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Analysis of Changes in Temperature Regime in Mt. Hope Bay With and Without Brayton Point Station in Operation with Resulting Effects on Saturated Dissolved Oxygen Levels

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Executive Summary

The thermal effects from the discharge of the Brayton Point Station on Mt. Hope Bay was assessed using a calibrated hydrothermal model applied under the auspices of various state and federal agencies, the Station operator, and other interested parties. A series of model runs were made which predicted the temperature regime in the Bay both with and without the Station in operation. These temperature predictions provided the information necessary to estimate the change in dissolved oxygen from existing conditions present in the mid-2000s when water quality data was acquired to when the plant is scheduled to go offline in 2017.

The average baywide temperature decrease was predicted to be 1.24°C. Using the relation between saturated DO concentration and temperature, the average baywide increase is 0.24 mg/L or 2.67% over permitted operations at the time. This increase is important since it comprises approximately one half of the DO deficit (~0.4 mg/L) measured in the mid-2000s in the upper Taunton estuary. Further DO improvements are also anticipated because other temperature dependent oxygen demanding components will create less DO consumption under a reduced temperature regime. This simplified temperature effects modeling approach could have been used in the draft permit for the Taunton WWTF to provide a meaningful estimate of the likely DO conditions when the Station went offline. In fact the sister water quality model, BFWASP, to the hydrothermal model, BFHYDRO, could have been used to definitively estimate resulting DO levels and confirm the significance of nutrients on the DO regime .

Finally, the use by USEPA of a sentinel station located in the far southeast corner of the Bay is not an appropriate methodology to predict DO conditions and nutrient reduction requirements in the Taunton Estuary since the hydrodynamics and therefore the transport and flushing at this site are significantly different from the rest of the Bay. Consequently, there is no reasonable basis to anticipate that nitrogen levels at the sentinel site provide a basis for predicting DO or algal growth potential at the other sites further up in the Bay or the Taunton River.

Background

RPS ASA (formerly Applied Science Associates) has performed field programs and modeling studies for the Brayton Point Station since 1996 as part of the Station's efforts to renew their permit from the U.S. Environmental Protection Agency for discharge of cooling water to Mt. Hope Bay. Subsequent to a recent change in ownership it was announced the Station will cease operations in 2017.

RPS ASA has performed a series of modeling studies that evaluated the thermal regime in the Bay using a sophisticated hydrothermal model calibrated, verified and optimized with extensive field observations. The model was accepted in September 2000 by the Brayton Point Station Technical Advisory Committee (TAC), consisting of state and federal agencies (including the USEPA) and other interested parties, as suitably calibrated for use in predicting the thermal structure of the Bay. The subsequent studies included modeling the three-dimensional, time varying temperature distribution for a series of Station operational alternatives including the case without the Station operating, i.e., ambient environmental background forcing only. These studies have been documented in a variety of publications authored by RPS ASA staff with the most recent being Swanson et al. (2006).

The City of Taunton, MA is seeking a permit renewal from the USEPA for the discharge of treated effluent from its wastewater treatment plant (WWTP). The new draft permit incorporates limits on total nitrogen (TN) concentrations in the discharge which attempts to improve dissolved oxygen (DO) levels in the Bay located 21 km (13 mi) south of the WWTP. The draft permit relies on data collected during the period 2004-2006 (SMAST, 2007) which indicates DO below the minimum level of 5 mg/L. Since temperature affects the saturation of DO in the Bay, the removal of the heat load from the Station will result in a reduction in temperature that will increase the dissolution potential of the waters of the Bay for DO. RPS ASA was asked to perform an analysis of the expected increase in the Bay DO concentration levels based on the cessation of operations of the Station.

The following tasks were performed for this effort:

- Identify model results from the earlier studies that predict the temperature distributions in the Bay for both the Station in operation as well as no Station operation.
- Calculate the resulting saturated concentration levels of DO for both operational scenarios and the DO concentration difference between the two.
- Assess the reasonableness of the USEPA-selected sentinel station that was used to characterize the waters downstream of the Taunton WWTF discharge.

Temperature Analysis for Mt. Hope Bay

Hydrothermal Model Application

A three-dimensional time-dependent hydrothermal computer model was used to assess the thermal effects of the Station discharge on the Bay. The system, known as WQMAP, was developed by RPS ASA and the University of Rhode Island (Spaulding et al., 1999). The system includes a suite of integrated environmental models, including a boundary-conforming grid generation model, BFGRID; the three-dimensional hydrothermal model, BFHYDRO; a set of pollutant transport and fate models (single- and multiple-constituent [BFMAX] and WASP5 (Water Quality Analysis Simulation Program) kinetics [BFWASP]). It should be noted that BFWASP is capable of simulating the DO concentration levels in the Bay using the BFHYDRO model output and appropriate rates required in the WASP5 kinetics. All operate on a boundary-conforming grid system and are supported by an embedded geographic information system and environmental data management tools.

The BFHYDRO model was applied by dividing the Bay into over 1000 three-dimensional grid cells where temperature, salinity, and velocities were calculated within each cell. It was successfully calibrated, verified and optimized with TAC oversight using an extensive set of observations collected in the Bay over a number of years as discussed in Swanson et al. (1998, 1999, and 2001) and summarized in Swanson et al. (2006).

Model Results

Two cases from the extensive modeling of various plant operational alternatives were chosen for the present analysis. First a No Plant (NoPlt) case was selected where the Station was not in operation and with the model run only with natural environmental forcing. The year 1999 was chosen as a reasonable worst-case warm-water year since there was concern about the potential for warm year biological impacts. The plant operational case, MOAII, was chosen since that was based on the interim permit levels documented but the second Memorandum of Agreement among the Station, various Massachusetts and Rhode Island state agencies, and the U.S. Environmental Protection Agency (1997). The MOAII restricted operations through all of the 2000s until closed cycle cooling began operations in 2011.

The selected model output was processed by taking the daily averaged temperatures over the simulated year (1999) for each grid cell whose volume was known so that the cumulative percent of the volume of the Bay that was greater than a specific temperature could be generated. This result was documented in various reports including the chapter appearing the journal *Northeast Naturalist* (Swanson et al., 2006). These results are repeated as Figure 1 below. The figure indicates temperature ranges from 0 to 27 °C with the NoPlt case always cooler than MOAII as expected. The difference in volume between the cases at a given temperature is not large, however. For example, at 5C, the NoPlt case shows 72% of the Bay volume is greater than this temperature compared to 82% for the MOAII case.

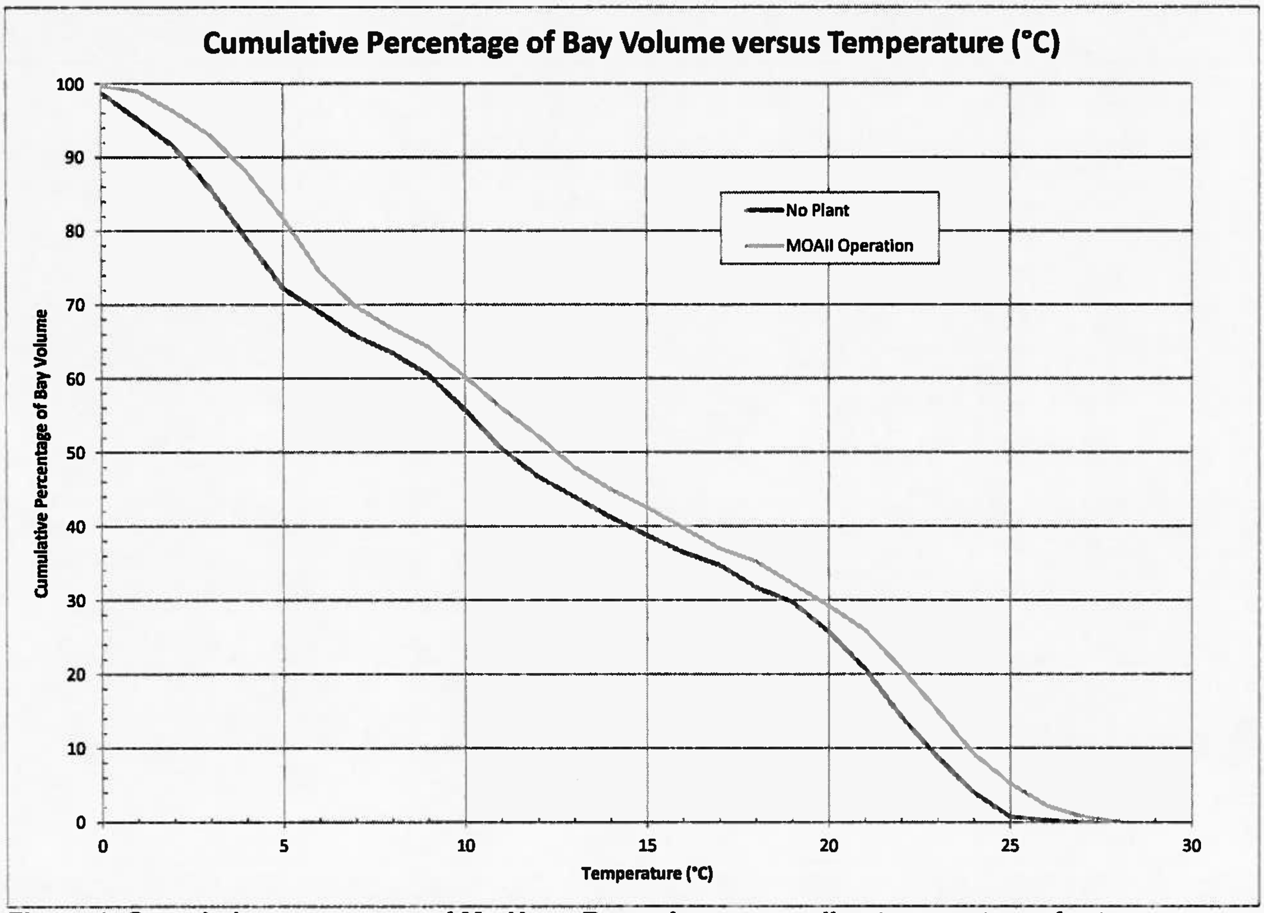

Figure 1. Cumulative percentage of Mt. Hope Bay volume exceeding temperatures for two modeled scenarios.

Dissolved Oxygen Analysis for Mt. Hope Bay

Estimates of Saturated DO Concentrations

The saturated DO concentrations decrease with both increasing temperature and salinity. A mean salinity of 30 psu was conservatively estimated based on previously collected data. Figure 2 shows the relationship between temperature and DO for a 30 psu salinity taken from the USGS website: http://water.usgs.gov/software/DOTABLES/. There is a 46% drop in saturated DO concentration levels between 0 and 30 °C, from 11.85 to 6.41 mg/L.

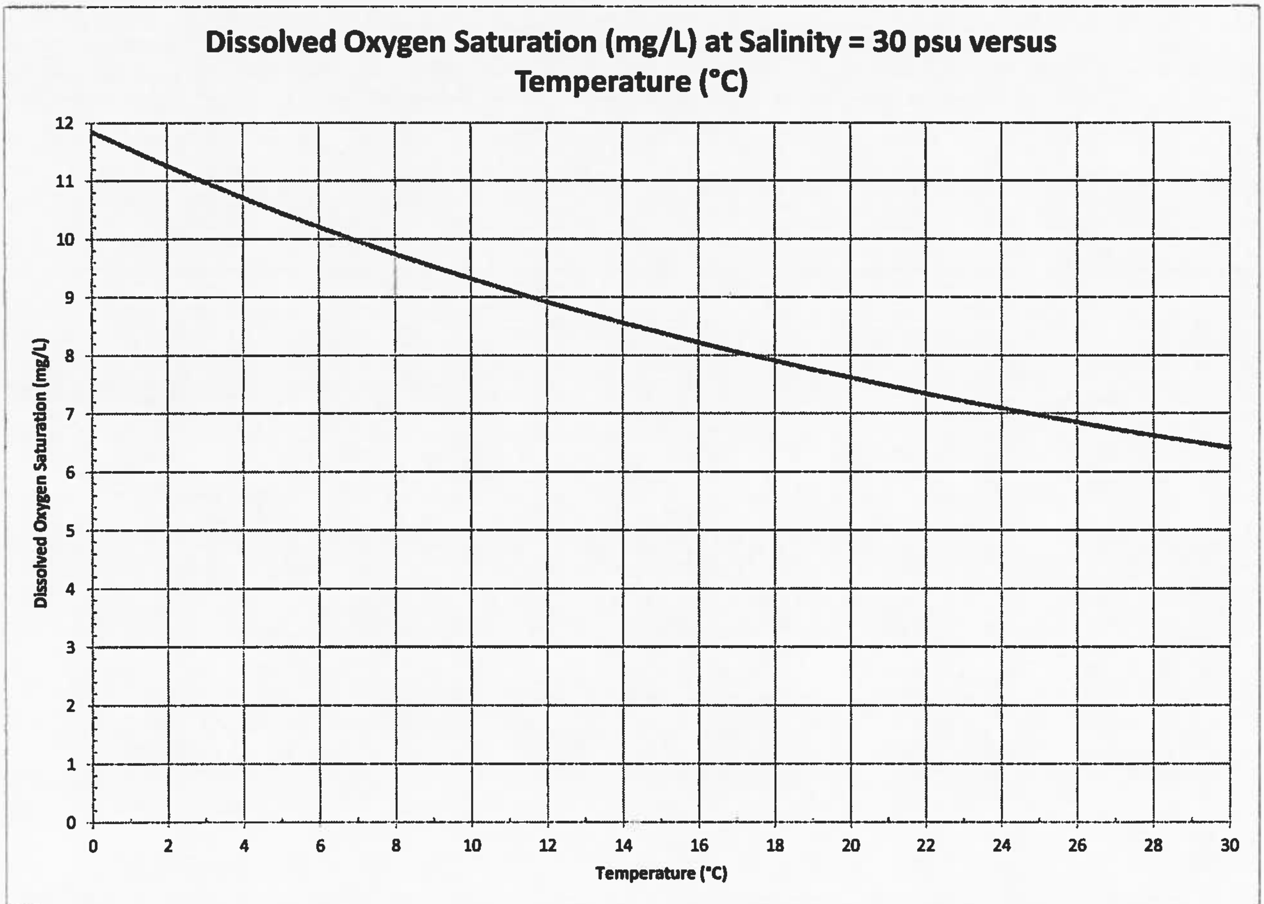

Figure 2. Variation of dissolved oxygen with respect to temperature for approximate mean the Bay salinity of 30 psu.

Figure 3 shows the relationship between cumulative percentage volume and DO in a manner similar to Figure 1 for cumulative percentage volume versus temperature. The figure indicates saturated DO for the NoPlt case always higher than MOAII as expected. The difference in volume between the cases at a given DO saturation concentration is not large, however. For example, at 10 mg/L, the NoPlt case shows 70% of the Bay cumulative volume is greater than this saturated DO level compared to 66% for the MOAII case.

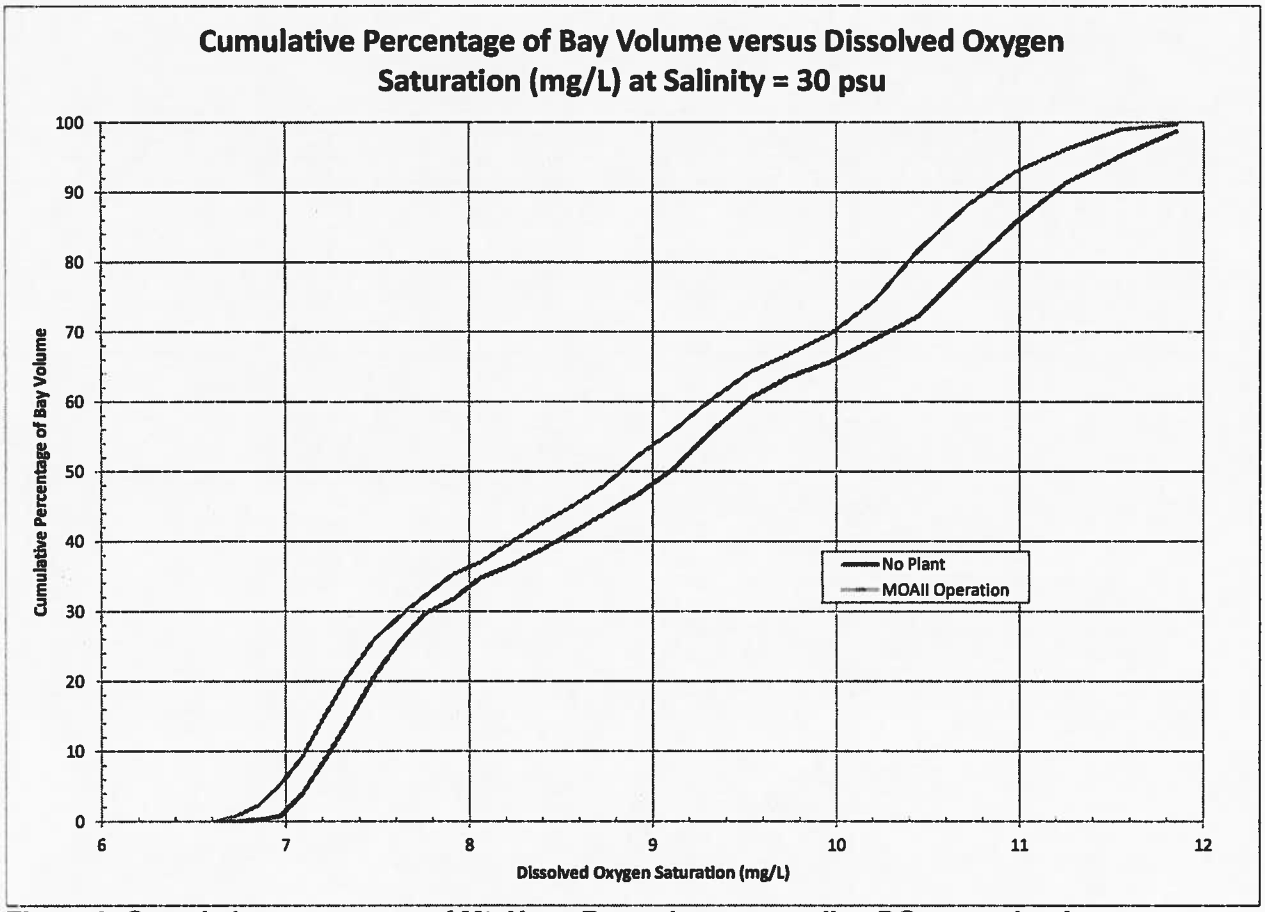

Figure 3. Cumulative percentage of Mt. Hope Bay volume exceeding DO saturation for two modeled scenarios.

Instead of cumulative volume percentage a more detailed approach is to evaluate the volume percentage change in 5% volume increments. Table 1 shows the change in saturated DO concentration between the NoPlt case and the MOAll case. Temperatures are shown for each increment for reference. The DO increases for the increments range from 0.13 to 0.37 mg/L with an average of 0.24 mg/L or 2.7%. Larger differences are seen for the colder waters, consistent with the relation between saturated DO concentration and temperature.

Table 1. Change in saturated DO concentration between the NoPlt and MOAll cases in 5% the Bay **volume increments.**

Volume % Lo	Volume % Hi	NoPlt T (°C)	MOAll T (°C)	NoPlt DO (mg/L)	MOAll DO (mg/L)	ΔDO (mg/L)	% Dif
0	5	24.84	26.47	6.99	6.79	0.20	2.89%
5	10	23.27	24.46	7.18	7.04	0.14	2.02%
10	15	22.40	23.46	7.29	7.15	0.13	1.86%
15	20	21.54	22.56	7.40	7.27	0.14	1.90%
20	25	20.61	21.60	7.53	7.40	0.14	1.88%
25	30	19.49	20.45	7.69	7.56	0.13	1.78%
30	35	17.60	18.91	7.97	7.77	0.20	2.54%
35	40	15.42	16.92	8.32	8.07	0.25	3.06%
40	45	13.56	14.90	8.64	8.41	0.23	2.77%
45	50	11.89	13.24	8.94	8.70	0.24	2.81%
50	55	10.67	11.86	9.19	8.95	0.24	2.65%
55	60	9.65	10.64	9.39	9.19	0.20	2.20%
60	65	8.27	9.42	9.68	9.44	0.24	2.57%
65	70	6.57	7.88	10.07	9.77	0.31	3.14%
70	75	5.16	6.47	10.41	10.10	0.32	3.12%
75	80	4.26	5.61	10.64	10.30	0.34	3.28%
80	85	3.53	4.87	10.84	10.48	0.35	3.38%
85	90	2.69	4.04	11.07	10.70	0.37	3.42%
90	95	1.63	2.92	11.37	11.00	0.36	3.30%
95	100	0.06	1.15	11.83	11.51	0.33	2.83%

Other Temperature Dependent Parameters Influencing the DO Regime

As noted above, temperature will be decreasing throughout the Bay due to the closure of the Station. Consequently, all temperature–dependent oxygen demanding processes are also projected to occur at a more reduced rate (algal growth, sediment oxygen demand, organic decay in the water column). Thus, the overall DO improvement in the system will be greater than projected simply from the saturation DO improvement.

Suitability of Sentinel Station Located at MHB16

A sentinel station approach was used by USEPA as part of its analysis of Total Nitrogen (TN) impacts from the Taunton WWTF discharge. A station included in the SMAST (2007) field program conducted in 2004-2006, MHB16, was chosen by EPA as the sentinel station. This station is located in the extreme southeast corner of the Bay just north of the connection of the Bay with the Sakonnet River, one of two connections (the other being to the East Passage of Narragansett Bay) to Rhode Island Sound and the Atlantic Ocean. From the perspective of the hydrodynamics in the Bay this is an unsupportable approach. The flow through the Sakonnet River Narrows is only 10 to 20% (Kincaid, 2006) of the flow through the main interface to Narragansett Bay so the flushing characteristics and factors influencing the DO regime would be entirely different from most of the rest of the Bay and certainly differ dramatically from conditions occurring in the Taunton Estuary. Consequently, one could not reasonably anticipate that the hydrodynamic conditions (including stratification) or algal growth influencing the DO regime at this location would be similar to the conditions controlling DO in the Taunton estuary that is subject to an entirely different set of oxygen demanding inputs and physical conditions.

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