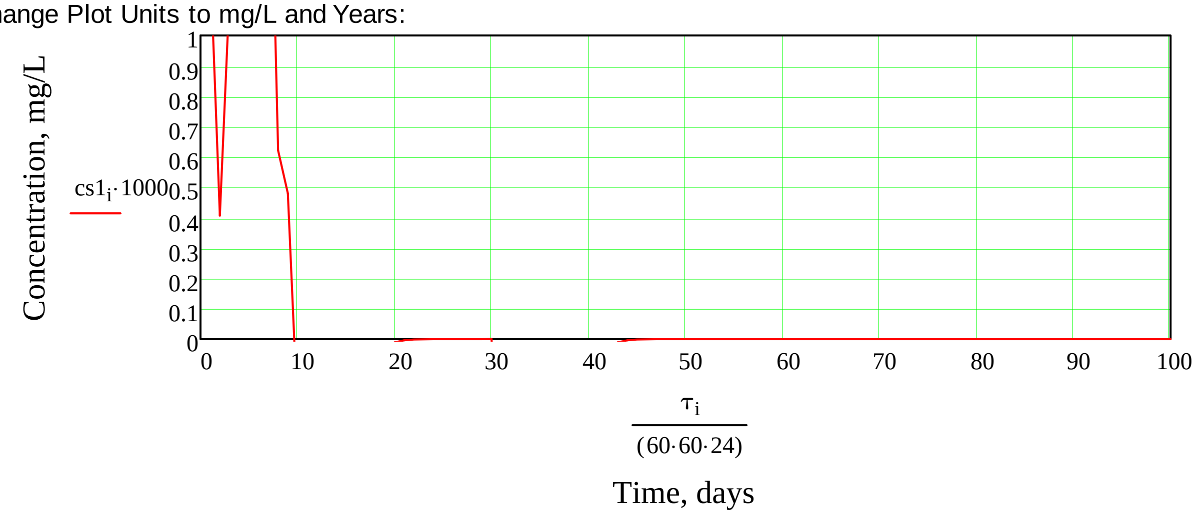
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

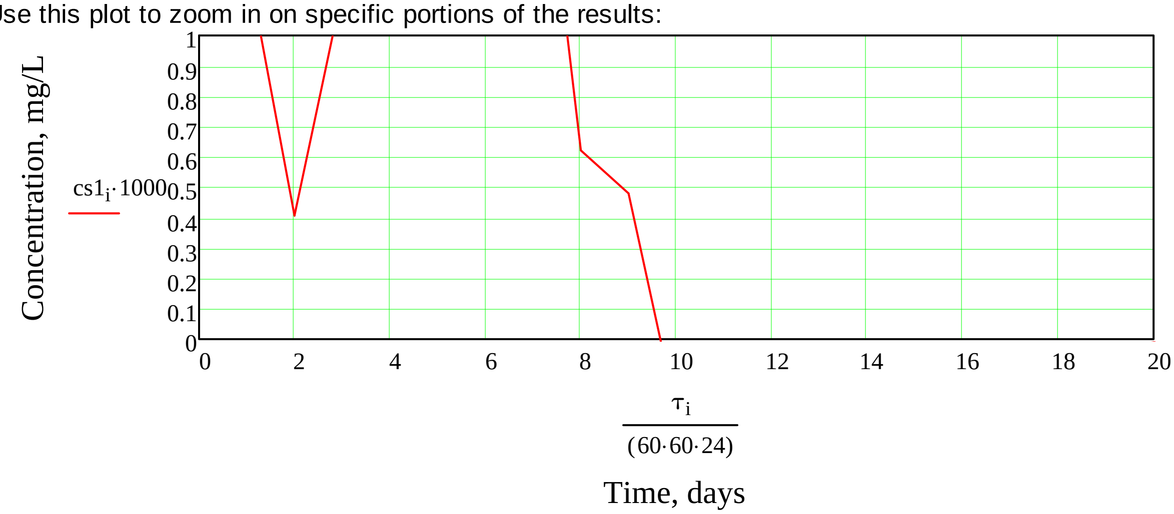
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years. Assuming No Common Borrow

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 151.703 \cdot ft$

Half-width of Source in Z-direction $b_2 := b_1 \qquad b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 112.5 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 112.5 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 7.5 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 7.5 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 7.5 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 7.5 \cdot ft$ Lateral

Note: This was rotated to use correct orientation from Tracer Test.

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 11.25 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.75 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.75 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot \exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

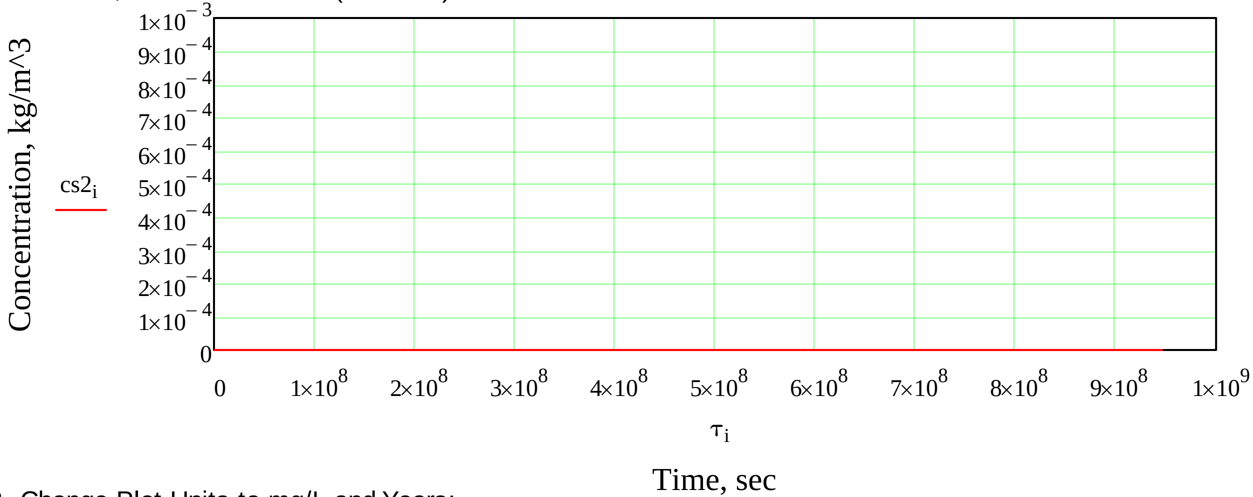
$i := 1,2 .. 10950$ $\qquad \tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{day}$$

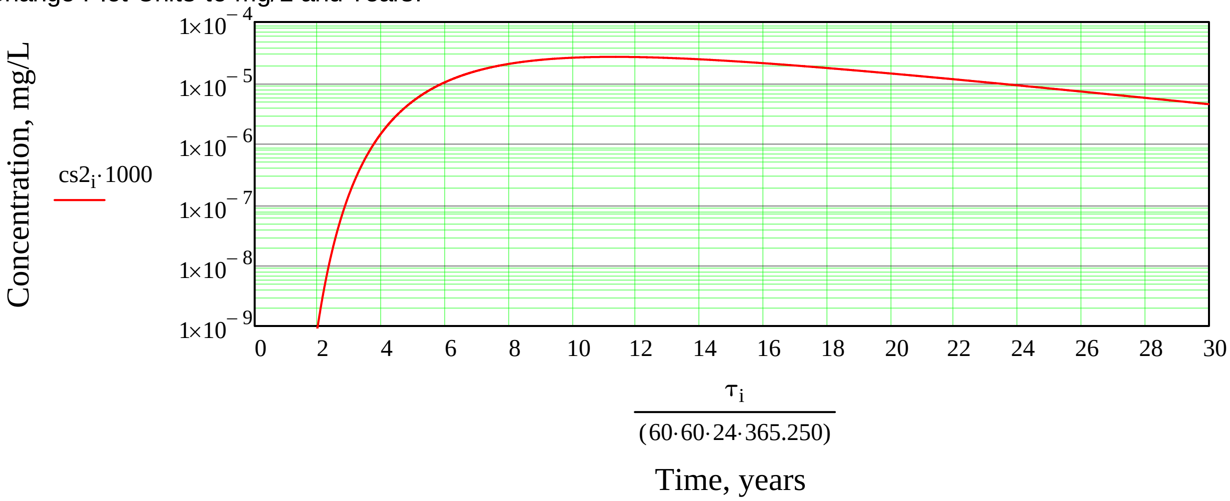
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

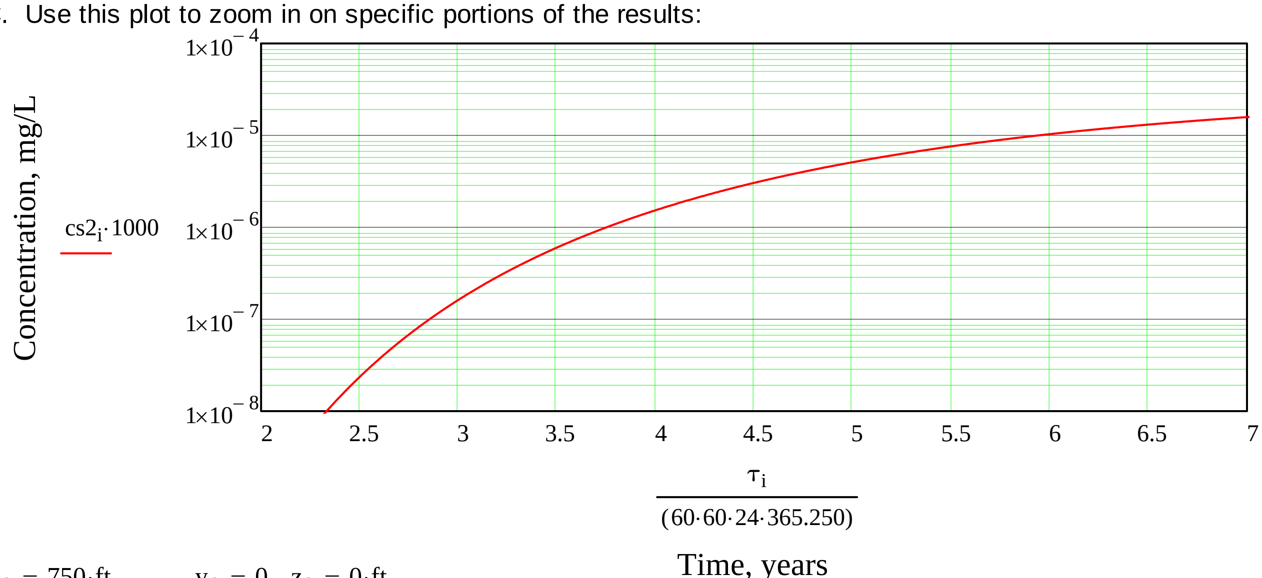
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

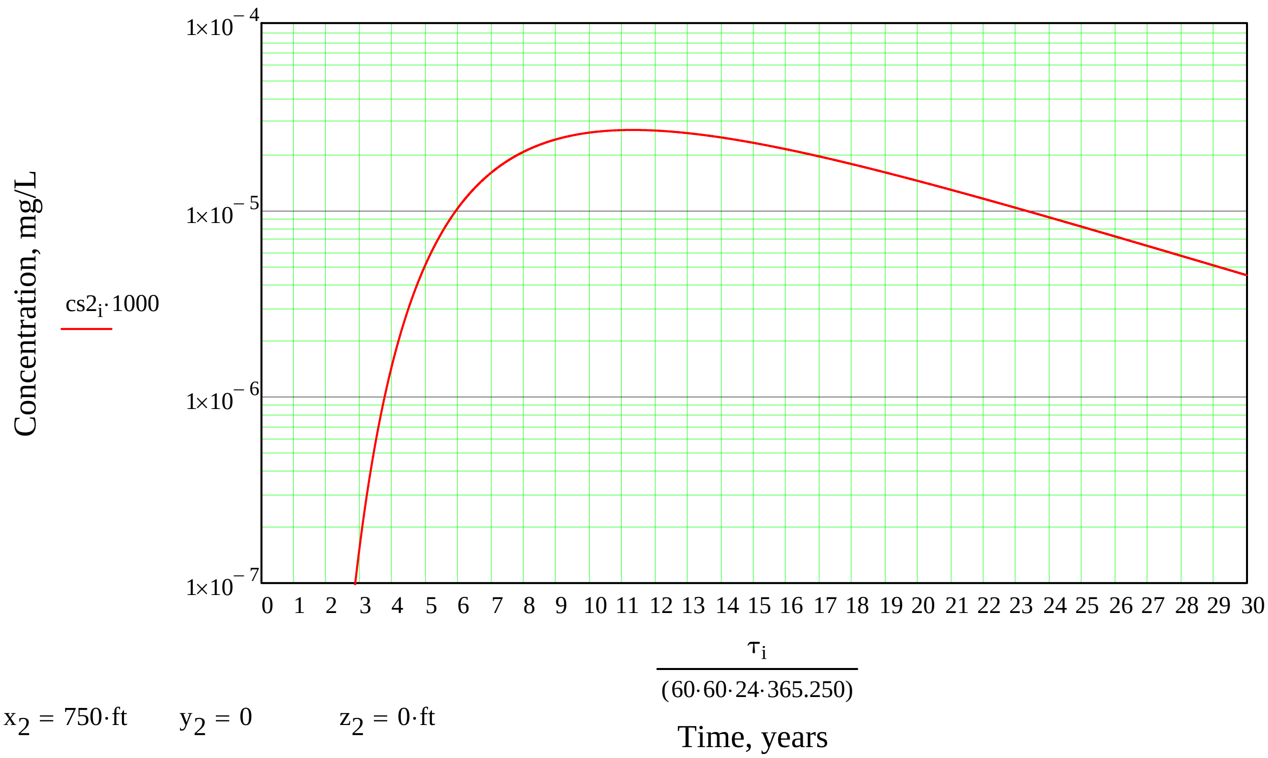


C. Use this plot to zoom in on specific portions of the results:



$x_2 = 750 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 750 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on West Side of Cell 14. No Common borrow is present above the till. Flow is vertically down through Layer 1 (Till); then horizontally through Layer 2 (Bedrock). **Flow is toward Site Sensitive Receptor D.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\qquad Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Native Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.001$
Distance in flow direction (x)	$x_1 := 15ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\qquad \Delta H_1 := x_1 + H_1$ $\qquad \Delta H_1 = 21 \cdot ft$

Hydraulic gradient (i) $\qquad i_1 := \frac{\Delta H_1}{x_1}$ $\qquad i_1 = 1.4$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 195.337 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.136 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.149 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 1.216 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Bedrock based on groundwater contours, from Fig 5-1:

$Head_{Cell\_14} := 201.34ft$ $\quad Head_D := 149ft$

$i_2 := \frac{(Head_{Cell\_14} + \Delta H_1) - Head_D}{750ft}$ $\quad i_2 = 0.098$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 9.702 \cdot \frac{ft}{day}$

JES has velocity = 5 ft/day as determined in the Bedrock Tracer Test

Velocity in the Bedrock used in this calculation: $v_2 := 10 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.101$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe at West side of Cell 14):

distance of interest (x): $x_2 := 750ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 8.704 \cdot ft$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Till)

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 15 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.15 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.15 \cdot ft$	Flow
$\alpha_{y\_1} := 0.1$		$\alpha_{y\_1} \cdot x_1 = 1.5 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 1.5 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.1$		$\alpha_{z\_1} \cdot x_1 = 1.5 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 1.5 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Bedrock):

					Direction
$\alpha_{x\_2} := 1.2$	$x_2 = 750 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 900 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 900 \cdot ft$	Flow
$\alpha_{y\_2} := 0.4$		$\alpha_{y\_2} \cdot x_2 = 300 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 300 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.02$		$\alpha_{z\_2} \cdot x_2 = 15 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 15 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$$

Since there is no common borrow, the leak freely enters The till and travels toward Receptor D.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.149 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 15 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.022 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.224 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.224 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

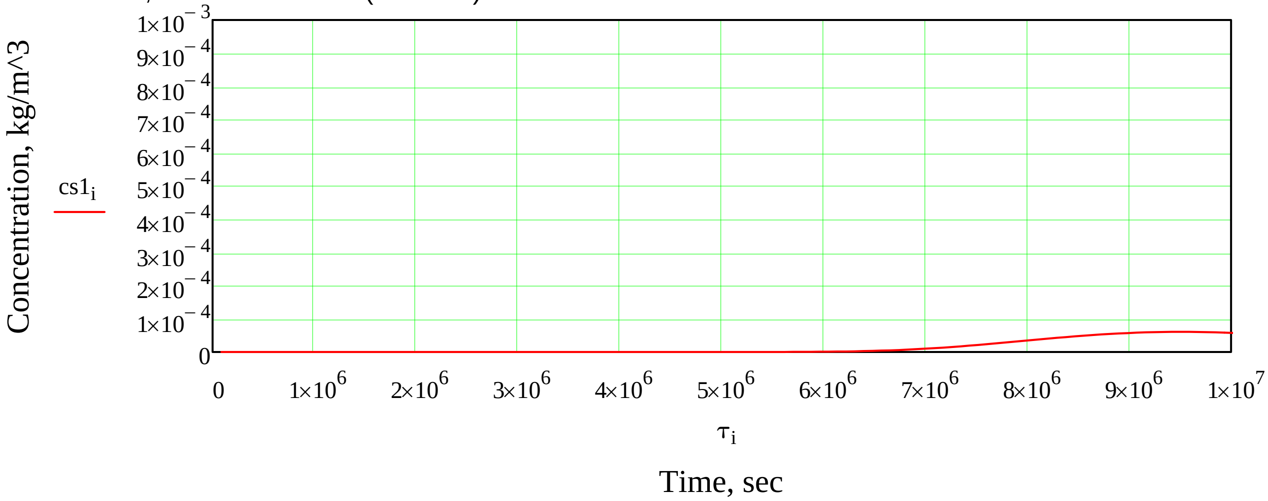
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1, 2 .. 1000$ $\qquad\qquad$ $\tau_i := i\cdot day$

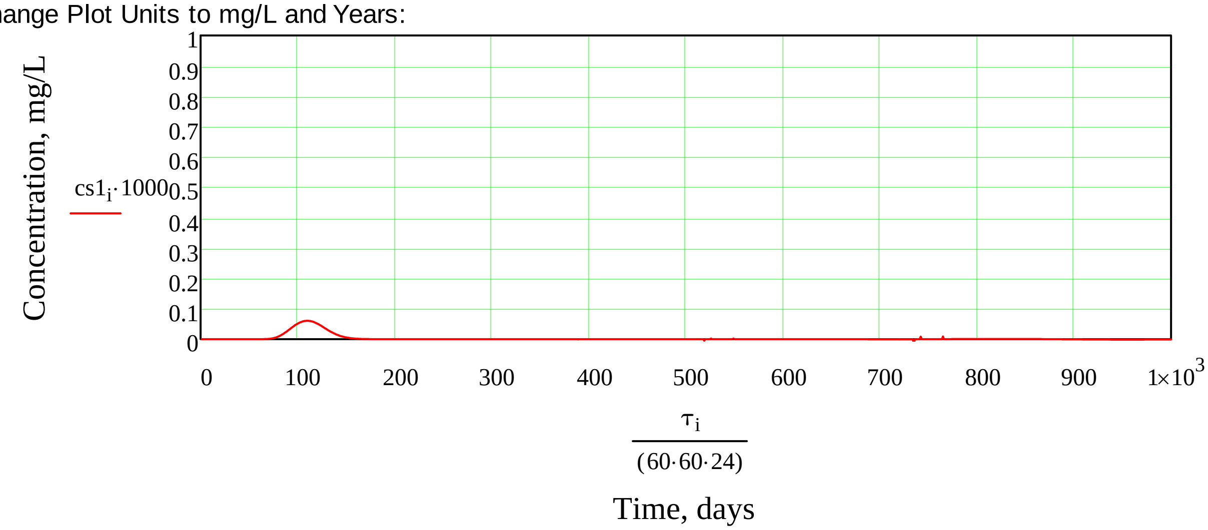
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1(x_1,y_1,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1(x_1,y_1,|\tau_i - ti_n|)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

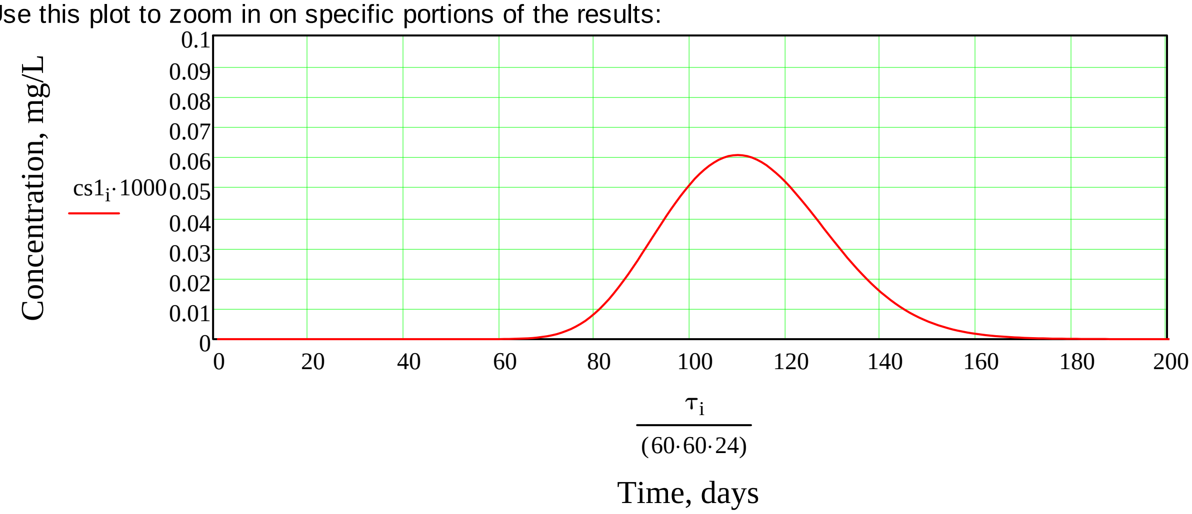
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.06 \\ 0.06 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 60 \\ 70 \\ 100 \\ 120 \\ 170 \\ 1000 \end{pmatrix} day$$

B. Input parameters (Layer 2):

This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 8.704 \cdot ft$

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 1.2$ $\alpha_{x\_2} \cdot x_2 = 900 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 900 \cdot ft$ Flow

$\alpha_{y\_2} = 0.4$ $\alpha_{y\_2} \cdot x_2 = 300 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 300 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.02$ $\alpha_{z\_2} \cdot x_2 = 15 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 15 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 9 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 3 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 150 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \text{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \text{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \text{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \text{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

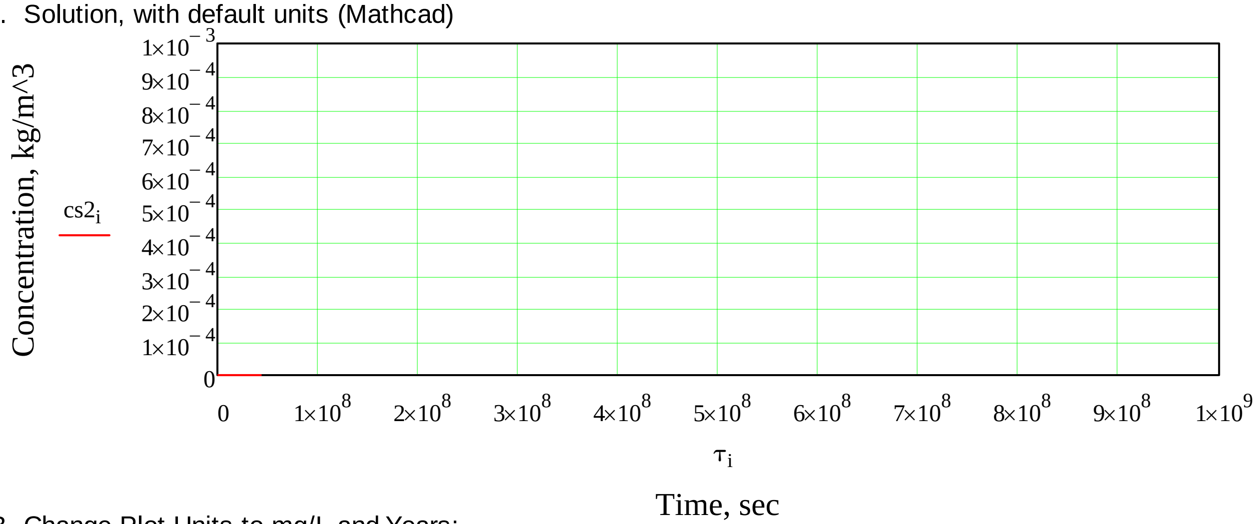
$i := 1, 2 .. 500$ $\tau_i := i\cdot day$

$$v_2 = 10\cdot\frac{ft}{day}$$

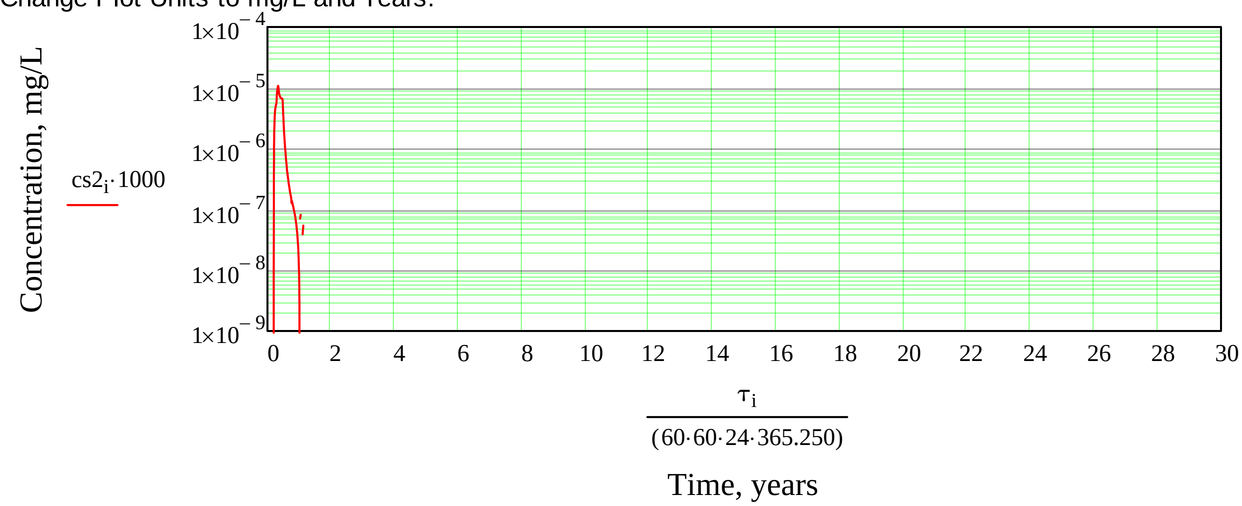
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

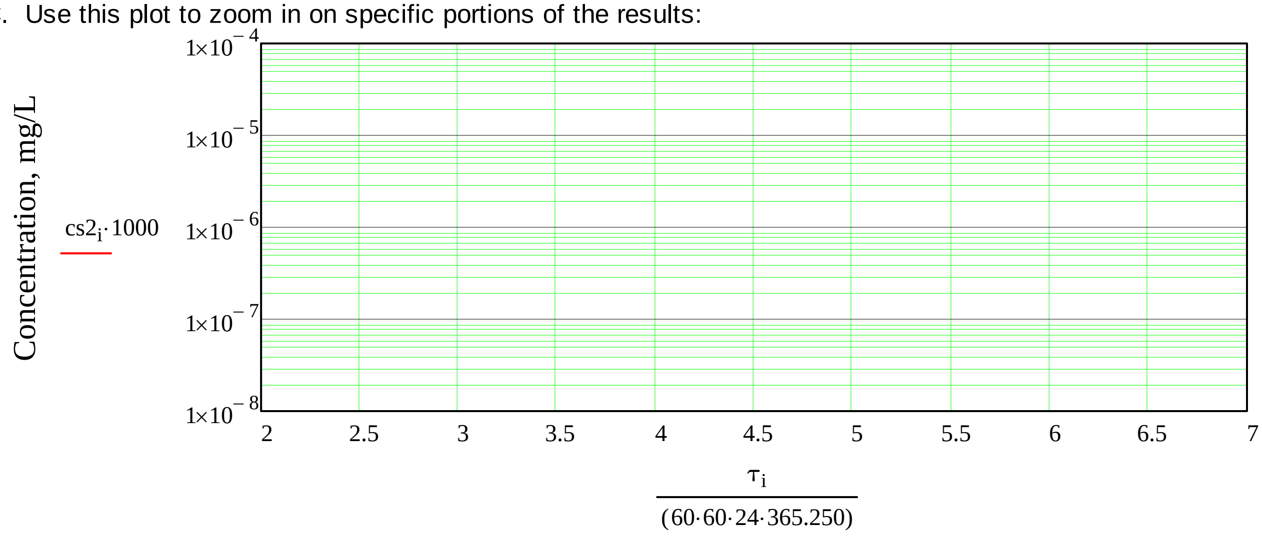
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

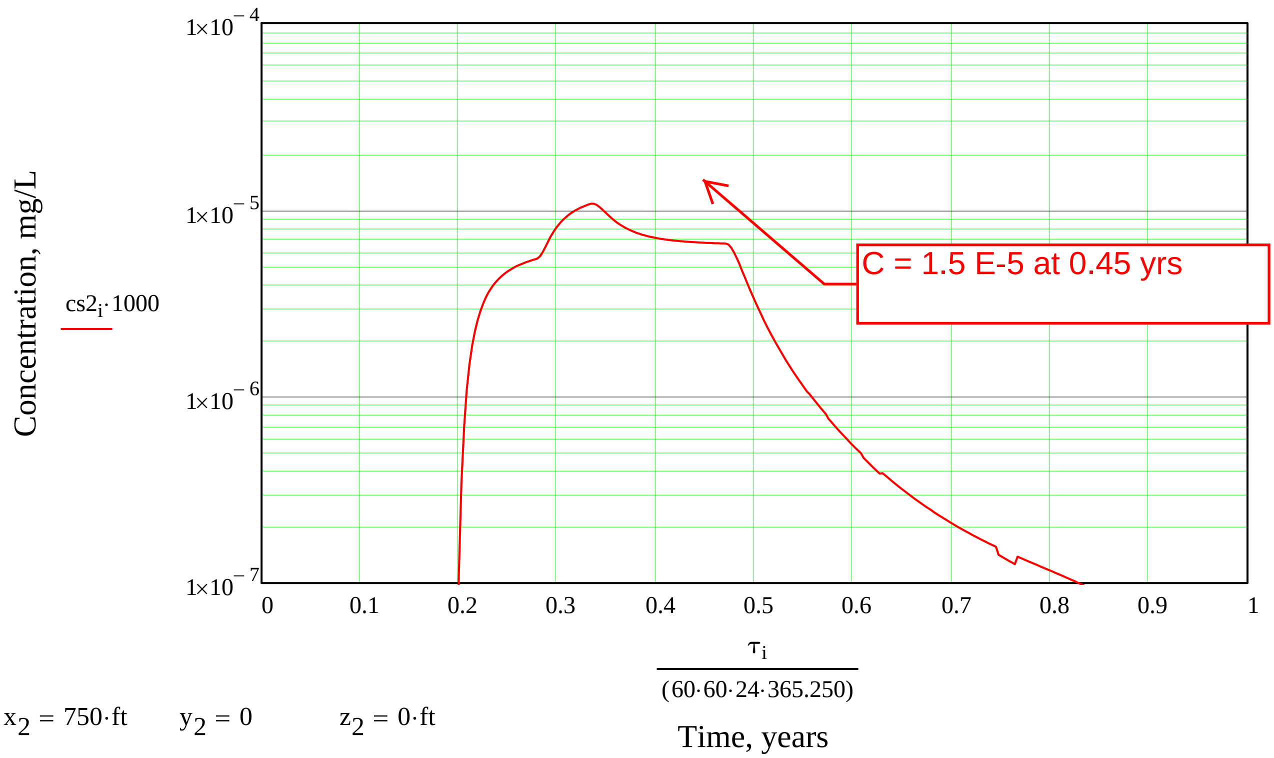


C. Use this plot to zoom in on specific portions of the results:



$x_2 = 750 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 750 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on West Side of Cell 14. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor E.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\qquad Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2
	Common Borrow	Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 5ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\qquad \Delta H_1 := x_1 + H_1$ $\qquad \Delta H_1 = 11 \cdot ft$

Hydraulic gradient (i) $\qquad i_1 := \frac{\Delta H_1}{x_1}$ $\qquad i_1 = 2.2$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 306.958 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.213 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.234 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 1.91 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_14} := 200.6ft$ $\quad Head_E := 72ft$

$i_2 := \frac{(Head_{Cell\_14} + \Delta H_1) - Head_E}{700ft}$ $\quad i_2 = 0.199$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 0.021 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.938$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe West of Cell 14):

distance of interest (x): $x_2 := 440ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 5.471 \cdot ft$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 5 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.05 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.05 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.05 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.05 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.05 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.05 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 440 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 66 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 66 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 4.4 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 4.4 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.234 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 5 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.012 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.012 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.012 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

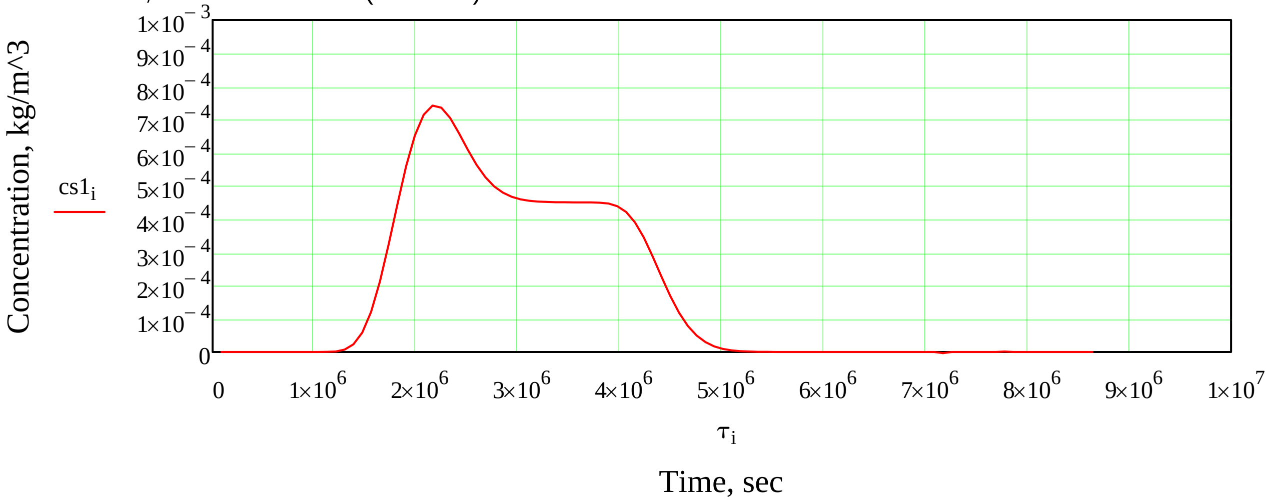
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\qquad\qquad$ $\tau_i := i\cdot day$

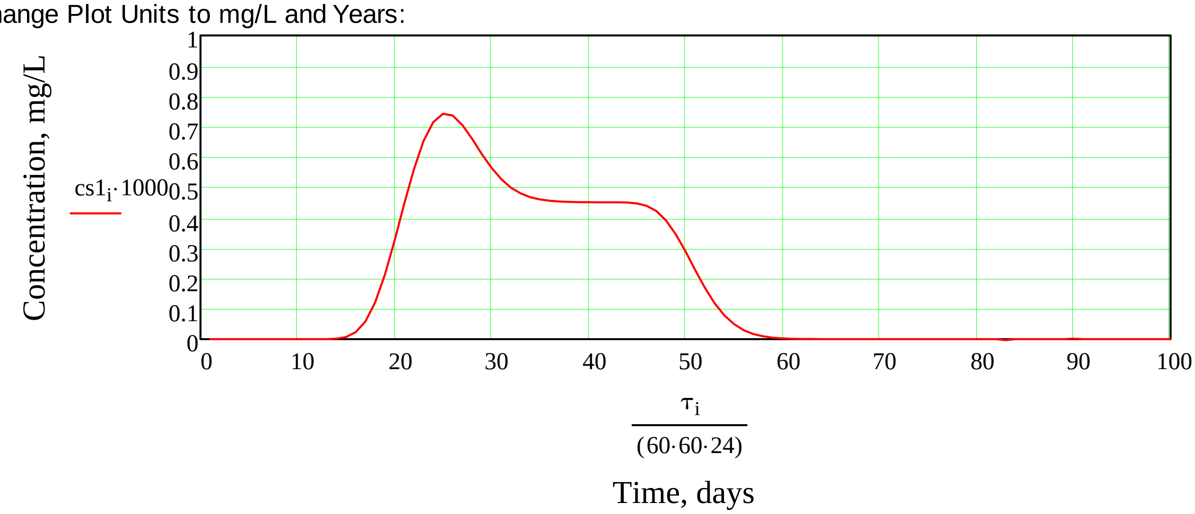
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

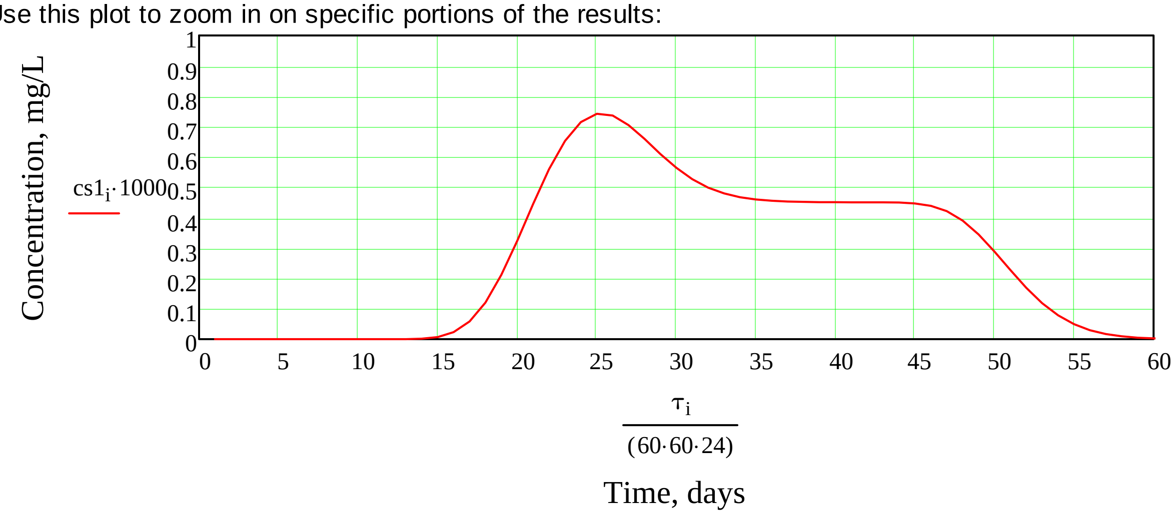
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.75 \\ 0.75 \\ 0.45 \\ 0.45 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 15 \\ 23 \\ 27 \\ 35 \\ 48 \\ 60 \end{pmatrix} day$$

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 5.471 \cdot ft$ **Exceeds till thickness**

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 66 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 66 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 4.4 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 4.4 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 4.4 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 4.4 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 6.6 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.44 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.44 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

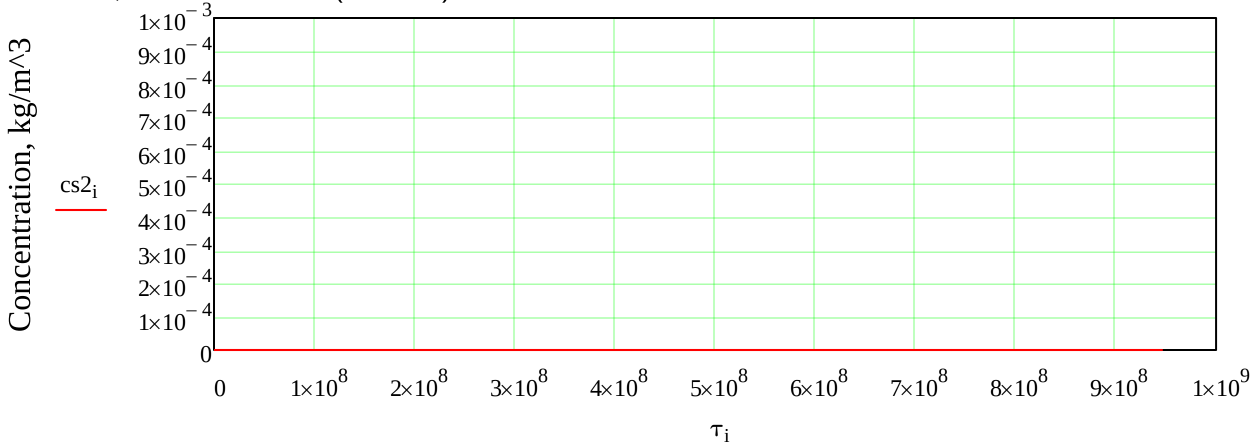
$i := 1,2..10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

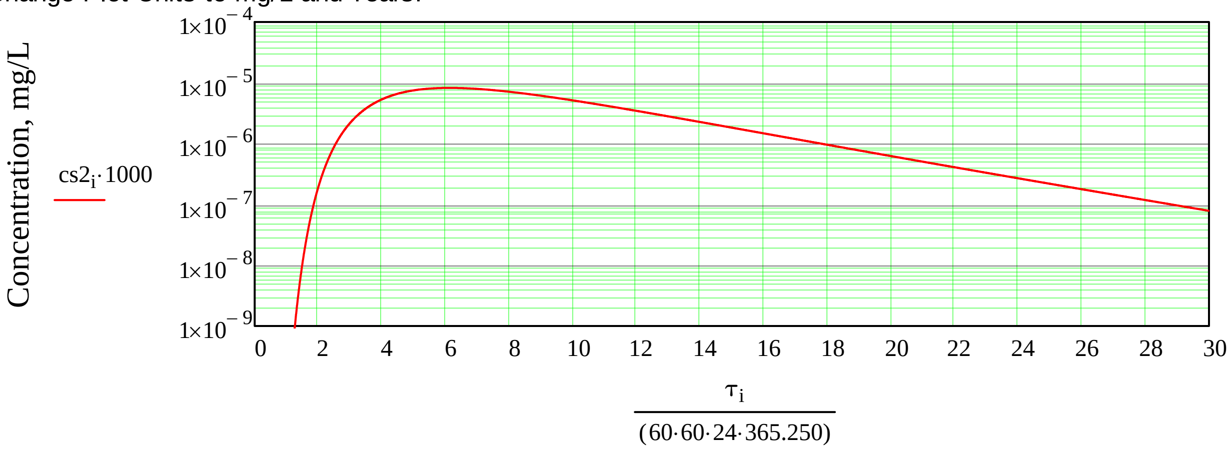
5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

A. Solution, with default units (Mathcad)



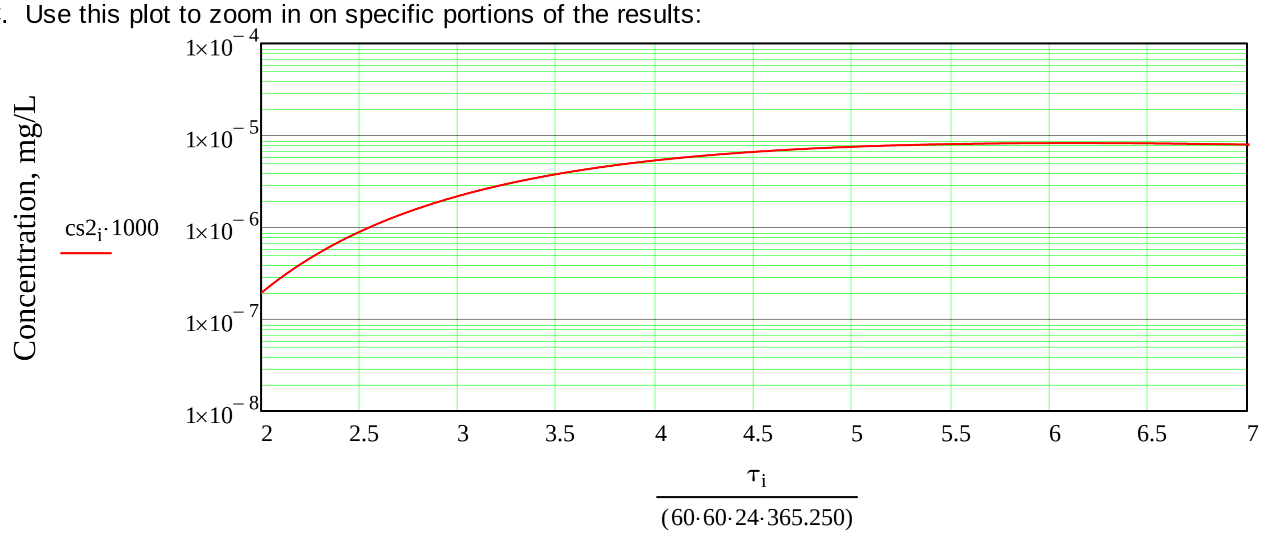
Time, sec

B. Change Plot Units to mg/L and Years:



Time, years

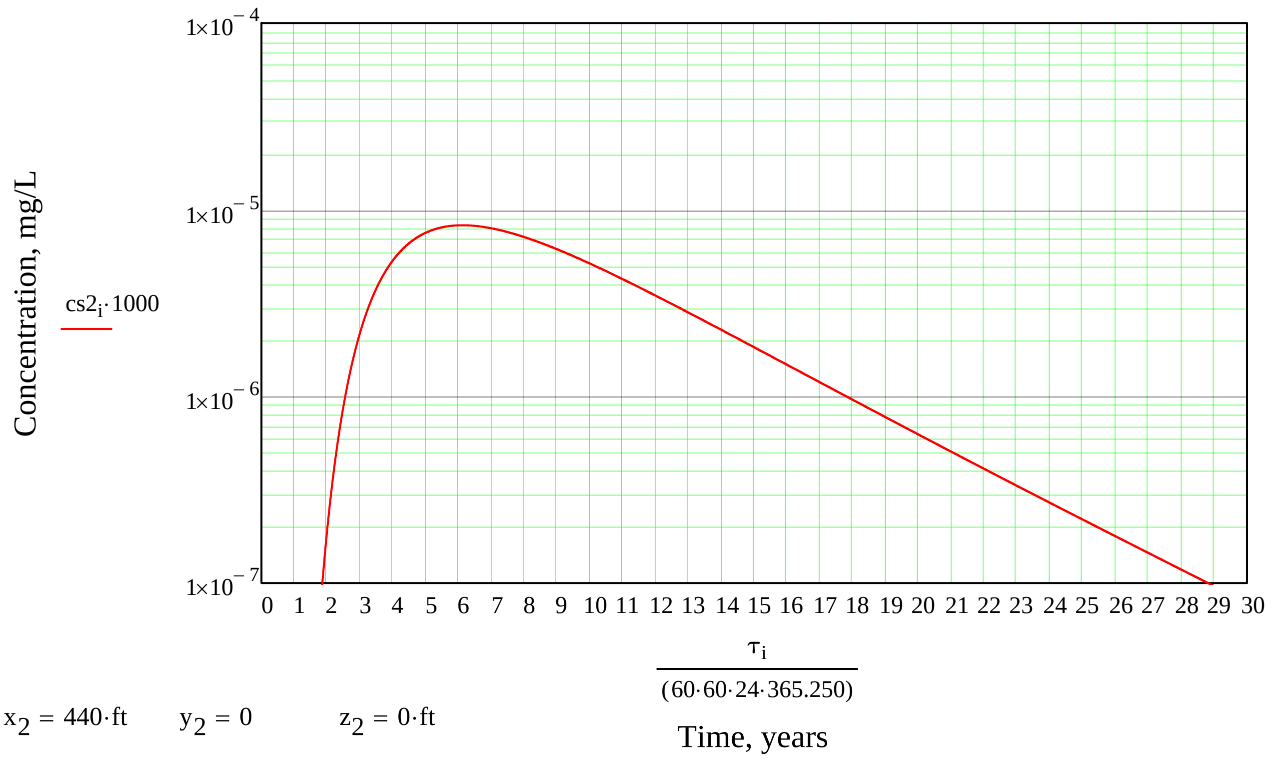
C. Use this plot to zoom in on specific portions of the results:



Time, years

$x_2 = 440 \cdot ft$ $\quad y_2 = 0 \quad z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 440 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
Leakey Force Main on West Corner of Cell 14. Flow is vertically down through Layer 1 (Common Borrow); then vertically through Layer 2 (Till); and thenhorizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor E.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Common Borrow	Native Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 6ft$	$x_2 := 20ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 12 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 2$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 279.053 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 0.194 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 0.213 \cdot \frac{ft}{day}$

$LQ := \frac{Q_1}{Area_1}$ $LQ = 1.737 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 0.213 \cdot \frac{ft}{day}$

LQ was Used to determine the value of a_3

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $i_2 = 2$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the west side of Cell 14):

distance of interest (x): $x_3 := 900ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 24.869 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 6 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.06 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.06 \cdot ft$	Flow
$\alpha_{y\_1} := 0.1$		$\alpha_{y\_1} \cdot x_1 = 0.6 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.6 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.1$		$\alpha_{z\_1} \cdot x_1 = 0.6 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.6 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 20 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.2 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.2 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 2 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 2 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 2 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 2 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

These Calcs

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$

Lateral dispersivity $\alpha_{y\_BR} := \dfrac{20ft}{Y_3}$ $\alpha_{y\_BR} = 0.4$ Z axis

Downgradient dispersivity: $\alpha_{x\_BR} := \dfrac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$ $\alpha_{x\_BR} = 1.2$ X axis

Vertical dispersivity $\alpha_{z\_BR} := \dfrac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$ $\alpha_{z\_BR} = 0.02$ Y axis

3.1 Source Definition, to Layer 1 (Common Borrow Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.213 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 6 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.013 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.128 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.128 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

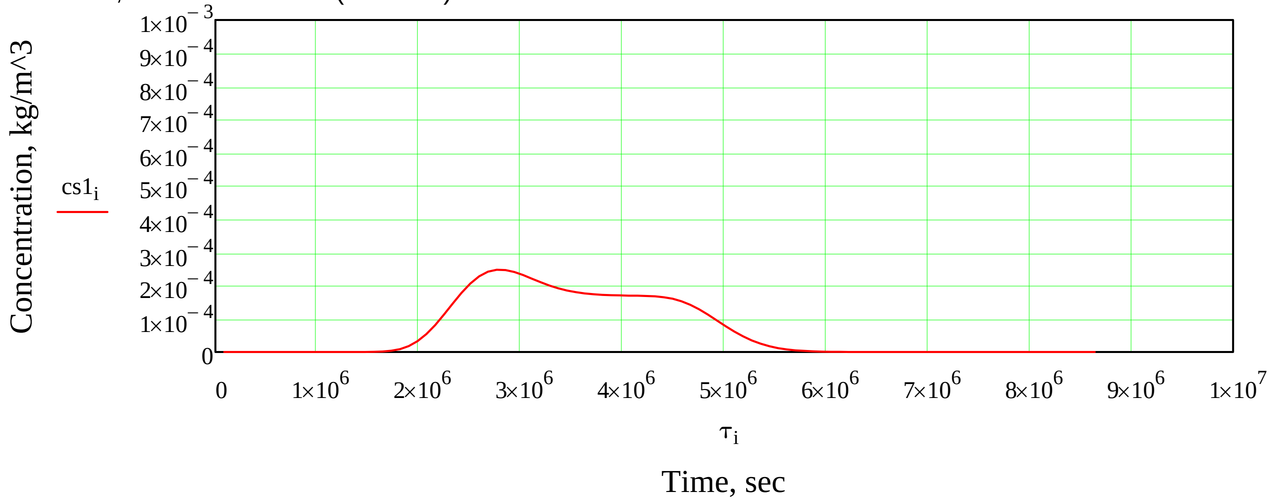
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\qquad\qquad$ $\tau_i := i\cdot day$

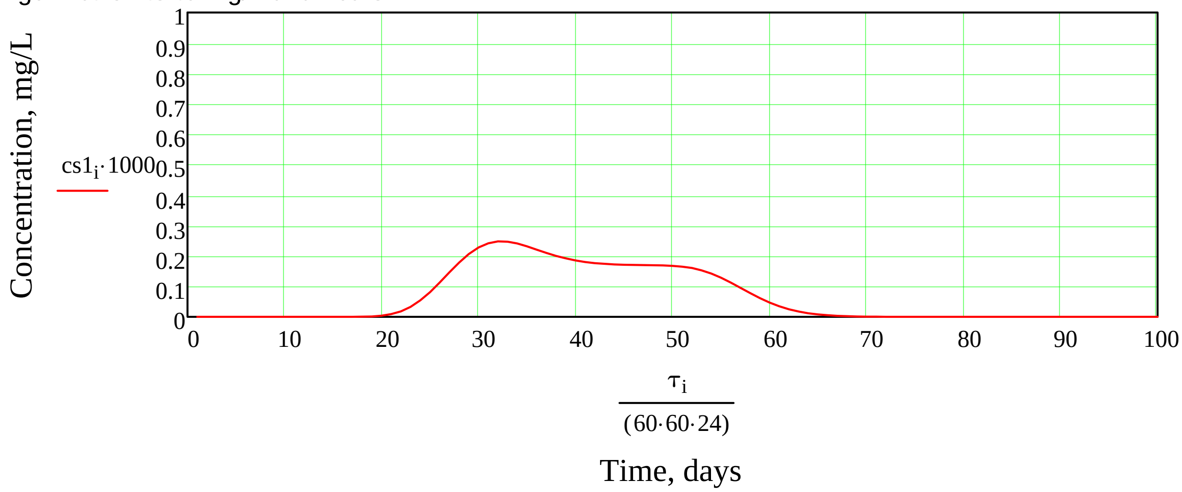
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

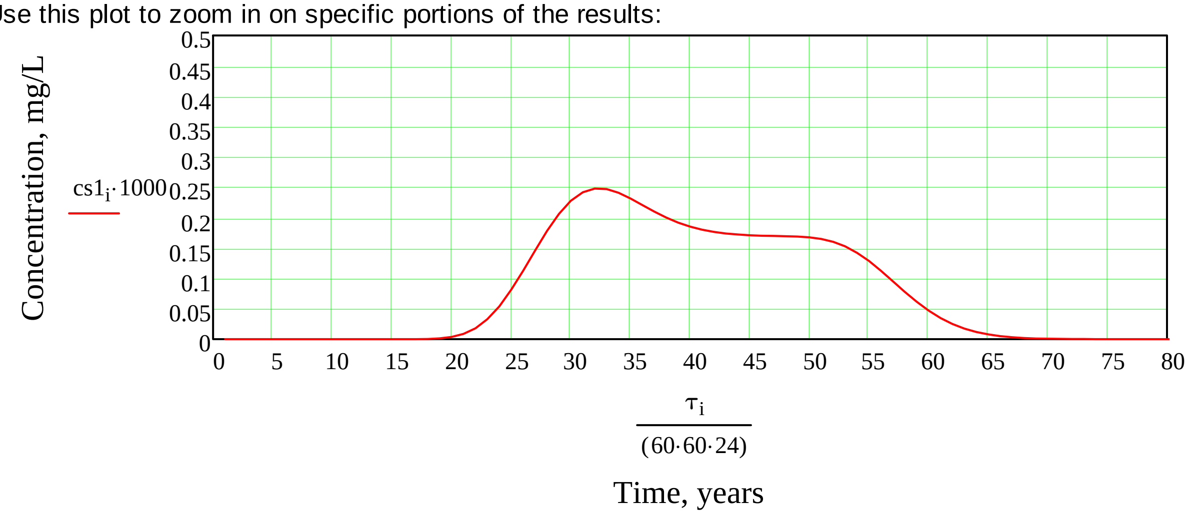
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 8$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0 \\ 0 \\ 0.25 \\ 0.25 \\ 0.18 \\ 0.18 \\ 0 \\ 0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 20 \\ 30 \\ 35 \\ 43 \\ 53 \\ 68 \\ 100 \end{pmatrix} day$$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 0.213 \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 20 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$

Lateal distance of interest (z): $z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 0.043 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.426 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.426 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

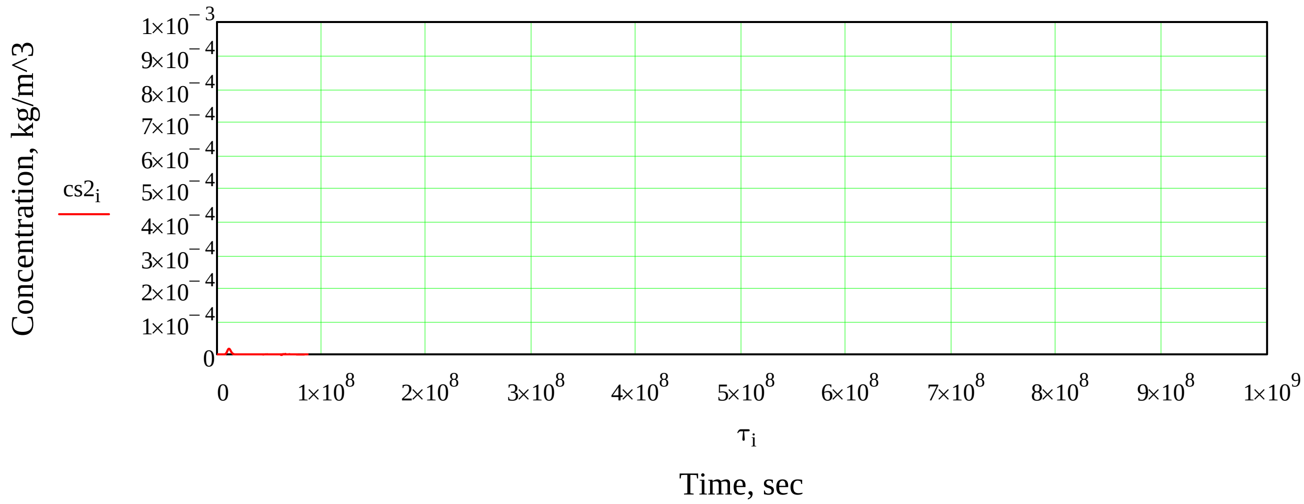
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 1,2..1000$ $\qquad$ $\tau_i := i\cdot day$

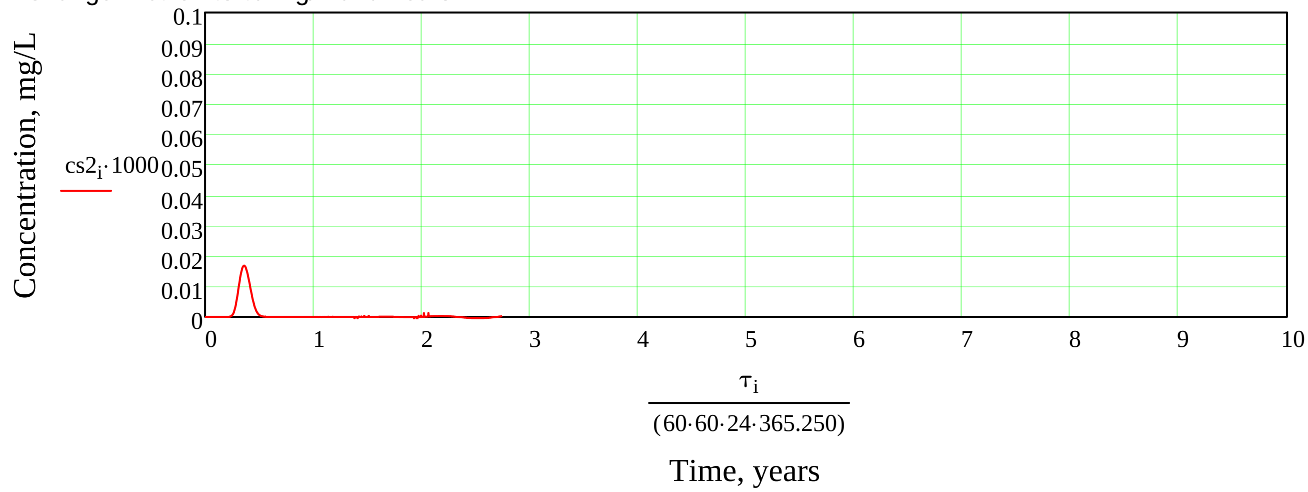
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

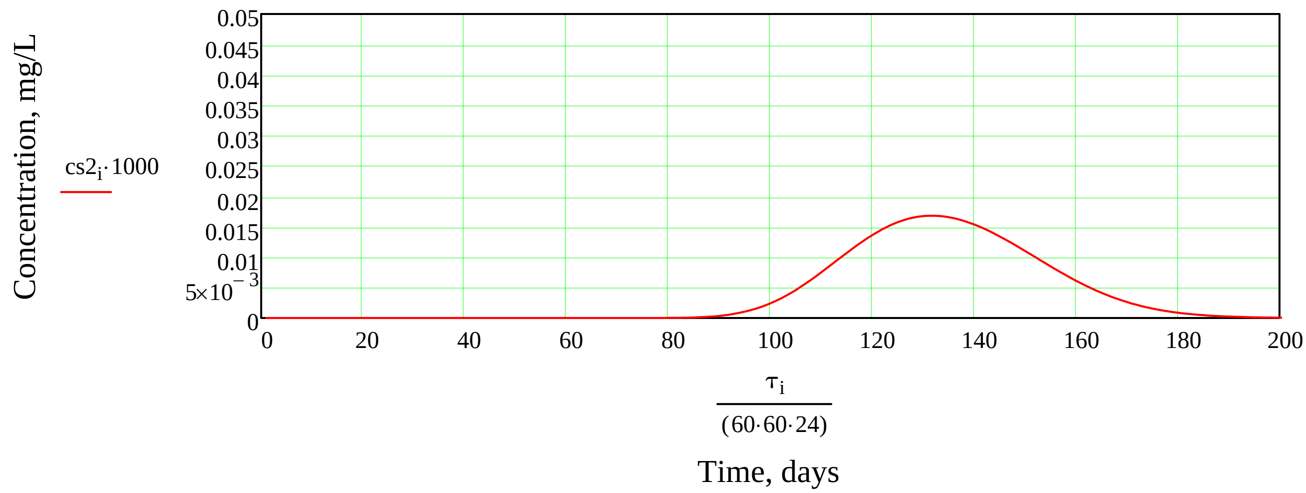
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.02 \\ 0.02 \\ 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 90 \\ 120 \\ 140 \\ 190 \\ 1000 \\ 10950 \end{pmatrix} day$$

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 24.869 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 1.167 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 1.08 \times$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 1.08 \times 10^3 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 360 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 360 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 18 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 18 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 5.4 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.8 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 90 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \operatorname{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \operatorname{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \operatorname{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \operatorname{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

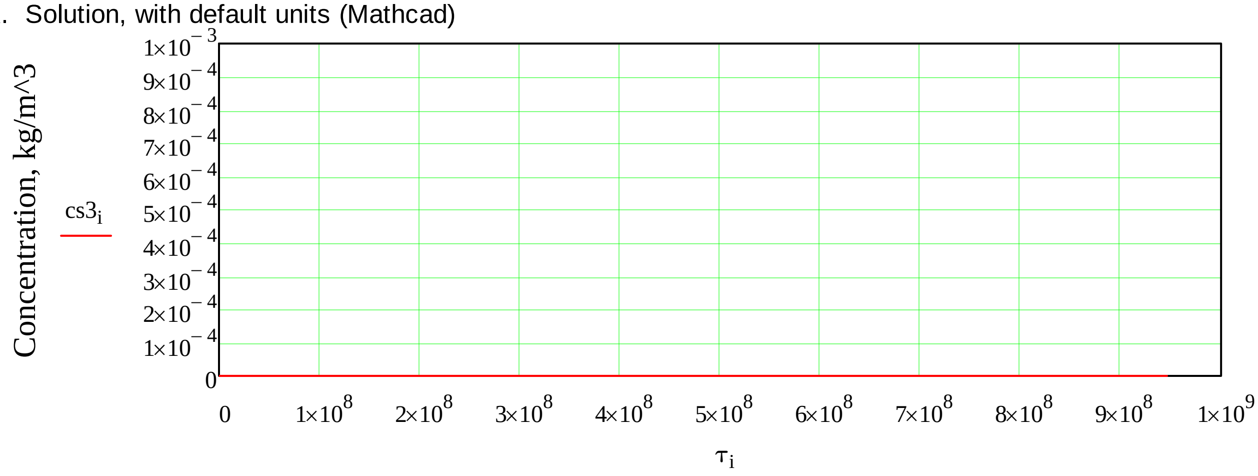
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1, 2 .. 10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

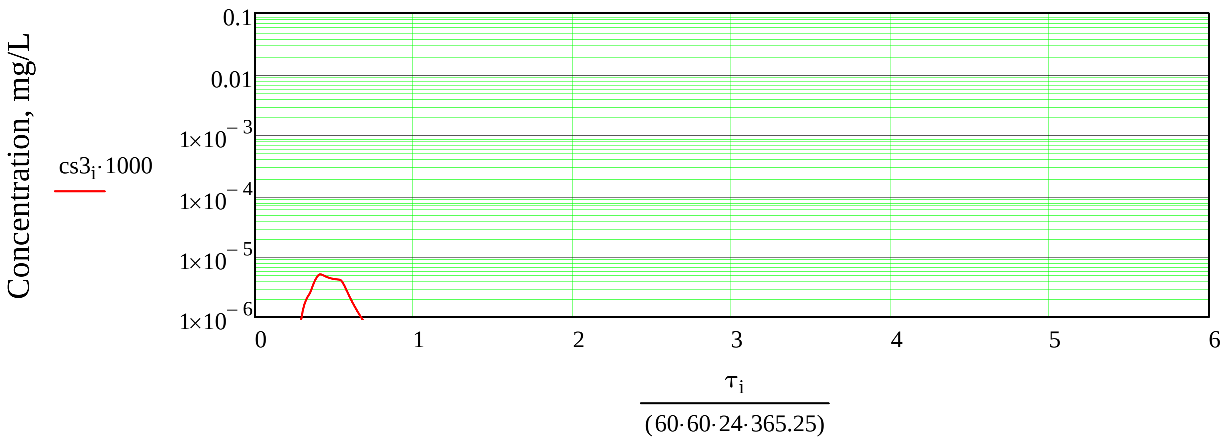
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_3(x_3,y_3,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_3(x_3,y_3,|\tau_i - ti_n|)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

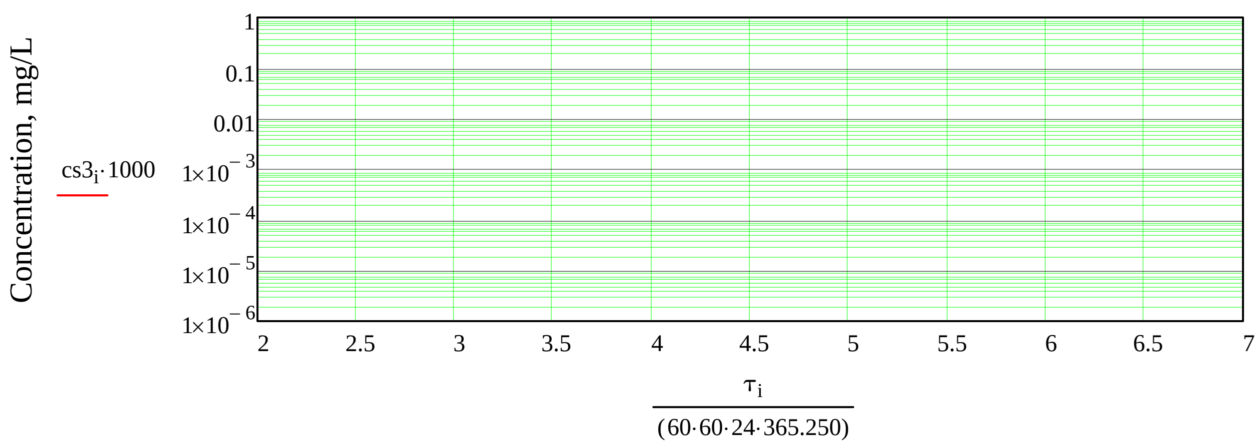
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

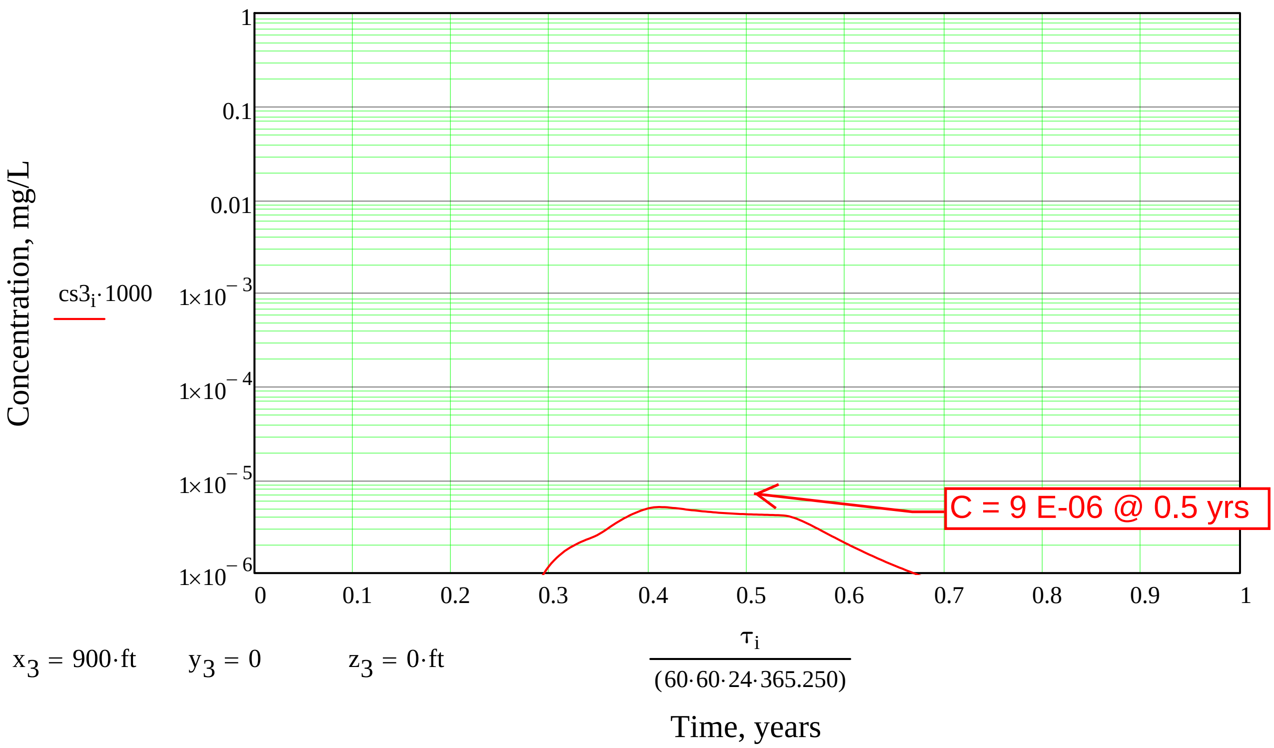


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot A shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 900 \cdot ft$ $y_3 = 0$ $z_3 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 900\cdot ft$ $y_3 = 0$ $z_3 = 0\cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on West Side of Cell 14. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor F.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\quad Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1 Common Borrow	LAYER 2 Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 15ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\quad \Delta H_1 := x_1 + H_1$ $\quad \Delta H_1 = 21 \cdot ft$

Hydraulic gradient (i) $\quad i_1 := \frac{\Delta H_1}{x_1}$ $\quad i_1 = 1.4$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 195.337 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.136 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.149 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 1.216 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_15} := 200.44ft$ $\quad Head_F := 77ft$

$i_2 := \frac{(Head_{Cell\_15} + \Delta H_1) - Head_F}{700ft}$ $\quad i_2 = 0.206$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 0.022 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.938$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe East of Cell 11):

distance of interest (x): $x_2 := 440ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 3.482 \cdot ft$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 15 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.15 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.15 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.15 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.15 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.15 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.15 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 440 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 66 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 66 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 4.4 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 4.4 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.149 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 15 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.022 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.022 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.022 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

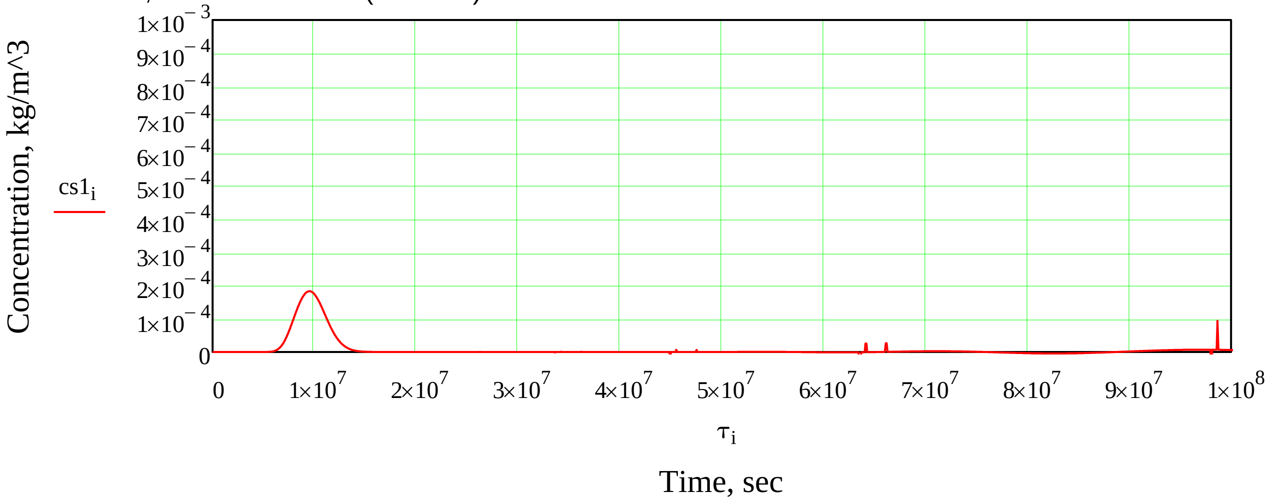
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

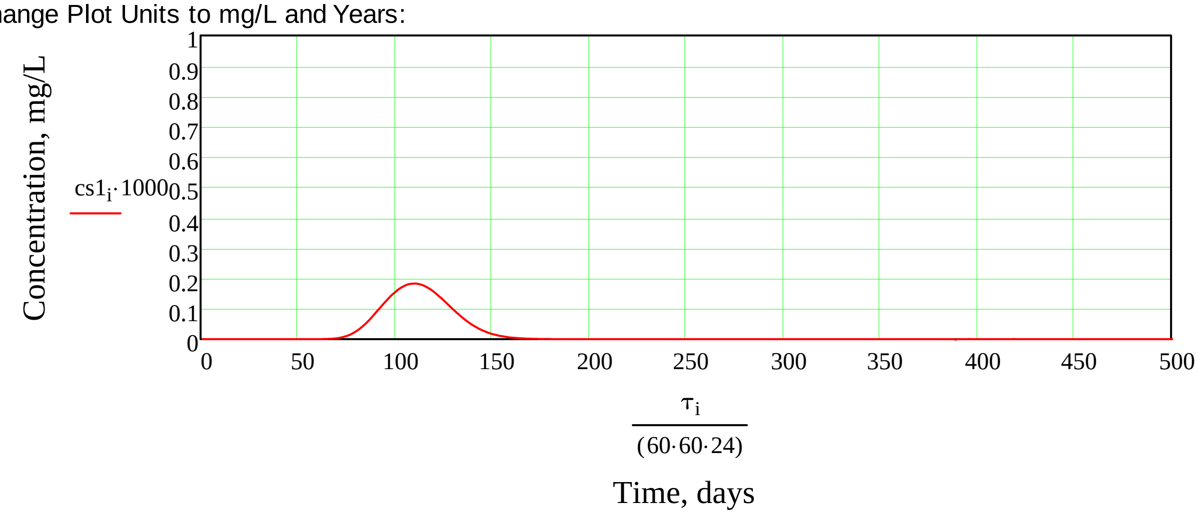
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

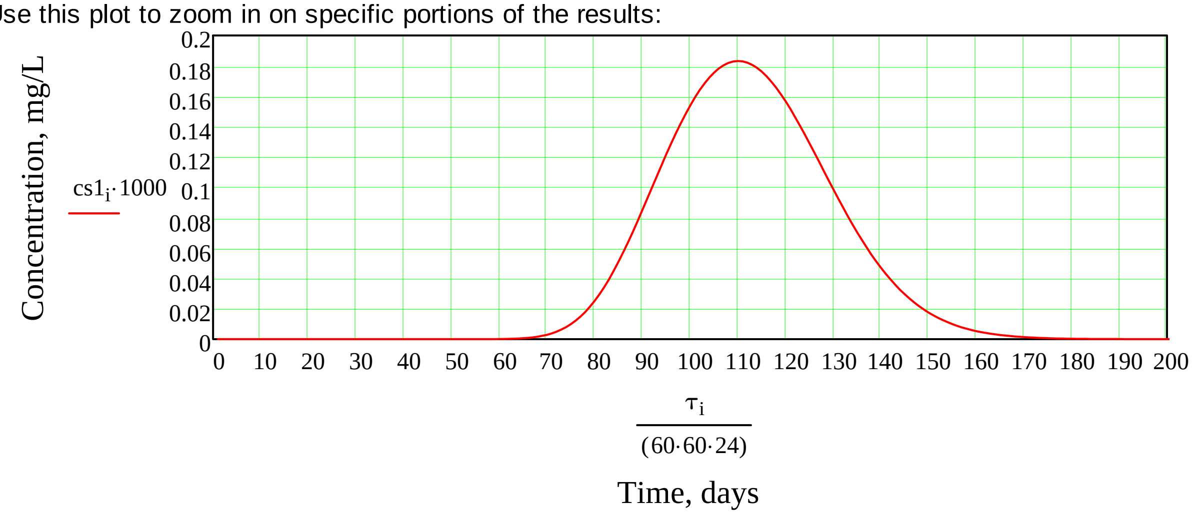
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.19 \\ 0.19 \\ 0 \\ 0 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 70 \\ 105 \\ 115 \\ 170 \\ 200 \\ 1000 \end{pmatrix} day$$

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Half-Height of Source in Y-direction $a_2 = 3.482 \cdot ft$ Vertical Thickness (See Section 1.(F))

Exceeds till thickness

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

$\alpha_{x\_2} = 0.15$	$\alpha_{x\_2} \cdot x_2 = 66 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 66 \cdot ft$	Flow
$\alpha_{y\_2} = 0.01$	$\alpha_{y\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 4.4 \cdot ft$	Vertical
$\alpha_{z\_2} = 0.01$	$\alpha_{z\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 4.4 \cdot ft$	Lateral

Note: This was rotated to use correct orientation from Tracer Test.

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 6.6 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.44 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.44 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

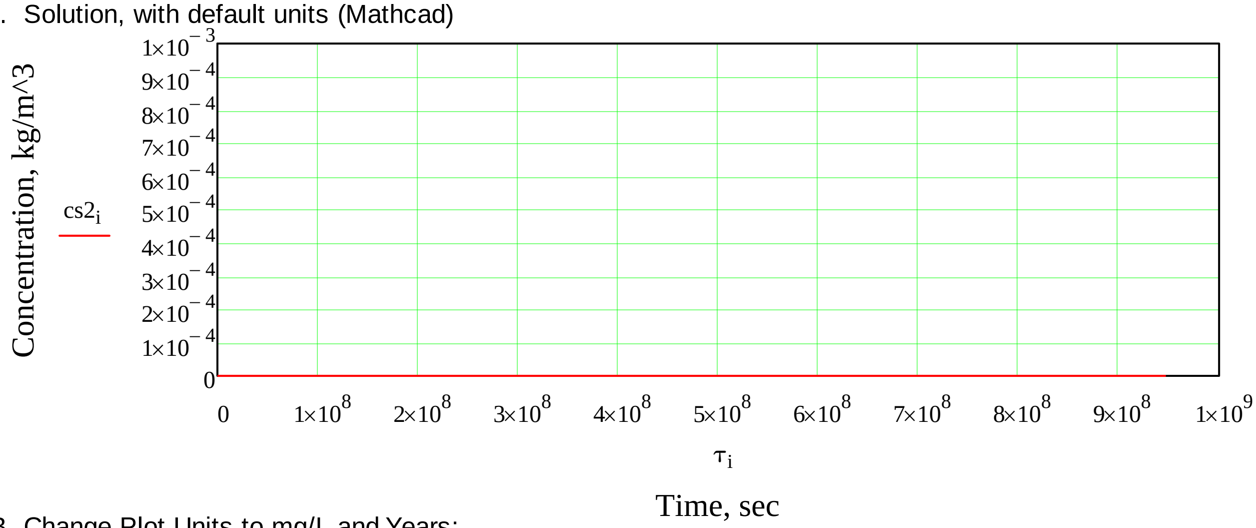
$i := 1,2..10950$ $\quad\quad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

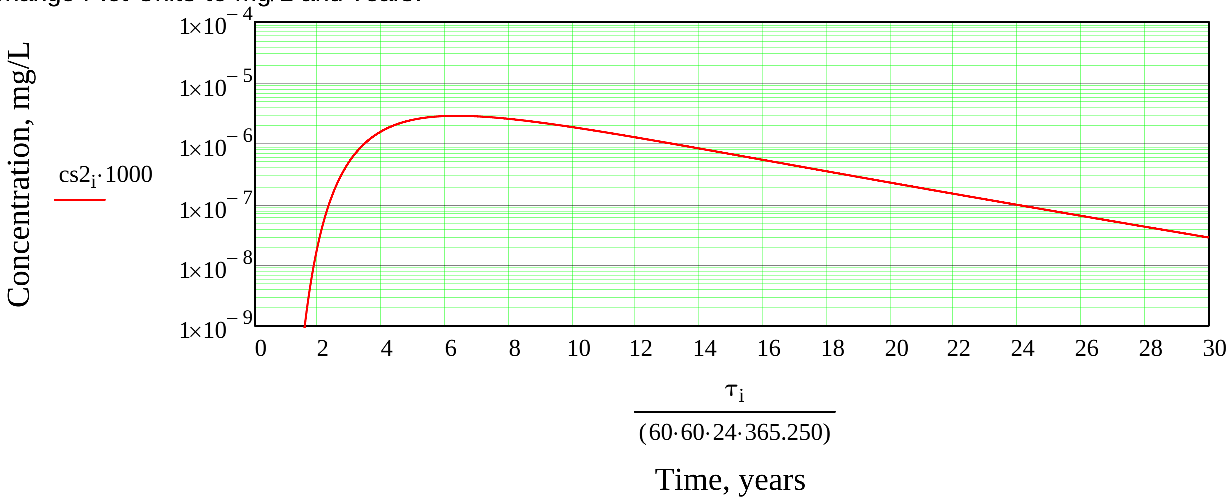
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

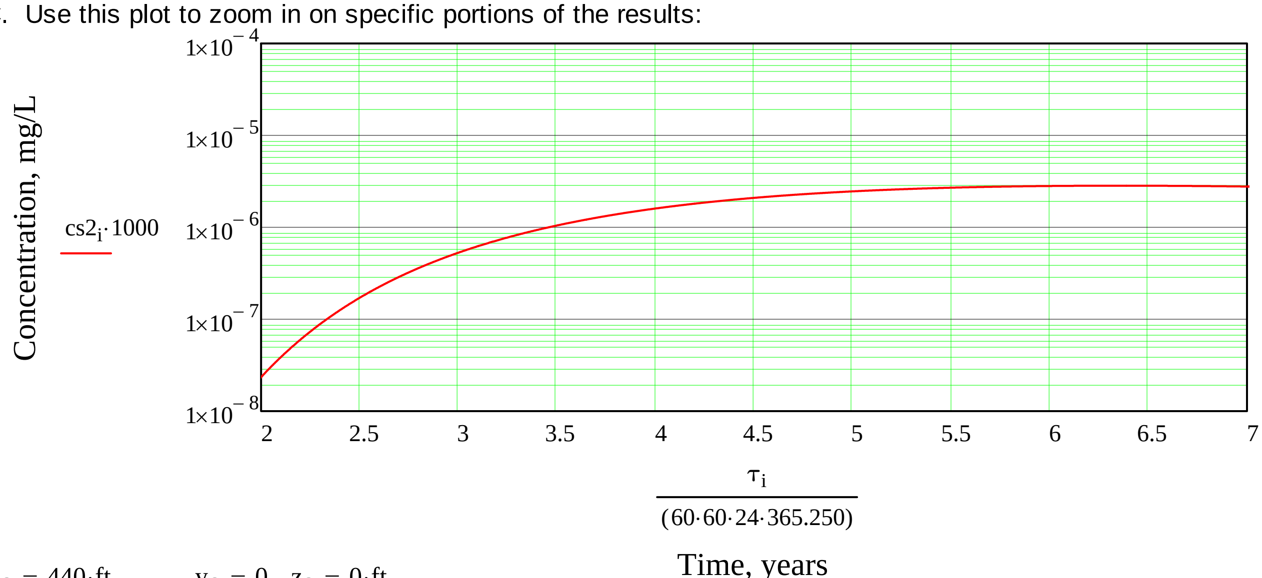
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

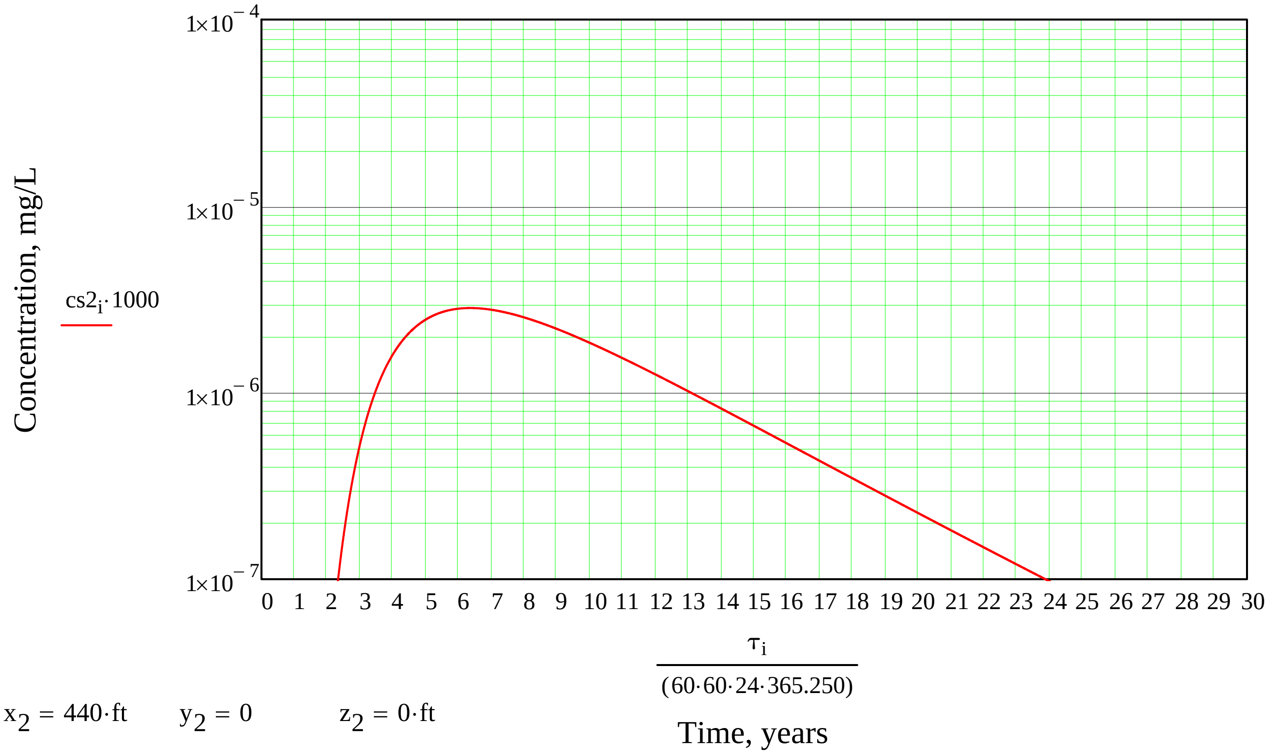


C. Use this plot to zoom in on specific portions of the results:



$x_2 = 440\cdot ft$ $\quad y_2 = 0 \quad z_2 = 0\cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 440 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
Leakey Force Main on West side of Cell 14. Flow is vertically down through Layer 1 (Common Borrow); then vertically through Layer 2 (Till); and thenhorizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor F.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Common Borrow	Native Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 15ft$	$x_2 := 2ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 21 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 1.4$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $Q_1 = 195.337 \cdot \frac{gal}{day}$ $Q_2 := Q_1$ $Q_1 = 0.136 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $v_1 = 0.149 \cdot \frac{ft}{day}$ $LQ := \frac{Q_1}{Area_1}$ $LQ = 1.216 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $v_2 = 0.149 \cdot \frac{ft}{day}$

LQ was Used to determine the value of a_3

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $i_2 = 1.4$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the northeast corner of Cell 13):

distance of interest (x): $x_3 := 440ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3} \qquad a_3 = 17.409 \cdot ft$$

Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 15 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.15 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.15 \cdot ft$	Flow
$\alpha_{y\_1} := 0.1$		$\alpha_{y\_1} \cdot x_1 = 1.5 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 1.5 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.1$		$\alpha_{z\_1} \cdot x_1 = 1.5 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 1.5 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 2 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 0.02 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 0.02 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 0.2 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 0.2 \cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 0.2 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 0.2 \cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$ These Calcs

Lateral dispersivity	$\alpha_{y\_BR} := \frac{20ft}{Y_3}$	$\alpha_{y\_BR} = 0.4$	Z axis
Downgradient dispersivity:	$\alpha_{x\_BR} := \frac{(3 \cdot \alpha_{y\_BR} \cdot X_3)}{X_3}$	$\alpha_{x\_BR} = 1.2$	X axis
Vertical dispersivity	$\alpha_{z\_BR} := \frac{(0.05 \cdot \alpha_{y\_BR} \cdot Y_3)}{Z_3}$	$\alpha_{z\_BR} = 0.02$	Y axis

3.1 Source Definition, to Layer 1 (Common Borrow Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.149 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 15 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.022 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.224 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.224 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \text{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \text{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \text{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \text{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

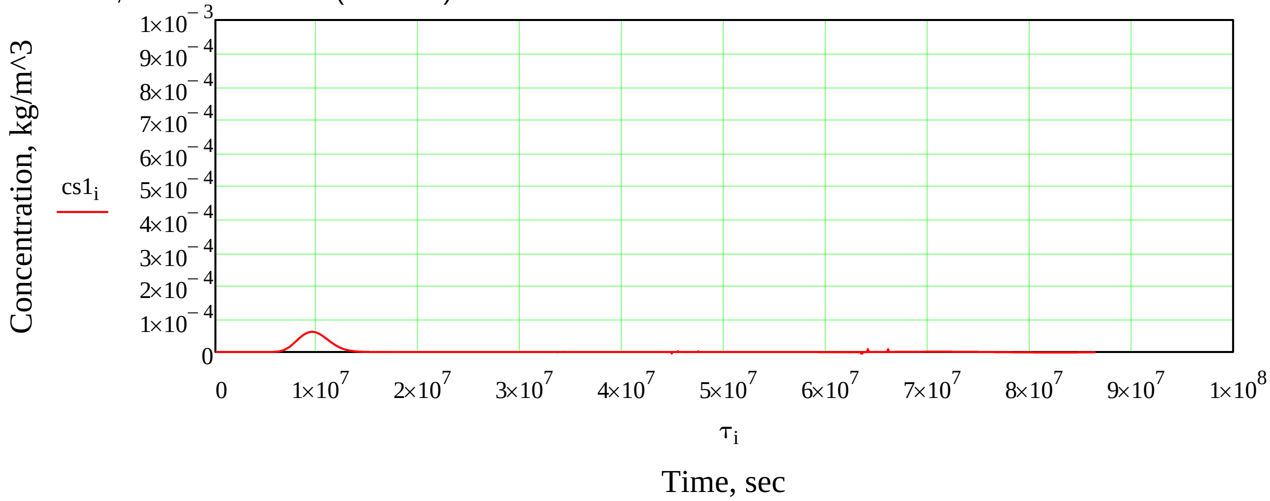
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..1000$ $\qquad \tau_i := i\cdot day$

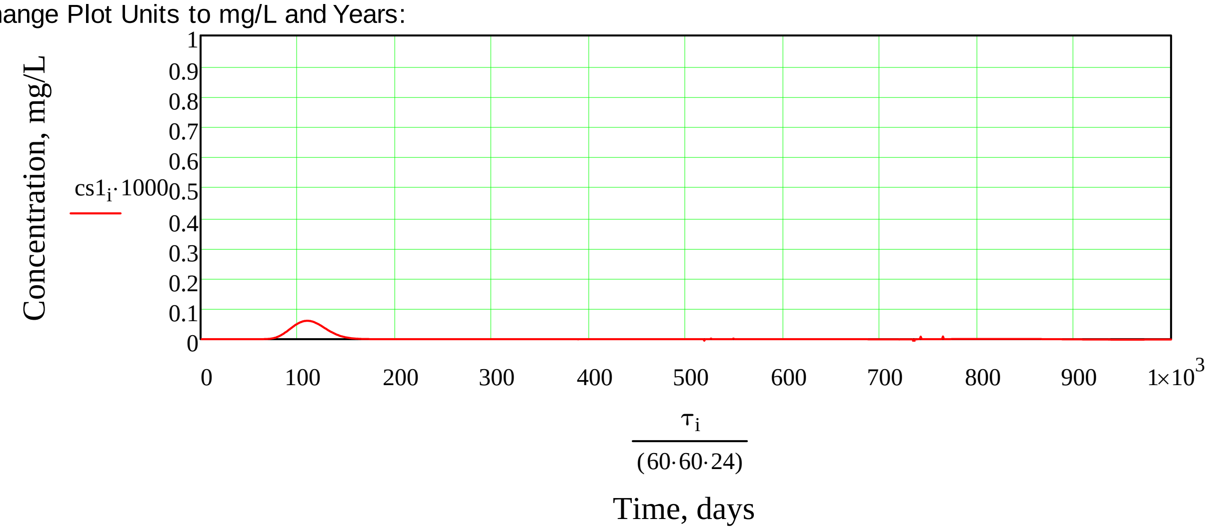
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

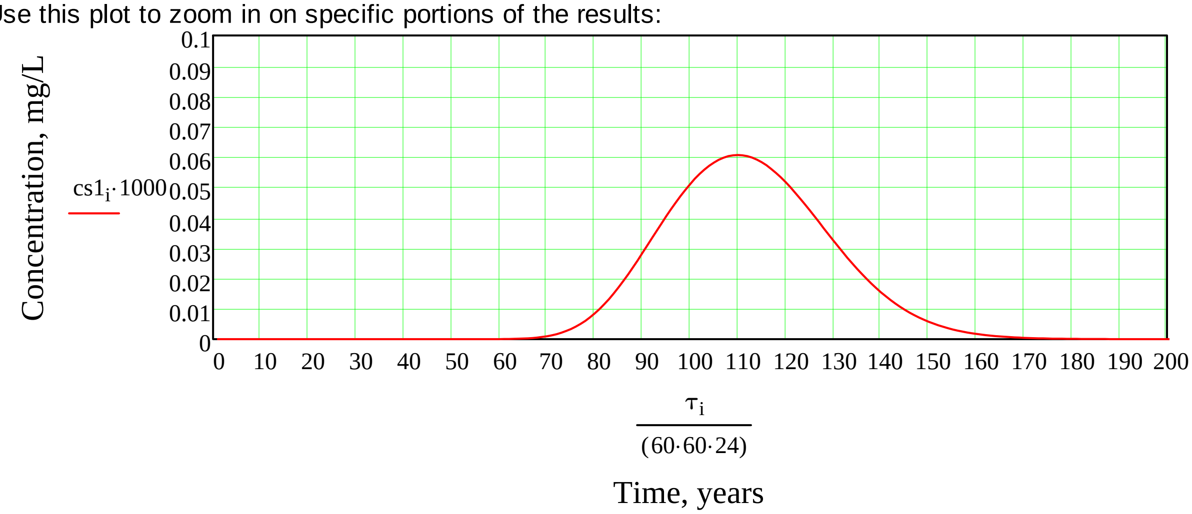
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 8$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co2 := \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0.06 \\ 0.06 \\ 0 \\ 0 \\ 0 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 70 \\ 71 \\ 100 \\ 120 \\ 170 \\ 1000 \\ 10950 \end{pmatrix} day$$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $a_2 := a_1$ $a_2 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 0.149 \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 2 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$

Lateal distance of interest (z): $z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 2.984 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.03 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.03 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

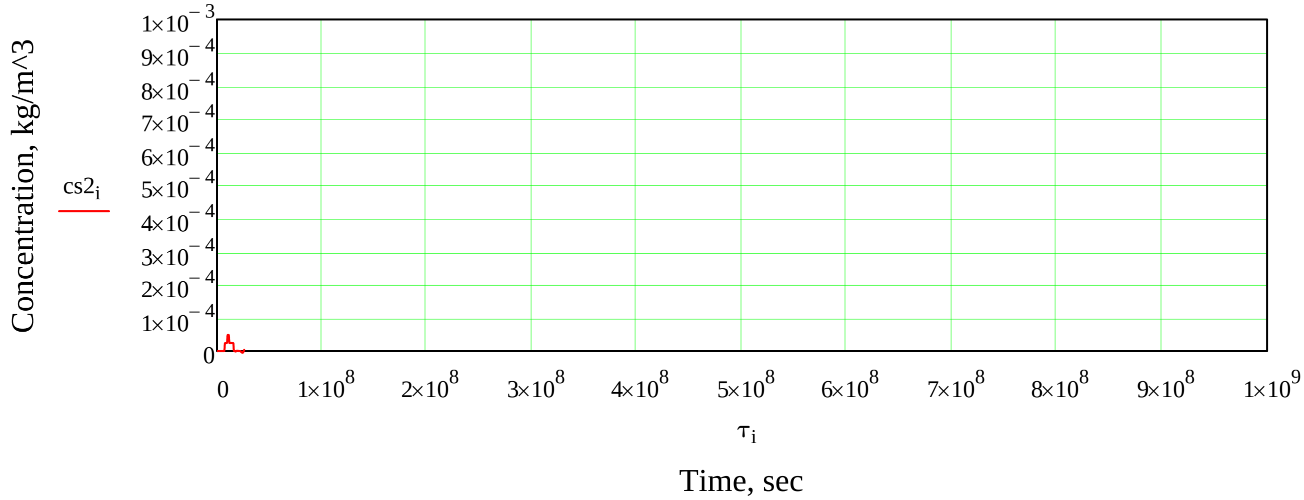
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 0,1..300$ $\tau_i := i\cdot day$

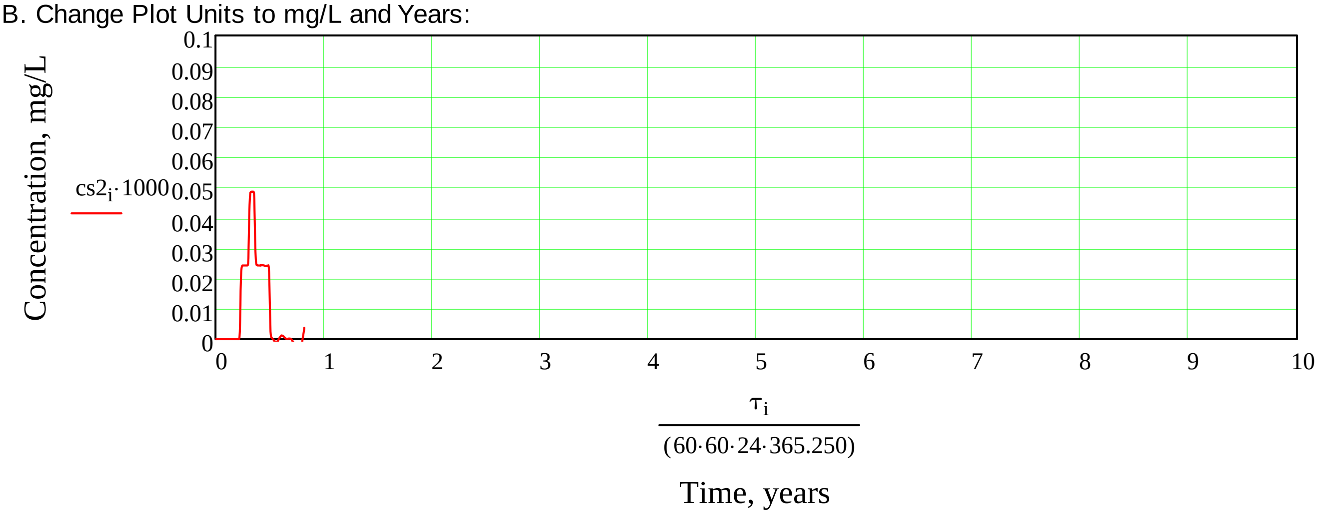
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

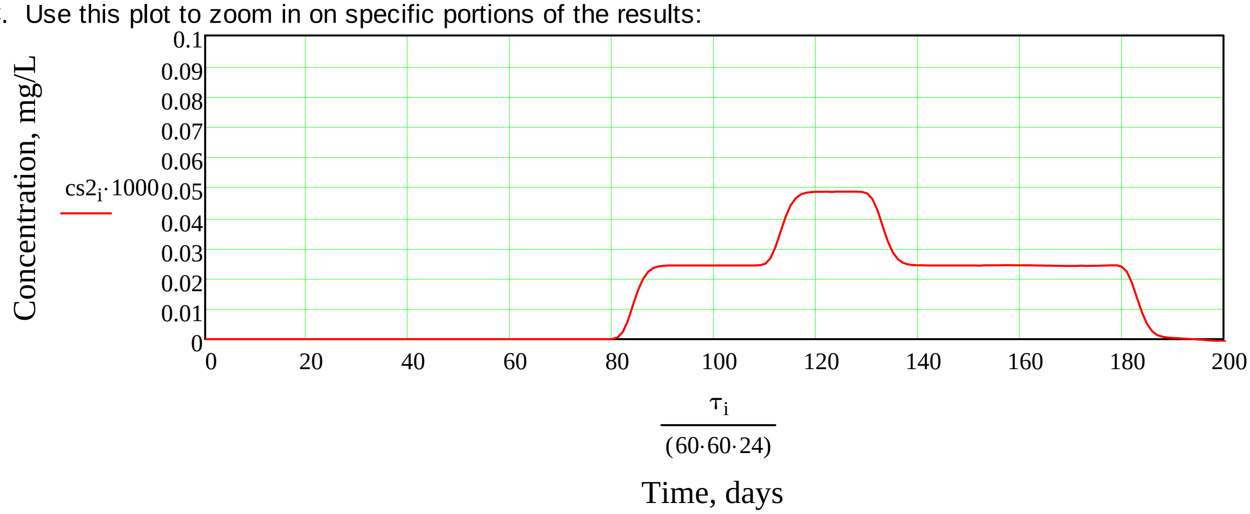
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.025 \\ 0.05 \\ 0.05 \\ 0.025 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 80 \\ 90 \\ 110 \\ 130 \\ 180 \\ 190 \end{pmatrix} day$$

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 17.409 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 1.167 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 528 \cdot ft$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 528 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 176 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 176 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 8.8 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 8.8 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 2.64 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 880 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 44 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \operatorname{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \operatorname{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \operatorname{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \operatorname{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

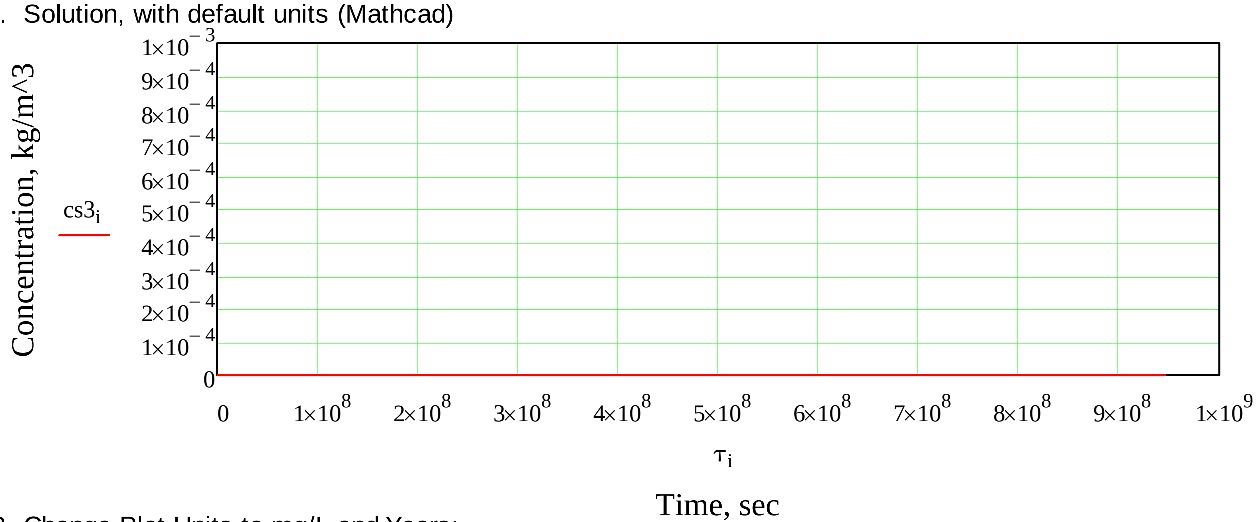
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2..10950$ $\qquad\qquad$ $\tau_i := i\cdot day$

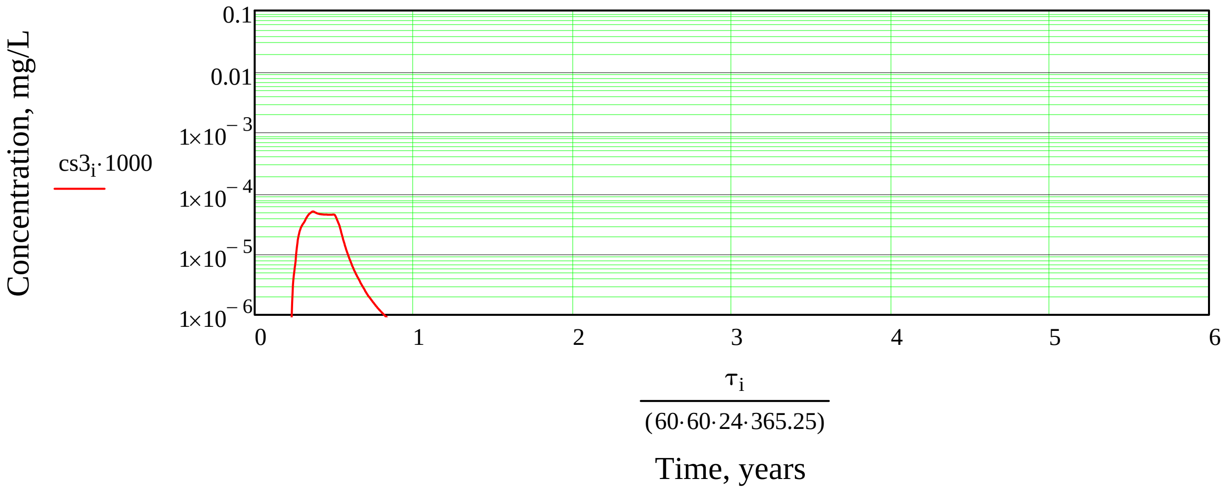
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi\left(\tau_i - ti_{n-1}\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi\left(\tau_i - ti_n\right)\cdot\left(C_3\left(x_3,y_3,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

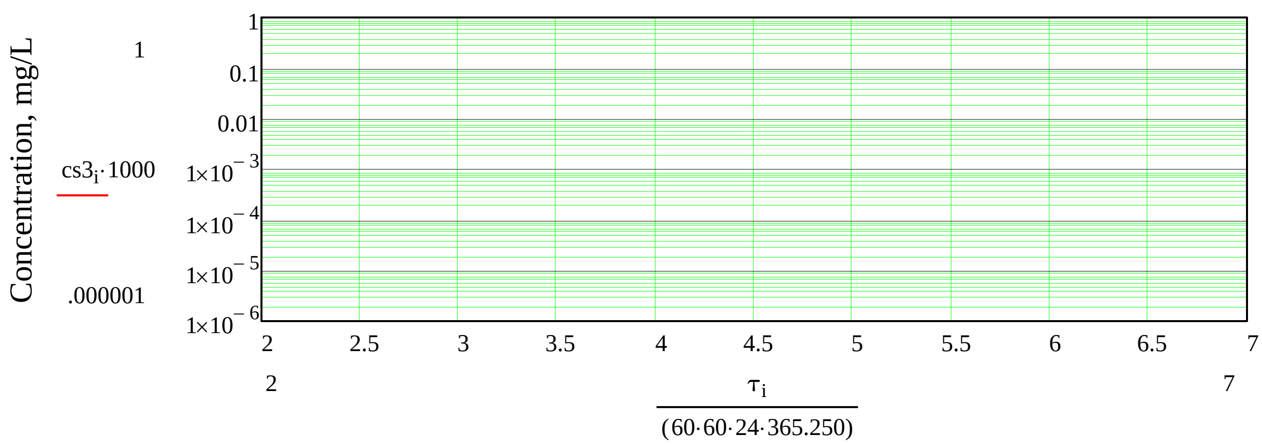
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

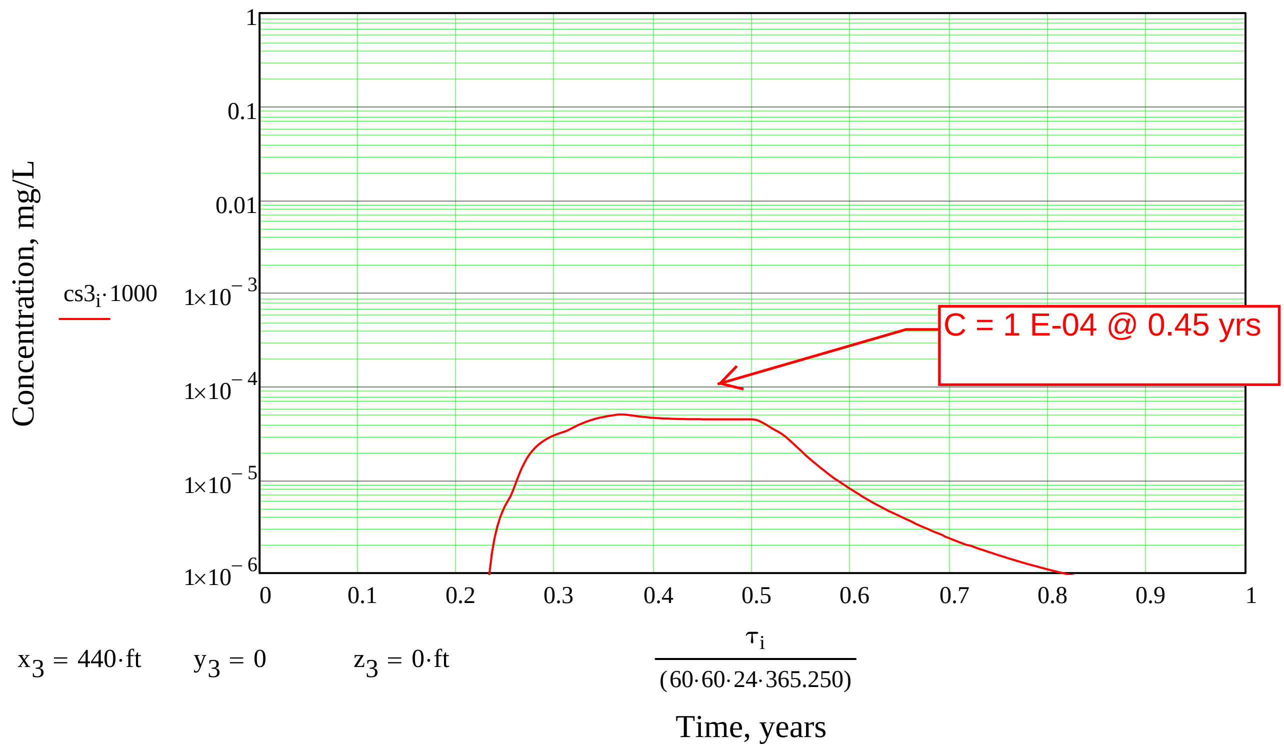


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot A shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 440 \cdot ft$ $y_3 = 0$ $z_3 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 440 \cdot ft$ $y_3 = 0$ $z_3 = 0 \cdot ft$

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on BNorthwest corner of Cell 15. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor G.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\qquad Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1 Common Borrow	LAYER 2 Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 10ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\qquad \Delta H_1 := x_1 + H_1$ $\qquad \Delta H_1 = 16 \cdot ft$

Hydraulic gradient (i) $\qquad i_1 := \frac{\Delta H_1}{x_1}$ $\qquad i_1 = 1.6$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 223.242 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.155 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.171 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 1.389 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_16} := 184.62ft$ $\quad Head_G := 165ft$

$i_2 := \frac{(Head_{Cell\_16} + \Delta H_1) - Head_G}{700ft}$ $\quad i_2 = 0.051$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 5.424 \times 10^{-3} \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.938$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe East of Cell 11):

distance of interest (x): $x_2 := 820ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$

F. Determine the thickness that the leak travels into the Till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 3.979 \cdot ft$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

				Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 10 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.1 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$ $\alpha x_1 = 0.1 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.1 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$ $\alpha y_1 = 0.1 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.1 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$ $\alpha z_1 = 0.1 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

				Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 820 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 123 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 123 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 8.2 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 8.2 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 8.2 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 8.2 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.171 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 10 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.017 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.017 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.017 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

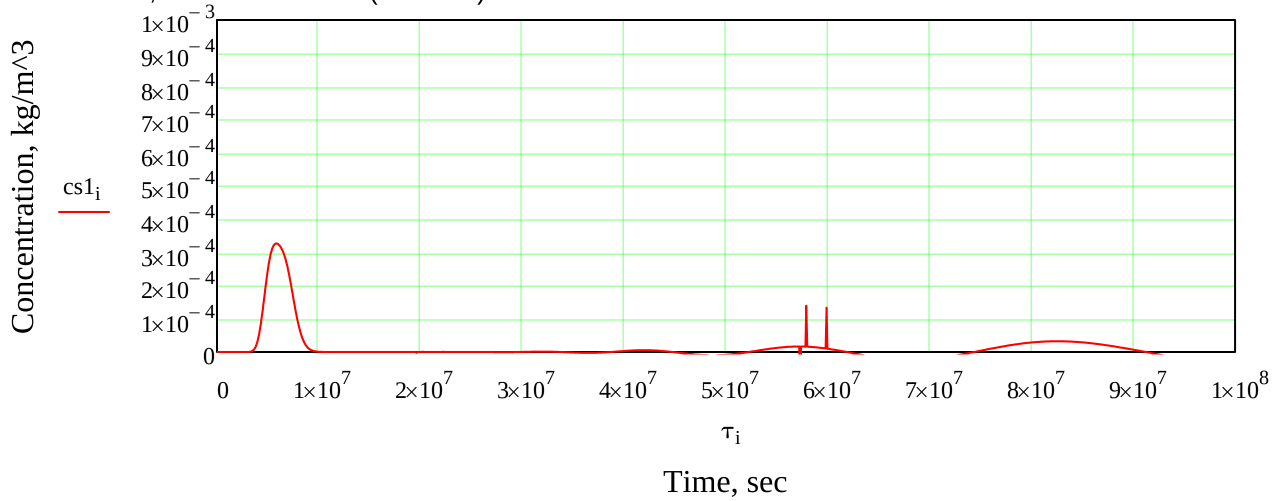
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2\,..\,10950$ $\qquad \tau_i := i\cdot day$

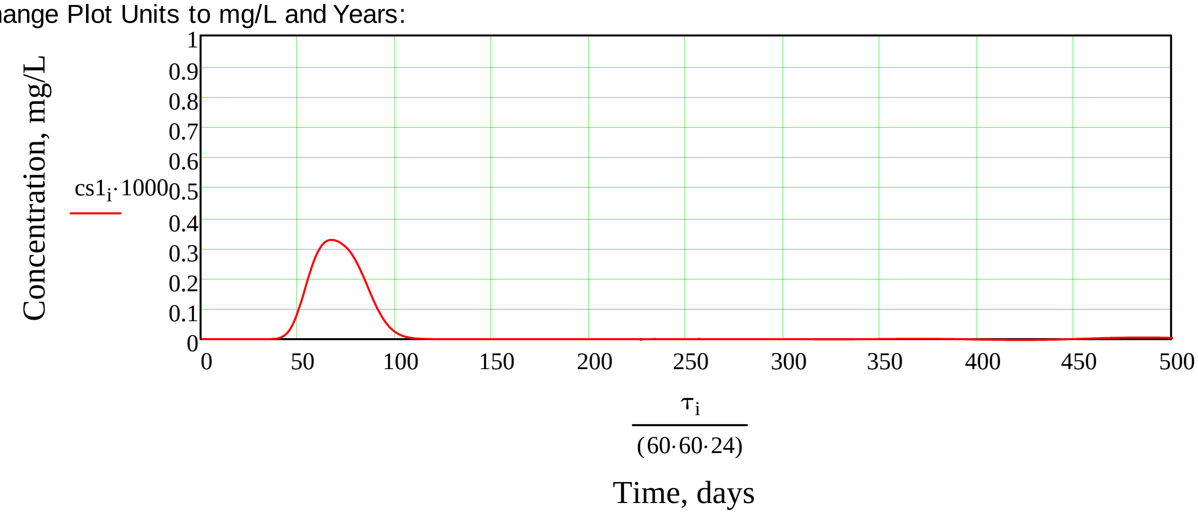
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

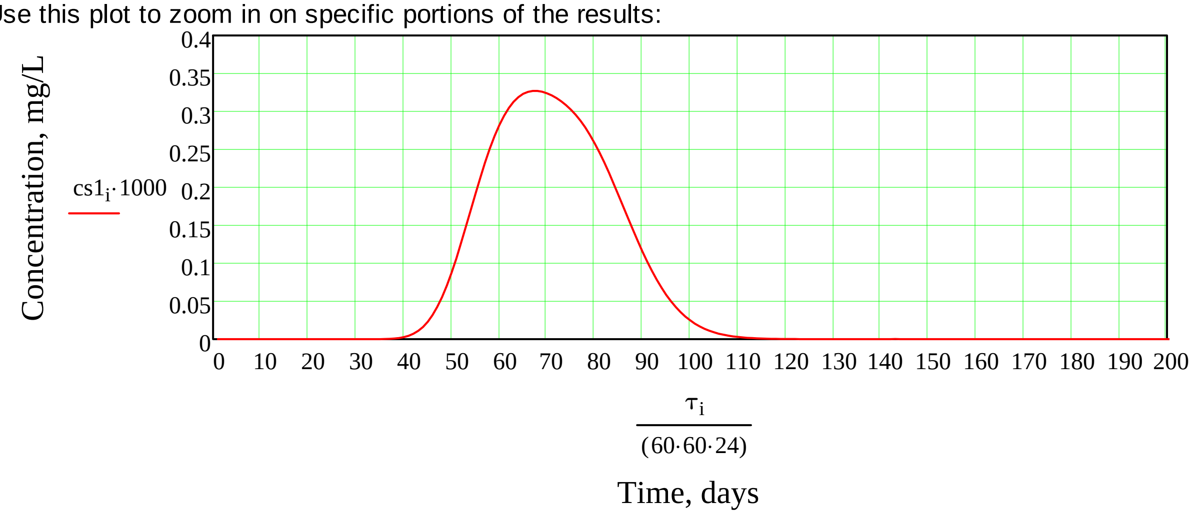
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.33 \\ 0.33 \\ 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 40 \\ 65 \\ 75 \\ 110 \\ 200 \\ 1000 \end{pmatrix} day$$

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 3.979 \cdot ft$

Exceeds till thickness

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$	$\alpha_{x\_2} \cdot x_2 = 123 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 123 \cdot ft$	Flow
$\alpha_{y\_2} = 0.01$	$\alpha_{y\_2} \cdot x_2 = 8.2 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 8.2 \cdot ft$	Vertical
$\alpha_{z\_2} = 0.01$	$\alpha_{z\_2} \cdot x_2 = 8.2 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 8.2 \cdot ft$	Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $\quad Dx_2 = 12.3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $\quad Dy_2 = 0.82 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $\quad Dz_2 = 0.82 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \text{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \text{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \text{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \text{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

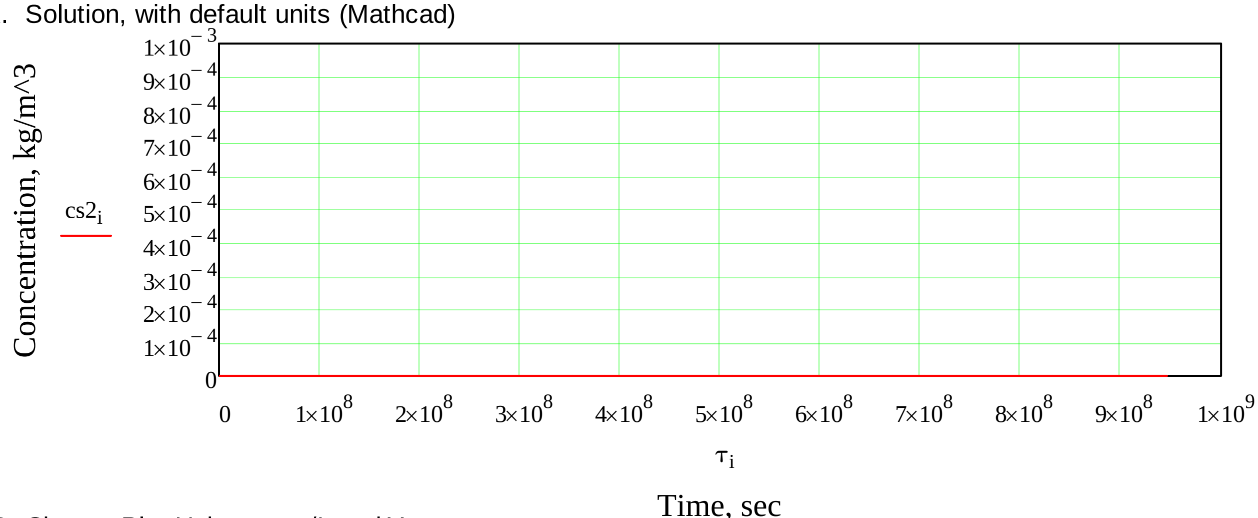
$i := 1,2..10950$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{dav}$$

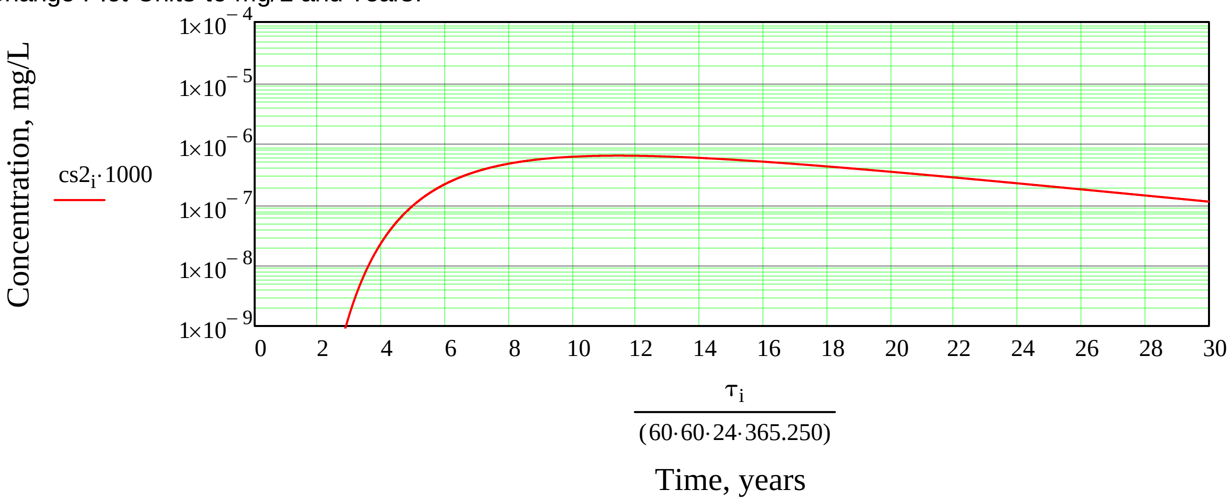
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

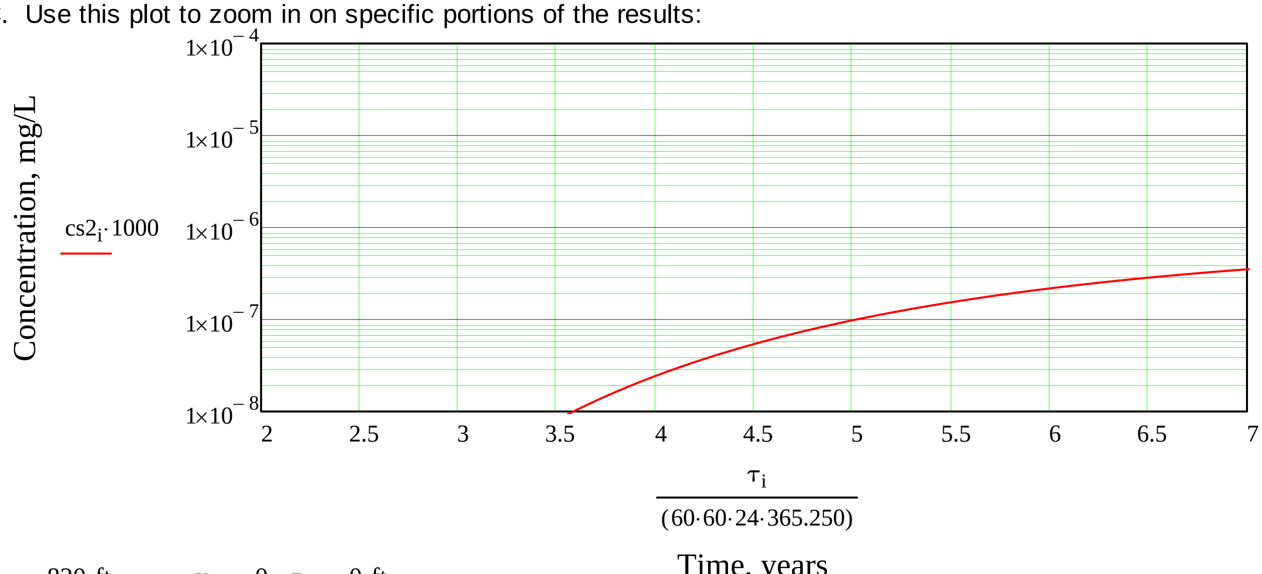
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

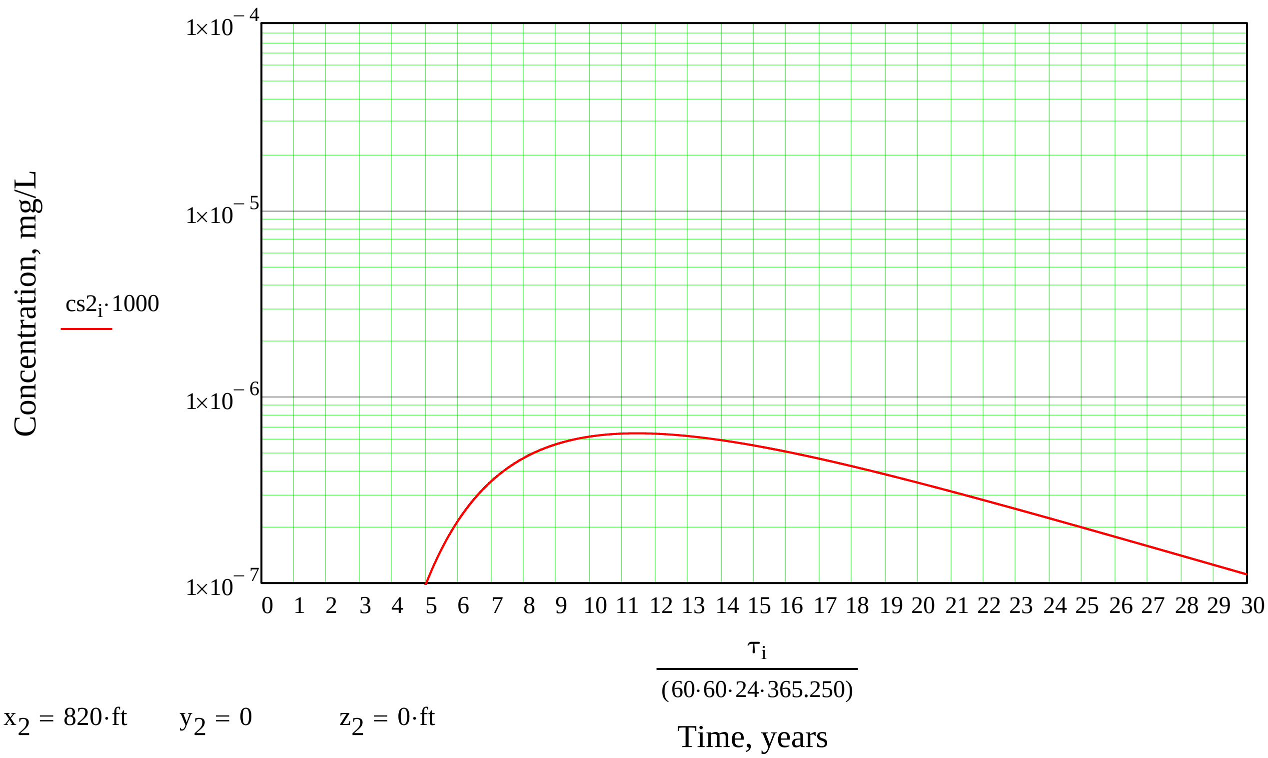


C. Use this plot to zoom in on specific portions of the results:



$x_2 = 820 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 820 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

This calculation evaluated a three layered system, by superimposing the solution from the first layer as the influent concentration to the second layer and so on.
Leakey Force Main on Northwest corner of Cell 16. Flow is vertically down through Layer 1 (Common Borrow); then vertically through Layer 2 (Till); and thenhorizontally through Layer 3 (Bedrock). **Flow is toward Site Sensitive Receptor G.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\quad Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1	LAYER 2	LAYER 3
	Common Borrow	Native Till	Bedrock (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_3 := 3.5 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$	$n_3 := 0.001$
Distance in flow direction (x)	$x_1 := 10ft$	$x_2 := 2ft$	X3 defined in Section 3.3

X_2 is from travel time calculations

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\quad \Delta H_1 := x_1 + H_1$ $\quad \Delta H_1 = 16 \cdot ft$

Hydraulic gradient (i) $\quad i_1 := \frac{\Delta H_1}{x_1}$ $\quad i_1 = 1.6$

C. Calculate flow rate through Layer 1 (Q=kia) (per unit area = 1 acre); and the velocity (v=Q/na):

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 223.242 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.155 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.171 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 1.389 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

$v_2 := \frac{Q_2}{n_2 \cdot Area_1}$ $\quad v_2 = 0.171 \cdot \frac{ft}{day}$

LQ was Used to determine the value of a_3

$v_3 := 5 \frac{ft}{day}$ Velocity in bedrock from the Bedrock Tracer Test was 5 ft/day.

D. Calculate the hydraulic gradient through layer 2 (i=Q/(ka))

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 1.6$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from the northeast corner of Cell 13):

distance of interest (x): $x_3 := 820ft$ to Sensitive Receptor (in Bedrock)

Vertical depth of interest (y): $y_3 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_3 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the bedrock (a_3), this is the source size in Bedrock.

$$a_3 := \frac{Q_1}{Length_1 \cdot n_3 \cdot v_3}$$

$a_3 = 19.895 \cdot ft$ Y Direction in Layer 3 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow Layer has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 10\cdot ft$	$\alpha_{x\_1}\cdot x_1 = 0.1\cdot ft$	$\alpha x_1 := \alpha_{x\_1}\cdot x_1$	$\alpha x_1 = 0.1\cdot ft$	Flow
$\alpha_{y\_1} := 0.1$		$\alpha_{y\_1}\cdot x_1 = 1\cdot ft$	$\alpha y_1 := \alpha_{y\_1}\cdot x_1$	$\alpha y_1 = 1\cdot ft$	Lateral
$\alpha_{z\_1} := 0.1$		$\alpha_{z\_1}\cdot x_1 = 1\cdot ft$	$\alpha z_1 := \alpha_{z\_1}\cdot x_1$	$\alpha z_1 = 1\cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Native Till and Fill):

					Direction
$\alpha_{x\_2} := 0.01$	$x_2 = 2\cdot ft$	$\alpha_{x\_2}\cdot x_2 = 0.02\cdot ft$	$\alpha x_2 := \alpha_{x\_2}\cdot x_2$	$\alpha x_2 = 0.02\cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2}\cdot x_2 = 0.2\cdot ft$	$\alpha y_2 := \alpha_{y\_2}\cdot x_2$	$\alpha y_2 = 0.2\cdot ft$	Lateral
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2}\cdot x_2 = 0.2\cdot ft$	$\alpha z_2 := \alpha_{z\_2}\cdot x_2$	$\alpha z_2 = 0.2\cdot ft$	Lateral

2.3 Determine Dispersion in Layer 3 (Bedrock) (From Bedrock Tracer Test):

2.3.1 From the Bedrock Tracer Test:

Original Geometry:

X = Direction of Flow (Northeast - Southwest))
Y = Width (Northwest - Southeast), perpendicular to horizontal flow
Z = Thickness (Vertical)

Downgradient distances: $X_3 := 50ft$ $Y_3 := 50ft$ $Z_3 := 50ft$ These Calcs

Lateral dispersivity $\alpha_{y\_BR} := \dfrac{20ft}{Y_3}$ $\alpha_{y\_BR} = 0.4$ Z axis

Downgradient dispersivity: $\alpha_{x\_BR} := \dfrac{(3\cdot\alpha_{y\_BR}\cdot X_3)}{X_3}$ $\alpha_{x\_BR} = 1.2$ X axis

Vertical dispersivity $\alpha_{z\_BR} := \dfrac{(0.05\cdot\alpha_{y\_BR}\cdot Y_3)}{Z_3}$ $\alpha_{z\_BR} = 0.02$ Y axis

3.1 Source Definition, to Layer 1 (Common Borrow Layer):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1 and 2 geometry

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.171 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 10 \cdot ft$ to Top of Layer 2, set on page 1

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.017 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.171 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.171 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

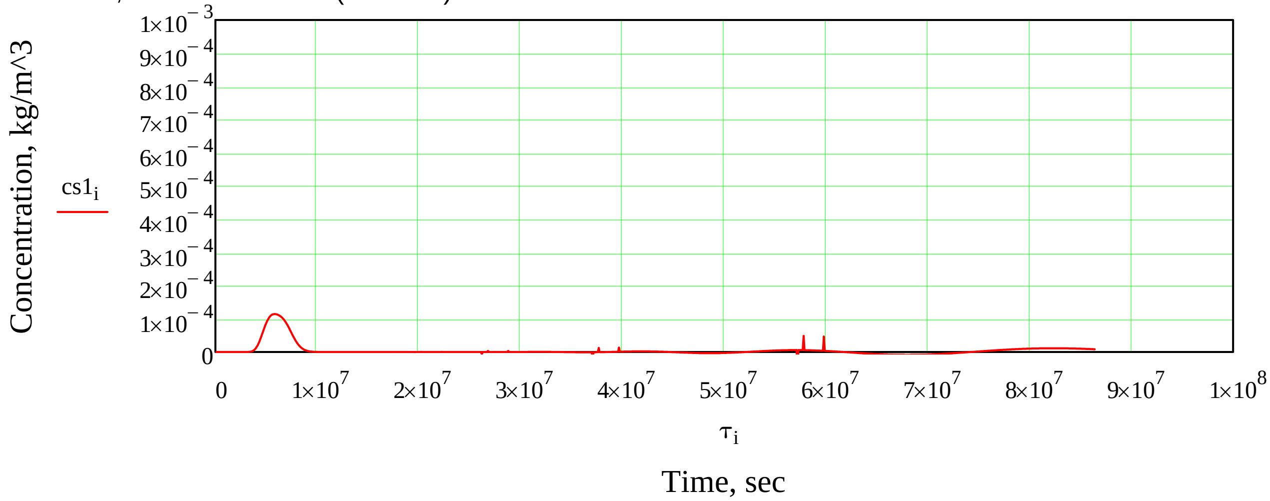
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..1000$ $\qquad\qquad$ $\tau_i := i\cdot day$

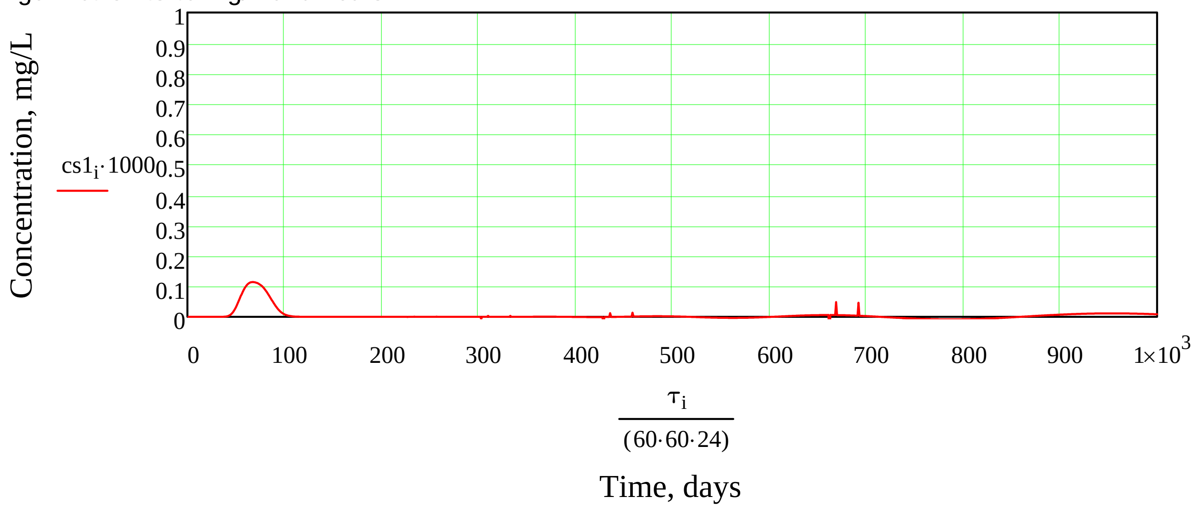
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1\left(x_1,y_1,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1

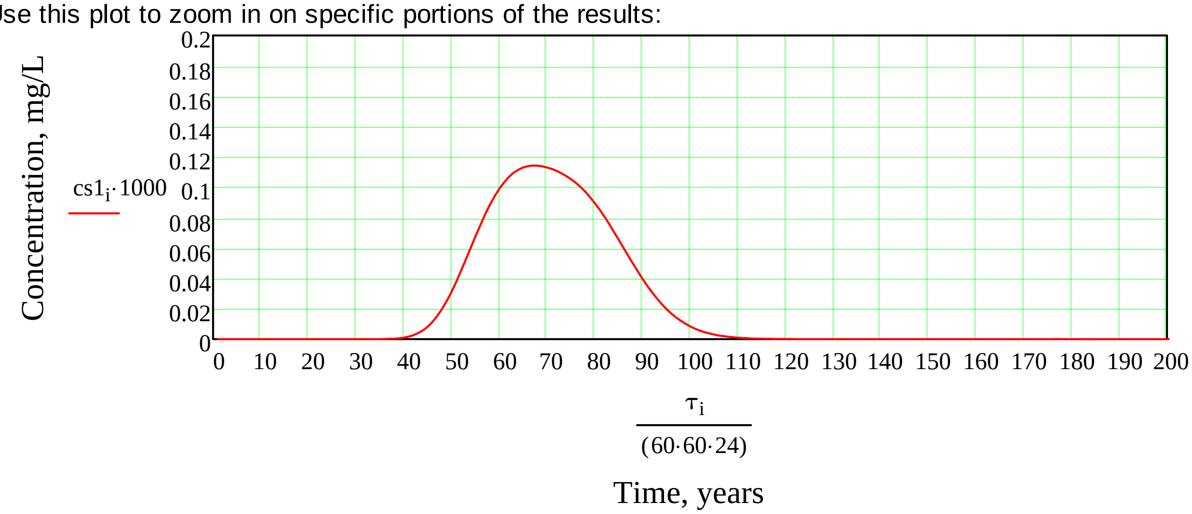
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till):

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 8$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l)	Source Term (days)
0	0
0	40
0	41
0.12	60
0.12	75
0	110
0	1000
0	10950

$co2 := (0, 0, 0, 0.12, 0.12, 0, 0, 0)^T \cdot \frac{mg}{L}$ $\quad ti := (0, 40, 41, 60, 75, 110, 1000, 10950)^T \cdot day$

B. Input parameters (Layer 2):

Half-Length of Source in Y-direction $a_2 := a_1$ $\quad a_2 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_2 := b_1$ $\quad b_2 = 1.167 \cdot ft$

Note that a plume would spread, while this calculation is the maximum value. It could be reduced by applying an average Concentration for the difused plume width to Layer 2.

Calculated breakthough curve (after Cleary and Ungs, 1978) (Layer 2):

Velocity (from above) $v_2 = 0.171 \cdot \frac{ft}{day}$

Distance of interest (x): $x_2 = 2 \cdot ft$ Vertical (down) to Top of Layer 3

Lateral distance of interest (y): $y_2 := 0ft$

Lateal distance of interest (z): $z_2 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $\quad Dx_2 = 3.411 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef (y): $Dy_2 := \alpha y_2 \cdot v_2$ $\quad Dy_2 = 0.034 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $\quad Dz_2 = 0.034 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

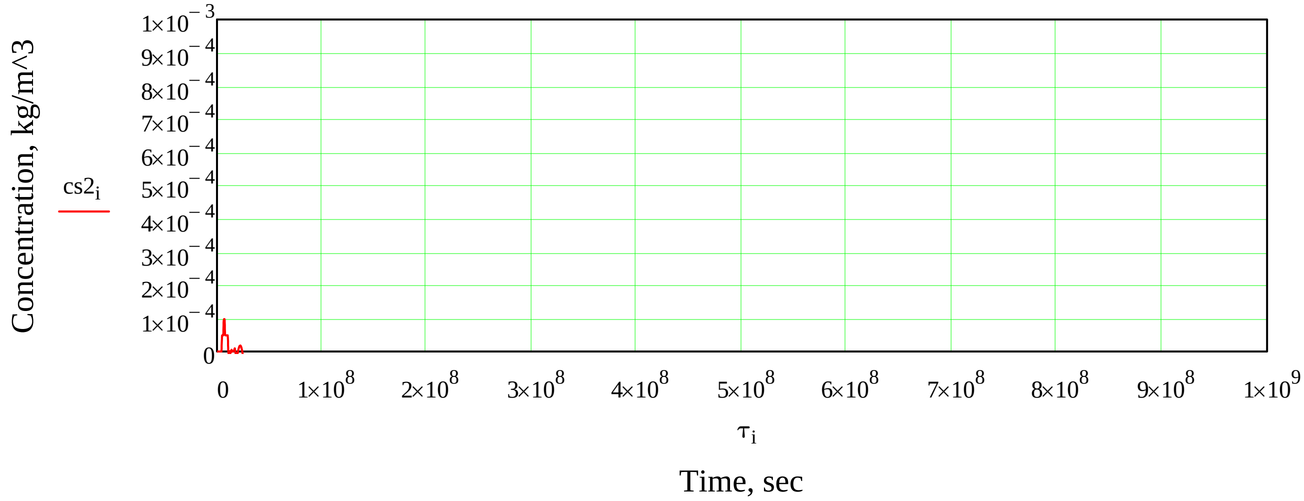
$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

$i := 0,1..300$ $\qquad\qquad$ $\tau_i := i\cdot day$

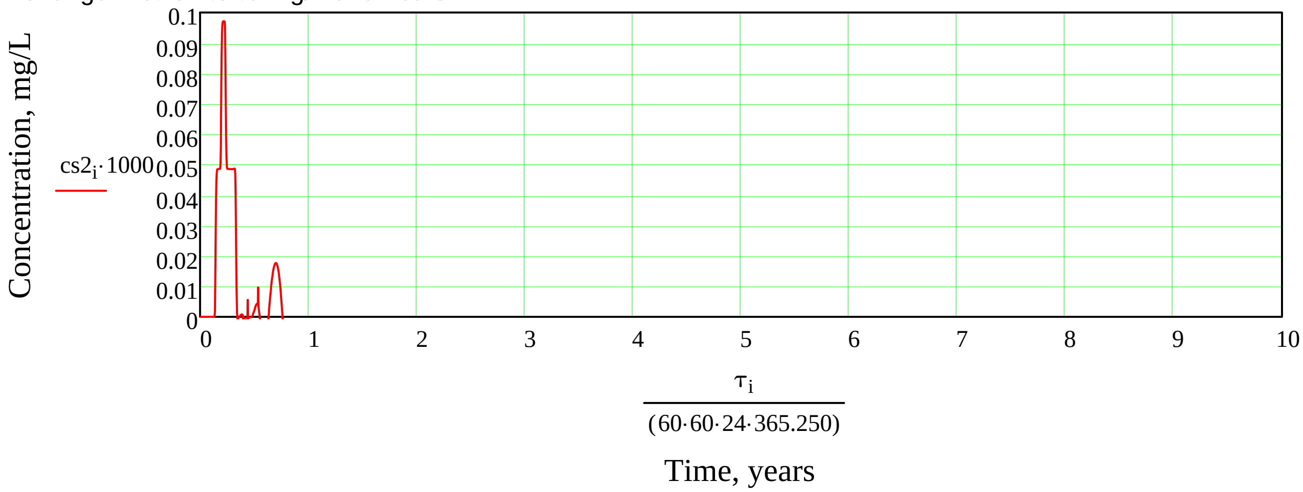
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Base of Layer 2, at X, Y and Z from Section 3.2

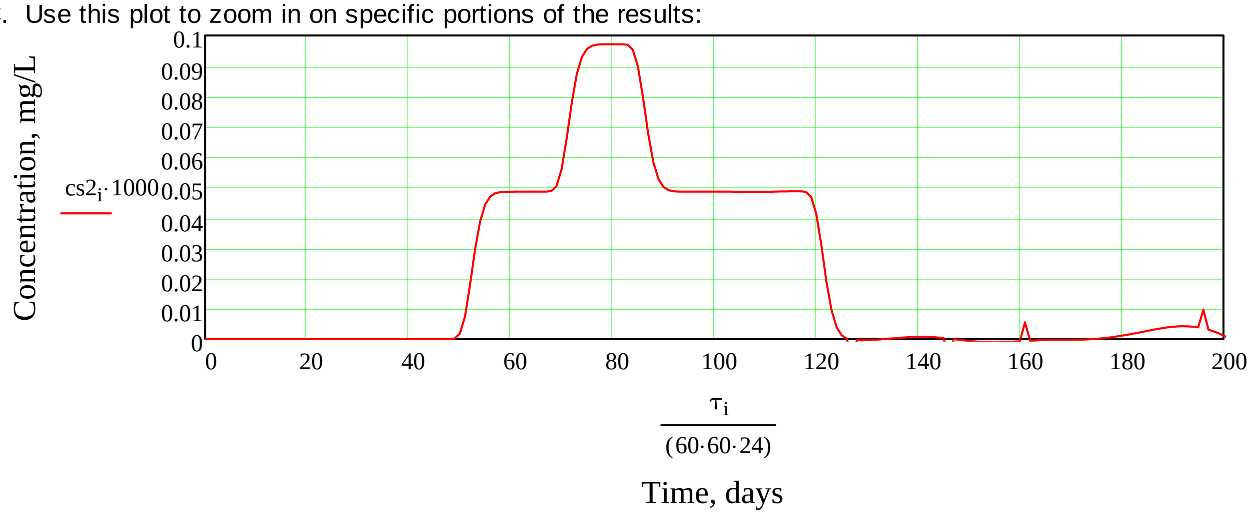
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.3 Source Definition, to Layer 3 (Bedrock):

The concentrations in 5.2 are divided up as follows, then applied as the source to Layer 3 (% peak):

A. Source to Layer 3:

number of concentration steps $j_3 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co3 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.05 \\ 0.1 \\ 0.05 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 50 \\ 55 \\ 80 \\ 120 \\ 125 \\ 1000 \end{pmatrix} day$$

Input parameters (Layer 3): This ordinate system is rotated from Layer 1 and 2. X now is Direction of Flow; Z is Lateral; and Y is vertical.

This assumes no increase in the width (b) of the plume as it moves through Layer 2 and enters Layer 3. It does apply the thickness (a) overwhich the bedrock will become satutared with the leak out of layer 2.

Half-Height of Source in Y-direction $a_3 = 19.895 \cdot ft$ Vertical Thickness (See Section 1.(F))

Half-width of Source in Z-direction $b_3 := b_1$ $b_3 = 1.167 \cdot ft$

3.3 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 3, this distance (x) - use values from Tracer Test:

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_3} := \alpha_{x\_BR}$ $\alpha_{x\_3} \cdot x_3 = 984 \cdot ft$ $\alpha x_3 := \alpha_{x\_3} \cdot x_3$ $\alpha x_3 = 984 \cdot ft$ Flow

$\alpha_{y\_3} := \alpha_{y\_BR}$ $\alpha_{y\_3} \cdot x_3 = 328 \cdot ft$ $\alpha y_3 := \alpha_{y\_3} \cdot x_3$ $\alpha y_3 = 328 \cdot ft$ Vertical

$\alpha_{z\_3} := \alpha_{z\_BR}$ $\alpha_{z\_3} \cdot x_3 = 16.4 \cdot ft$ $\alpha z_3 := \alpha_{z\_3} \cdot x_3$ $\alpha z_3 = 16.4 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_3 := \alpha x_3 \cdot v_3$ $Dx_3 = 4.92 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_3 := \alpha y_3 \cdot v_3$ $Dy_3 = 1.64 \times 10^3 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_3 := \alpha z_3 \cdot v_3$ $Dz_3 = 82 \cdot \frac{ft^2}{day}$

4.3 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 3):

$$A_3(x_3) := \left(\frac{x_3}{8\cdot\sqrt{Dx_3\cdot\pi}}\right)\cdot\exp\left(\frac{v_3\cdot x_3}{2Dx_3}\right)$$

$$B_3(x_3,t) := \exp\left(-\frac{{v_3}^2}{4\cdot Dx_3}\cdot t - \frac{{x_3}^2}{4\cdot Dx_3\cdot t}\right)$$

$$E_3(x_3,y_3,t) := \mathrm{erf}\left(\frac{b_3 - y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right) + \mathrm{erf}\left(\frac{b_3 + y_3}{2\cdot\sqrt{Dy_3\cdot t}}\right)$$

$$F_3(x_3,z_3,t) := \mathrm{erf}\left(\frac{a_3 - z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right) + \mathrm{erf}\left(\frac{a_3 + z_3}{2\cdot\sqrt{Dz_3\cdot t}}\right)$$

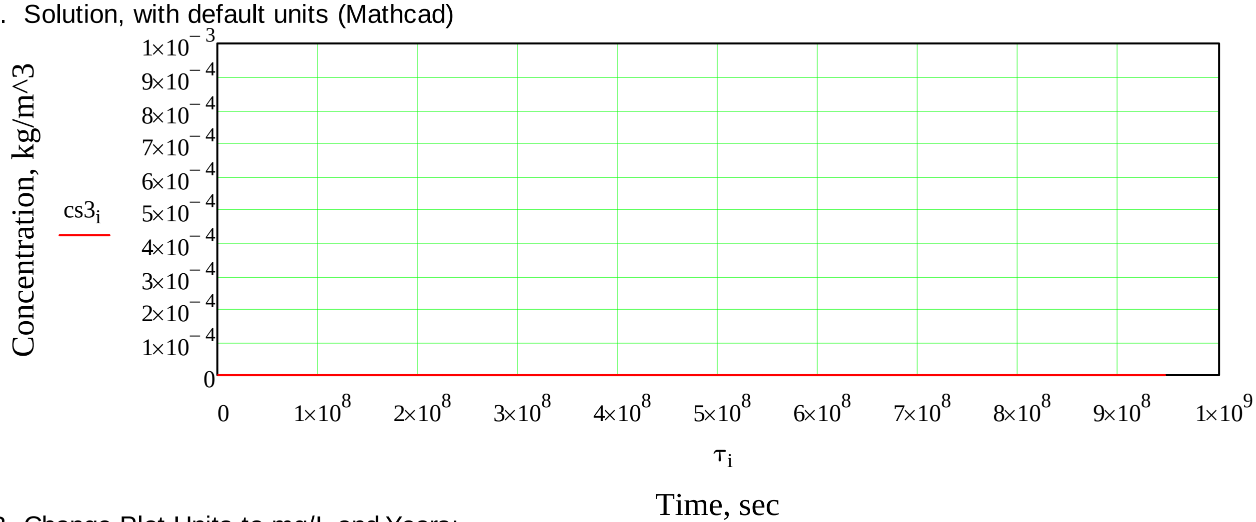
$$C_3(x_3,y_3,\eta) := A_3(x_3)\cdot\int_{0.01day}^{\eta} B_3(x_3,t)\cdot t^{-1.5}\cdot E_3(x_3,y_3,t)\cdot F_3(x_3,z_3,t)\,dt$$

$i := 1,2..10950$ $\qquad$ $\tau_i := i\cdot day$

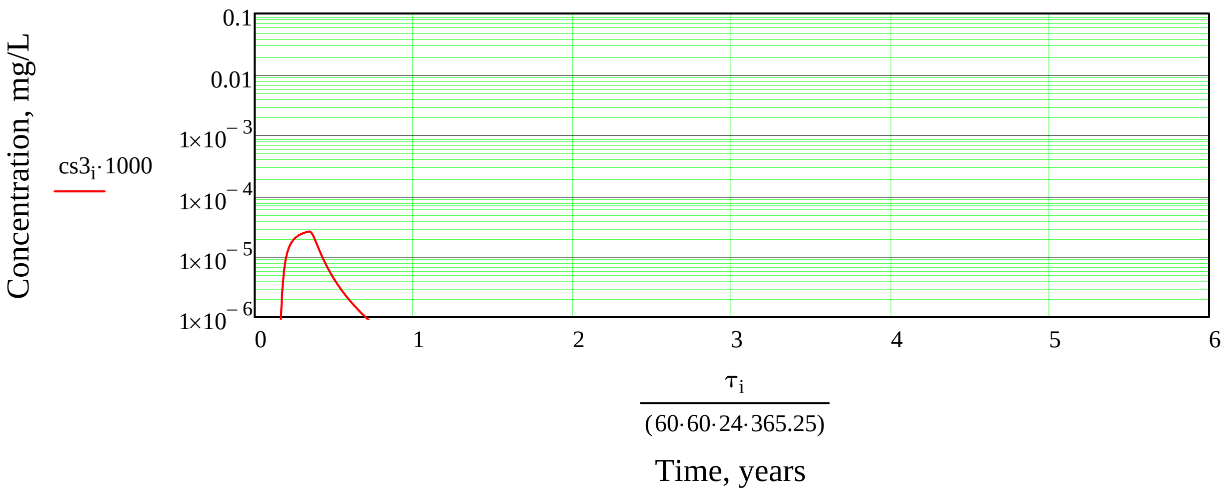
$$cs3_i := \sum_{n=1}^{j_3-1}\left[\left(\frac{co3_n + co3_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_3(x_3,y_3,\left|\tau_i - ti_{n-1}\right|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_3(x_3,y_3,\left|\tau_i - ti_n\right|)\right)\right]\right]$$

5.3 Plots of Concentration in Base of Layer 3, at X, Y and Z from Section 3.2

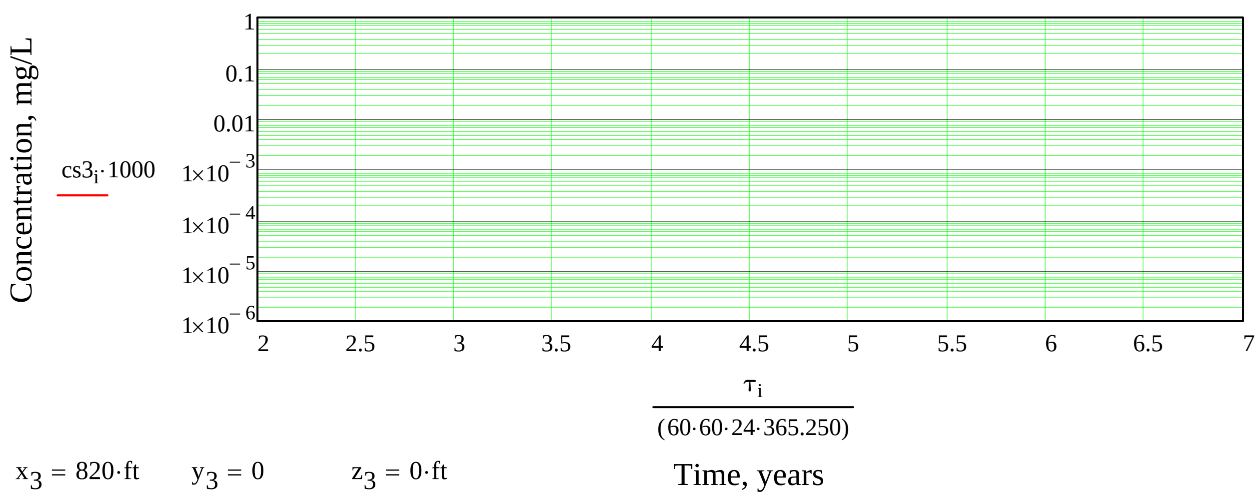
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

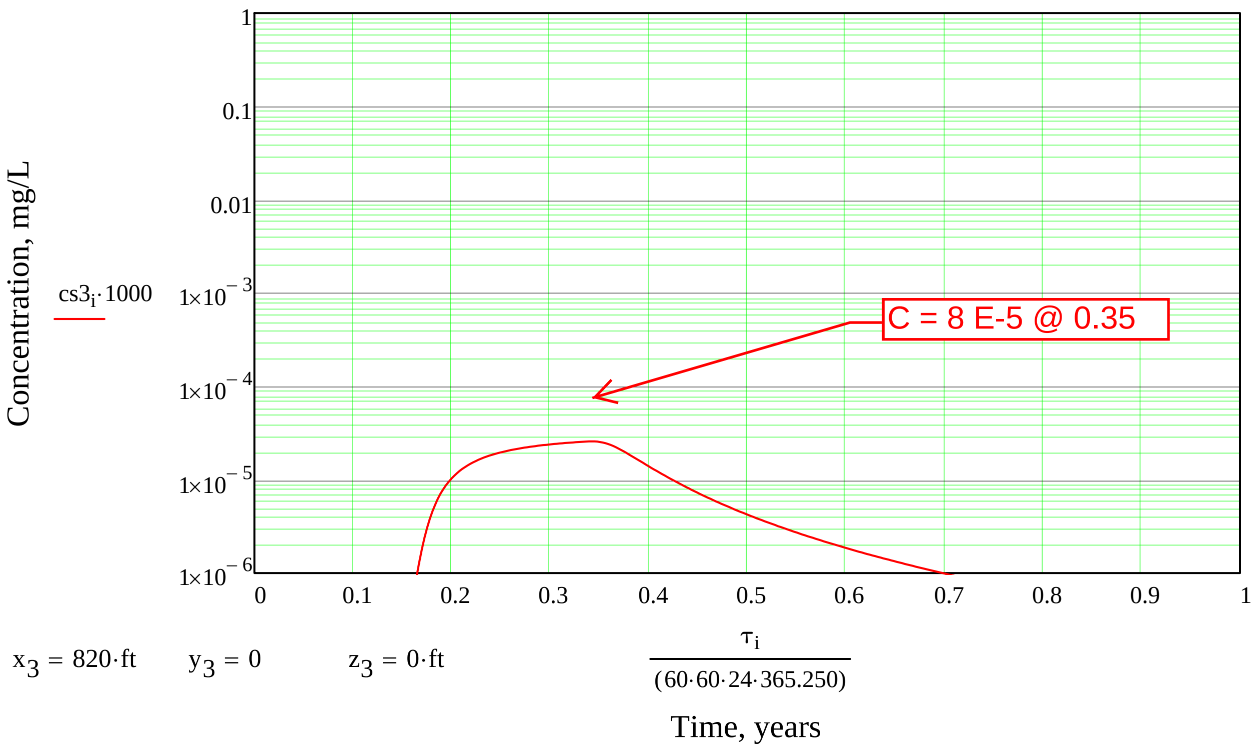


C. Concentration at 3 and 6 years (no red line indicates that the values are not within the plotted scale, if Plot A shows red line at 0 on this period, results are less than 1 x 10^{-6}.



$x_3 = 820 \cdot ft$ $y_3 = 0$ $z_3 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_3 = 820 \cdot ft$ $y_3 = 0$ $z_3 = 0 \cdot ft$

SUMMARY OF SENSITIVITY ANALYSIS – CONTAMINANT TRANSPORT EVALUATION

Hydraulic Properties Used in Contaminant Transport Analysis	***Base Condition***	***Sensitivity Analysis***	***Base Condition***	***Sensitivity Analysis***
	Concentration (mg/L) at 3 Years		*Time to Reach Maximum, Years (Concentration, mg/L)*	
Common Borrow and Till Hydraulic Conductivity (cm/sec): Base: 9.4×10^{-6} Sensitivity: 1.7×10^{-5}	0.00066	0.00098	6 (0.0029)	6 (0.0036)
Effective Porosity: Base: 0.25 Sensitivity: 0.18	0.00066	0.00098	6 (0.0029)	6 (0.0036)
Dispersivity (α, ft): Base: Note 1 Sensitivity, Low: Note 2 Sensitivity, High: Note 3	0.00066	<0.00033 0.00036	6 (0.0029)	11 (0.036) 1 (0.0016)

NOTES:
1. Base:
   Common Borrow, Vertical: $\alpha_x = 0.01$; $\alpha_y = \alpha_z = 0.01$
   Till, Horizontal: $\alpha_x = 0.15$; $\alpha_y = \alpha_z = 0.01$
2. Sensitivity, Low:
   Common Borrow, Vertical: $\alpha_x = 0.001$; $\alpha_y = \alpha_z = 0.001$
   Till, Horizontal: $\alpha_x = 0.015$; $\alpha_y = \alpha_z = 0.001$
3. Sensitivity, High:
   Common Borrow, Vertical: $\alpha_x = 0.1$; $\alpha_y = \alpha_z = 0.1$
   Till, Horizontal: $\alpha_x = 1.5$; $\alpha_y = \alpha_z = 0.1$

SENSITIVITY ANALYSIS - JRL - Expansion Contaminant Transport Evaluation - Leaky Pipe - Western Flow

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on West Side of Cell 14. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor E.**
Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1 Common Borrow	LAYER 2 Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 1.7 \cdot 10^{-5} \frac{cm}{sec}$	$k_2 := 1.7 \cdot 10^{-5} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 5ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 11 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 2.2$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 555.137 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.386 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.424 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 3.455 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_14} := 200.6ft$ $\quad Head_E := 72ft$

$i_2 := \frac{(Head_{Cell\_14} + \Delta H_1) - Head_E}{700ft}$ $\quad i_2 = 0.199$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 0.038 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.519$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe West of Cell 14):

distance of interest (x): $x_2 := 440ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 9.895 \cdot ft$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 5 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.05 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.05 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.05 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.05 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.05 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.05 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 440 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 66 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 66 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 4.4 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 4.4 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.424 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 5 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.021 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.021 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.021 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

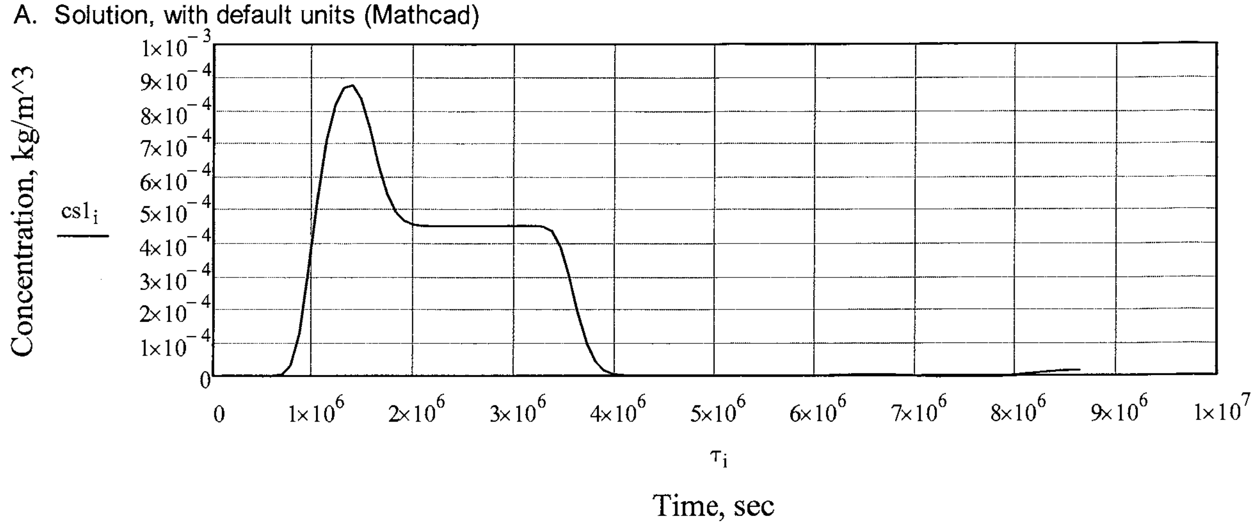
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\qquad\qquad$ $\tau_i := i\cdot day$

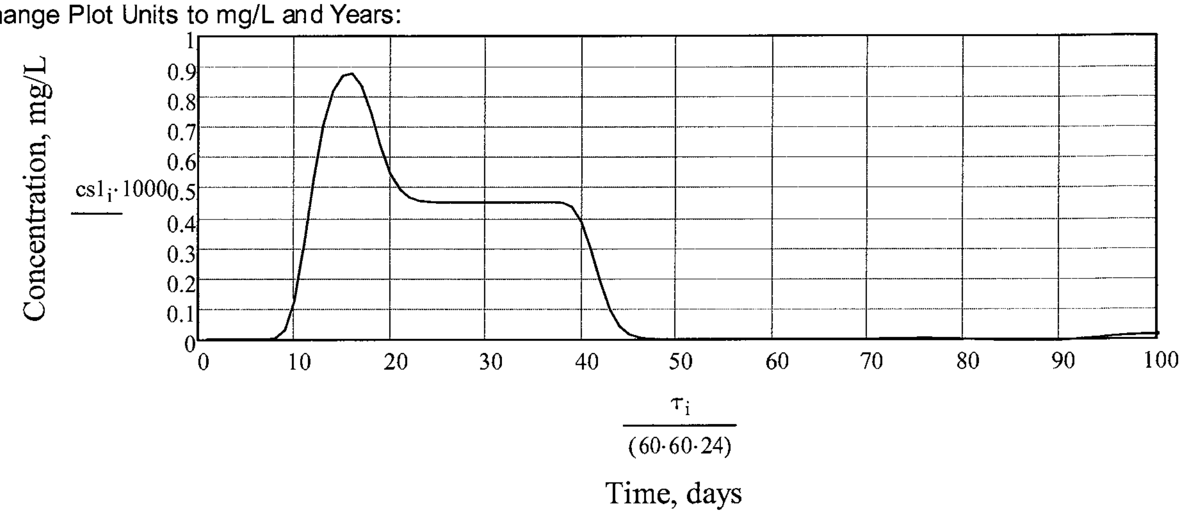
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1(x_1,y_1,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1(x_1,y_1,|\tau_i - ti_n|)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

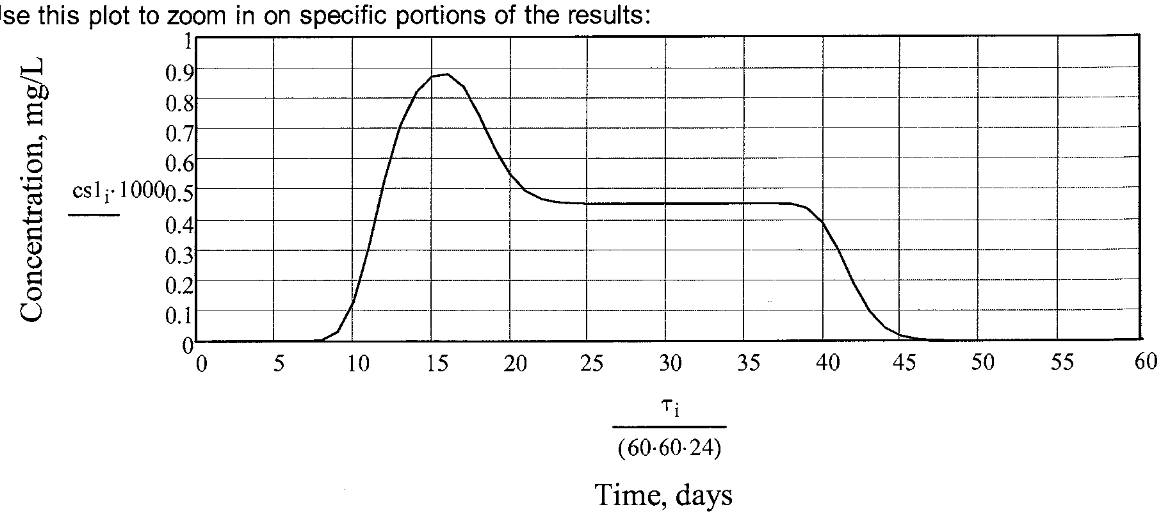
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration

Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.9 \\ 0.9 \\ 0.45 \\ 0.45 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 15 \\ 13 \\ 17 \\ 22 \\ 40 \\ 46 \end{pmatrix} day$$

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 9.895 \cdot ft$

Exceeds till thickness

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

$\alpha_{x\_2} = 0.15$	$\alpha_{x\_2} \cdot x_2 = 66 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 66 \cdot ft$	Flow
$\alpha_{y\_2} = 0.01$	$\alpha_{y\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 4.4 \cdot ft$	Vertical
$\alpha_{z\_2} = 0.01$	$\alpha_{z\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 4.4 \cdot ft$	Lateral

Note: This was rotated to use correct orientation from Tracer Test.

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $\quad Dx_2 = 6.6 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $\quad Dy_2 = 0.44 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $\quad Dz_2 = 0.44 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{v_2^{\,2}}{4\cdot Dx_2}\cdot t - \frac{x_2^{\,2}}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

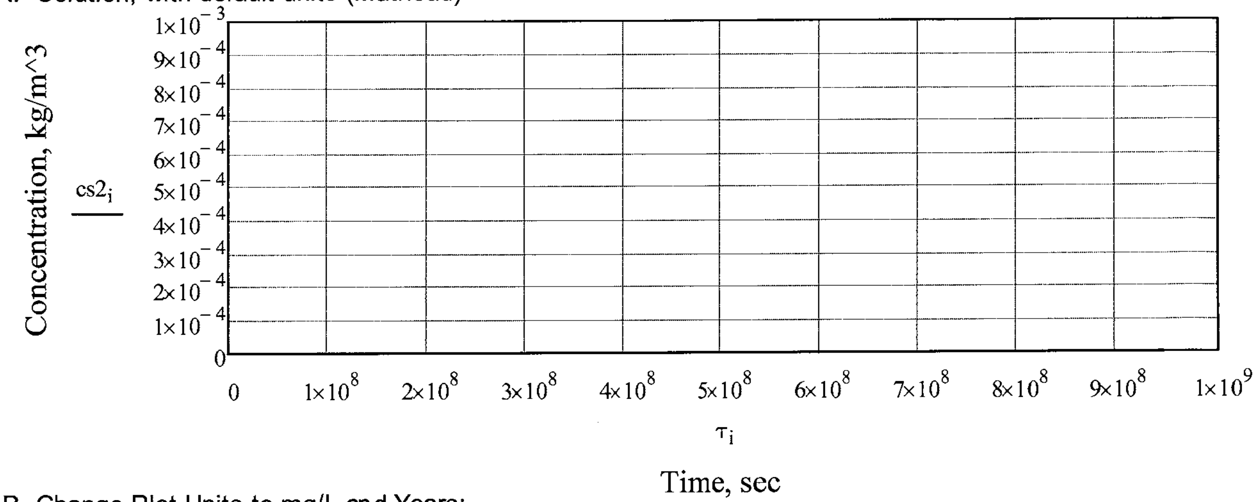
$i := 1,2..10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{day}$$

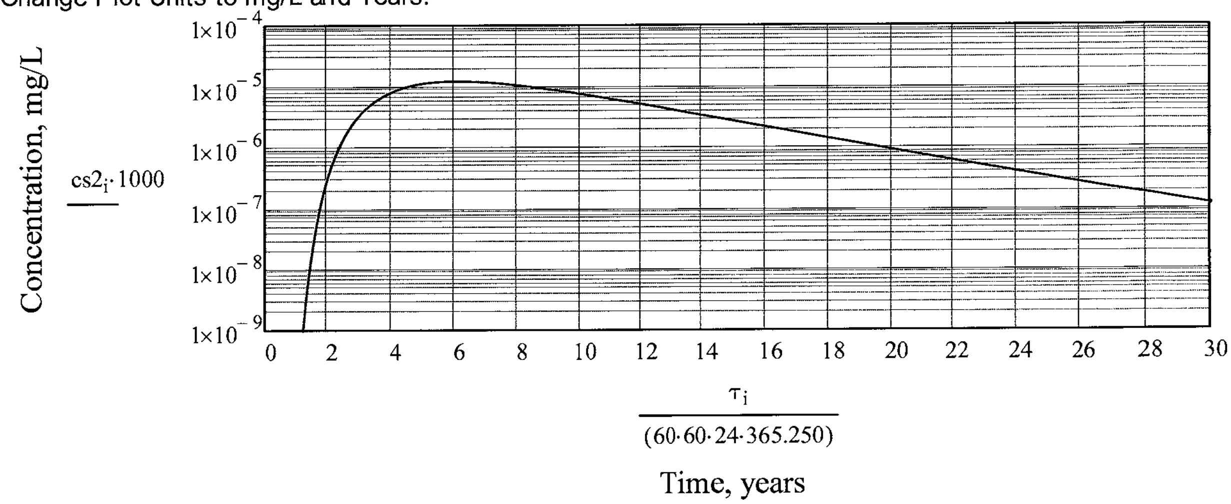
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

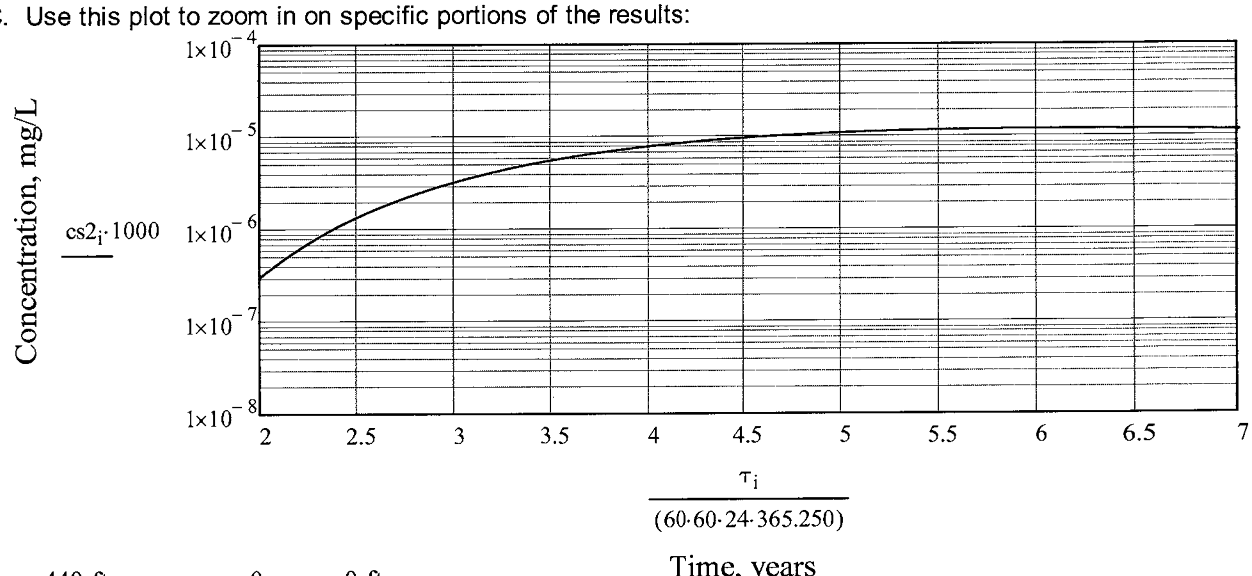
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

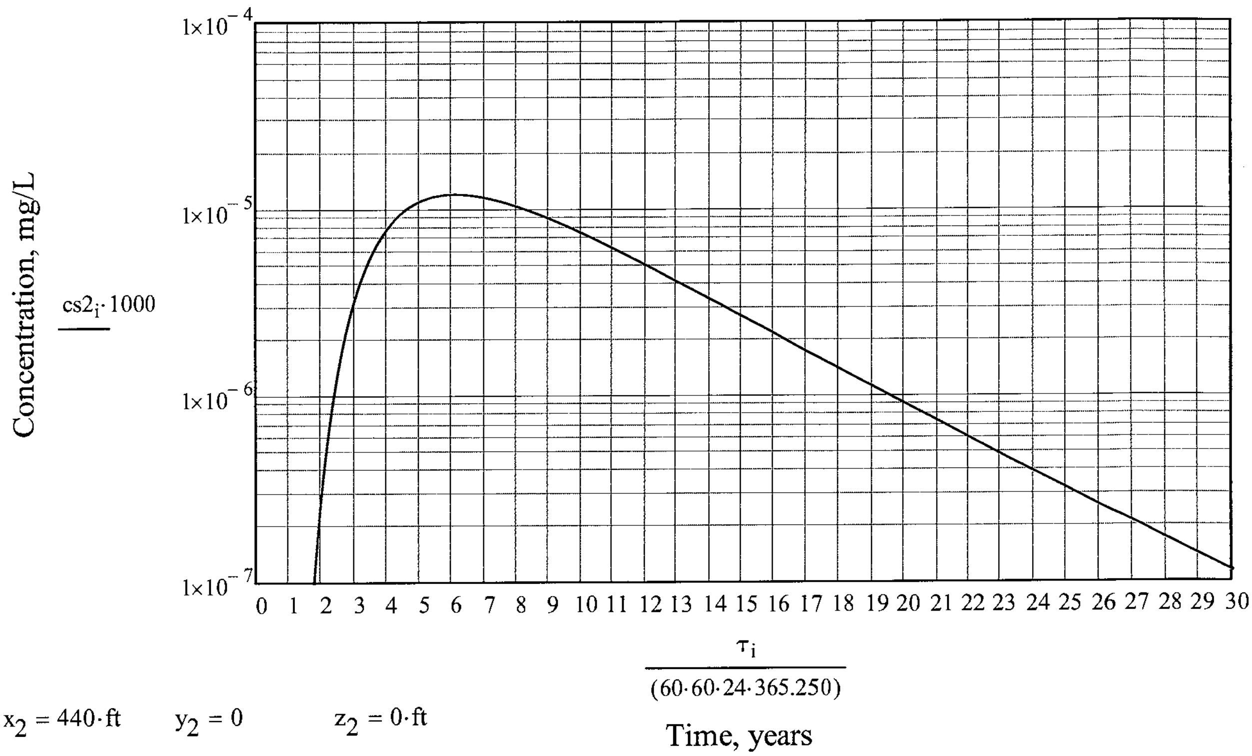


C. Use this plot to zoom in on specific portions of the results:



$x_2 = 440 \cdot ft$ $\quad y_2 = 0 \quad z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 440 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

SENSITIVITY ANALYSIS JRL - Expansion Contaminant Transport Evaluation - Leaky Pipe - Western Flow

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on West Side of Cell 14. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor E.**
Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1 Common Borrow	LAYER 2 Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 5ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 11 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 2.2$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 306.958 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.213 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.234 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 1.91 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_14} := 200.6ft$ $\quad Head_E := 72ft$

$i_2 := \frac{(Head_{Cell\_14} + \Delta H_1) - Head_E}{700ft}$ $\quad i_2 = 0.199$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 0.021 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.938$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe West of Cell 14):

distance of interest (x): $x_2 := 440ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 5.471 \cdot ft$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.001$	$x_1 = 5 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 5 \times 10^{-3} \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 5 \times 10^{-3} \cdot ft$	Flow
$\alpha_{y\_1} := 0.001$		$\alpha_{y\_1} \cdot x_1 = 5 \times 10^{-3} \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 5 \times 10^{-3} \cdot ft$	Lateral
$\alpha_{z\_1} := 0.001$		$\alpha_{z\_1} \cdot x_1 = 5 \times 10^{-3} \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 5 \times 10^{-3} \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.015$	$x_2 = 440 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 6.6 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 6.6 \cdot ft$	Flow
$\alpha_{y\_2} := 0.001$		$\alpha_{y\_2} \cdot x_2 = 0.44 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 0.44 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.001$		$\alpha_{z\_2} \cdot x_2 = 0.44 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 0.44 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L}$ $ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.234 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 5 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 1.172 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 1.172 \times 10^{-3} \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 1.172 \times 10^{-3} \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \operatorname{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \operatorname{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \operatorname{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \operatorname{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

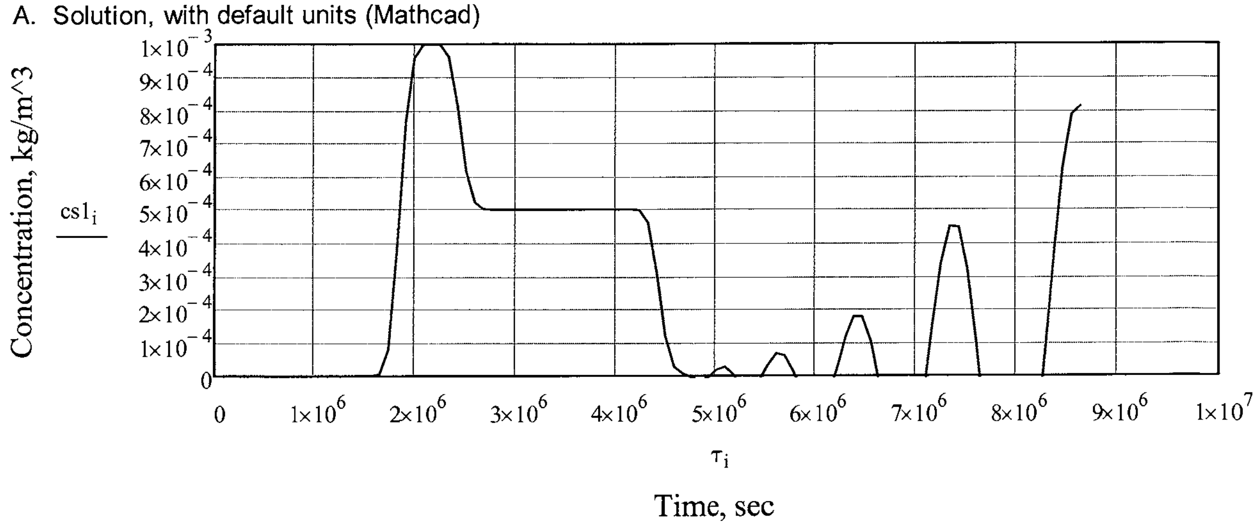
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01day}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\tau_i := i\cdot day$

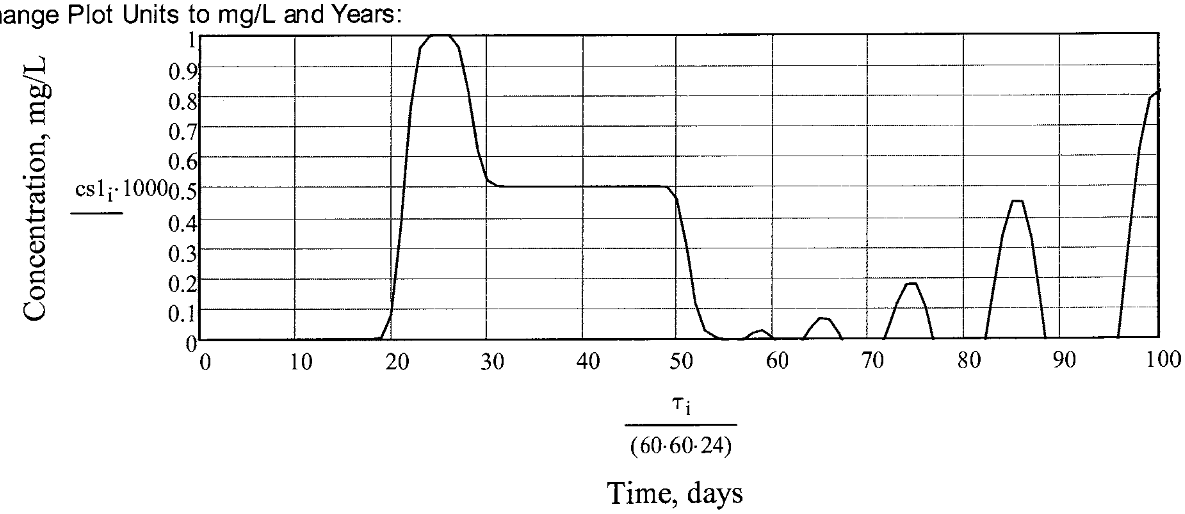
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1(x_1,y_1,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1(x_1,y_1,|\tau_i - ti_n|)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

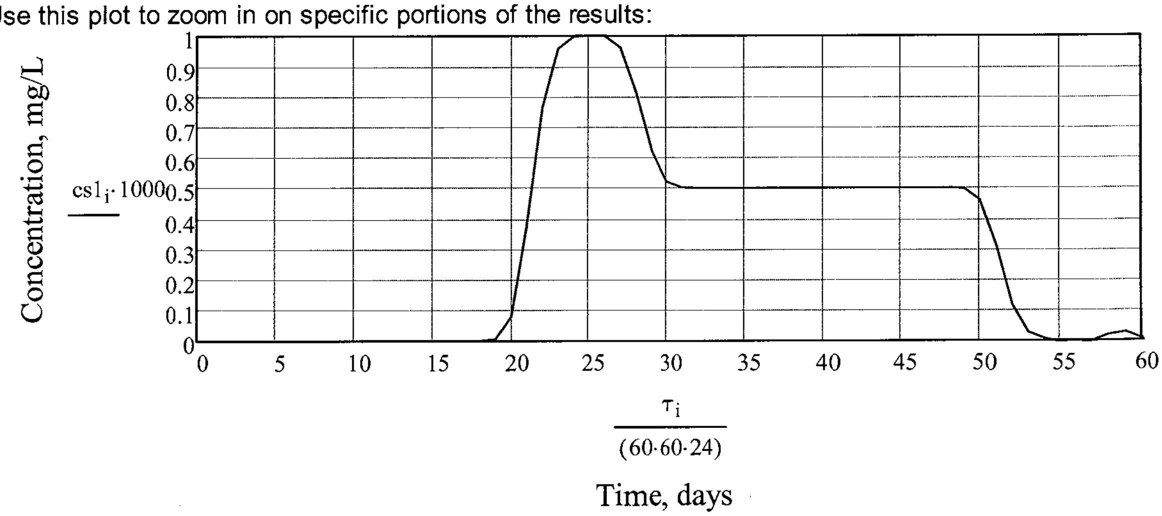
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 1 \\ 1 \\ .5 \\ .5 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 15 \\ 23 \\ 27 \\ 30 \\ 50 \\ 60 \end{pmatrix} day$$

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 5.471 \cdot ft$ **Exceeds till thickness**

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.015$ $\alpha_{x\_2} \cdot x_2 = 6.6 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 6.6 \cdot ft$ Flow

$\alpha_{y\_2} = 1 \times 10^{-3}$ $\alpha_{y\_2} \cdot x_2 = 0.44 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 0.44 \cdot ft$ Vertical

$\alpha_{z\_2} = 1 \times 10^{-3}$ $\alpha_{z\_2} \cdot x_2 = 0.44 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 0.44 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 0.66 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.044 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.044 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{v_2^{\ 2}}{4\cdot Dx_2}\cdot t - \frac{x_2^{\ 2}}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \text{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \text{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \text{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \text{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01\text{day}}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

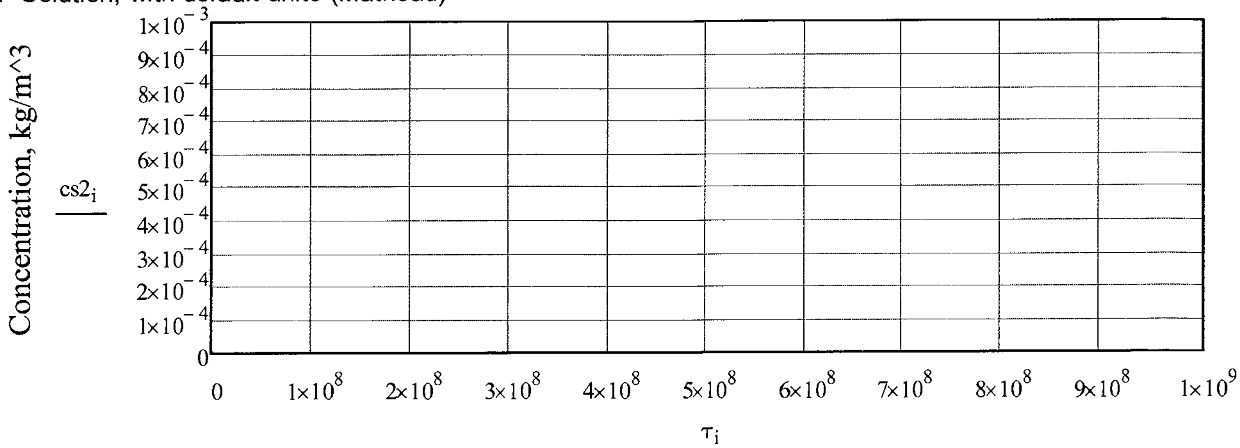
$i := 1,2..10950$ $\qquad$ $\tau_i := i\cdot\text{day}$

$$v_2 = 0.1\cdot\frac{\text{ft}}{\text{day}}$$

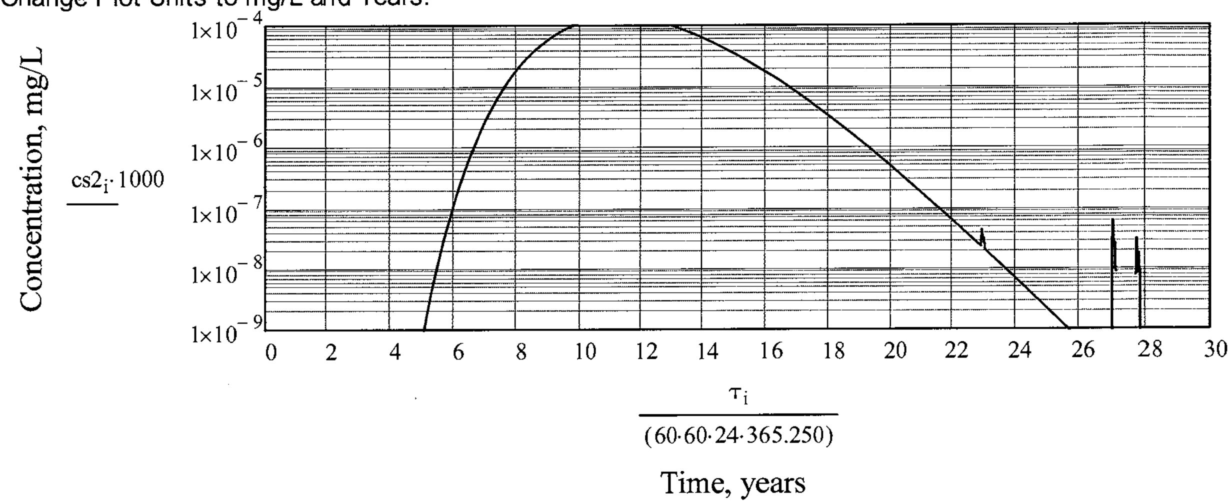
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2(x_2,y_2,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2(x_2,y_2,|\tau_i - ti_n|)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

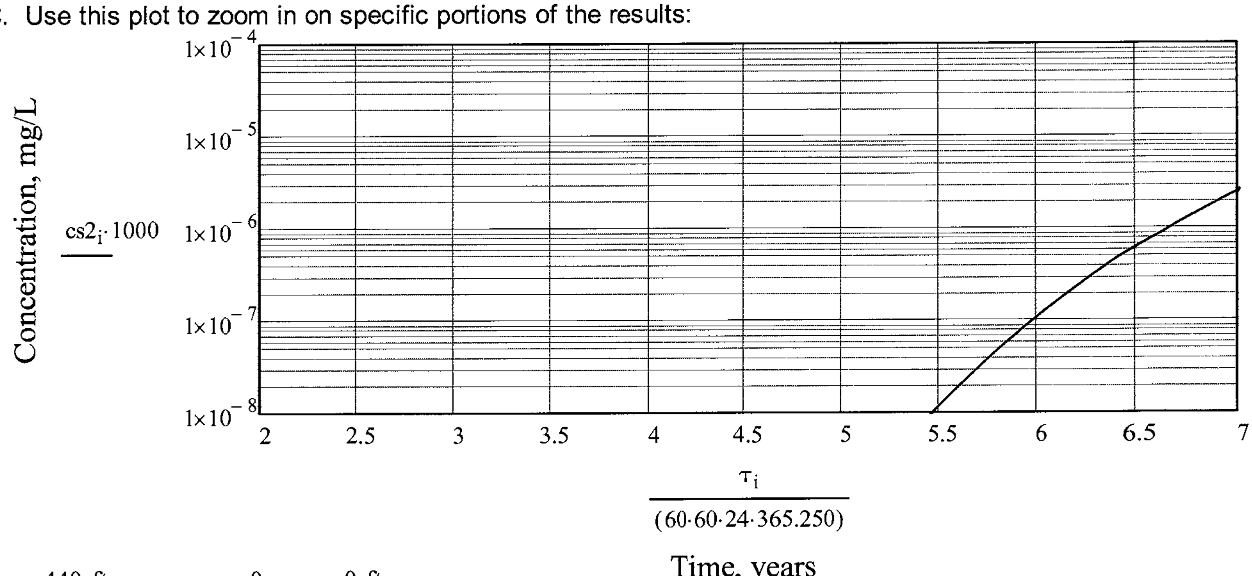
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

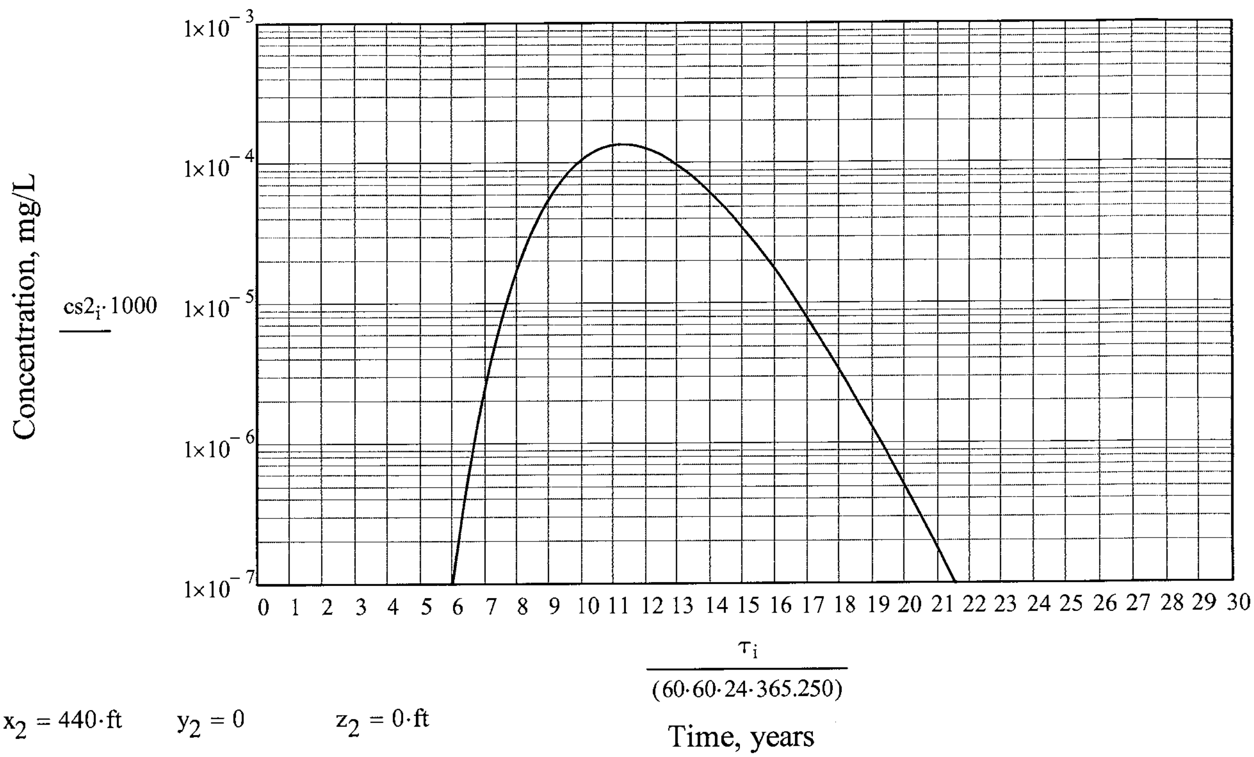


C. Use this plot to zoom in on specific portions of the results:



$x_2 = 440 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 440 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

SENSITIVITY ANALYSIS JRL - Expansion Contaminant Transport Evaluation - Leaky Pipe - Western Flow

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on West Side of Cell 14. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor E.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $\qquad Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1 Common Borrow	LAYER 2 Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.25$	$n_2 := 0.25$
Distance in flow direction (x)	$x_1 := 5ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\qquad \Delta H_1 := x_1 + H_1$ $\qquad \Delta H_1 = 11 \cdot ft$

Hydraulic gradient (i) $\qquad i_1 := \frac{\Delta H_1}{x_1}$ $\qquad i_1 = 2.2$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 306.958 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.213 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.234 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 1.91 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_14} := 200.6ft$ $\quad Head_E := 72ft$

$i_2 := \frac{(Head_{Cell\_14} + \Delta H_1) - Head_E}{700ft}$ $\quad i_2 = 0.199$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 0.021 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.938$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe West of Cell 14):

distance of interest (x): $x_2 := 440ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 5.471 \cdot ft$ $\quad$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.1$	$x_1 = 5 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.5 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.5 \cdot ft$	Flow
$\alpha_{y\_1} := 0.1$		$\alpha_{y\_1} \cdot x_1 = 0.5 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.5 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.1$		$\alpha_{z\_1} \cdot x_1 = 0.5 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.5 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 1.5$	$x_2 = 440 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 660 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 660 \cdot ft$	Flow
$\alpha_{y\_2} := 0.1$		$\alpha_{y\_2} \cdot x_2 = 44 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 44 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.1$		$\alpha_{z\_2} \cdot x_2 = 44 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 44 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.234 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 5 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.117 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.117 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.117 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{v_1^{\,2}}{4\cdot Dx_1}\cdot t - \frac{x_1^{\,2}}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \text{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \text{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \text{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \text{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

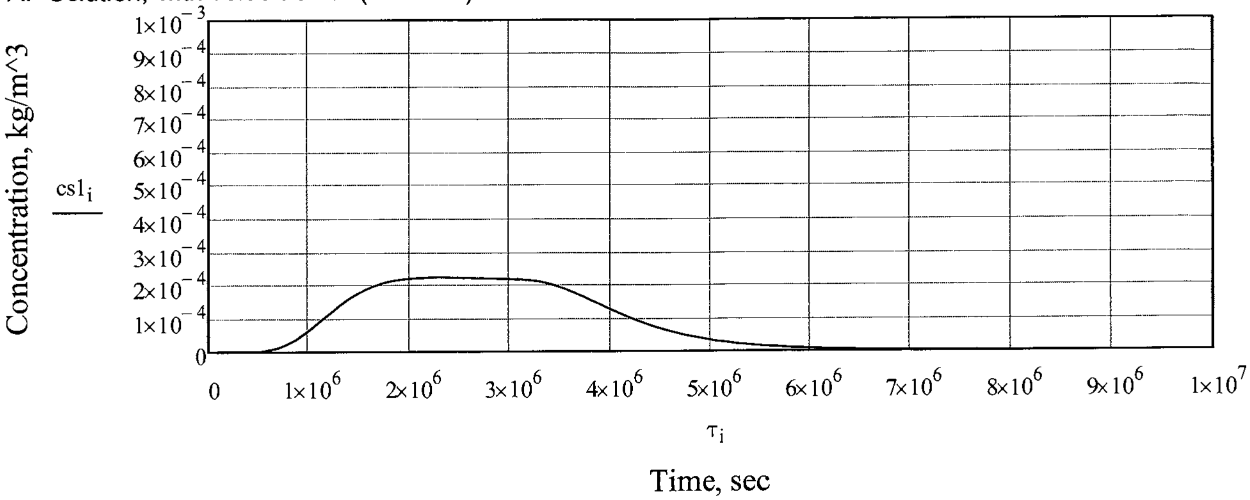
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01\text{day}}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\tau_i := i\cdot\text{day}$

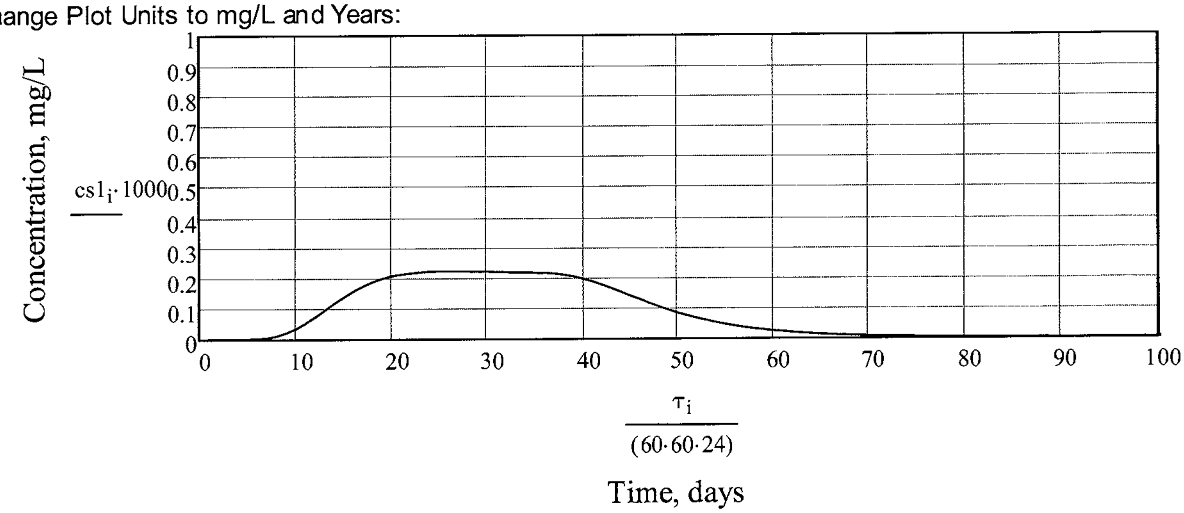
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1(x_1,y_1,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1(x_1,y_1,|\tau_i - ti_n|)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

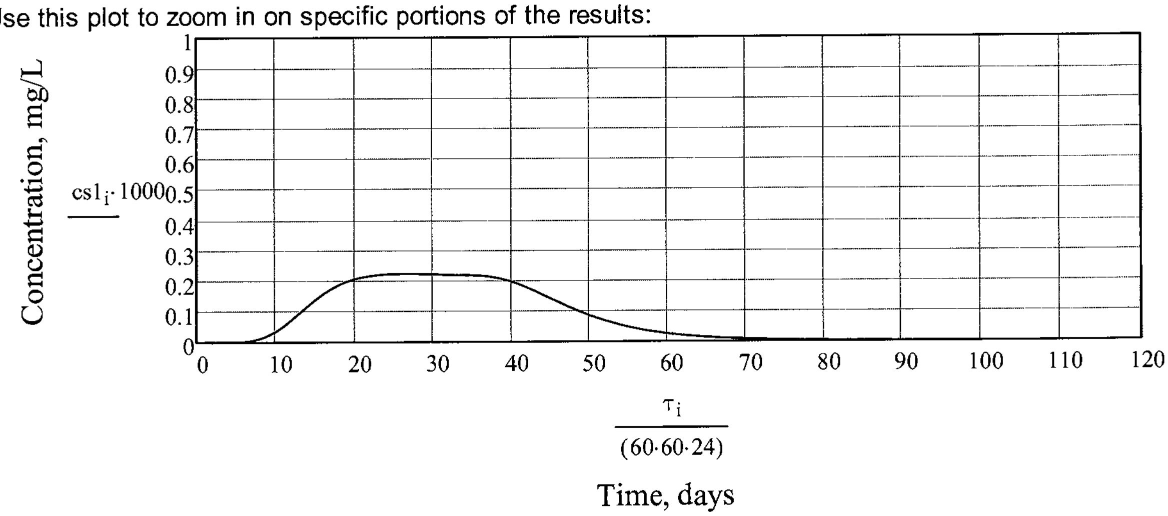
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration / Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.25 \\ 0.25 \\ 0.1 \\ 0.03 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 20 \\ 40 \\ 50 \\ 60 \\ 70 \end{pmatrix} day$$

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 5.471 \cdot ft$ **Exceeds till thickness**

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

$\alpha_{x\_2} = 1.5$ $\quad \alpha_{x\_2} \cdot x_2 = 660 \cdot ft$ $\quad \alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\quad \alpha x_2 = 660 \cdot ft$ Flow

$\alpha_{y\_2} = 0.1$ $\quad \alpha_{y\_2} \cdot x_2 = 44 \cdot ft$ $\quad \alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\quad \alpha y_2 = 44 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.1$ $\quad \alpha_{z\_2} \cdot x_2 = 44 \cdot ft$ $\quad \alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\quad \alpha z_2 = 44 \cdot ft$ Lateral

Note: This was rotated to use correct orientation from Tracer Test.

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $\quad Dx_2 = 66 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $\quad Dy_2 = 4.4 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $\quad Dz_2 = 4.4 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{{v_2}^2}{4\cdot Dx_2}\cdot t - \frac{{x_2}^2}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \operatorname{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \operatorname{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \operatorname{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \operatorname{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01\mathrm{day}}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

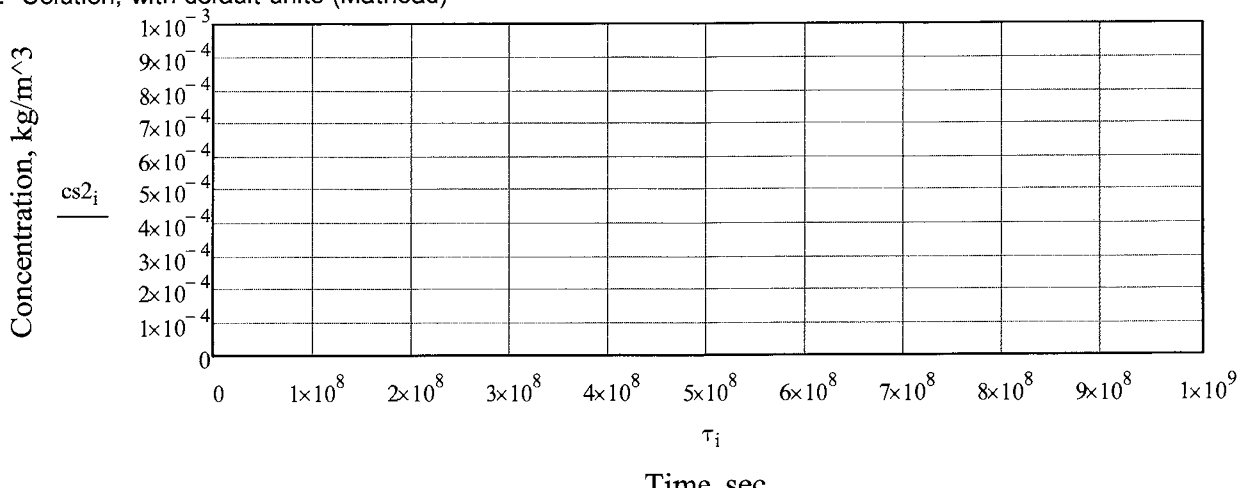
$i := 1,2..10950$ $\tau_i := i\cdot \mathrm{day}$

$$v_2 = 0.1\cdot\frac{\mathrm{ft}}{\mathrm{day}}$$

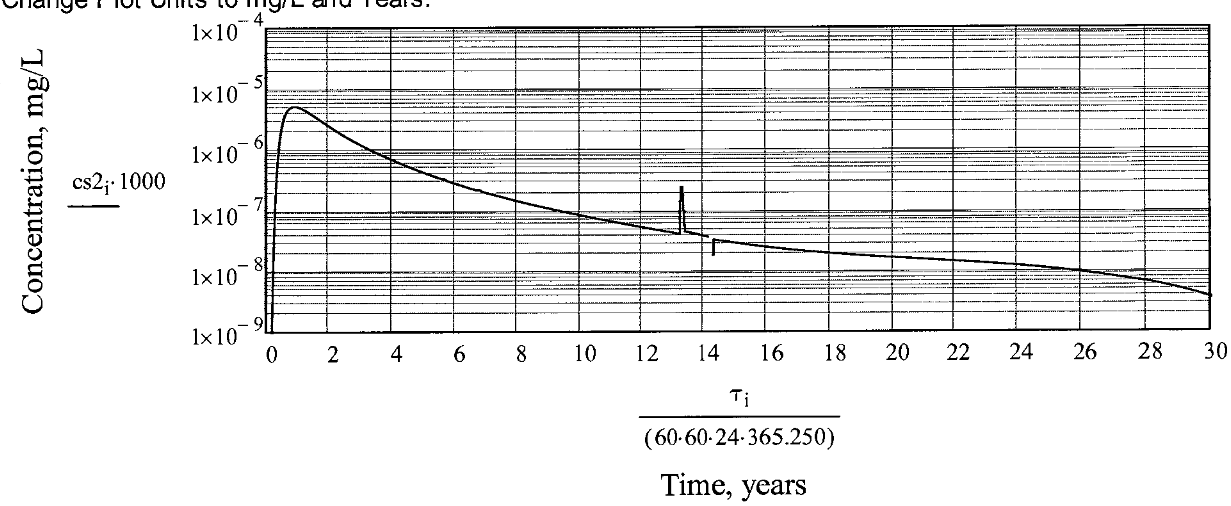
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2(x_2,y_2,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2(x_2,y_2,|\tau_i - ti_n|)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

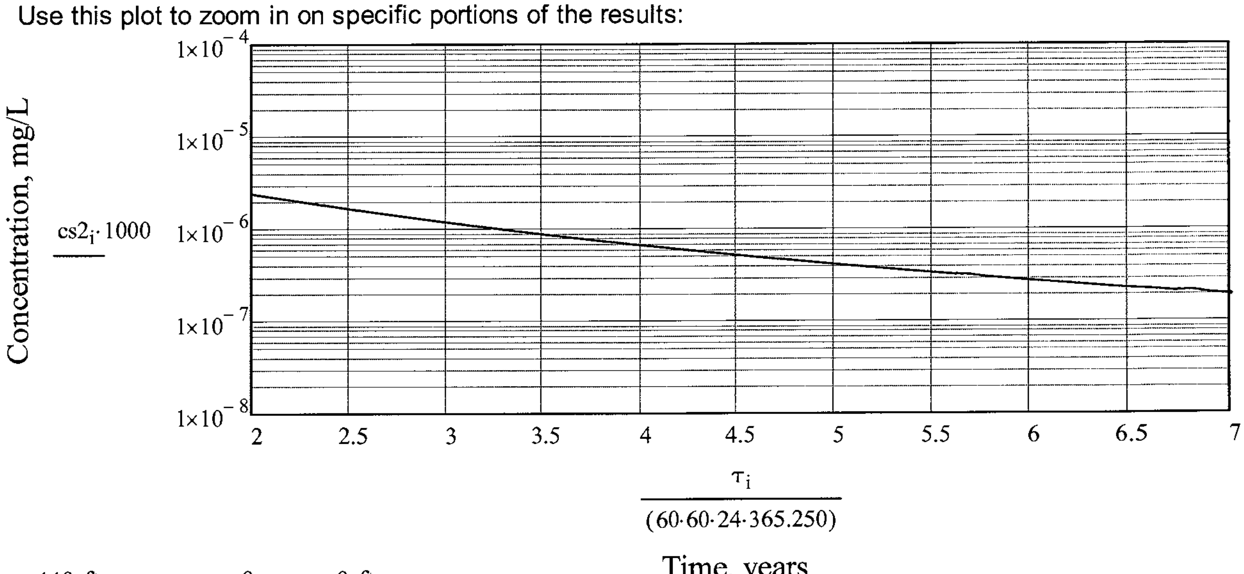
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

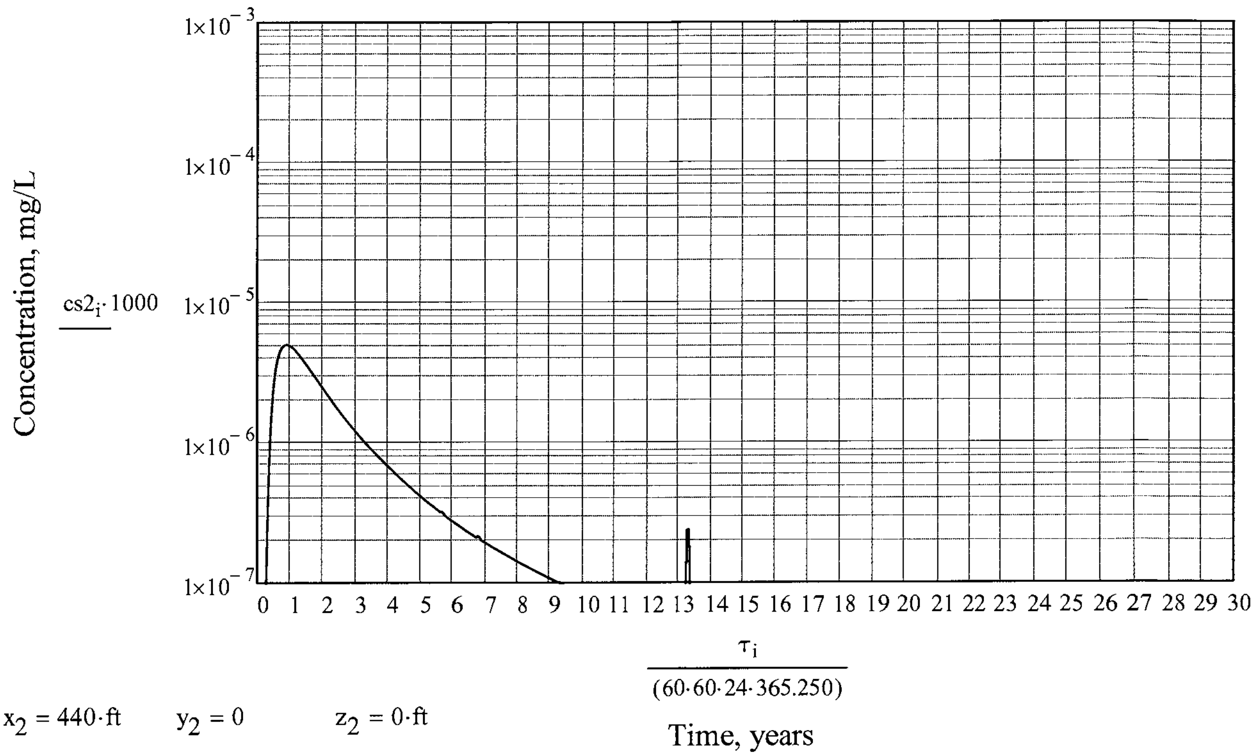


C. Use this plot to zoom in on specific portions of the results:



$x_2 = 440 \cdot ft$ $\quad y_2 = 0 \quad z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 440 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

SENSITIVITY ANALYSIS - JRL - Expansion Contaminant Transport Evaluation - Leaky Pipe - Western Flow

This calculation evaluated a two layered system, by superimposing the solution from the first layer as the influent concentration to the second layerand so on.

Leakey Force Main on West Side of Cell 14. Berm Fill Soil is included above the Till. Flow is vertically down through Layer 1 (Common Borrow); then horizontally through Layer 2 (Till). **Flow is toward Site Sensitive Receptor E.**

Section Numbers relate to Topics and Sub-sections indicate layers.

1.0 Problem Definition

Leak Definition (Width is perpendicular to the horizontal flow direction):

Z axis (all layers) $Width_1 := 28in$ Southeast - Northwest

$Length_1 := 300ft$ Layers 1,2 = Northeast - Southwest (Y-axis)

$Area_1 := Length_1 \cdot Width_1$ $Area_1 = 0.016 \cdot acre$

A. Material Properties:

PARAMETER	LAYER 1 Common Borrow	LAYER 2 Till (Horizontal)
Hydraulic conductivity (k)	$k_1 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$	$k_2 := 9.4 \cdot 10^{-6} \frac{cm}{sec}$
Porosity (n)	$n_1 := 0.18$	$n_2 := 0.18$
Distance in flow direction (x)	$x_1 := 5ft$	X3 defined in Section 3.2

B. Hydraulic conditions applied are:

Assume the head in the trench is at ground surface. Layer 1 is free draining and sets the system flow rate.

Head in Trench: $H_1 := 6ft$ $\Delta H_1 := x_1 + H_1$ $\Delta H_1 = 11 \cdot ft$

Hydraulic gradient (i) $i_1 := \frac{\Delta H_1}{x_1}$ $i_1 = 2.2$

C. Calculate flow rate through Layer 1 & 2:

$Q_1 := k_1 \cdot i_1 \cdot Area_1$ $\quad Q_1 = 306.958 \cdot \frac{gal}{day}$ $\quad Q_2 := Q_1$ $\quad Q_1 = 0.213 \cdot \frac{gal}{min}$

$v_1 := \frac{Q_1}{n_1 \cdot Area_1}$ $\quad v_1 = 0.326 \cdot \frac{ft}{day}$ $\quad LQ := \frac{Q_1}{Area_1}$ $\quad LQ = 1.91 \times 10^4 \cdot \frac{\frac{gal}{acre}}{day}$

Velocity in Till, based on groundwater contours, from Fig 5-1:

$Head_{Cell\_14} := 200.6ft$ $\quad Head_E := 72ft$

$i_2 := \frac{(Head_{Cell\_14} + \Delta H_1) - Head_E}{700ft}$ $\quad i_2 = 0.199$ $\quad v_{gw} := \frac{k_2 \cdot i_2}{n_2}$ $\quad v_{gw} = 0.03 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Using Tewey's velocity: $V_t := 38 \frac{ft}{yr}$ $\quad V_t = 0.104 \cdot \frac{ft}{day}$

JES has velocity = 0.03 ft/day as determined in the Till Tracer Test

Velocity in the Till, used in this calculation: $v_2 := 0.1 \frac{ft}{day}$

D. Calculate the hydraulic gradient through layer 2:

$i_2 := \frac{v_2 \cdot n_2}{(k_2)}$ $\quad i_2 = 0.676$

E. Locations of Site Sensitive Receptors (Where concentrations are calculated)

Change X and Z based on Distance to Site Sensitive Receptor (from Leachate Pipe West of Cell 14):

distance of interest (x): $x_2 := 440ft$ to Sensitive Receptor (in Till)

Vertical depth of interest (y): $y_2 := 0ft$ Vertical (Depth) Concentration is maximum at y=0

Lateral distance of interest (z): $z_2 := 0ft$ Lateral

F. Determine the thickness that the leak travels into the till (a_2), this is the source size in Till.

$a_2 := \frac{Q_1}{Length_1 \cdot n_2 \cdot v_2}$ $\quad a_2 = 7.599 \cdot ft$ Y Direction in Layer 2 (Vertical)

2.0 Dispersivity Assumptions

2.1 Dispersivity in Layer 1 (Common Borrow Layer):

Assume that the Common Borrow has uniform dispersivity of 0.01/ft (X, Y and Z).

					Direction
$\alpha_{x\_1} := 0.01$	$x_1 = 5 \cdot ft$	$\alpha_{x\_1} \cdot x_1 = 0.05 \cdot ft$	$\alpha x_1 := \alpha_{x\_1} \cdot x_1$	$\alpha x_1 = 0.05 \cdot ft$	Flow
$\alpha_{y\_1} := 0.01$		$\alpha_{y\_1} \cdot x_1 = 0.05 \cdot ft$	$\alpha y_1 := \alpha_{y\_1} \cdot x_1$	$\alpha y_1 = 0.05 \cdot ft$	Lateral
$\alpha_{z\_1} := 0.01$		$\alpha_{z\_1} \cdot x_1 = 0.05 \cdot ft$	$\alpha z_1 := \alpha_{z\_1} \cdot x_1$	$\alpha z_1 = 0.05 \cdot ft$	Lateral

2.2 Dispersion in Layer 2 (Till):

					Direction
$\alpha_{x\_2} := 0.15$	$x_2 = 440 \cdot ft$	$\alpha_{x\_2} \cdot x_2 = 66 \cdot ft$	$\alpha x_2 := \alpha_{x\_2} \cdot x_2$	$\alpha x_2 = 66 \cdot ft$	Flow
$\alpha_{y\_2} := 0.01$		$\alpha_{y\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha y_2 := \alpha_{y\_2} \cdot x_2$	$\alpha y_2 = 4.4 \cdot ft$	Vertical
$\alpha_{z\_2} := 0.01$		$\alpha_{z\_2} \cdot x_2 = 4.4 \cdot ft$	$\alpha z_2 := \alpha_{z\_2} \cdot x_2$	$\alpha z_2 = 4.4 \cdot ft$	Lateral

3.1 Source Definition, to Layer 1 (Road Fill):

number of concentration steps $j_1 := 4$

Iteration intervals $i := 1, 2 .. 10950$

Concentration (mg/l) Source Term (days)

$$co := \begin{pmatrix} 1.00 \\ 1.00 \\ 0.00 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 7 \\ 30 \\ 10950 \end{pmatrix} \cdot day$$

This is a continuous source for 7 days, decaying from 7 to 30 days from 100 to 0, then it travels for 30 years.

Input Parameters: For Layer 1

A. Calculate Source Dimentions (this is a half-space solution)

Half-Length of Source in Y-direction $a_1 := \frac{Length_1}{2}$ $a_1 = 150 \cdot ft$

Half-Width of Source in Z-direction $b_1 := \frac{Width_1}{2}$ $b_1 = 1.167 \cdot ft$

B. Calculated breakthough curve (after Cleary and Ungs, 1978):

Velocity (from above) $v_1 = 0.326 \cdot \frac{ft}{day}$

Distance of interest (x): $x_1 = 5 \cdot ft$ to Top of Layer 2

Lateral distance of interest (y): $y_1 := 0ft$

Lateral distance of interest (z): $z_1 := 0ft$

Y&Z = 0 yields the maximum concentration

longitudinal dispersion coef. (x): $Dx_1 := \alpha x_1 \cdot v_1$ $Dx_1 = 0.016 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_1 := \alpha y_1 \cdot v_1$ $Dy_1 = 0.016 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_1 := \alpha z_1 \cdot v_1$ $Dz_1 = 0.016 \cdot \frac{ft^2}{day}$

4.1 Equations to determine concentration at any point X,Y and Z at any time (t):

$$A_1(x_1) := \left(\frac{x_1}{8\cdot\sqrt{Dx_1\cdot\pi}}\right)\cdot\exp\left(\frac{v_1\cdot x_1}{2Dx_1}\right)$$

$$B_1(x_1,t) := \exp\left(-\frac{{v_1}^2}{4\cdot Dx_1}\cdot t - \frac{{x_1}^2}{4\cdot Dx_1\cdot t}\right)$$

$$E_1(x_1,y_1,t) := \mathrm{erf}\left(\frac{b_1 - y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right) + \mathrm{erf}\left(\frac{b_1 + y_1}{2\cdot\sqrt{Dy_1\cdot t}}\right)$$

$$F_1(x_1,z_1,t) := \mathrm{erf}\left(\frac{a_1 - z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right) + \mathrm{erf}\left(\frac{a_1 + z_1}{2\cdot\sqrt{Dz_1\cdot t}}\right)$$

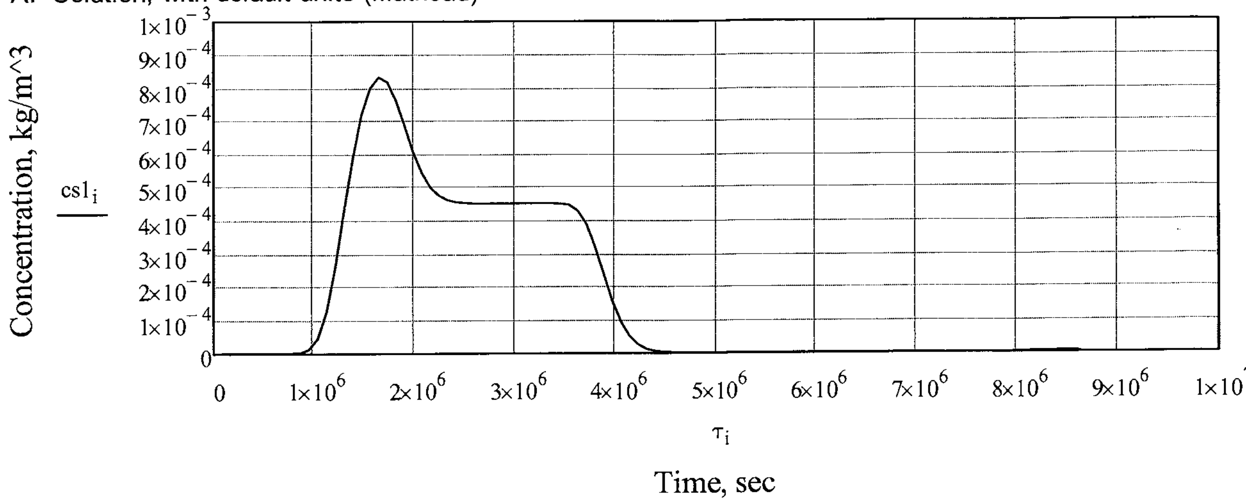
$$C_1(x_1,y_1,\eta) := A_1(x_1)\cdot\int_{0.01\mathrm{day}}^{\eta} B_1(x_1,t)\cdot t^{-1.5}\cdot E_1(x_1,y_1,t)\cdot F_1(x_1,z_1,t)\,dt$$

$i := 1,2..100$ $\qquad\qquad$ $\tau_i := i\cdot\mathrm{day}$

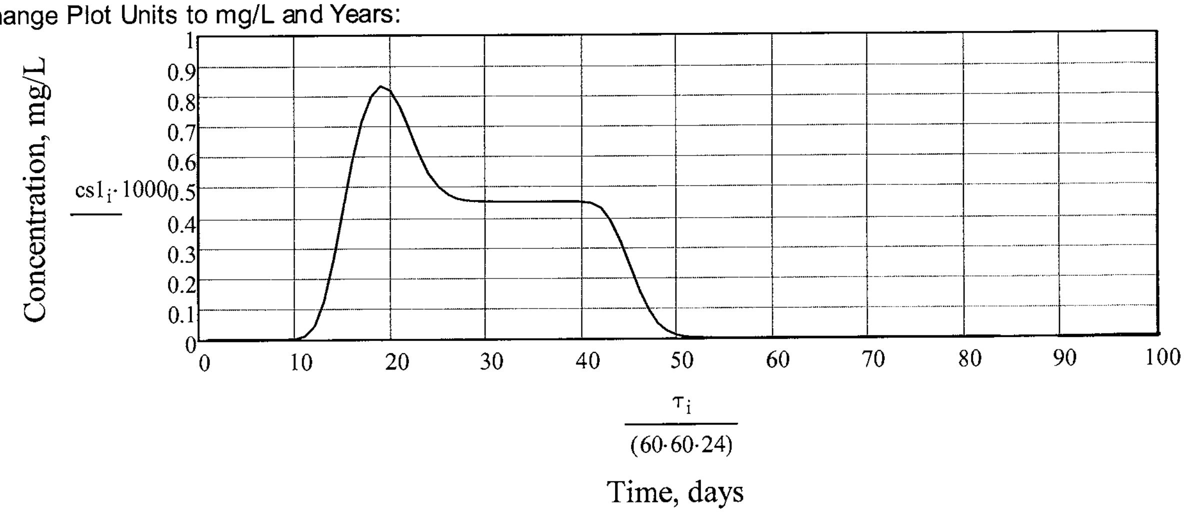
$$cs1_i := \sum_{n=1}^{j_1-1}\left[\left(\frac{co_n + co_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_1(x_1,y_1,|\tau_i - ti_{n-1}|)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_1(x_1,y_1,|\tau_i - ti_n|)\right)\right]\right]$$

5.1 Plots of Concentration in Base of Layer 1, at X, Y and Z from Section 3.1(B)

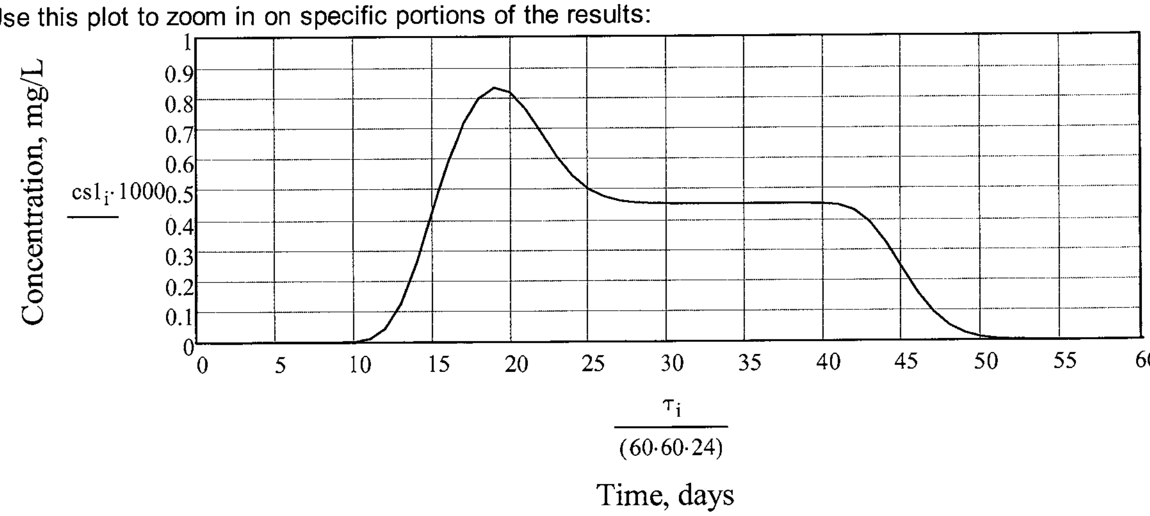
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:



C. Use this plot to zoom in on specific portions of the results:



3.2 Source Definition, to Layer 2 (Till)

The concentrations in 5.1 are divided up as follows, then applied as the source to Layer 2:

A. Source to Layer 2:

number of concentration steps $j_2 := 7$

Iteration intervals $i := 1, 2 .. 10950$

Concentration   Source Term

$$co2 := \begin{pmatrix} 0.00 \\ 0.00 \\ 0.85 \\ 0.85 \\ 0.45 \\ 0.45 \\ 0.00 \end{pmatrix} \frac{mg}{L} \qquad ti := \begin{pmatrix} 0 \\ 10 \\ 17 \\ 21 \\ 26 \\ 43 \\ 50 \end{pmatrix} day$$

B. Input parameters (Layer 2): This ordinate system is rotated from Layer 1. X now is Direction of Flow; Z is Lateral; and Y is vertical.

Vertical Thickness (See Section 1.(F))

Half-Height of Source in Y-direction $a_2 = 7.599 \cdot ft$ **Exceeds till thickness**

Half-width of Source in Z-direction $b_2 := b_1$ $b_2 = 1.167 \cdot ft$

3.2 (continued) Calculated breakthough curve (after Cleary and Ungs, 1978):

Dispersivity in Layer 2, this distance (x) - use values from Till Tracer Test (see Section 2.2):

Note: This was rotated to use correct orientation from Tracer Test.

$\alpha_{x\_2} = 0.15$ $\alpha_{x\_2} \cdot x_2 = 66 \cdot ft$ $\alpha x_2 := \alpha_{x\_2} \cdot x_2$ $\alpha x_2 = 66 \cdot ft$ Flow

$\alpha_{y\_2} = 0.01$ $\alpha_{y\_2} \cdot x_2 = 4.4 \cdot ft$ $\alpha y_2 := \alpha_{y\_2} \cdot x_2$ $\alpha y_2 = 4.4 \cdot ft$ Vertical

$\alpha_{z\_2} = 0.01$ $\alpha_{z\_2} \cdot x_2 = 4.4 \cdot ft$ $\alpha z_2 := \alpha_{z\_2} \cdot x_2$ $\alpha z_2 = 4.4 \cdot ft$ Lateral

longitudinal dispersion coef. (x): $Dx_2 := \alpha x_2 \cdot v_2$ $Dx_2 = 6.6 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (y): $Dy_2 := \alpha y_2 \cdot v_2$ $Dy_2 = 0.44 \cdot \frac{ft^2}{day}$

longitudinal dispersion coef. (z): $Dz_2 := \alpha z_2 \cdot v_2$ $Dz_2 = 0.44 \cdot \frac{ft^2}{day}$

4.2 Equations to determine concentration at any point X,Y and Z at any time (t) (Layer 2):

$$A_2(x_2) := \left(\frac{x_2}{8\cdot\sqrt{Dx_2\cdot\pi}}\right)\cdot\exp\left(\frac{v_2\cdot x_2}{2Dx_2}\right)$$

$$B_2(x_2,t) := \exp\left(-\frac{v_2^{\,2}}{4\cdot Dx_2}\cdot t - \frac{x_2^{\,2}}{4\cdot Dx_2\cdot t}\right)$$

$$E_2(x_2,y_2,t) := \mathrm{erf}\left(\frac{b_2 - y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right) + \mathrm{erf}\left(\frac{b_2 + y_2}{2\cdot\sqrt{Dy_2\cdot t}}\right)$$

$$F_2(x_2,z_2,t) := \mathrm{erf}\left(\frac{a_2 - z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right) + \mathrm{erf}\left(\frac{a_2 + z_2}{2\cdot\sqrt{Dz_2\cdot t}}\right)$$

$$C_2(x_2,y_2,\eta) := A_2(x_2)\cdot\int_{0.01day}^{\eta} B_2(x_2,t)\cdot t^{-1.5}\cdot E_2(x_2,y_2,t)\cdot F_2(x_2,z_2,t)\,dt$$

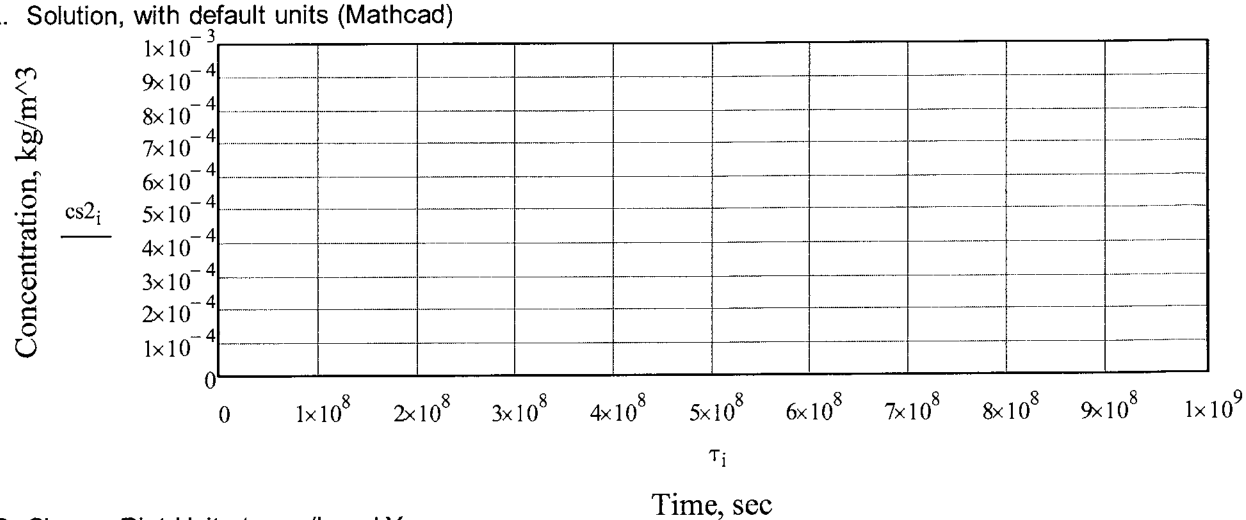
$i := 1,2..10950$ $\qquad$ $\tau_i := i\cdot day$

$$v_2 = 0.1\cdot\frac{ft}{day}$$

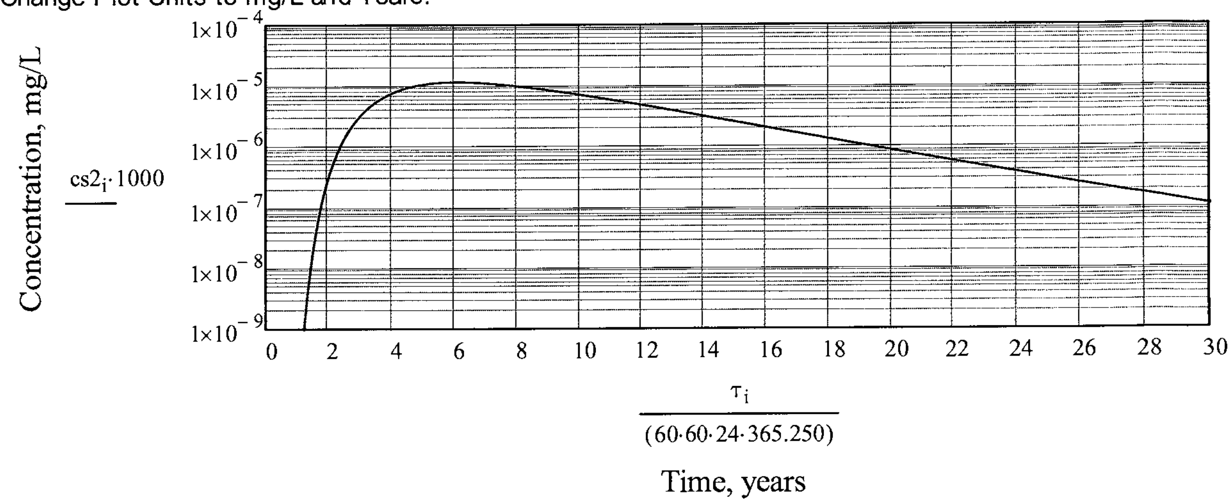
$$cs2_i := \sum_{n=1}^{j_2-1}\left[\left(\frac{co2_n + co2_{n-1}}{2}\right)\cdot\left[\Phi(\tau_i - ti_{n-1})\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_{n-1}\right|\right)\right) - \Phi(\tau_i - ti_n)\cdot\left(C_2\left(x_2,y_2,\left|\tau_i - ti_n\right|\right)\right)\right]\right]$$

5.2 Plots of Concentration in Edge of Layer 2, at X, Y and Z from Section 3.2

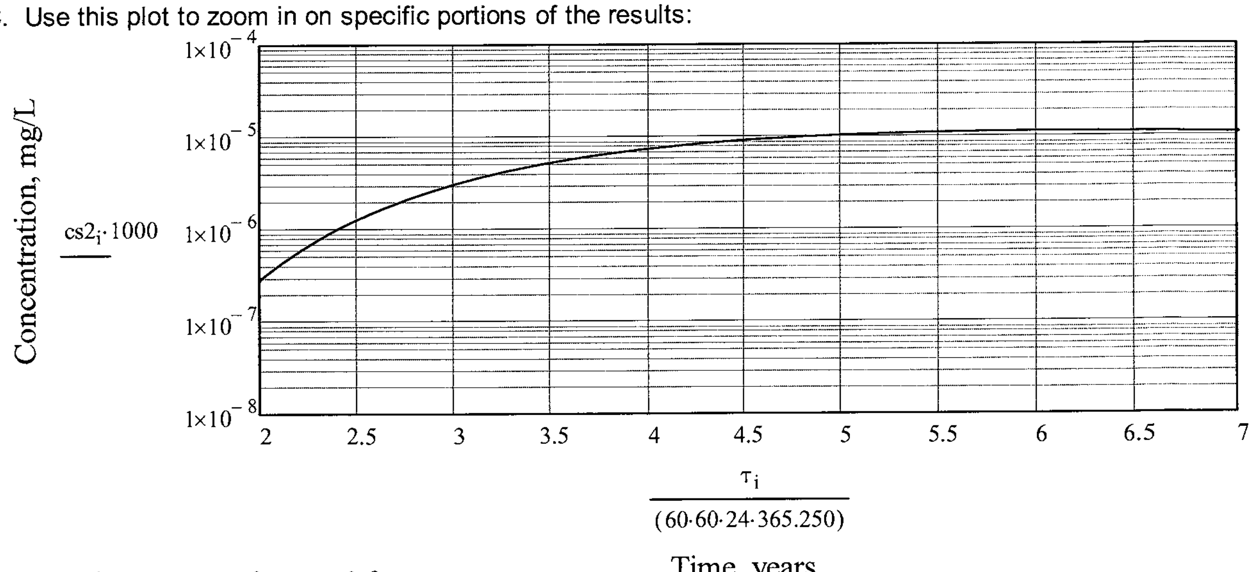
A. Solution, with default units (Mathcad)



B. Change Plot Units to mg/L and Years:

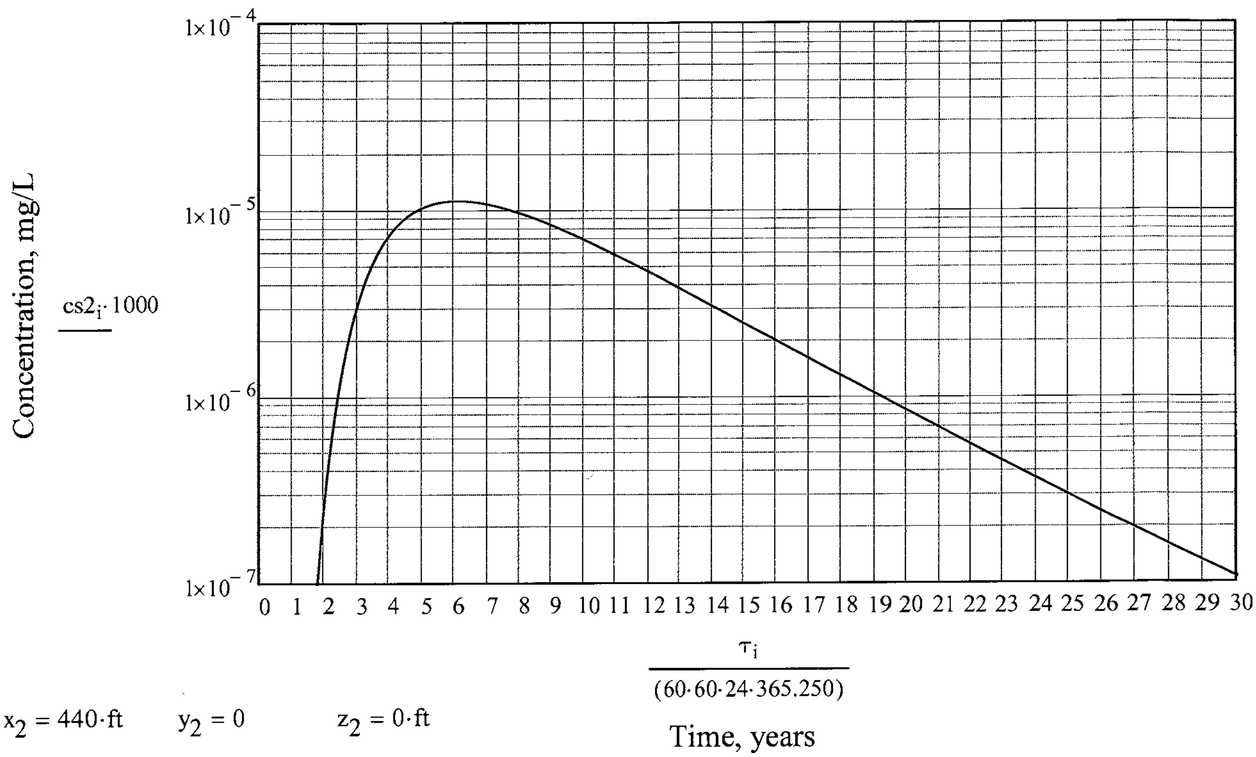


C. Use this plot to zoom in on specific portions of the results:



$x_2 = 440 \cdot ft$ $\quad y_2 = 0 \quad z_2 = 0 \cdot ft$

D. Time to reach Criteria; Steady State; and Maximum.
Note: To interpolate between steps, connect peaks; then, determine value.



$x_2 = 440 \cdot ft$ $y_2 = 0$ $z_2 = 0 \cdot ft$

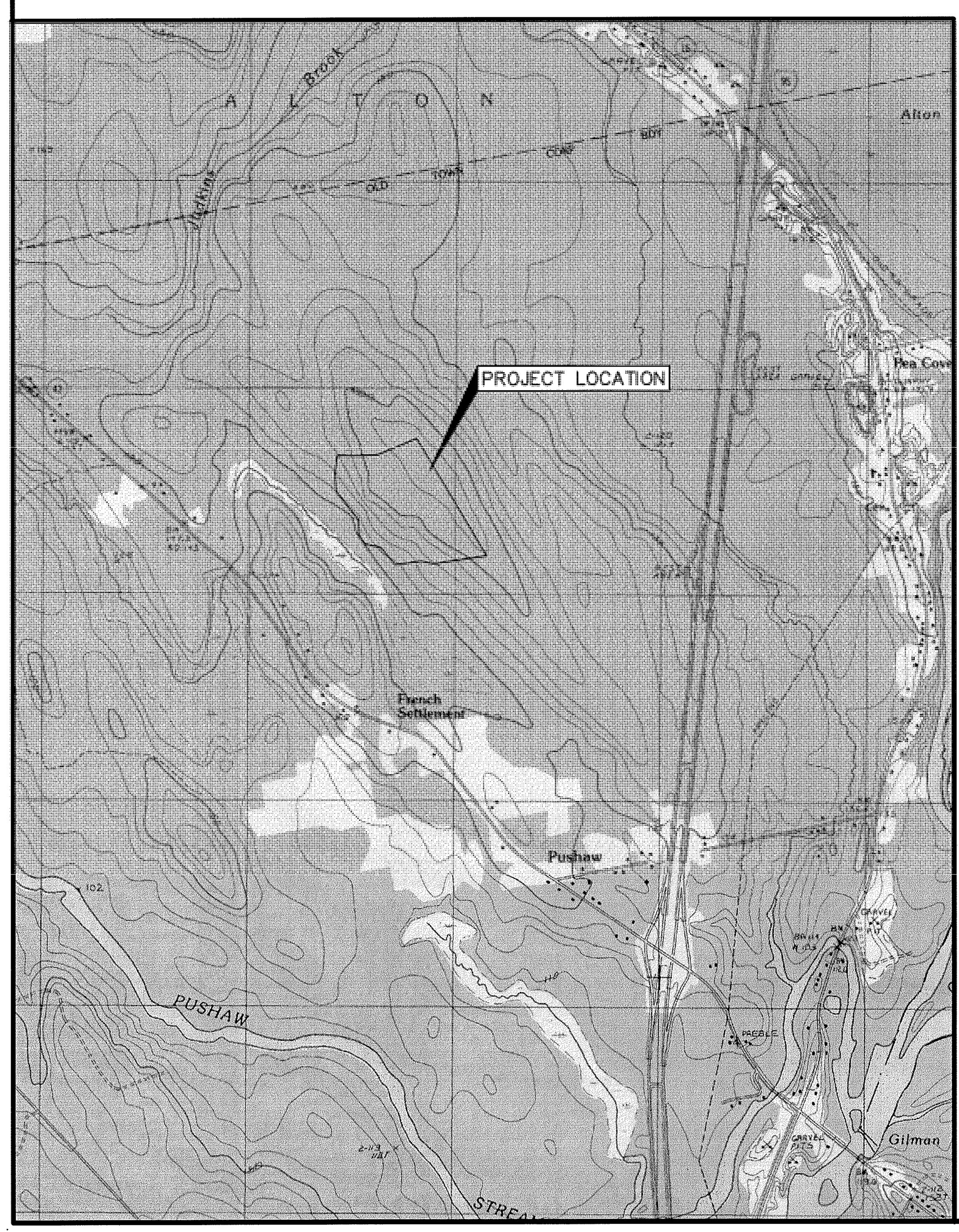
APPENDIX K

CELL 11 DESIGN DRAWINGS

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

TITLE	DWG NO
COVER SHEET	
SYMBOLS & ABBREVIATIONS	C-100
EXISTING CONDITIONS PLAN	C-101
BASE GRADING PLAN	C-102
LEAK DETECTION PIPING PLAN	C-103
LEACHATE COLLECTION PIPING PLAN	C-104
PLAN AND PROFILES	C-200
SECTIONS AND DETAILS	C-300
SECTIONS AND DETAILS	C-301
SECTIONS AND DETAILS	C-302
SECTIONS AND DETAILS	C-303
SECTIONS AND DETAILS	C-304
SECTIONS AND DETAILS	C-305
SECTIONS AND DETAILS	C-306
SECTIONS AND DETAILS	C-307

LOCATION MAP



SME
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SYMBOLS

EXISTING	PROPOSED	
		NORTH ARROW (TRUE)
DATE		NORTH ARROW (MAGNETIC)
		NORTH ARROW (PLAN NORTH)
25	25	CONTOUR LINES
	INV 25.56	SPOT ELEVATION (INVERT ELEVATION)
		EXISTING GROUND
		SURVEY BASELINE WITH TRIANGULATION OR INTERSECTION PT.
		PROPERTY LINE OR R.O.W.
N35°-10'-10"W 251.17'	N35°-10'-10"W 251.17'	PROPERTY LINE W/ BEARING AND DISTANCE
7		CELL DESIGNATION
		BOUNDARY LINE (State, County, Municipality)
		SURVEY MONUMENT
		SURVEY CONTROL
		PROPERTY PIN, DRILL HOLE, PK, OR STAKE
		WOODS OR BRUSH LINE
		INDIVIDUAL TREE
		WETLAND DELINEATED
		WETLAND PHOTO INTERPRETED
		WETLAND TO BE IMPACTED
		GAS VENT
		GAS VENT (CAPPED)
		CLEAN OUT STRUCTURE
		SAMPLE SUMP
		CULVERT
		SLOPE INCLINOMETER
		VIBRATING WIRE SETTLEMENT CELL
		VERTICAL/HORIZONTAL DISPLACEMENT MONUMENT
		VERTICAL DISPLACEMENT MONUMENT

EXISTING	PROPOSED	
		DRAINAGE COURSE (WITH DIRECTION)
		EDGE OF WATER
		WATER ELEVATION (GROUND OR SURFACE)
		FENCE LINE (WOOD)
x	x	FENCE LINE (WIRE)
		STONE WALL
		RETAINING WALL
		GUARD RAIL
		BUILDING AND STRUCTURES
	1 2 OR 2:1	SLOPE RATIO (HORIZONTAL TO VERTICAL)
TOP OF SLOPE 2:1	TOP OF SLOPE 2:1	SLOPES (WITH SLOPE RATIO)
		EDGE OF ROAD
		CUT OR FILL LINE
		BITUMINOUS PAVEMENT
		CONCRETE
B-12 MW-12 P-12	B-12 MW-12 P-12	TEST BORING, MONITORING WELL, OR PIEZOMETER AND NUMBER
TP-12	TP-12	TEST PIT AND NUMBER
SW-12	SW-12	SURFACE WATER SAMPLE LOCATION
		GAS EXTRACTION WELL
		GAS CONDENSATE TRAP
		MANHOLE
		CATCH BASIN
		WATER OR GAS VALVE
		HYDRANT
		AIR RELEASE VALVE
		SURGE RELEASE VALVE
		UTILITY POLE
		LIGHT POLE

EXISTING	PROPOSED	
G	UG	UNDERGROUND GAS MAIN
T	UT	UNDERGROUND TELEPHONE LINE
E	UE	UNDERGROUND ELECTRICAL LINE
OE	OE	OVERHEAD ELECTRICAL LINE
OT	OT	OVERHEAD TELEPHONE LINE
12" SS	12" SS	SANITARY SEWER
8" FM	8" FM	FORCE MAIN
8" W	8" W	WATER MAIN
12" SD	12" SD	STORM DRAIN
8" UD	8" UD	UNDERDRAIN
6" PD	6" PD	PERIMETER DRAIN
6" LT	6" LT	LEACHATE TRANSPORT
6" LC	6" LC	LEACHATE COLLECTION
LD	6" LD	LEAK DETECTION
GC	6" GC	GAS COLLECTION
GT	6" GT	GAS TRANSPORT
		REDUCER
		MECHANICAL CAP OR PLUG
		COUPLING
		BEND
		TEE
		PIPE TO BE ABANDONED
		RISER PIPE & INLET GRATE
		STORM GRATE
		DRAINAGE INLET STRUCTURE
		UNDERDRAIN SUMP
	SF	SILTATION FENCE
	CLL	CLEARING OR CONSTRUCTION LIMIT LINE

GENERAL NOTES

1. THE JUNIPER RIDGE LANDFILL IS AN ACTIVE FACILITY THAT RECEIVES WASTES ON A DAILY BASIS. IT WILL BE THE RESPONSIBILITY OF THE CONTRACTOR TO COORDINATE WITH THE OWNER WITH REGARD TO USE OF PREMISES, INCLUDING HAUL ROUTES AND VEHICULAR ACCESS. THE CONTRACTOR SHALL COORDINATE ALL CONSTRUCTION ACTIVITIES SO AS NOT TO INTERFERE WITH ACTIVE LANDFILLING OPERATIONS. THE CONTRACTOR SHALL OBEY ALL TRAFFIC, NOISE, AND DUST CONTROL POLICIES OF THE JUNIPER RIDGE LANDFILL. THE CONTRACTOR SHALL MINIMIZE THE USE OF EQUIPMENT JAKE BRAKES AT THE INTERSECTION OF ROUTE 16 AND ALONG THE SITE ACCESS ROAD.

2. THE CONTRACTOR SHALL COMPLY FULLY WITH CONDITIONS OF THE MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION (MEDEP) BOARD ORDER (SEE APPENDIX 1 OF TECHNICAL SPECIFICATIONS), MEDEP NRPA PERMIT BY RULE CONDITIONS, MEDEP CONSTRUCTION GENERAL PERMIT, MEDEP "MAINE EROSION AND SEDIMENT CONTROL HANDBOOK FOR CONSTRUCTION: BEST MANAGEMENT PRACTICES", AND MAINE DEPARTMENT OF TRANSPORTATION (MDOT) ENTRANCE PERMIT REQUIREMENTS, AS APPLICABLE.

3. THE CONTRACTOR AND ITS SUBCONTRACTORS SHALL ABIDE BY ALL SAFETY REQUIREMENTS ASSOCIATED WITH WORKING AT AN ACTIVE SOLID WASTE LANDFILL FACILITY (i.e., RISK OF WORKER EXPOSURE TO LANDFILL GASES, LEACHATE, SOLID WASTE) INCLUDING THE FOLLOWING:
   - COMPLY WITH ALL OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) REGULATIONS;
   - COMPLY WITH ALL NEWSME OPERATIONS SAFETY REQUIREMENTS, INCLUDING USE OF HARD HATS, SAFETY GLASSES, AND FLUORESCENT SAFETY VESTS AT ALL TIMES;
   - FOLLOW CONFINED SPACE ENTRY RULES ESTABLISHED BY NEWSME OPERATIONS AND OSHA FOR THE SITE, INCLUDING, BUT NOT LIMITED TO, MANHOLES, CATCH BASINS, PUMP STATIONS, TEST PITS, TRENCHES, ETC., AND
   - ALL EQUIPMENT USED ON SITE SHALL BE EQUIPPED WITH BACK-UP WARNING LIGHTS.

4. THE CONTRACTOR SHALL TAKE EVERY PRECAUTION TO ENSURE THAT NO SILTATION OF STORMWATER DRAINAGE COURSES OCCURS AS A RESULT OF SOIL DISTURBANCE ASSOCIATED WITH THE CONTRACT SCOPE OF WORK.

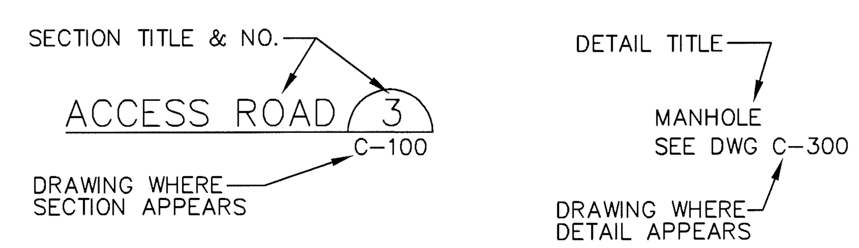
5. THE CONTRACTOR SHALL BE RESPONSIBLE FOR PROVIDING COMPLETE PROTECTION OF THE PROJECT DURING CONSTRUCTION FROM ANY ACTS OF NATURE OR MAN, SUCH AS, BUT NOT LIMITED TO, FLOODS, WIND DAMAGE, EARTH SLIDES, AND SLOPE FAILURES. DAMAGE TO THE PROJECT CAUSED BY SUCH ACTS WILL NOT BE SUFFICIENT CAUSE TO INCREASE CONTRACT COSTS TO THE OWNER.

6. THE CONTRACTOR SHALL PROTECT EXISTING ON-SITE STRUCTURES FROM DAMAGE DURING CONSTRUCTION, INCLUDING: MONITORING WELLS, POWER LINES, MAINTENANCE FACILITIES, CELL 1, 2, 3A, 3B, 4, 5, 6, 7 AND 8 LINER AND EXISTING LEACHATE COLLECTION AND TRANSPORT SYSTEMS, ETC. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL REPAIRS REQUIRED TO CORRECT DAMAGE MADE TO EXISTING ON-SITE STRUCTURES DESCRIBED ABOVE RESULTING FROM ANY CONSTRUCTION ACTIVITY.

ABBREVIATIONS

ACCMP	ASPHALT COATED CMP
ACP	ASBESTOS CEMENT PIPE
AC	ACRE
AGG	AGGREGATE
ALUM	ALUMINUM
APPD	APPROVED
APPROX	APPROXIMATE
ARMH	AIR RELEASE MANHOLE
ASB	ASBESTOS
ASP	ASPHALT
AUTO	AUTOMATIC
AUX	AUXILIARY
AVE	AVENUE
AZ	AZIMUTH
BCCMP	BITUMINOUS COATED CMP
BM	BENCH MARK
BIT	BITUMINOUS
BLDG	BUILDING
BOT	BOTTOM
BRG	BEARING
BV	BALL VALVE
CB	CATCH BASIN
CEN	CENTER
CEM LIN	CEMENT LINED
CMP	CORRUGATED METAL PIPE
CO	CLEAN OUT
CF	CUBIC FEET
CFS	CUBIC FEET PER SECOND
CI	CAST IRON
CL	CLASS
CONC	CONCRETE
CONST	CONSTRUCTION
CONTR	CONTRACTOR
CS	CURB STOP
CTR	CENTER
CU	COPPER
CY	CUBIC YARD
D	DEGREE OF CURVE
DBL	DOUBLE
DEG OR °	DEGREE
DEPT	DEPARTMENT
DI	DUCTILE IRON
DIA OR ø	DIAMETER
DIM	DIMENSION
DIST	DISTANCE
DN	DOWN
DR	DRAIN
DWG	DRAWING
EA	EACH
EG	EXISTING GROUND OR GRADE
ELEC	ELECTRIC
EL	ELEVATION
ELB	ELBOW
EOP	EDGE OF PAVEMENT
EQUIP	EQUIPMENT
EST	ESTIMATED
EXC	EXCAVATE
EXIST	EXISTING
FG	FINISH GRADE
FBRGL	FIBERGLASS
FDN	FOUNDATION
FLEX	FLEXIBLE
FLG	FLANGE
FLR	FLOOR
FPS	FEET PER SECOND
FT OR '	FEET
FTG	FOOTING
GA	GAUGE
GAL	GALLON
GALV	GALVANIZED
GPD	GALLONS PER DAY
GPM	GALLONS PER MINUTE
HDPE	HIGH DENSITY POLYETHYLENE
HORIZ	HORIZONTAL
HP	HORSEPOWER
HYD	HYDRANT
ID	INSIDE DIAMETER
IN OR "	INCHES
INV	INVERT
INV EL	INVERT ELEVATION
LB	POUND
LC	LEACHATE COLLECTION
LD	LEAK DETECTION
LF	LINEAR FEET
LOC	LOCATION
LT	LEACHATE TRANSPORT
MH	MANHOLE
MJ	MECHANICAL JOINT
MATL	MATERIAL
MAX	MAXIMUM
MFR	MANUFACTURE
MIN	MINIMUM
MISC	MISCELLANEOUS
MON	MONUMENT
NITC	NOT IN THIS CONTRACT
NTS	NOT TO SCALE
N/F	NOW OR FORMERLY
NO OR #	NUMBER
OC	ON CENTER
OD	OUTSIDE DIAMETER
PC	POINT OF CURVE
PD	PERIMETER DRAIN
PI	POINT OF INTERSECTION
PIV	POST INDICATOR VALVE
PT	POINT OF TANGENT
PERF	PERFORATED
PP	POWER POLE
PSI	POUNDS PER SQUARE INCH
PVC	POLYVINYL CHLORIDE
PVMT	PAVEMENT
QTY	QUANTITY
RCP	REINFORCED CONCRETE PIPE
ROW	RIGHT OF WAY
RAD	RADIUS
REQD	REQUIRED
RT	RIGHT
RTE	ROUTE
S	SLOPE
SCH	SCHEDULE
SF	SQUARE FEET
SHT	SHEET
SMH	SANITARY MANHOLE
ST	STREET
STA	STATION
SY	SQUARE YARD
TAN	TANGENT
TDH	TOTAL DYNAMIC HEAD
TEMP	TEMPORARY
TYP	TYPICAL
UD	UNDERDRAIN
V	VOLTS
VA TEE	VALVE ANCHORING TEE
VERT	VERTICAL
WG	WATER GATE
W/	WITH
W/O	WITHOUT
YD	YARD

VIEW MARKERS & IDENTIFICATION



REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE · GUY H. COTE, JR. · No. 5144 · LICENSED · PROFESSIONAL ENGINEER

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

SYMBOLS & ABBREVIATIONS

SME
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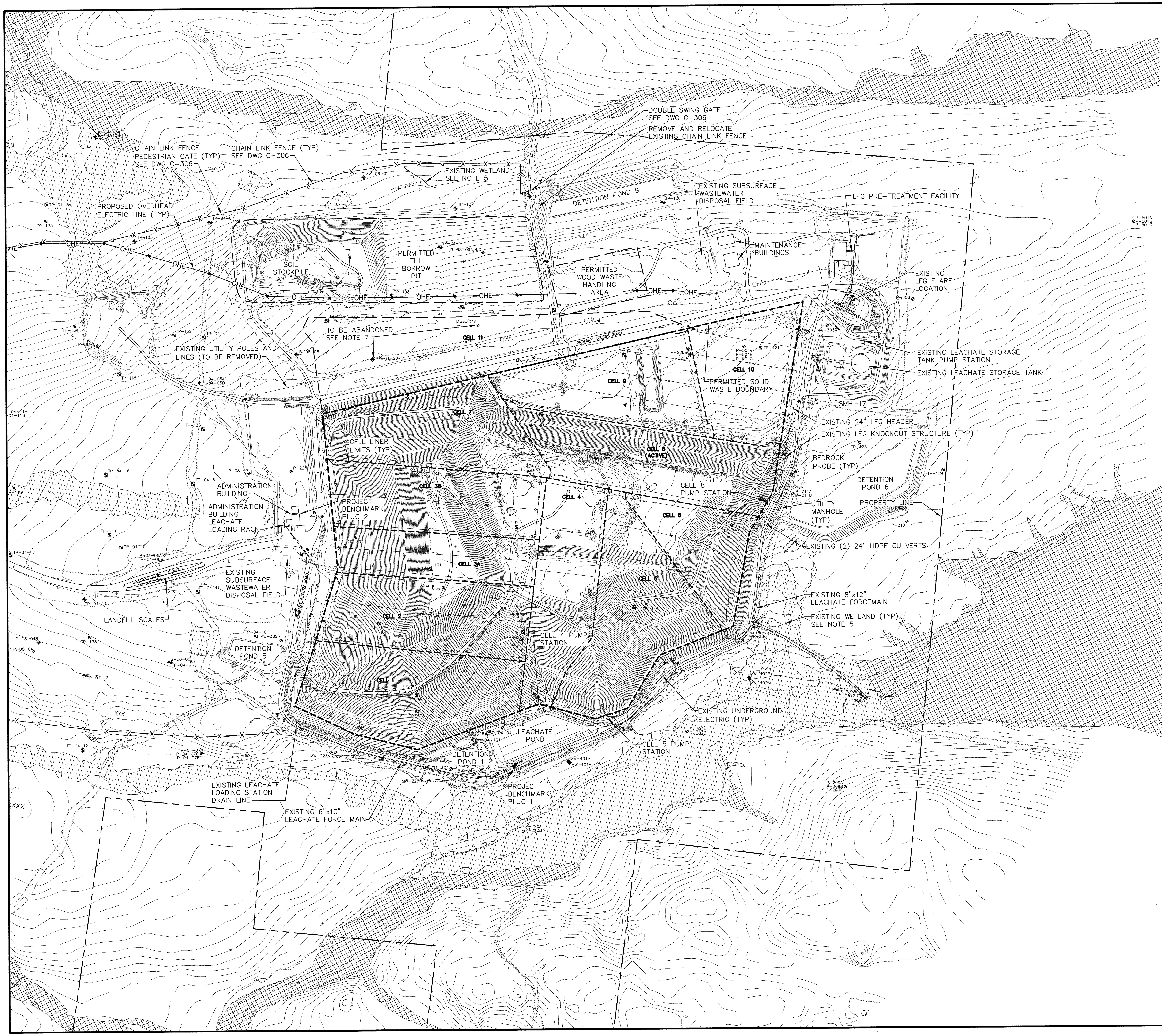
DESIGN BY: PCM
DRAWN BY: SJM
DATE: 12/5/2014
CHECKED BY:
LMN: NONE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE DETAILS

C-100



NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION AND AT THE ADMINISTRATION BUILDING. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

   PLUG 2 IS A BRASS PLUG AT THE ADMINISTRATION BUILDING LOCATED AT COORDINATES NORTHING 479497.17, EASTING 926131.46, ELEVATION 215.12

2. EXISTING TOPOGRAPHY SHOWN AT 2-FOOT INTERVALS. EXISTING TOPOGRAPHY SHOWN ON THE DRAWINGS REPRESENT GRADES AT THE TIME OF THE SURVEY. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.

3. LOCATIONS OF EXISTING UNDERGROUND UTILITIES INCLUDING ELECTRICAL AND PIPING BASED ON FIELD SURVEY DURING CONSTRUCTION OF CELLS 1, 2, 3A, 3B, 4, 5, 6, 7, 8, LEACHATE POND AND LANDFILL GAS HEADER AND FLARE RE-LOCATIONS. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.

4. LEACHATE COLLECTION PIPE SHOWN IN CELLS 9 AND 10 IS PROPOSED AS OF JULY 2015. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.

5. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.

6. BORINGS & TEST PIT LOCATIONS ARE APPROXIMATE AND BASED ON FIELD SURVEY BY SEVEE & MAHER ENGINEERS, INC., CUMBERLAND, MAINE.

7. EXISTING MONITORING WELLS AND PIEZOMETERS TO BE ABANDONED PRIOR TO CONSTRUCTION INCLUDE MW-11-207R AND MW-304.

REV.	BY	DATE	STATUS
	PCM	7/2015	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE
GUY H. COTE
No. 5184
LICENSED PROFESSIONAL ENGINEER

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

EXISTING SITE CONDITIONS PLAN

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE
4 Blanchard Road, PO Box 85A, Cumberland Center, Maine 04021
Phone 207.829.5016 • Fax 207.829.5692 • www.smemaine.com

DESIGN BY:	
DRAWN BY:	SJM
DATE:	12/2013
CHECKED BY:	
LMN:	EXSITECOND
CTB:	SME-STD

JOB NO. 14101 DWG FILE CELL9-SITEPLAN C-101

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

   PLUG 2 IS A BRASS PLUG AT THE ADMINISTRATION BUILDING LOCATED AT COORDINATES NORTHING 479497.17, EASTING 926131.46, ELEVATION 215.12

2. EXISTING TOPOGRAPHY SHOWN AT 2-FOOT INTERVALS. EXISTING TOPOGRAPHY SHOWN ON THE DRAWINGS REPRESENT GRADES AT THE TIME OF THE SURVEY. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.

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4. LEACHATE COLLECTION PIPE SHOWN IN CELLS 9 AND 10 IS PROPOSED AS OF JULY 2015. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.

5. WETLAND BOUNDARIES DELINEATED BY WOODLOT ALTERNATIVES, INC. IN 2004 AND STANTEC CONSULTING SERVICES 2008, 2014 AND 2015.

6. MONITORING WELLS AND OBSERVATION WELLS TO BE INSTALLED INCLUDE MW-501, OW-601A, OW-601B, OW-602A, OW-603B AND OW-604A.

7. GRUB AND STRIP IN ALL AREAS WHERE FILL WILL BE PLACED TO REMOVE ORGANIC AND OTHER DELETERIOUS MATERIAL OR A MINIMUM OF 8 INCHES.

8. CONTRACTOR SHALL SUBMIT TO THE ENGINEER A WRITTEN PLAN FOR EXCAVATION, EXCAVATION STABILITY AND STORMWATER RUNOFF CONTROL PRIOR TO ANY CELL 11 TO CELL 7 OR CELL 9 CONNECTION CONSTRUCTION ACTIVITIES.

9. CONTRACTOR TO SUPPLY STORMWATER MANAGEMENT PLAN FOR DIVERSION OF WATER DRAINAGE OFF THE GEOSYNTHETIC COVER LOCATED ON EXISTING SIDESLOPE OF CELLS ADJACENT TO CELL 11.

10. SILT FENCE SHALL BE INSTALLED IN LOCATION OF CLEARING LIMIT LINE WHERE THE LINES ARE SHOWN ADJACENT TO EACH OTHER (OFFSET SHOWN IS FOR CLARITY).

11. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.

12. AREA IDENTIFIED SHALL BE UNDERCUT 1-FOOT BELOW BASEGRADE. THE SECONDARY LINER SHALL BE AUGMENTED IN THIS AREA AS DETAILED ON DRAWING C-300.

13. DETENTION POND 9 SHALL BE EXPANDED TO THE FINISH GRADES SHOWN. ALL DISTURBED AREAS AND GRADED SURFACES SHALL RECEIVE 4-INCHES OF TOPSOIL AND BE SEEDED AND MULCH.

BASE GRADE INTERIOR LAYOUT POINTS

POINT #	NORTHING	EASTING	ELEVATION
100	479660.3	926881.7	215.1
101	479643.3	926934.4	201.2
102	479647.9	926943.9	200.9
103	479651.9	926952.2	200.6
104	479644.1	926954.9	200.9
105	479640.1	926946.6	201.1
106	479139.3	927126.3	214.0
107	478668.2	927294.2	216.0
108	478281.7	927431.9	217.6
109	478148.5	927423.3	217.8
110	479058.2	926888.4	219.0
111	479053.5	926881.6	221.7
112	479098.7	926854.7	222.0
113	479381.9	926685.1	224.1
114	479444.5	926692.6	211.0
115	479504.8	926649.9	210.3
116	479501.0	926597.5	225.0
117	479509.2	926570.9	225.0
118	479531.7	926615.4	225.0

BASE GRADE EXTERIOR LAYOUT POINTS

POINT #	NORTHING	EASTING	ELEVATION
500	479759.4	926959.1	212.0
501	479760.7	926963.4	212.0
502	479761.6	926966.2	210.5
503	479774.7	927007.2	209.7
504	479661.4	926991.1	214.0
505	479662.8	926995.4	214.0
506	479663.6	926998.3	212.5
507	479515.0	927090.3	214.6
508	479502.9	927145.3	219.7
509	479476.2	927153.7	219.7
510	479428.0	927117.8	216.2
511	479328.7	927104.2	218.7
512	479148.6	927153.3	223.5
513	479150.0	927157.5	223.5
514	479151.0	927160.4	222.0
515	479165.7	927200.8	221.1
516	478762.3	927348.5	219.9
517	478760.0	927418.4	214.2
518	478738.3	927437.4	214.0
519	478676.0	927318.2	224.4
520	478677.4	927322.4	224.4
521	478679.5	927329.5	220.7
522	478680.6	927332.7	220.7

BASE GRADE EXTERIOR LAYOUT POINTS

POINT #	NORTHING	EASTING	ELEVATION
523	478679.1	927379.0	219.8
524	478424.8	927420.9	220.0
525	478426.2	927425.8	220.0
526	478284.8	927454.7	225.1
527	478285.4	927459.2	225.1
528	478294.5	927467.8	219.6
529	478296.5	927473.4	219.6
530	478307.6	927515.1	218.8
531	478215.9	927468.8	218.0
532	478123.7	927466.6	216.0
533	478099.1	927491.1	215.0
534	478089.3	927509.2	214.2
535	478097.6	927550.4	213.8
536	477995.4	927564.1	213.2
537	478062.8	927481.0	216.0
538	478108.7	927442.8	225.1
539	478104.9	927445.1	225.1
540	479515.7	926549.6	225.1
541	479540.7	926611.1	225.1
542	479669.6	926877.9	225.1
543	479716.5	926909.6	199.5
544	479726.0	926906.4	199.3
545	479735.0	926924.3	198.7

ROADWAY CENTERLINE TABLE

CL STATION	EASTING	NORTHING	BASEGRADE ELEVATION	ID
0+00.00	926337.3	479462.7	220.0	CL
0+50.00	926383.6	479481.4	220.0	CL AT PC
1+00.00	926426.3	479507.1	220.0	CL
1+38.42	926452.6	479535.0	219.5	CL AT PT
2+00.00	926489.0	479584.6	217.0	CL
3+00.00	926548.2	479665.2	212.9	CL
4+00.00	926607.4	479745.8	208.7	CL
5+00.00	926666.7	479826.4	204.5	CL
5+46.63	926694.3	479864.0	202.6	CL AT PC
6+00.00	926731.9	479901.4	200.4	CL
7+00.00	926826.1	479929.6	201.9	CL
8+00.00	926918.4	479895.9	207.7	CL
8+96.78	926971.4	479816.7	209.3	CL AT PT
9+00.00	926972.4	479813.7	209.4	CL
9+46.00	926986.8	749770.2	210.0	CL
9+65.27	926992.9	479751.7	210.4	CL
10+00.00	927003.6	479718.7	211.1	CL
10+71.29	927025.6	479650.9	212.4	CL
11+00.00	927034.2	479623.5	212.9	CL
12+00.00	927064.4	479528.1	214.7	CL
13+00.00	927094.5	479432.8	216.5	CL
14+00.00	927124.7	479337.4	218.2	CL
15+00.00	927154.8	479242.1	220.0	CL
15+87.17	927181.1	479159.0	221.6	CL
16+00.00	927185.5	479146.9	221.5	CL
17+00.00	927219.9	479053.0	221.3	CL
18+00.00	927254.3	478959.1	221.0	CL
19+00.00	927288.7	478865.2	220.8	CL
20+00.00	927323.1	478771.3	220.5	CL
21+00.00	927357.5	478677.4	220.2	CL
22+00.00	927391.9	478583.5	219.9	CL
23+00.00	927426.3	478489.6	219.4	CL
24+00.00	927460.6	478395.7	218.8	CL
24+99.59	927494.9	478302.2	218.3	CL
25+00.00	927495.0	478301.8	218.3	CL
26+00.00	927512.0	478203.3	216.6	CL
26+84.89	927526.5	478119.6	214.5	CL
27+00.00	927528.5	478104.6	214.2	CL
27+60.40	927536.5	478044.8	212.7	CL

ROADWAY CENTERLINE TABLE LEGEND
CL = CENTERLINE
PC = POINT OF CURVE
PT = POINT OF TANGENT

REV.	BY	DATE	STATUS
	PCM	7/2015	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE
GUY H. COTE, JR.
No. 5144
LICENSED PROFESSIONAL ENGINEER

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

BASE GRADING PLAN

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE
4 Blanchard Road, PO Box 85A, Cumberland Center, Maine 04021
Phone 207.829.5016 • Fax 207.829.5692 • www.smemaine.com

DESIGN BY: PCM
DRAWN BY: SJM
DATE: 5/2015
CHECKED BY:
LMN: C11-BASEGRADE
CTB: SME-STD

JOB NO. 14101 DWG FILE CELL11-SITEPLAN

C-102

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

   PLUG 1 IS A BRASS PLUG ON FORMER LEACHATE POND PUMP STATION LOCATED AT COORDINATES NORTHING 478242.05, EASTING 925376.35 ELEVATION 167.93

   PLUG 2 IS A BRASS PLUG AT THE ADMINISTRATION BUILDING LOCATED AT COORDINATES NORTHING 479497.17, EASTING 926131.46, ELEVATION 215.12

2. EXISTING TOPOGRAPHY SHOWN AT 2-FOOT INTERVALS. EXISTING TOPOGRAPHY SHOWN ON THE DRAWINGS REPRESENT GRADES AT THE TIME OF THE SURVEY. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.
3. LOCATIONS OF EXISTING UNDERGROUND UTILITIES INCLUDING ELECTRICAL AND PIPING BASED ON FIELD SURVEY DURING CONSTRUCTION OF CELLS 1, 2, 3A, 3B, 4, 5, 6, 7, 8, LEACHATE POND AND LANDFILL GAS HEADER AND FLARE RE-LOCATIONS. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.
4. GRADES SHOWN WITHIN THE LIMITS OF CELLS 9 AND 10 REPRESENT TOP OF SUBGRADE PRIOR TO CELL LINER CONSTRUCTION (TOP OF THE 12-INCH UNDERDRAIN LAYER).
5. GRUB AND STRIP IN ALL AREAS WHERE FILL WILL BE PLACED TO REMOVE ORGANIC AND OTHER DELETERIOUS MATERIAL OR A MINIMUM OF 8 INCHES.
6. CONTRACTOR SHALL SUBMIT TO THE ENGINEER A WRITTEN PLAN FOR EXCAVATION, EXCAVATION STABILITY AND STORMWATER RUNOFF CONTROL PRIOR TO ANY CELL 11 TO CELL 7 OR CELL 9 CONNECTION CONSTRUCTION ACTIVITIES.
7. CONTRACTOR TO SUPPLY STORMWATER MANAGEMENT PLAN FOR DIVERSION OF WATER DRAINAGE OFF THE GEOSYNTHETIC COVER LOCATED ON EXISTING SIDESLOPE OF CELLS ADJACENT TO CELL 11.
8. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.

REV.	BY	DATE	STATUS
	PCM	7/2015	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE GUY H. COTE No. 5124 LICENSED PROFESSIONAL ENGINEER

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

LEAK DETECTION PIPING PLAN

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE
4 Blanchard Road, PO Box 85A, Cumberland Center, Maine 04021
Phone 207.829.5016 • Fax 207.829.5692 • www.smemaine.com

DESIGN BY: PCM
DRAWN BY: SJM
DATE: 5/2015
CHECKED BY:
LMN: LCPIPING
CTB: SME-STD

JOB NO. 14101 DWG FILE CELL11-SITEPLAN C-103

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

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2. EXISTING TOPOGRAPHY SHOWN AT 2-FOOT INTERVALS. EXISTING TOPOGRAPHY SHOWN ON THE DRAWINGS REPRESENT GRADES AT THE TIME OF THE SURVEY. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.

3. LOCATIONS OF EXISTING UNDERGROUND UTILITIES INCLUDING ELECTRICAL AND PIPING BASED ON FIELD SURVEY DURING CONSTRUCTION OF CELLS 1, 2, 3A, 3B, 4, 5, 6, 7, 8, LEACHATE POND AND LANDFILL GAS HEADER AND FLARE RE-LOCATIONS. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.

4. GRADES SHOWN WITHIN THE LIMITS OF CELLS 9 AND 10 REPRESENT TOP OF SUBGRADE PRIOR TO CELL LINER CONSTRUCTION (TOP OF THE 12-INCH UNDERDRAIN LAYER).

5. LEACHATE COLLECTION PIPE SHOWN IN CELLS 9 AND 10 IS PROPOSED AS OF JULY 2015. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.

6. GRUB AND STRIP IN ALL AREAS WHERE FILL WILL BE PLACED TO REMOVE ORGANIC AND OTHER DELETERIOUS MATERIAL OR A MINIMUM OF 8 INCHES.

7. CONTRACTOR SHALL SUBMIT TO THE ENGINEER A WRITTEN PLAN FOR EXCAVATION, EXCAVATION STABILITY AND STORMWATER RUNOFF CONTROL PRIOR TO ANY CELL 11 TO CELL 7 OR CELL 9 CONNECTION CONSTRUCTION ACTIVITIES.

8. CONTRACTOR TO SUPPLY STORMWATER MANAGEMENT PLAN FOR DIVERSION OF WATER DRAINAGE OFF THE GEOSYNTHETIC COVER LOCATED ON EXISTING SIDESLOPE OF CELLS ADJACENT TO CELL 11.

9. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.

10. THE CONTRACTOR SHALL SUPPLY PIPE AND FITTINGS TO THE OWNER AND PROVIDE INSTALLATION SUPPORT AS NECESSARY TO EXTEND CLEANOUTS. EXTENSIONS SHALL BE INSTALLED IN THE SOFT WASTE LAYER. PIPE SHALL BE HPDE SOLID WALL PIPE SLOPED 2 PERCENT MINIMUM DOWN TO CELL 7 AND CELL 9.

REV.	BY	DATE	STATUS
	PCM	7/2015	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE · GUY H. COTE, JR. · No. 5144 · LICENSED PROFESSIONAL ENGINEER

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

LEACHATE COLLECTION PIPING PLAN

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4 Blanchard Road, PO Box 85A, Cumberland Center, Maine 04021
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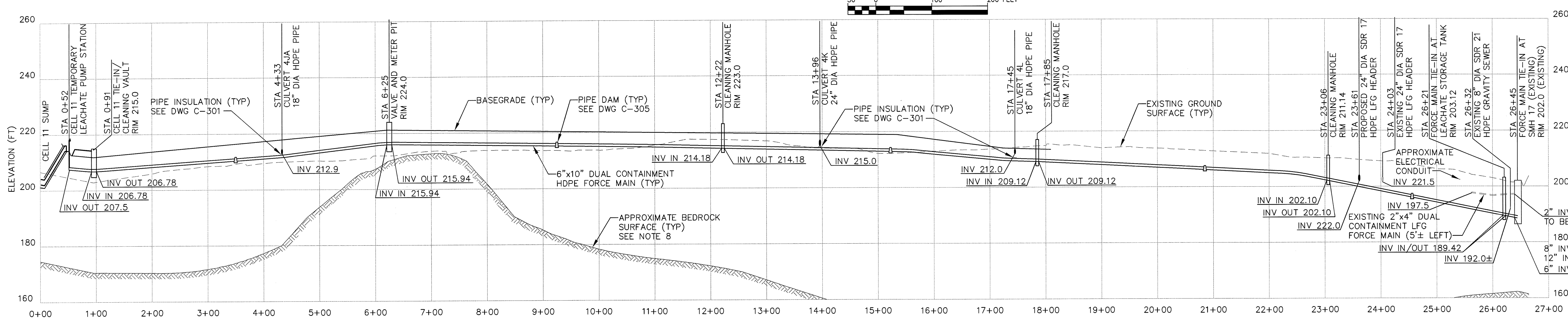
DESIGN BY:	PCM
DRAWN BY:	SJM
DATE:	5/2015
CHECKED BY:	[signature]
LMN:	LCPIPING
CTB:	SME-STD

JOB NO. 14101 DWG FILE CELL11-SITEPLAN

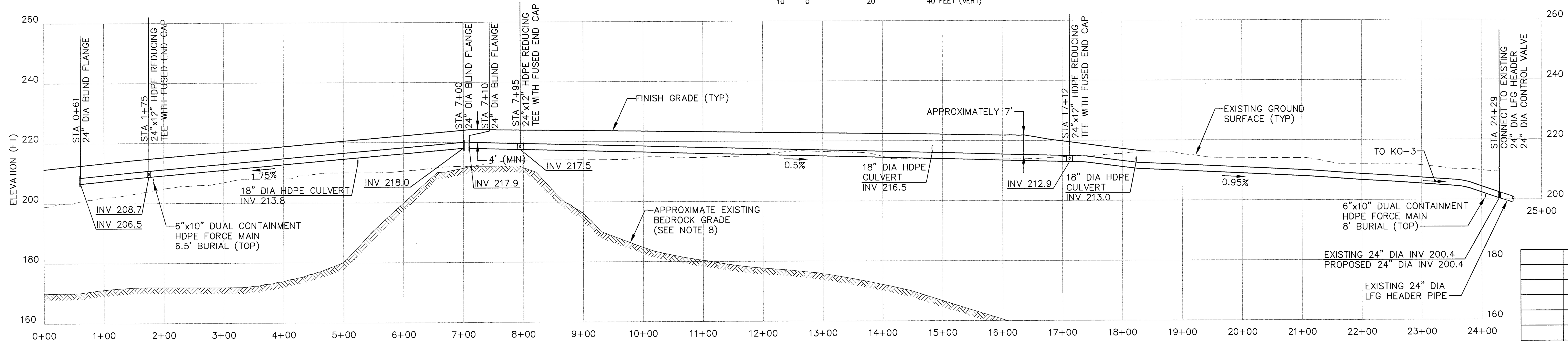
C-104

FORCE MAIN AND LFG HEADER PLAN

FORCE MAIN CENTERLINE LOCATION TABLE		
Northing	Easting	Description
479638.3	926948.6	STA 0+00
479664.5	927040.1	FM VAULT
479160.8	927199.9	FM VAULT
478599.7	927404.8	CLEANING MH
478328.1	927504.8	STA 15+11
478059.4	927552.6	CLEANING MH
477601.5	927797.7	CLEANING MH
477580.4	927760.4	STA 23+49
477547.6	927665.7	STA 24+49
477544.1	927583.8	STA 25+31
477524.2	927496.2	CLEANING MH



FORCE MAIN PROFILE



LANDFILL GAS HEADER CENTERLINE LOCATION TABLE		
Northing	Easting	Description
479828.2	926951.6	STA 0+00
479770.3	926970.7	STA 0+61
479163.3	927163.8	STA 7+00
479157.5	927165.7	STA 7+10
479078.7	927194.5	STA 7+95
478298.3	927480.3	STA 16+19
478021.0	927525.0	STA 19+00
477629.5	927744.9	STA 23+50
477553.5	927746.5	STA 24+29

LANDFILL GAS HEADER PROFILE

NOTES:

1. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., NORRIDGEWOCK, MAINE. PHOTO DATE 12/31/14. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE. STANDARD PRACTICE DICTATES THAT PLANS COMPILED IN THIS MANNER SHOULD BE FIELD VERIFIED BY THE CONTRACTOR PRIOR TO CONSTRUCTION. SITE BENCHMARK INFORMATION:

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5. LEACHATE COLLECTION PIPE SHOWN IN CELLS 9 AND 10 IS PROPOSED AS OF JULY 2015. CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTRUCTION.

6. GRUB AND STRIP IN ALL AREAS WHERE FILL WILL BE PLACED TO REMOVE ORGANIC AND OTHER DELETERIOUS MATERIAL OR A MINIMUM OF 8 INCHES.

7. PROPOSED EXPANSION GRADES WITHIN THE PROPOSED SOLID WASTE LIMIT REPRESENT BASE GRADES PRIOR TO PLACEMENT OF THE IMPORTED CLAY AND CONSTRUCTION OF THE LINER SYSTEM. THE PROPOSED GRADES SHOWN OUTSIDE THE PROPOSED SOLID WASTE LIMIT ARE SUBBASE ROAD GRADES.

8. EXISTING BEDROCK SURFACE INTERPRETED FROM SITE EXPLORATIONS (BORINGS, PROBES AND TEST PITS). CONTRACTOR SHOULD FIELD VERIFY THE EXISTING CONDITIONS PRIOR TO CONSTURCTION.

9. LANDFILL GAS INFRASTRUCTURE FROM PLANS ENTITLED "LFG SYSTEM EXPANSION MASTER PLAN" BY SANBORN HEAD, DATED JUNE 2015. THE PROFILE OF THE LFG HEADER WAS TAKEN FROM DRAWING ENTITLED "PERIMETER LFG HEADER PIPE PROFILE". THE LFG HEADER PROFILE SHOWN ON THE CELL 11 DRAWING SHOWS THE PIPE FROM STATION 9+61 TO STATION 33+29 AS ON THE REFERENCED DRAWING. STATION 0+00 ON THE CELL 11 LFG PROFILE IS EQUAL TO STATION 9+00 ON THE REFERENCED DRAWINGS.

REV.	BY	DATE	STATUS
	PCM	7/2015	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

FORCE MAIN AND LANDFILL GAS HEADER PLAN AND PROFILE

SME
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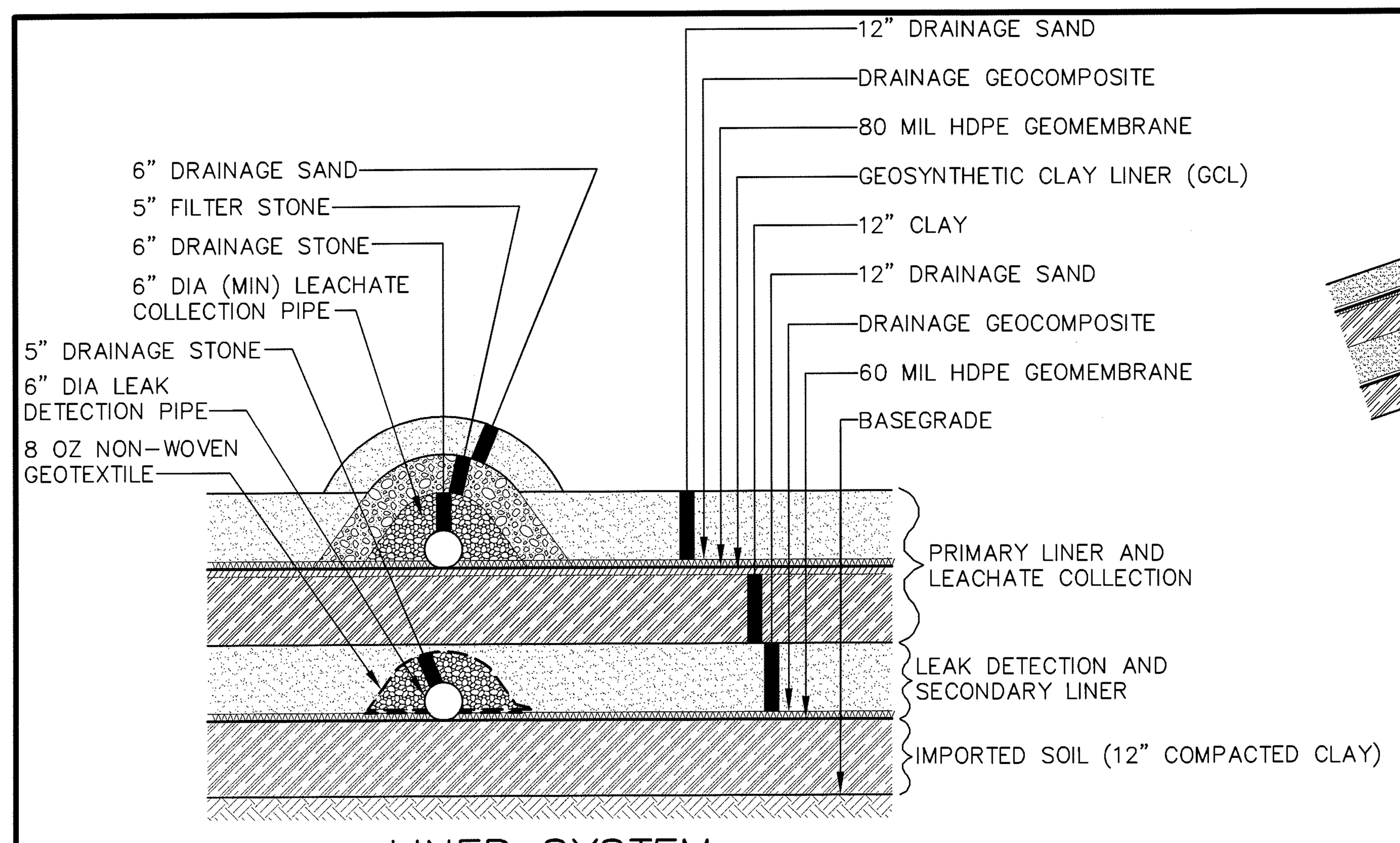
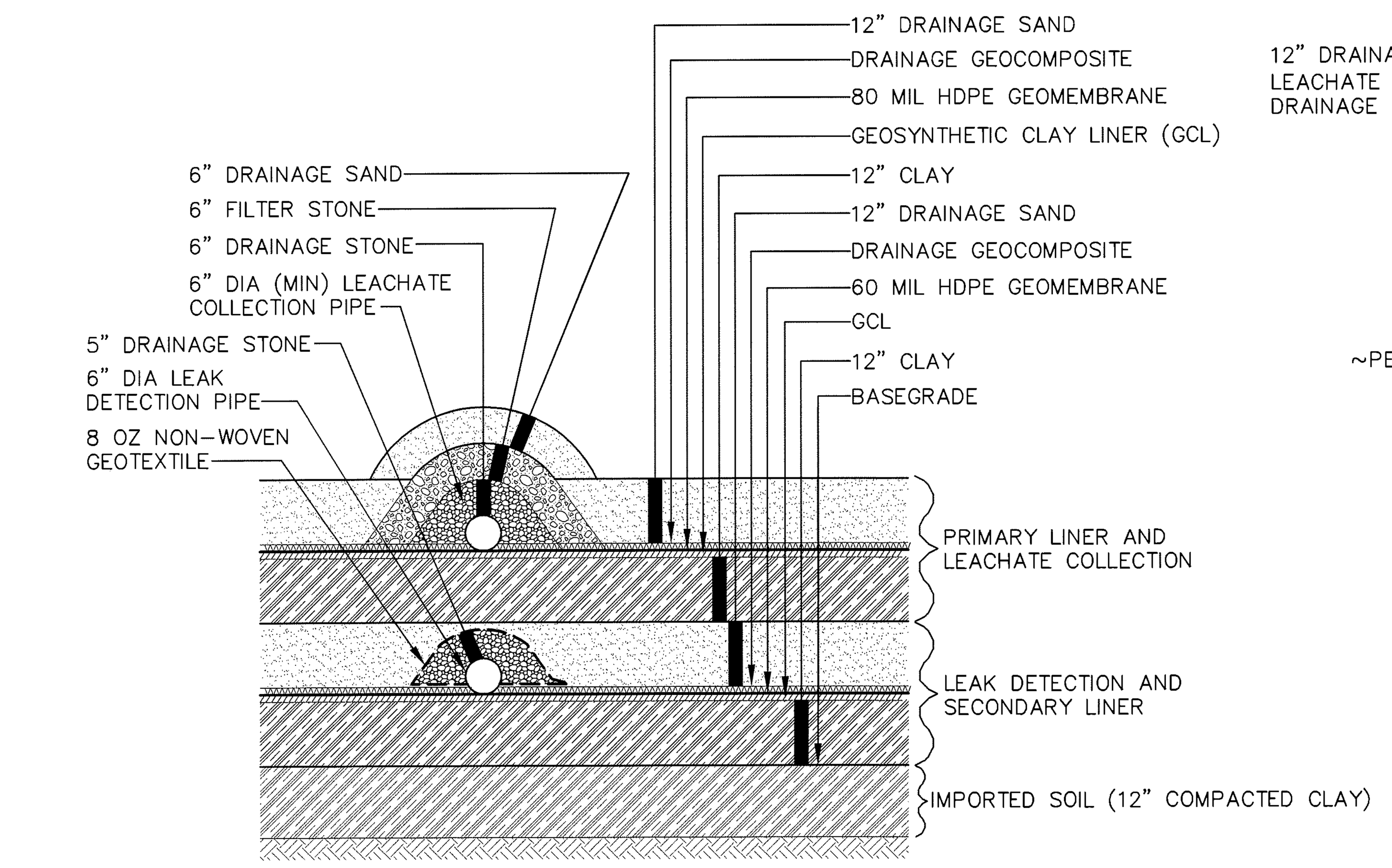
DRAWN BY:	SJM
DATE:	5/2015
CHECKED BY:	
LMN:	FM PLANPROF
CTB:	SME-STD

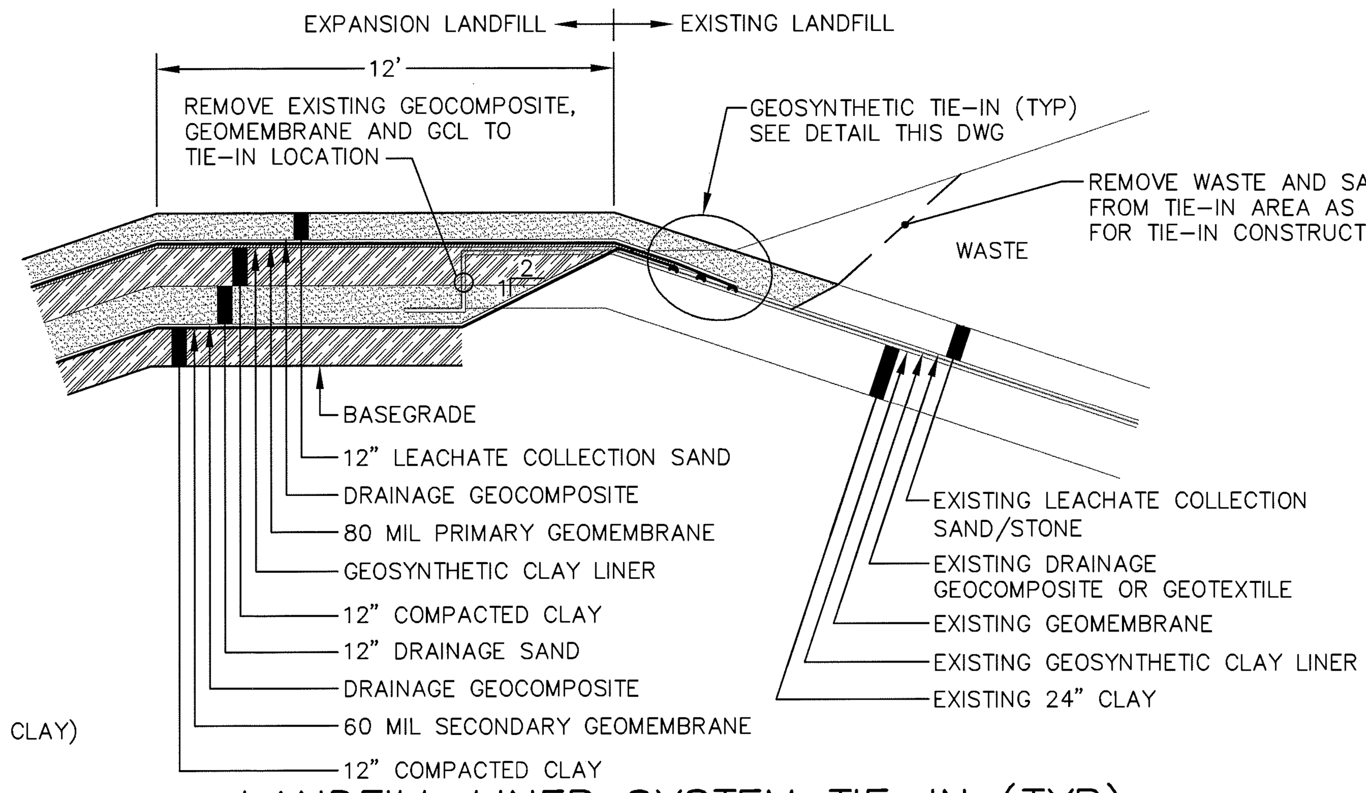
JOB NO. 14101 DWG FILE CELL11-SITEPLAN C-200



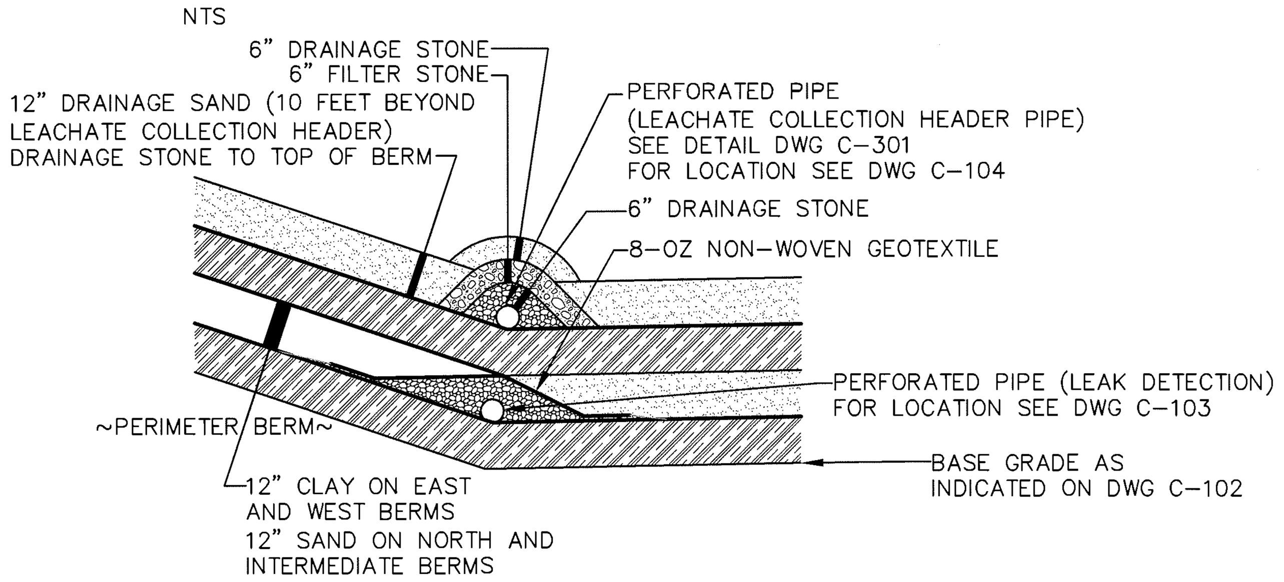
LINER SYSTEM
NTS



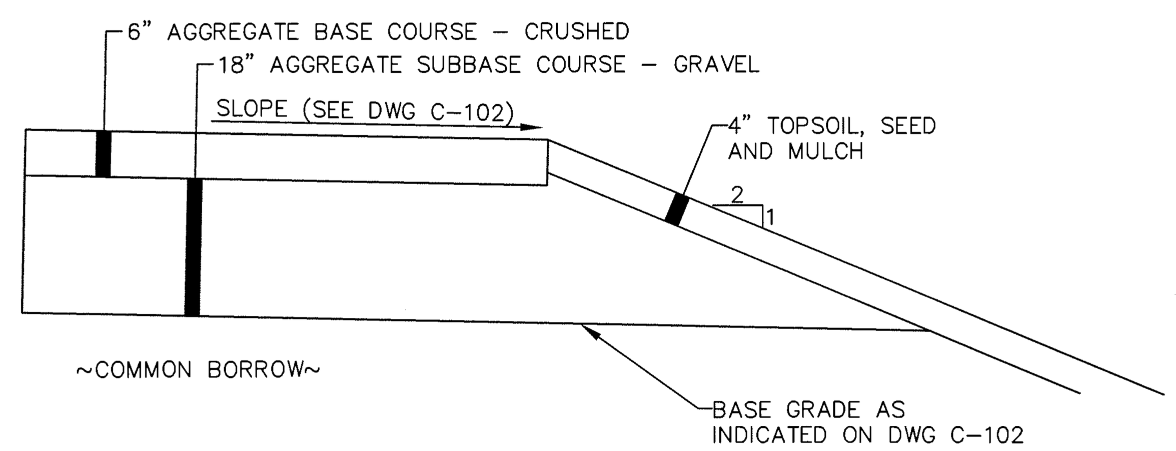
LINER SYSTEM WITH AUGMENTED SECONDARY LINER
NTS



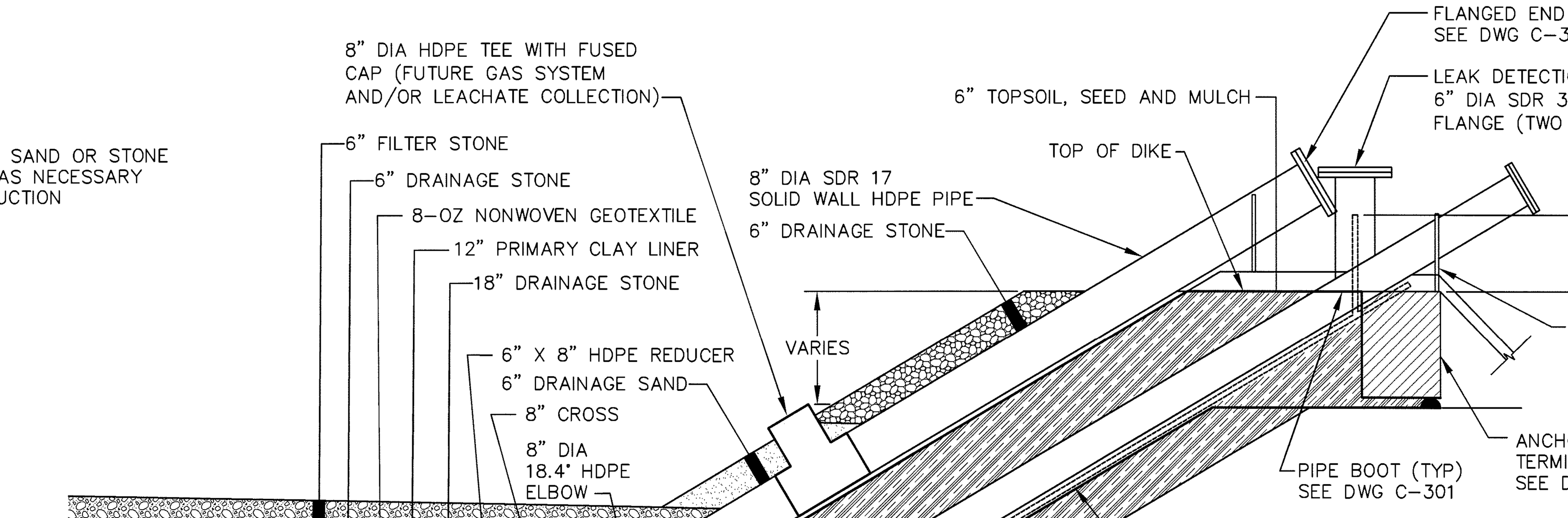
LANDFILL LINER SYSTEM TIE-IN (TYP)
NTS



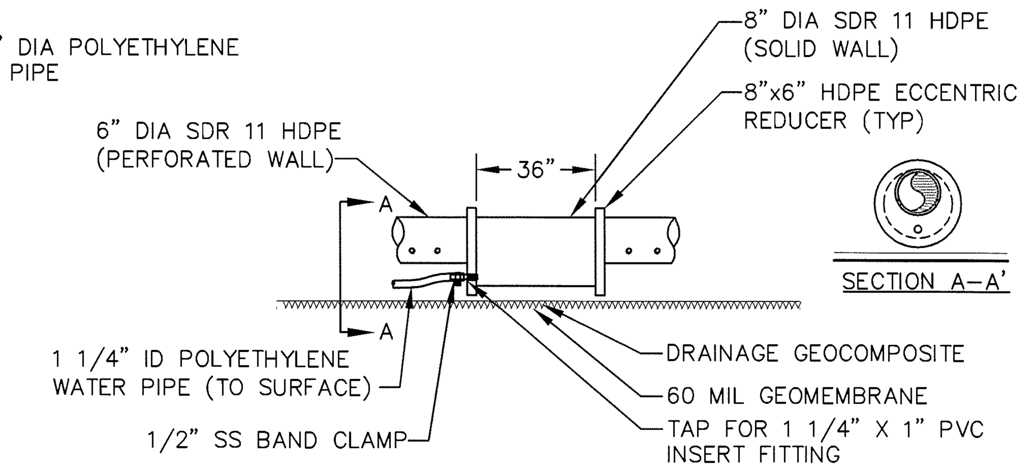
PIPING AT PERIMETER BERM
NTS



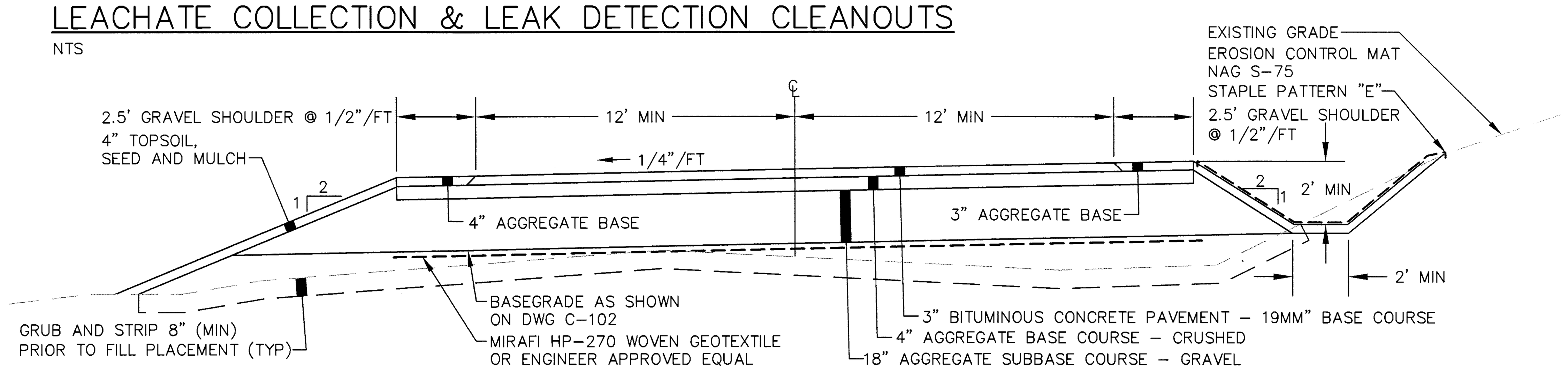
GRAVEL ROAD BUILD-UP
NTS



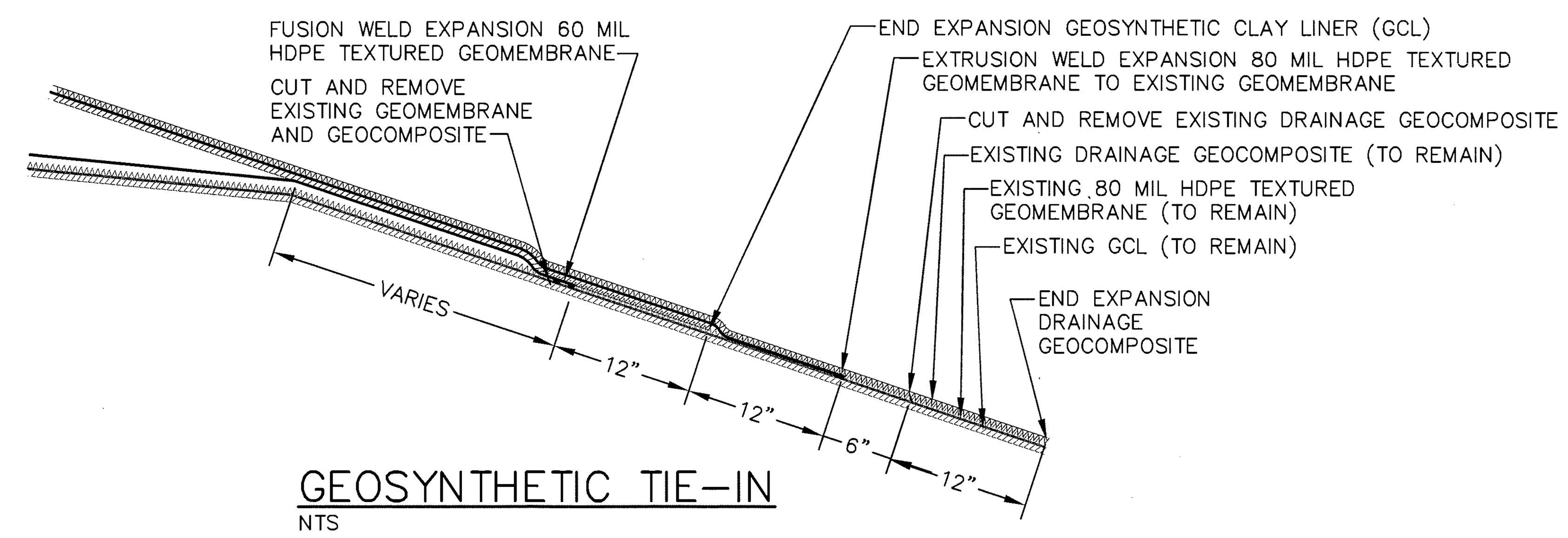
LEACHATE COLLECTION & LEAK DETECTION CLEANOUTS
NTS



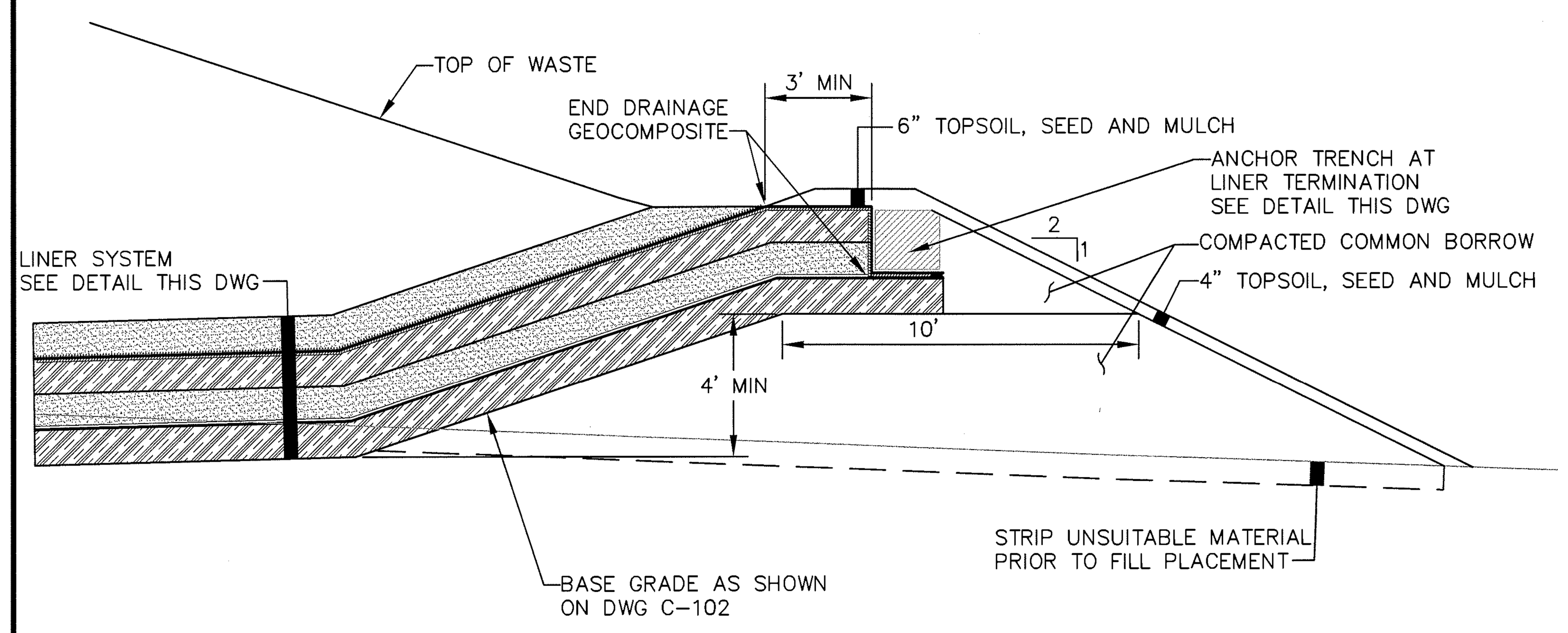
SAMPLE SUMP
NTS



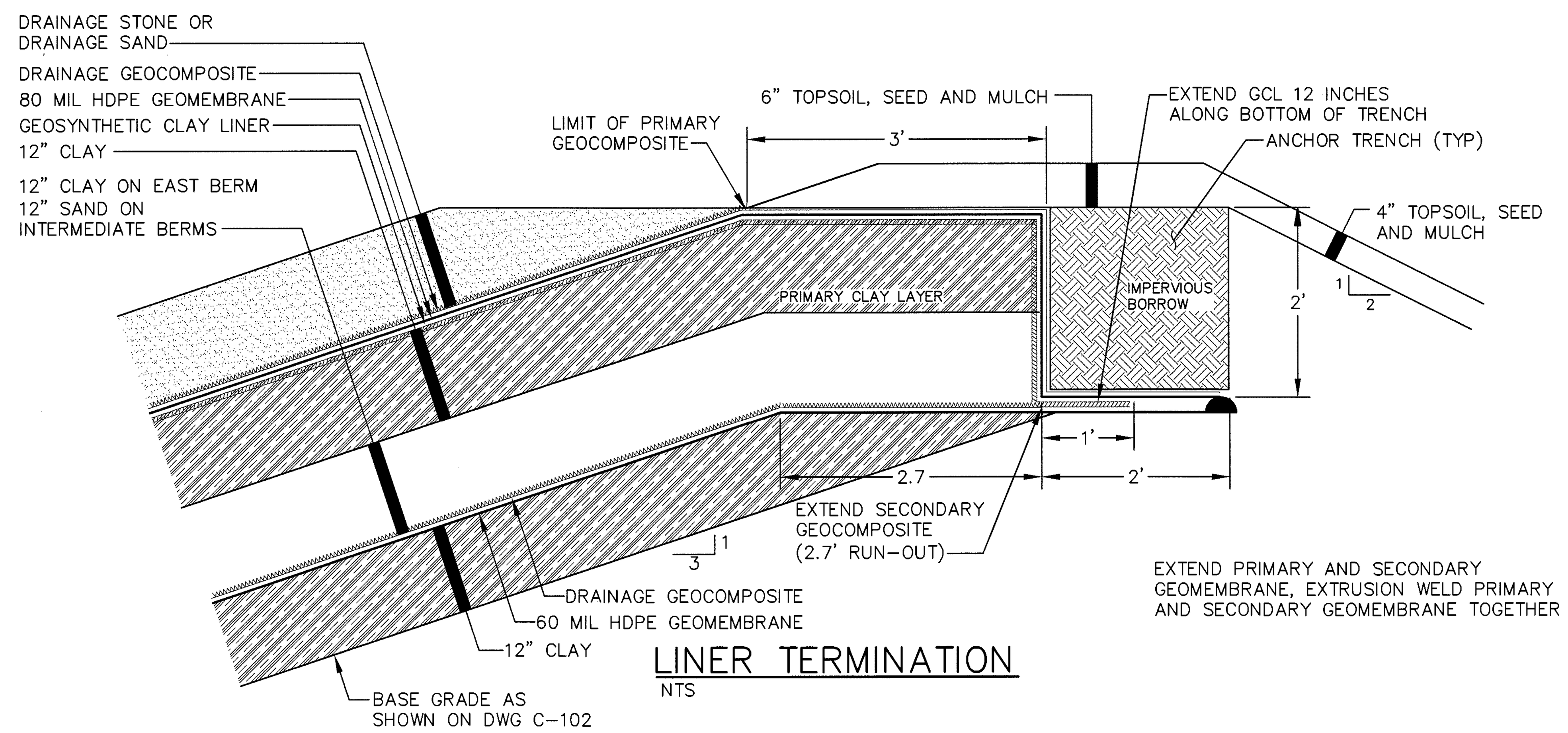
24'-WIDE TEMPORARY PAVED ACCESS ROAD
NTS



GEOSYNTHETIC TIE-IN
NTS



INTERMEDIATE CELL BERM (1)
NTS
C-102
C-103
C-104
C-200



LINER TERMINATION
NTS

REV.	BY	DATE	STATUS
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CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

SECTIONS AND DETAILS

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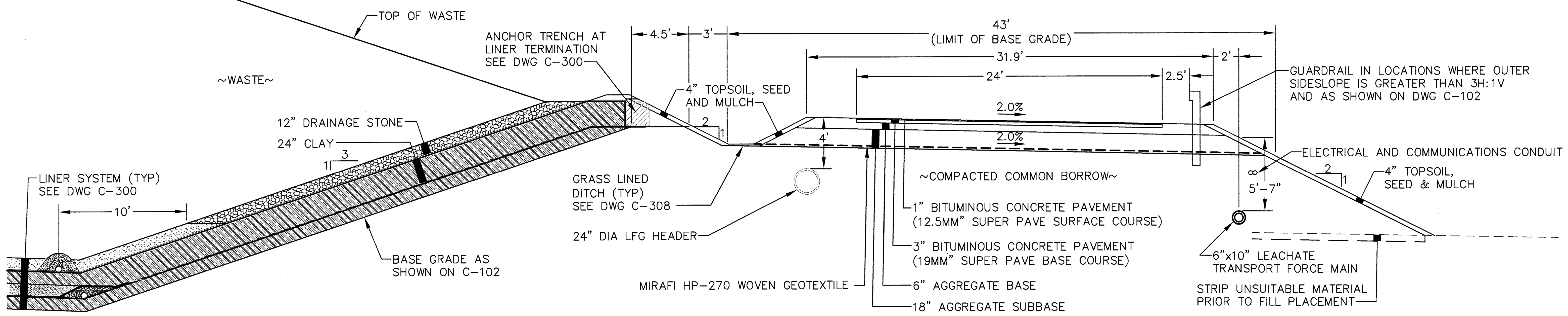
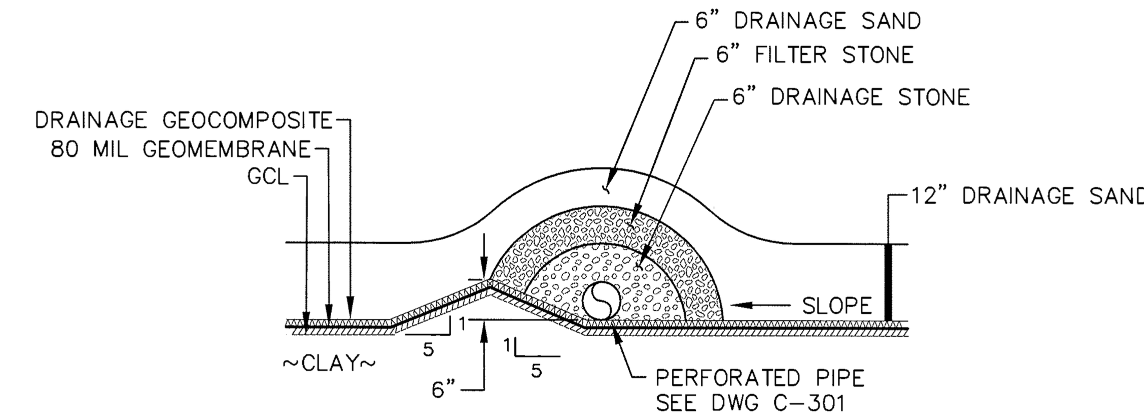
DATE: 12/5/2014
CHECKED BY:
LMN: NONE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE DETAILS

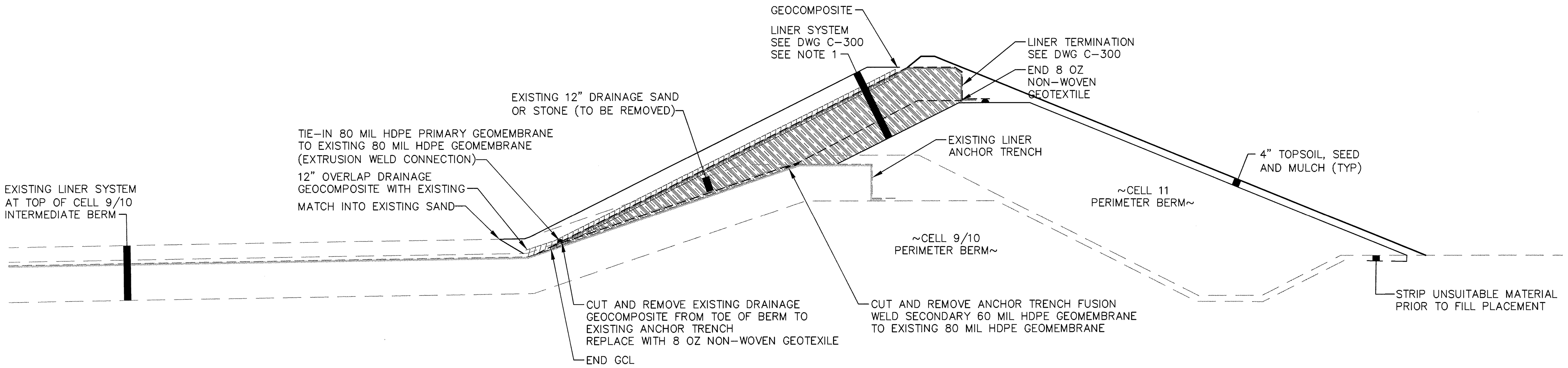
C-300



EAST SIDE PERIMETER BERM AND ACCESS ROAD (1)
NTS
C-102
C-103
C-104
C-105
C-107
C-108

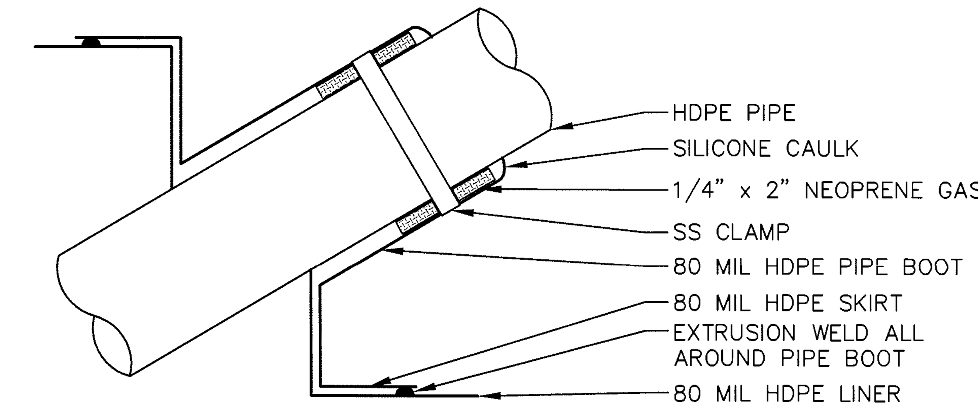


LEACHATE COLLECTION LATERAL (TYP)
NTS

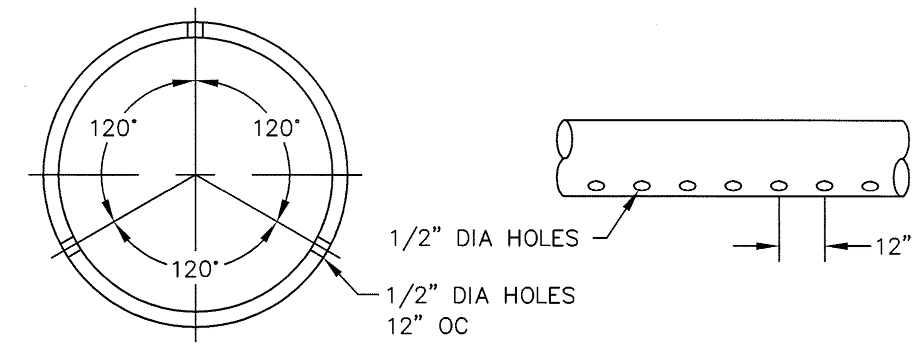


NOTE:
1. ON THE SIDESLOPE OF THE PERIMETER BERM THE LEAK DETECTION SAND LAYER IS REPLACED WITH 12-INCHES OF CLAY.

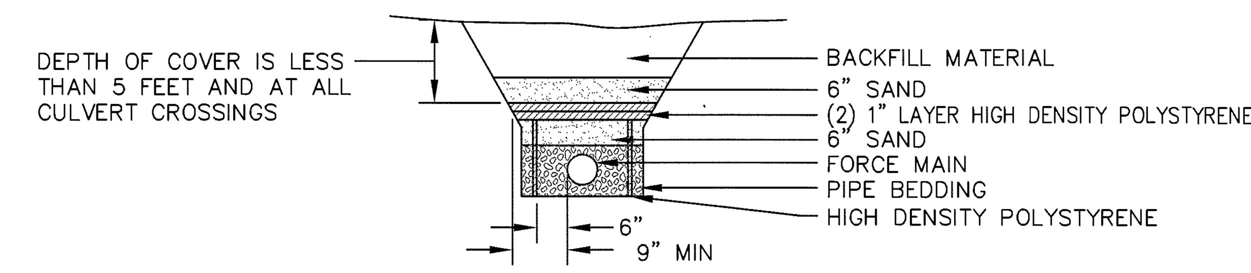
SECTION A-A'
NTS



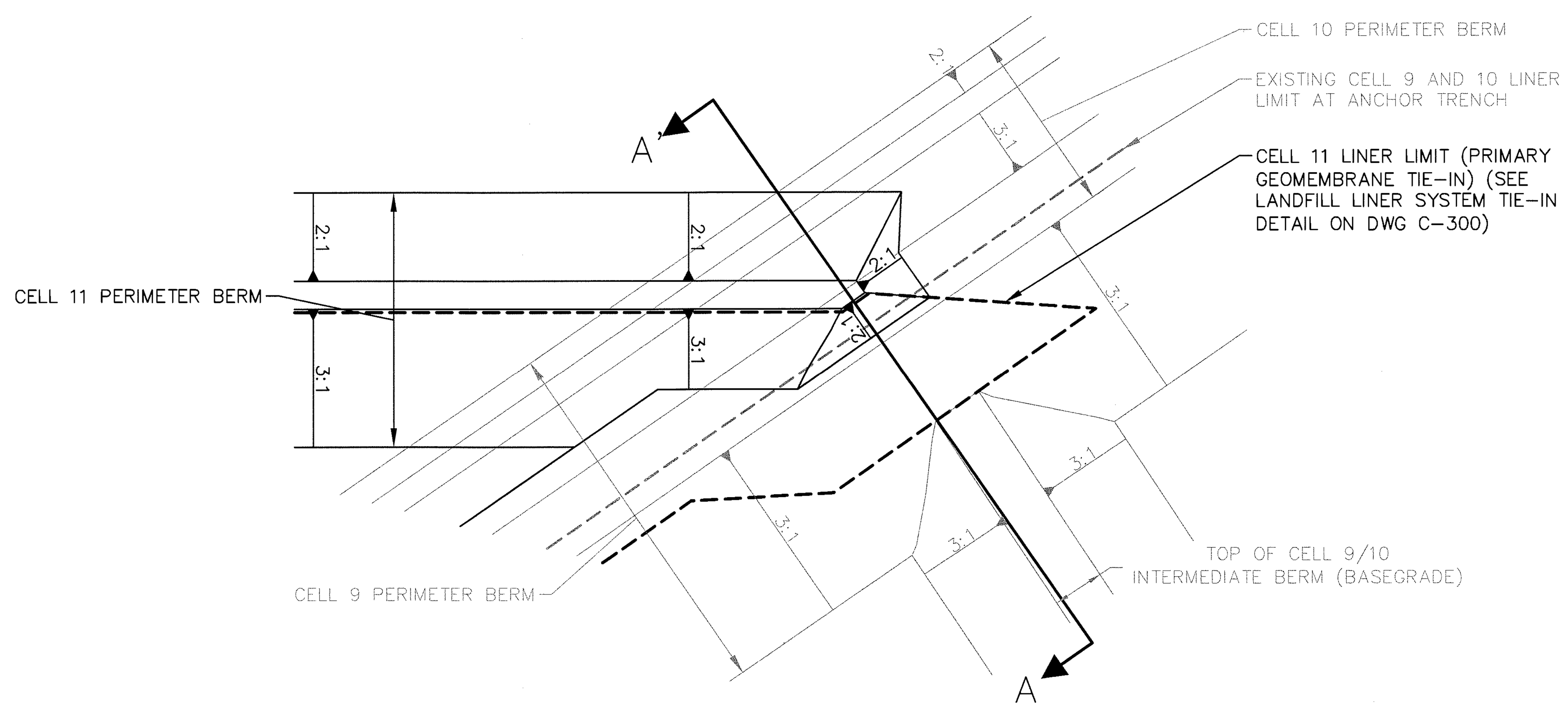
PIPE BOOT
NTS



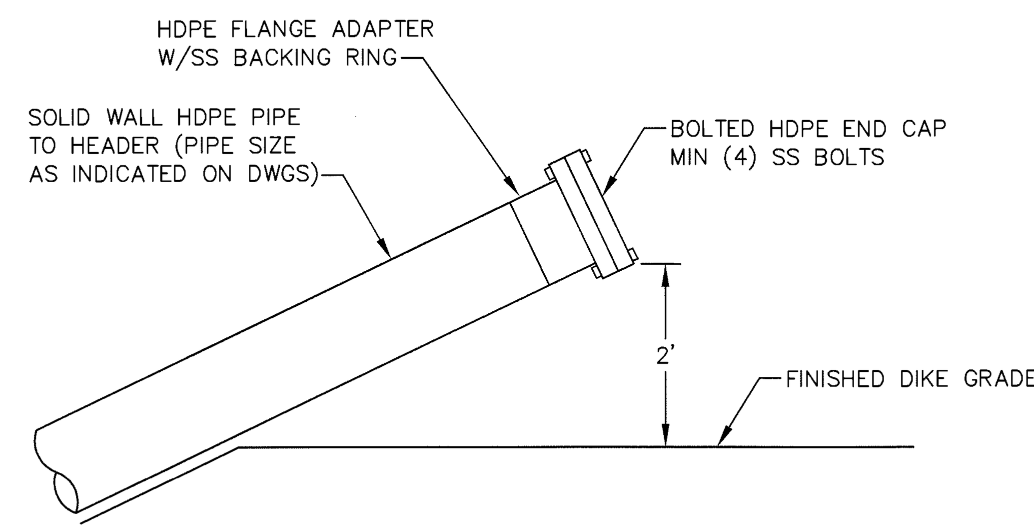
PERFORATED PIPE
NTS



PIPE INSULATION
NTS



PERIMETER BERM TIE-IN AT SOUTH END OF CELL 11
NTS



FLANGED END CAP
NTS

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CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

SECTIONS AND DETAILS

STATE OF MAINE — GUY H. COTE, JR. No. 5146 — LICENSED PROFESSIONAL ENGINEER

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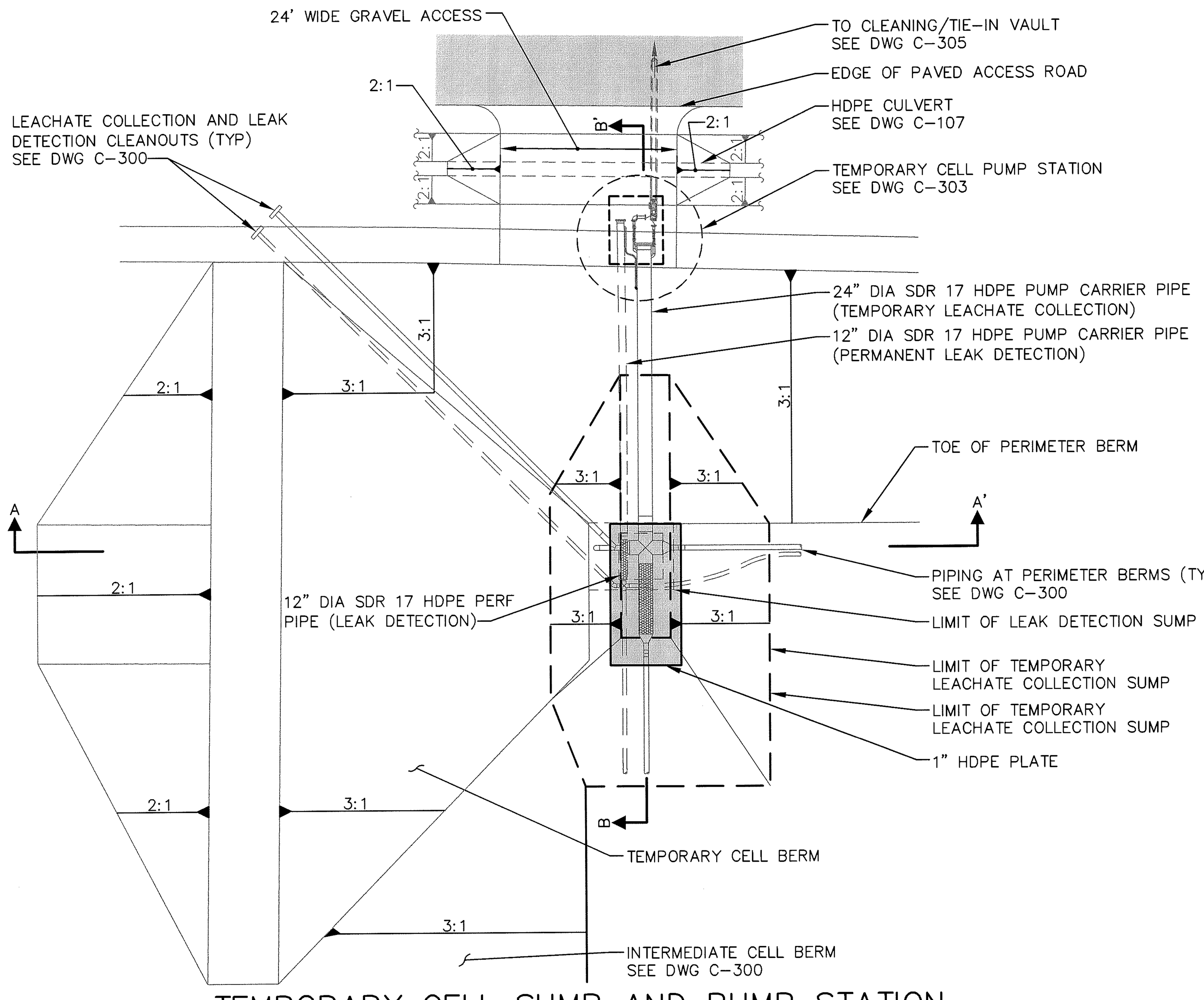
LMN: NONE
CTB: SME-STD

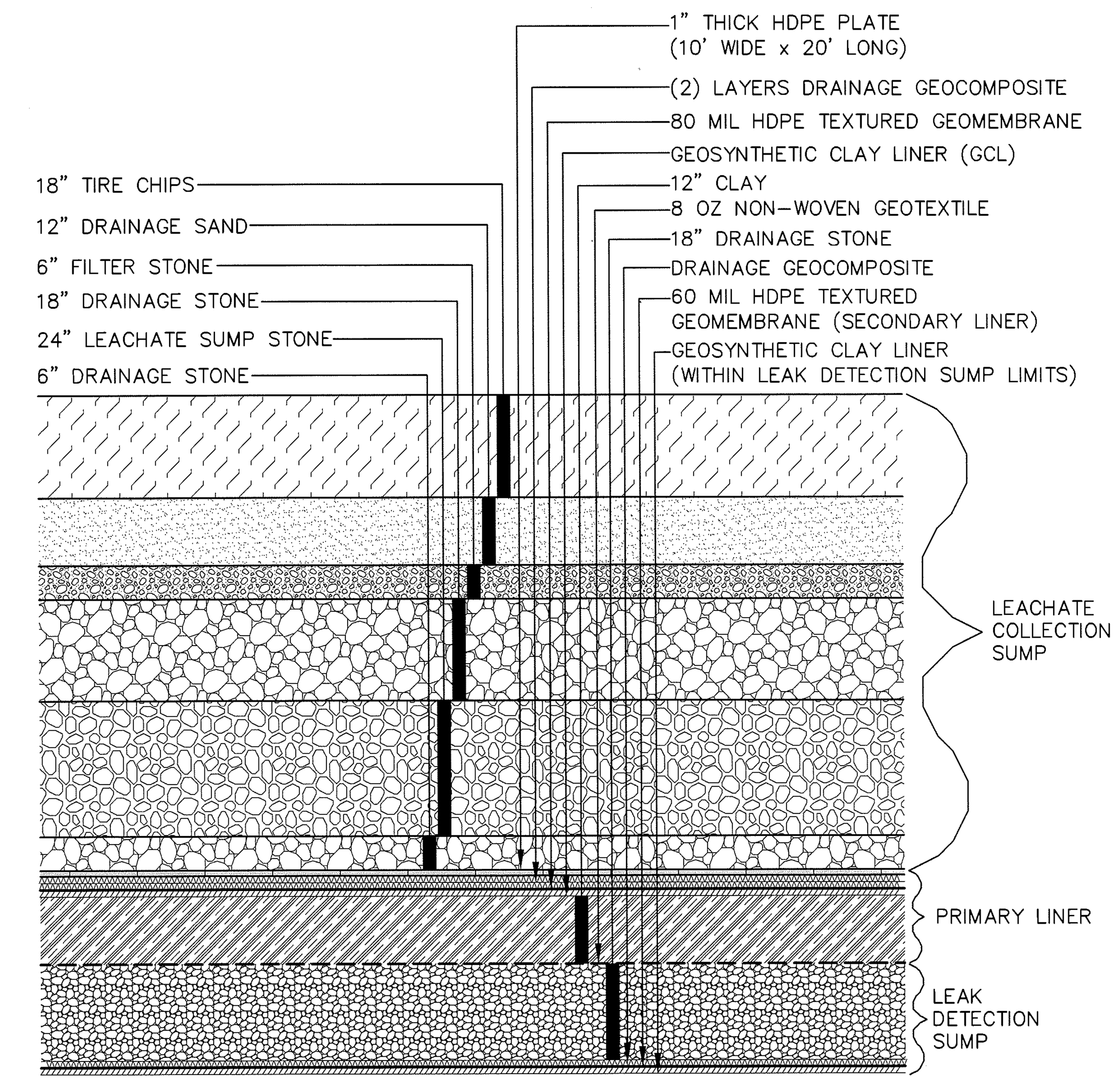
JOB NO. 14101.00 DWG FILE DETAILS
C-301

SECTION A–A'
NTS

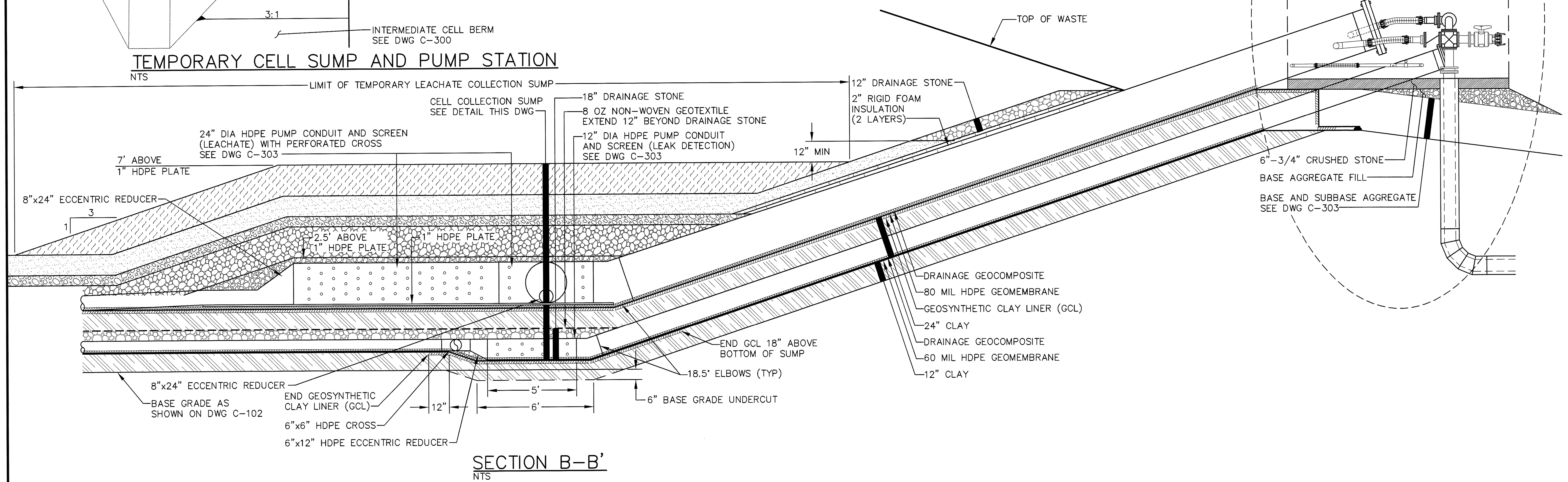
NOTES:
1. UNDERDRAIN AND AUGMENTED SECONDARY LINER ARE NOT SHOWN IN DETAIL. BASE GRADE SHALL BE UNDERCUT AN ADDITIONAL 1-FOOT IN THOSE LOCATIONS
2. LIMIT OF LEACHATE COLLECTION SUMP IS DEFINED BY THE LIMIT OF THE 18" TIRE CHIPS LAYER



TEMPORARY CELL SUMP AND PUMP STATION
NTS



CELL COLLECTION SUMP
NTS



SECTION B–B'
NTS

REV.	BY	DATE	STATUS
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CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

SECTIONS AND DETAILS

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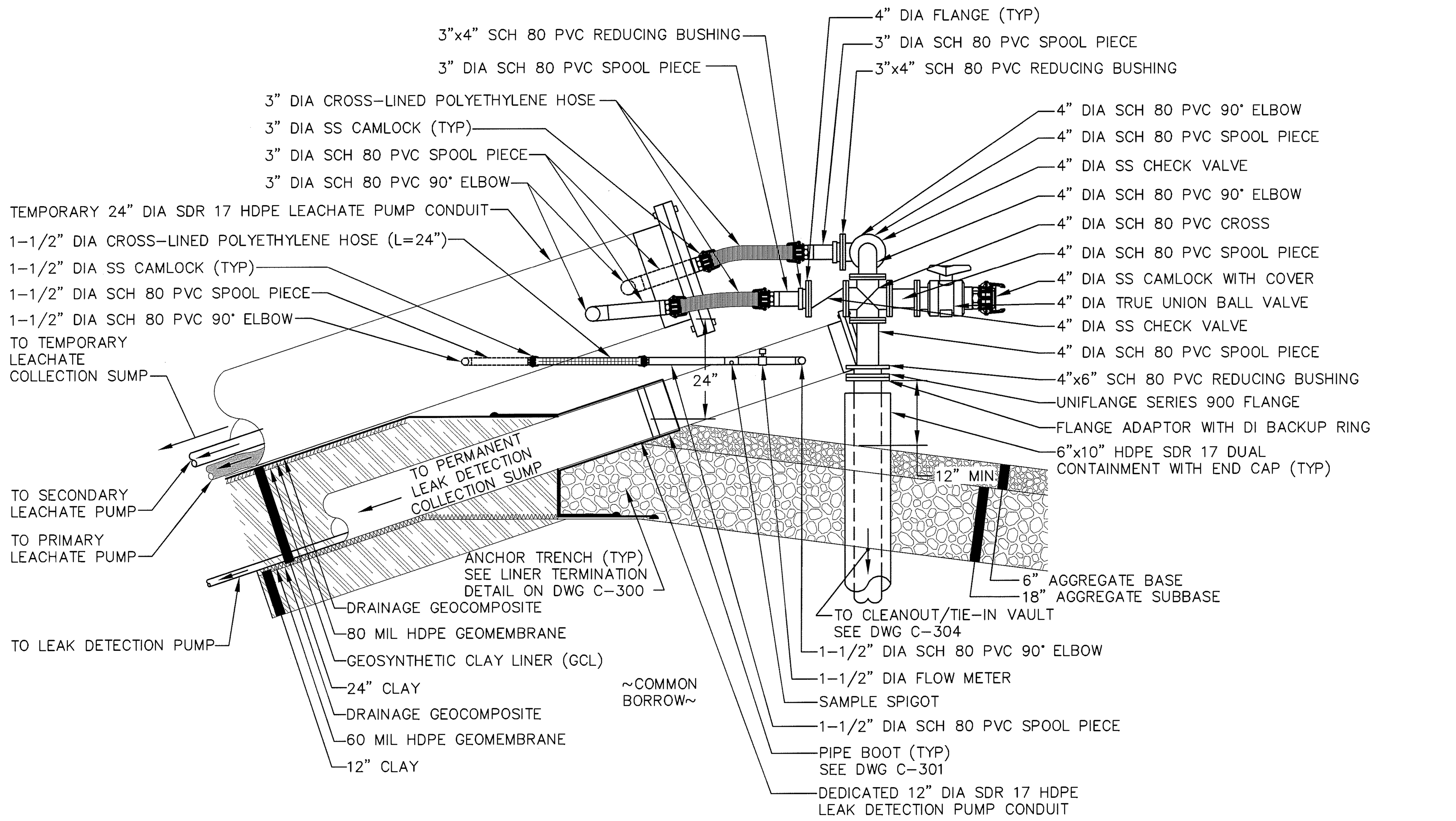
DATE:	12/5/2014
CHECKED BY:	
LMN:	NONE
CTB:	SME-STD

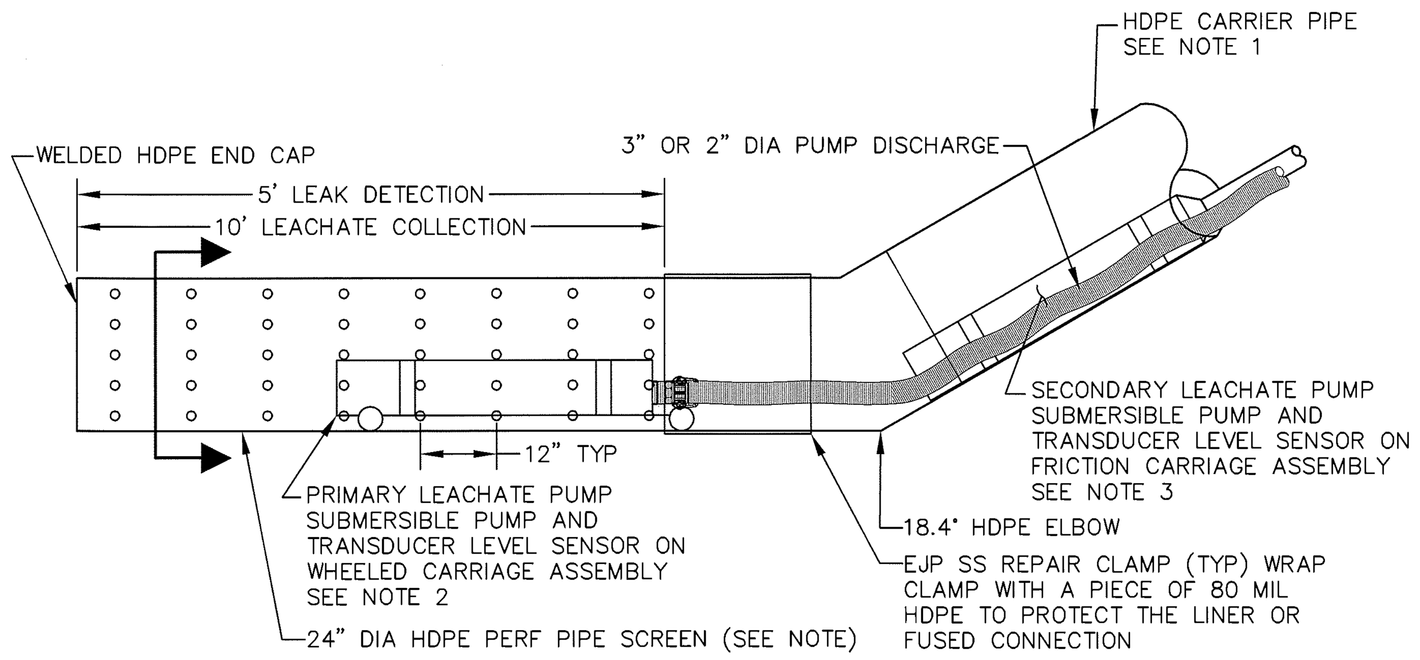
JOB NO. 14101.00 DWG FILE DETAILS

C-302

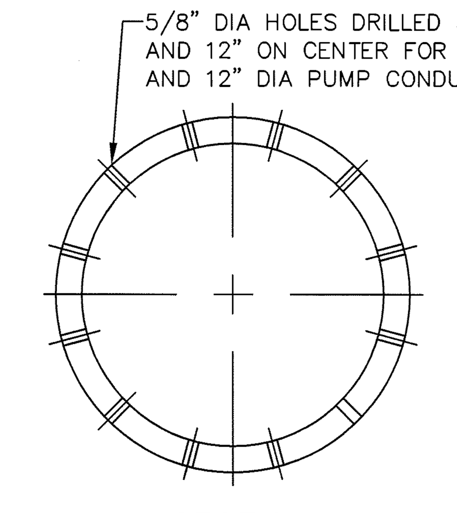


NOTE:
ALL LEACHATE COLLECTION PUMPS AND TRANSPORT PIPING SHOWN ARE TEMPORARY AND SHALL BE REMOVED OR ABANDONED AS SUBSEQUENT DOWNSTREAM CELL IS CONSTRUCTED. THE 24" PUMP CARRIER PIPE SHALL REMAIN IN PLACE AS A CLEANOUT. THE LEAK DETECTION PUMP AND PIPING IS PERMANENT AND SHALL REMAIN IN PLACE.

SECTION A–A'



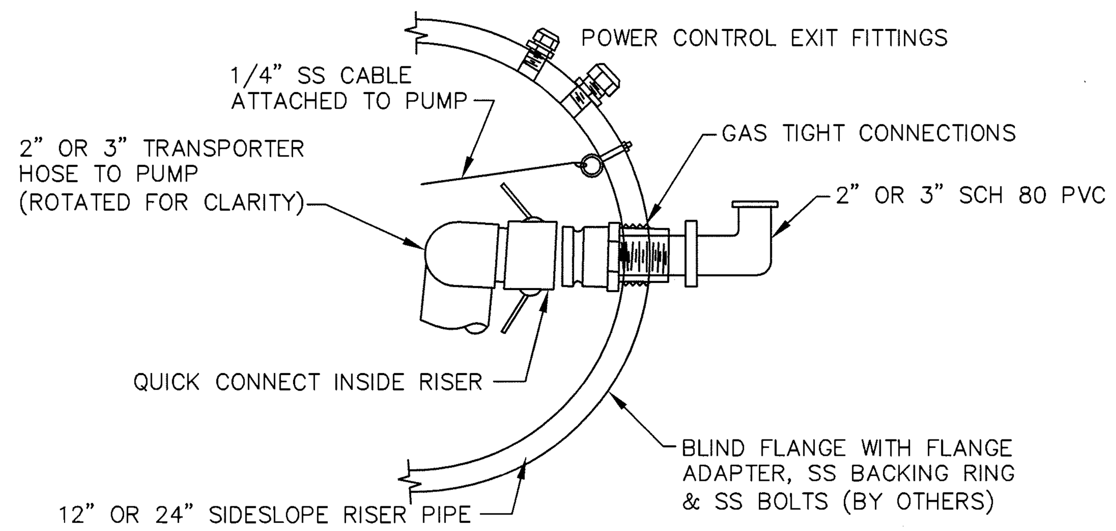
HDPE PUMP CONDUIT AND SCREEN
NTS



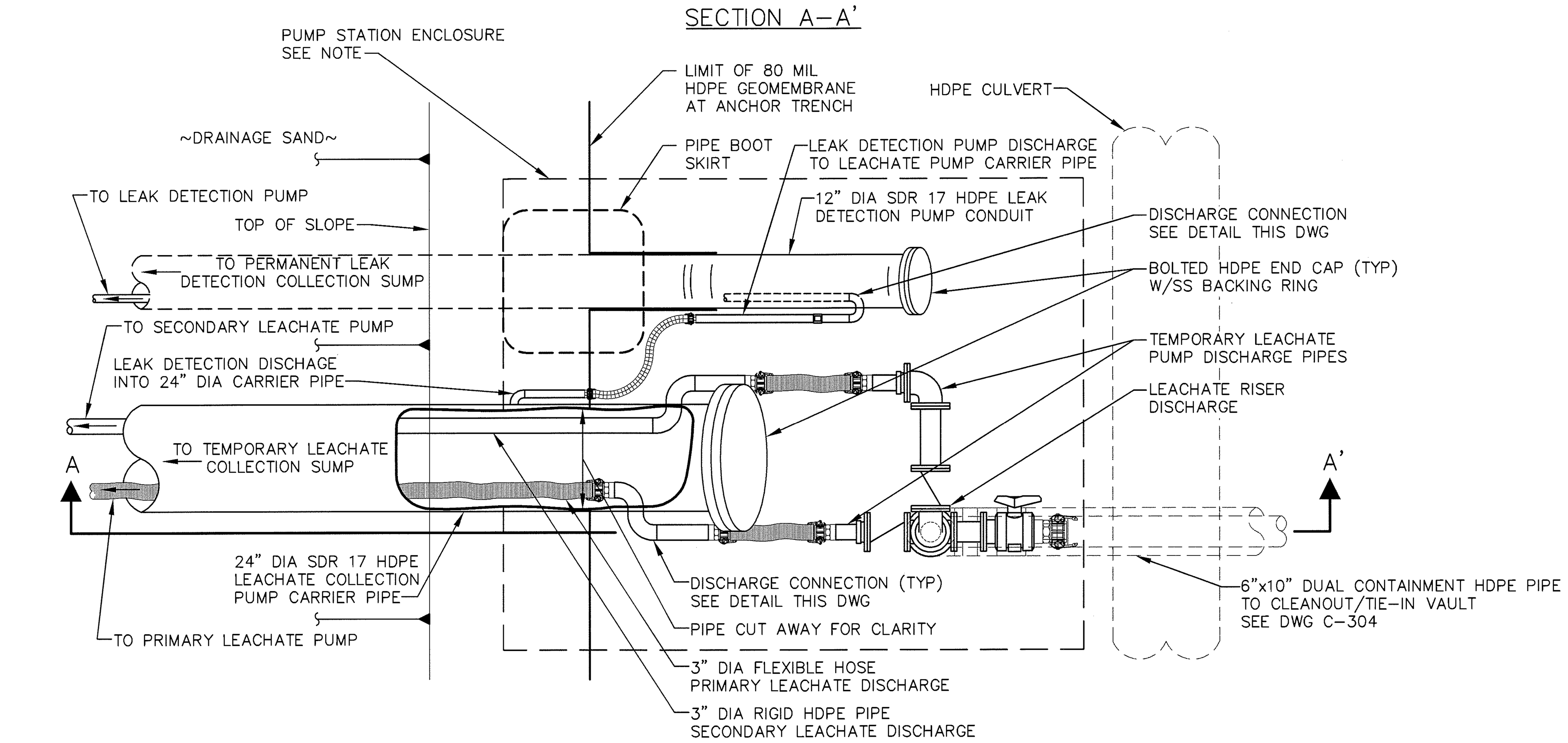
SECTION

NOTES:

1. DIAMETER OF PUMP CONDUIT AND SCREEN IS EITHER 12" FOR LEAK DETECTION SYSTEM OR 24" FOR LEACHATE COLLECTION SYSTEM.
2. PRIMARY LEACHATE PUMP SHALL BE AT THE BOTTOM OF SUMP AND SIT HORIZONTALLY ON SUMP FLOOR.
3. SECONDARY LEACHATE PUMP SHALL BE POSITIONED ON THE INCLINED SIDESLOPE AND BE LOWERED TO THE TOW OF SLOPE.
4. LEAK DETECTION PUMP SHALL BE POSITIONED AT THE BOTTOM OF THE LEAK DETECTION SUMP AND SIT HORIZONTALLY ON SUMP FLOOR. LEAK DETECTION DISCHARGE HOSE IS 2-INCH DIAMETER.



DISCHARGE CONNECTION
NTS



NOTE:
THE PUMP STATION ENCLOSURE IS TO BE A WOOD FRAMED BUILDING MOUNTED TO A PRESSURE TREATED WOOD FRAMED SKID. THE CONTRACTOR SHALL SUBMIT SHOP DRAWINGS OF THE PUMP STATION ENCLOSURE TO THE ENGINEER AND OWNER FOR APPROVAL. THE PUMP STATION SHALL INCLUDE BUT NOT BE LIMITED TO, 2"x6" WOOD FRAMING, INSULATION, METAL ROOF, T-111 SIDING, ELECTRICAL LIGHTING, GFIC RECEPTACLE, INSULATED DOUBLE STEEL DOORS, PASSIVE VENTILATION AND GAS MONITORING SYSTEM.

TEMPORARY CELL PUMP STATION
NTS

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STATE OF MAINE · GUY H. COTE, JR. · No. 5144 · LICENSED · PROFESSIONAL ENGINEER

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

SECTIONS AND DETAILS

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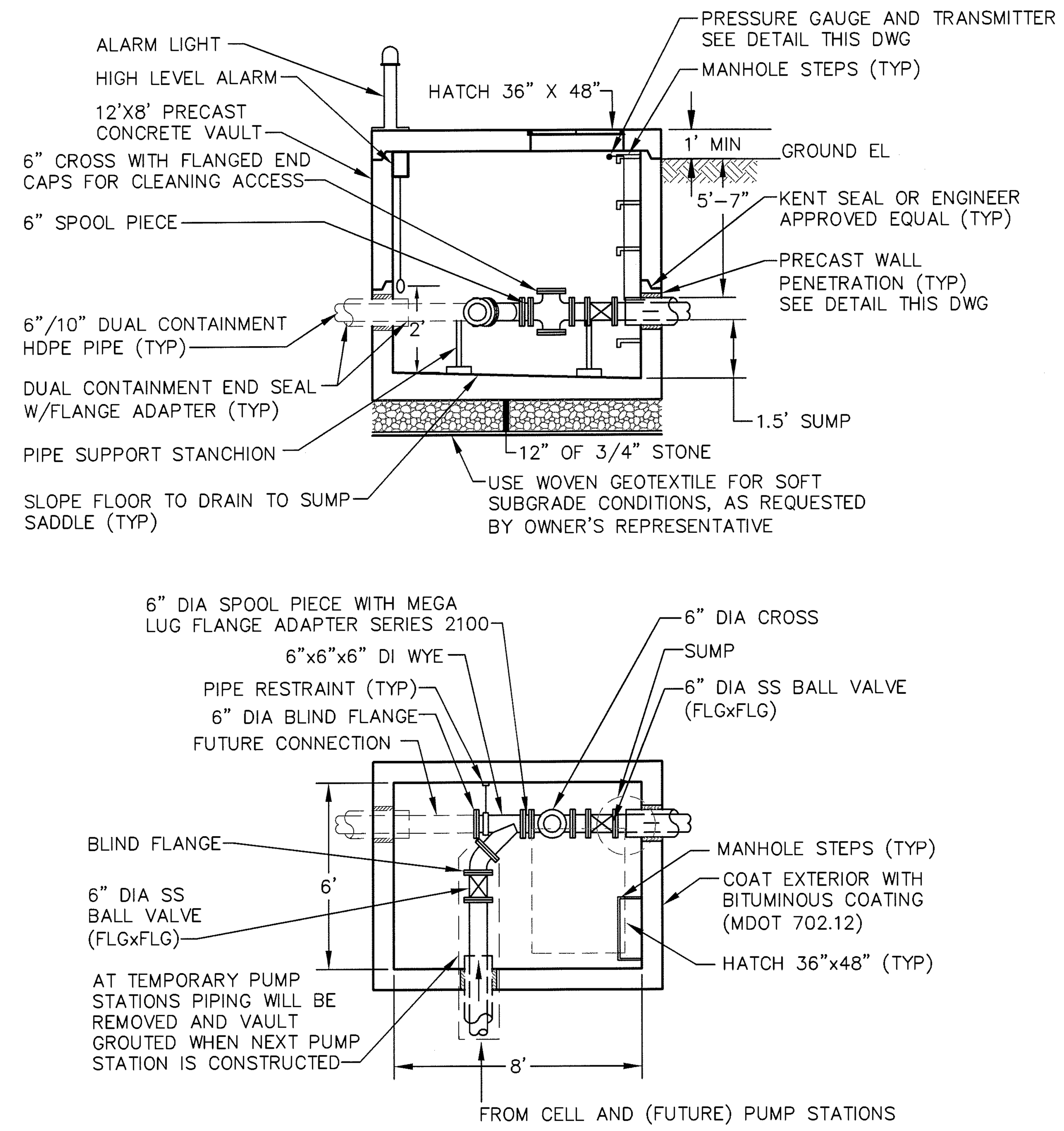
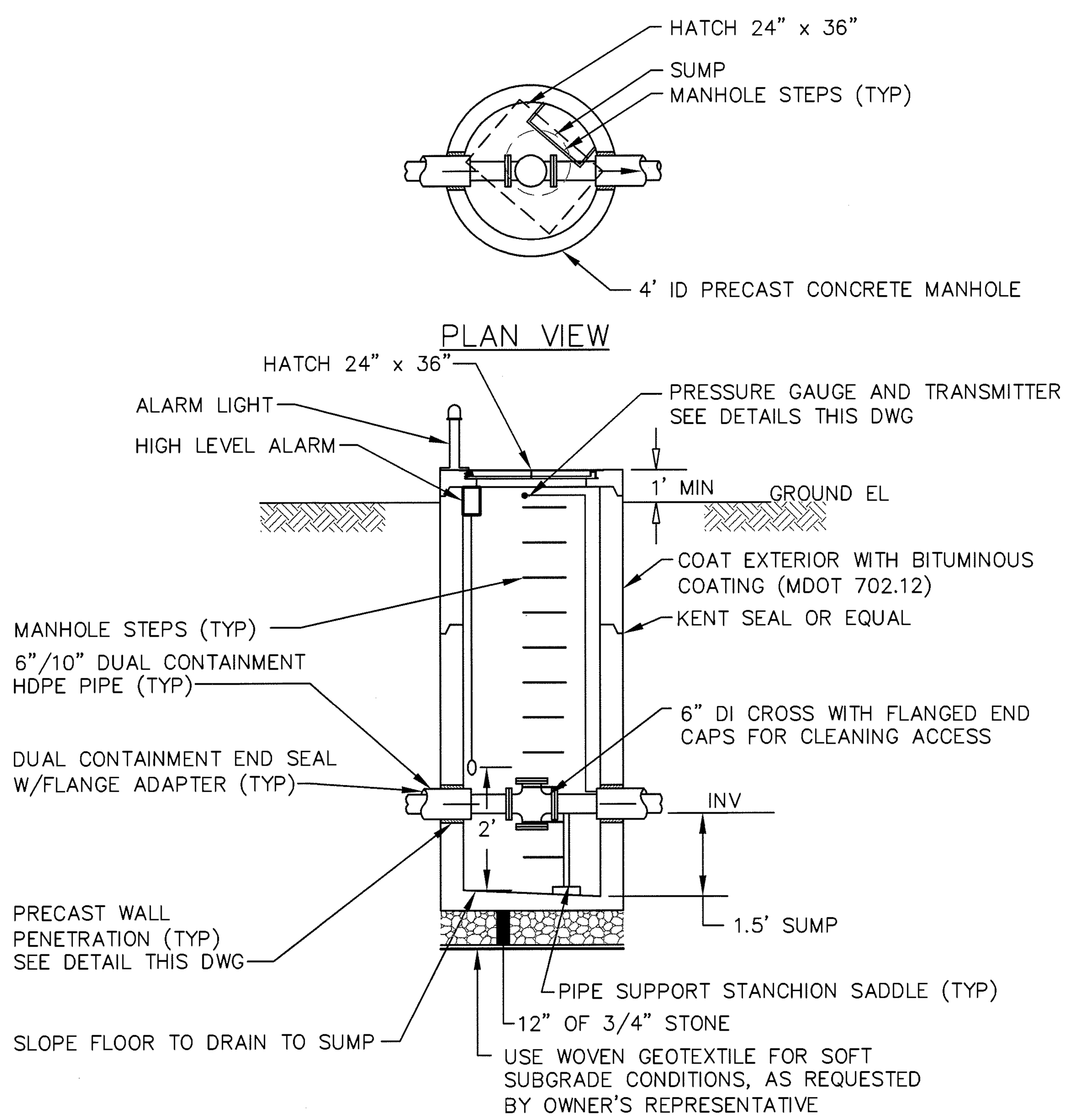
LMN: NONE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE DETAILS

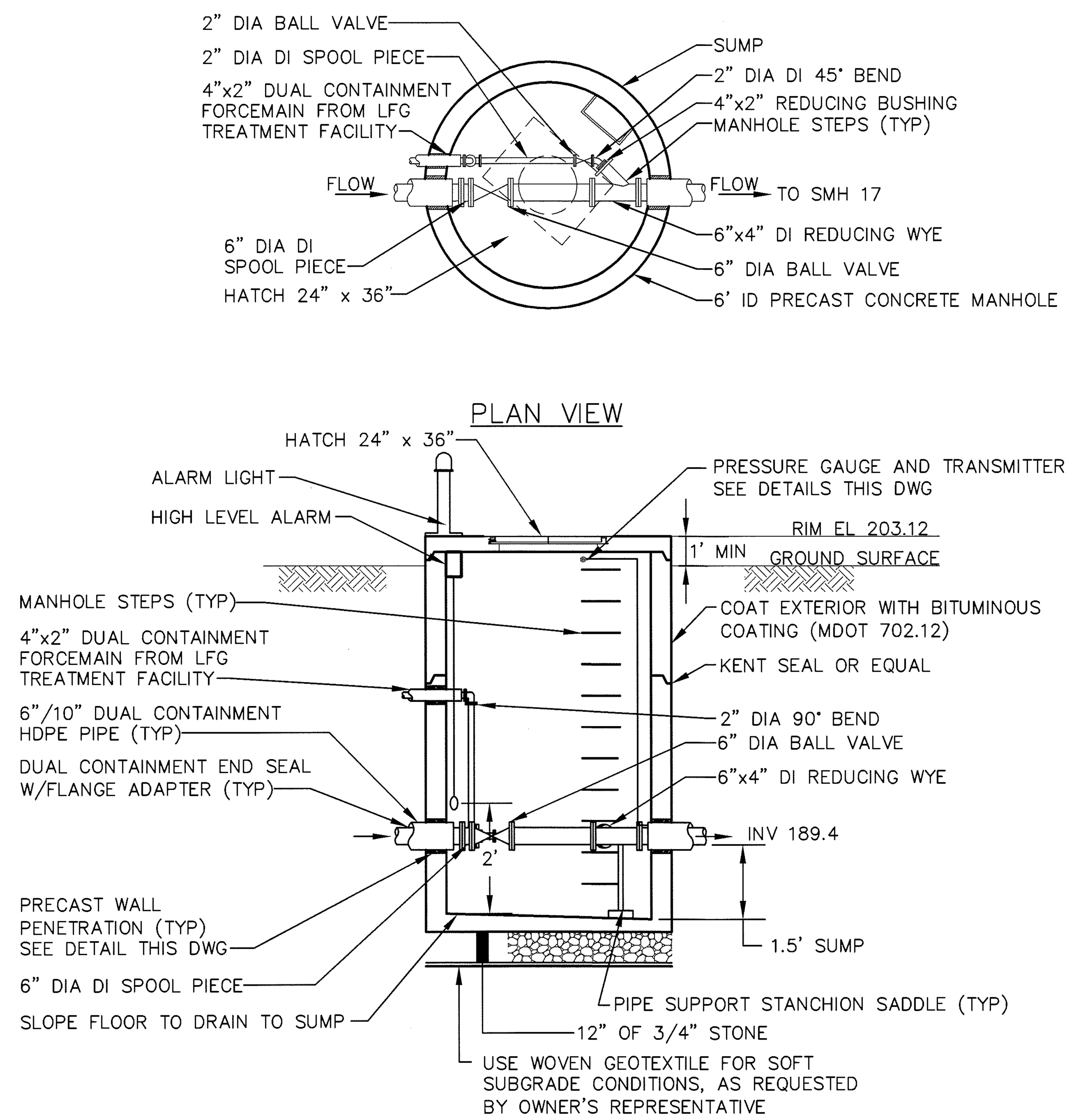
C–303



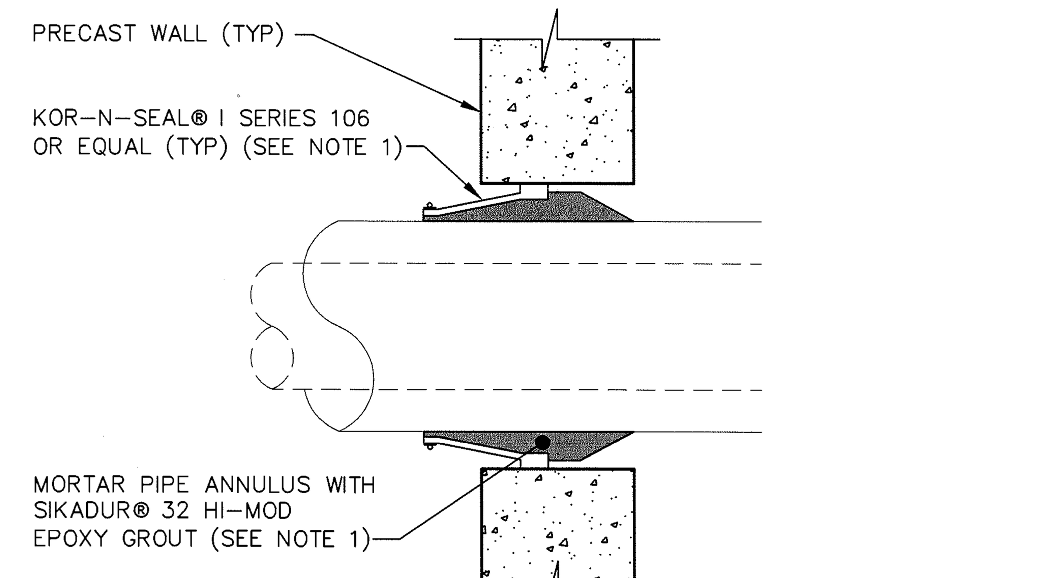
CLEANING/TIE-IN VAULT
NTS



CLEANING MANHOLE
NTS



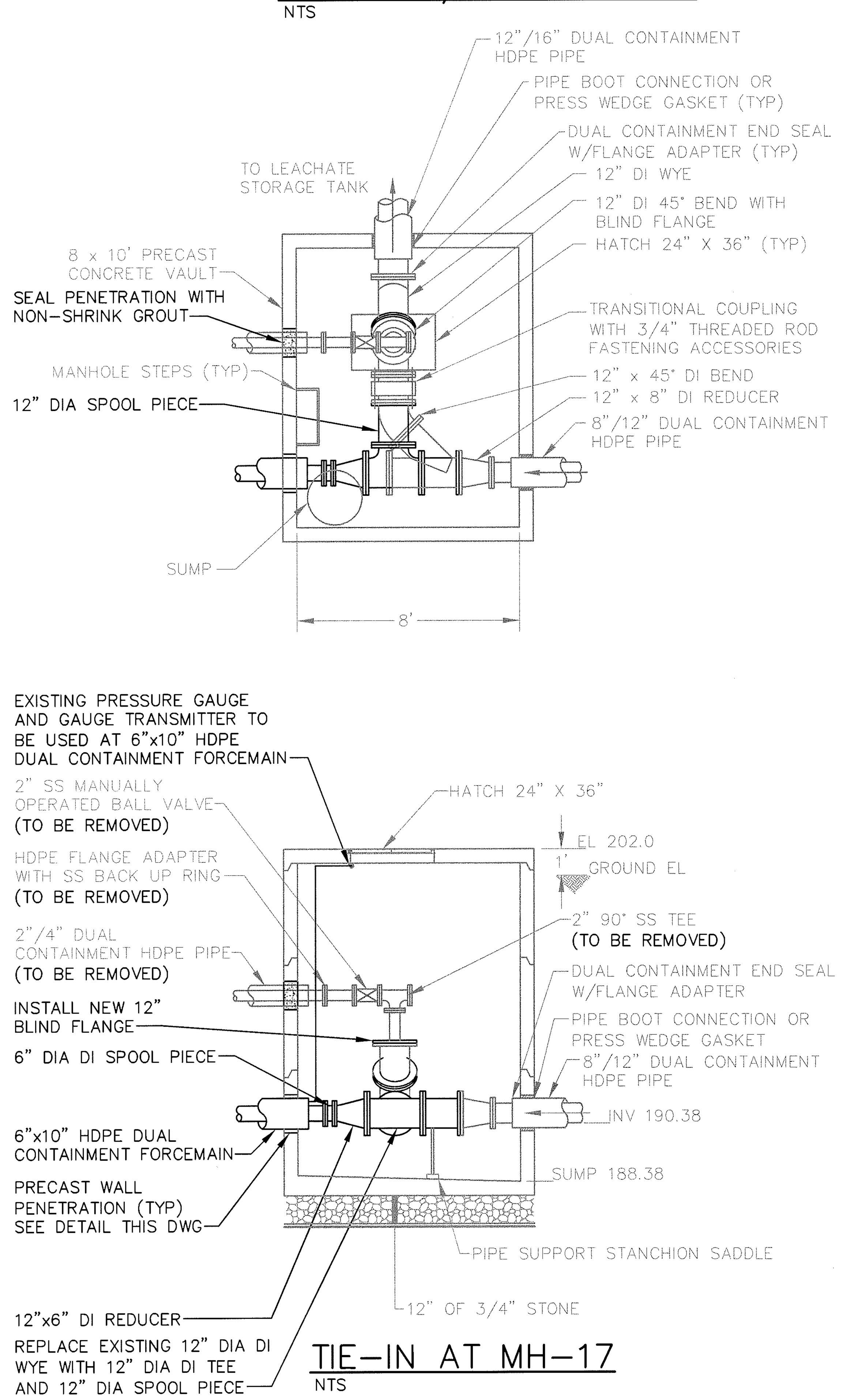
FORCEMAIN TIE-IN AT LEACHATE STORAGE TANK
NTS



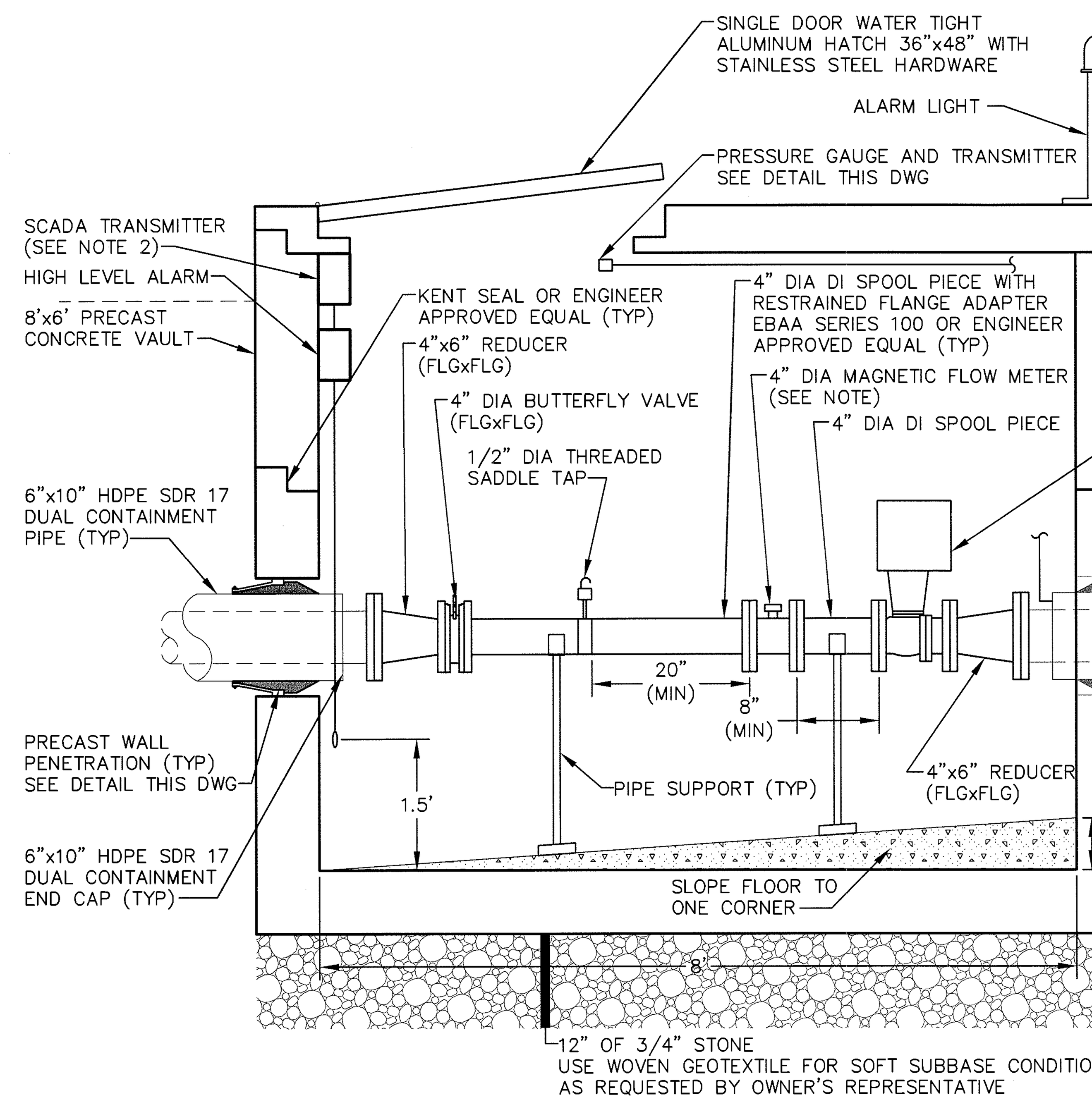
NOTE:

THE JOINTS FOR THE PIPES THROUGH PRECAST WALLS SHALL BE WEDGE STYLE KOR-N-SEAL®I SERIES 106 AS MANUFACTURED BY TRELLEBORG OR EQUAL. THE ANNULUS SHALL BE MORTARED WITH SIKADUR®32 HI-MOD GROUT AS MANUFACTURED BY SIKA CORPORATION. THE CONTRACTOR SHALL FOLLOW THE MANUFACTURERS INSTRUCTIONS TO MIX AND APPLY THE EPOXY GROUT. THE FINAL MORTARED PLUG SHALL YIELD A STRONG AND RIGID SEAL AROUND THE PIPE. COMPLETE VACUUM TESTING PRIOR TO THE INSTALLATION OF GROUT.

PRECAST WALL PENETRATION
NTS



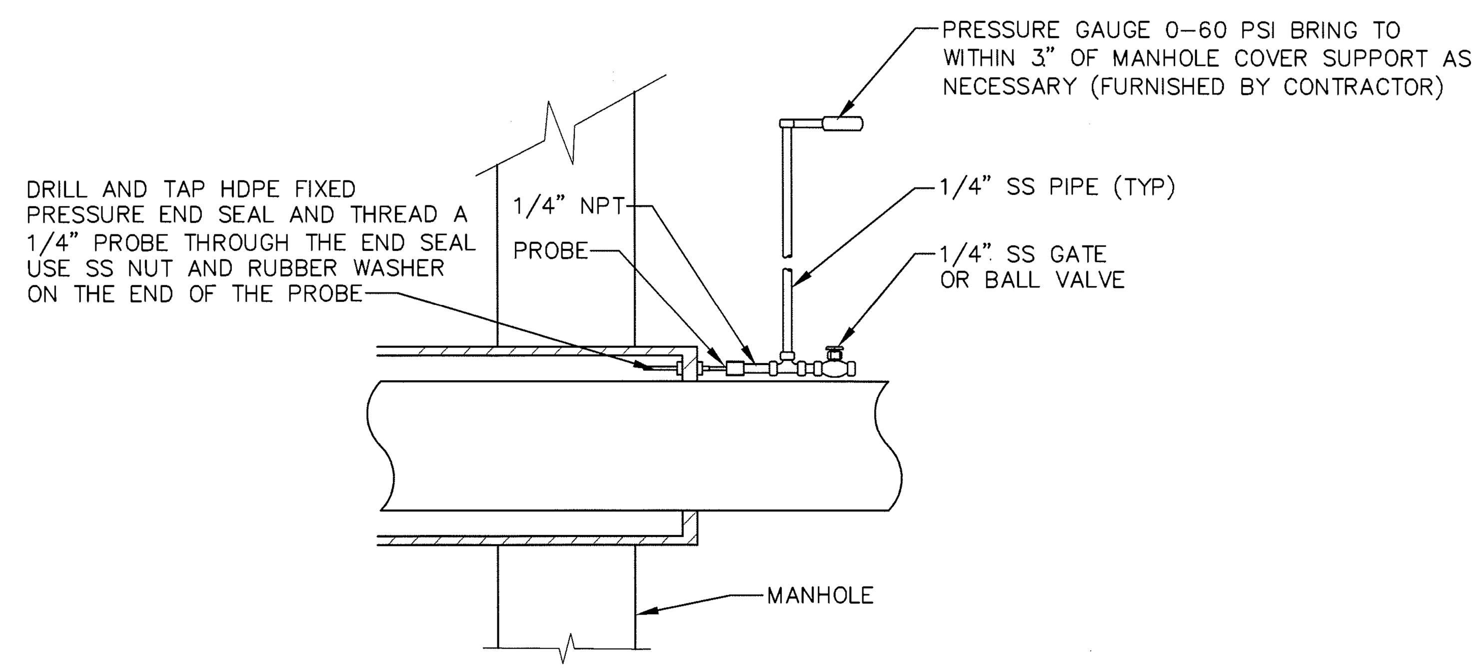
TIE-IN AT MH-17
NTS



NOTE:

FLOW METER AND BALL VALVE WITH ELECTRIC ACTUATOR SHALL BE CONNECTED TO SCADA TRANSMITTER.

FORCE MAIN METER AND VALVE PIT
NTS



PRESSURE PROBE AND GAUGE
NTS

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OLD TOWN, MAINE

SECTIONS AND DETAILS

STATE OF MAINE — GUY H. COTE, JR. — No. 5144 — LICENSED — PROFESSIONAL ENGINEER

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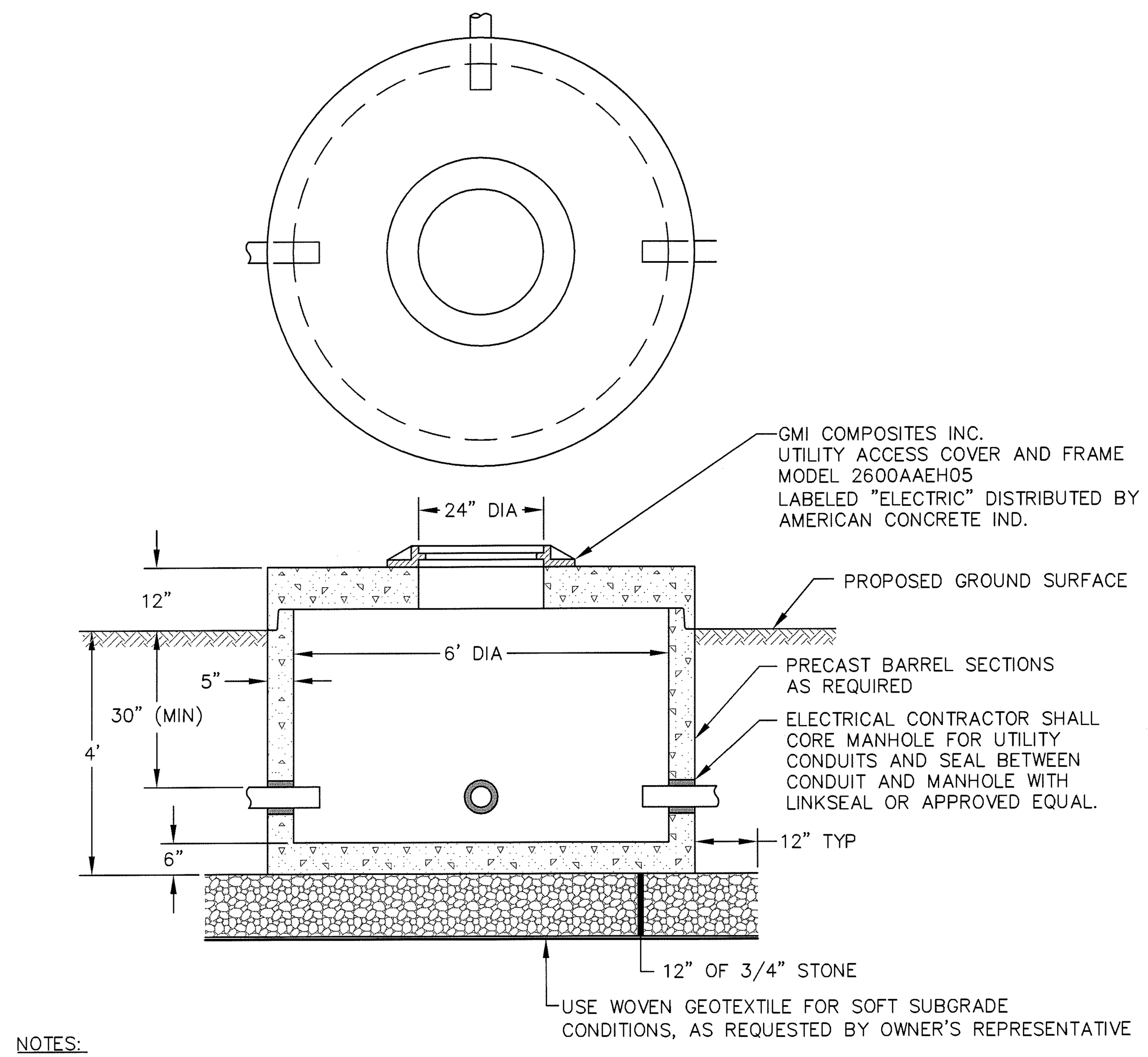
LMN: NONE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE DETAILS

C-304

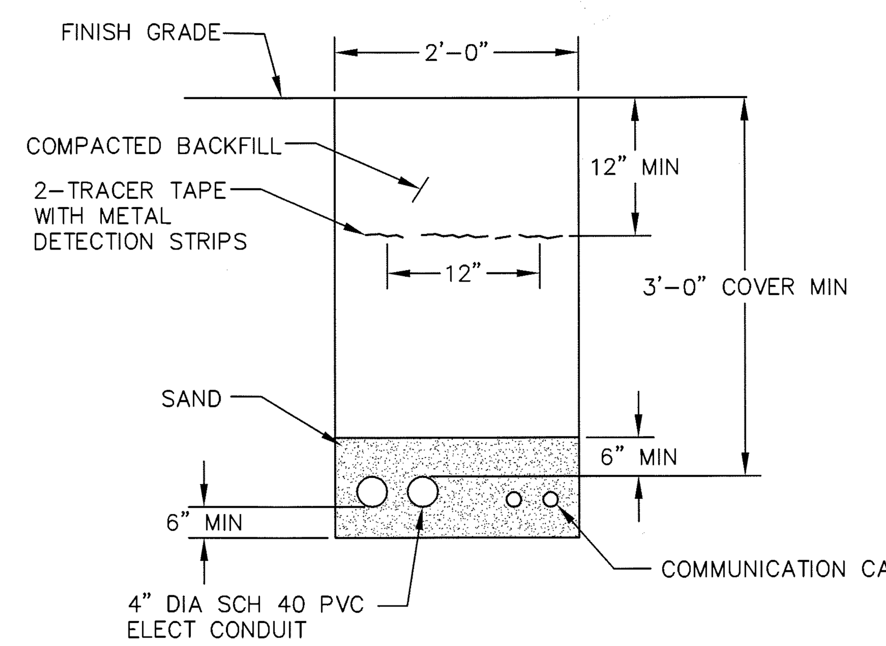


NOTES:

1. 6' DIA MANHOLE AS MANUFACTURED BY AMERICAN CONCRETE INDUSTRIES OR ENGINEER APPROVED EQUAL.
2. 4000 PSI CONCRETE AT 28 DAYS.
3. DESIGNED FOR H-20 WHEEL LOADING.
4. CONFORMS TO ASTM C-478 SPECIFICATIONS.
5. REINFORCED TO 0.12 IN SQ/LF.
6. SHIPLAP JOINTS SEALED WITH BUTYL RUBBER.
7. EXTERIOR COATED WITH ASPHALTIC PROTECTIVE DAMPROOFING.
8. BOTTOM MIN 5'-0" BELOW FINISH GRADE.
9. PRECAST CONCRETE VAULT MANUFACTURER TO PROVIDE ANTI-FLOATATION EXTENDED BASE SLAB AS NECESSARY. ANTI-FLOATATION DESIGN AND SHOP DRAWINGS SHALL BE PREPARED BY THE MANUFACTURER AND SUBMITTED TO THE ENGINEER FOR APPROVAL.

ELECTRIC UTILITY MANHOLE

NTS



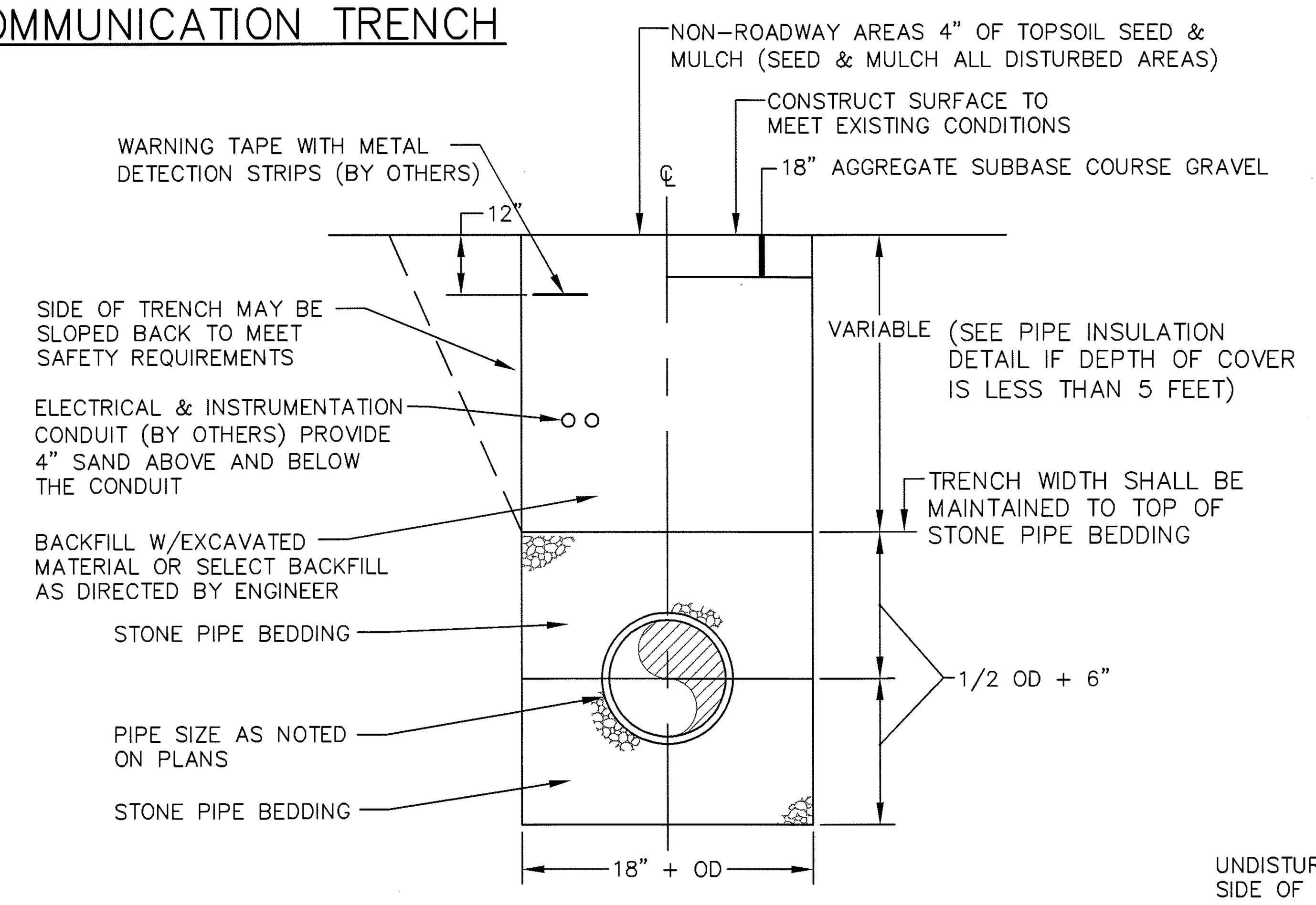
UNDERGROUND ELECTRIC AND COMMUNICATION TRENCH

NTS

CULVERTS	DIAMETER (IN)	LENGTH (FT)	SLOPE (FT/FT)	INV IN (FT)	INV OUT (FT)
C-4BA	24	78	0.01	204.4	203.7
C-4BB	24	78	0.01	204.4	203.7
C-11-T1	18	90	0.07	198.0	192.0
C-11-T2	24	50	0.06	192.0	189.0
C-4I	18	80	0.13	202.5	192.0
C-4IA	18	40	0.02	212.9	212.2
C-4JA	18	60	0.03	214.0	212.3
C-4JB	24	73	0.02	211.5	210.0
C-4JC	24	73	0.02	211.5	210.0
C-4K	24	51	0.04	216.5	214.3
C-4L	18	121	0.02	213.0	211.0

CULVERT SCHEDULE

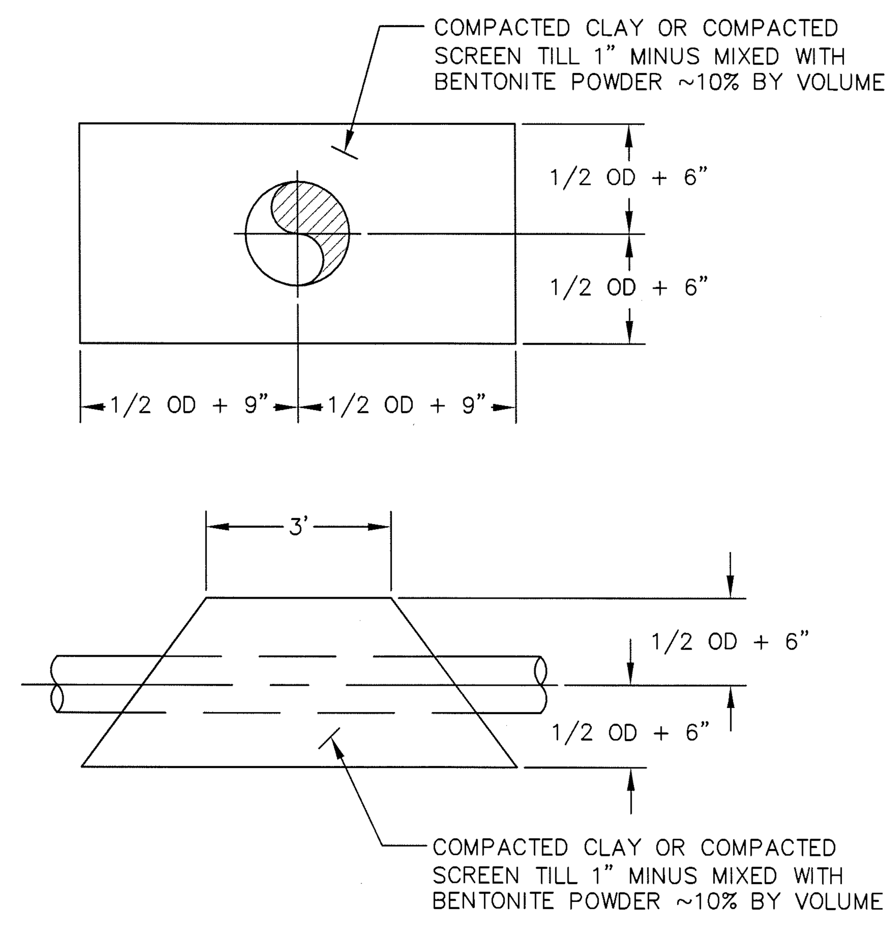
NTS



PIPE TRENCH

NTS

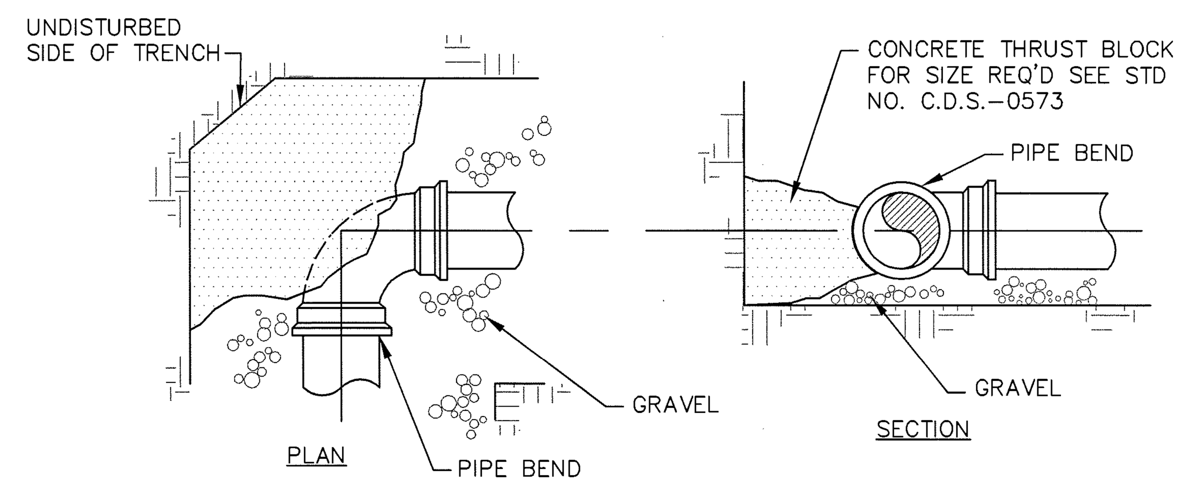
NOTE: DAMS SPACED AT 150' ALONG FORCE MAIN AND AT LOCATION SHOWN ON PLAN DRAWINGS



PIPE DAM

NTS

SIZE REQUIREMENTS FOR CONCRETE THRUST BLOCKS					
	BEARING ON UNDISTURBED SOIL (SQ FT)				
FITTINGS		90° BENDS	45° BENDS	TEES & PLUGS	HYDRANTS
PIPE SIZE	4"	2.0	1.0	1.0	N/A
	6"	3.0	2.0	2.0	6.0
	8"	5.0	3.0	4.0	N/A
	10"	7.0	4.0	5.0	N/A
	12"	10.0	6.0	7.0	N/A
	14"	13.0	7.0	10.0	N/A
	16"	17.0	9.0	12.0	N/A

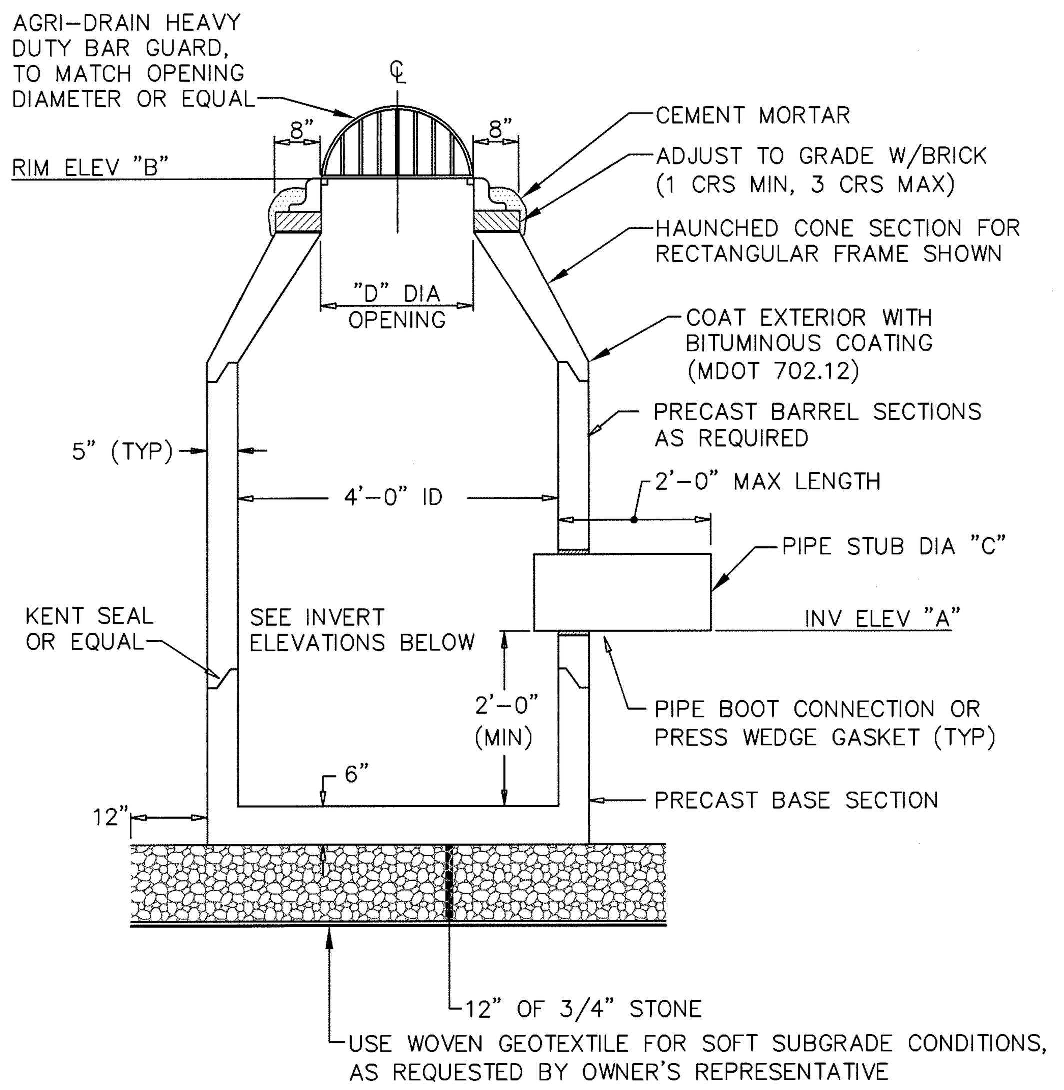


TYPICAL THRUST BLOCK PLACEMENT ON BENDS

NTS

CATCH BASIN SCHEDULE A

CATCH BASIN DESIGNATION	PIPE INV EL "A" (FT)	RIM EL "B" (FT)	PIPE DIA "C" (IN)	TOP OPENING DIA "D" (IN)
CB-4I	202.5	207.6	18"	24"
CB-4JA	214.0	218.7	18"	30"

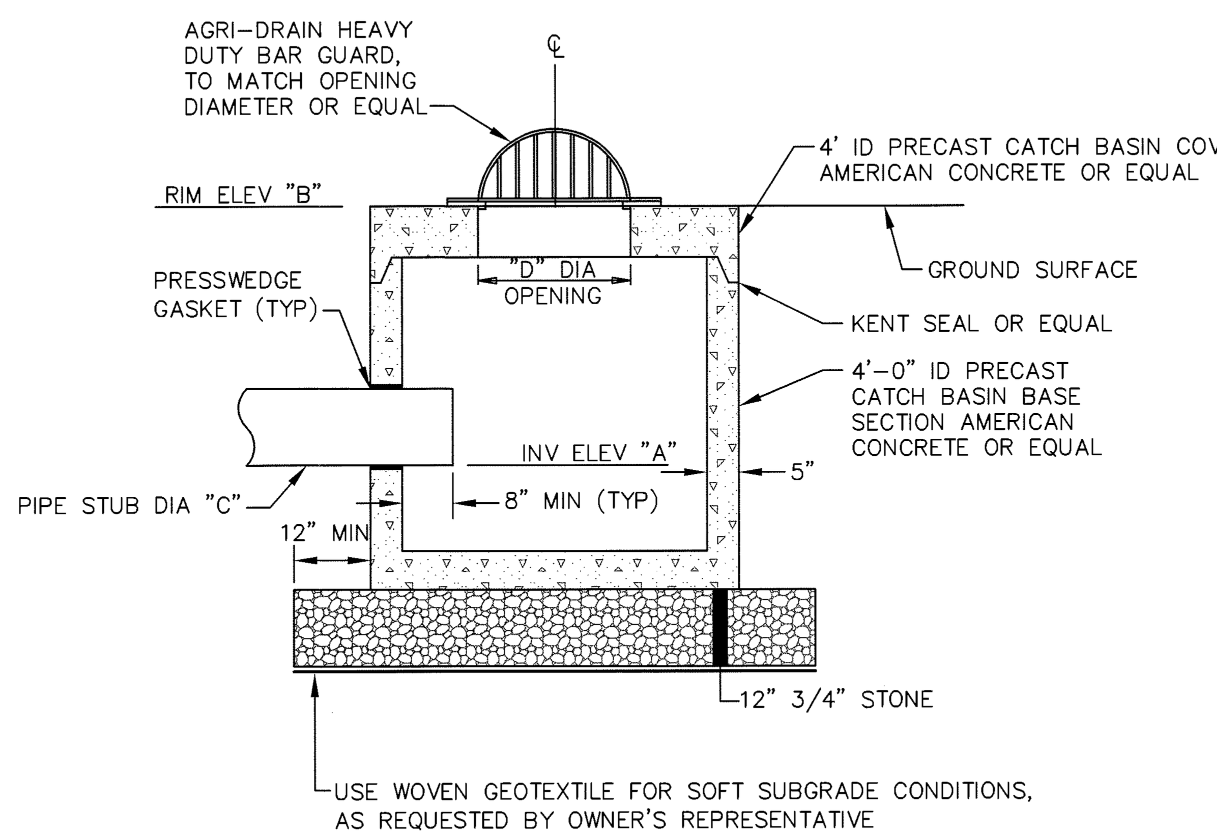


CATCH BASINS 4I AND 4JA

NTS

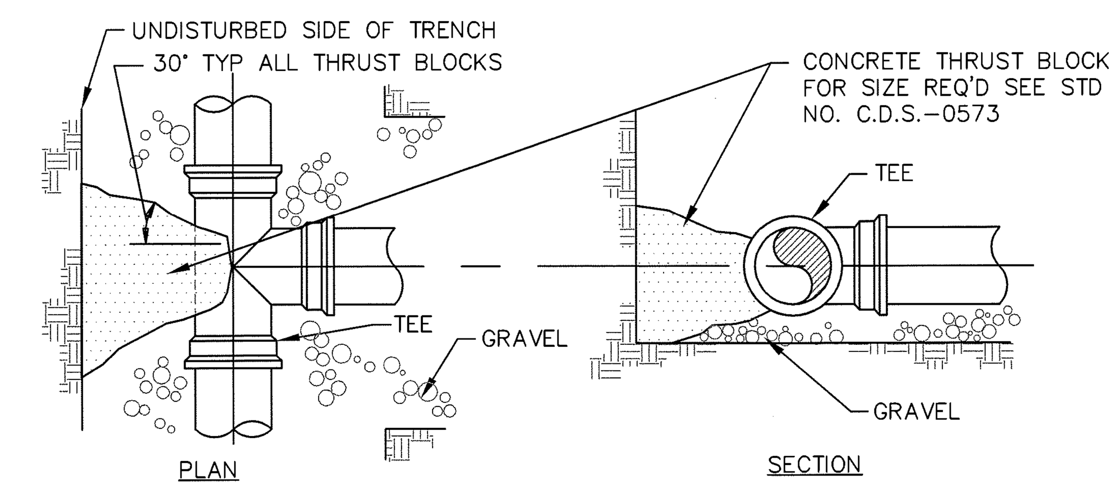
CATCH BASIN SCHEDULE B

CATCH BASIN DESIGNATION	PIPE INV EL "A" (FT)	RIM EL "B" (FT)	PIPE DIA "C" (IN)	TOP OPENING DIA "D" (IN)
CB-4K	216.5	220.0	24"	30"
CB-4L	213.0	215.0	18"	24"



CATCH BASINS 4K & 4L

NTS



TYPICAL THRUST BLOCK PLACEMENT ON TEES

NTS

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE
GUY H. COTE, JR.
No. 5104
LICENSED PROFESSIONAL ENGINEER

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

SECTIONS AND DETAILS

SME
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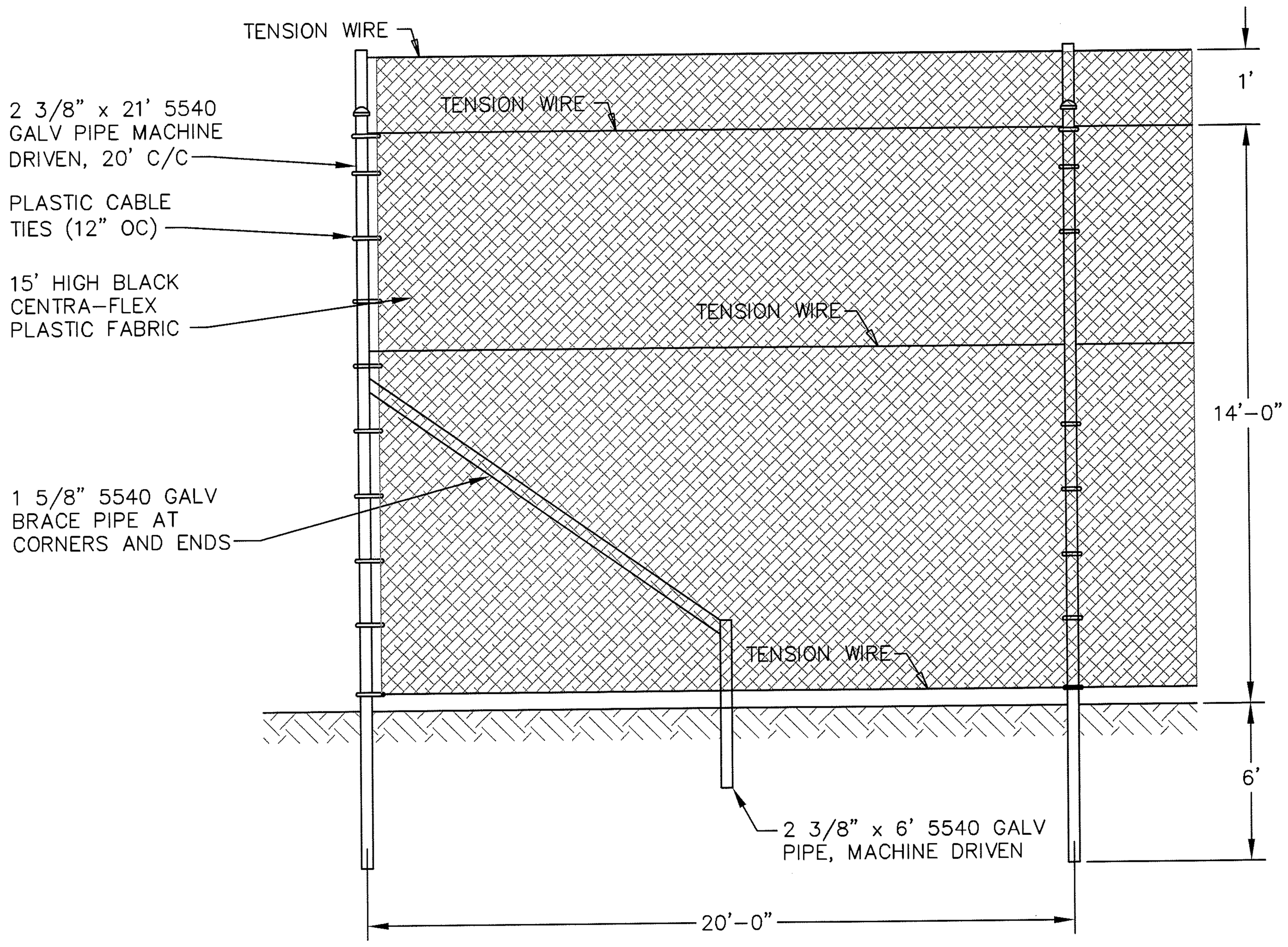
DESIGN BY: PCM
DRAWN BY: SJM
DATE: 12/5/2014
CHECKED BY:
LMN: NONE
CTB: SME-STD

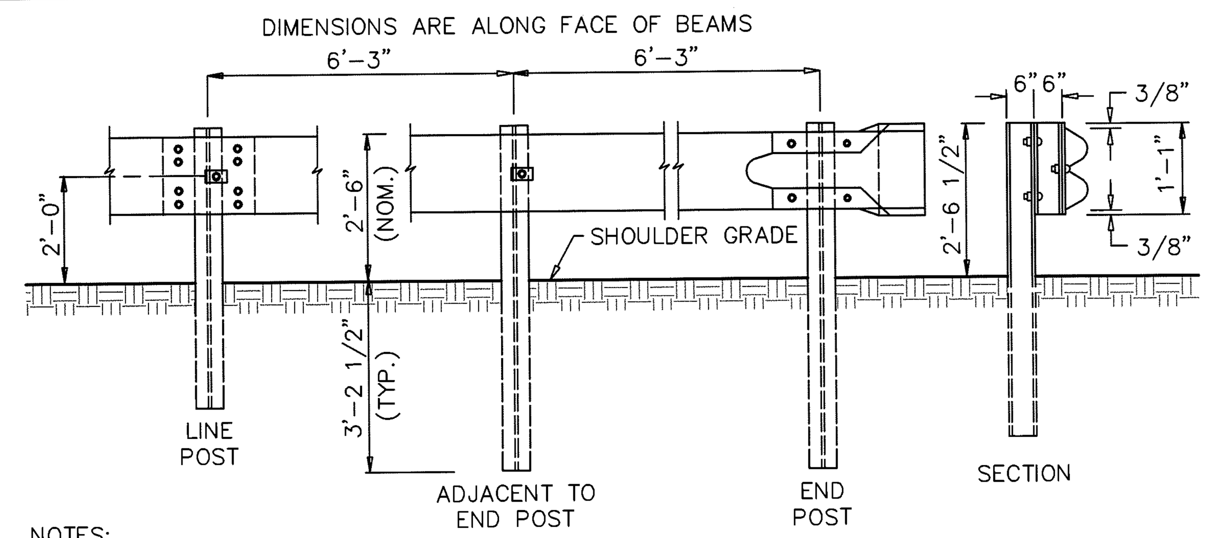
JOB NO. 14101.00 DWG FILE DETAILS

C-305



LITTER FENCE

NTS

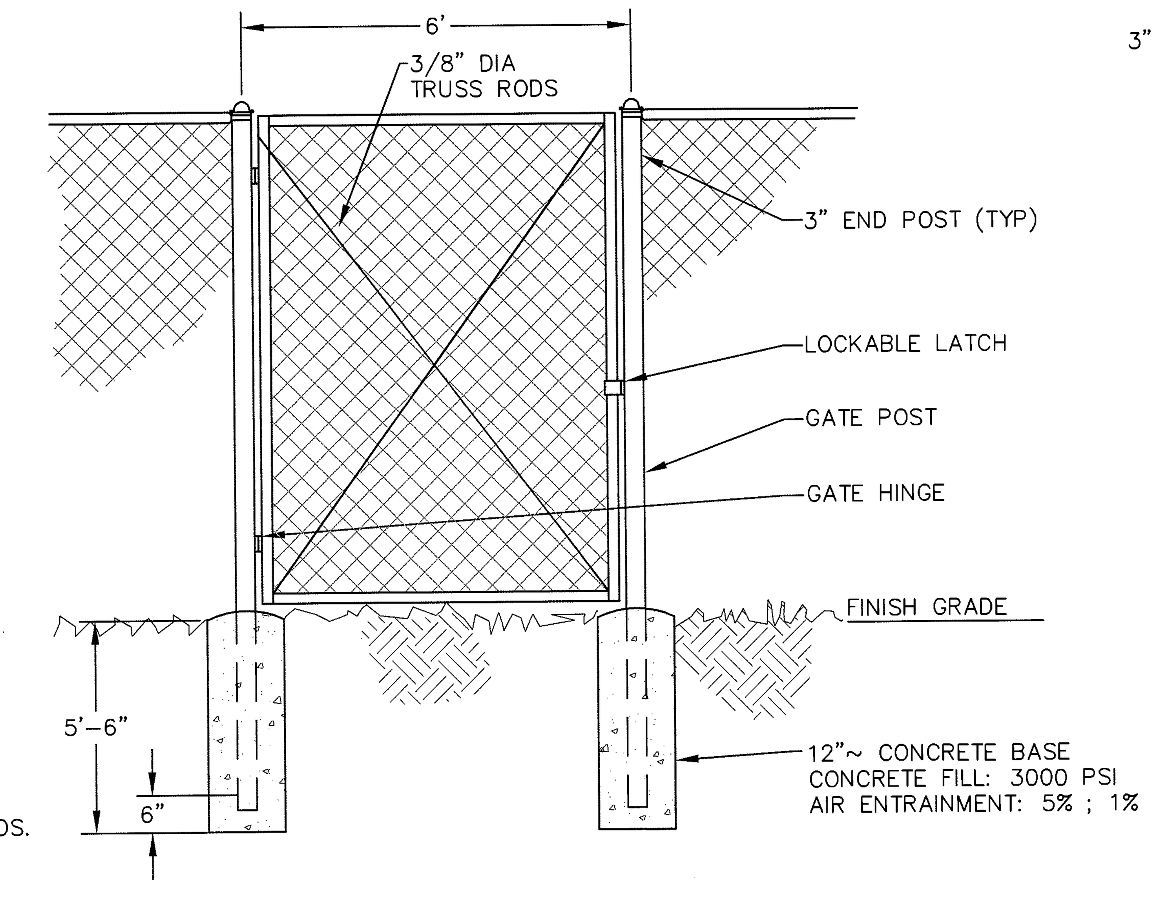


NOTES:

1. INTERMEDIATE POST SPACING SHALL BE 6'-3" UNLESS OTHERWISE SHOWN.
2. POST AND OFFSET BRACKETS SHALL BE 4"x 6" I-BEAM 8.5 OR 9.0 LBS/FT. LENGTH OF 5'-9" ATTACHED WITH 5/8" DIA BOLTS WITH HEX NUTS.
3. ALL HOLES IN BEAM TO BE SHOP-PUNCHED PRIOR TO GALVANIZING.
4. RAIL PANELS AND END SECTIONS TO BE 12 GAUGE STEEL.
5. BACK-UP PLATE TO BE PLACED BEHIND RAIL ELEMENTS AT INTERMEDIATE STEEL POSTS (NON-SPLICE POSTS).
6. ALL PARTS SHALL CONFORM TO CURRENT MAINE DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS.
7. WHEN GUARDRAIL IS CONSTRUCTED AT UP TO FOUR FEET FROM THE EDGE OF PAVEMENT, THE GUARDRAIL WILL BE SET FROM THE GRADE AT THE FACE OF RAIL.
8. END SECTIONS TO BE IN ACCORDANCE WITH MAINE DEPARTMENT OF TRANSPORTATION STANDARDS.
9. GUARDRAIL SET ON A RADIUS OF 150 FEET OR LESS TO BE CIRCULAR.

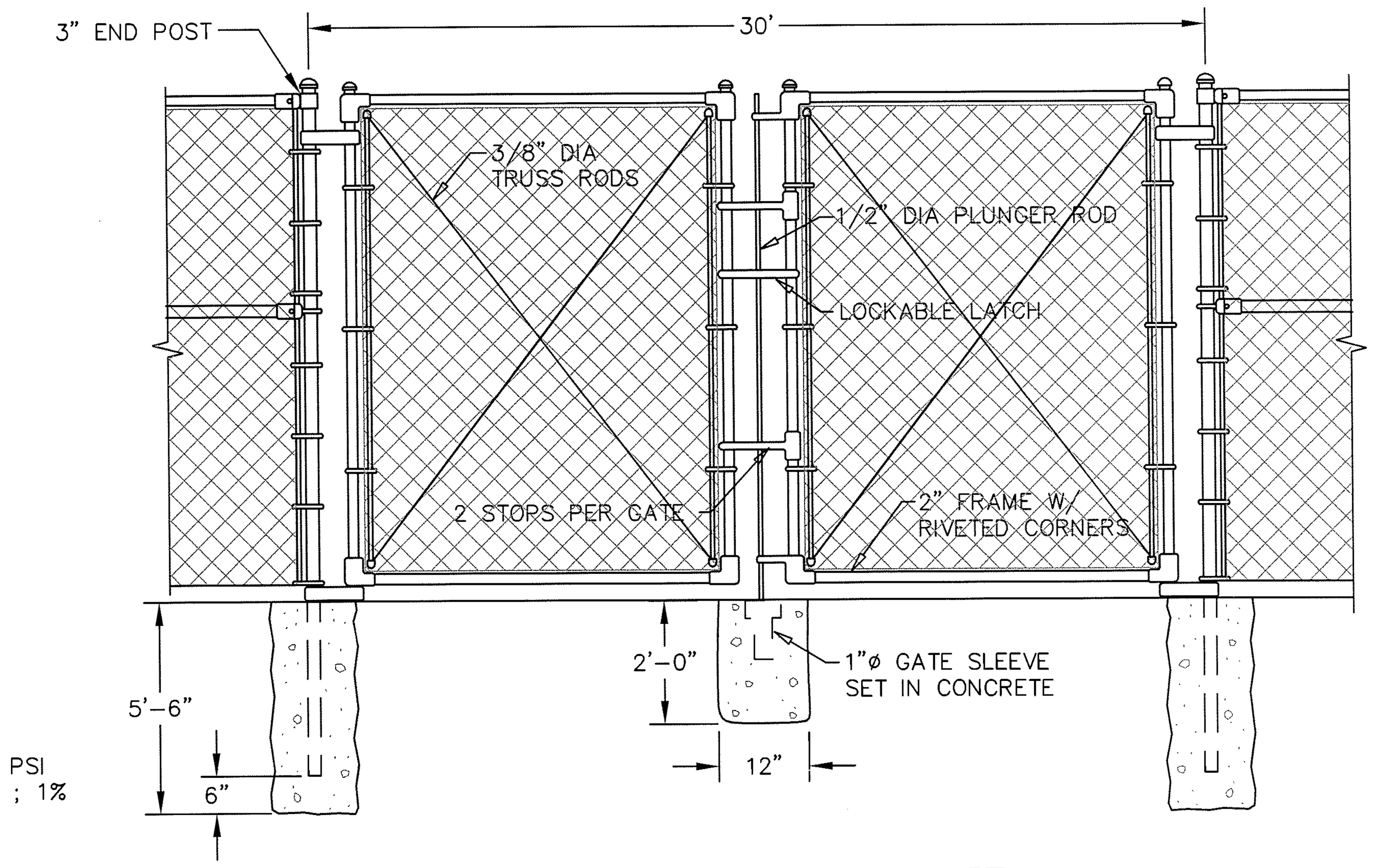
GUARDRAIL

NTS



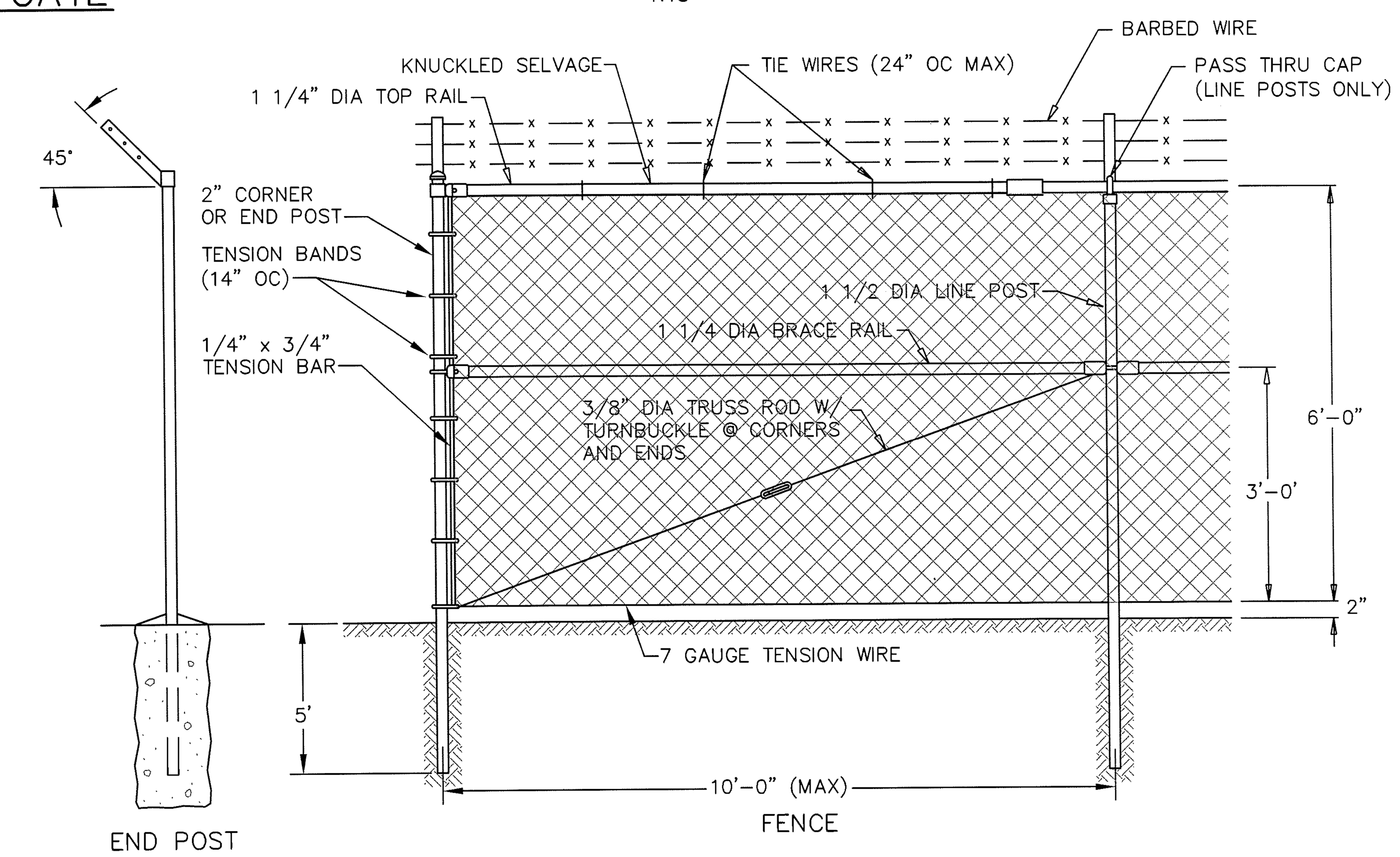
CHAIN LINK FENCE PEDESTRIAN GATE

NTS



DOUBLE SWING GATE

NTS

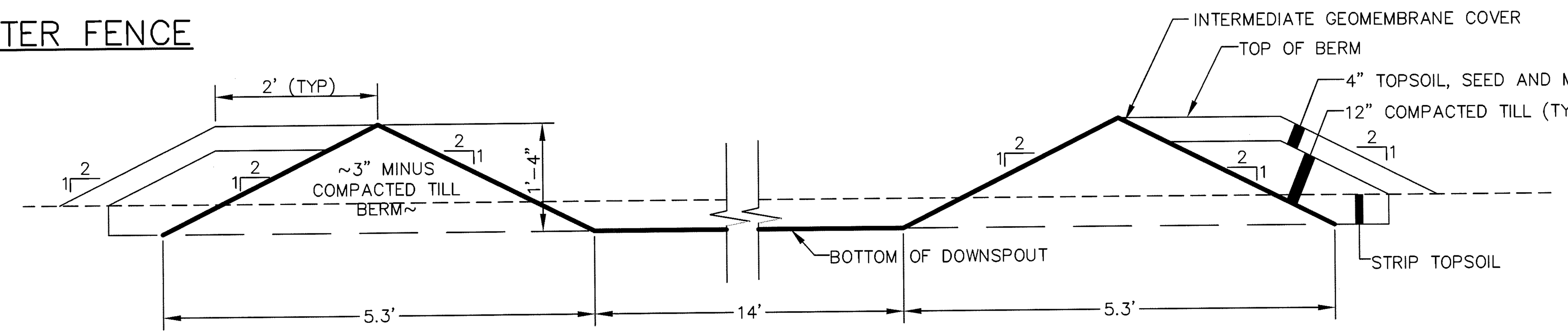


NOTES:

1. END OR CORNER POSTS: NOM 2" DIA GALV STL PIPE, MIN 3.65 LB/LF OR 2 1/4" x 2" "H" SECTION, 4.10 LB/LF, OR 3 1/2" x 3 1/2" "L" SECTION WITH INTEGRAL FABRIC LOOPS 5.14 LB/LF.
2. LINE POSTS: NOM 1 1/2" DIA GALV STL PIPE, MIN 2.72 LB/LF OR 1 7/8" x 1 5/8" "H" SECTION, 2.70 LB/LF, OR 1 7/8" x 1 5/8" "C" SECTION, 2.28 LB/LF.
3. TOP & BRACE RAILS: NOM 1 1/4" DIA GALV STL PIPE, MIN 2.27 LB/LF OR 1 5/8" x 1 1/4" "⊓" SHAPED, ROLLED FORMED SECTION.
4. STRETCHER BARS: LENGTH TO BE 1" LESS THAN FULL HEIGHT OF FABRIC. ONE STRETCHER BAR FOR EACH GATE AND END POST, AND TWO STRETCHER BARS FOR CORNER AND BRACING.
5. CLEARING LIMIT 10 FEET EACH SIDE OF FENCE.

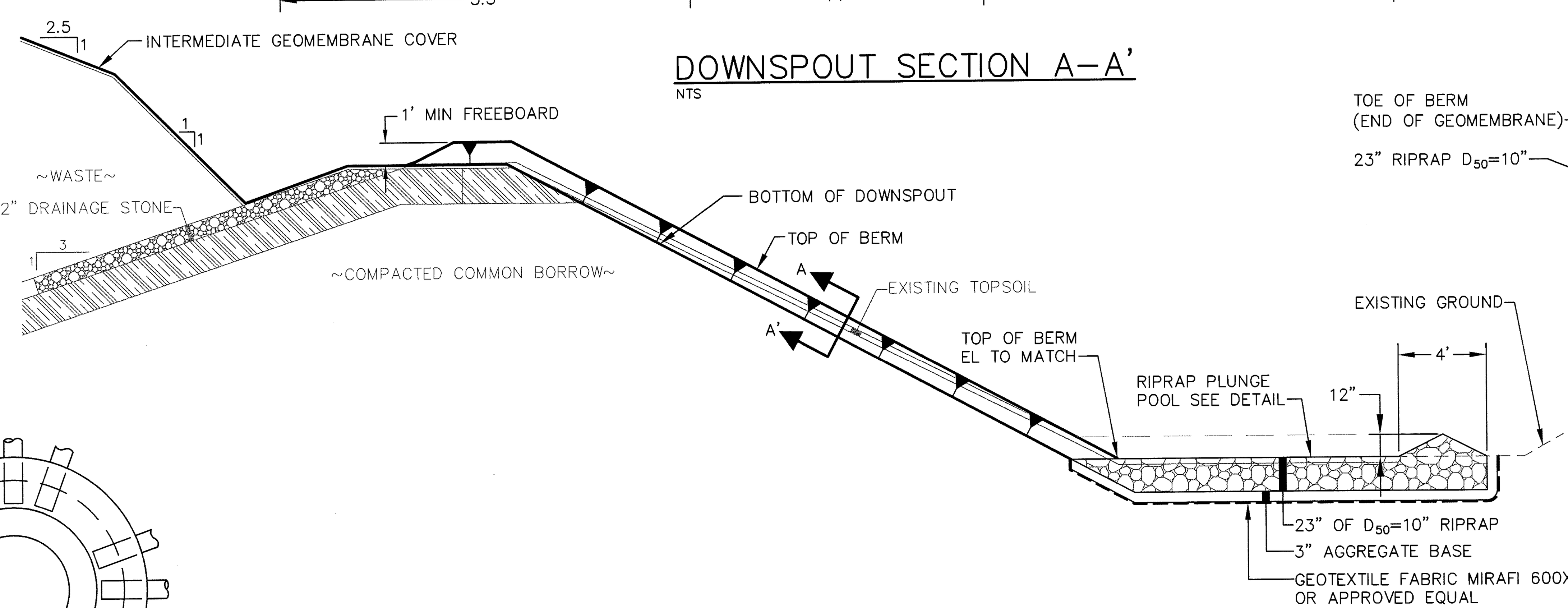
CHAIN LINK FENCE

NTS



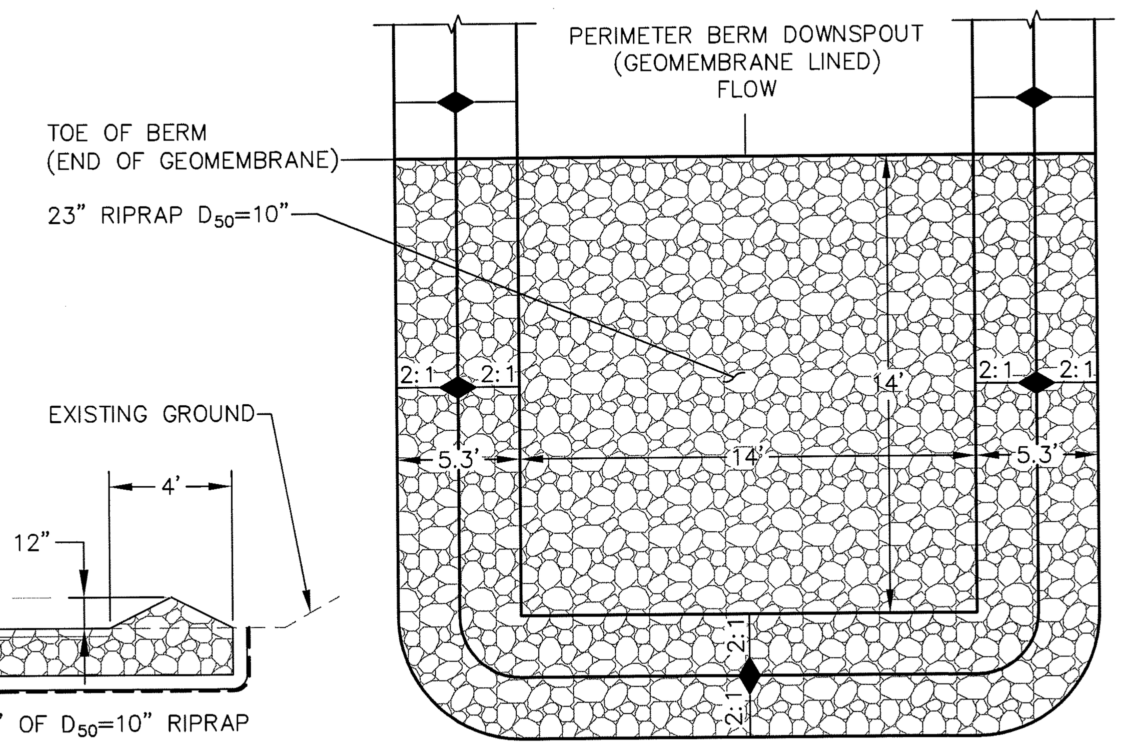
DOWNSPOUT SECTION A-A'

NTS



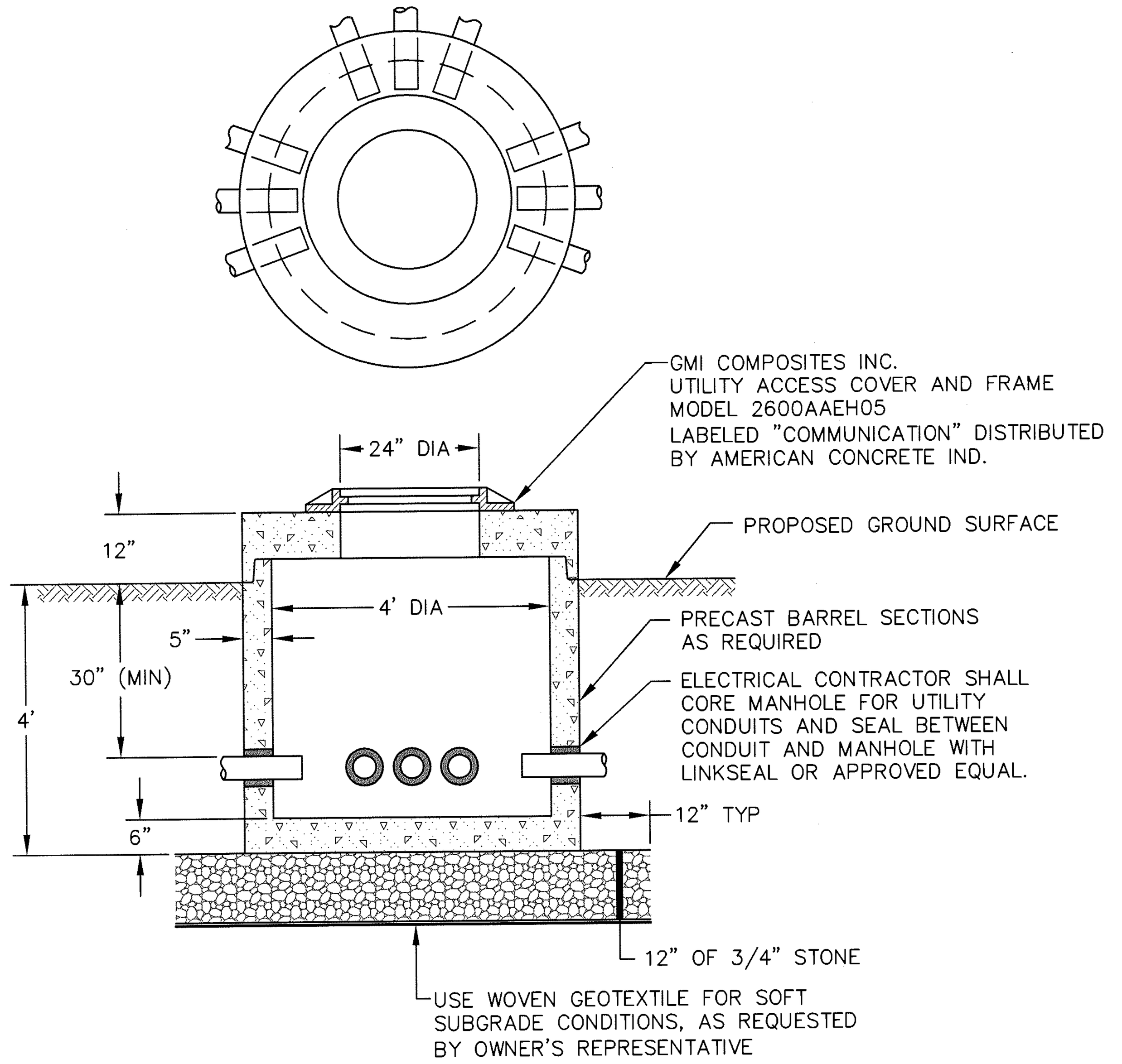
PERIMETER BERM DOWNSPOUT

NTS



PLUNGE POOL

NTS



COMMUNICATION UTILITY MANHOLE

NTS

NOTES:

1. 4' DIA MANHOLE AS MANUFACTURED BY AMERICAN CONCRETE INDUSTRIES OR ENGINEER APPROVED EQUAL.
2. 4000 PSI CONCRETE AT 28 DAYS.
3. DESIGNED FOR H-20 WHEEL LOADING.
4. CONFORMS TO ASTM C-478 SPECIFICATIONS.
5. REINFORCED TO 0.12 IN SQ/LF.
6. SHIPLAP JOINTS SEALED WITH BUTYL RUBBER.
7. EXTERIOR COATED WITH ASPHALTIC PROTECTIVE DAMPPROOFING.
8. BOTTOM MIN 5'-0" BELOW FINISH GRADE.
9. PRECAST CONCRETE VAULT MANUFACTURER TO PROVIDE ANTI-FLOATATION EXTENDED BASE SLAB AS NECESSARY. ANTI-FLOATATION DESIGN AND SHOP DRAWINGS SHALL BE PREPARED BY THE MANUFACTURER AND SUBMITTED TO THE ENGINEER FOR APPROVAL.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

SECTIONS AND DETAILS

STATE OF MAINE
LICENSED PROFESSIONAL ENGINEER
No. 5144

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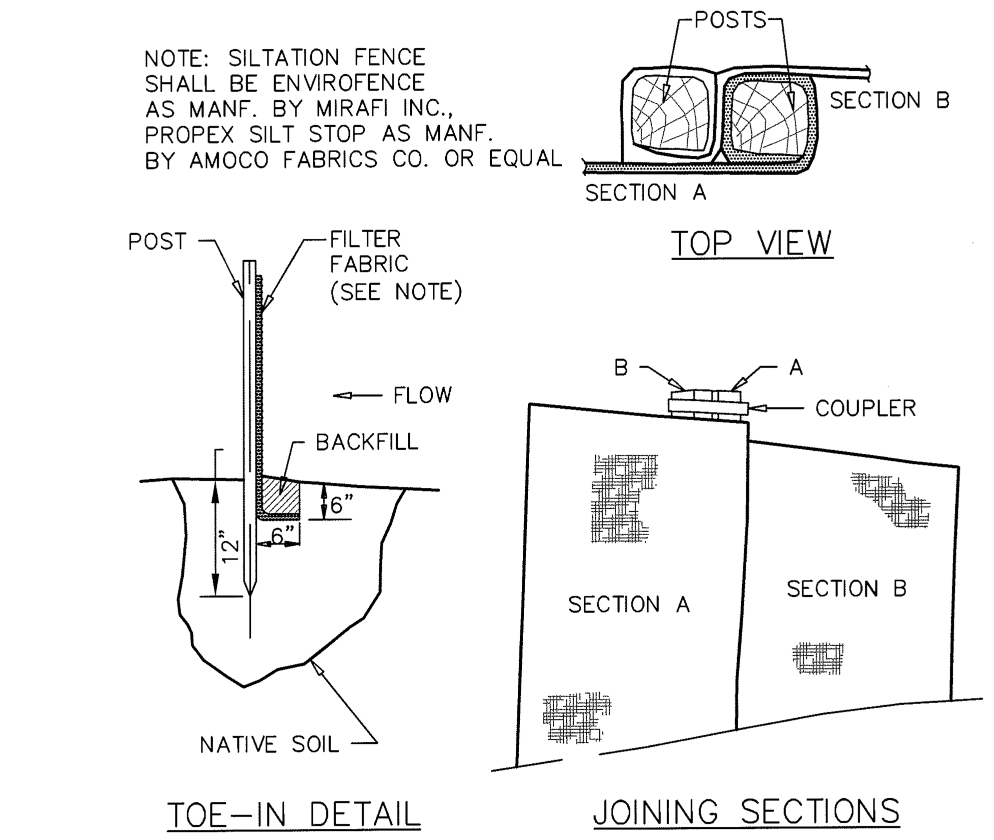
DESIGN BY:	PCM
DRAWN BY:	SJM
DATE:	12/5/2014
CHECKED BY:	
LMN:	NONE
CTB:	SME-STD

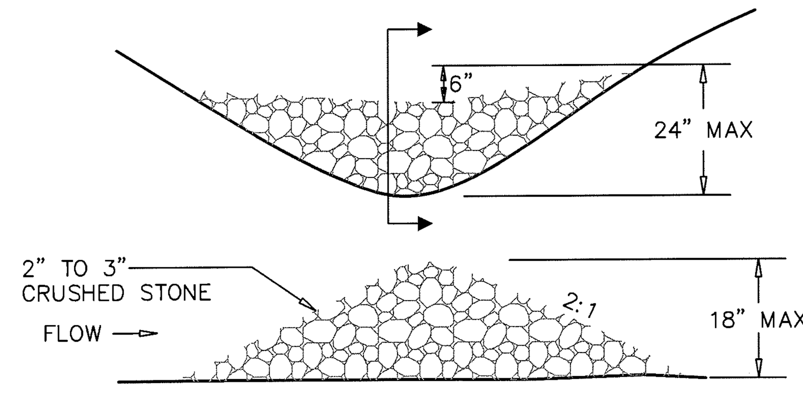
JOB NO. 14101.00 DWG FILE DETAILS

C-306

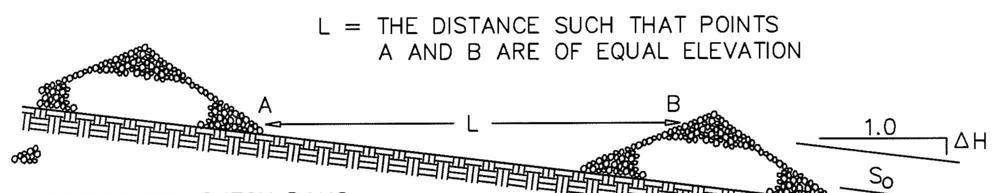


SILTATION FENCE

NTS



SECTION

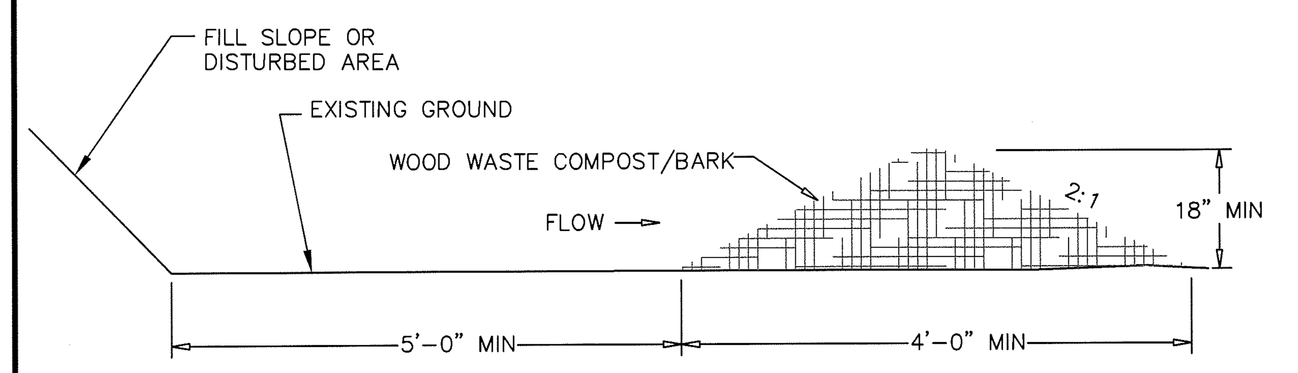


SPACING BETWEEN CHECK DAMS

S_o (FT/FT)	L (FT)
0.020	75
0.030	50
0.040	40
0.050	30
0.080	20
0.100	10

STONE CHECK DAM

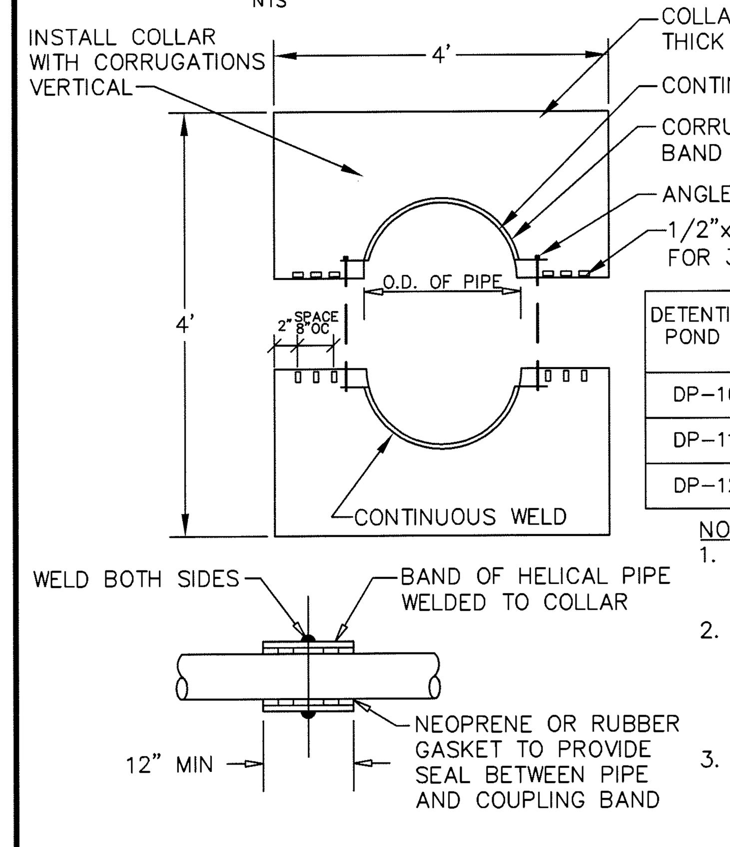
NTS



NOTE:
BARK MULCH SEDIMENT BARRIERS MAY BE USED AS AN ALTERNATE TO SILT FENCE WHEN APPROVED BY THE ENGINEER.

BARK MULCH SEDIMENT BARRIER

NTS

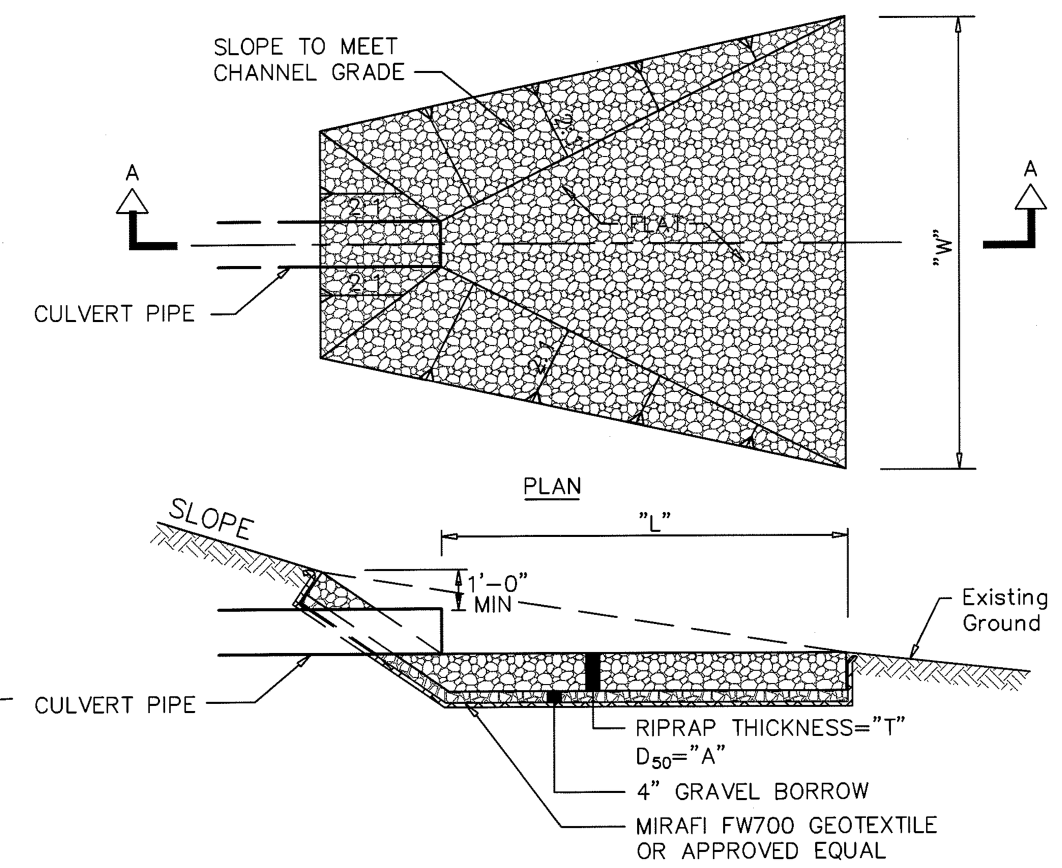


DETENTION POND #	OUTLET PIPE DIA (IN)	PIPE LENGTH (FT)	SATURATED LENGTH (FT)	# OF COLLARS	SPACING (FT)
DP-10	18	70	32	2	11
DP-11	18	92	30	2	10
DP-12	18	80	31	2	10

NOTES:
1. UNASSEMBLED COLLAR SHALL BE MARKED BY PAINTING OR TAGGING TO IDENTIFY MATCHING PARTS.
2. THE LAP BETWEEN THE TWO HALF SECTIONS AND BETWEEN THE PIPE AND CONNECTING BAND SHALL BE CAULKED WITH ASPHALT MASTIC AT TIME OF INSTALLATION.
3. RIPLEY'S DAM BY MCRIP MANUFACTURING MAY BE USED WITH ENGINEERS APPROVAL PROVIDING THAT LENGTH AND WIDTH OF COLLAR IS EQUAL TO OR GREATER THAN THAT SPECIFIED IN THE DETAIL.

ANTI-SEEP COLLAR

NTS

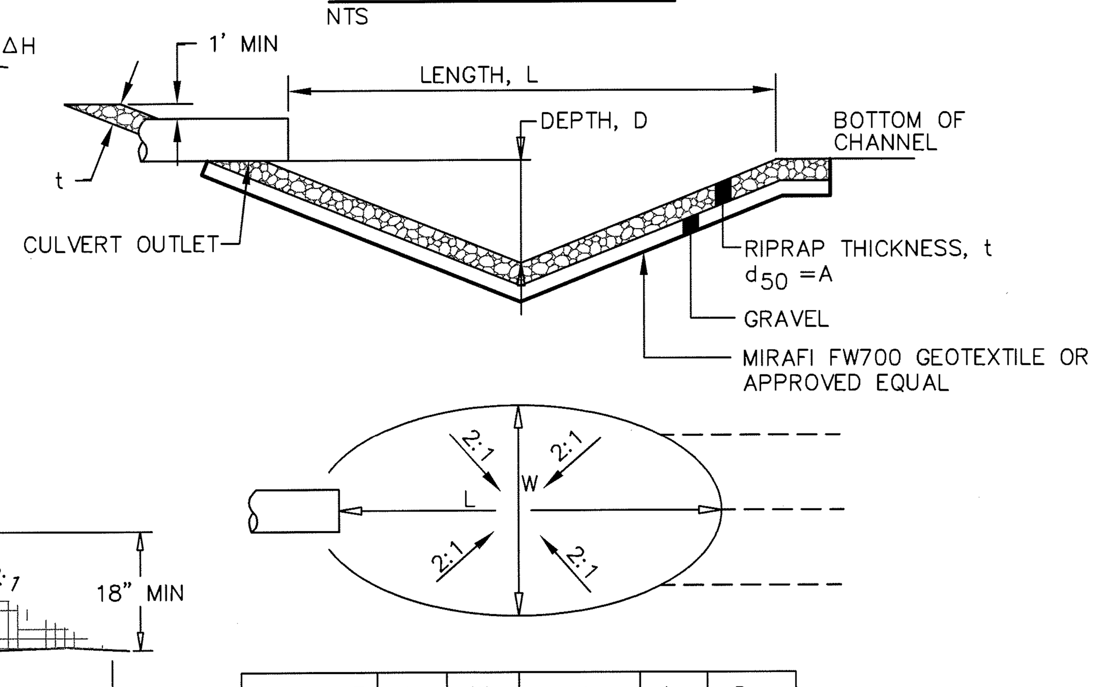


SECTION A-A

CULVERT OUTLET	L (FT)	W (FT)	A (d_{50}) IN.	t (IN)
4BA	12	14	5	12
4BB	12	14	5	12
T1	14	16	5	12
T2	14	16	5	12
4I	18	20	10	23
4IA	10	12	4	9
4JA	18	20	10	23
4JB	12	14	5	12
4JC	12	14	5	12
4K	12	14	5	12
4L	14	16	8	18

RIPRAP APRON

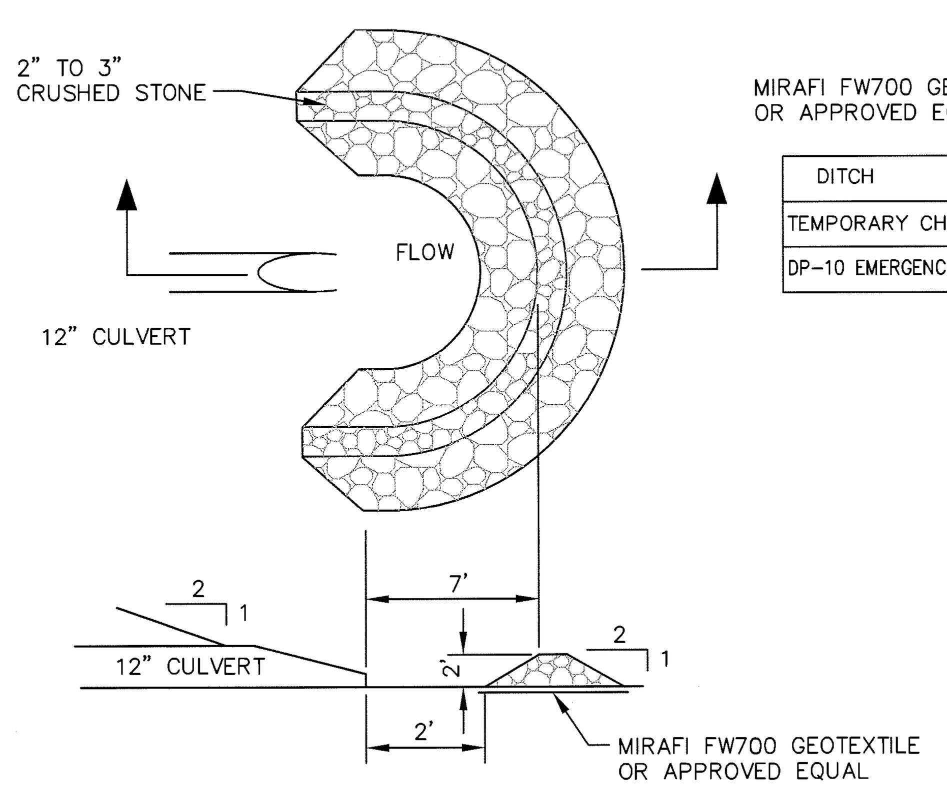
NTS



CULVERT OUTLET	L (FT)	W (FT)	A (d_{50}) IN.	t (IN)	D (FT)
DP-10	6	6	8	18	1.5
DP-11	6	6	4	9	1.5
DP-12	6	6	4	9	1.5

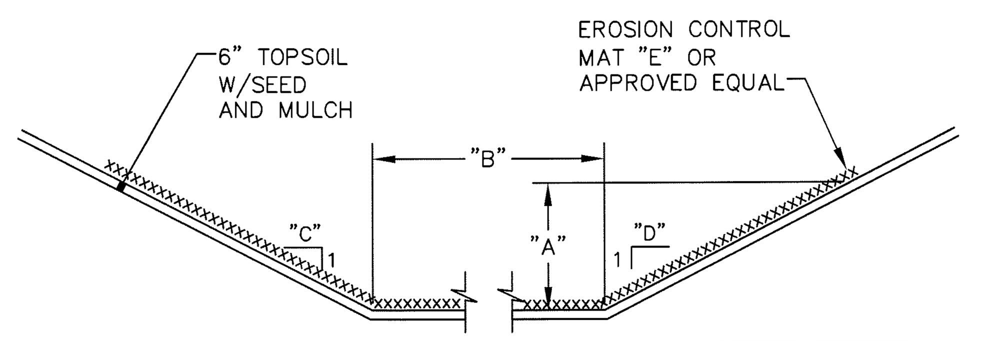
RIPRAP PLUNGE POOL

NTS



RIPRAP CULVERT INLET PROTECTION (TEMPORARY)

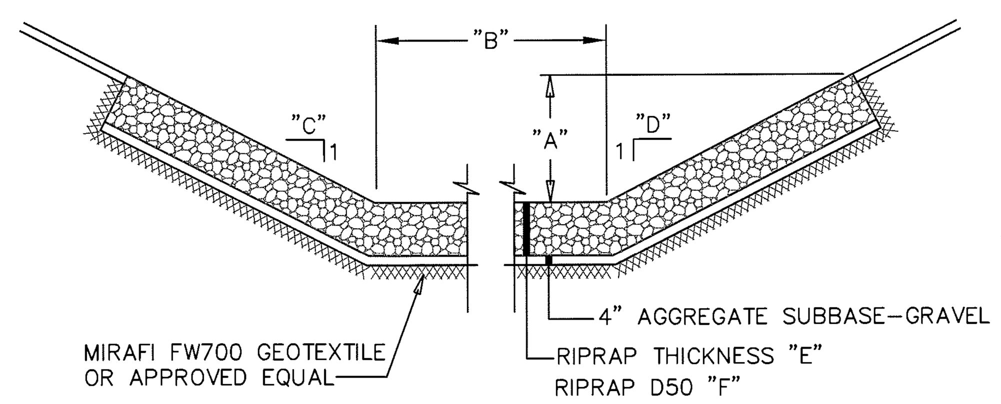
NTS



DITCH	"A"	"B"	"C"	"D"	"E"
TOE DITCH	2'	2'	2'	2'	NAG S75
DP-10 DITCH SEGMENTS 1 & 2	2'	2'	2'	2'	NAG S75
DITCH 4B-1	2'	2'	2'	2'	NAG S75
TEMPORARY ROAD DITCH	2'	2'	2'	2'	NAG S75

GRASS DITCH

NTS



DITCH	"A"	"B"	"C"	"D"	"E"	"F"
TEMPORARY CHANNEL	2'	2'	2'	2'	9"	4"
DP-10 EMERGENCY SPILLWAY	2'	10'	2'	2'	9"	4"

RIPRAP DITCH

NTS

EROSION AND SEDIMENTATION CONTROL TEMPORARY AND PERMANENT

A. GENERAL

1. Soil erosion and sediment control will be done in accordance with the Maine Erosion and Sediment Control: Best Management Practices, Maine Department of Environmental Protection, March 2003.

2. The contractor will be responsible for the repair/replacement/ maintenance of all erosion control measures until all disturbed areas are stabilized.

3. Disturbed areas will be permanently stabilized within 7 days of final grading. Disturbed areas not to be worked upon within 14 days of disturbance, shall be temporarily stabilized within 7 days of the disturbance.

4. Removal of trees, bushes and other vegetation, as well as disturbance of topsoil will be kept to a minimum while allowing proper site operations.

5. Suitable topsoil will be stripped and stockpiled for reuse in final grading. Topsoil will be stockpiled in a manner such that natural drainage is not obstructed and no off-site sediment damage will result. If a stockpile is necessary, the side slopes of the topsoil stockpile will not exceed 2:1. Silt fence will be installed around the perimeter of all topsoil stockpiles. Topsoil stockpiles will be temporarily seeded with Aroostook rye, annual or perennial ryegrass, within 7 days of formation, or temporarily mulched if seeding cannot be done within the recommended seeding dates. Recommended seeding dates and application rates are as follows:

* Aroostook Rye: Recommended Seeding Dates: 9/15 – 11/1
  Application Rate: 112 lbs/acre

* Annual Ryegrass: Recommended Seeding Dates: 4/1 – 7/1
  Application Rate: 40 lbs/acre

* Perennial Ryegrass: Recommended Seeding Dates: 8/15 – 9/15
  Application Rate: 40 lbs/acre

Mulch:

o Hay or Straw: Application Rate: 1.5 – 2.0 tons/acre. Anchor with mulch netting (installed per manufacturer's recommendations)

o Wood Fiber Cellulose: Application Rate: 4,000 lbs/acre. Anchoring not required

B. TEMPORARY MEASURES

1. Silt Fence

(a) Silt fence will be installed prior to and downgradient of all construction activity where soil disturbance may result in erosion.

(b) The height of a silt fence will not exceed 36 inches.

(c) Unless a prefabricated system is utilized, the filter fabric will be purchased in a continuous roll cut to the length of the barrier to avoid the use of joints. When joints are necessary, filter cloth will be spliced together only at a support post, with a minimum 6-inch overlap, and securely sealed.

(d) Posts will be spaced a maximum of 10 feet apart at the barrier location and driven securely into the ground (minimum of 12 inches). When extra strength fabric is used without the wire support fence, post spacing will not exceed 6 feet.

(e) A trench will be excavated approximately 6 inches wide and 6 inches deep along the line of posts and upgradient from the barrier.

(f) The fabric will not extend more than 36 inches above the original ground surface. Filter fabric will not be stapled to existing trees.

(g) When extra strength filter fabric and closer post spacing are used, the wire mesh support fence may be eliminated. In such a case, the filter fabric will be stapled or wired directly to the posts with all other provisions of item (f) applying.

(h) The trench will be backfilled and the soil compacted over the filter fabric.

(i) Silt fences will be removed when they have served their useful purpose, but not before the upgradient areas have been permanently stabilized.

(j) Silt fences will be inspected immediately after each rainfall, which exceeds 1 inch in a 24-hour period, and at least daily during prolonged rainfall. If there are any signs of erosion or sedimentation below them, appropriate repairs will be made. If there are signs of undercutting at the center or the edges, or impounding of large volumes of water behind them, they will be replaced with a temporary crushed stone check dam.

(k) Should the fabric on a silt fence decompose or become ineffective prior to the end of the expected usable life, and the barrier still be necessary, the fabric will be replaced promptly.

(l) Sediment deposits should be removed after each storm event if significant buildup has occurred or if deposits exceed 15 inches in depth.

(m) In lieu of providing the 4" x 4" trench for conditions of frozen ground, severe rocky soil or hummucky conditions with large roots, or other prohibitive conditions. A wood waste compost/bark mulch filler berm may be used in such situations.

2. Stone Check Dams

(a) Stone check dams should be constructed of 2 to 3 inch stone. The stone should be placed according to the configuration shown on the detail. Hand or mechanical placement will be necessary to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges.

(b) Check dams should be installed as the swale is being constructed.

(c) Sediment will be removed from behind the check dams when it has accumulated to one half of the original height of the dam.

(d) Check dams will be removed when the grass has matured sufficiently to protect the ditch or swale. The area beneath the check dams will be seeded and mulched immediately after the check dams are removed.

(e) Regular inspections will be made to ensure that the center of the dam is lower than the edges. Erosion caused by high flows around the edges of the dam will be corrected. If evidence of siltation in the water is apparent downstream from the check dam, the check dam will be inspected and adjusted. Check dams will be checked for sediment accumulation after each significant rainfall.

CONSTRUCTION SEQUENCE

1. Construct temporary sediment and erosion control facilities. Erosion and sediment measures shall be installed prior to any earth moving operation in the area of work.
2. All permanent ditches are to be stabilized with vegetation or stone check dams prior to directing runoff to them.
3. Inspect and maintain all erosion and sediment control measures.
4. Complete permanent erosion control measures which may include seeding, mulching, and landscaping.
5. Remove all temporary erosion control measures.
6. Each stage will be stabilized prior to initiating the next stage.
7. Any exposed areas will be hay mulched prior to winter shutdown, if necessary.

EROSION CONTROL MEASURES

1. The smallest practical area of land shall be exposed to construction at any one time.
2. The temporary erosion control measures shall be maintained until permanent erosion control measures are present.
3. All areas disturbed by construction shall have available loam placed before seeding (or an acceptable alternative).
4. After construction is terminated, all temporary erosion control measures shall be removed and accumulated sediment disposed of in a secure location.
5. Mulch shall be mowings of acceptable herbaceous growth, free from noxious weeds or woody stems, and shall be dry.

3. Wood Waste Compost/Bark Mulch Filter Berms

(a) The filter berm shall consist of an approved wood waste compost/bark mulch mix or recycled composted bark flume grit and fragmented wood generated from water-flume log handling systems or small shredding of stumpage (6 inches long x 1/2" dia.). The mixture needs to be a well-graded blend of organic and mineral substance. The composition is usually manufactured on or off site and by blending it with a well graded sand and gravel. The objective is a tight, heavy, non-erodible mixture that is not composed of one uniform material, i.e. just bark mulch will not suffice. Comparable composted mixes can be used upon approval of the Department of Environmental Protection, Bureau of Land and Water Quality.

(b) The mix shall conform to the following standards:

* Moisture Content 30 – 60%
* PH-5.0-8.0
* Screen Size – 100% less than 3" max.; 70% less than one inch.
* No less than 40% organic material (dry weight) by loss of ignition.
* No stones larger than 2 inch diameter.
* Silts, clays or sugar sands are not acceptable in the mix.

(c) Installation and Size of Berm:

The dimensions of the berm are more a function of the strength of the material than the flows (forces) it will encounter. At a minimum the berm shall be 4 feet wide and 18 inches high. The berm shall be placed, uncompacted along a relatively level contour. Wherever possible the existing surface must be scoured and the mixture keyed in like any other sediment control measure.

(d) Maintenance:

All deficiencies shall be immediately corrected with additional material place on top of the berm to reach the desired height. When the berm is decomposed, clogged with sediment, eroded, or becomes ineffective, it shall be replaced.

(e) Clean up and Retrieval:

At the end of the job, an erosion control berm shall be removed or spread out so that the native earth can be seen below.

(f) Rock Filter Berms

To provide more filtering capacity or to act as a velocity check dam, a berm's center can be composed of clean crushed rock ranging in size from the French drain stone to riprap. The rocks shall be laid on geotextile to facilitate removal and the geotextile shall be wrapped over the core layer of stone and then covered with another layer of erosion control mix. The center core of stone shall be approx. 12 inches high or two-thirds the height of the filter berm. Rock filter berms shall be a minimum of 18 inches high by 4 feet wide.

4. Stabilized Construction Entrance

(a) Aggregate size: Use 2 inch stone, or reclaimed or recycled concrete equivalent.

(b) Aggregate thickness: Not less than eight inches.

(c) Width: 16 foot minimum, but not less than the full width of where ingress or egress occurs.

(d) Length: as required, but not less than 50 feet.

(e) Geotextile: To be placed over the entire area to be covered with aggregate. Piping of surface water under entrance shall be provided as required. All piping is impossible, a mountable berm with 5:1 slopes will be permitted.

(f) Criteria for Geotextile: The filter cloth shall be woven or NON-WOVEN fabric consisting only of continuous chain polymeric filaments or yards of polyester. The fabric shall be inert to commonly encountered chemicals, hydrocarbons, mildew and rot resistant.

(1) Acceptable materials are Trivira Spunbound 1135, Mirafi 600X, or equivalent.
(2) Fabrics not meeting these specifications may be used only when design procedure and supporting documentation are supplied to determine aggregate depth and fabric strength.

(g) Maintenance: The entrance shall be maintained in a condition which will prevent tracking of sediment onto public rights-of-way. When washing is required, it shall be done in on an area stabilized with aggregate which drains into an approved sediment trapping device. All sediment shall be prevented from entering storm drains, ditches, or waterways.

5. Erosion Control Mats

(a) During the growing season (April 15 to September 15) use mats specified in the drawings or, if not specifically identified, use North American Green S75 or equal or mulch with netting on:

* The base of grassed waterways and steep slopes (>15 percent)
* Any disturbed soil within 100 feet of streams and wetlands.

During the late fall and winter (September 15 to April 15) use heavy grade mats specified in the drawings or, if not specifically specified, use North American Green SC150 or equal on all areas noted above, plus use lighter grade mats or mulch with netting on:

* Sideslopes of grassed waterways
* Moderate slopes (>8 percent)

(2) Install mats in accordance with manufacturers' recommendations.

C. PERMANENT MEASURES

1. Riprapped Aprons and Plunge Pools

(a) Construct riprapped aprons in accordance with the details shown on the drawings.

(b) Stone for riprap will consist of sub-angular field stone or rough unhewn quarry stone. The stone will be hard and of such quality that it will not disintegrate on exposure to water or weathering, be chemically stable and suitable in all other respects for the purpose intended. The bulk specific gravity (saturated surface-dry basis) of the individual stones will be at least 2.5.

(c) The riprap should be placed so that it produces a dense well-graded mass of stone with a minimum of voids. The desired distribution of stones throughout the mass may be obtained by selective loading at the quarry, controlled clumping of successive loads during final placing, or by combination of these methods. The riprap should be placed to its full thickness on one operation. The riprap should not be placed in layers. The riprap should not be placed by dumping into chutes or similar methods which are likely to cause segregation of the various stone sizes. Care should be taken not to dislodge the underlying material when placing the stones.

The finished slope should be free of pockets of small stone or clusters of large stones. Hand placing may be necessary to achieve the required grades and a good distribution of stone sizes. Final thickness of the riprap blanket should be within plus or minus 1/4 of the specified thickness.

(d) Riprap will be inspected periodically to determine if high flows have caused scour beneath the riprap or dislodged any of the stone. If repairs are needed, they should be accomplished immediately.

2. Topsoil, Seed, Mulch

(a) Topsoil: Use stockpiled materials spread to the depths shown on the plans, if available. Approved topsoil substitutes may be used (refer to Section C-2 of Erosion and Sediment Control BMP, see Note 2).

(b) Seeding should be completed by August 15 of each year. Late season seeding may be done between August 15 and September 15. Areas not seeded or which do not obtain satisfactory growth by October 1, will be seeded with Aroostook Rye or mulched at rates previously specified herein. After November 1, or the first killing frost, disturbed areas should be treated as specified in (c) below.

SEEDING SPECIFICATIONS

Permanent Seeding (120 lbs/acre)		Temporary Seeding
Tall Fescue	54 lbs/acre	(120 lbs/acre)
Red Fescue	25 lbs/acres	(Aroostook Rye 100%)
Red Top	5 lbs/acres	
Ladino Clover	13 lbs/acre	
Annual Ryegrass	8 lbs/acre	
Birdsfoot Trefoil	5 lbs/acre	
Timothy	10 lbs/acre	

(2) Fertilizer: Apply 1300 pounds per acre of 10-10-10 fertilizer or equivalent per acre (29.8 lbs/1,000 sq. ft.).

(3) Lime: Apply ground limestone at a rate of 3 tons per acre (138 lbs/1,000 sq. ft.).

(4) Mulch: Mulch with hay or straw at 2.0 – 3.0 tons per acre, or 2-3 bales per 1,000 sq. ft.

Anchor mulch with mulch netting installed per manufacturer's recommendations.

(c) If permanent vegetated stabilization cannot be established due to the season of the year, all exposed and disturbed areas not to undergo further disturbance are to have dormant seeding applied and be temporarily mulched to protect the site. The following methods may be used to perform a dormant seeding:

(1) Prepare the seedbed, add the required amounts of lime and fertilizer, then mulch and anchor. After the first killing frost and before snow fall, broadcast or hydroseed the selected seed mixture. Double the regular seeding rates for this type seeding.

(2) When soil conditions permit, between the first killing frost and before snow fall, prepare the seedbed, lime and fertilize, apply the selected seed mixture, and mulch and anchor. Double the regular seeding rates for this type of seeding.

Dormant seedings need to be anchored extremely well on slopes, ditch bases and areas of concentrated flows.

Dormant seeding requires inspection and reseeding as needed in the spring. All areas where cover is inadequate must be immediately reseeded and mulched as soon as possible.

(3) Erosion Control Mats

(a) During the growing season (April 15-Sept 15) use mats indicated on drawings or, if not specified use North American Green S75 or equal or mulch with netting on:

* The base of grassed waterways
* Steep slapes (>15%)
* Any disturbed soil within 100 feet of lakes, streams and wetlands

During the late fall and winter (Sept 15-April 15) use heavy grade mats indicated on drawings or, if not specified use North American Green SC150 or equal on all areas noted above plus use lighter grade mats or mulch with netting on:

* Side slopes of grassed waterways
* Moderate slopes (>8%)

(b) Install mats in accordance with manufacturers' recommendations.

3. Lined Ditches

On designated ditches, use reinforced mats (North American Green as specified or approved equal) as permanent stabilization. Install mats in accordance with manufacturers' recommendations.

D. CONSTRUCTION SEQUENCE

It is anticipated that construction will commence upon receipt of all necessary permits and approvals. The following outlines the preliminary construction sequence:

a. Install silt fence and other temporary erosion control measures for the construction of Cell and accessory facilities such as detention ponds, berms, and service roads;

b. Construct upslope stormwater diversion berms, ditches, culvert outlets, and control structures:

c. Clear and grub Cell areas;

d. Construct service road;

e.. Construct Cell base grade and underdrain system;

f. Construct Cell liner system, and leachate collection system;

g. Operate Cell;

h. As permanent erosion control measures become stabilized, remove temporary measures (e.g., silt fence, stone check dams); and

i. Install intermediate and final cover on cells filled to capacity in areas shown in the Cell Development Plans – Appendix C of this application.

E. CONSTRUCTION INSPECTIONS

Inspections will be undertaken by qualified personnel to ensure that temporary and permanent erosion and sedimentotion controls are properly installed and correctly functioning, and that additional erosion control measures are installed if needed. Such inspections will occur bi-weekly and after each significant rainfall event (1 inch or more within a 24 hour period) during construction until permanent erosion control measures have been properly installed and the site is stabilized.

REV.	BY	DATE	STATUS
	PCM	7/15	ISSUED FOR MEDEP SOLID WASTE PERMIT APPLICATION

STATE OF MAINE – GUY H. COTE, JR. – No. 5149 – LICENSED – PROFESSIONAL ENGINEER

CELL 11 CONSTRUCTION
JUNIPER RIDGE LANDFILL
NEWSME LANDFILL OPERATIONS LLC
OLD TOWN, MAINE

SECTIONS AND DETAILS

SME
Sevee & Maher Engineers, Inc.
ENVIRONMENTAL • CIVIL • GEOTECHNICAL • WATER • COMPLIANCE
4 Blanchard Road, PO Box 85A, Cumberland Center, Maine 04021
Phone 207.829.5016 • Fax 207.829.5692 • www.smemaine.com

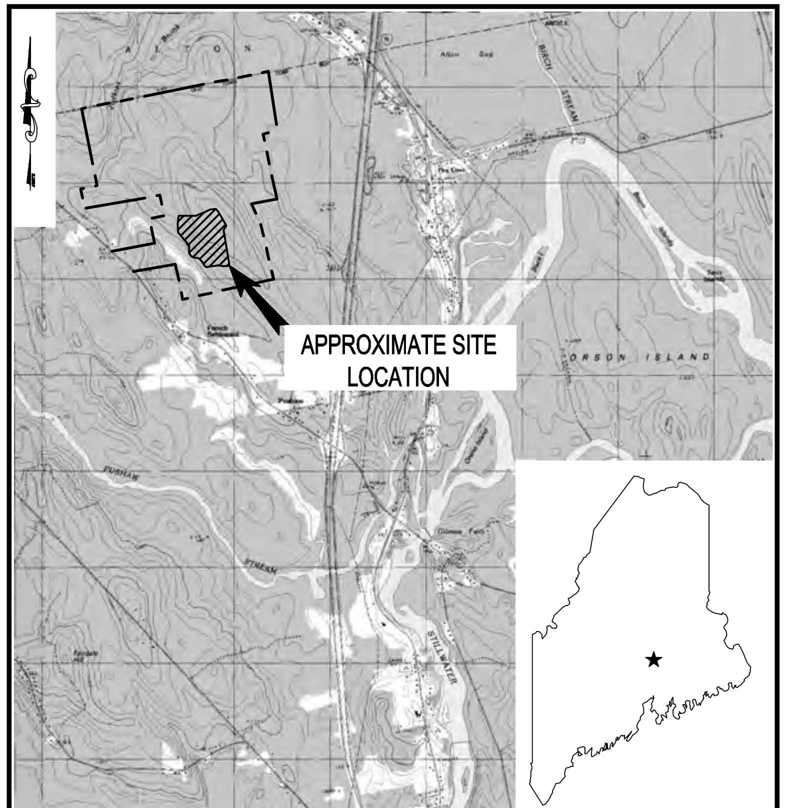
DESIGN BY: PCM
DRAWN BY: SJM
DATE: 12/5/2014
CHECKED BY:
LMN: NONE
CTB: SME-STD

JOB NO. 14101.00 DWG FILE DETAILS

C-307

CELL 11 LANDFILL GAS SYSTEM EXPANSION DRAWINGS

JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE
JUNE 2015



FROM: USGS TOPOGRAPHIC MAP- OLD TOWN, MAINE (1988)

LOCUS PLAN
SCALE: 1"=1000'

SHEET INDEX

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

ISSUED FOR MAINE DEP APPROVAL AND CONSTRUCTION
6/24/15

PREPARED FOR:

NEW ENGLAND WASTE SERVICES

NEWSME LANDFILL OPERATIONS, LLC

JUNIPER RIDGE LANDFILL

OLD TOWN, MAINE

PREPARED BY:

SANBORN HEAD

20 FOUNDRY STREET, CONCORD, NEW HAMPSHIRE 03301
(603) 229-1900 FAX (603) 229-1919

PROJ.#: 2536.27 "CELL 11 LANDFILL GAS SYSTEM EXPANSION DRAWINGS, JUNIPER RIDGE LANDFILL, OLD TOWN, MAINE" JUNE 2015.

NOTES:

1. THE EXISTING LANDFILL GAS EXTRACTION SYSTEM INFRASTRUCTURE FEATURES SHOWN ARE BASED ON A COMBINATION OF DESIGN AND AS-BUILT DOCUMENTATION AVAILABLE TO SANBORN, HEAD & ASSOCIATES, INC. (SANBORN HEAD). ACTUAL LOCATIONS OF INDIVIDUAL FEATURES MAY BE DIFFERENT THAN SHOWN.
2. BASE MAP PREPARED BY AERIAL SURVEY & PHOTO INC., OF NORRIDGEWOCK, MAINE. PHOTO DATE DECEMBER 31, 2014. VERTICAL DATUM: BRASS PLUG AT PUMP STATION. HORIZONTAL DATUM: MAINE STATE COORDINATES EAST ZONE NAD 83. GROUND CONTROL BY PLISGA & DAY LAND SURVEYORS, BANGOR, MAINE.

LEGEND:

EXISTING

190	10-FOOT CONTOUR
	2-FOOT CONTOUR
	LIMIT OF WASTE CONTAINMENT
	CELL LIMIT
	EDGE OF ROAD
	LANDFILL GAS CONVEYANCE PIPE
	LANDFILL GAS COLLECTION TRENCH (PERFORATED PIPE)
	TREELINE
	FENCE LINE
GW-9	LANDFILL GAS EXTRACTION WELL
GCT-21	COLLECTION TRENCH WELLHEAD
	COLLECTION TRENCH TERMINATION
	PIPE END CAP
	LEACHATE COLLECTION PIPE CLEANOUT
	LEACHATE COLLECTION INLET
	LANDFILL GAS EXTRACTION WELLHEAD
	RIPRAP

SANBORN HEAD

GRAPHICAL SCALE
100' 50' 0 100' 200'

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

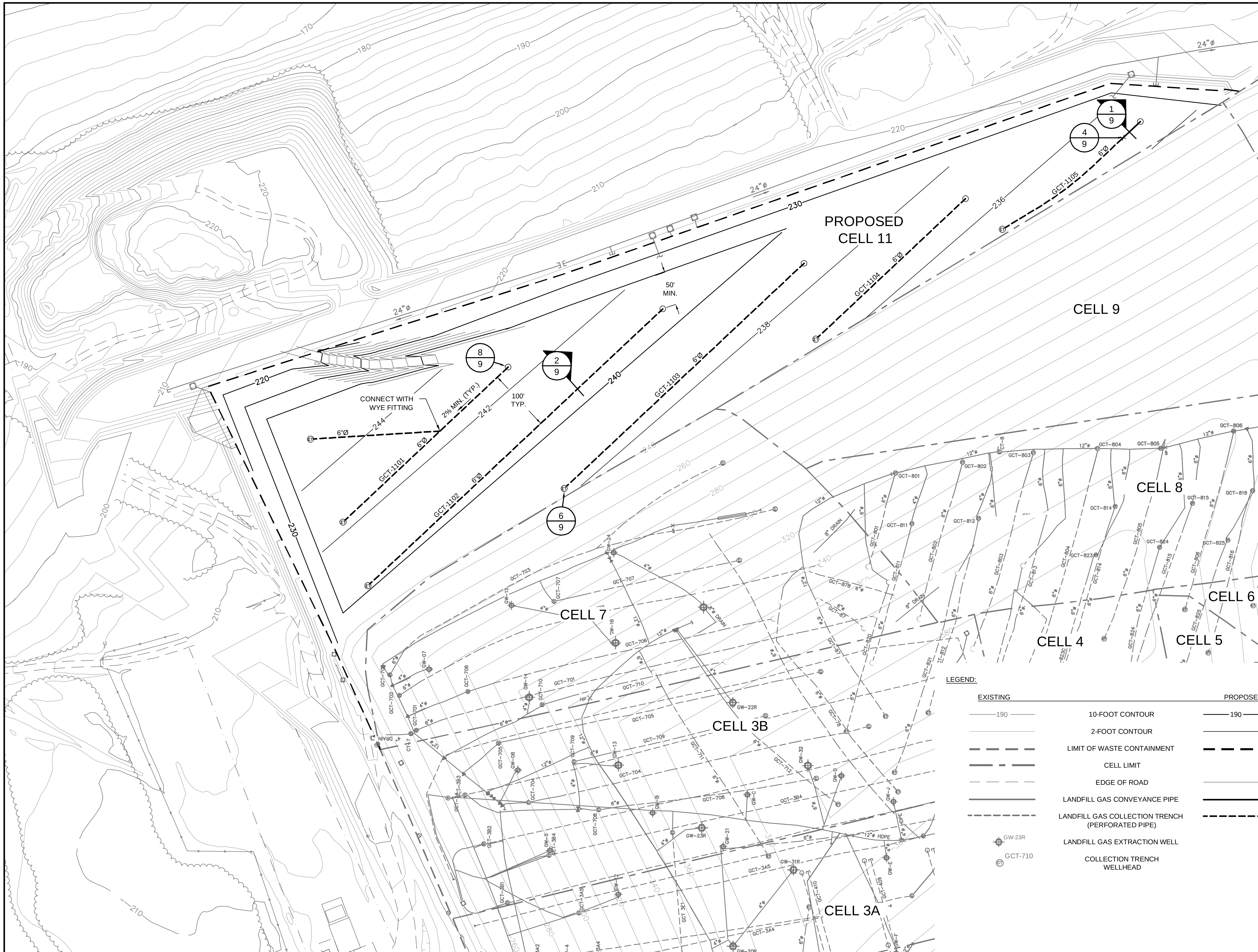
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: R. CLAY
PIC: E. STEINHAUSER
DATE: JUNE 2015

CELL 11 LFG SYSTEM EXPANSION DRAWINGS
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

EXISTING CONDITIONS PLAN

PROJECT NUMBER: 2536.27

SHEET NUMBER: 1 OF 11



NOTES:

1. REFER TO SHEET 1 FOR ADDITIONAL NOTES AND LEGEND.
2. PROPOSED GRADES FOR CELL 11 STAGE 1 WERE OBTAINED FROM A DRAWING PROVIDED ELECTRONICALLY BY SEVEE & MAHER, (SME) INC. OF CUMBERLAND, MAINE, TITLED "CELLDEV-CELL11-STAGE1.DWG", RECEIVED ON MAY 22, 2015.
3. GRADES SHOWN WITHIN THE EXISTING LANDFILL REPRESENT ANTICIPATED EXISTING GRADES DURING CELL 11 FILLING AND WERE PROVIDED TO SANBORN HEAD BY SME.
4. ACTUAL GRADES MAY DIFFER FROM GRADES SHOWN ON DRAWINGS AT THE TIME OF CONSTRUCTION.
5. THIS PLAN ILLUSTRATES THE PROPOSED MODIFICATIONS TO THE LANDFILL GAS EXTRACTION SYSTEM. ACTUAL LOCATION OF WELLS, PIPE, AND VALVES MAY CHANGE DEPENDING ON SITE CONDITIONS AND CONSTRAINTS DURING CONSTRUCTION.
6. SOLID LANDFILL GAS CONVEYANCE PIPE SHALL BE INSTALLED AT A MINIMUM SLOPE OF 7 PERCENT. PERFORATED LANDFILL GAS COLLECTION TRENCHES SHALL BE INSTALLED AT A MINIMUM SLOPE OF 2 PERCENT.
7. HDPE PIPE AND FITTINGS SHALL BE SDR-17.

LEGEND:

EXISTING		PROPOSED
190	10-FOOT CONTOUR	190
	2-FOOT CONTOUR	
	LIMIT OF WASTE CONTAINMENT	
	CELL LIMIT	
	EDGE OF ROAD	
	LANDFILL GAS CONVEYANCE PIPE	
	LANDFILL GAS COLLECTION TRENCH (PERFORATED PIPE)	
GW-23R	LANDFILL GAS EXTRACTION WELL	
GCT-710	COLLECTION TRENCH WELLHEAD	

EXISTING		PROPOSED
	COLLECTION TRENCH TERMINATION	
	PIPE END CAP	
	LEACHATE COLLECTION PIPE CLEANOUT	
	VERTICAL RISER	
	TEE PIPE CONNECTION STUB	
HP	HIGH POINT	
	ROAD CROSSING CULVERT	
	ISOLATION VALVE	
	SOLID TO PERFORATED PIPE TRANSITION	
	TEMPORARY COLLECTION TRENCH RISER	

ISSUED FOR
MAINE DEP APPROVAL
AND CONSTRUCTION
6/24/15

SANBORN HEAD

GRAPHICAL SCALE
80' 40' 0' 80' 160'

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

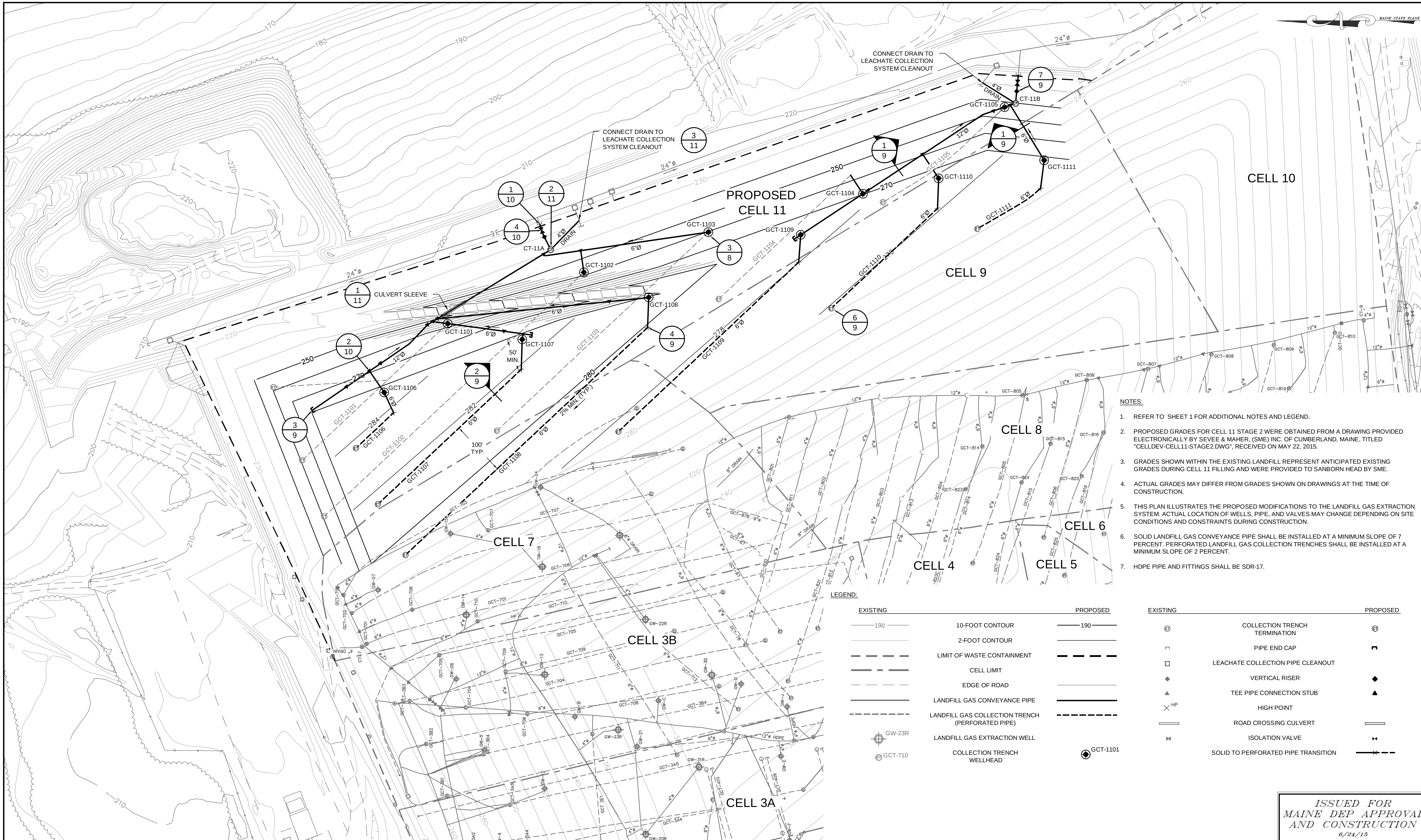
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: R. CLAY
PIC: E. STEINHAUSER
DATE: JUNE 2015

CELL 11 LFG SYSTEM EXPANSION DRAWINGS
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LFG INFRASTRUCTURE
DEVELOPMENT PLAN - STAGE 1

PROJECT NUMBER: 2536.27

SHEET NUMBER: 2 OF 11



NOTES:

1. REFER TO SHEET 1 FOR ADDITIONAL NOTES AND LEGEND.
2. PROPOSED GRADES FOR CELL 11 STAGE 2 WERE OBTAINED FROM A DRAWING PROVIDED ELECTRONICALLY BY SEVEE & MAHER, (SME) INC. OF CUMBERLAND, MAINE, TITLED "CELLDEV-CELL11-STAGE2.DWG", RECEIVED ON MAY 22, 2015.
3. GRADES SHOWN WITHIN THE EXISTING LANDFILL REPRESENT ANTICIPATED EXISTING GRADES DURING CELL 11 FILLING AND WERE PROVIDED TO SANBORN HEAD BY SME.
4. ACTUAL GRADES MAY DIFFER FROM GRADES SHOWN ON DRAWINGS AT THE TIME OF CONSTRUCTION.
5. THIS PLAN ILLUSTRATES THE PROPOSED MODIFICATIONS TO THE LANDFILL GAS EXTRACTION SYSTEM. ACTUAL LOCATION OF WELLS, PIPE, AND VALVES MAY CHANGE DEPENDING ON SITE CONDITIONS AND CONSTRAINTS DURING CONSTRUCTION.
6. SOLID LANDFILL GAS CONVEYANCE PIPE SHALL BE INSTALLED AT A MINIMUM SLOPE OF 7 PERCENT. PERFORATED LANDFILL GAS COLLECTION TRENCHES SHALL BE INSTALLED AT A MINIMUM SLOPE OF 2 PERCENT.
7. HDPE PIPE AND FITTINGS SHALL BE SDR-17.

LEGEND:

EXISTING		PROPOSED
190	10-FOOT CONTOUR	190
	2-FOOT CONTOUR	
	LIMIT OF WASTE CONTAINMENT	
	CELL LIMIT	
	EDGE OF ROAD	
	LANDFILL GAS CONVEYANCE PIPE	
	LANDFILL GAS COLLECTION TRENCH (PERFORATED PIPE)	
GW-23R	LANDFILL GAS EXTRACTION WELL	
GCT-710	COLLECTION TRENCH WELLHEAD	GCT-1101

EXISTING		PROPOSED
	COLLECTION TRENCH TERMINATION	
	PIPE END CAP	
	LEACHATE COLLECTION PIPE CLEANOUT	
	VERTICAL RISER	
	TEE PIPE CONNECTION STUB	
HP	HIGH POINT	
	ROAD CROSSING CULVERT	
	ISOLATION VALVE	
	SOLID TO PERFORATED PIPE TRANSITION	

ISSUED FOR MAINE DEP APPROVAL AND CONSTRUCTION
6/24/15

SANBORN HEAD

GRAPHICAL SCALE
80' 40' 0' 80' 160'

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

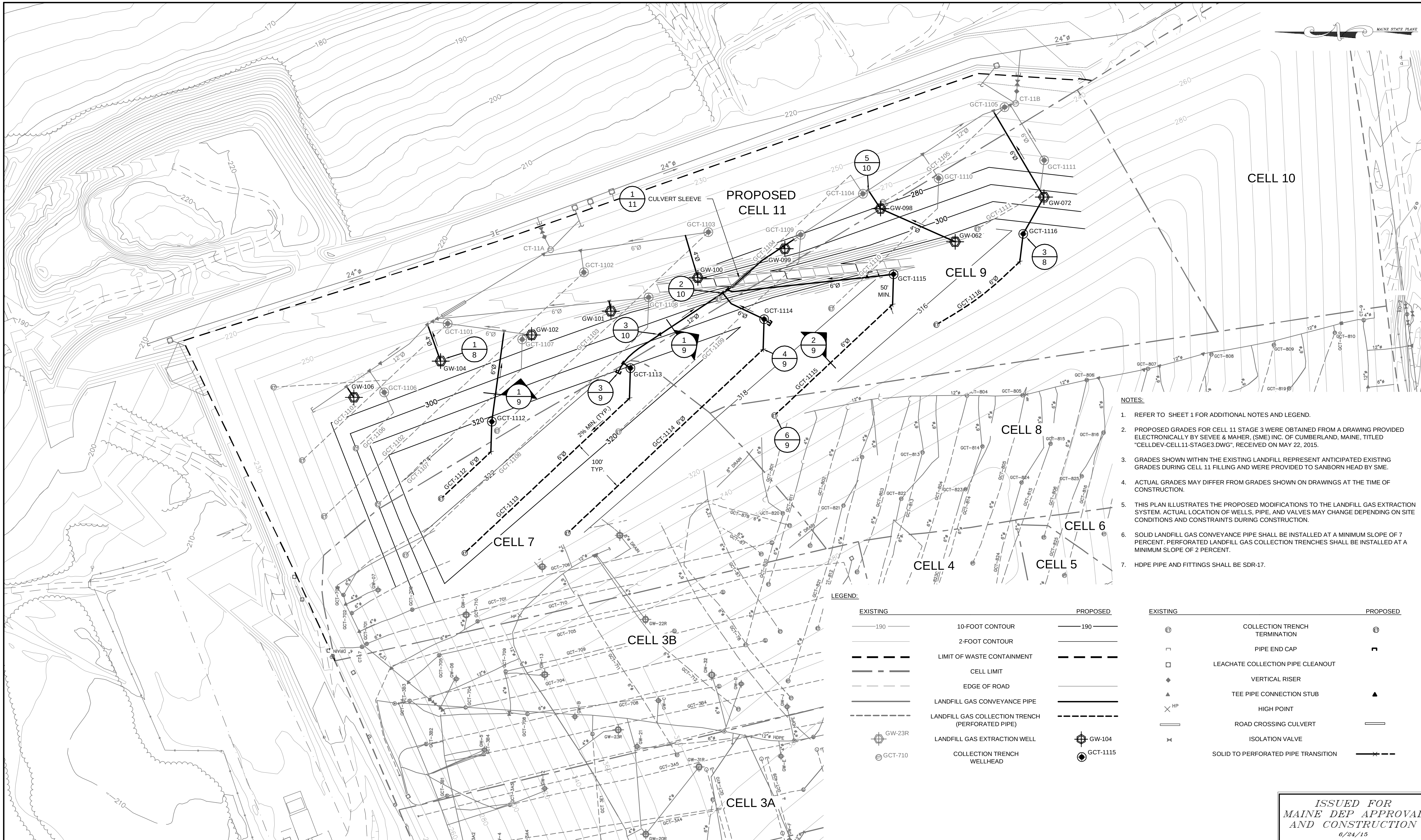
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: R. CLAY
PIC: E. STEINHAUSER
DATE: JUNE 2015

CELL 11 LFG SYSTEM EXPANSION DRAWINGS
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LFG INFRASTRUCTURE DEVELOPMENT PLAN - STAGE 2

PROJECT NUMBER: 2536.27

SHEET NUMBER: 3 OF 11



NOTES:

1. REFER TO SHEET 1 FOR ADDITIONAL NOTES AND LEGEND.
2. PROPOSED GRADES FOR CELL 11 STAGE 3 WERE OBTAINED FROM A DRAWING PROVIDED ELECTRONICALLY BY SEVEE & MAHER, (SME) INC. OF CUMBERLAND, MAINE, TITLED "CELLDEV-CELL11-STAGE3.DWG", RECEIVED ON MAY 22, 2015.
3. GRADES SHOWN WITHIN THE EXISTING LANDFILL REPRESENT ANTICIPATED EXISTING GRADES DURING CELL 11 FILLING AND WERE PROVIDED TO SANBORN HEAD BY SME.
4. ACTUAL GRADES MAY DIFFER FROM GRADES SHOWN ON DRAWINGS AT THE TIME OF CONSTRUCTION.
5. THIS PLAN ILLUSTRATES THE PROPOSED MODIFICATIONS TO THE LANDFILL GAS EXTRACTION SYSTEM. ACTUAL LOCATION OF WELLS, PIPE, AND VALVES MAY CHANGE DEPENDING ON SITE CONDITIONS AND CONSTRAINTS DURING CONSTRUCTION.
6. SOLID LANDFILL GAS CONVEYANCE PIPE SHALL BE INSTALLED AT A MINIMUM SLOPE OF 7 PERCENT. PERFORATED LANDFILL GAS COLLECTION TRENCHES SHALL BE INSTALLED AT A MINIMUM SLOPE OF 2 PERCENT.
7. HDPE PIPE AND FITTINGS SHALL BE SDR-17.

LEGEND:

EXISTING		PROPOSED
190	10-FOOT CONTOUR	190
	2-FOOT CONTOUR	
	LIMIT OF WASTE CONTAINMENT	
	CELL LIMIT	
	EDGE OF ROAD	
	LANDFILL GAS CONVEYANCE PIPE	
	LANDFILL GAS COLLECTION TRENCH (PERFORATED PIPE)	
GW-23R	LANDFILL GAS EXTRACTION WELL	GW-104
GCT-710	COLLECTION TRENCH WELLHEAD	GCT-1115

EXISTING		PROPOSED
	COLLECTION TRENCH TERMINATION	
	PIPE END CAP	
	LEACHATE COLLECTION PIPE CLEANOUT	
	VERTICAL RISER	
	TEE PIPE CONNECTION STUB	
HP	HIGH POINT	
	ROAD CROSSING CULVERT	
	ISOLATION VALVE	
	SOLID TO PERFORATED PIPE TRANSITION	

ISSUED FOR MAINE DEP APPROVAL AND CONSTRUCTION
6/24/15

SANBORN HEAD

GRAPHICAL SCALE
80' 40' 0' 80' 160'

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

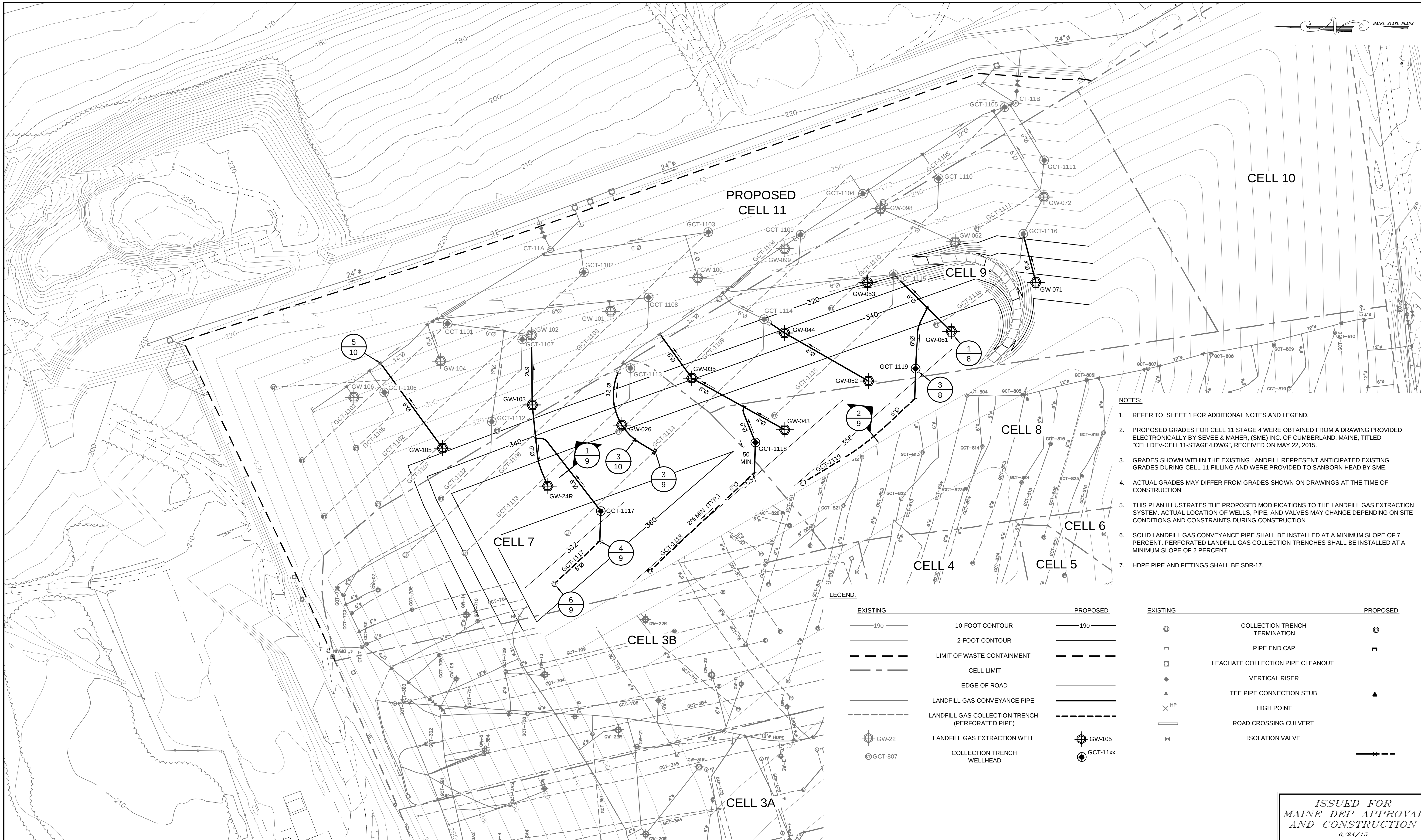
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: R. CLAY
PIC: E. STEINHAUSER
DATE: JUNE 2015

CELL 11 LFG SYSTEM EXPANSION DRAWINGS
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LFG INFRASTRUCTURE DEVELOPMENT PLAN - STAGE 3

PROJECT NUMBER: 2536.27

SHEET NUMBER: 4 OF 11



NOTES:

1. REFER TO SHEET 1 FOR ADDITIONAL NOTES AND LEGEND.
2. PROPOSED GRADES FOR CELL 11 STAGE 4 WERE OBTAINED FROM A DRAWING PROVIDED ELECTRONICALLY BY SEVEE & MAHER, (SME) INC. OF CUMBERLAND, MAINE, TITLED "CELLDEV-CELL11-STAGE4.DWG", RECEIVED ON MAY 22, 2015.
3. GRADES SHOWN WITHIN THE EXISTING LANDFILL REPRESENT ANTICIPATED EXISTING GRADES DURING CELL 11 FILLING AND WERE PROVIDED TO SANBORN HEAD BY SME.
4. ACTUAL GRADES MAY DIFFER FROM GRADES SHOWN ON DRAWINGS AT THE TIME OF CONSTRUCTION.
5. THIS PLAN ILLUSTRATES THE PROPOSED MODIFICATIONS TO THE LANDFILL GAS EXTRACTION SYSTEM. ACTUAL LOCATION OF WELLS, PIPE, AND VALVES MAY CHANGE DEPENDING ON SITE CONDITIONS AND CONSTRAINTS DURING CONSTRUCTION.
6. SOLID LANDFILL GAS CONVEYANCE PIPE SHALL BE INSTALLED AT A MINIMUM SLOPE OF 7 PERCENT. PERFORATED LANDFILL GAS COLLECTION TRENCHES SHALL BE INSTALLED AT A MINIMUM SLOPE OF 2 PERCENT.
7. HDPE PIPE AND FITTINGS SHALL BE SDR-17.

LEGEND:

EXISTING		PROPOSED
190	10-FOOT CONTOUR	190
	2-FOOT CONTOUR	
	LIMIT OF WASTE CONTAINMENT	
	CELL LIMIT	
	EDGE OF ROAD	
	LANDFILL GAS CONVEYANCE PIPE	
	LANDFILL GAS COLLECTION TRENCH (PERFORATED PIPE)	
GW-22	LANDFILL GAS EXTRACTION WELL	GW-105
GCT-807	COLLECTION TRENCH WELLHEAD	GCT-11xx

EXISTING		PROPOSED
	COLLECTION TRENCH TERMINATION	
	PIPE END CAP	
	LEACHATE COLLECTION PIPE CLEANOUT	
	VERTICAL RISER	
	TEE PIPE CONNECTION STUB	
HP	HIGH POINT	
	ROAD CROSSING CULVERT	
	ISOLATION VALVE	

ISSUED FOR MAINE DEP APPROVAL AND CONSTRUCTION
6/24/15

SANBORN | HEAD

GRAPHICAL SCALE
80' 40' 0' 80' 160'

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

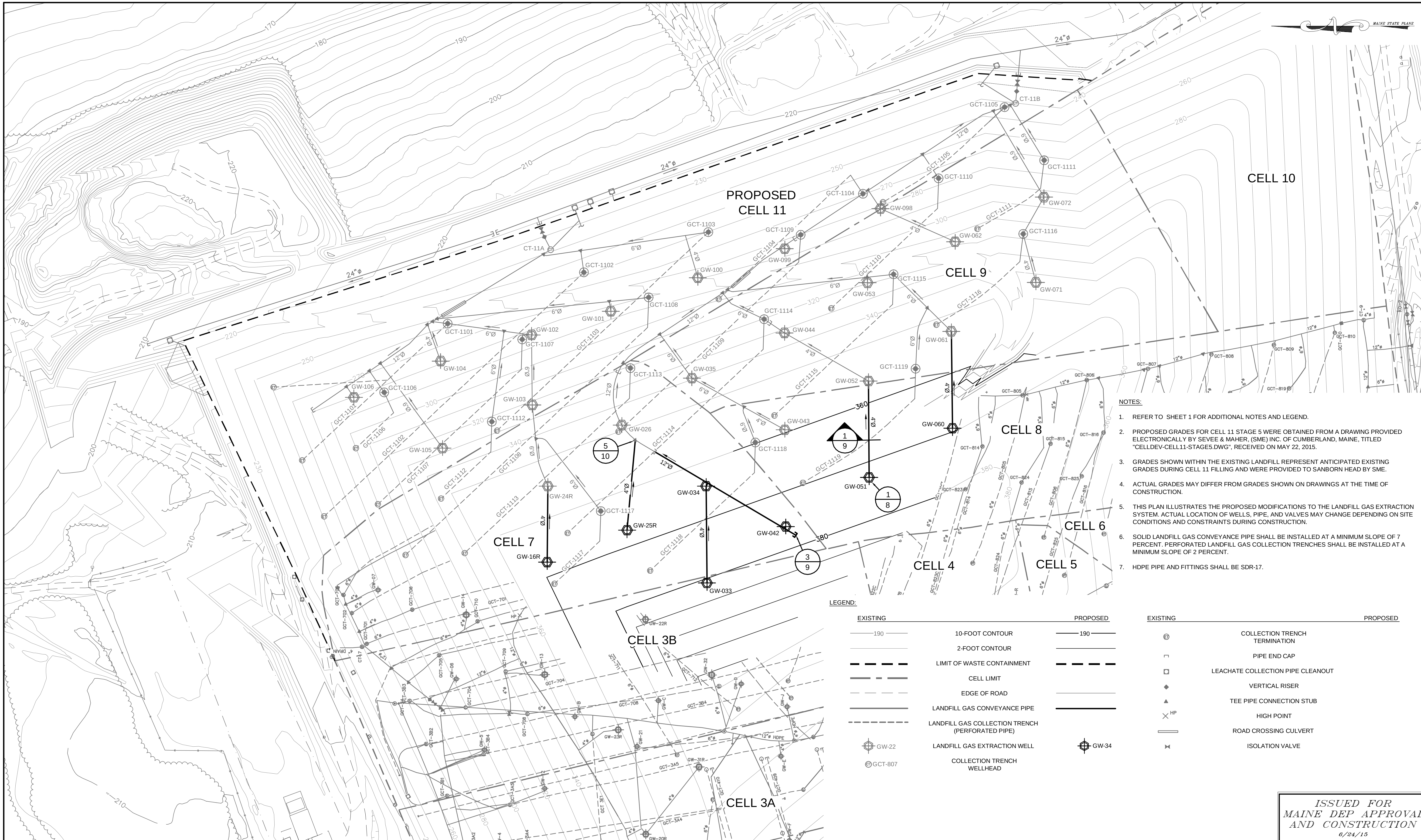
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: R. CLAY
PIC: E. STEINHAUSER
DATE: JUNE 2015

CELL 11 LFG SYSTEM EXPANSION DRAWINGS
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LFG INFRASTRUCTURE DEVELOPMENT PLAN - STAGE 4

PROJECT NUMBER: 2536.27

SHEET NUMBER: 5 OF 11



NOTES:

1. REFER TO SHEET 1 FOR ADDITIONAL NOTES AND LEGEND.
2. PROPOSED GRADES FOR CELL 11 STAGE 5 WERE OBTAINED FROM A DRAWING PROVIDED ELECTRONICALLY BY SEVEE & MAHER, (SME) INC. OF CUMBERLAND, MAINE, TITLED "CELLDEV-CELL11-STAGE5.DWG", RECEIVED ON MAY 22, 2015.
3. GRADES SHOWN WITHIN THE EXISTING LANDFILL REPRESENT ANTICIPATED EXISTING GRADES DURING CELL 11 FILLING AND WERE PROVIDED TO SANBORN HEAD BY SME.
4. ACTUAL GRADES MAY DIFFER FROM GRADES SHOWN ON DRAWINGS AT THE TIME OF CONSTRUCTION.
5. THIS PLAN ILLUSTRATES THE PROPOSED MODIFICATIONS TO THE LANDFILL GAS EXTRACTION SYSTEM. ACTUAL LOCATION OF WELLS, PIPE, AND VALVES MAY CHANGE DEPENDING ON SITE CONDITIONS AND CONSTRAINTS DURING CONSTRUCTION.
6. SOLID LANDFILL GAS CONVEYANCE PIPE SHALL BE INSTALLED AT A MINIMUM SLOPE OF 7 PERCENT. PERFORATED LANDFILL GAS COLLECTION TRENCHES SHALL BE INSTALLED AT A MINIMUM SLOPE OF 2 PERCENT.
7. HDPE PIPE AND FITTINGS SHALL BE SDR-17.

LEGEND:

EXISTING		PROPOSED
190	10-FOOT CONTOUR	190
	2-FOOT CONTOUR	
	LIMIT OF WASTE CONTAINMENT	
	CELL LIMIT	
	EDGE OF ROAD	
	LANDFILL GAS CONVEYANCE PIPE	
	LANDFILL GAS COLLECTION TRENCH (PERFORATED PIPE)	
GW-22	LANDFILL GAS EXTRACTION WELL	GW-34
GCT-807	COLLECTION TRENCH WELLHEAD	

EXISTING		PROPOSED
	COLLECTION TRENCH TERMINATION	
	PIPE END CAP	
	LEACHATE COLLECTION PIPE CLEANOUT	
	VERTICAL RISER	
	TEE PIPE CONNECTION STUB	
HP	HIGH POINT	
	ROAD CROSSING CULVERT	
	ISOLATION VALVE	

ISSUED FOR MAINE DEP APPROVAL AND CONSTRUCTION
6/24/15

SANBORN HEAD

GRAPHICAL SCALE
80' 40' 0' 80' 160'

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

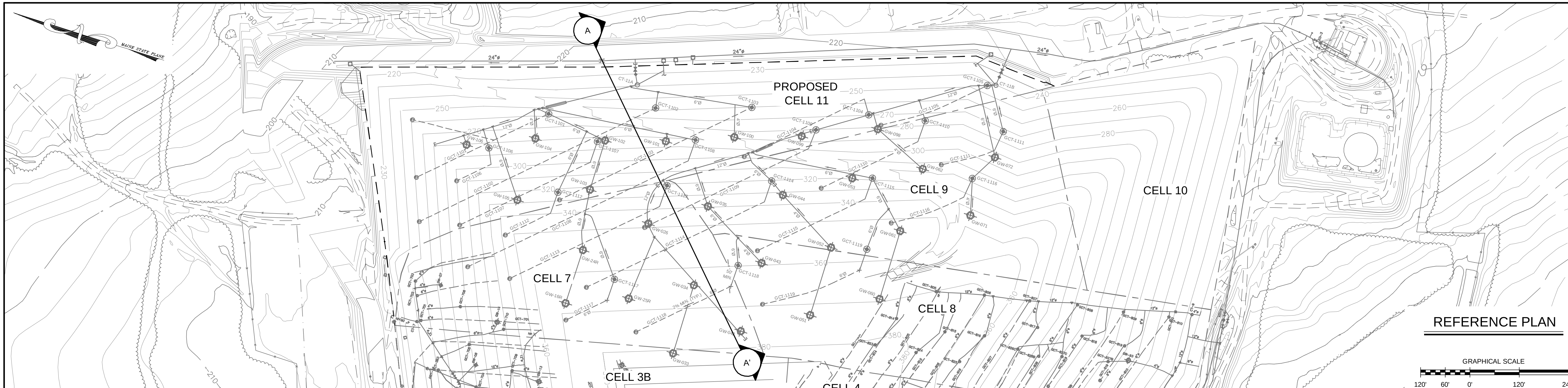
DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: R. CLAY
PIC: E. STEINHAUSER
DATE: JUNE 2015

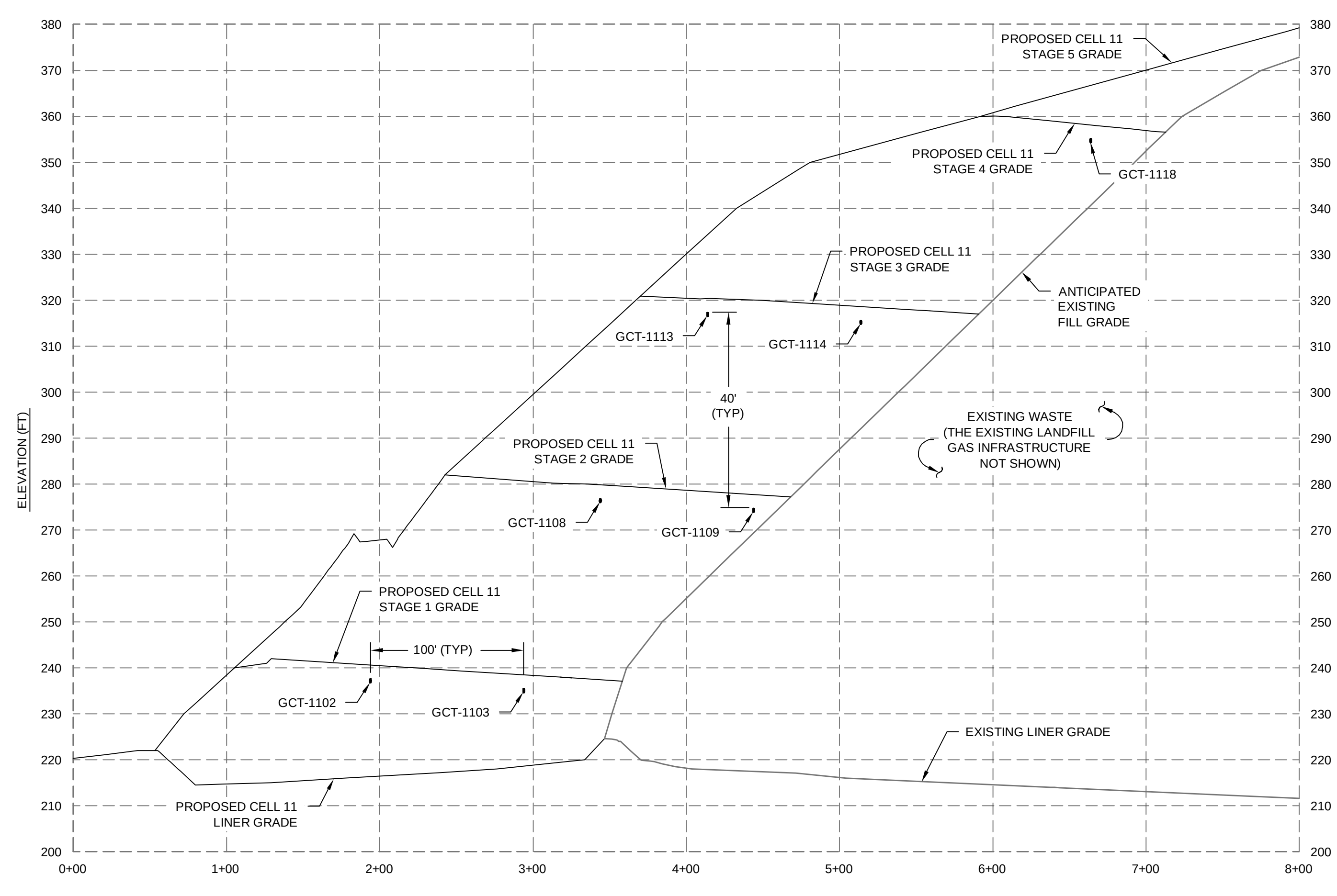
CELL 11 LFG SYSTEM EXPANSION DRAWINGS
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

LFG INFRASTRUCTURE DEVELOPMENT PLAN - STAGE 5

PROJECT NUMBER: 2536.27

SHEET NUMBER: 6 OF 11





SECTION A-A'

VERTICAL SCALE
20' 10' 0 20' 40'
60' 30' 0 60' 120'
HORIZONTAL SCALE

NOTES:

1. THE CROSS SECTION SHOWN ON THIS SHEET ILLUSTRATES THE PROPOSED LAYOUT AND SPACING OF GAS COLLECTION TRENCHES IN CELL 11. ACTUAL GRADES MAY DIFFER FROM THE GRADES SHOWN AT THE TIME OF CONSTRUCTION. THE LOCATIONS OF COLLECTION TRENCHES MAY CHANGE DEPENDING ON SITE CONDITIONS AND CONSTRAINTS DURING CONSTRUCTION. VERTICAL WELLS ARE NOT SHOWN ON THE CROSS SECTION FOR CLARITY.
2. REFER TO SHEET 1 FOR ADDITIONAL NOTES AND LEGEND.

ISSUED FOR MAINE DEP APPROVAL AND CONSTRUCTION
6/24/15

SANBORN HEAD

SCALE AS NOTED

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: R. CLAY
PIC: E. STEINHAUSER
DATE: JUNE 2015

CELL 11 LFG SYSTEM EXPANSION DRAWINGS
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

CROSS SECTION

PROJECT NUMBER: 2536.27

SHEET NUMBER: 7 OF 11

NOTES:

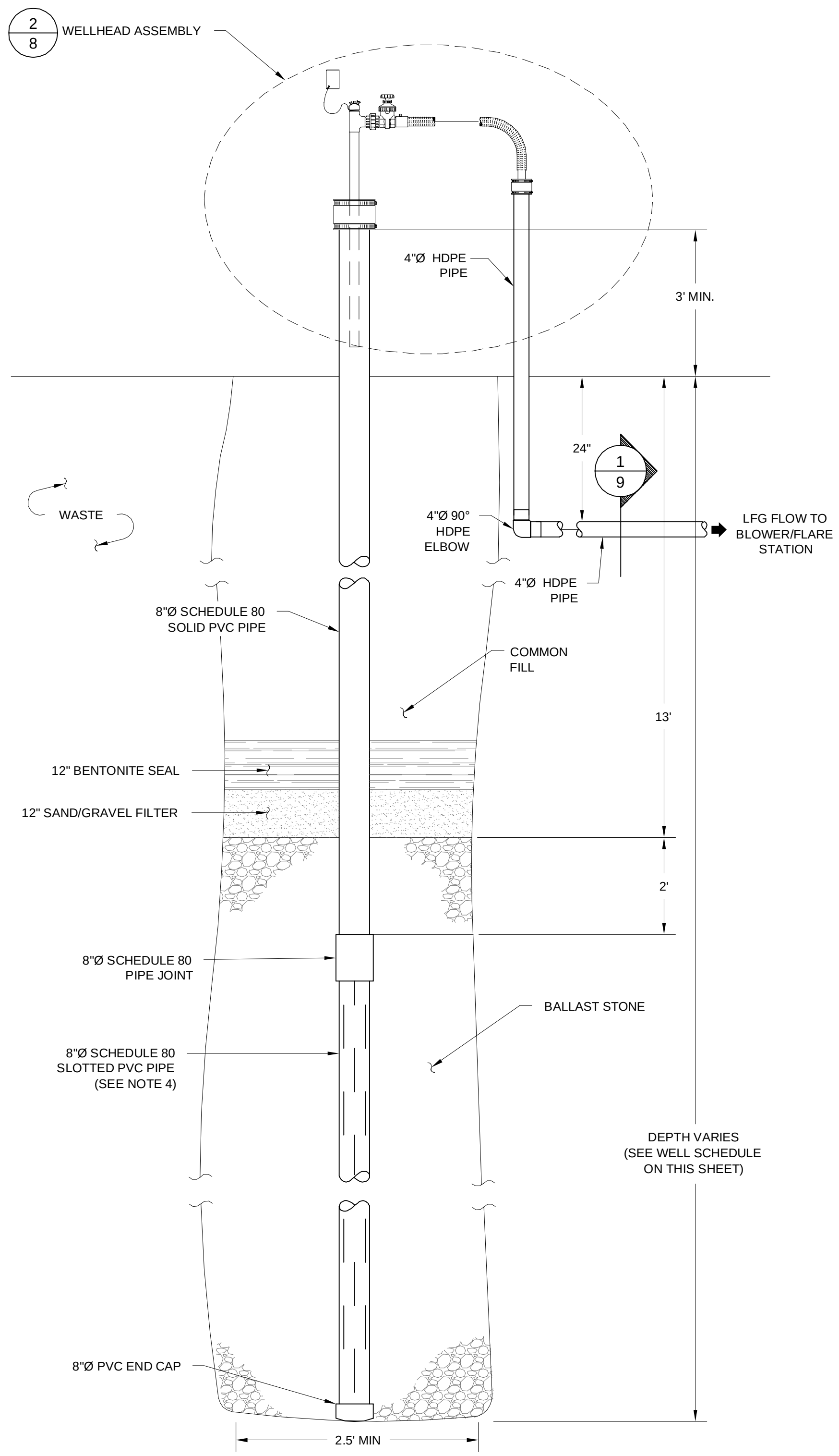
1. ALL HDPE PIPE SHALL BE SDR-17, UNLESS OTHERWISE NOTED.
2. ALL SOLID HDPE PIPE SHALL BE BUTT-FUSION WELDED UNLESS OTHERWISE INDICATED OR AN ALTERNATIVE IS APPROVED BY THE ENGINEER.
3. COVER SOLID HDPE PIPE ON LANDFILL SLOPES WITH MINIMUM 2 FEET OF SOIL AND STABILIZE AGAINST EROSION.
4. PIPE PERFORATED WITH SLOTS 3/8" TO 1/2" WIDE BY 8" LONG. FOUR SLOTS PER ROW SPACED 90° APART, WITH ADJACENT ROWS OFFSET BY 45°.

WELL SCHEDULE NOTES:

1. LFG EXTRACTION WELLS SHALL BE INSTALLED WITHIN ONE FOOT OF LISTED LOCATIONS.
2. A TEMPORARY BENCHMARK WITH ELEVATION SHALL BE ESTABLISHED AT EACH WELL PRIOR TO DRILLING.
3. 15 FEET OF SOLID RISER IS TO BE PROVIDED BELOW INTERMEDIATE COVER GRADES. THE INTENT IS TO PROVIDE 3 FEET OF STICK UP ABOVE FILL GRADES.
4. ELEVATIONS SHALL BE CONFIRMED AGAINST AS-BUILT TOP OF PRIMARY SAND GRADES AND FILL GRADES PRIOR TO CONSTRUCTION.

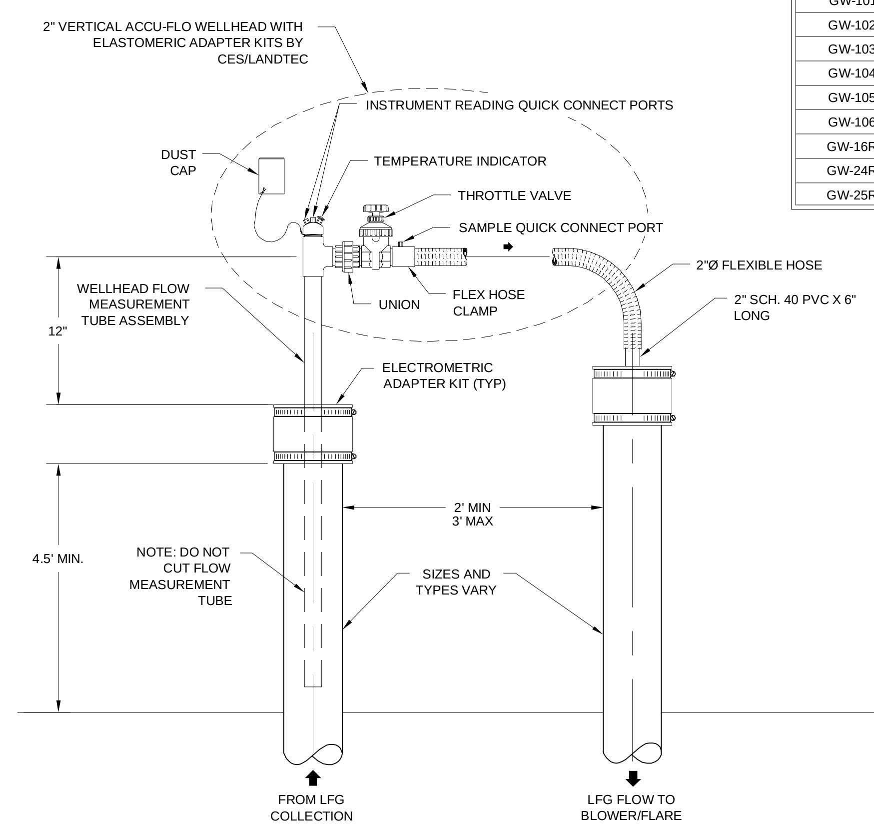
WELL SCHEDULE

WELL DESIGNATION	NORTHING	EASTING	BOTTOM OF WASTE (FT)	TOP OF EXISTING WASTE (FT)	TOTAL WELL DEPTH (FT)	BOTTOM OF WELL SCREEN (FT)	TOP OF WELL SCREEN (FT)	SCREEN LENGTH (FT)	TOP OF CASING ELEV. (FT)
GW-026	478922.2	926825.3	217.1	349.1	116.9	232.1	334.1	101.9	352.1
GW-033	478769.9	926542.9	214.8	380.4	150.6	229.8	365.4	135.6	383.4
GW-034	478771.5	926716.1	214.3	364.4	135.1	229.3	349.4	120.1	367.4
GW-035	478796.8	926909.2	217.6	339.1	106.6	232.6	324.1	91.6	342.1
GW-042	478629.0	926643.7	212.0	376.0	149.0	227.0	361.0	134.0	379.0
GW-043	478630.6	926816.9	213.5	359.6	131.1	228.5	344.6	116.1	362.6
GW-044	478631.1	926990.1	215.3	332.2	101.8	230.3	317.2	86.8	335.2
GW-051	478479.8	926731.7	210.8	372.7	146.8	225.8	357.7	131.8	375.7
GW-052	478480.9	926903.9	214.7	356.4	126.7	229.7	341.4	111.7	359.4
GW-053	478482.6	927079.8	214.5	320.6	91.1	229.5	305.6	76.1	323.6
GW-060	478330.7	926819.7	209.7	369.4	144.7	224.7	354.4	129.7	372.4
GW-061	478332.7	926992.9	211.8	353.0	126.1	226.8	338.0	111.1	356.0
GW-062	478326.0	927153.1	213.2	315.0	86.8	228.2	300.0	71.8	318.0
GW-071	478181.5	927080.5	210.5	345.0	119.4	225.5	330.0	104.4	348.0
GW-072	478167.1	927233.0	212.3	293.9	66.6	227.3	278.9	51.6	296.9
GW-098	478459.4	927212.4	220.9	281.5	45.6	235.9	266.5	30.6	284.5
GW-099	478630.8	927140.8	219.9	284.9	50.0	234.9	269.9	35.0	287.9
GW-100	478786.2	927088.7	218.6	283.9	50.3	233.6	268.9	35.3	286.9
GW-101	478941.9	927028.9	217.8	285.4	52.6	232.8	270.4	37.6	288.4
GW-102	479083.5	926986.5	217.0	282.9	50.8	232.0	267.9	35.8	285.9
GW-103	479082.4	926861.4	221.5	322.1	85.6	236.5	307.1	70.6	325.1
GW-104	479246.4	926939.8	213.0	278.4	50.4	228.0	263.4	35.4	281.4
GW-105	479243.1	926784.1	218.5	327.4	93.9	233.5	312.4	78.9	330.4
GW-106	479401.5	926874.9	209.8	280.5	55.7	224.8	265.5	40.7	283.5
GW-16R	479055.8	926580.2	216.3	367.5	136.2	231.3	352.5	121.2	370.5
GW-24R	479054.6	926716.2	217.6	354.8	122.2	232.6	339.8	107.2	357.8
GW-25R	478912.8	926637.2	215.2	367.1	136.9	230.2	352.1	121.9	370.1



1 LFG EXTRACTION WELL DETAIL

NOT TO SCALE



WELLHEAD NOTES:

A. CES-LANDTEC ACCU-FLOW WELLHEAD SHALL BE INSTALLED IN ACCORDANCE WITH THE MANUFACTURER'S INSTALLATION INSTRUCTION MANUAL. INSTRUCTIONS SHALL BE THOROUGHLY READ BEFORE ATTEMPTING ASSEMBLY AND INSTALLATION OF WELLHEAD.

B. WELLHEAD AND FLOW MEASUREMENT TUBE ASSEMBLY SHALL BE COMPATIBLE WITH CES-LANDTEC GEM-2000 (LANDFILL GAS INSTRUMENT).

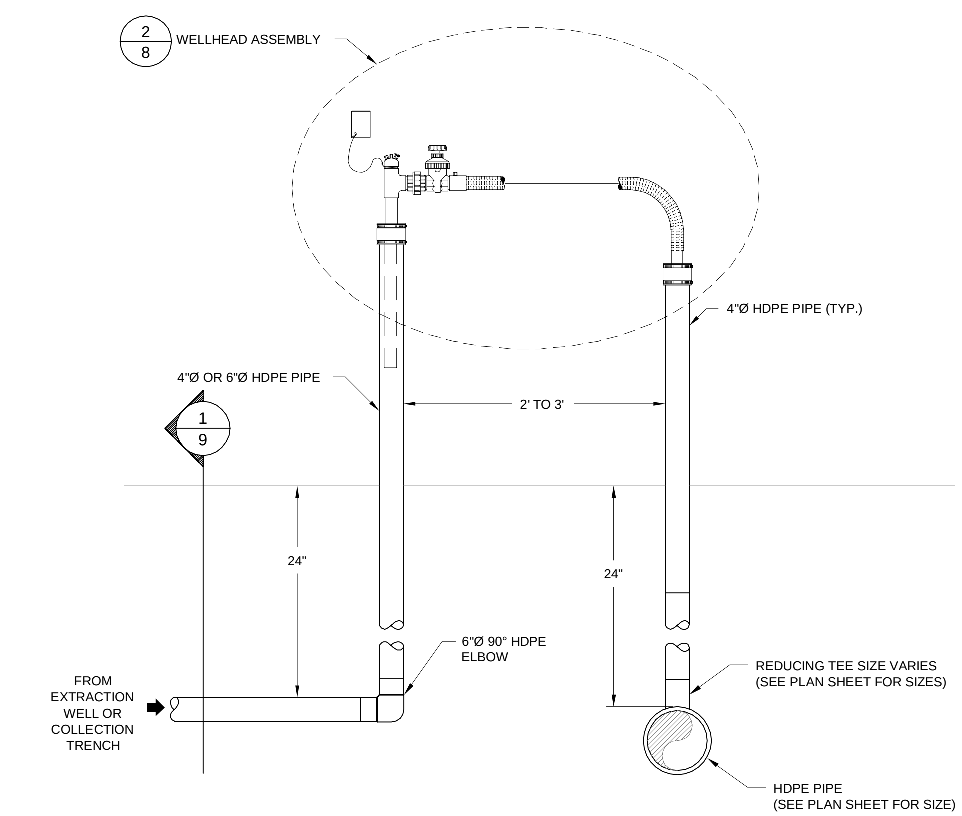
C. FOR FLEXIBLE CONNECTIONS TO PIPE, USE ONLY "IPS WELD-ON 795" PLASTIC PIPE CEMENT OR EQUAL APPROVED BY THE ENGINEER.

D. WARNING: DO NOT CUT THE FLOW MEASUREMENT TUBE ASSEMBLY. FAILURE TO HEED THIS WARNING WILL RESULT IN A DAMAGED OR INOPERATIVE WELLHEAD AND VOID THE WARRANTY. SUCH DAMAGE WOULD REQUIRE REPLACEMENT OF THE WELLHEAD AT THE CONTRACTOR'S EXPENSE.

E. ALLOW SUFFICIENT SLACK IN FLEX HOSE FOR PIPE EXPANSION AND CONTRACTION; AN EXTRA 8 TO 12 INCHES IS RECOMMENDED.

2 WELLHEAD ASSEMBLY DETAIL

NOT TO SCALE



3 COLLECTION TRENCH WELLHEAD

NOT TO SCALE

ISSUED FOR MAINE DEP APPROVAL AND CONSTRUCTION
6/24/15

SANBORN HEAD

SCALE AS NOTED

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

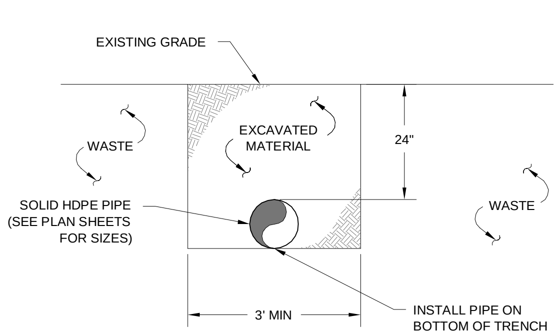
DRAWN BY: R.CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: R. CLAY
PIC: E. STEINHAUSER
DATE: JUNE 2015

CELL 11 LFG SYSTEM EXPANSION DRAWINGS
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

DETAILS

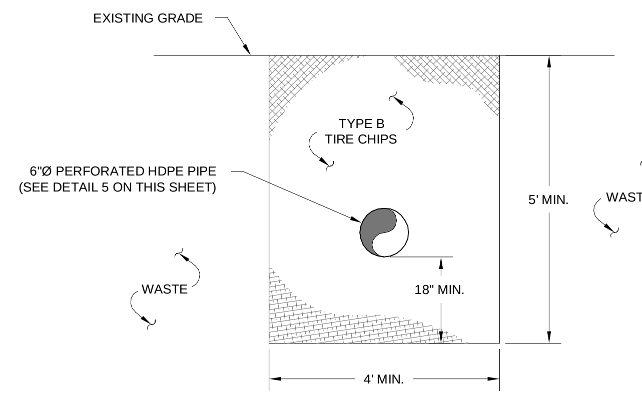
PROJECT NUMBER: 2536.27

SHEET NUMBER: 8 OF 11



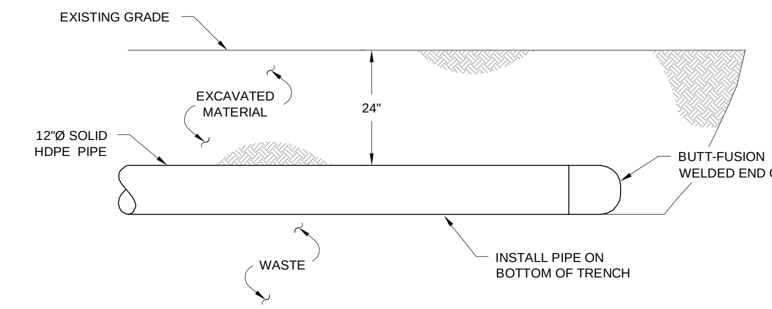
1 SOLID PIPE TRENCH

NOT TO SCALE



2 PERFORATED PIPE TRENCH

NOT TO SCALE



3 TEMPORARY PIPE TERMINATION

NOT TO SCALE

NOTES:

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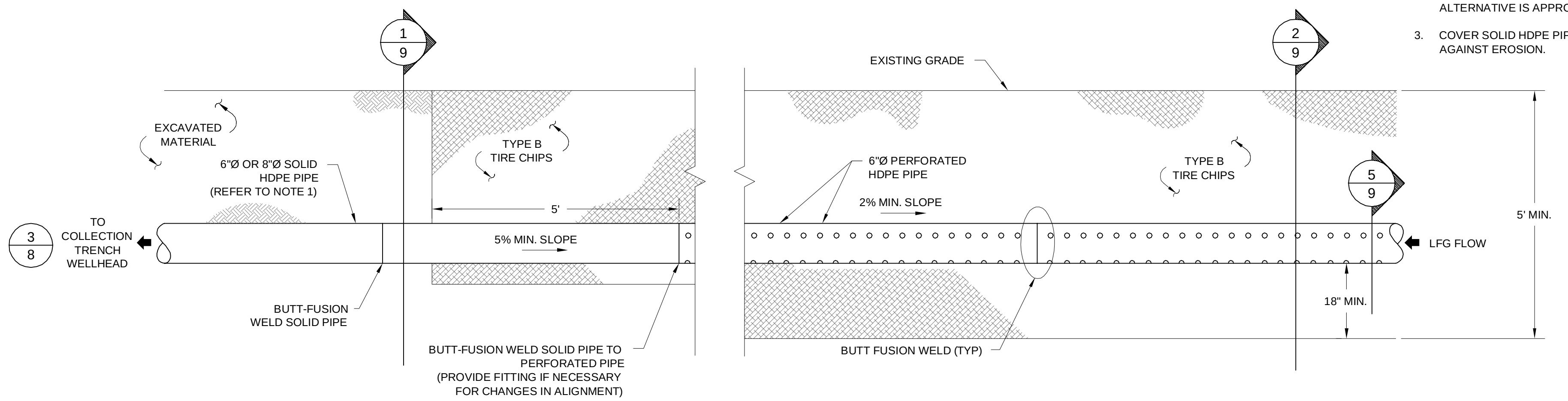
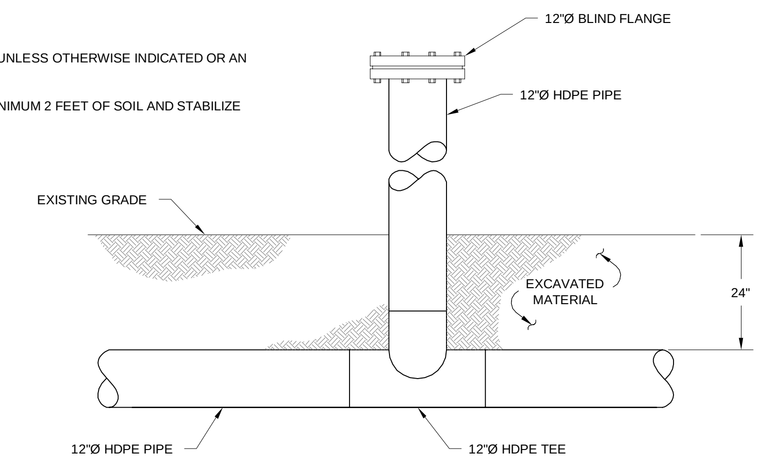
2. ALL SOLID HDPE PIPE SHALL BE BUTT-FUSION WELDED UNLESS OTHERWISE INDICATED OR AN ALTERNATIVE IS APPROVED BY THE ENGINEER.
3. COVER SOLID HDPE PIPE ON LANDFILL SLOPES WITH MINIMUM 2 FEET OF SOIL AND STABILIZE AGAINST EROSION.



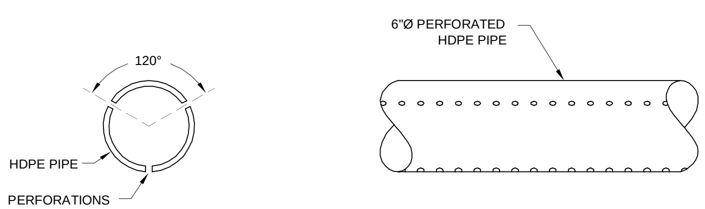
4 LFG COLLECTION TRENCH TRANSITION

NOT TO SCALE



7 VERTICAL RISER

NOT TO SCALE

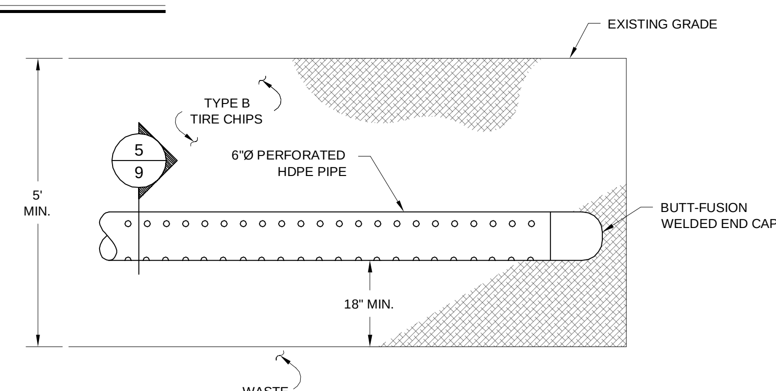


NOTE:

1. HOLES SHALL BE 1/2"Ø DRILLED HOLES SPACED 12" APART ALONG THE LENGTH OF THE PIPE OR APPROVED EQUIVALENT BY OWNER.

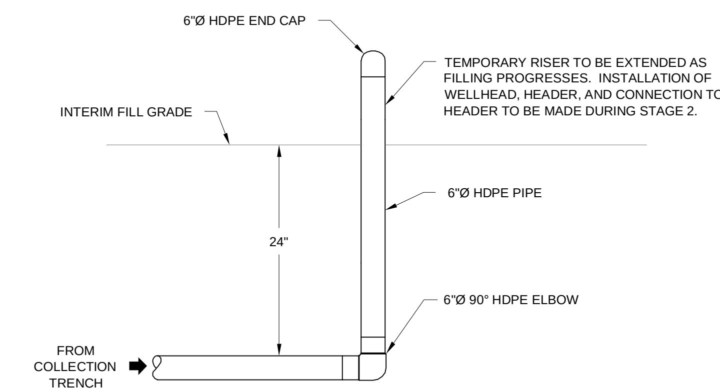
5 TYPICAL PERFORATED PIPE

NOT TO SCALE



6 COLLECTION TRENCH TERMINATION

NOT TO SCALE



8 TEMPORARY COLLECTION TRENCH RISER

NOT TO SCALE

ISSUED FOR MAINE DEP APPROVAL AND CONSTRUCTION 6/24/15

SANBORN HEAD

SCALE AS NOTED

STATE OF MAINE — Eric S. Steinhauser — 10809 — PROFESSIONAL ENGINEER

NO.	DATE	DESCRIPTION	BY

DRAWN BY: R. CLAY
DESIGNED BY: R. CLAY
REVIEWED BY: E. STEINHAUSER
PROJECT MGR: R. CLAY
PIC: E. STEINHAUSER
DATE: JUNE 2015

CELL 11 LFG SYSTEM EXPANSION DRAWINGS

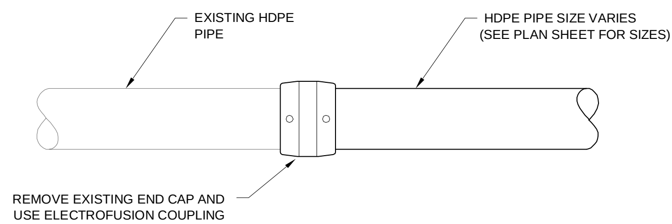
JUNIPER RIDGE LANDFILL

OLD TOWN, MAINE

DETAILS

PROJECT NUMBER: 2536.27

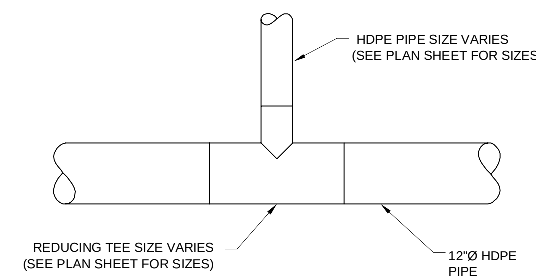
SHEET NUMBER: 9 OF 11



EXISTING CONVEYANCE PIPE CONNECTION

1

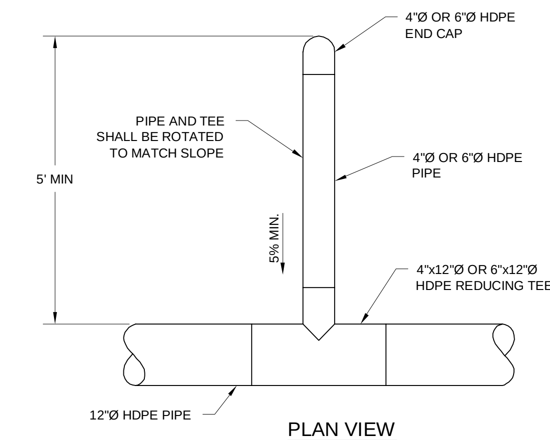
NOT TO SCALE



"TEE" CONNECTION

2

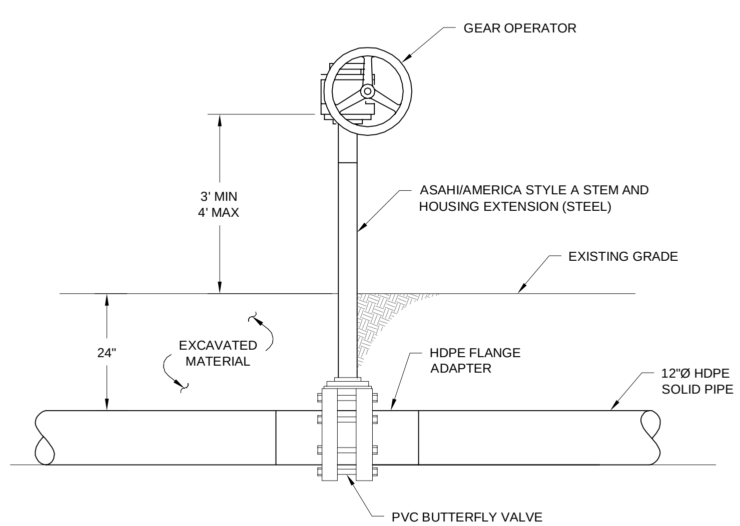
NOT TO SCALE



TEE PIPE CONNECTION STUB

3

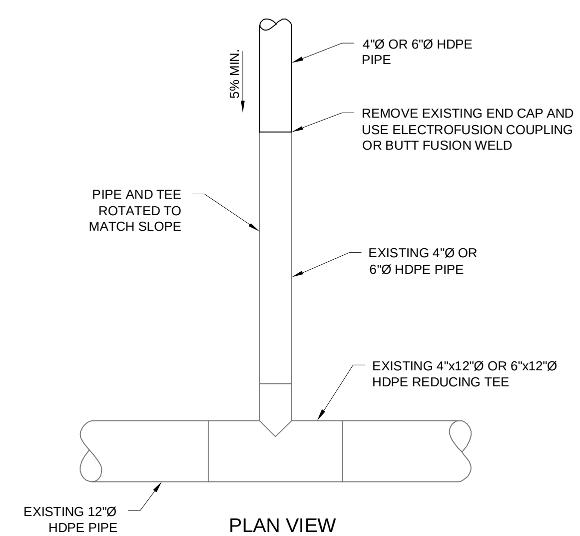
NOT TO SCALE



LFG FLOW CONTROL VALVE

4

NOT TO SCALE



CONNECTION TO TEE PIPE STUB

5

NOT TO SCALE

NOTES:

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ISSUED FOR MAINE DEP APPROVAL AND CONSTRUCTION
6/24/15

SANBORN HEAD

SCALE AS NOTED

STATE OF MAINE
Eric S. Steinhauser
10809
PROFESSIONAL ENGINEER

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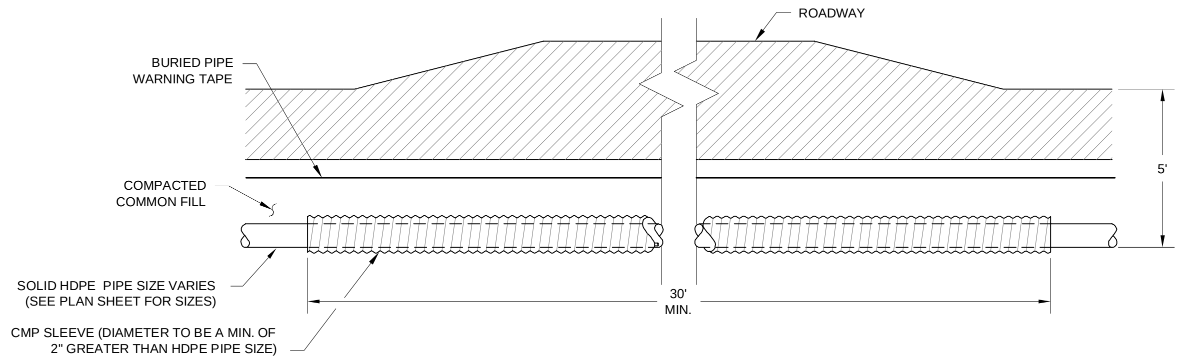
CELL 11 LFG SYSTEM EXPANSION DRAWINGS
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

DETAILS

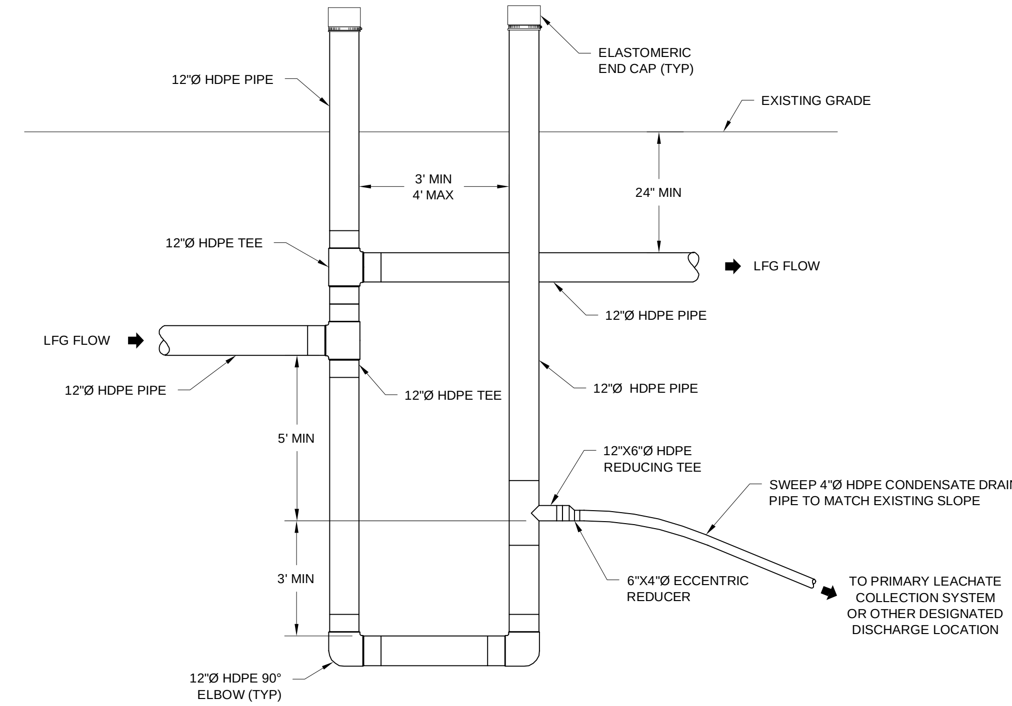
PROJECT NUMBER: 2536.27

SHEET NUMBER: 10 OF 11



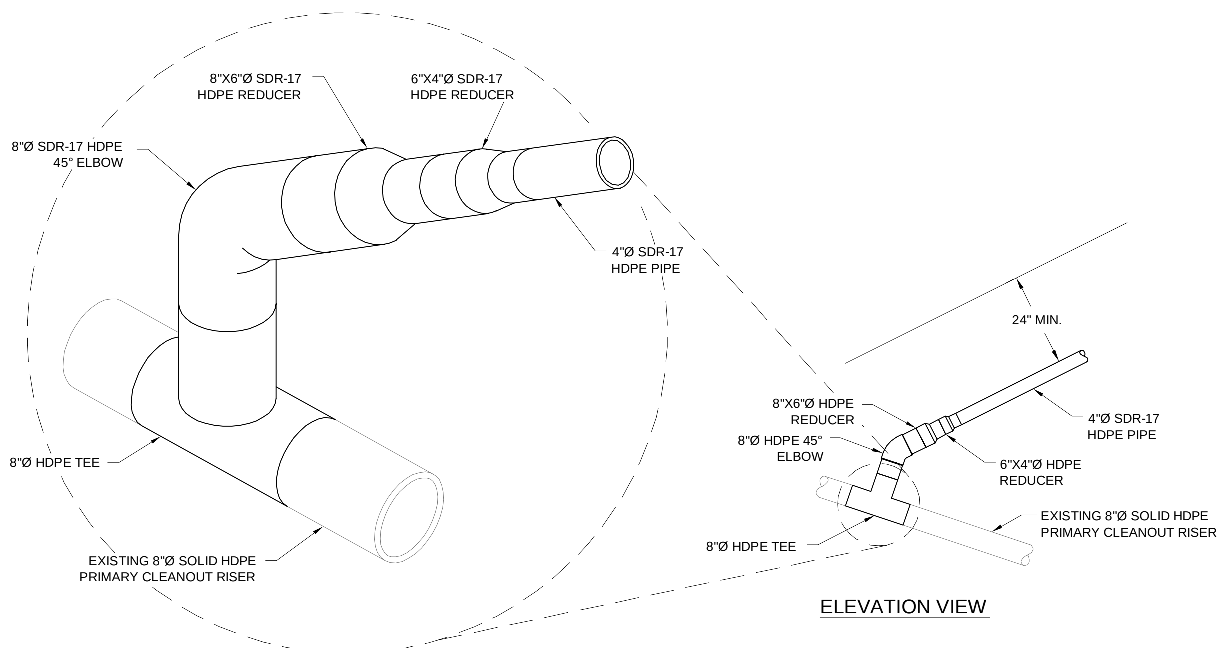
1 ROAD CROSSING PIPE SLEEVE

NOT TO SCALE



2 CONDENSATE TRAP

NOT TO SCALE



3 CONDENSATE DRAIN PIPE CONNECTION TO LEACHATE COLLECTION INLET/CLEANOUT SECTION

NOT TO SCALE

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6/24/15

SANBORN HEAD

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STATE OF MAINE
Eric S. Steinhauser
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CELL 11 LFG SYSTEM EXPANSION DRAWINGS
JUNIPER RIDGE LANDFILL
OLD TOWN, MAINE

DETAILS

PROJECT NUMBER: 2536.27

SHEET NUMBER: 11 OF 11