STATE OF MAINE

DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF REMEDIATION AND WASTE MANAGEMENT
DIVISION OF TECHNICAL SERVICES

M E M O R A N D U M

TO: Linda Butler, Project Manager

FROM: Gail Lipfert, PhD, C.G. # GE506 Hydrogeologist

DATE: June 22, 2020

RE: Response to Comments on Phase 14 Solid Waste Permit Application, Volume III, Crossroads Landfill, Waste Management Disposal Services of Maine (WMDSM), Norridgewock, Maine

CC: Chris Evans, C.G., Hydrogeology Unit supervisor, Kathy Tarbuck, P.E., Project Engineer

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Most of the responses to our comments are acceptable, but we still have some points of disagreement, most importantly with the time-of travel estimations. The following comments address those disagreements.

It is my understanding that unlike DOD or Superfund sites, landfill applications and licensing do not require final versions or revised applications, so I withdraw my request for a red-line strike out version.

1. **Response acceptable**.
2. **Response acceptable**.
3. 2.1.1 Soil and Bedrock Borings,
    a. **Response acceptable**.
    b. **Response acceptable**.
    c. **Response acceptable**.
    d. **Response acceptable.**
4. 2.1.3 Piezometer and Monitoring Well Installation.
    a. **Response acceptable**.
    b. **We will not require further response, but in the future, we will follow the rules for piezometers more closely. Piezometers should be used primarily to measure heads. If identification of the water table is desired, then water table wells should be installed.**

    c. Please provide a justification for the monitoring well screen lengths. Ch. 405 (5)(A)(8) states that screens for monitoring wells must not exceed 10 feet in length, yet four of the bedrock wells have 20-foot screens.

Response: The four bedrock wells are the only wells with screens greater than 10 feet. Golder constructed the bedrock wells with 20-foot long wells screens for the reasons described below. The bedrock wells were designed with 20-foot long wells screens based on site specific characteristics to ensure that:

- *the screened intervals intersected enough fractures such that the wells produce sufficient water for slug testing and water quality monitoring*
- *the potentiometric surface is representative of the shallow bedrock formation and not just isolated fractures*

The necessity of the longer well screens is highlighted by the slug testing results for the bedrock wells. Two of the four wells have slug testing results in the low to mid-1.0E10-6 cm/sec range. If these wells were constructed with shorter wells screens, they likely would not be capable of producing sufficient water for sampling. It is Golder's opinion that the construction of the bedrock wells is appropriate for the site-specific conditions, meets the needs objectives of the installations, and is consistent with Ch. 405 (5)(A)(8), which allows for lengths other than 10 feet to meet site-specific needs.
Follow-on Comment: It is unclear what site-specific conditions Golder referring to. They did not know the hydraulic conductivity until after the screens were installed and it doesn't justify the other two wells. They have not presented any site-specific characteristics such as fracture or geophysical evidence to support the need for 20-foot screens. There are no notes in the well logs that indicate a water-bearing fracture was encountered and well recovery rates are not presented. It is unclear how the locations for the screens were identified. Golder did not present sufficient site-specific characteristics to warrant the installation of 20-foot screens. We recommend abandoning these bedrock wells after the pumping test is completed. See Comment 29 for further discussion of bedrock wells. No response is necessary.

d. **Response acceptable**.

5. **Response acceptable**.
6. **Response acceptable**.
7. **Response acceptable**.
8. **Response acceptable.**
9. **Response acceptable.**
10. 4.3 Glacial Till, last paragraph, Figure 8b. The till thickness does not equal the difference between the top of till surface and the top of bedrock at some locations, such as MW14-01B, MW14-04B, and MW14-05D, so please check the thickness values used to create the isopach maps and correct the maps if needed.
Response: Golder has reviewed the isopach thickness and surface contour maps. The till thickness listed at MW14-01B is in error. The till thickness at MW14-04B and MW14-05D are correct. An updated Glacial Till Isopach map (Figure 8b) is included as Attachment A to this memorandum.
Follow-on Comment: Thank you for correcting the MW14-01B data on Figure 8b, but we are still confused about MW14-05D, which shows till from 26 ft to 46.6 ft on the well log. This would be a till thickness of 20.6 ft, but Figure 8b shows a thickness of 22.2 ft. Are we misinterpreting the logs?

11. **Response acceptable.**

12. 5.0 Site Hydrogeology,

a. First bullet. Please present the evidence that the water in the silty fine sand is perched.
Response: Water within the silty fine sand was characterized as being perched because the sand is underlain by the much lower permeability Presumpscot Clays which isolate phreatic water in the sand over the clay from groundwater in the till and bedrock groundwater under the clay. The term perched is also applicable because areas of sand saturation are disconnected and in some cases are only seasonally saturated. The degree of hydraulic isolation is evidenced by the very high gradients across the clay, sometimes greater than 1.0 (see response to Comment 16, below).
Follow-on Comment: MEDEP affirms that the water in the sand could be perched, but in order to confirm that it is perched, one needs evidence of unsaturated soil under the saturated soil. The high hydraulic gradients across the clay indicate that this is an aquitard but does not confirm that the water above it is perched. No response necessary.

b. Second bullet. Please present the evidence that the heads in the till are artesian.
Response: The term "artesian" is used to indicate that the potentiometric level in the till is above the top of the till (top of the "aquifer"). As discussed in the response to Comment 12c below, the groundwater in the till is confined, and the potentiometric surface is above the top of the till, and therefore by definition1, the heads are described as being artesian.
Follow-on Comment: MEDEP concurs that the heads in the till are probably artesian. In order to confirm that they are artesian, one needs evidence that the water is under pressure and the overlying unit is confining. In reviewing boring logs from the 1992 investigation, we recently came across several notes that artesian pressure was encountered when transitioning from the clay to the till. This is the type of evidence for artesian conditions in the till that we were asking for. No response necessary.

c. Third bullet. Please present the evidence that the till is confined.
Response: Hydrostratigraphic units are commonly defined as being unconfined when the water table defines the top of the hydrostratigraphic unit and confined when the elevation of the potentiometric surface is higher than the physical top of the hydrostratigraphic unit. The till is overlain by the much lower permeability Presumpscot clays, which hydraulically confine the till. The figure presented in Attachment B illustrates the potentiometric level in the till (Figure 13b from Volume III) superimposed on the top of the till (i.e., bottom of clay) surface (Figure 8b from Volume III). Comparison of these two surfaces shows that the potentiometric surface in the till is above the top of the till surface at all locations except one (PZ-7D), indicating that the potentiometric surface in the till is confined beneath the clay.
Follow-on Comment: MEDEP concurs that the till is probably confined given the presence of an aquitard and the evidence for artesian conditions in the till at other phases at the Crossroads Landfill. No response necessary.

d. **Response acceptable.**

13. 5.1.1.2 Phreatic Surface.
    a. **Response acceptable.**
    b. **Response acceptable.**
    c. **Response acceptable**
14. 5.1.1.3 Glacial Till,
    a. **Response acceptable**.
    b. **Response acceptable.**
    c. **Response acceptable**.
15. 5.1.1.4 Bedrock,
    a. First paragraph.
        i. **Response acceptable.**
        ii. There are only four data points in Figure 14a that were used to generate the equipotential lines. In our opinion, the northward curve on the west side is unsupported by the data from the four data points. Please provide an explanation for the strong curvature to the lines in the western part of the map.

            Response: The northward curvature of the bedrock potentiometric surface on the west side of Phase 14 is driven by the water level measured in bedrock monitoring well 617C east of ASB shown on Figure 14b. The northward curvature is also consistent with the regional topography and the location of regional groundwater divides as depicted on Figure 14C.

            MEDEP does not concur with the northward curvature in Figure 14C. See Comment 15bii. No response necessary.

    b. Second paragraph. This paragraph states that the bedrock is primarily recharged from the north-northeast.
        i. The modeled bedrock potentiometric surface from the 1992 modeling efforts show that groundwater in the Phase 14 area comes from the north-northwest. Please explain why the model does not agree with this paragraph and evaluate whether the model needs to be redone based on a revised conceptual site model.

            Response: The bedrock potentiometric surface illustrated on Figures 14a, 14b, and 14c is based on head measurements collected from bedrock wells installed in the immediate area of Phase 14. These data were not available at the time of Gerber's model development in 1992. While the Gerber model does illustrate upgradient flow from a more northerly direction, the modeled potentiometric flow pattern beneath and downgradient of Phase 14 are remarkedly consistent with the interpreted potentiometric contours illustrated in Figures 14a, 14b, and 14c, particularly given the difference in datasets available at the time to calibrate the model and the datasets used to develop the Phase 14 potentiometric figures.

            Results of Gerber's numerical modeling were used to corroborate the analytical time-of-travel calculations as presented in Section 6.4. Given the consistency of the model with conditions beneath and downgradient of Phase 14, the results of the groundwater

modeling are appropriate for use to support the time-of-travel calculations presented in the Phase 14 application.
Follow-on Comment. MEDEP concurs that the bedrock groundwater flow direction is similar in the model as measured in the field. We note that the model results are very simplistic near the Phase 14 area because the input was simplistic outside the area the model was designed to model. We are interested in the statement that the model results were used to corroborate the time-of-travel estimations. Would you please elaborate on how this was done? Did you use the output of the model with a particle-tracking model? Did you compare the output heads with the measured heads in the Phase 14 area?

ii. MEDEP does not concur that Figure 14b is an accurate representation of the potentiometric surface of the bedrock groundwater. This figure shows a curve in the contour lines that bend up around 310D and 617C. These two wells have screen depths of 172-184 and 150-199.5 ft, respectively, which are significantly deeper than the new Phase 14 bedrock wells which have screen depths varying from 36 to 92 ft. Because these two wells are measuring groundwater potential much deeper in the aquifer, they should not be used with wells of shallower depth in potentiometric maps. Also, there are several elevations on Figure 14b that don't match up with the equipotential lines, such as the Gerber pumping test locations, and were obviously not used in generating the lines. Please clearly identify data on equipotential maps that are not used in generating them. Also, it's not clear if 627A and 628A were used in generating this map. Please provide the screen depths of 627A and 628A and other wells which were used to generate these equipotential lines.

Response: As described in response to Comment 15.a.ii, the potentiometric surface depicted in Figure 14b was developed to be consistent with the regional topography and the location of regional groundwater divides as depicted on Figure 14C. While it is recognized that the screen depths for 310D and 617C are deeper than the bedrock wells at Phase 14, we believe it is appropriate to use water levels from these for interpretation of the bedrock potentiometric surface at the site-wide scale. Vertical gradients in the bedrock are weak so any error introduced by the differing screened intervals would be limited, particularly at the site-wide scale. Lastly, we note that water levels from 310D and 617C have long been used to develop site-wide bedrock potentiometric contours at the Crossroads facility. The water level elevations obtained from these wells are consistent with the interpretation of regional bedrock flow conditions and yield horizontal hydraulic gradients consistent with those elsewhere at the Crossroads facility.
MEDEP is correct that some of the elevations depicted on Figure 14B were not used for contouring. The elevations at the wells listed as "Gerber Bedrock Pumping Wells" were an inadvertent editorial addition to the figure and are not water levels.
Data from wells 627A and 628A were not used for contouring however, the data are provided to illustrate bedrock head values near to the south of Phase 10. Well screen/open intervals for wells outside of Phase 14 used to generate Figure 14b are summarized in the following table. [omitted]

Follow-on Comment: MEDEP appreciates the clarification of the elevations used in creating Figure 14b. However, we disagree that the vertical gradient can be ignored at 310D and 617C. The distortion in the potentiometric surface in Figure 14b near 310D and 17C indicate that the heads from those two wells may be anomalous. The most logical explanation for this distortion is that we are measuring deeper equipotential lines at those two wells because the well screens are much deeper than at the other wells. There may be insufficient bedrock wells with compatible screen depths to accurately map groundwater heads in the bedrock across the entire area of Figure 14b. No response necessary.

16. 5.1.2 Vertical Hydraulic Gradients, last paragraph. "…vertical groundwater flow through the Presumpscot clays is negligible due to the very low vertical hydraulic conductivity of the clays, which precludes recharge of the underlying glacial till and bedrock through the clays in the immediate area of Phase 14." MEDEP does not concur with this statement. Due to the low hydraulic conductivity, the flow of water through aquitards such as the Presumpscot Formation would be primarily vertical rather than horizontal, although the flow would be very slow in the absence of fractures. In the presence of fractures in the clay downward flow would be very rapid, so there may be areas where the till is recharged through the clay. For more information, please see K.R. Bradbury et al., 2006, Contaminant Transport Through Aquitard: Technical Guidance for Aquitard Assessment, AWWA Research Foundation.

    Response: Golder agrees with MEDEP that the primary flow direction through the aquitard would be vertical, and never stated otherwise. However, the fact that strong vertical gradients exist across the clays is evidence of the very low vertical hydraulic conductivity of the clay. If there was significant flow across the clay, heads between the clay and till would equilibrate, and vertical gradients would be low, as observed between the till and bedrock (see response to Comment 15). See response to Comments 17a and 17b regarding the potential for fractures in the clay.
    Follow-on Comment: MEDEP appreciates the clarification on flow direction. We would like to clarify that we are more concerned about flow across the clay than through it. We concur that flow through unfractured clay will be slow, as we stated, but the presence of fractures could result in rapid transport across it. Significant flow across the clay through fractures might not involve water from within the clay, so heads within the clay wouldn't equilibrate with heads in the till. No response necessary.

17. 5.2.2 Presumpscot Formation.
    a. Third paragraph. "…consistent with the finding that post-depositional features such as desiccation fissures, disruption by roots, frost fracturing, and expansion fracturing were infrequently observed…" Please address our concern that these were infrequently noted rather than infrequently observed. We noticed that no descriptions of the clay included anything other than color, stiffness, moistness, except for the descriptions of PZ-1 through PZ-5 which mentioned red mottling and partings. We also noted that these five borings were logged by STD (who also logged PZ-6), but other people logged the other borings, which only described color, stiffness and moistness. Is it possible a lack of post-depositional features was because they were not noted in the boring logs by the other loggers?

Response: MEDEP's comment implies that lithologic descriptions of the clays by STD differ significantly from those by others, and that STD's descriptions include descriptions of post-depositional features such as desiccation fissures, disruption by roots, frost fracturing, and expansion fracturing. STD did not record any observations of post-depositional features such as desiccation features, roots, frost fracturing and expansion fracturing. The only difference between STD's lithologic descriptions of the Presumpscot clay and those by others is STD's occasional descriptions of "minor" and "some" red/orange mottling in the upper most portion of the clay. STD also describes "minor silt partings" near the contact between the stiff upper clay and soft lower clay in one of the six borings he logged (PZ-4S), where the total clay thickness is approximately 15 feet. Silt partings are not post-depositional features.

None of the post-depositional features listed by MEDEP (desiccation fissures, disruption by roots, frost fracturing, and expansion fracturing) were observed by any of the trained professionals (both Golder employees and Geosyntec employees) who logged the boreholes during the Phase 14 field investigations.

The geologic history of the Phase 14 area includes the deposition of the silty fine sands, and thus the Presumpscot clay in the Phase 14 area may not have been exposed to the ground surface/atmosphere for long periods of time and subject to significant post-depositional features like has been observed elsewhere. The lack of evidence of post-depositional features visual to the field staff during the boring investigation and engineers and/or hydrogeologists who post-processed the samples to validate the boring logs for Phase 14 clays corroborates that these features were not observed. The observation and description of "minor silt partings" in one boring logged by STD and the absence of documentation of other post-depositional features indicates they were not found at the location.

Follow-on Comment: In this response, Golder states that desiccation fissures, disruption by roots, frost fracturing, and expansion fracturing were not observed, yet a 2015 paper by Luettich, et al., described the upper clay at the Crossroads Landfill as often exhibiting "a wide range of post-depositional features such as desiccation fissures, disruption by roots, frost fracturing, and expansion fracturing." In the 1992 investigation, almost all of the borings (B-305, B-1001 to B-1044, B-103, B-310, B-614, B-615, B-617, B-618, B-620) described the stiff olive clayey silt as mottled, fissured, containing roots and sand seams and the soft gray clayey silt as having sand seams. The test pits logs (31) describe the stiff clay as mottled, fractured, containing roots, sand seams. We examined the photographs of the GB borings, which were the only images provided, and noticed that there were features, such as gray clay mottled with green or brown areas, sandy lenses, and apparent fractures, in the upper stiff clay, but these features were not described in the boring logs. Some examples of images that show features that are not described are GB7-13'-15, GB13-11'-13'(2), GB15-3'-7', GB17-7'-9', PZ-5M-9'-11'. etc. This reinforces our concern that the descriptions of the borings for which we don't have photographs may be missing some information.

Not all the 1992 test pits encountered the soft clay, but when they did, it is described as generally featureless, but 12 of them described sand layers or seams and a couple

describes the presence of vesicles, polygonal fractures or fissures. After a depth of approximately 15 feet, very few features are described in the gray till. Unfortunately, we don't have the boring or test pit logs for Phases 11 and 12.

Please explain why the upper stiff and lower soft clay units at other phases at the Crossroads Landfill exhibit features that aren't seen at Phase 14, 2500 feet away.

b. Fifth paragraph. MEDEP requests a pumping test in the Phase 14 area to assess the vertical hydraulic conductivity. The estimates of vertical hydraulic conductivity were based on laboratory measurements, hence, the differences in hydraulic conductivity between the field-measured slug test results and the laboratory tests is more likely due to the difference in the testing methods rather than a difference in the horizontal or vertical hydraulic conductivity. Because of the possibility of undetected fractures in the clay can allow rapid transport of contaminants to aquifers beneath the clay, it is important to have a good estimate of the vertical hydraulic conductivity. The 1991 and 1992 pumping tests provided vertical hydraulic conductivity estimates in a more reliable method than the laboratory test, but they tested the soft gray clay only and not the stiff brown clay. The soft clay tested at the other phases varied from 21.5 to 78 feet thick, much greater than the 0 to 17.2 feet thickness within the footprint at Phase 14. The fact that the clay is much thinner at Phase 14 and that the gray clay is missing over about ¼ of the landfill footprint would warrant another pumping test in the Phase 14 area to assess potential fracturing and the vertical hydraulic conductivity in the stiff clay. It is recommended that multilevel monitoring equipment be installed within aquitards (K.R. Bradbury et al., 2006), with piezometers near the changes in lithology, not in the center of units, to evaluate them properly, so they may need to evaluate the need for installing more piezometers with properly short screens. Please send a detailed plan for conducting a pumping test at Phase 14. We recommend pumping the till aquifer and monitoring wells and piezometers in the till and clay.

Response: Golder disagrees that "the differences in hydraulic conductivity between the field-measured slug test results and the laboratory tests is more likely due to the difference in the testing methods rather than a difference in the horizontal or vertical hydraulic conductivity". In the documents referenced by MEDEP (K.R. Bradbury et al., 2006), the "operating principal" for conducting slug tests in aquitards is described as follows:

"The single-well displacement "slug" test is a simple technique for estimating Kh [horizontal hydraulic conductivity] in the field using wells or piezometers. By measuring the response of a well or piezometer to a rapid pulse, the investigator estimates Kh around the well screen or piezometer tip"

Further, K.R. Bradbury et al., 2006 states that:

"Due to the stratified nature of geologic materials, the horizontal hydraulic conductivity is typically higher than the vertical conductivity by one or more orders of magnitude."

Golder maintains that differences between the field-measured slug test results and the laboratory tests is primarily due to the difference in the horizontal and vertical hydraulic conductivity of the clay and that the results of both testing methods are appropriately representative of the materials tested.

As has been discussed with MEDEP, Golder does not share the Department's concern regarding "the possibility that undetected fractures in the clay can allow rapid transport of contaminants to aquifers beneath the clay" for the following reasons:

- *Field and laboratory investigations did not find evidence of vertical micro-fractures or desiccation cracks.*
- *In-situ hydraulic conductivity tests were completed at eight locations, and no test indicated rapid transport.*
- *Laboratory permeameter tests of the clay did not indicate rapid transport.*
- *The Presumpscot Formation in the Phase 14 area is overlain by both fill and native fine silty sand. The lower few feet of the silty fine sand correspond to the groundwater level and supports the observations as documented on the boring logs that both the upper stiff and lower soft clay facies are moist or saturated. In the moist climate of New England, cracks and micro-fractures would typically only propagate within a freeze-thaw zone above the water table. Our analysis of the boring, CPT, and piezometer locations with respect to the present-day water table and a conservative frost-penetration depth of 6 feet bgs of (ignoring fill) shows no evidence that the lower soft clay would have been subject to frost effects. Likewise, any macro-features caused by frost in the upper stiff clay would have occurred only above the water table.*
- *As stated in the response to comment 16, the fact that strong vertical gradients exist across the clays strongly supports the conclusion of very low vertical hydraulic conductivity of the clay. If there was significant flow across the clay, heads between the clay and till would equilibrate, and vertical gradients would be low.*

Regardless, as has been discussed with MEDEP, WMDSM has agreed to conduct a groundwater pumping test to evaluate the bulk vertical hydraulic conductivity of the Presumpscot clay. MEDEP has agreed that existing wells and piezometers are adequate for conducting and monitoring the pumping test. A Work Plan for conducting the pumping test was submitted to the MEDEP on May 29, 2020 and the test will be conducted in June 20202. Results of the pumping test will be presented as a supplementary submittal to Volume III, Geologic and Hydrogeologic Assessment, of the Phase 14 Solid Waste Permit Application.

Follow-on Comment: We are pleased that WMDSM has agreed to conduct a pumping test and to install two new monitoring wells in the clay, but we want to respond to several points they made in their response:

Golder disagrees that the difference in the result of the laboratory test and the field test is related to scale or methodology, but thinks it is mostly due to the difference in vertical and horizontal hydraulic conductivity. Not only do we disagree with them, but the former Crossroads consultant for the 1987, 1992, and 1996 investigations, R.G. Gerber Inc, disagreed. Holland and Tolman (1987) (https://umaine.edu/presumpscot-symposium/wp-content/uploads/sites/425/2015/04/holland-1987-presumpscot.pdf) state, "We have

concluded that a representative measurement of permeability in samples of fissured clays or silts cannot be obtained without first obtaining a representative sample of the fissures as they exist in the field. Even alleged 'undisturbed' sampling techniques currently in use for conventional drilling projects cause sidewall trauma to the sample, and undoubtedly reduce the aperture of the fissures.", and, "Because of the pronounced vertical prismatic structure of the deposit, the in situ vertical permeability is higher than the lateral permeability, a feature which distinguishes it markedly from the underlying unweathered gray Presumpscot clay/silt." And when referring to the soft, gray clay, "…at field scale where the presence of sand laminae appears to exert a greater influence than at laboratory scale, expect the clay to behave anisotropically with vertical permeability 10 times less than horizontal permeability on average."

Laboratory permeameter tests of soil cores provide estimates of the bulk hydraulic conductivity of a section of core (2.5 to 3.5 inches long and less than 3 inches in diameter) that is at a much smaller scale than an in-situ slug test or pumping test. The larger the scale of the test, the more likely fractures or large-scale sandy zones will be encountered. To quote Bradbury et al., 2006:

"One of the major issues in most investigations of aquitard integrity is the determination of whether or not fractures are an important feature. The measurements of physical properties of core samples does not accomplish this determination on its own because the probability of any of the cores having active fractures is small. Fractures generally occur at a spatial scale (i.e., spacing) that is large relative to core size. Therefore, to address the issue of fractures, and to make major use of the core data, field tests using boreholes and wells must also be conducted."

This is also supported by Smith et al., 2016 (https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2015WR018448), which states, "While laboratory test can provide an approximate range of small-scale K, they cannot be used to assess the impact of heterogeneity or secondary features such as fractures."

MEDEP is not persuaded by their lack of concern that "the possibility that undetected fractures in the clay can allow rapid transport of contaminants to aquifers beneath the clay". MEDEP shares the opinion of Bradbury et al (2006) who state: "In reality, flow and transport through aquitards is often dominated by heterogeneities such as fractures, macropores, or sand seams" and "Depending on the contaminant of interest, it may be appropriate to assume an aquitard has through-going fractures until field evidence shows otherwise." The following is our rebuttal to their assertions:

- **They claim that they did not find vertical fractures in this investigation, but in the 1992 investigation of neighboring and contiguous clay units, every test pit and almost every boring showed vertical and horizontal fissures, vesicles, sandy layers and seams. In a paper for the 2015 Symposium on the Presumpscot Formation in**

Portland Maine, Luettich et al. (https://umaine.edu/presumpscot-symposium/wp-content/uploads/sites/425/2015/10/Luettich_etal_2015_Presumpscot.pdf) describe the upper olive-brown clay unit as exhibiting "a wide range of post-depositional features such as desiccation fissures, disruption by roots, frost fracturing, and expansion fracturing." The likelihood of intercepting vertical fractures with vertical, 2-inch borings is very small and could explain why they did not encounter fractures.

- **Short-term slug tests within units are unlikely to show transport across units. To quote Holland and Tolman (1987), "We believe that conventional cased drilling techniques render even in-situ permeability tests in fissured clay invalid, again because of damage to the secondary structure." Also, small fractures that would allow the transport of contamination may not**
- **Laboratory permeameter tests only test bulk properties and the likelihood of encountering a fracture in a small piece of clay is tiny. See our comments above regarding permeameter tests.**
- **They claim that freeze-thaw fractures would only occur above the water table, which would be in the sand or fill. This may be true, but the fact is that polygonal fissures were described in the stiff clay in every test pit in the 1992 investigation, and, although rare, fractures were described in the gray clay to depths of 15 feet.**

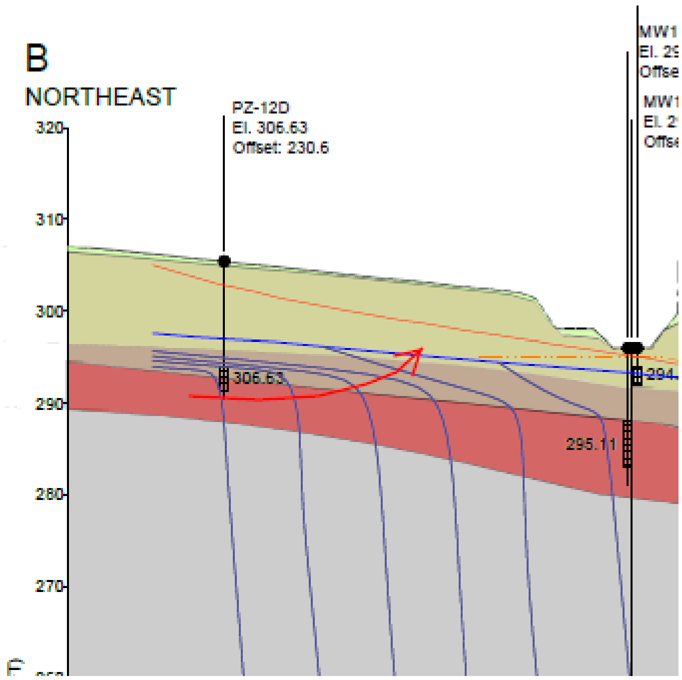
In summary, there is abundant evidence that the stiff clay at the Crossroads landfill contains fissures/fractures, sand seams, vesicles, and mottling. Based on Holland and Tolman's previous work at the site and our knowledge of the differences between laboratory permeameter tests and field-scale test, we find that the vertical hydraulic conductivity results from the permeameter tests are probably inaccurate and should not be used for time of travel estimations. No response necessary.

18. 5.3 Hydrostratigraphic Cross-Section. Water in the till to the NE appears to flow upward, discharging to the sand in an uphill area. Because there is no surface water body there, this representation is probably inaccurate. See diagram below. Please redo the cross-section.

    Response: As described in response to Comments 12B and 12C, the groundwater in the till is confined, and the potentiometric surface is above the top of the till. In some areas on the north side of Phase 14, the heads in the till are above the top of the Presumpscot Clay, indicating an upward gradient from the till to the overlying sand. Like the situation where strong downward vertical gradients are present across the clay aquitard, the upward gradients observed on the north side of Phase 14 confirm the confining nature of the Presumpscot clay. While upward gradients exist on the north side of Phase 14, the volume of water that migrates through the clay is considered negligible. The transition from upward gradients on the north side of Phase 14 to downward gradients on the south side or Phase 14 is consistent with the conceptual hydrogeologic model presented in Section 5.3. Therefore, no changes to the hydrostratigraphic crosssection are necessary.

    Follow-on Comment: MEDEP does not concur that upward gradients at MW14-01 on the north side of Phase 14 indicate confining conditions. One can get upward or downward flow across confining aquitards. Upward flow indicates a discharge zone and downward flow indicates a recharge zone. At MW14-01, we note that the gradient

between the sand and the till wells is typically downward for most dates when it was measured, but it was upward on the date chosen for the cross-section (5/2/2019). The heads in the bedrock well are consistently higher that in the till well, which may indicate the screen in the bedrock intersects a fracture that is directly connected to an area farther upgradient. We do not concur that there is a discharge zone around upgradient well MW14-01. No response necessary.



19. **Response acceptable**.
20. **Response acceptable**.
21. **Response acceptable**.
22. 6.2 Potential Pathways, fourth bullet. We do not agree with the conceptual model for this pathway. This pathway assumes horizontal migration through the stiff upper clay, but due to the low hydraulic conductivity, transport through aquitards is typically vertical, not horizontal. The aquitard is thin in Pathway 1, which increases the probability of fractures which allows for rapid transport through the aquitard to the underlying till. The gradient is downward at S-4 which indicates that phreatic water doesn't discharge there. Consider a vertical path through the clay, then a horizontal path through the till. This would have a different flow path to a discharge point, but it might be more realistic. Also, consider a short-circuited path through the clay through fractures and how that would impact the time of travel.

    Response: Golder agrees that a purely horizontal pathway through the clay is unlikely at this location. However, Golder took the conservative approach of evaluating this pathway to evaluate time-of-travel to the two intermittent Class B streams located downgradient of Phase 14. Class B streams are identified as potential sensitive receptors.

The vertical pathway through the clay into the till is evaluated in WMDSM's "Pathway 3" evaluation. This pathway terminates at the downgradient water supply well, which is the closest sensitive receptor for the till pathway. The till unit does not discharge to Class B steams in the vicinity of Phase 14.
Follow-on Comment: MEDEP disagrees that a pathway horizontally though the clay (instead of vertical through the clay then horizontal through the till) is a conservative approach. To demonstrate, we calculated the time of travel assuming a 10-ft downward vertical path through the clay, an 800-ft horizontal path through the till (assuming it had to travel further to discharge, then back up through 10 feet of clay (a rough estimate), using the geometric mean K values used in Golder's calculation. Our calculation resulted in 55 years instead of 637 years that Golder estimated, which shows that Golder's approach is not conservative.

Our estimation shows that, if the clay and till at this location have the average K values, then the travel time exceeds the required travel time of 6 years, but if the clay and till at this location have the maximum K values, then the travel time would be 2.25 years, which is short of the required 6 years. No response necessary.

23. 6.2 Potential Pathways, fifth bullet. See Comment 22 and consider a vertical path through the clay, then a horizontal path through the till to the stream and assess how the presence of fractures would impact the time of travel.

    Response: See response to Comment 22. Groundwater in the till does not discharge to the nearby streams. As MEDEP has identified, vertical gradients across the clay in this area of the site are downward, precluding the upward flow of groundwater from the till to the streams. Golder does evaluate a vertical pathway through the clay into the till as part of "Pathway 3". The closest potential sensitive receptor along this pathway is the "New Office Well".
    Follow-on Comment: We are disappointed that WMDSM did not comply with our request, but we have estimated the requested time of travel ourselves. Assuming a downward vertical path through the clay of 14 feet, a horizontal path through the till of 1000 feet (assuming it would take longer to reach a discharge point in the stream), an upward vertical path through clay of 14 feet (rough estimate), and using the geometric mean K values, we estimated a travel time of 79 years. As with pathway 1 (Comment 22), the longer pathway, but with most of it through the till, results in a much shorter travel time. Assuming the K values are the maximum values, the travel time would be 3.24 years. No response necessary.
24. **Response acceptable.**
25. **Response acceptable.**
26. 6.4 Time of Travel Results. We do not agree with using the mean values of hydraulic conductivity (K) for assessing time of travel. We are interested in worse-case scenarios, so the highest K values are more appropriate. Please present a range of travel times based on the range of K values.

    Response: It is Golder's opinion that using average values for parameters such as hydraulic conductivity is appropriate because they more accurately reflect the range of hydraulic *conductivities that exist over an extended pathway. Nonetheless, as discussed with the Department, Golder will conduct a sensitivity analyses of the time-of-travel input parameters (e.g., hydraulic conductivity, gradient, porosity) to provide a range of potential travel times based on a range of hydraulic conductivity. The sensitivity analysis will be included in the supplemental submittal.*

Follow-on Comment: Golder has agreed to a sensitivity analysis but has not described what that would entail. Please let us know what ranges will be used.

27. **Response acceptable.**
28. **Response acceptable.**
29. 7.1 Proposed Groundwater Water Quality Monitoring Program, first paragraph. Ch. 405 (2)(A)(1)(b) requires that each hydrogeologic unit is monitored, yet no bedrock wells are selected as monitoring wells. Please provide locations for at least two bedrock monitoring wells and demonstrate that water released from the landfill would be intersected by these wells.

    Response: Any release from the landfill would be detected in the till before being detected in the bedrock. Also, as discussed in Response to Comment 12d, vertical gradients between the till and the bedrock are directionally variable and weak. Given these conditions, it would take a very long time, if ever, for a release from the landfill to be detected in the bedrock. As such, Golder did not include monitoring of bedrock in the water quality monitoring program and maintains that bedrock water quality monitoring is not necessary. Nonetheless, the existing bedrock monitoring wells will be maintained. If a release were to be detected or suspected based on monitoring results from the phreatic wells and/or the till wells, monitoring of bedrock water quality can be conducted.

    Follow-on Comment: MEDEP agrees that given their location, it is unlikely the current bedrock wells will intercept groundwater coming from Phase 14. A groundwater model would answer this better, but we estimate that a bedrock well 50-100 feet away from the landfill would be better situated to intercept groundwater flowing from the landfill. We also agree that the till wells would be the first line of defense and it wouldn't be necessary to sample bedrock wells unless a problem arises in the till wells. We would, however, need background data on the water quality at any well prior to the deposition of the waste in the landfill, so bedrock wells should be installed and sampled prior to that. We recommend obtaining at least 8 rounds of data at the bedrock wells, after which time the bedrock wells would not need to be sampled unless the till wells indicate a possible release. This should provide sufficient data for comparison to any later monitoring results.

    Again, Ch. 405 (2)(A)(1)(b) requires that each hydrogeologic unit is monitored. Please provide locations for at least two new down-gradient bedrock monitoring wells and demonstrate that water released from the landfill would be intersected by these wells. Also, provide a plan to sample all the wells established to monitor Phase 14 before waste placement. The other bedrock wells should be abandoned in accordance with the rules.

30. 7.1 Proposed Groundwater Water Quality Monitoring Program, last paragraph. We recommend completing two years of three sampling rounds, which would provide a better understanding of the natural data variability at the site. Four sampling rounds are proposed

for the site characterization monitoring, but Ch. 405 (2)(C) states that the actual number of samples required depends on the rate of groundwater flow, data quality and variability of results, so this may need to be adjusted.
Response: It is Golder's opinion that four characterization monitoring events is typical and adequate and requests additional information regarding the basis for this request.
Follow-on Comment: As we said, the actual number of samples depend on the data and its variability, so this may need to be adjusted when the results come in. We recommend starting to sample as soon as possible.

31. **Response acceptable**.
32. **Response acceptable**.
33. **Response acceptable**.