Inner Little Harbor 2008 Tide Level and Water Quality Summary Report

Prepared for the Town of Cohasset Town Manager and Conservation Commission

Prepared as a technical assistance service by:

Jason Burtner
Massachusetts Office of Coastal Zone Management

and

Christian Krahforst
Massachusetts Bays National Marine Estuary Program

August 2009

1.0 Introduction

This report summarizes tide level and water quality data from Inner Little Harbor (ILH), Cohasset, collected during the 2008 monitoring season. This monitoring effort utilized existing equipment from the Coastal Zone Management (CZM) Wetlands Restoration Program (WRP) and the Massachusetts Bays National Estuary Program (MBP). Monitoring services were provided as project support and technical assistance as requested by the Town of Cohasset. The technical assistance consisted of reviews of existing reports, the collection and syntheses of water quality, and preparation of summaries of the data as it pertains to regulatory, standards, and management considerations.

1.1 Goals and Objectives

The ecological health and management of ILH has been an issue of local concern dating back to the turn of the century. These concerns are: perceived and real nuisances of undesirable plants, diminished habitat value, invasive species, stagnant poorly-flushed surface water, eutrophication, fragmented ecology, and poor aesthetics. In order to investigate the health of ILH and inform management options, the Town of Cohasset has commissioned several studies which are summarized and discussed below. However, those studies are now several years old and additional contemporary water quality data is needed in order to better inform the understanding of the current health of the estuary and the function of the existing tide gates at Cat Dam. At the direction of the Conservation Commission, the Town of Cohasset has issued a Request of Qualifications (RFQ) for the development of a Tide Gate Operations and Maintenance (O&M) Plan that will accompany the overall plan as part of a Notice of Intent (NOI) for tide gate operations under the State Wetlands Protection Act (WPA).

Thus, the overarching goals of this study are to provide a current understanding of ecological health of ILH by;

- Utilizing in-situ monitoring equipment to obtain long-term high temporal resolution data not provided in previous studies;
- Provide contemporary water quality data and analysis to help inform tide gate management operations.
- Discuss findings as they relate to the Wetlands Protection Act and the Massachusetts State Water Quality Standards.

1.2 Study Area

The Little/ILH system is a 171 acre tidal estuary located on the northern coast of Cohasset (see Figure 1-1: Locus). The main body of Little Harbor covers an area of approximately 154 acres and ILH of approximately 18 acres. Contributing area watersheds are approximately 655 acres and 246 acres respectively. Richardson Brook is the primary tributary to ILH. Little Harbor and ILH are separated by a dam and tide gate structure located on Nichols Road known locally as Cat Dam. A 1991 study of ILH conducted by IEP, Inc. included bathymetric survey (provided in Appendix A) and calculated depth/volume values. Maximum water depth is reported as 5 feet, mean water depth as 1.7 feet, and the total water volume as 1.29 M cu ft.

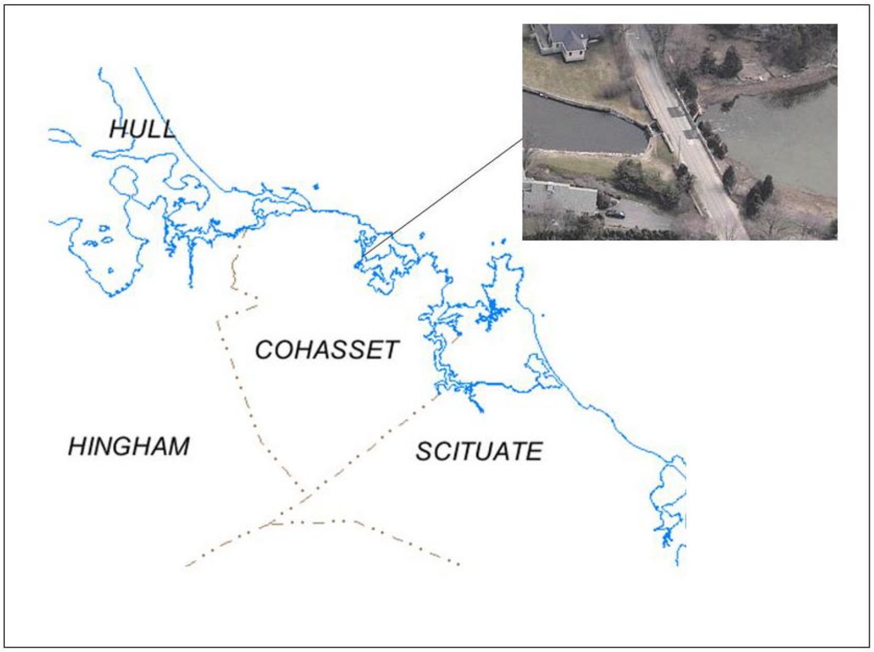


Figure 1-1: Little Harbor Locus and Cat Dam Location

The Massachusetts Surface Water Quality Standards, 314 CMR 4.06, identify Little Harbor as a Class SA waterbody with a qualifier of Shellfishing. The regulations at 314 CMR 4.05(4)(a)(1-8) for Coastal and Marine Class SA waters state: “These waters are designated as an excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas). These waters shall have excellent aesthetic value.” These regulations provide both quantities and qualitative standards for classification that include dissolved oxygen, temperature, pH, bacteria, solids, color and turbidity, oil and grease, and taste and odor. In addition to these class specific standards 314 CMR 4.05(5) articulates Additional Minimum Criteria Applicable to all Surface Waters that include aesthetics, bottom pollutants or alterations, nutrients, radioactivity, and toxic pollutants.

The State Wetlands Protection Act regulations, 310 CMR 10.00, provides definitions and procedures for both inland and coastal resource areas, articulates resource values and functions, and provides performance standards for work in or abutting these areas. Inner and Little Harbors contain a variety of relevant jurisdictional resource areas that include Salt Marsh, Land Under the Ocean, Coastal Beaches (which are defined to include tide flats), and Land Containing Shellfish.

1.4 Background

The Nichols Road (Cat) Dam is a 135 ft. long earth embankment dam with a primary spillway. The upstream side (Little Harbor Reservoir) consists of a retaining wall and earthen slope graded at approximately 3:1(horizontal:vertical) and the downstream slope (Little Harbor) is graded to approximately 2H:1V and is armored with large slope protection stones (Weston and Sampson, 2006). The primary spillway consists of a 15 ft. wide concrete channel. The tide gates are composed of three timber gates on steel frames. The 4 ft. x 5 ft gates are constructed of 6in x 6in timbers. In the closed position, the gates rest against a timber and metal framework (Figure 1-2a and b). The flapper style gates are oriented inward so that incoming tides will, once sufficient tidal elevation and head pressure is achieved, open the gates and allow flood tides to enter the harbor (See Figure 1-3a).

Figure 1-2a and b: Tide gate construction and timber and metal seating framework

On the ebb tide, out flowing water seat the gates against the timber and metal framework structure preventing water from completely draining the upstream basin. Water levels that exceed the top elevation of the gates and the backstop cross members (typically during the flood tide) will spill over the tide gate structure (Figure 1-3b). Once the water level in ILH reaches or falls below the elevation of the top of the gates/backstop cross members, the basin continues to drain through gaps between the gates and gate supports (Figure 1-3c). Chain stays are used to hold the tide gates in an open position for operations related to routine maintenance or when increased tidal exchange is desired (Figure 1-3d). Generally, the tide gates are maintained in a closed position with the exception during the winter when they are chained open for several months to prevent ice damage and for 1-3 days a month during the summer months for when enhanced tidal flushing is desired by the Town of Cohasset. It should be noted that, due to their inward facing orientation, the tide gates do not serve a tidal flood control or storm damage prevention function.

A 1991 Diagnostic/Feasibility Study of ILH, Cohasset was conducted by IEP, Inc based on concerns regarding excessive algae growth in ILH resulting in the formation of "unsightly, floating mats and production of obnoxious odors then the algae die and decay during summer". This study found that "Excessive algae growth occurs most summers in ILH resulting in the formation of unsightly floating mats that cover much of the surface and the production of obnoxious odors when the algae die and decay. Physical characteristics of the ecosystem function to promote the growth of tremendous amounts of algal biomass. These characteristics are the following:

- Large areas of substrate overlain by shallow water. (This provides optimal conditions of temperature and lighting for the epipelic stage of algae growth.)
- Thick deposits of nutrient-rich, organic sediment. (This sediment provides an abundant source of nutrients required for algae growth.)
- Quiescent water with little internal circulation and limited flushing with the main estuary beyond Cat Dam. (The lack of energetic water movement within Inner Little Harbor allows canopy and mat formation by the algae to progress undisturbed and with maximum efficiency.)

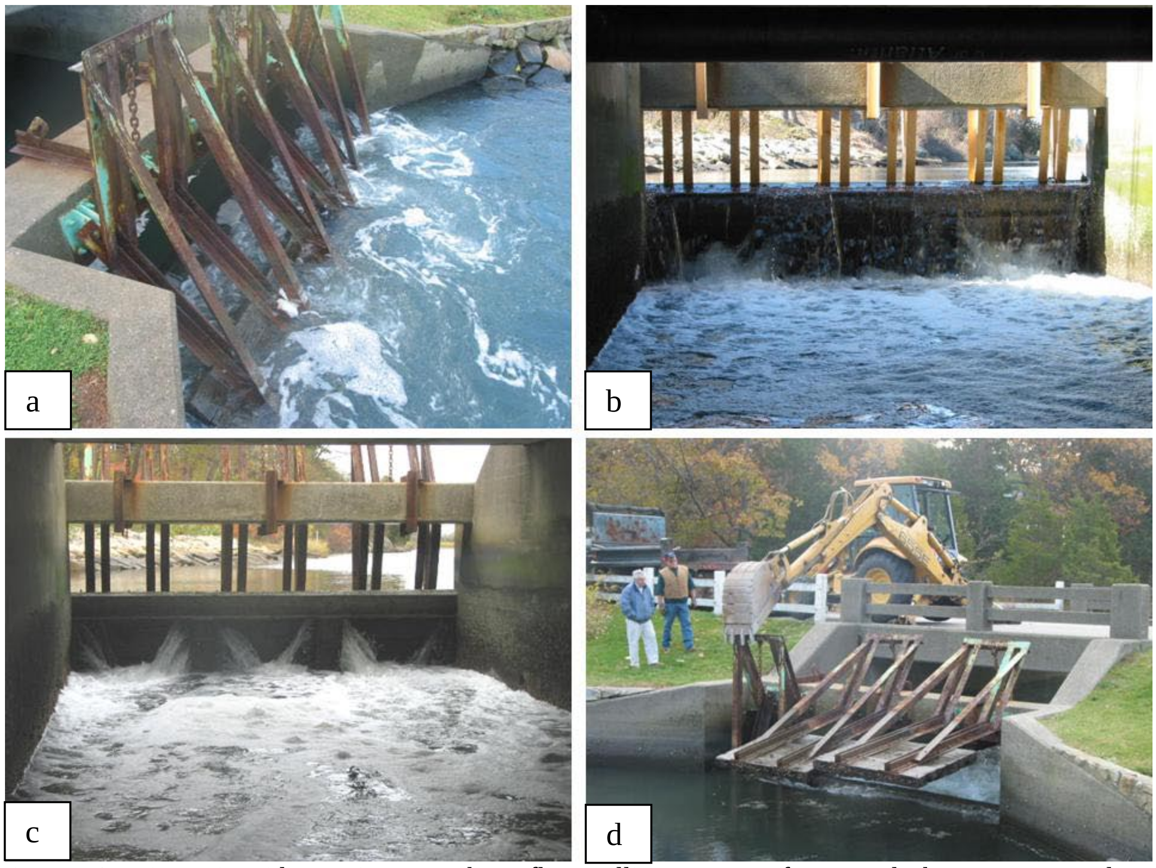


Figure 1-3: a, incoming tide opening gates; b, outflow spilling over top of gates; c, leakage past gates; d, opening and securing of tide gates.

In combination, the above characteristics make Inner Little Harbor an ideal incubation container for algae growth."

Photographic documentation of recent algae mat biomass production is provided in Appendix B. The study also indicated sediments samples from within ILH had an organic contact greater than 10% and that sediments with this high a proportion of organic solids are characteristic of eutrophic systems. The report stated that the organic compounds contained within the system are derived from remains of littoral vegetation, mat algae, and planktonic organisms.

A 1999 Water Quality Study of Little Harbor was conducted by Camp Dresser & McKee (CDM) included water quality monitoring, pollution source identification, nutrient loading assessment and water level and flushing analysis.

As part of this study automated tidal data loggers were used to record tidal elevations in Little Harbor, ILH, and Massachusetts Bay. These tidal elevations and the bathymetry from the 1991 IEP study were used to calculate tidal flushing rates for the Harbors. From this analysis the 1999 CDM report determined that when the tide gates were functioning in the closed position the average tidal range in ILH was 0.8 feet with a corresponding tidal flushing rate of about 544,068 ft^3, or about 42% of the total volume of ILH. With the tide gates in the open position the average tidal range was 3.8 feet, or three feet greater than with the gates in the closed position. This tidal range had a corresponding volume of 1,284,413 ft^3, representing about 99.5% of the total volume. The report also determined the tidal range in main body of Little Harbor was 3.9 feet and the tidal range in Massachusetts Bay (at Whitehead Bridge) was 8.6 feet.

With regards to nutrients, the CDM report concludes "harbor monitoring data suggest that the overall water quality in the MAIN portion of Little Harbor is very good. Nutrient levels are generally found not to be elevated throughout most parts of the Main Harbor during both dry and wet weather conditions. Most likely, it is the significant and consistent flushing that occurs in the Main Harbor that helps to keep nutrient levels from rising". The CDM report continues: "the Inner Little Harbor, however, *does* show evidence of increased organic activity along with elevated nutrient levels when compared to the Main Harbor and Massachusetts Bay. The data also suggests a typical pattern of higher nutrients and organic and algae activity in the Inner Harbor and around monitoring locations in the Main Harbor that are close to the Inner Harbor". The report goes on to conclude: "Since Inner Little Harbor suffers from elevated nutrients and little flushing, opening of Cat Dam will provide a relief to eutrophic conditions. For there to be a more permanent remedial response in the harbor, the dam will need to be opened indefinitely. While opening the dam for 1-3 days at a time does provide temporary relief, eutrophic conditions return shortly after the dam is closed again, when flushing is returned to a minimal amount. With the dam opened or removed, nutrient levels in the Inner Little Harbor will be similar to the Main Little Harbor and, in turn, similar to Massachusetts Bay due to the high degree of flushing".

With regards to temperature and dissolved oxygen the CDM report states "temperature is almost always higher and dissolved oxygen and saturation are almost always lower in the Inner Harbor than in the Main Harbor".

2.0 Tide Level and Tidal Exchange

2.1 2008 Tidal Monitoring

A Global Water W15 series barometrically compensated automated water level data logger was used to monitor water levels in June and July 2008. The data logger was deployed in the center region of the main body of ILH and was programmed to collect a water level data point every 6 minutes so that it could be easily compared to the NOAA

Boston tide monitoring station. The logger was mounted on a metal fence post and a 1.5 inch slotted PVC tube was used as a stilling well into which the pressure sensor was inserted. During the data collection period field measurements of the water level in reference to the top of the tide gates were obtained in order to provide a reference for water level sensor data in relation to the gate elevation. Water level results are provided Figures 2-1 and 2-2. Water level is represented by the blue line and the relative top-of-gate elevation is represented by the dashed black line. It should be noted that the tidal elevation presented for ILH is not absolute water depth and is not tied to a specific elevation datum. The tidal results in Figure 2-2 are presented as relative water depth in order to be consistent and comparable to the 1999 CDM study. A correction factor of 0.92 was used to convert the NOAA Boston tidal station to a local (White Head) tidal reference for comparative purposes. The tidal datum for the Boston tide level data was Mean Lower Low Water (MLLW). It should be stressed that, as presented, the ILH/White Head data overlay is not tied to a specific datum. The ILH/White Head tidal curves are presented as superimposed data sets in order to present an easily understandable depiction of the tidal range on the Cohasset Coast necessary to introduce tidal waters into ILH.

2.3 Tidal Exchange

Data from the 1999 CDM study, along with a similar tidal monitoring effort conducted by CZM in 2006, indicate that when the tide gates are in a closed “high tide” position tidal ranges between the three investigations are relatively comparable and the “gate closed” flushing rate determined by the CDM study appear reasonable (see Appendix C). A copy of the MS PowerPoint slides from a December 19, 2006 presentation given to the ILH ad-hoc working group regarding the 2006 investigation is provided as an attachment to this summary. It is worth noting that it takes a tidal elevation of approximately 9.5 feet or greater, using Boston as the reference station with a Mean Lower Low Water (MLLW) datum, to raise the water level in ILH above the level maintained by the tide gates. Therefore not all high tides raise the water level and introduce flood tide into ILH.

However, there is disagreement between the 1999 CDM report and the 2008 CZM tidal data as it relates to low water elevations when the gates are in an open position. The CDM water level monitoring indicate when the gates are in an open position low water levels decrease from a level of 4 feet to approximately 1 foot, or an additional 3 feet of tidal fluctuation. Data from the 2008 monitoring indicate low water levels during the gate-open period water levels decrease from a level of 2.4 feet to approximately 0.4 feet. These results are significant in that there appears to be a reduction of 1 foot of tidal range between the two studies and a significant reduction in the volume of water exchanged between Inner and Main Little Harbor. Narrative from the 1999 CDM study indicates the tide gage in ILH had to be moved from its original location in a cove to a location at a small backwater area near Cat Dam that did not go dry when Cat Dam was opened. This corresponds to the 4-5 feet contour of the IEP bathymetry, near the tide gates, provided in Appendix A. Recent site investigations in ILH immediately adjacent to Cat Dam reveal the presence of a rocky berm that currently acts as a low-water tidal restriction that impounds water in the inner ILH Harbor and prevents complete drainage (See Appendix

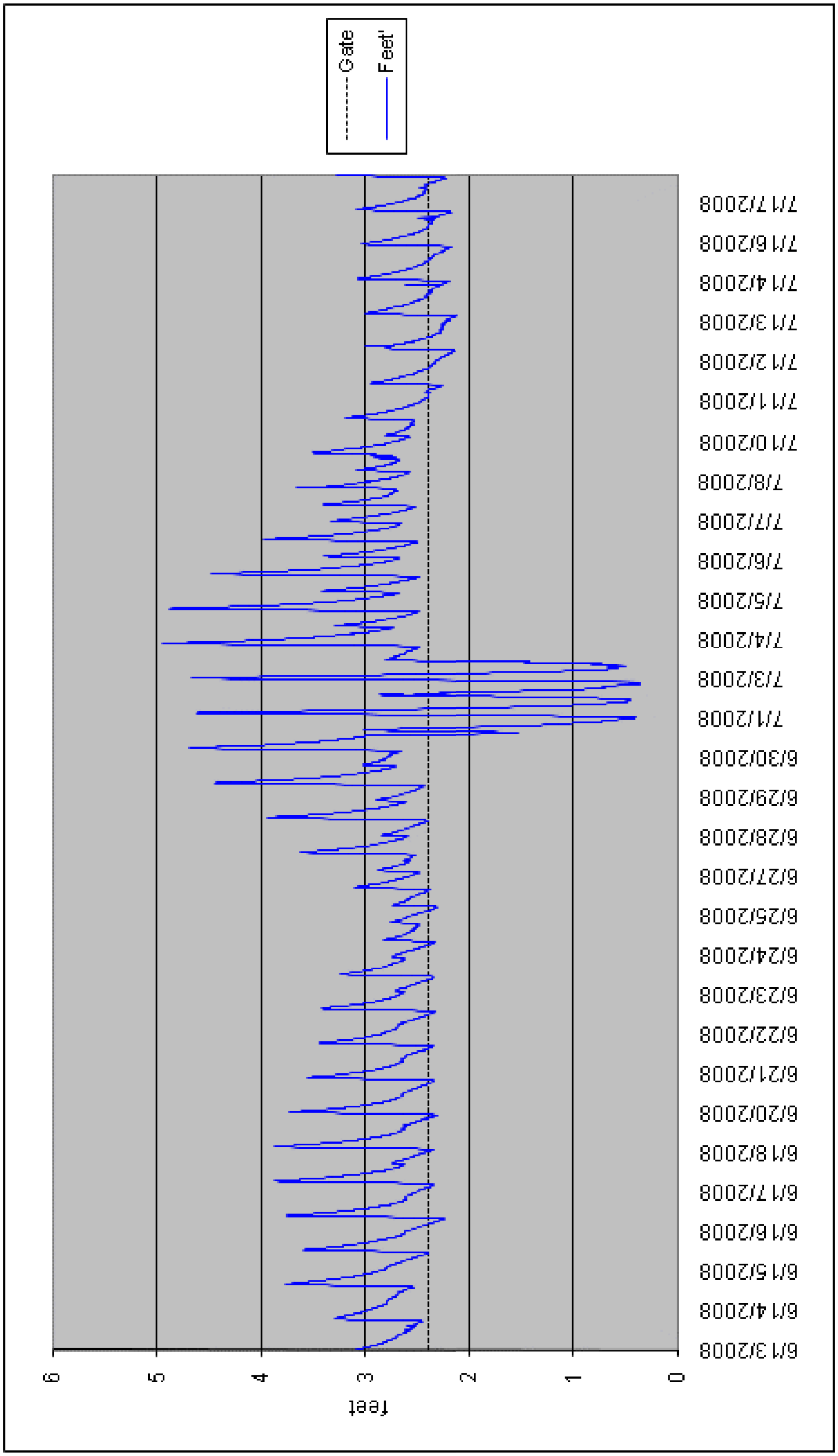


Figure 2-1, ILH tidal level w/top of gate

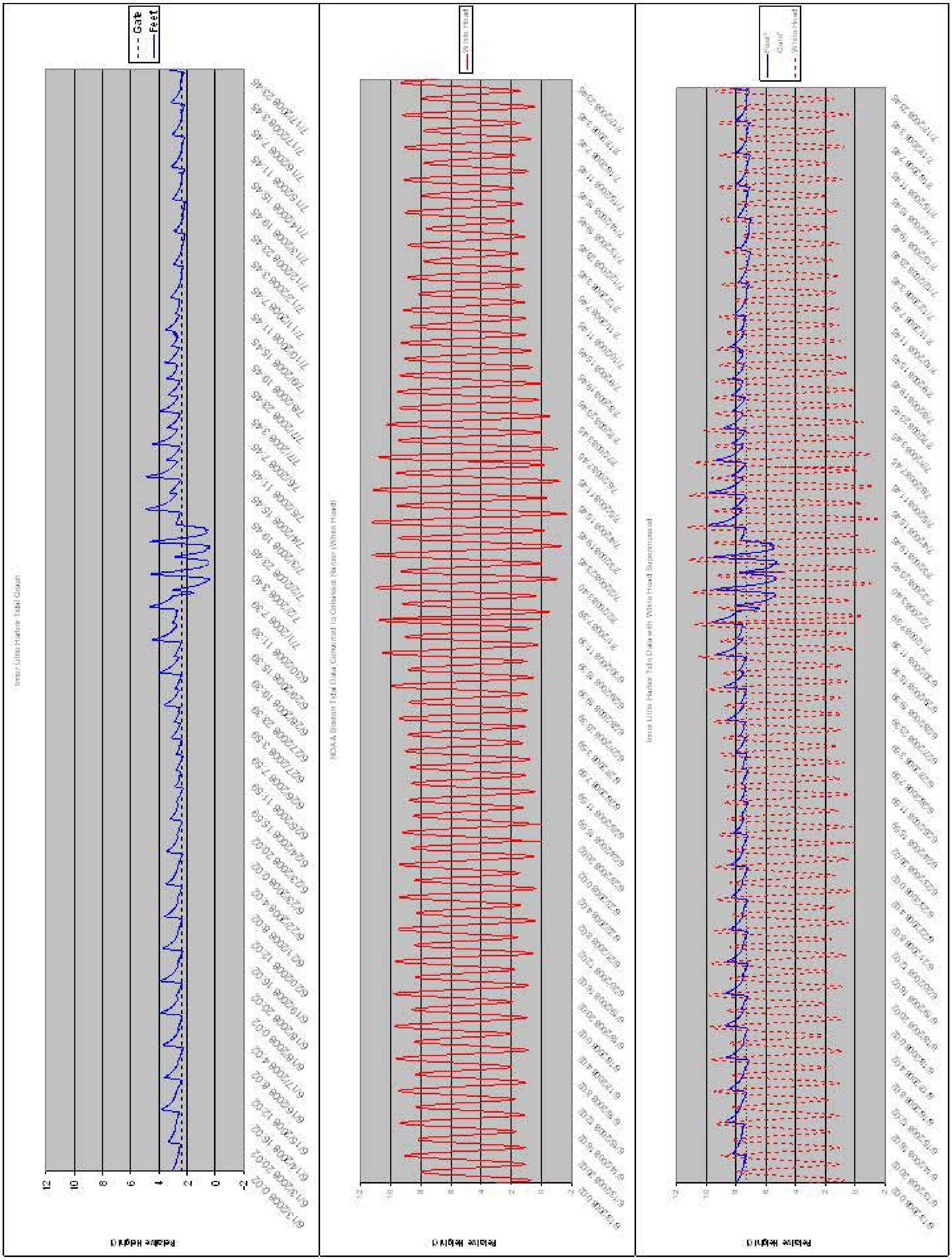


Figure 2-2, ILH, Whitehead (corrected) and superimposed relative water levels

D). When the low-water conditions of ILH (Appendix. C) is compared to the IEP bathymetry it appears that the low water level corresponds with the 3 foot elevation contour. This would indicate that at low tide there is approximately 189,133 cu ft, or 15 % of the water volume of the Harbor. This results in a maximum 90% flushing volume as compared to the 99+% volume determined in the CDM study (this accounts for the base 1,290341 cu ft base volume with the additional 537,352 cu ft volume associated with the additional 0.8 ft average high tide elevation).

It has been suggested that the leakage around the tide gates, as depicted in Figure 1-3b, is a calculated design feature that: (1) allows for the slow discharge of water to continue after ebb tide water levels reach the top of the tide gates, (2) is designed to retain 10-12 inches of water throughout the harbor at low tide (this assumes a uniform water depth throughout IHL); 3) ultimately allows for approximately 80-85% tidal volume flushing (as opposed to 100% if the structure did not exist), and (4), that this design element was not recognized or accounted for in the development of the 1999 CDM flushing calculations. The available data does not support this assertion. As discussed above, tidal flushing rates were based on recorded tidal elevations and existing bathymetry. If the slow tidal flushing dynamic was taking place as described it would be reflected in the CDM tidal curves which would show a low tidal elevation of approximately 2 ft. In contrast, the CDM tidal curves display observed levels of 4 ft. with the gates closed. . Further, the presence of the current rocky berm adjacent to the Cat Dam tide gates reduces the potential maximum tidal exchange to approximately 90% of the Harbor volume, inclusive of the 0.8 average high flood tidal level that exceeds the top elevation of the gates. If the above described "slow discharge" were taking place the tidal *ranges* between the gate open and gate closed condition as depicted in the data for this study would be very similar with only the *rate of the tidal curve* changing. The effective "slow discharge" design is not supported by either the 1999 CDM study or from the results presented here. Also, from the ILH bathymetry it is apparent the bottom topography of ILH is not uniformly shallow. Low tide water level conditions under this suggested scenario, which are roughly comparable to current gate-open water levels due to the rocky berm, have exposed tidal flats at the eastern end of the Harbor as well as in both the northerly and southerly coves.

3.0 Water Quality

As described above, previous studies performed water quality sampling that included parameters such as dissolved oxygen, temperature, salinity, pH, nutrients, and chlorophyll. While these samples were collected at locations throughout the system and provided reasonable spatial coverage, these were point-in-time samples, or snapshots, over the durations of the various studies. Important or significant changes in water quality can happen over much shorter time periods than can be adequately represented by discrete sampling methods. In order to address the temporal limitation in data, the current initiative employs a YSI Series 6600 *in-situ* multi-parameter sonde with capabilities for recording dissolved oxygen (% concentration and mg/L), salinity, temperature, specific conductivity, and chlorophyll fluorescence. The sonde was placed in ILH and programmed to log discrete observations at 15 minute intervals. The sonde is also capable of recording water depth values but is not barometrically compensated and therefore the specific accuracy is not as reliable as the water level data collected by the Global Logger L15 over time. However, the two depth data sets correspond well and therefore YSI depth data used in the water quality discussions below provides reasonable representation of water level dynamics but is limited from computations involving absolute elevation.

The YSI 6600 was installed in a central region of the main body of ILH. The installation was performed by driving a ¾ inch galvanized metal pipe into the sediment for stabilization. A 1.5 inch PVC pipe was then inserted over the metal pipe and driven into the sediments. A 12 inch plywood collar what then placed around the PVC pipe and lowered to the sediment surface. The YSI was secured to a 2.0 inch PVC pipe with hose clamps so that the sonde sensors were approximately 14 inches from the end of the pipe. When this configuration was inserted over the 1.5 inch pipe, the 2.0 inch pipe bottomed out on the collar, ensuring a consistent sonde depth for when the unit was retrieved for data download/servicing for redeployment and that the sensors, some of which have a mechanical wiping capability for long-term deployment, would be adequately distanced from the bottom and not fouled. Installation location and photo of deployment mock-up are provided in Appendix E.

3.1 Dissolved Oxygen

Dissolved Oxygen (DO) values (% concentration and mg/L) collected during the monitoring period are presented in figures 3-1 and 3-2 respectively. For the time period 5/23/08 thru 6/2/08 the graph for DO % concentration provide values that range from 60% to nearly 350% dissolved concentration. These super-saturation values, while considered very high, are attributable to a high degree of oxygen generation due to primary production and have been observed of highly productive systems. On 6/2/08 through 6/4/08, the tide gates were opened allowing for tidal exchange between Little and Inner Little Harbors. This was also a period of extensive algae coverage as depicted in Appendix B, page 2. This tidal exchange was followed by a prolonged hypoxic/anoxic event that lasted approximately 10 days. This low DO event is attributable to the exchange of super-saturated ILH water volume water from Little Harbor and Massachusetts Bay. It is possible that the high biological oxygen demand of the organic-rich ILH system and the loss of hyper-active oxygen production from ILH algal mats contributed to in subsequent hypoxic event. After this initial hypoxic event the dissolved oxygen saturation increased and stabilized but remained high due to the organic enrichment of the system, probably as the indigenous aquatic biota (e.g. algal mats) became re-established or as a seasonal succession in algae taxa dominance took place.

As part of the 1991 IEP study a macrophyte and algae mat survey was conducted. This study found that a seasonal succession of algae takes place within ILH and a summary of this succession is provided in Table 7 of the IEP report. The study found that in May *Schizomeris* was the dominant algae with *Chlorhormidium*, *Lungbya*, and *Vaucheria* being common as well. In June, Chlorhormidium was the dominant algae with Lyngbya and *Schizomeris* being common. In July, Lyngbya was the dominant species with *Chlorhormidium* and *Calothriz* being commonly found was well. By the end of July the algae mats were observed to be dying or decomposing. The report suggests the onset of

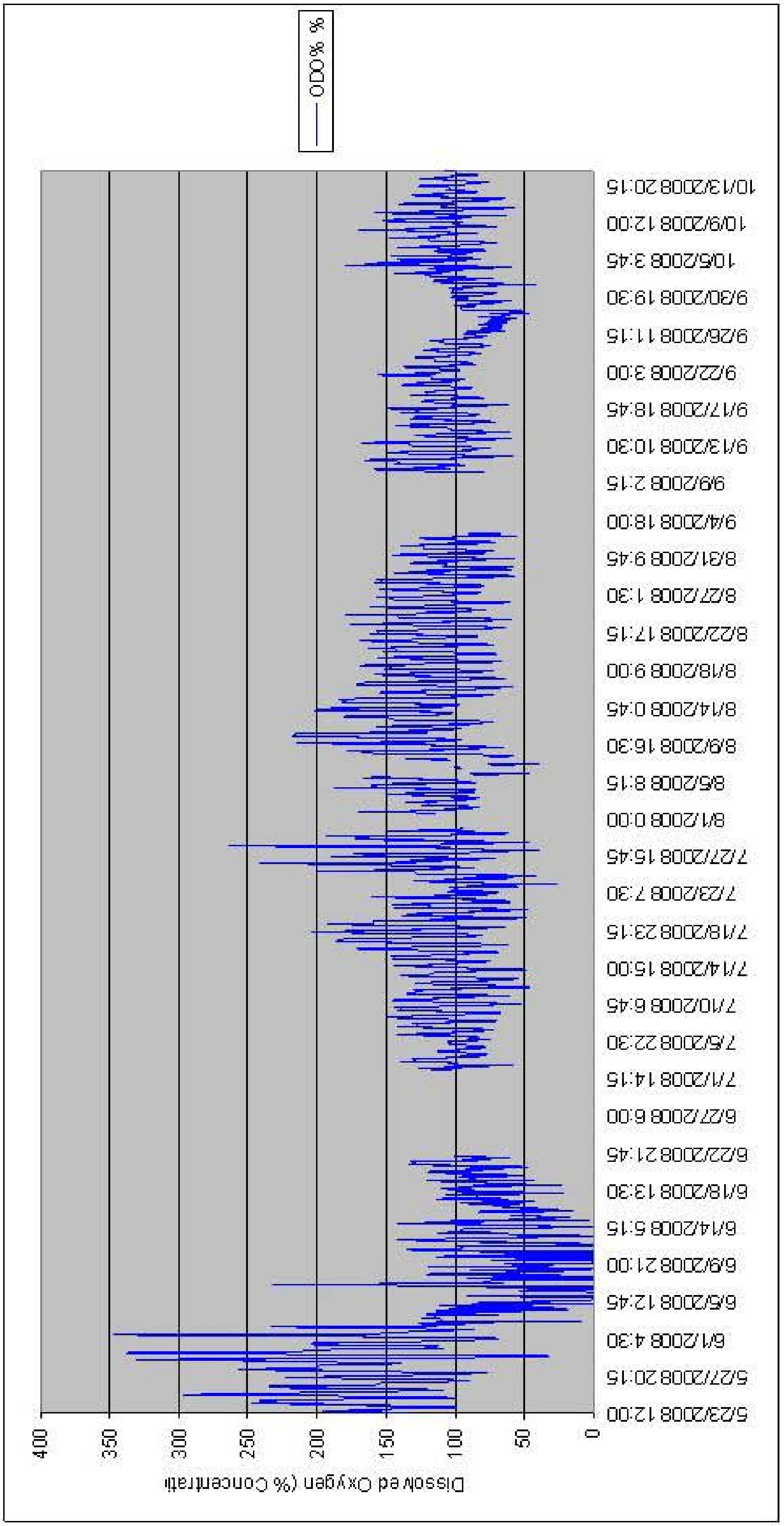


Figure 3-1, ILH Dissolved Oxygen % Concentration

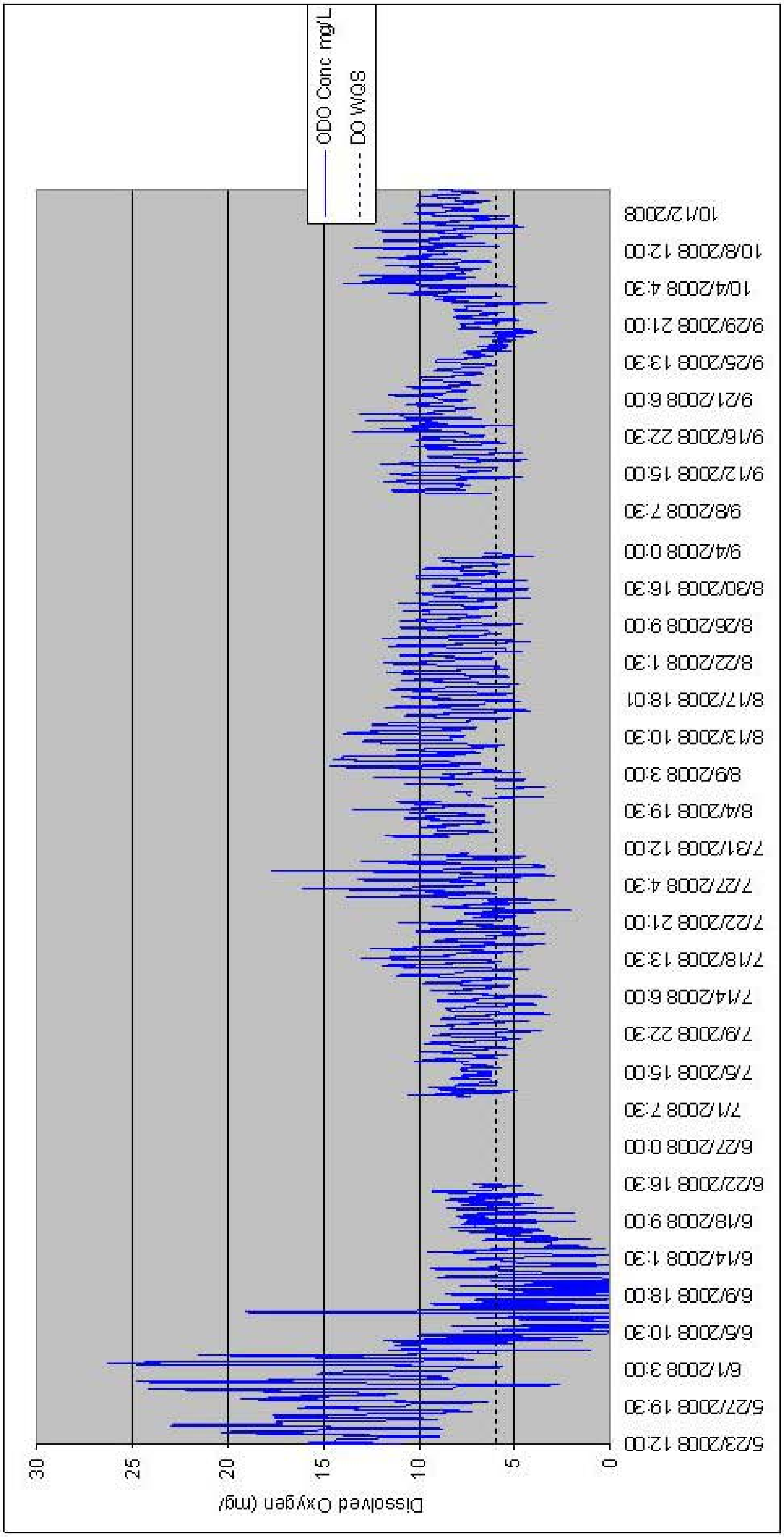


Figure 3-2, ILH Dissolved Oxygen, mg/L

this process could be due to natural life-cycle of the algae or due to generation and accumulation of metabolic by-products in the system that are toxic to the algae. Section 3.2 of the IEP study provides an extensive narrative regarding algae abundance and seasonal succession.

Dissolved Oxygen values (mg L^{-1}) collected during the monitoring period for the current monitoring initiative are presented in 3-2. For the time period 5/23 thru 6/2 the graph for DO concentration provides values that range from 3 to as high at 26 mg L^{-1} and by values that range from 0 to the high single digits following the tidal exchange when the gates were opened between 6/2-4/08. This is followed by a stabilization of concentration values that range between 3 and 18 mg $L^{-1}$for the reminder of the sampling period.

The Massachusetts Surface Water Quality Standards for Class SA waters at 314 CMR 4.05(4)(a)(1) indicate that dissolved oxygen shall not be less that 6.0 mg $L^{-1}$and that natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. In addition to the anoxic/hypoxic event described above dissolved oxygen concentrations in ILH frequently fall below the 6.0 mg/L L^{-1} minimum and therefore routinely violate the state water quality standards. In addition, the Wetlands Protection Act for resource areas such as Land Under the Ocean, 310 CMR 10.25, Land Under Salt Pond, 310 CMR 10.33, and Land Containing Shellfish, 310 CMR 10.34, recognizes that Land Under the Ocean is likely to be significant to the protection of marine fisheries and, where there are shellfish, to protection of land containing shellfish by provides feeding areas, spawning and nursery grounds and shelter for many coastal organisms related to marine fisheries. Factors critical to the protection of such interests include water circulation, water quality, finfish habitat, and important food for wildlife. Performance standards for these areas include: alterations of water circulation and changes in water quality, including, but not limited to, other than natural fluctuations in the levels of salinity, dissolved oxygen, nutrients, temperature or turbidity, or the addition of pollutants that would negatively impact these resource areas.

The periodic opening of the tide gate on 6/2/08 was associated with a prolonged anoxic/hypoxic event and the dissolved oxygen concentration in ILH routinely violates state water quality standards and thereby does not conform to the performance standards outlined in the Wetland Protection Act for relevant jurisdictional areas.

3.2 Temperature

Temperature (^{O}C) for ILH is represented by the blue line on the graph shown in Figure 3-3. Water temperature from NOAA Boston tidal station was obtained and used as a surrogate, or reference, for Massachusetts Bay exchanging with Little Harbor, and is represented by the yellow line. The water in ILH responds quickly to ambient air temperature and solar heating due to its large surface area and shallow depth. Due to this rapid responsiveness, ILH water temperature is most often higher than the reference coastal water temperatures of Massachusetts Bay. During the period from 5/23/08 thru 6/2/08, water temperatures were significantly higher in ILH than the reference temperature, in some cases by as much as 10 ^{O}C. Following the opening of the gates from 6/2-4/08, ILH water temperatures fell and approached background. However, once the tide gates were closed, water temperatures again quickly rose to a range of 24 – 28 ^{O}C. illustrating the very responsive nature of the system to changes environmental conditions. Figure 3-4 provides a detailed view of water temperature fluctuation in relation to tidal exchange and the influence of Little Harbor tidal water entering the ILH. An increase in water level from an incoming tide, as indicated by the dashed black line corresponds with a sharp drop in ILH water temperature, demonstrating the water temperature dependence on conditions associated with tidal exchange.

The Massachusetts Surface Water Quality Standards for Class SA waters at 314 CMR 4.05(4)(a)(2) state that temperature shall not exceed 85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°0C) and that there shall be no change from natural background that would impair any uses assigned to this class including those conditions necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms. This 29.4 °C temperature standard is represented as a dashed black line in Figures 3-2 and 3-3. Water temperatures in ILH exceeded this maximum on a number of occasions during the study period. More noticeable is the significant and prolonged departure from reference temperatures, with daytime water temperatures in ILH reaching as much as 10 °C above background. In addition to the direct consequences of thermal stress of organisms in ILH, there exists a secondary two-pronged ramification for high water temperature in this system. The Massachusetts Estuaries Project (MEP) investigation of critical indicators of nutrient and eutrophication states "temperature is an important indicator relating to system sensitivity to eutrophication through two processes. First, the solubility of oxygen is directly related to water temperature, with lower solubility at higher temperatures. Second, biological processes are positively related to temperature. Respiration rates (oxygen consumption) typically increased two-to three-fold for every 10 °C increase in water temperature. The result is higher rates of oxygen consumption from a smaller oxygen pool in summer. Due to these interrelationships with oxygen, warm water will generally be more sensitive to the organic matter production resulting from nitrogen than will colder waters" (MEP, 2003). Therefore, the increased water temperature in ILH due to its physical characteristics and limited exchange with cooler background water from Little Harbor and Massachusetts Bay may contribute significantly to the lower dissolved oxygen values presented and discussed above.

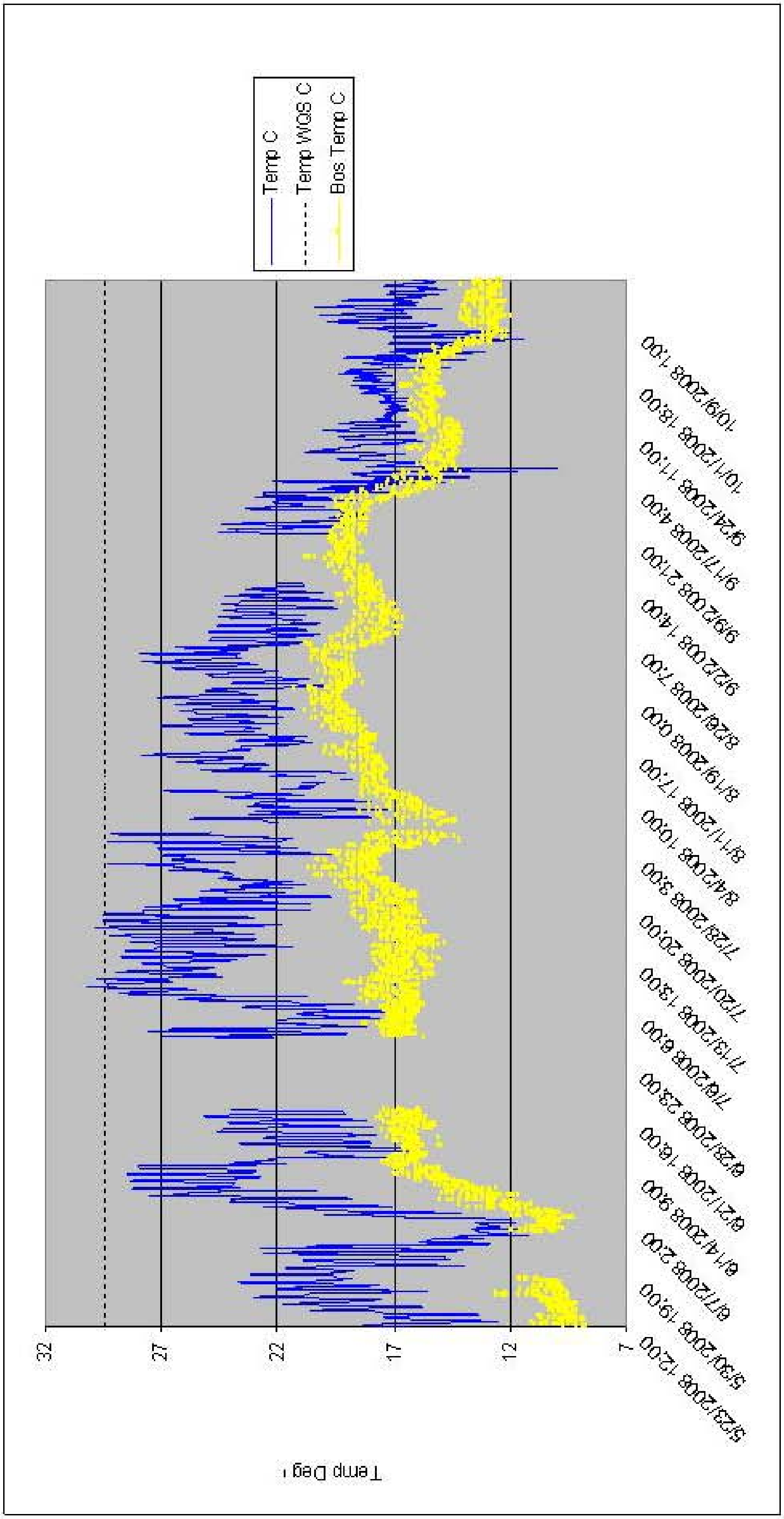


Figure 3-3, ILH Temperature 0^{C}

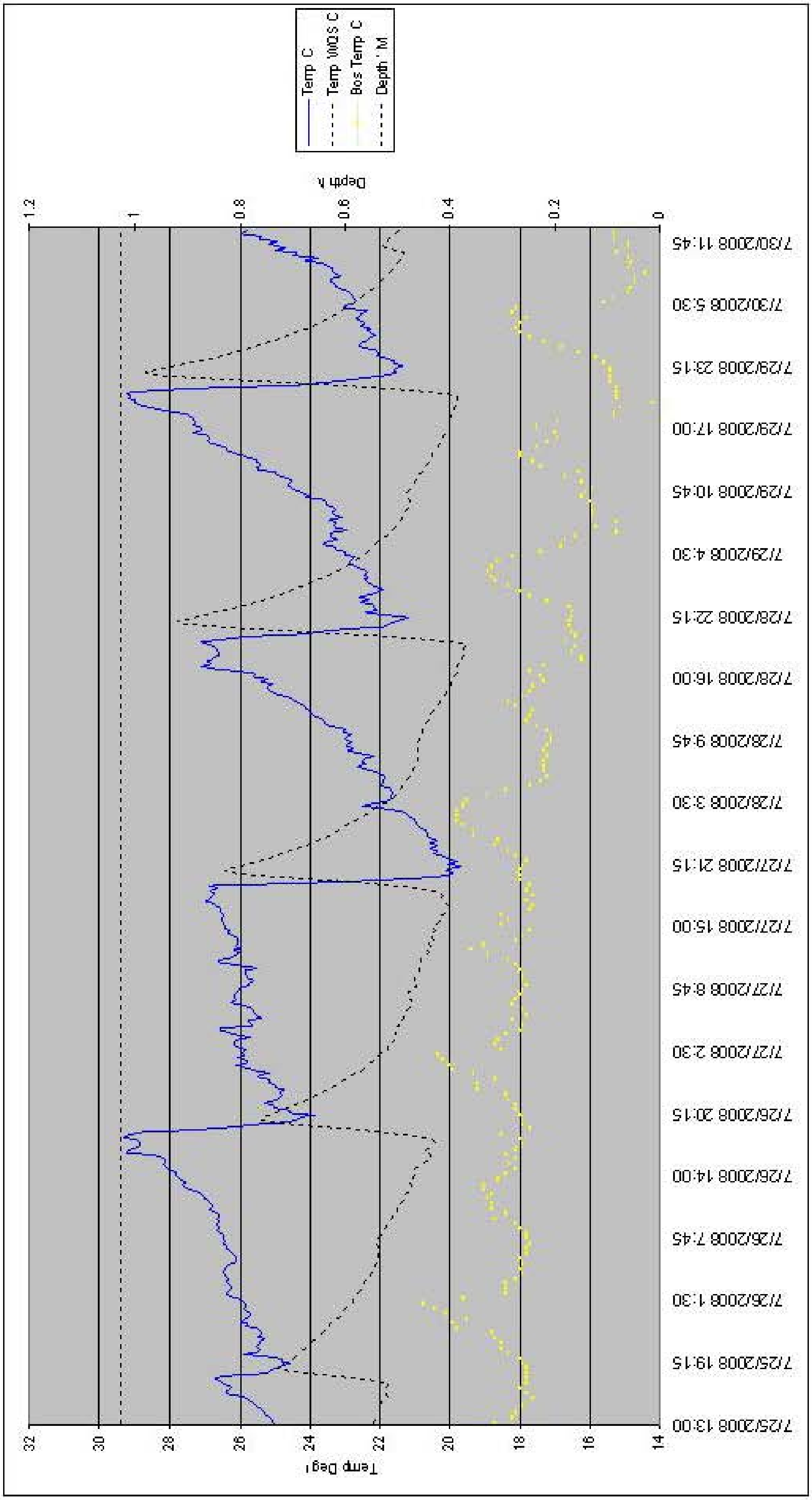


Figure 3-4, ILH Temperature 0C , detailed view

In addition, the Wetlands Protection Act for resource areas such as Land Under the Ocean, 310 CMR 10.25, Land Under Salt Pond, 310 CMR 10.33, Land Containing Shellfish, 310 CMR 10.34, and Coastal Beach (inclusive of tidal flats), 310 CMR 10.27 indicate these resources are likely to be significant to the protection of marine fisheries and, where there are shellfish, to protection of land containing shellfish by provides feeding areas, spawning and nursery grounds and shelter for many coastal organisms related to marine fisheries. Factors critical to the protection of such interests include water circulation, water quality, finfish habitat, and important food for wildlife. Performance standards for these areas include: alterations of water circulation, changes in water quality, including, but not limited to, other than natural fluctuations in the levels of salinity, dissolved oxygen, nutrients, temperature or turbidity, or the addition of pollutants that would negatively impact these resource areas.

3.3 Salinity

For the monitoring period, salinity in ILH ranged from approximately 24 - 33 parts per thousand (PPT) and is provided in Figure 3-5. For comparative purposes, fresh water has a salinity of 0 ppt and marine, or saltwater, has a salinity of approximately 32 ppt. What is important to note from the graph are the degree and duration of salinity depression associated with rainfall events. For example, Figure 3-6 depicts salinity in ILH from 7/17/08 thru 8/3/08. 24-hour rainfall data for the corresponding period, provided by the Cohasset Water Department, is depicted in the histogram portion of the chart. This rainfall resulted in a reduction in ILH salinity from approximately 32 to nearly 25ppt.

In addition to the degree of salinity depression it is also important to note the duration of salinity depression. Salinity levels did not recover until nearly 8/2/08 (data gap is due to retrieval/redeployment of the YSI sonde for periodic data download and servicing). Figure 3-6 also depicts sharp changes in salinity associated with exchanges of high salinity Little Harbors waters. As discussed in Section 1.2, the main body of Little Harbor covers an area of approximately 154 acres while ILH occupies approximately 18 acres. The contributing watershed areas are approximately 655 acres and 246 acres, respectively. Thus, ILH has, by proportion, a greater contributing watershed area than Little Harbor and a direct source of freshwater from Richardson Brook. The tide gates at Cat Dam impound fresh water inputs to ILH by limiting tidal exchange. These factors combine to increase the extent and duration of salinity depressions associated with local precipitation events. Further, the salinity depression referenced and depicted in Figure 3-6 took place in late July and early August when evapotransporation was high, associated groundwater and stream flows would be corresponding low, and retention in the contributing watershed would be at a seasonal high (e.g. uptake of rainwater by vegetation and soils). These factors would contribute to a reduction in the amount of precipitation that made it to ILH as runoff, or from inputs from streams or groundwater.

Salinity is one of the most fundamental elements within estuarine systems in determining zonation patters within the system and can influence both plant and animal community composition and structure. A number of estuarine fish and invertebrates have the ability to exist within a range of salinities. Many do this through actively pumping salt from

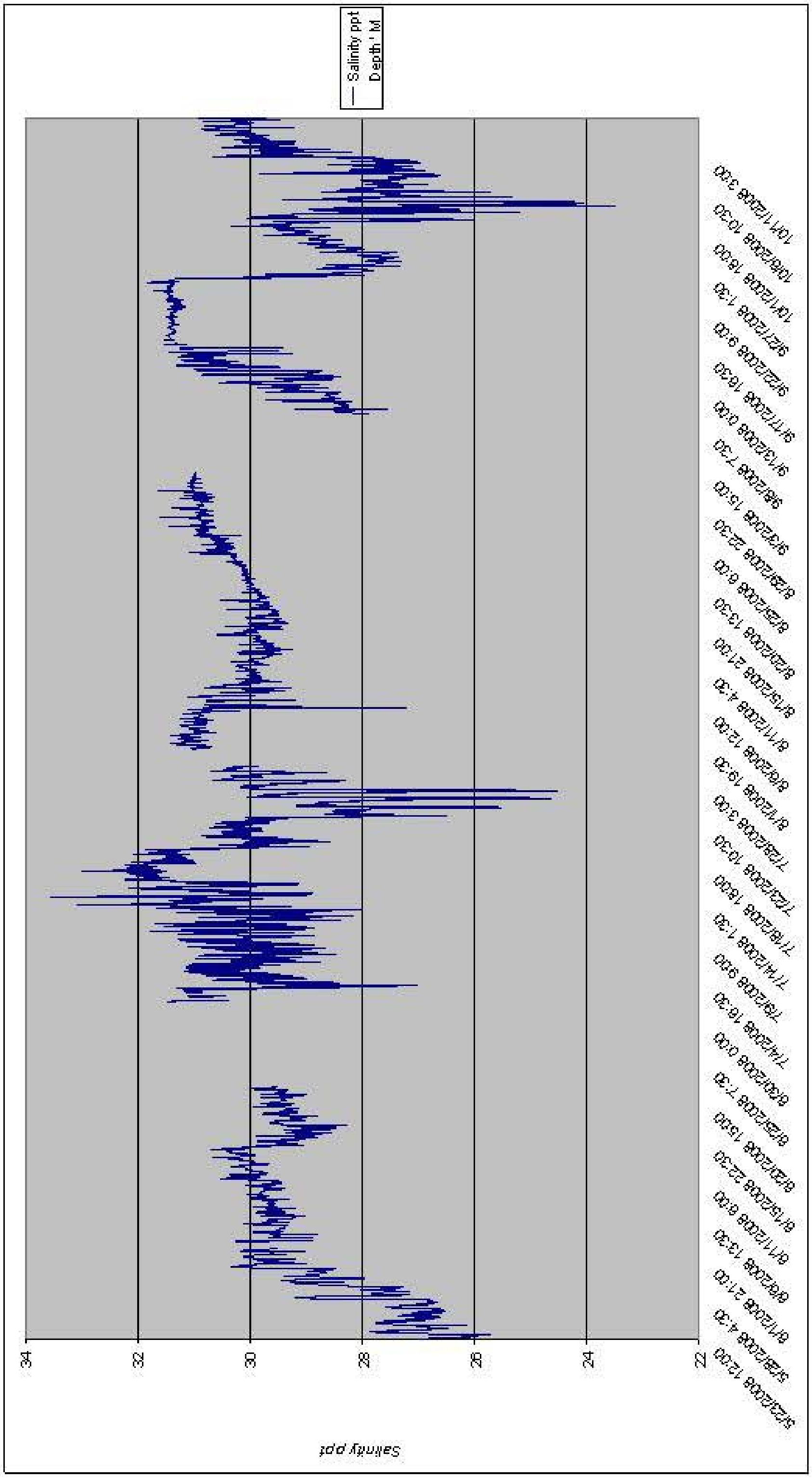


Figure 3-5, ILH Salinity (ppt)

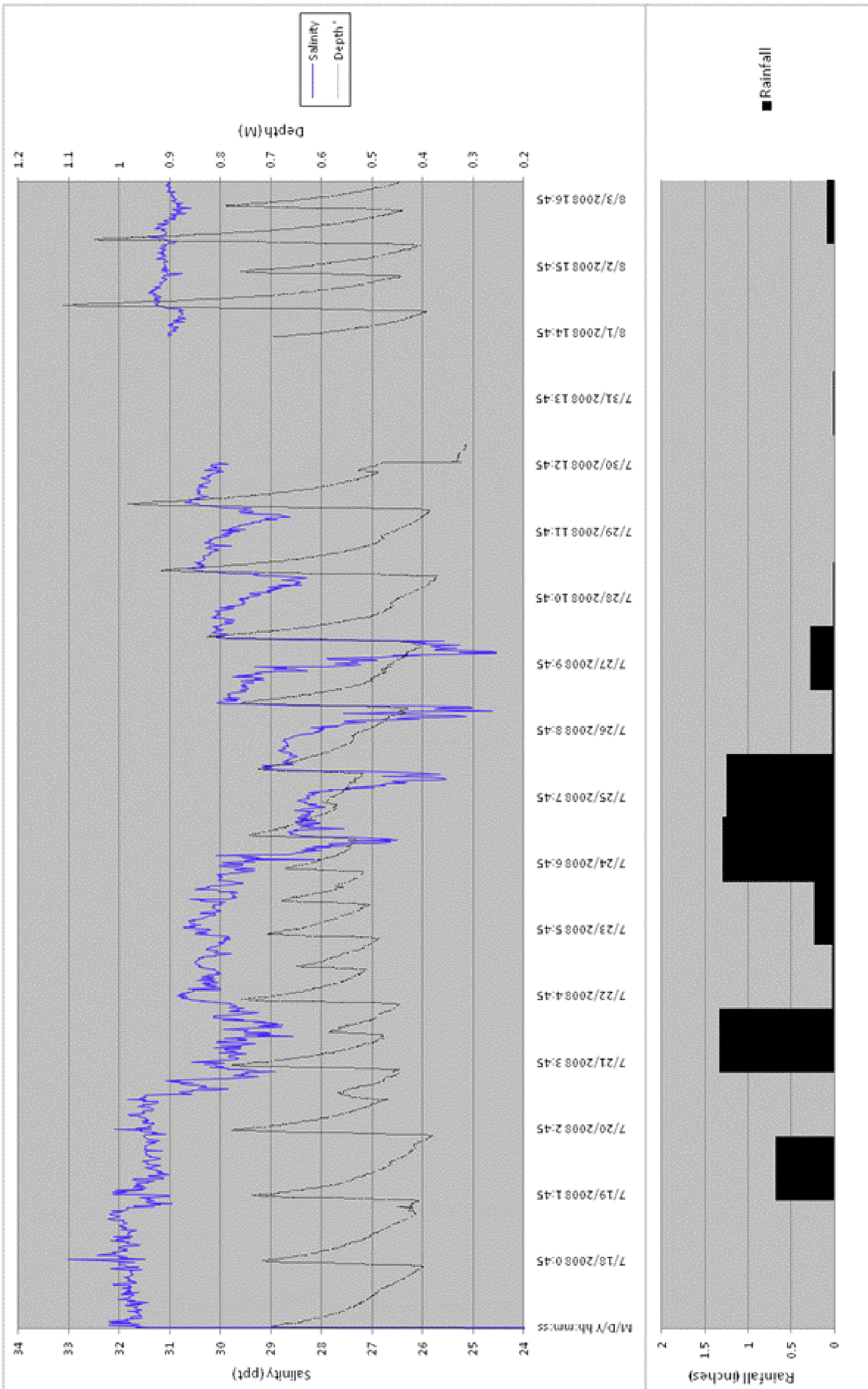


Figure 3-6, ILH Salinity w/depth and precipitation

their bodies (osmo-regulators) or by conforming their body chemistry to accommodate for changes in water column salinity (osmo-conformers). However, to do this is energetically costly and dramatic or prolonged shifts in water column salinity can overwhelm an organism's ability to accommodate for salinity changes. Physiological stress due to dramatic or prolonged shifts in salinity can also predispose an organism to secondary impacts associated with other environmental conditions such as high water temperatures or low dissolved oxygen.

The Massachusetts Surface Water Quality Standards do not have specific values for salinity. However, the Wetlands Protection Act, for resource areas including Land Under the Ocean, 310 CMR 10.25, Land Under Salt Pond, 310 CMR 10.33, and Coastal Beach (inclusive of tidal flats), 310 CMR 10.27 has performance standards that include: alterations of water circulation, changes in water quality, including, but not limited to, other than natural fluctuations in the levels of salinity, dissolved oxygen, nutrients, temperature or turbidity, or the addition of pollutants that would negatively impact these resource areas.

Regulations for Salt Marsh resource areas, 310 CMR 12.32(1)(b) indicate characteristics critical to the protection of WPA interests include the flow and level of tidal and fresh water (for protection of marine fisheries and wildlife habitat, prevention of pollution). Regulations for Land Containing Shellfish, 310 CMR 10.34(4) states any project on land containing shellfish shall not adversely affect such land or marine fisheries by a change in the productivity of such land caused by: alterations of water circulation, alterations in natural drainage from adjacent land, or changes in water quality, including, but not limited to, other than natural fluctuations in the levels of salinity, dissolved oxygen, nutrients, temperature or turbidity, or the addition of pollutants.

3.4 Chlorophyll *a*

Chlorophyll *a* observations during the 2008 field season for ILH are provided in Figure 3-7 and Figure 3-8. For the initial sonde deployment, chlorophyll *a* was recorded in Relative Fluorescence Units and for the remainder of the monitoring season recorded in ug L^{-1} (Figure 3.7). An initial spike in chlorophyll, as expressed as RFU, followed the 6/2 - 4/08 tide gate opening. The chlorophyll sensors are not sensitive to the presence of large or fixed primary producers like algal species such as *Schizomeris* and *Chlorhormidium* and the apparent chlorophyll spike may be due to changes in the phytoplankton assemblage accompanying the tidal exchange with Little Harbor. Figure 3-8 depicts changes in chlorophyll associated with tidal exchange. In this figure increases in chlorophyll concentrations are periodically reduced by the incoming tide from Little Harbor.

Chlorophyll *a* is a physical water quality parameter that measures pigment in phytoplankton. This parameter is related to water column clarity and primary production associated with nutrient loading and can be a significant quantitative indicator of nutrient enrichment within an embayment (Howes, et al 2003).

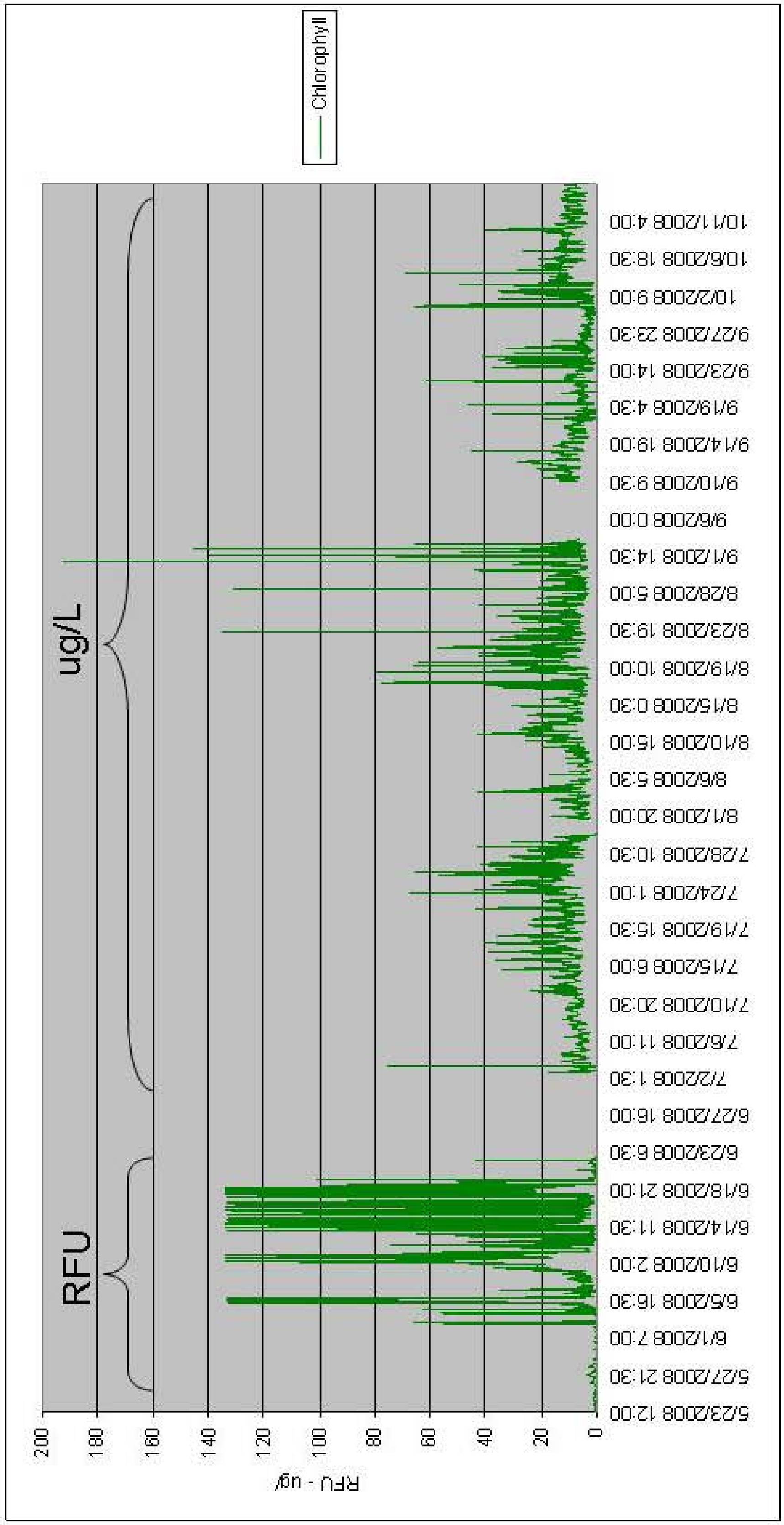


Figure 3-7, ILH Chlorophyll *a*

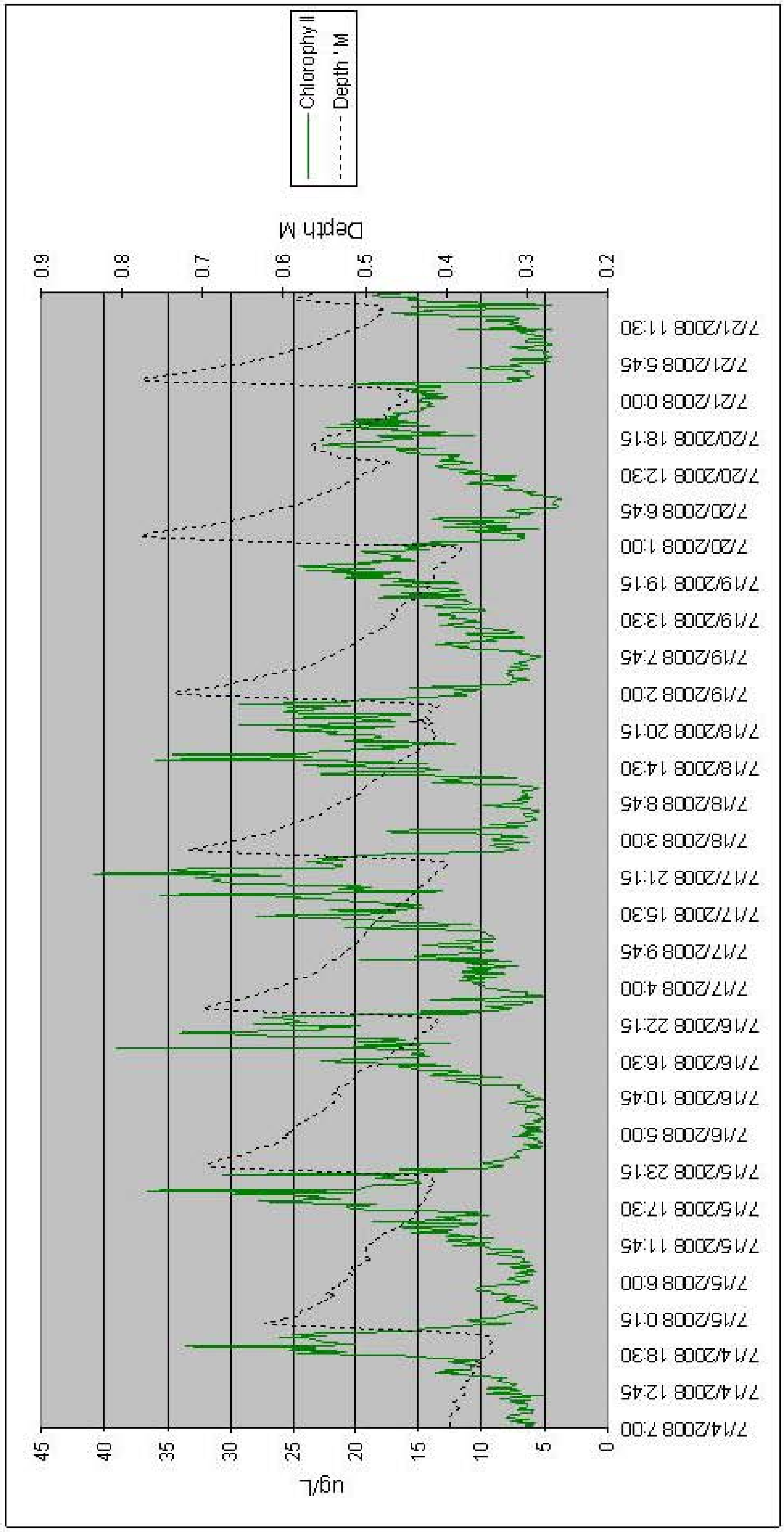


Figure 3-8, Chlorophyll a detailed view w/tide depth

While the Massachusetts Surface Water Quality Standards do not have specific values for chlorophyll, the Massachusetts Estuaries Project (Howes, et al 2003) has developed a tiered classification for nutrient-impaired or eutrophic systems. Within this classification scenario, chlorophyll *a* levels to around 10 ug L^{-1}, are associated with systems characterized as moderately impaired health and systems with chlorophyll a levels of approximately 20 ug L^{-1} area characterized as significantly impaired.

3.5 Additional Minimum Criteria Applicable to all Surface Waters

In addition to the Standards for Class SA waters, 314 CMR 4.05(5) provides Additional Minimum Criteria Applicable to all Surface Waters. These include:

(a) Aesthetics. All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.

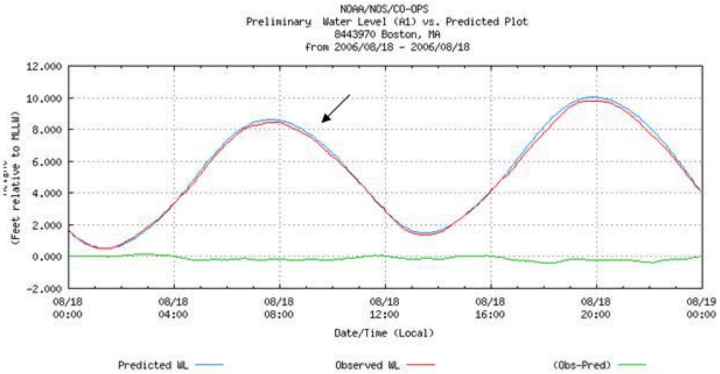
(b) Bottom Pollutants or Alterations. All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms.

(c) Nutrients. Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses.

As described above, ILH suffers from nuisance algae blooms and odor. The IEP report indicates that organic loading has resulted in highly organic sediments indicative of eutrophic systems. Nutrient levels in ILH (CDM 1999) are sufficient to cause the proliferation of algae mats in such densities to lead to the eutrophication of the embayment.

4.0 Fisheries and Wildlife Considerations

Construction and operation of the current tide gate mechanism is described in Section 1.4 and depicted in Figure 1-3. The current gate configuration and operation is not well suited to support fish passage. As depicted in Figure 3-1 and Appendix A, not all tides are of sufficient height to open the current tide gates. When tides are of sufficient height to open the gates the duration of the opening is relatively short relative to the tidal exchange dynamics of Little Harbor. As example, Figure 4.1 shows a school of small fish congregated on the Little Harbor side of the tide gates. The NOAA (National Oceanic and Atmospheric Administration) Boston tide records indicates low tidal amplitude for the existing tide gate for this tide preventing the opening of the tide gates and the fish were not able to enter ILH.



For fish and other organisms trying to exit ILH, the tide gate design also presents challenges. Although exiting tides can spill over the top of the tide gates there is no plunge pool designed into the bottom of the culvert spillway. A plunge pool is a water-filled depression at the base of a waterfall or spill way that absorbs and dissipates water energy so that fish and other organisms that are carried in the water over the falls are not injured after landing. There is no such design feature in the Cat Dam spillway. Figure 4-2 shows the bottom of the Cat Dam spillways consist of a concrete slab. This would provide fish or other organism carried over the top of the tide gates by ebbing water minimal protection from injury due to impact with the concrete pad of the channel bottom.

5.0 Conclusions and Recommendations

In response to concerns regarding water quality impairment, habitat degradation, and aesthetics several studies have been commissioned by the Town of Scituate. These investigations have clearly linked the tide gates at Cat Dam to the water quality and impairment of this resource area. This study, which utilized in-situ monitoring equipment to obtain long-term high temporal resolution data not provided in previous studies, documented water quality impairments to dissolved oxygen, salinity, and temperature. Each of these parameters does not meet numerical state water quality standards for the resource water's classification and/or were not consistent with standards for relevant jurisdictional areas under the WPA. ILH also did not meet the additional minimum criteria for all surface waters for Aesthetics and Bottom Pollutants or Alterations as described in Section 3.5. The tide gates also fragment ILH from LH posing a barrier to fish and wildlife passage thereby reducing ecological continuity and habitat integrity. Further, utilizing the tiered habitat quality classification as described by Howes for a Class SA water ILH would fall within the Significantly Impaired Health classification based on nitrogen levels (as described in the CDM report), Chlorophyll *a*, large phytoplankton blooms, significant macro-algal blooms, aesthetic/odor problems, and periodic hypoxia.

Recent conversations regarding tide gate operation have focused exclusively on increasing the number of day in which the tide gates are left open (i.e. increasing days open from two to four or five). However, as the CDR report indicates, this may provide temporary benefit while that gates are open but once closed eutrophic conditions quickly return. This would also be the case for temperature and salinity dynamics and would also still significantly limit fish and wildlife passage for the time when the gates are in a closed position. In order to address water quality degradation, ecological impairment, and habitat impairment associated with the existing tide gates at Cat Dam the Operations and Maintenance Plans/Notice of Intent should provide for greater tidal exchange taking in to consideration the degree, duration, and frequency of tidal exchange. A range of potential options should be considered including, but not limited to:

- Using the existing chain stays to keep one of the tide gates in an open position or removal of a single gate. This would allow for improved tidal exchange and fish and wildlife passage while increasing draw-town time thereby extending water sheet coverage for a greater percentage of the tidal cycle.

- Removing several of the 6x6 timbers from the *bottom* of the tide gates allowing for greater tidal exchange and fish passage. Removing timbers from the top of the tide gate would also allow for greater tidal exchange. However, this would not provide for fish and wildlife passage as there is no plunge pool to dissipate energy associated with the waterfall. Contemporary "fish-friendly" tide gates open from the bottom to provide for effective fish passage. Removal of timbers from the bottom of the existing tide gates would replicate this feature.

- Opening or removing all of the tide gates. This option would maximize potential water quality, habitat, and ecological continuity benefit. As the trajectory (rate and extent) of ecological mitigation/restoration is based on the level of impairment and the degree of restorative action this option would provide the most immediate and greatest potential restoration of ILH.

Regardless of the option for improving tidal exchange and fish and wildlife passage, as defined by the O&M plan and associated Order of Conditions, an ongoing monitoring initiative is necessary to determine the efficacy of management actions and, if necessary, the need for additional mitigation actions. The MBP, CZM/WRP, and the Center for Student Coastal Research has indicated a commitment to continued technical assistance through restoration monitoring to help inform management of this coastal resource area.

As ecological mitigation and restoration involves a variety of cross-cutting disciplines and issues CZM recommends the Conservation Commission and Town Manager convene an ad-hoc advisory group of relevant state and federal resource agency staff to assist the town in the identification and evaluation of tide gate operation scenarios during the development of the NOI. Provided below are agency staff and contact information for consideration.

Christian Krahforst,	MBP	Christian.Krahforst@state.ma.us
Sara Grady, Ph. D	MBP	Sara@nsrwa.org
Hunt Durey	CZM/WRP	Hunt.Durey@state.ma.us
Jason Burtner	CZM	Jason.Burtner@state.ma.us
Margo Clerkin	MA DEP	Margo.Clerkin@state.ma.us
Gregory DeCeaser	MA DEP	Gregory.DeCeseare@state.ma.us
Eileen Feeney	MA DMF	Eileen.Feeney@state.ma.us
Eric Hutchins	NOAA/NMFS	Eric.Hutchins@noaa.gov
Eric Derlith	US FWS	Eric_Derleth@fws.gov
Ed Reiner	US EPA	reiner.ed@epamail.epa.gov

REFERENCES:

Brian L. Howes, Roland Samimy, Brian Dudley For: Massachusetts Department of Environmental Protection (DEP), July21, 2003, Revised: September 16, 2003, Revised: December 22, 2003. Massachusetts Estuaries Project Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators Interim Report http://www.mass.gov/dep/water/resources/nitroest.pdf

Camp, Dresser & McKee, December 1999. Final Report, Town of Cohasset: Little Harbor Water Quality Monitoring Report;

IEP, Inc. October, 30, 1991. Final Report, Diagnostic/Feasibility Study of Inner Little Harbor, Cohasset

Weston & Sampson, November 1, 2006. Nichols Road Dam – Inspection/Evaluation Report

Appendix A

Inner Little Harbor Bathymetry

IEP, Inc.

October 1991

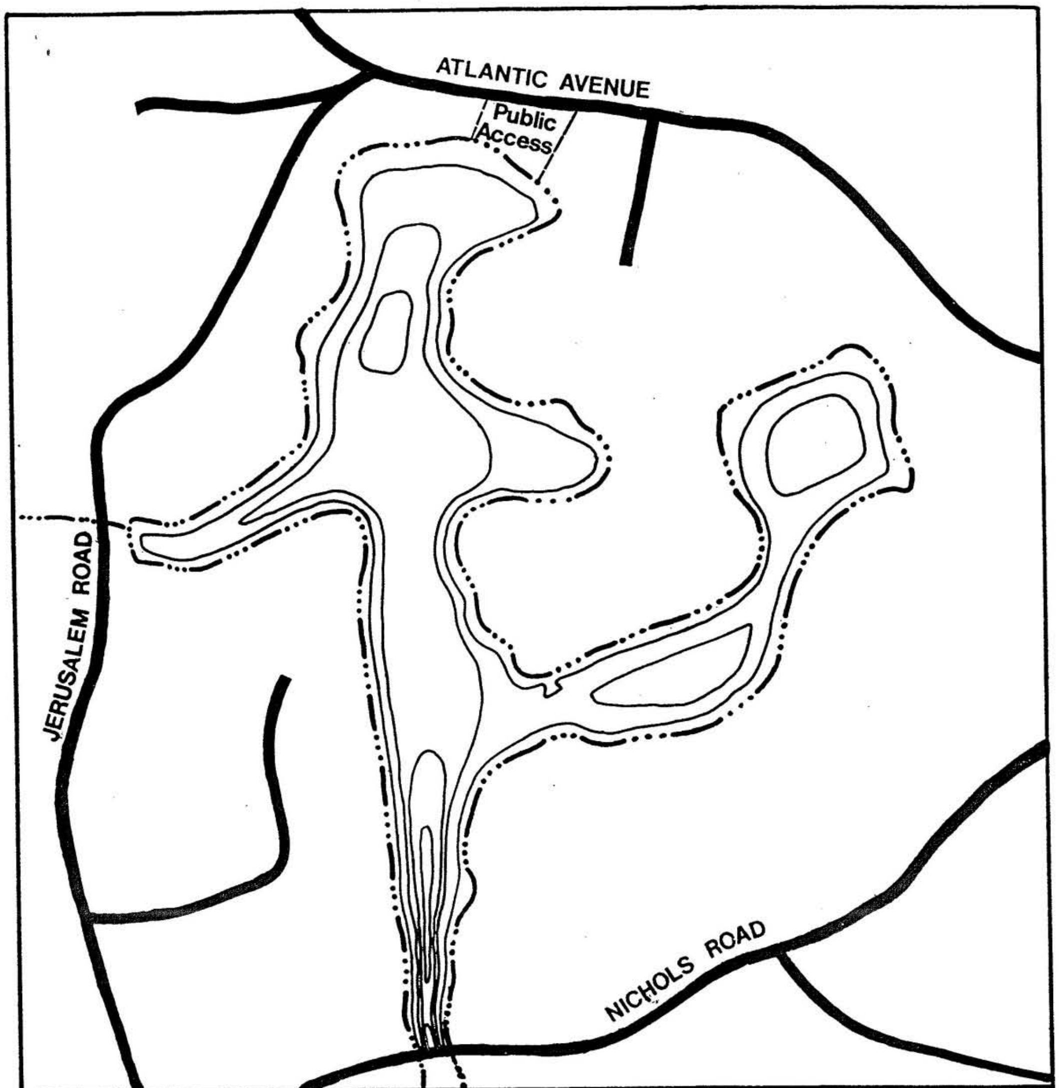


FIGURE 2:
BATHYMETRY
(Contours at 1-foot intervals)

INNER LITTLE HARBOR,
COHASSET, MA

DIAGNOSTIC/FEASIBILITY STUDY
PREPARED FOR THE
TOWN OF COHASSET
BOARD OF SELECTMEN

SCALE IN FEET
0 285 570 855

iEP inc.

Appendix B

June 2007 and June 2008 Algae Coverage


6/11/2007 7:44:33 AM


6/11/2007 7:45:29 AM


6/11/2007 7:49:18 AM


6/11/2008 9:39:39 AM


6/11/2008 9:40:42 AM

Appendix C

CDM 1999 Tidal Data
And
CZM 2006 Tidal Data

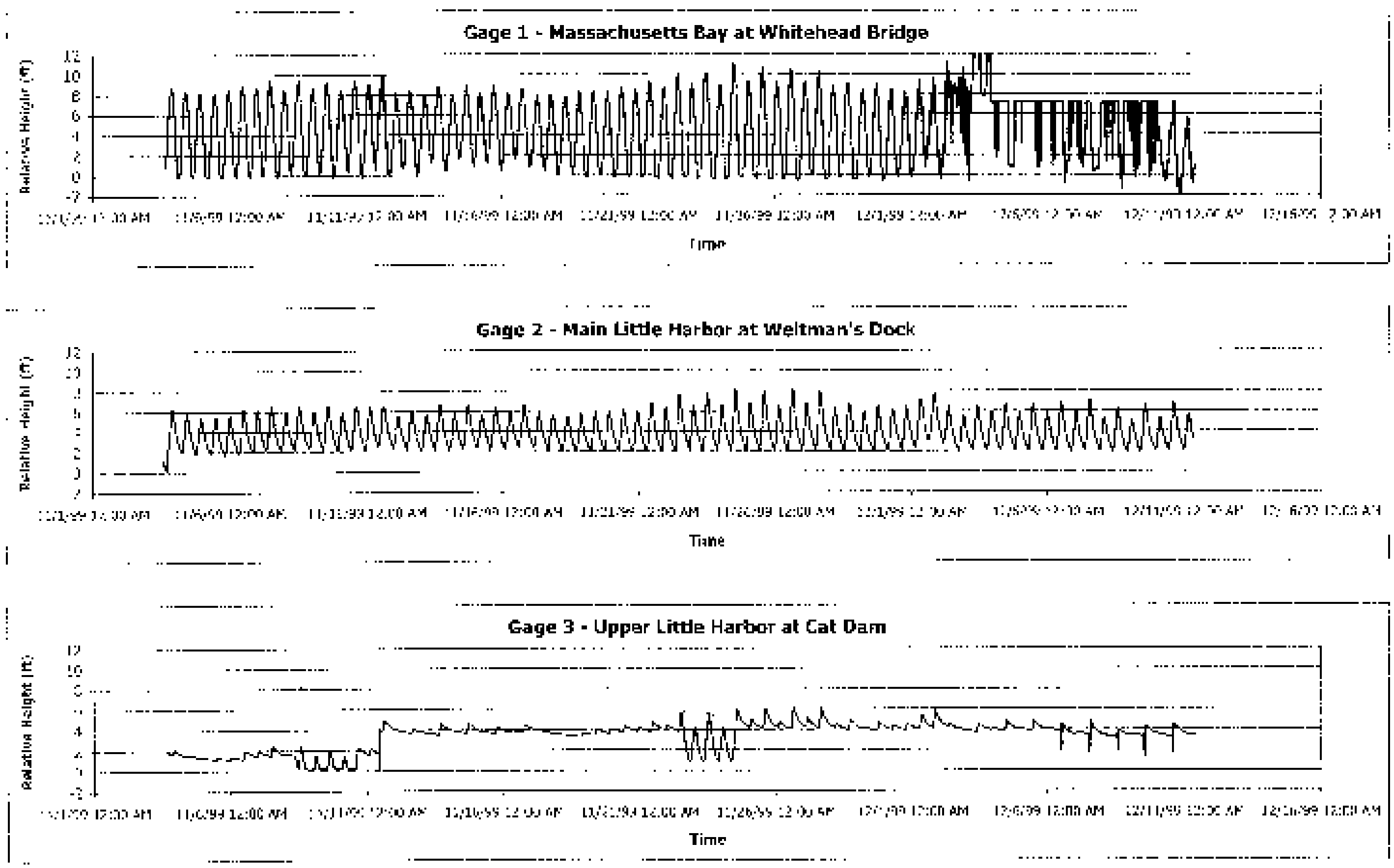
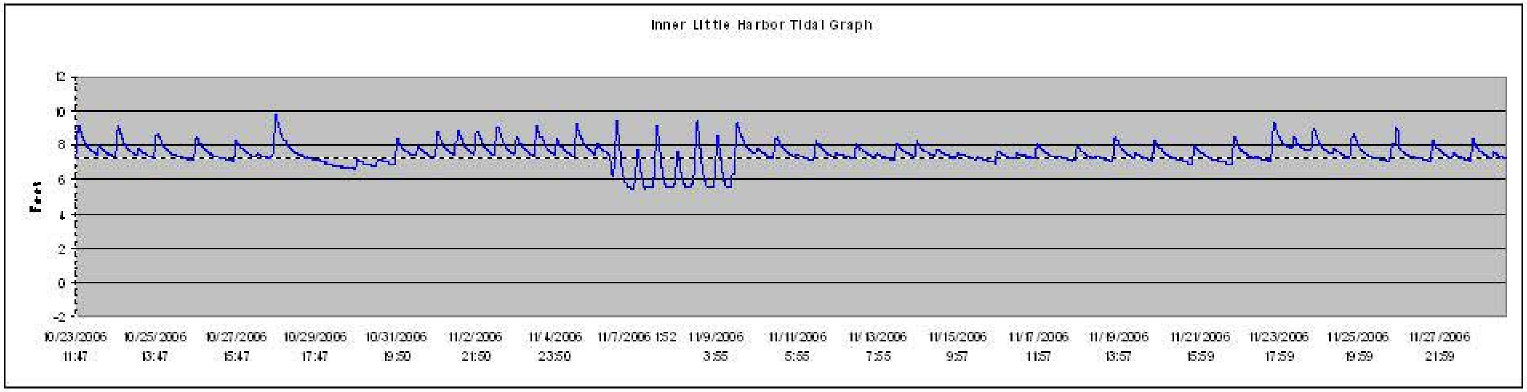
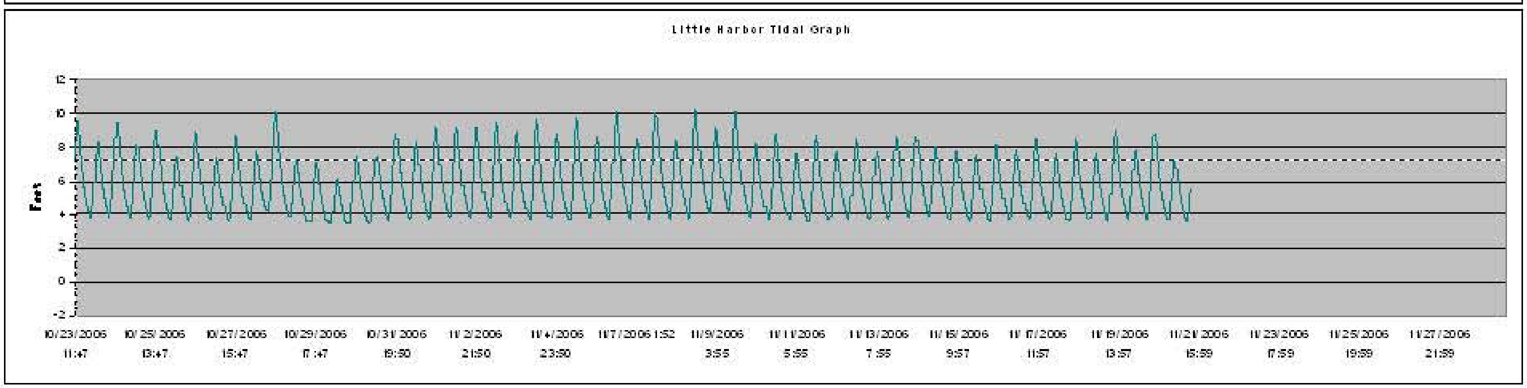


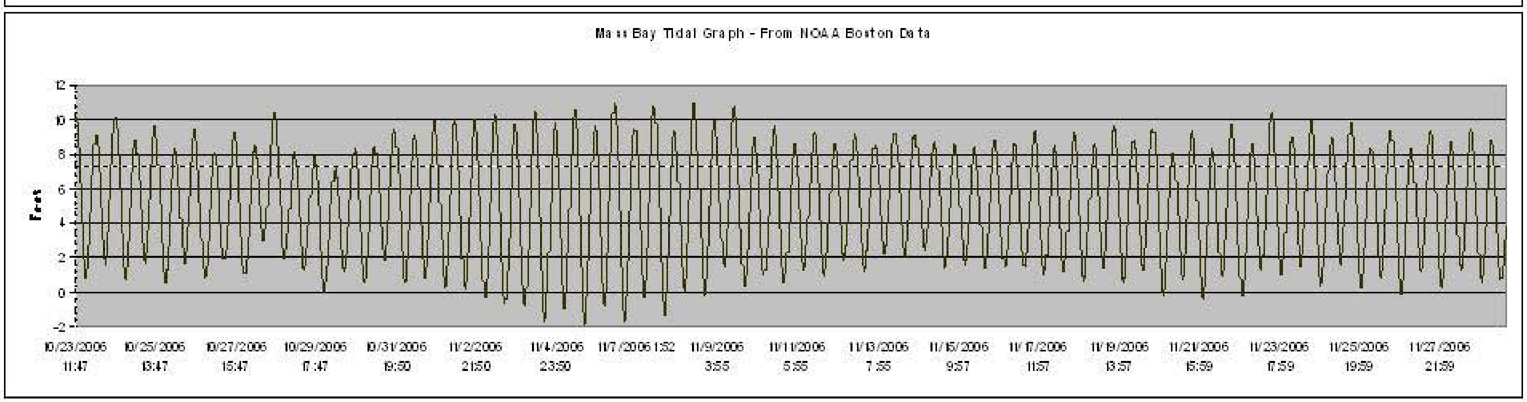
Figure 2-33
Results of Tide Gaging for
Massachusetts Bay, Main Little Harbor, and Upper Little Harbor
Cohasset, MA



Inner Little Harbor Tidal Graph
Feet
12
10
8
6
4
2
0
-2
10/23/2006 11:47
10/25/2006 13:47
10/27/2006 15:47
10/29/2006 17:47
10/31/2006 19:50
11/2/2006 21:50
11/4/2006 23:50
11/7/2006 1:52
11/9/2006 3:55
11/11/2006 5:55
11/13/2006 7:55
11/15/2006 9:57
11/17/2006 11:57
11/19/2006 13:57
11/21/2006 15:59
11/23/2006 17:59
11/25/2006 19:59
11/27/2006 21:59



Little Harbor Tidal Graph
Feet
12
10
8
6
4
2
0
-2
10/23/2006 11:47
10/25/2006 13:47
10/27/2006 15:47
10/29/2006 17:47
10/31/2006 19:50
11/2/2006 21:50
11/4/2006 23:50
11/7/2006 1:52
11/9/2006 3:55
11/11/2006 5:55
11/13/2006 7:55
11/15/2006 9:57
11/17/2006 11:57
11/19/2006 13:57
11/21/2006 15:59
11/23/2006 17:59
11/25/2006 19:59
11/27/2006 21:59



Mass Bay Tidal Graph - From NOAA Boston Data
Feet
12
10
8
6
4
2
0
-2
10/23/2006 11:47
10/25/2006 13:47
10/27/2006 15:47
10/29/2006 17:47
10/31/2006 19:50
11/2/2006 21:50
11/4/2006 23:50
11/7/2006 1:52
11/9/2006 3:55
11/11/2006 5:55
11/13/2006 7:55
11/15/2006 9:57
11/17/2006 11:57
11/19/2006 13:57
11/21/2006 15:59
11/23/2006 17:59
11/25/2006 19:59
11/27/2006 21:59

Appendix D

Low Tide Elevation/Restriction


1/9/2008 9:26:52 AM


1/9/2008 9:32:07 AM


1/9/2008 9:27:45 AM

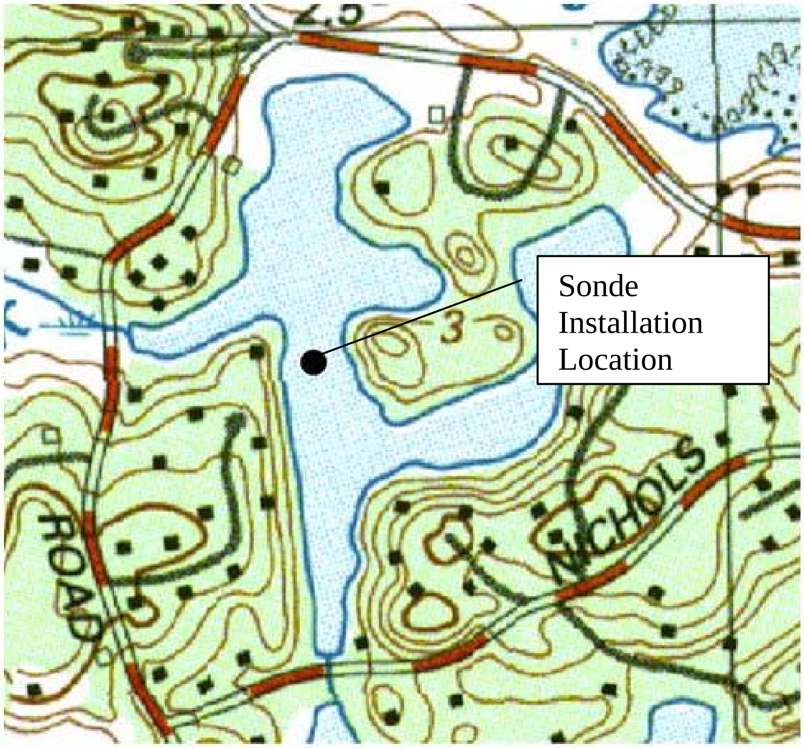

1/9/2008 9:32:53 AM

Appendix E

YSI 6600 Installation Location

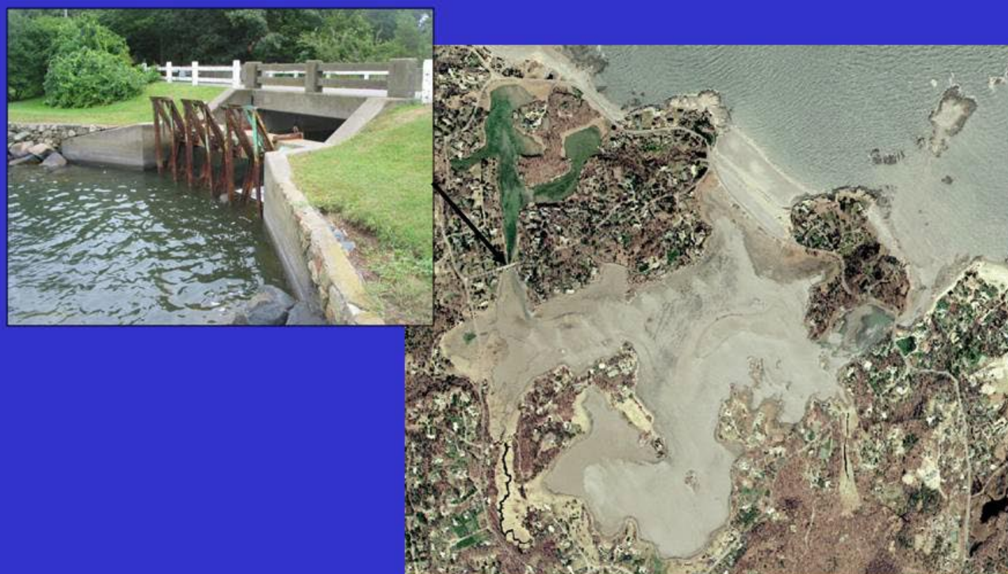
and

Installation Mock-Up


Sonde
Installation
Location
3
ROAD
NICHOLS

December 19th, 2006
Immer Little Harbor Presentation

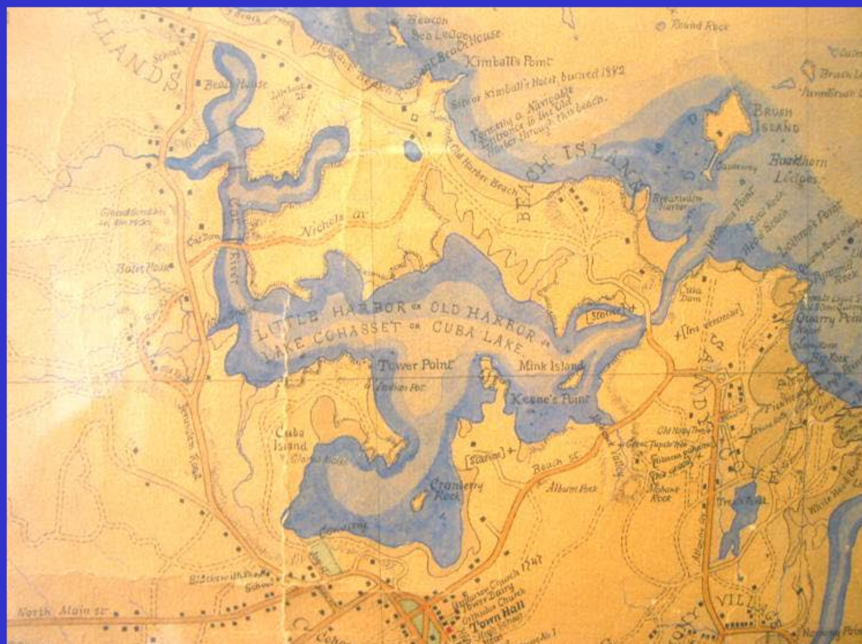
Cohasset Inner & Little Harbors
Cat Dam



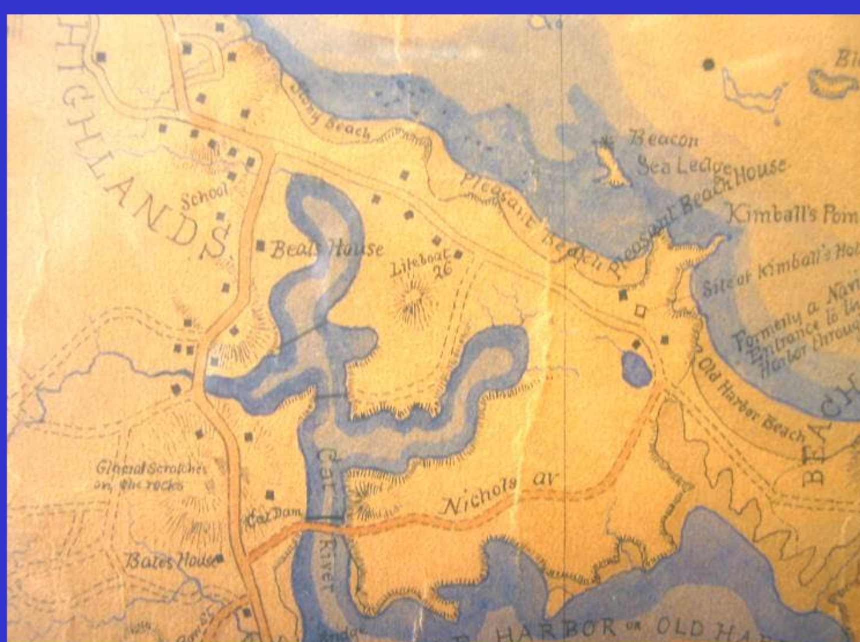
Cohasset Inner & Little Harbors
Cat Dam

- Previous Studies
- CZM Tidal Monitoring
- Current Operation
- Condition of Tide Gate and Supporting Structure
- "Leakage"

The Historic View



The Historic View



Previous Studies: 1991 IEP

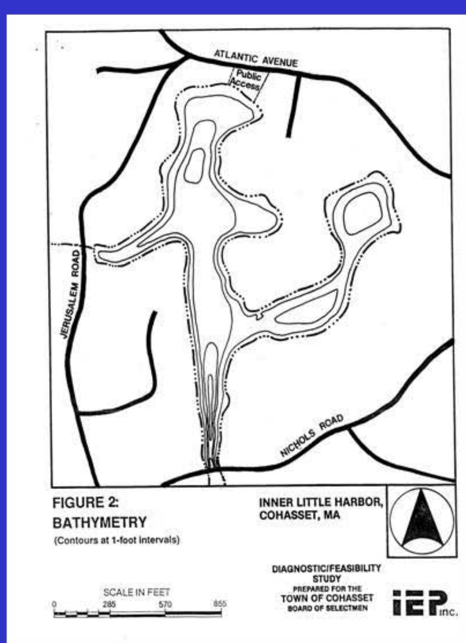
ILH Characteristics per IEP Study:

Large areas of substrate overlain by shallow water. (This provides optimal conditions of temperature and lighting for the epipelic state of algae growth.

Thick deposits of nutrient-rich, organic sediment. (This sediment provides an abundant source of the nutrients required for algae growth).

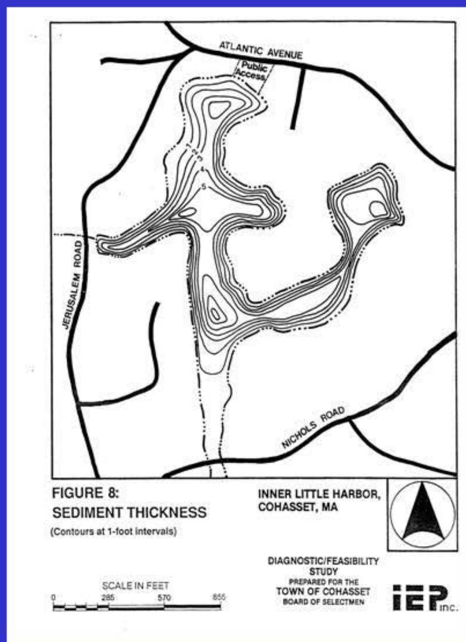
Quiescent water with little internal circulation and limited flushing with the main estuary beyond Cat Dam. The lack of energetic water movement within Inner Little Harbor allows canopy and mat formation by the algae to progress undisturbed and with maximum efficiency).

Previous Studies: 1991 IEP



Watershed Area	226 ac
Surface Area	17.8 ac
Maximum Depth	5 ft
Mean Depth	1.7 ft
Volume	1,290,341 cu ft
0 to 1 ft	671,690 cu ft – 52%
1 to 2 ft	429,518 cu ft – 33%
2 to 3 ft	165,780 cu ft – 13%
3 to 4 ft	21,444 cu ft – < 2%
5 to 5 ft	1,909 cu ft – < 1%

Previous Studies: 1991 IEP



Sediment thickness ranged from 0 – greater than 7.0 feet

At both monitoring stations greater than 10% of sediment is organic, characteristic of eutrophic systems

Organic compounds in sediment are derived largely from littoral vegetation and the remains of mat algae and planktonic organisms.

Previous Studies: 1999 CDM Study

Little Harbor Water Quality Study

Study Components:

- Shoreline Survey
- Infrared Study
- Monthly Harbor Monitoring (12 stations)
- Dry – Weather Discharge Sampling
- Wet - Weather Discharge and Harbor Sampling
- Tidal Gaging and Flushing Study

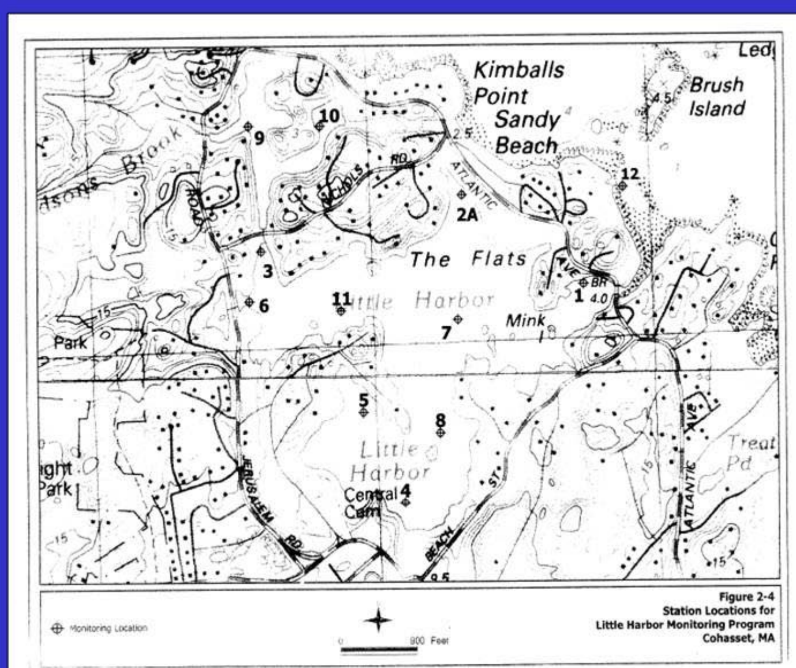
Previous Studies: 1999 CDM Study

LH/ILH Characteristics per CDM Study:

Harbor monitoring data suggests that overall water quality of the MAIN Little Harbor is very good. Nutrient levels are generally not found to be elevated throughout most parts of the harbor. Most likely, it is the significant and constant flushing that occurs in the Main Harbor that keeps nutrient levels from rising.

The Inner Little Harbor, however *does* show evidence of increased organic activity along with elevated nutrient levels when compared to the Main Harbor and Mass Bay. The data suggest a typical patter of higher nutrients and organic and algal activity in the Inner Harbor and around monitoring locations in the Main Harbor that are close the Inner Harbor.

Previous Studies: 1999 CDM Study



Previous Studies: 1999 CDM Study

LH/ILH Characteristics per CDM Study:

DON and POC are often higher in the Inner Little Harbor when compared to the average concentrations in Little Harbor and Mass Bay.

Similar trends are observed with Chlorophyll-a and Phaeophyton, indicating some increased levels observed in Inner Little Harbor on several sampling rounds, with the Main Harbor generally being comparable to those levels measured in Mass Bay.

Temperature is almost always higher and dissolved oxygen and saturation are almost always lower in the Inner Harbor than in the Main Harbor

Previous Studies: 1999 CDM Study

LH/ILH Characteristics per CDM Study: Nutrient Loading

The nutrient loading model suggests that the major contributor to the nutrient load is residential septic sources, with nutrients from lawn fertilization also contributing significantly. Also, the relative contribution of the residential septic load is greater in the inner Little Harbor than in the Main Little Harbor – there is a higher density of homes in the Inner Little Harbor.

Previous Studies: 1999 CDM Study

LH/ILH Characteristics per CDM Study: Nutrient Loading

Since the Inner Little Harbor shows signs of elevated nutrients and algal activity, and since residential septic is a significant portion of the load, sewering portions of the Inner Little Harbor might have more of an impact to reducing the nutrient load into the Inner Little Harbor.

The Main Little Harbor does not appear to suffer from excess nutrients, where flushing appears to override the benefits of sewering around this portion of the watershed.

Previous Studies: 1999 CDM Study

LH/ILH Characteristics per CDM Study: Tidal Flushing

Tidal flushing is a significant process to help remove nutrients and other pollutants and is extremely effective in the Main Little Harbor, where it is estimated that over 99% of the volume of that portion of the harbor is flushed with each tidal cycle.

The Inner Little Harbor experiences much less flushing when Cat Dam is closed – allowing for only 42% of the volume to be flushed. When Cat Dam is opened, flushing characteristics similar to the Main Little Harbor are observed.

Previous Studies: 1999 CDM Study

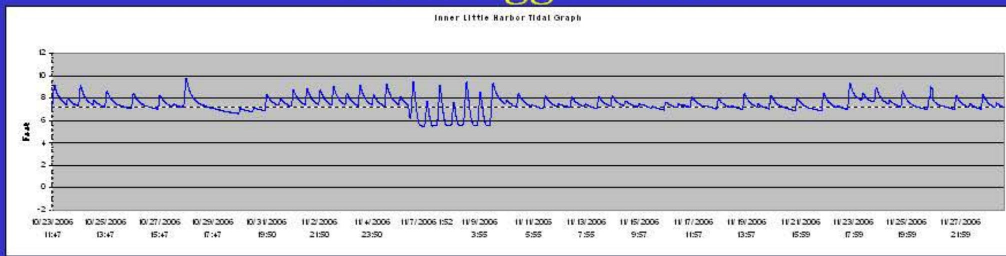
LH/ILH Characteristics per CDM Study: Tidal Flushing

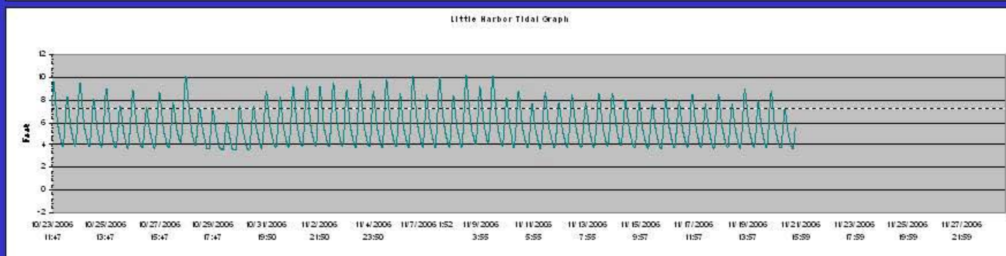
Since Inner Little Harbor suffers from elevated nutrients and little flushing, opening of Cat Dam will likely provide a relief to eutrophic conditions. However, for there to be a more permanent remedial response in the harbor, the dam will most likely need to be open indefinitely.

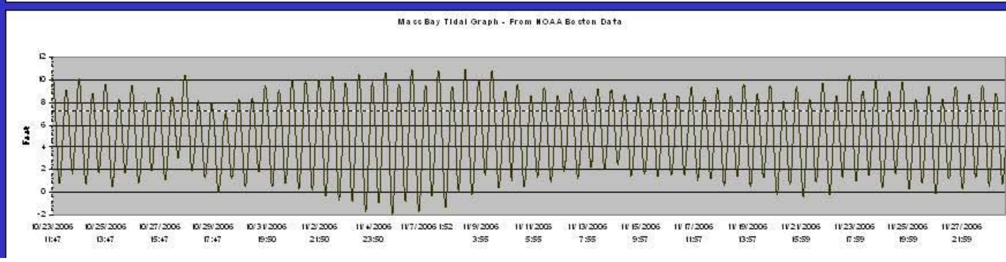
While opening the dam for 1-3 days at a time does provide temporary relief, eutrophic conditions return shortly after the dam is closed again, when flushing is returned to a minimal amount.

Tidal Logger Data

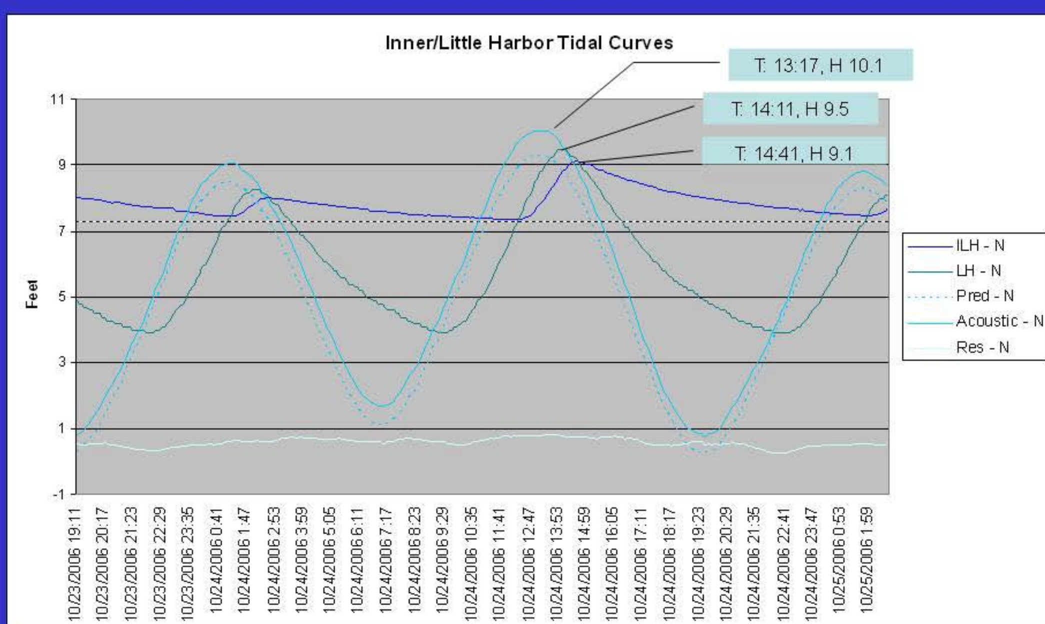
Tidal Logger Data



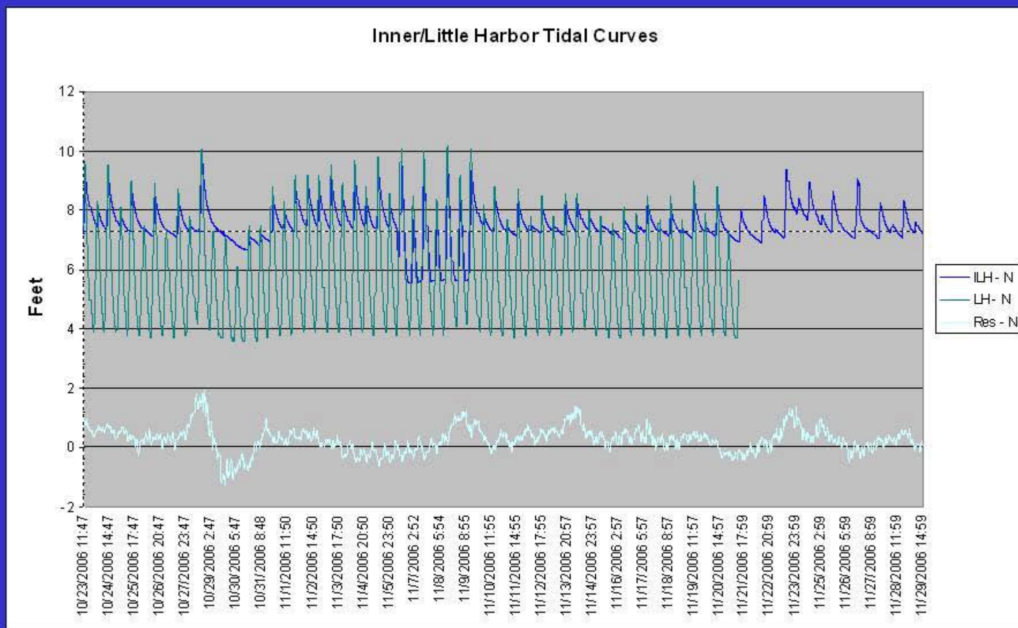




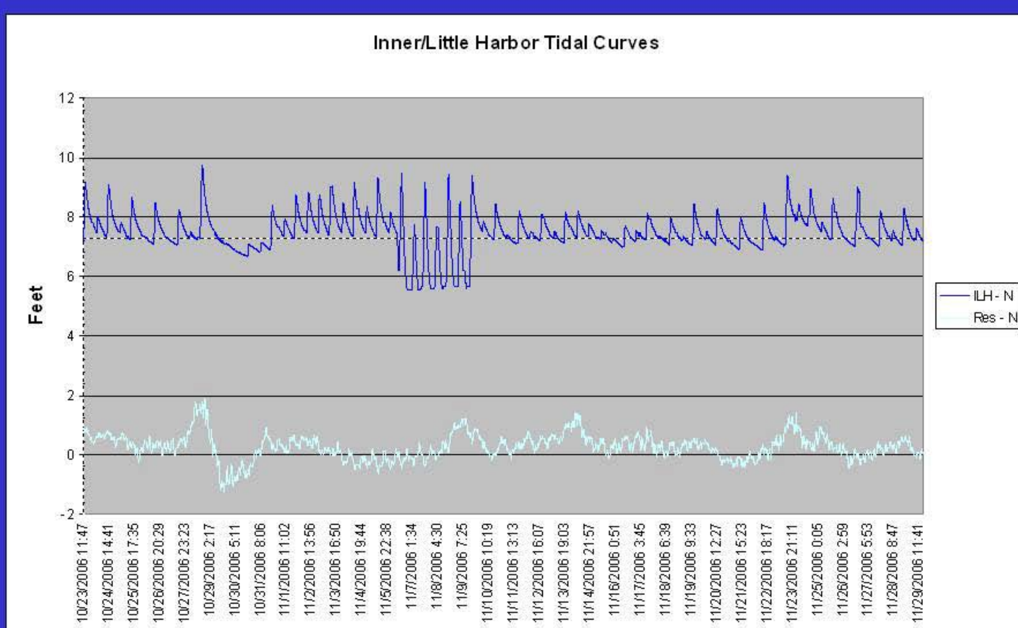
Tidal Logger Data



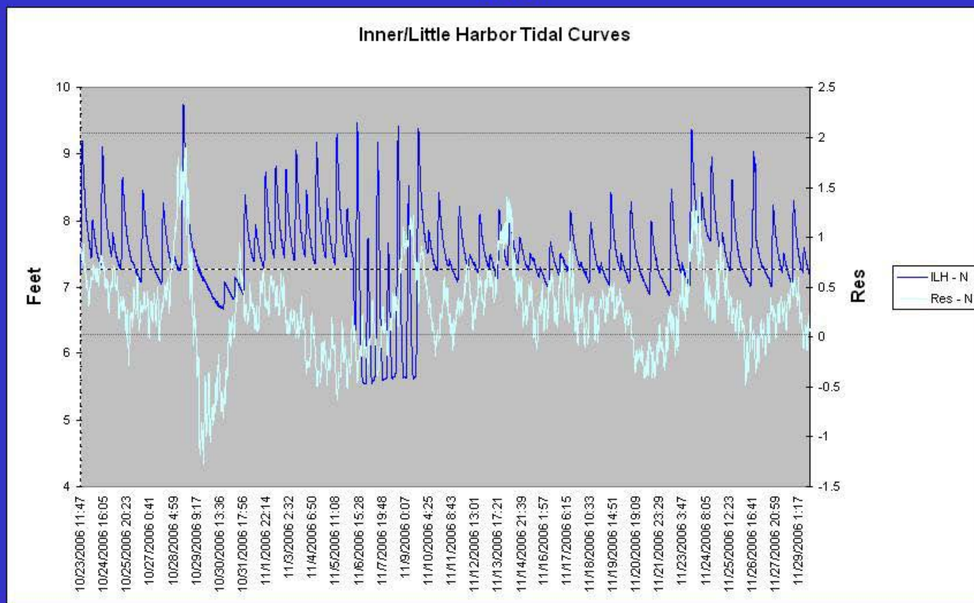
Tidal Logger Data



Tidal Logger Data



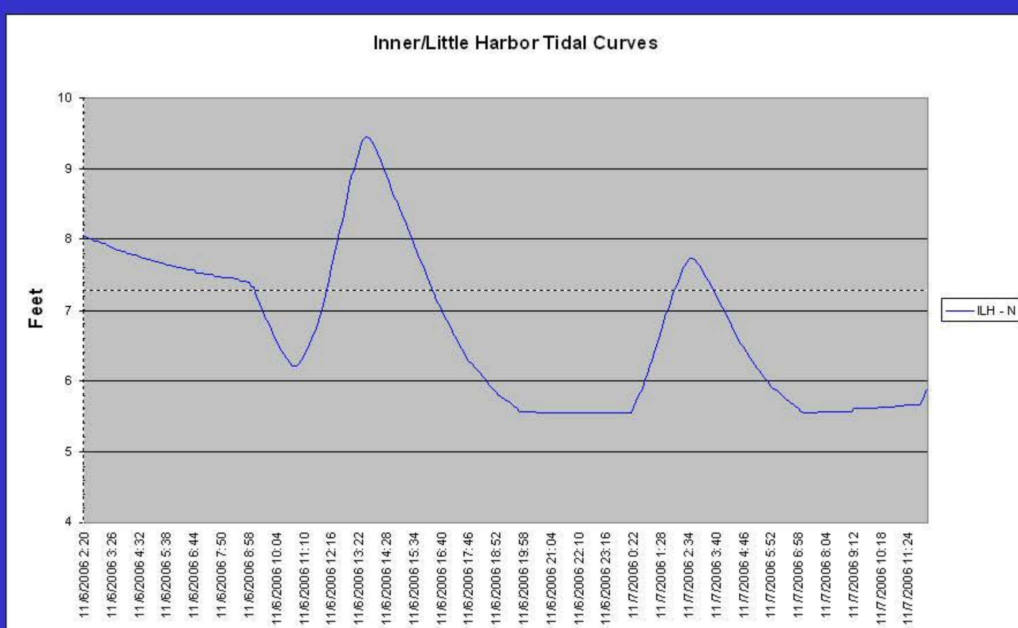
Tidal Logger Data



Flapper Gate Operation

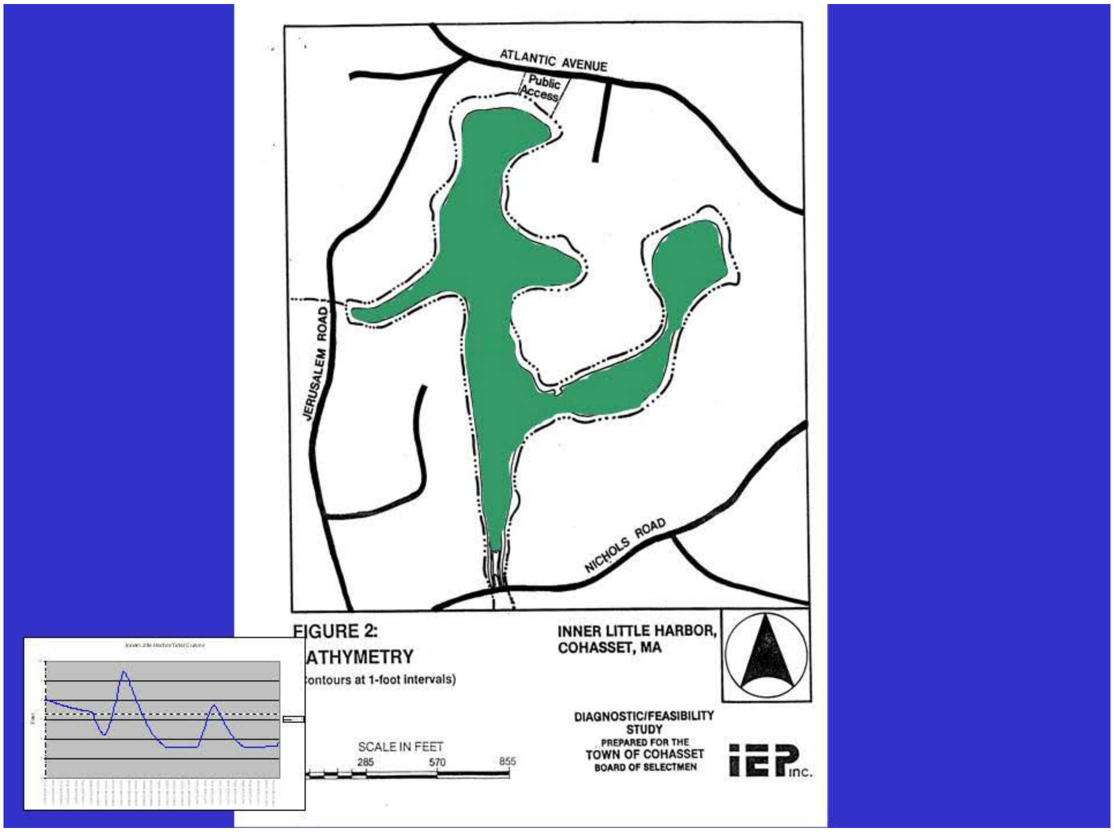
Flapper Gate Operation

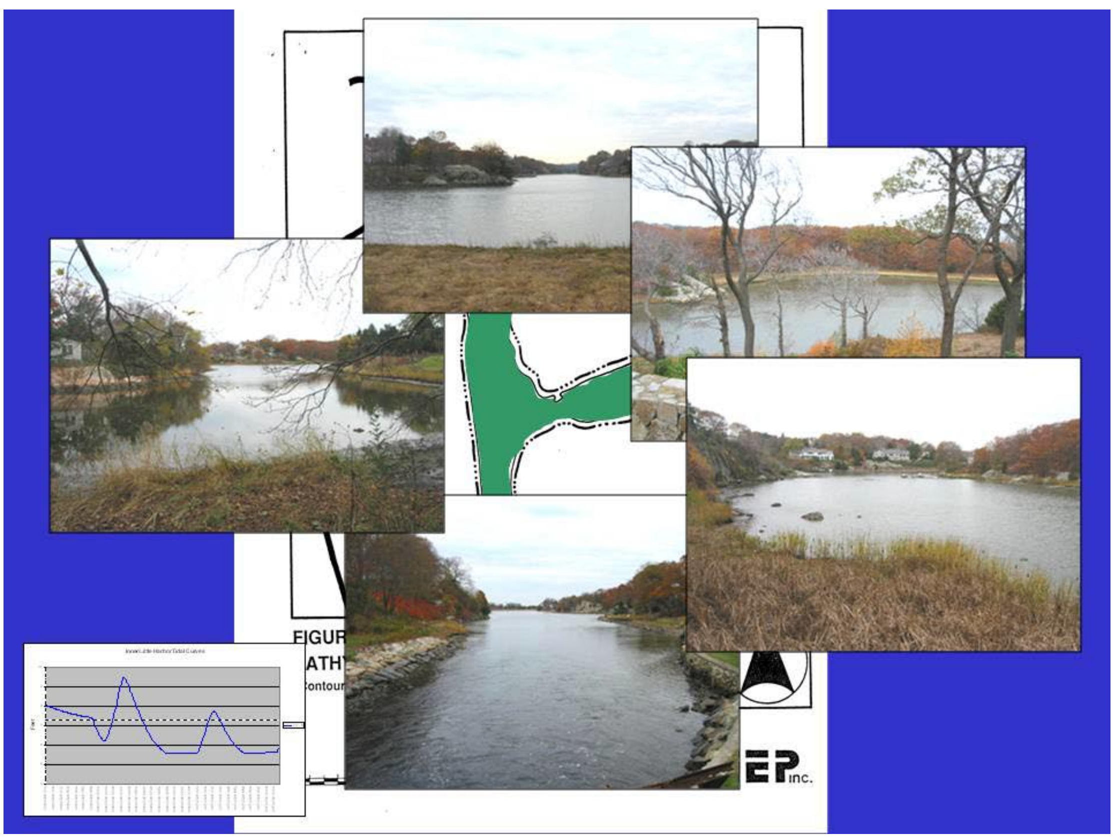
Tidal Logger Data

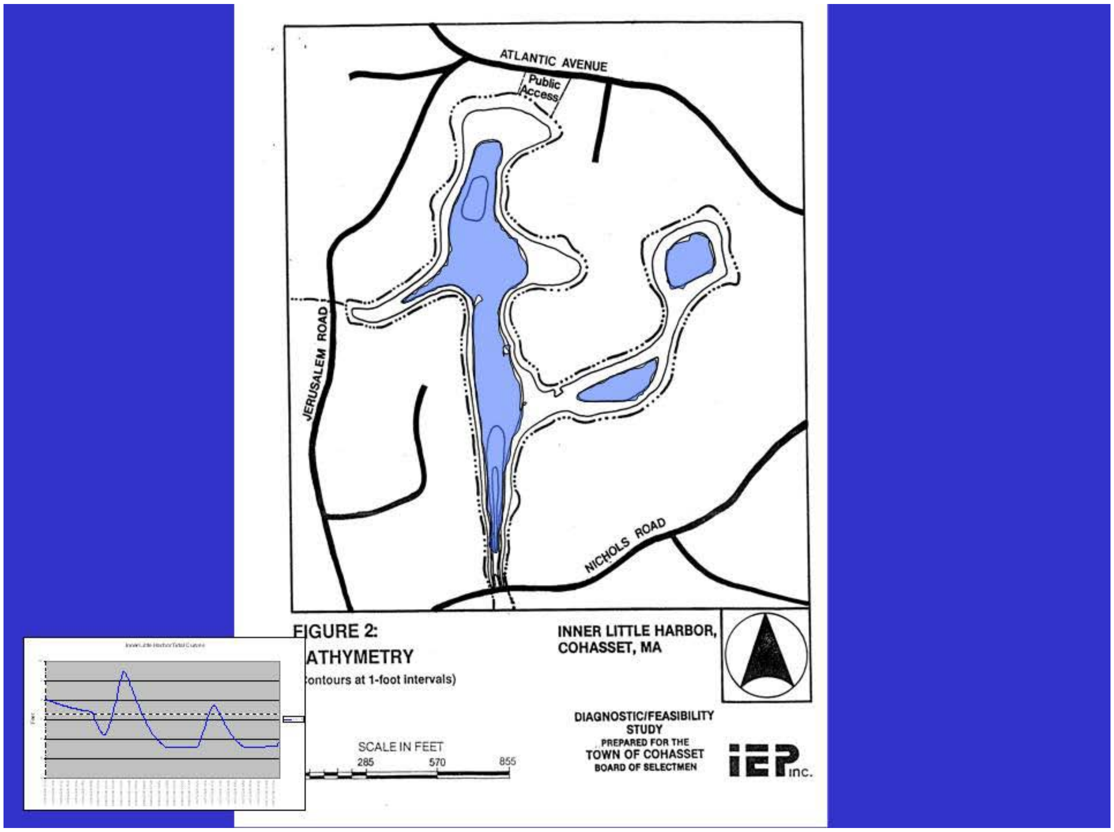


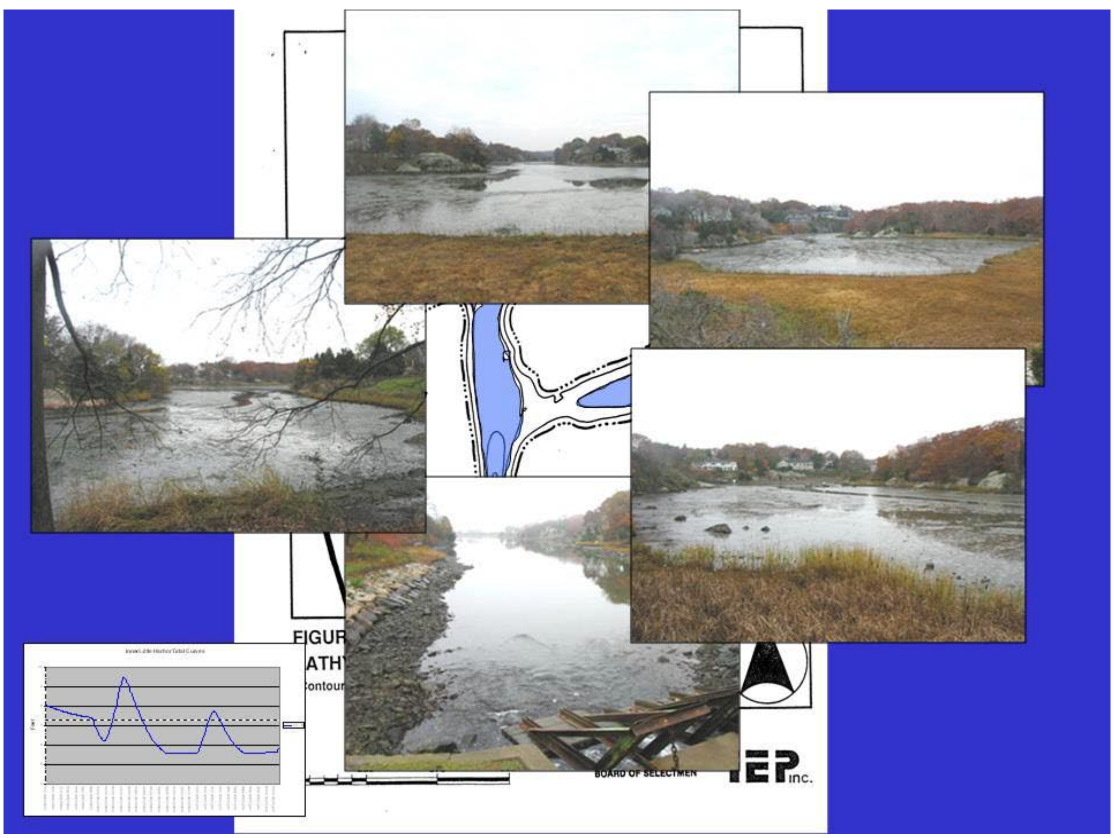
Tide Gate Operation

Hydraulic Restriction


ATLANTIC AVENUE
Public Access
JERUSALEM ROAD
NICHOLS ROAD
FIGURE 2:
ATHYMETRY
ontours at 1-foot intervals)
SCALE IN FEET
285
570
855
INNER LITTLE HARBOR,
COHASSET, MA
DIAGNOSTIC/FEASIBILITY
STUDY
PREPARED FOR THE
TOWN OF COHASSET
BOARD OF SELECTMEN
iEP inc.


FIGUR
ATHY
ontour
EP inc.


ATLANTIC AVENUE
Public Access
JERUSALEM ROAD
NICHOLS ROAD
FIGURE 2:
ATHYMETRY
ontours at 1-foot intervals)
INNER LITTLE HARBOR, COHASSET, MA
DIAGNOSTIC/FEASIBILITY STUDY
PREPARED FOR THE
TOWN OF COHASSET
BOARD OF SELECTMEN
SCALE IN FEET
285
570
855
iEP inc.


FIGUR
ATHY
ontour
BOARD OF SELECTMEN
iEP inc.

Tide Gate Condition

Tide Gate Condition

Leakage

Leakage

Leakage

Leakage


Leakage