St Georges River Data Report

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Introduction

The St Georges River (Georges River) is located in the central coastal area of Maine in Knox and Waldo counties. The drainage area of the Georges River is 182 square miles in Warren and 258 square miles at its mouth. The area of interest is a ten-mile tidal segment that originates at head of tide in Warren and ends in Cushing near Fort Point. The classification of the river here is SB requiring minimum dissolved oxygen criteria of 85% of saturation.

The proposal to build a new state prison facility that would tie in to the Warren WWTP has initiated this study to assure that any increased loading of pollutants to the estuary still result in maintaining dissolved oxygen criteria. A DEP study began in the spring of 1999 involving various stakeholders of the St. Georges River such as the Warren S.D., Georges River Tidewater Association, Thomaston PCD, DMR, and Woodard and Curran. The purpose of this study is twofold. First updated information is needed to determine whether or not the existing water quality presently meets class SB dissolved oxygen criteria. Older data taken by DEP in 1990 and 1993 is available and indicated that non-attainment of dissolved oxygen criteria occurred during that time period. Second, if non-attainment is measured, the contribution of various sources of pollution to dissolved oxygen depletion in the estuary must be determined and possible cleanup plans developed. A work plan for the water quality monitoring was developed in June of 1999 by DEP with input from the stakeholders. This data will be used to develop a water quality model that will mathematically simulate the dissolved oxygen and other chemical parameters

A very ambitious water quality sampling effort was planned for the summer of 1999. An extended drought occurred during the sampling period resulting in conditions under which we were able to measure water quality under “worse case” conditions. This resulted in sampling under minimum dilution of pollutants, and a longer estuary flushing time, both under which the minimum dissolved oxygen readings are most likely to occur. The requirement specified in the work plan of having no significant runoff prior and during the surveys was always met. Sampling under runoff conditions results in unsteady flow and variable input load conditions that would be difficult to quantify. Both would make the model calibration more difficult.

Technical Design of Study

The technical design of the study is explained in detail in the St Georges Work Plan. Some of the highlights are repeated here for convenience. The study involves three separate independent sampling surveys each consisting of four consecutive days of sampling and with the Warren S.D. discharge controlled to defined conditions. A summary of intensive survey conditions is as follows:

Table 1 Summary Information For Intensive Surveys

Survey	Dates	Discharge Condition Warren S.D.	Effluent Flow (gpd)	Effl. Flow % License	Ave Tidal Prism (ft) at Thomaston	Runoff	Tributary Flow
1	July 20 - 23	Zero	0	0%	7.9	None	Drought
2	Aug. 3 - 6	Normal	66300	43.9%	10.0	None	Drought
3	Aug. 16 - 20	Full Licensed	141800	93.9%	8.0	None	Drought

In addition, two individual one-day surveys were scheduled for June 29 and Sept 17. These data will primarily be used for assessment of attainment / non-attainment of dissolved oxygen criteria, the trophic state of the estuary, and provide nutrient information that together with the other data are intended to cover conditions seasonally over an entire summer. The Sept 17 data were not collected due to a substantial rain event from tropical depression Floyd.

The original plan for sampling as discussed in the Work Plan was as follows:

"The three-day intensive data sets in August, taken when the Warren S. D. is discharging will involve sampling dissolved oxygen, temperature, and salinity at low and high tides at eight locations in the Georges River estuary. The Warren S. D. discharge, upstream boundary at Payson Park (just north of route 90 crossing) and four tributary sites will be sampled one day prior to the three day intensive survey, since the water quality measured in the estuary is due to load inputs from the previous day. Chlorophyll a, nitrogen series (TKN, NH3-N, NO2+NO3-N), phosphorus series (total phosphorus and PO4-P), and ultimate BOD will be measured at six locations. Four of these locations will be sampled at two locations in the vertical (top and bottom). In additional secchi depth will be measured in-between 9 AM to 3 PM in the tidal portion at eight locations once at both high and low tides. Fecal coliform sampling will be done at nine ambient locations. DMR has offered to do the analysis for this work.

The July intensive survey that is undertaken at zero discharge conditions involves a reduced sampling effort for chlorophyll a, nutrients, and BOD due to financial and laboratory constraints. Only the inputs (tributaries, landward and seaward boundaries) are sampled for these parameters. Dissolved oxygen, temperature, and salinity are still sampled at all locations.

The seaward boundary station at the Narrows is suppose to represent ocean water quality and for this reason is only being sampled at high tide conditions. Although it is two to three miles from open waters, water quality parameters collected at high tide here should not be much different from ocean conditions."

The actual sampling effort deviated slightly from this (see table 2 for a summary of sampling conditions and parameters). Additional funding was provided by the Warren S.D., so that the July data set under zero discharge conditions was also a complete sampling effort similar to the August data sets. Bottom samples were not always collected, due to a lack of depth and vertical density gradient, in particular at SGE7, the South Warren site at low tide. (The decision not to collect bottom samples was actually consistent with the work plan, since in the sampling procedures, it is explained that a bottom sample may not be collected when insufficient depth or lack of a significant vertical density gradient occurs.) In the first August data set (3-6), in addition to the surface low tide core samples, early AM surface core samples were collected at SGE 4,7,and 9 rather than the low tide bottom samples at these locations. The lower low tide experienced then would have resulted in not enough water depth to obtain the bottom samples and it was judged that the early AM samples should replace the bottom samples. In the third intensive survey, the bottom samples were collected at these locations on the 17th and 18th but dropped in favor of high tide samples at these locations on the 19th and 20th.

In the August data sets, samples at Mill Stream were only collected one day rather than the planned three days due to practically zero flow here. It was reasoned that sampling under these conditions would not be typical and obtaining a water column sample free from sediments could be difficult.

Flow was gaged at head of tide (SGE1a, Payson Park), and at each tributary site on the first day of each survey. In addition flow stage was recorded at Payson Park and the Oyster River fresh water site at the falls.

Sediment Oxygen Demand analysis was provided by USEPA at five sites (SGE 2,4,7,9,11) during the week of the second intensive survey (Aug 2 – 6).

The sampling procedures are explained in detail in the work plan and were followed throughout the summer. For specific details, one should consult the work plan (MDEP; Paul Mitnik, P.E.; June 1999).

Hydrologic and Tidal Conditions

As discussed earlier, low river flow conditions in tributary sources and the estuary's upstream boundary at head of tide in Payson Park (SGE1a) are the worse case conditions. Tributary flows were extremely low during all three intensive surveys. The flowing portions where tributaries were gaged (excluding stagnant portions) were typically limited to stream widths of one to two feet and depths of three inches or less. It is estimated that probably no runoff occurred during the entire sampling period (late June to August 20) and very little occurred in the late spring and early summer prior to the sampling period. Rainfall data provided by the Thomaston PCD indicates that rainfall for the sampling period was only about 36% of normal (table 3).

The tidal conditions typically desired for worse case conditions when the lowest dissolved oxygen readings occur are neap tide and early morning low tide occurring simultaneously. Neap tide is when the slowest flushing of the estuary occurs and early morning is when the lowest dissolved oxygen readings typically occur. The lack of a low neap tide occurring during early morning hours in the summer of 1999 at suitable sampling times (not evening or weekends) resulted in a compromise of the most desirable worse case parameters. Low tide was typically sampled in the late morning or early afternoon following an early morning high tide sampling run. The neap tidal prism elevation at Thomaston of 6.5 to 7 feet was approached in the first and third intensive data sets (7.9 and 8 feet, respectively) but about 50% higher than neap in the second intensive survey (10 feet) (table 4).

In addition to the available reported tidal data at Thomaston, tidal stage was measured at Warren village and South Warren to determine the extent of the tide in the upper portion of the estuary (table 4). These data indicate that about 65% and 90% of the tidal stage height at Thomaston were measured at Warren and South Warren, respectively during, the three intensive surveys.

Tidal velocity measurements were collected near the Warren S.D. outfall during a single tidal cycle on Sept 20. Measurements were taken at two locations located at approximately at one-third and two-thirds points in a transect of the tidal channel. A plot of the data shows that the measured tidal velocity ranged from a low of 0.5 fps to a high of 1.7 fps (figure 1). The data were taken after a significant rain event, tropical depression Floyd, and velocity measurements may have been influenced by significant runoff. Salinity measurements on this date ranged from a high of 26 ppt to a low of 5 ppt at high and low tide, respectively, and in comparison, ranged from 30 to 23 ppt during the intensive data sets. The lower salinity measurements would indicate that more fresh water was present in the estuary. Tidal velocity measurements at low tides would be the most influenced by this and would likely be somewhat higher than tides at lower flow conditions.

Ambient Estuarine Chemical Data

Ambient data collected for the intensive surveys included temperature, salinity, dissolved oxygen (DO.), secchi depth, fecal coliform (FC), total kjeldhal nitrogen (TKN), ammonia nitrogen (NH3-N), nitrite plus nitrate nitrogen (NO2+NO3-N); total phosphorus (TP), orthophosphorus (PO4-P), ultimate BOD (TBODu) (partitioned into both the carbonaceous (CBODu) and nitrogenous (NBODu) components), chlorophyll a (chla), and sediment oxygen demand (SOD). The dissolved oxygen, temperature, and salinity were collected at nine estuary locations twice daily (early AM and low tide). Secchi depth transparency was similarly collected at nine estuary locations at high and low tides once through the 3-day survey. Nitrogen, phosphorus, BODu, and chlorophyll a were sampled at five estuary locations, typically at low tide, except the ocean boundary (SGE20) which was sampled at high tide. Fecal coliform was sampled at 8 estuary sites in the early AM and low tide. In addition, all parameters were measured at the headwater boundary site at head of tide (Payson Park) and four tributaries sites. For details one should consult table 2.

The laboratory analysis for the majority of the samples was undertaken by the Health and Environmental Testing Laboratory of the Dept. Human Services in Auguata, Maine.

Temperature, Salinity and Dissolved Oxygen

All of the dissolved oxygen, temperature, and salinity data were taken collectively in one meter profiles on the upper estuary and in two meter profiles on the lower estuary. Portable YSI meters were used to collect this data. Rigorous quality control procedures were exercised to assure good data were collected that included the cross checking of meters prior to and after each sampling run and frequent field calibration checks. In addition, the meters were checked in the laboratory prior to a sampling event. For details, one should consult the QC section of this report.

Water temperature is an important parameter when considering worse case pollution conditions resulting in low dissolved oxygen. Higher water temperatures result in a decrease of the dissolved oxygen saturation value with increasing temperature, and the decay of organic material as BOD in the water column and SOD in the estuary bottom increases with increasing temperature. In addition, the growth of algae and development of undesirable nuisance blooms are more frequent with higher water temperatures. All of these factors typically result in the lowest dissolved oxygen readings occurring during high water temperature periods.

A review of the temperature data collected when comparing the three intensive surveys indicates temperatures did not change much at each location. The average temperatures for the three intensive surveys at each individual estuarine location did not deviate more than 2 ^{o}C (Figure 2). Temperature for the third intensive data set was typically 1^{o}C cooler than the first two intensive data sets.

When comparing the trend of temperature at different locations, the highest temperatures (23 ^{o}C to 25 ^{o}C) typically occurred at head of tide (Payson Park) and declined in the seaward direction to a low of 14 ^{o}C at the downstream boundary (narrows near Bird Point). Temperatures were typically above 20 ^{o}C from head of tide to the state Prison at Thomaston.

A review of the average salinity data also reveals that consistent readings occurred at each location when comparing all the data sets. Salinity measured in the estuary ranged from average low and high tide values of 17 and 19 ppt, respectively at the site one mile below Warren village (SGE2) to 23 and 29 ppt, respectively near the Warren S.D. outfall eventually reaching ocean values (30 ppt for both tides) just below the Thomaston boat landing (SGE13) (see figure 3).

Salinity values at each location vertically were consistently similar indicating a well-mixed system. At low tide there was sometimes one higher salinity reading near the bottom at the first two upper tidal stations (SGE2, SGE4), but this was generally limited to a narrow wedge estimated to be only about one foot thick in the water column (total low tide depth was 2 to 3 meters). This narrow salt wedge always disappeared at high tide due to tidal mixing and was therefore not stable. A more defined salt wedge was sometimes observed in the 1990 and 1993 data taken by DEP. It is deduced that the lack of this salinity stratification in the upper sample locations in the 1999 summer data was due to the much lower volume of fresh water flow entering the estuary as a result of the drought conditions.

The early morning dissolved oxygen readings were almost always lower than the late morning or early afternoon readings, regardless of tidal conditions, indicating that the respiration of algae could be a major source of dissolved oxygen depletion. The early morning dissolved oxygen data are plotted comparatively for each intensive survey at all individual sampling locations on the estuary as a minimum of all measured values (figure 4a) and average of all measured values (figure 4 b). The data reveal that class SB minimum dissolved oxygen criteria were not met in six of the nine locations in the estuary reaching a low of 75% of saturation. The non-attainment readings in the lower wider portion of the estuary (McCarthy Point, and Narrows) were generally limited to a single reading at one depth in the water column. The non-attainment readings at four sampling locations (1 mile south of Warren, ½ way down, S Warren, and near Warren S.D. outfall) in the upper narrower portion of the estuary were more prevalent and typically occurred at many depths on multiple sampling days.

When the difference between minimum dissolved oxygen readings of the first data set (July 21-23) are compared to the third data set August 17-19), it can be observed that readings for the latter data set were typically lower by 3% to 5% of saturation. A similar trend is observed when dissolved oxygen is plotted as a daily average (figure 4c).

The diurnal dissolved oxygen (difference of PM and AM dissolved oxygen) is a good indication of algae activity. When algae is prevalent in a system, the lowest dissolved oxygen readings typically occur in the early morning hours after a full evening of respiration, and the maximum dissolved oxygen readings in the late afternoon after extended daytime photosynthesis. A large difference in the AM and PM readings indicate algal activity. Without algal activity, the lowest dissolved oxygen readings in Maine estuaries are typically at low tide. In the sampling stations at and above the Warren S.D. outfall, the diurnal effect from algae dominates to the extent that the tidal effect is absent. (The lowest dissolved oxygen readings were in the early morning at conditions close to high tide rather than low tide in the late morning). The diurnal change in dissolved oxygen at these locations as a three day average ranged from 0.4 to 1.4 ppm and typically averaged 0.8 to 0.9 ppm (figure 4d) indicating slight to moderate algal activity. No consistent diurnal trend is evident when comparing data sets. In the lower estuary, a tidal effect of 0.2 to 0.4 ppm dissolved oxygen was typically evident.

The single day survey of June 29 resulted in the lowest dissolved oxygen readings of the summer. Percent saturation values in the low 70 percent range were recorded at all estuarine locations and included a single reading near the bottom of a station one mile below Warren village of 62% of saturation. These data were collected when low tide occurred in the early morning. However, dissolved oxygen readings for an unscheduled run on August 12 during an early morning low tide all exceeded 80% of saturation.

The tributary and upstream boundarydissolved oxygen data indicated that dissolved oxygen criteria were always met except at Mill River and Oyster River sites. The Mill River had one reading of 2.0 ppm and another of 4.1 ppm and several others lower than the required class B dissolved oxygen criteria of 7 ppm. The Oyster River tidal site was often in the 70's for percent saturation, which does not meet the required class SB dissolved oxygen criteria of 85% of saturation. The Oyster River fresh water site occasionally had dissolved oxygen readings that were 1% to 2% under the required class B criteria of 75% of saturation.

Fecal Coliform

Fecal Coliform was sampled twice daily at nine estuary locations and three tributary sites. The laboratory analysis for most of the sampling days was undertaken by the Dept. of Marine Resources who uses the multiple tube fermentation technique. The fecal coliform analysis for the first sampling days of each survey (7/20, 8/3, 8/16) which involved sampling estuary load inputs was done by the HETL in Augusta using the membrane filtration technique. The readings were not evaluated for shellfish criteria, since a minimum of 30 samples is needed for this (personal communication, Fran Pierce, DMR). Elevated readings occasionally occurred at Payson Park sample stations and some locations below this (figure 5a). The highest readings occurred at the Mill River and Oyster River (tidal) tributary sites. Readings for the Warren S.D. effluent were generally low. The higher readings may be an indication of pollution of unknown origin. Additional fecal coliform data for work undertaken by DMR and some background information on shellfish closure criteria is contained in the appendix of this report.

Secchi Depth

Secchi depth is a measure of water transparency or clarity. The test for this is undertaken by an observer in a boat who lowers a black and white disk on a chain into the water column. Secchi depth was measured at high and low tides once during each intensive survey. Values ranged from 1.2 to 3.4 meters and averaged about 2 meters for each survey (table 5, figure 5b). The lowest secchi depth readings were recorded in the upper estuary and gradually increased in the seaward direction except for a higher inflection point at SGE11 (near state prison). A gravel to cobble substrate was observed in this area and is probably the reason for the higher readings.

Secchi depth readings of less than two meters in lakes generally indicate the presence of an algae bloom. In rivers and estuaries, in particular, the secchi depth readings are frequently an indication of turbidity caused by both algae and other sources (runoff, resuspension of bottom sediment) and are not necessarily a cause for concern. The secchi depth readings will be used in the water quality model to define light penetration into the water column which is an important part of simulating the growth of algae.

Ultimate BOD

A distinction should be first explained between the five-day BOD test (BOD5) and the ultimate BOD test (BODu). The five day test is used in effluent compliance monitoring and the ultimate BOD test is used in ambient monitoring studies. The ultimate BOD is considered a much better test when considering impact upon water quality but the length of the test (>60 days) makes it impractical for effluent compliance monitoring.

The ultimate biochemical oxygen demand (BODu) procedure follows the overall BOD5 test of standard methods with some modifications. The tests are run for a duration of 60 days or more with a requirement that there is no more significant depletion of dissolved oxygen when the test is stopped. Ambient samples are run with no additions of any reagents. When sample readings for dissolved oxygen approach 2 ppm, the samples are reaerated. A minimum of 10 to 12 readings are preferred over the duration of the test.

The final result first requires an estimation of total BOD (TBODu) and then a partitioning of carbonaceous and nitrogenous portions. The TBODu is estimated from a plot of BOD (D.O. consumed) versus time curve and is typically a "leveling off" of the curve or where no additional oxygen is consumed over time. This value is not necessarily the last BOD reading of the test and may be estimated with a model. The model result and final BOD reading should be very similar for the value of TBODu to be considered reliable.

If the final nitrate reading (taken after commencement of test) is larger than the initial nitrate reading, it can be deduced that ammonia nitrogen has oxidized to nitrate nitrogen, consuming oxygen in the process as nitrogenous BOD (NBOD). An estimation of NBODu is made by the difference of initial and final nitrate readings times 4.33, the stoichiometric coefficient of nitrogen, i.e. amount of O_2 consumed per nitrogen converted. Carbonaceous BOD (CBODu) is then obtained by the difference of TBODu and NBODu.

The BODu samples were run out to a period of 60 days or more and ten to twelve readings of D.O. made during this time. Total ultimate BOD (TBODu) readings were the highest on the upper St Georges estuary station (1/2 way down) and Payson Park (4 to 6 ppm) (Figure 6). TBODu at the remainder of the sampling locations was typically under 4 ppm reaching a low of about 2 ppm at the ocean boundary (figure 6). It can be observed that when comparing TBODu levels of the various sampling surveys, levels were not significantly different. When the partitioning of the carbonaceous and nitrogenous components of BOD are considered, BOD at the estuary sampling locations is typically about 80% carbonaceous. Nitrogenous NBOD levels were often less than 1 ppm and never exceeded 1.5 ppm.

TBODu values for the Oyster River freshwater site and an unnamed tributary near the Prison Farm were in the four ppm range. The Oyster River tidal site (Route 131) and the Mill River both had higher TBOD levels that were often greater than 6 ppm, and on the Mill River, occasionally over 10 ppm.

Nutrients

When phosphorus and nitrogen are in excess in a water body, the growth of an undesirable algae bloom can result in low early morning dissolved oxygen readings. The nitrogen to phosphorus ratio is an important part of considering which nutrient is limiting and therefore needs to be controlled to improve water quality in a water body. N/P ratios of less than 5 indicate nitrogen limitation and greater than 10 phosphorus limitation (in-between 5 and 10 both are limiting). The N/P ratios measured on the St Georges estuary were generally under 5 indicating nitrogen limitation. Nitrogen limitation is typical of most estuaries and is therefore expected. The lower levels of total dissolved nitrogen (TDN) (figure 8) when compared to total phosphorus (figure 9) are also an indication of nitrogen limitation, as is the high orthophosphorus observed that is typically absent in phosphorus limited systems.

TDN values in the estuary were usually in-between a range of 20 to 60 ppb.

Chlorophyll A

Chlorophyll a is used as an indicator of the amount of algal biomass in a water body. Higher values are generally undesirable and can result in a poor aesthetic quality from green tainted waters, dissolved oxygen depletion in deeper waters, and low early morning dissolved oxygen readings. The algae produce oxygen during daylight hours, which often results in supersaturated dissolved oxygen in the afternoon and consume oxygen during nighttime hours resulting in minimum D.O. readings at dawn. Chlorophyll a levels of 8 ppb or greater are used by the lake assessment section of DEP as the indication of an algae bloom.

Chlorophyll a levels at most of the sampling locations were usually 4 ppb or less, except at the upper estuary stations (1/2 way down and South Warren) where values approaching bloom conditions were observed (6 to 11 ppb) (figure 9). When comparing chlorophyll a for the different surveys, levels were not significantly different. It is important to note that the locations with all the higher chlorophyll a readings also had the lowest dissolved oxygen readings and the largest range of diurnal dissolved oxygen.

Average chlorophyll a was low at the upstream boundary at Payson Park (typically <2 ppb), Oyster River freshwater site (2 to 3 ppb), and the unnamed Prison Farm tributary (2 to 3 ppb). Moderately elevated levels were observed at the Oyster River tidal site (route 131) (4 to 6 ppb) and high levels that were often over 10 ppb were measured on the Mill River.

Sediment Oxygen Demand

Sediment oxygen demand analysis was provided by USEPA during the week of the second intensive survey (August 2-6). Core samples of sediment were collected and analyzed in their mobile laboratory, which was set up at the Warren S.D. The results are as follows

Table 6 Sediment Oxygen Demand

Station	Location	SOD (g/m^2/day0
SGE2	1 Mile South of Warren Village	0.61
SGE4	Halfway Down to South Warren	0.55
SGE7	South Warren above Oyster River	1.52
SGE9	Near Warren WWTP	1.56
SGE11	Near State Prison, Thomaston	1.3

The results in the upper estuary stations (.61, .55 g/m^2/day) are very low SOD values for an estuary. The substrate here was sandy with low organic matter content (personal communication with Jack Parr, USEPA, 11/3/99). The SOD values in the lower three sites (1.52, 1.56, 1.3 g/m^2/day) are similar to values measured in other Maine estuaries .

Quality Control

Proper quality control is essential for any sampling effort to assure that the data collected are good. Quality control procedures were practiced in both field sampling and the laboratory analysis of various parameters. Dissolved oxygen meters were calibrated prior to and frequently during sampling. In addition, meters were cross-checked amongst adjacent sampling teams to assure consistency and accuracy of results. The work plan specified that dissolved oxygen readings amongst sampling teams should be within 0.3 ppm and temperature within 2 ^{o}C when cross checking readings. The D.O. meters were cross-checked after initial morning calibration and again after commencement of sampling. This procedure was repeated for the afternoon sampling run. If meters did not agree favorable after commencement of sampling, meters were re calibrated and rechecked.

Dissolved oxygen, temperature and salinity meter cross checks always agreed to within the specified criteria, except the following. In the first intensive sampling run in July, the team 2 salinity values were low when compared to the other meters. The salinity corrections for these data ranged from 2.5 to 4 ppt at the locations sampled by team 2 (SGE11, 13,16,19,20). Since salinity influences dissolved oxygen saturation and ultimately the meter calibration, minor corrections of 0.1 ppm were made to the dissolved oxygen data at these locations.

One duplicate sample per sampling team was collected daily resulting in an overall coverage of more than 20% of all samples. The duplicate samples are compared to the original samples in a series of column plots (see appendix). About 85% of the samples had comparisons that were accurate to within 10%.

The chlorophyll a data for the Warren effluent did not always compare well. On August 3, although no duplicate was collected, the reported value of 343 ppb does not compare well to the other values measured on the August 4 and 5 (131/129 ppb and 84/75 ppb, respectively). The effluent sample on August 3 was a grab sample rather than a composite and may not as reliable. The result on August 3 is being rejected. Similarly on August 16 a grab sample was collected and the reported chlorophyll a of 659 ppb is rejected.

It is concluded that the good comparison of the duplicate samples and meter cross checks that was observed results in data of high quality.

Tables and Figures

Duplicate Sample Comparisons

Water Quality Data