University of Massachusetts Dartmouth
The School for Marine Science and Technology

DEP #2003-04/604

Summary of Water Quality Monitoring Program for the Plymouth, Kingston and Duxbury Harbor Embayment System (2003 – 2004)

(Draft Final July 20, 2005)

South Coastal Basin Estuaries Monitoring 604(b) Grant

Submitted to:

MA Department of Environmental Protection

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For:

Town of Kingston
Town of Duxbury
Town of Plymouth

and the

MA DEP 604(b) Program

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Submitted to: MA Department of Environmental Protection

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TABLE OF CONTENTS

1.0 BACKGROUND AND OVERVIEW: 7
2.0 METHODS: 10
2.1 Lab analyses: 10
2.2 Field Data Collection: 10
2.3 Personnel: 10
2.4 Materials: 11
2.5 Estuarine and Stream Sample Locations: 11
3.0 RESULTS AND DISCUSSION 16
3.1 Estuarine Water Quality Monitoring Data 17
3.2 Stream Discharge and Water Quality Monitoring Data 26
Surfacewater transport and Nitrogen Load Determination 26
Surface water Discharge and Watershed Nitrogen Load: Jones River to Kingston Bay 37
Surface water Discharge and Watershed Nitrogen Load: Town Brook to Plymouth Harbor 42
Surface water Discharge and Watershed Nitrogen Load: Eel River to Plymouth Harbor 47
Surface water Discharge and Watershed Nitrogen Load: Savery Pond Creek to Ellisville Harbor 52
4.0 CONCLUSIONS AND RECOMMENDATIONS 58
5.0 DATA QUALITY ASSURANCE AND CONTROL 60
APPENDIX – A 61
FIELD SAMPLING PROTOCOL (NUTRIENTS) 61
APPENDIX – B 69
CHAIN OF CUSTODY AND FIELD DATA SHEETS 69
APPENDIX – C 74
EQUIPMENT TO BE USED AND CALIBRATION 74
APPENDIX – D 78
NUTRIENT WATER QUALITY DATA 78
APPENDIX – E 79
BACTERIAL DATA 79

LIST OF FIGURES

Figure 1 – Locus map depicting Plymouth Harbor, Duxbury Harbor, Kingston Bay and Ellisville Harbor 9
Figure 2 - Plymouth Harbor, Duxbury Harbor, Kingston Bay estuarine sampling station locations occupied in summers 2003 and 2004 14
Figure 3 - Ellisville Harbor estuarine sampling stations occupied in summers 2003 and 2004 ... 15
Figure 4 - Nutrient Related Water Quality of Plymouth-Duxbury Harbor based upon monitoring data from stations in Figure 3. The Health Index was developed for Buzzards Bay and is described in Howes et al. 1999 and also at www.savebuzzardsbay.org. Triangles show estuarine stations and white circles, stream stations 24
Figure 5 - Nutrient Related Water Quality of Ellisville Harbor based upon monitoring data from stations in Figure 3. The Health Index was developed for Buzzards Bay and is described in Howes et al. 1999 and also at www.savebuzzardsbay.org. Triangles show estuarine stations and white circles, stream stations. Note that the index focuses on embayments and Ellisville Harbor is primarily a salt marsh system and therefore likely has higher habitat health than indicated by the index 25
Figure 6 – Location of stream gages in the project study area 31
Figure 7 – Stream gage location on the Jones River relative to USGS long term stream gaging station 33

Figure 8 – Location of stream gage deployed in Town Brook 34
Figure 9 - Location of stream gage deployed in the Eel River 35
Figure 10 – Location of Stream gages deployed in the Ellisville Harbor embayment system 36
Figure 11 – Predicted daily discharge for the Jones River discharging to Duxbury Harbor 39
Figure 12 - Predicted daily discharge and Total Nitrogen (TN) concentrations for the Jones River discharging to Duxbury Harbor 40
Figure 13 – Predicted daily discharge and Nitrate + Nitrite (NOx) concentrations for the Jones River discharging to Duxbury Harbor 41
Figure 14 - Predicted daily discharge for Town Brook discharging to Plymouth Harbor 44
Figure 15 - Predicted daily discharge for Town Brook relative to Total Nitrogen (TN) concentrations 45
Figure 16 - Predicted daily discharge for Town Brook relative to Nitrate + Nitrite (NOx) concentrations 46
Figure 17 – Predicted daily discharge in the Eel River discharging to Plymouth Harbor 49
Figure 18 - Predicted daily discharge for Eel River relative to Total Nitrogen (TN) concentrations 50
Figure 19 - Predicted daily discharge for Eel River relative to Nitrate + Nitrite (NOx) concentrations 51
Figure 20 – Predicted daily discharge for the stream flowing from Savery Pond to the head of the Ellisville Harbor system 54
Figure 21 – Predicted daily discharge relative to Total Nitrogen (TN) concentrations for the stream flowing from Savery Pond to the head of the Ellisville Harbor system 55

Figure 22 – Predicted daily discharge relative to Nitrate + Nitrite (NOx) concentrations for the stream flowing from Savery Pond to the head of the Ellisville Harbor system..... 56

LIST OF TABLES

Table 1 - Summary Table of Parameters to be Analyzed for Marine and Freshwater Samples... 13
Table 2 - Summary of average levels of primary nutrient related water quality parameters measured in the summers of 2003 and 2004 in Ellisville Harbor and Plymouth-Duxbury Harbor Systems by volunteers from Kingston, Duxbury and Plymouth and SMAST Coastal Systems Staff. Raw data is presented in Appendix B 21
Table 3 - Reference values used in the Bay Health Index. Scores are generated for each parameter and the mean score computed. In some cases where Secchi data is not available, the mean of the other 4 parameters may be used. Index values of >65 indicate high quality, 35-65 moderate quality and <35 fair/poor quality (described in Howes et al. 1999 and also at www.savebuzzardsbay.org.) 23

1.0 BACKGROUND AND OVERVIEW:

The project goal was to collect and analyze water samples and associated field parameters relevant to the nutrient related water quality of the Plymouth Harbor-Duxbury Harbor-Kingston Bay System and adjacent Ellisville Harbor. This water quality monitoring effort is a collaborative effort between the Towns of Kingston, Duxbury, and Plymouth whereby each Town fielded a water sampling team trained and coordinated by University of Massachusetts – Dartmouth, School of Marine Science and Technology (SMAST), Coastal Systems Laboratory Staff under the direction of Jen Antosca (field oversight) or Dale Goehringer (logistics coordination). Each water sampling team was responsible for collection of water samples at assigned sampling stations with logistical support by SMAST. Personnel from the Coastal Systems Laboratory within SMAST were also involved in the field sampling in order to assist in the collection of samples and insure proper transport and delivery of samples to the Coastal Systems Analytical Facility where chemical assays were performed.

The water quality data collected by the combined efforts of each Town's sampling team is required for application of the Linked Watershed-Embayment Approach of the Massachusetts Estuaries Project (MEP). All embayments undergoing MEP analysis require a minimum of three years of high-quality water chemistry and field data related to nitrogen dynamics. Although there is some existing water quality data that may be incorporated into the Estuaries Project approach, a complete water quality monitoring effort must be implemented in order to satisfy the full water quality monitoring data requirements of the MEP. In order to initiate the needed data collection for the Plymouth Harbor/Duxbury Harbor/Kingston Bay System, and Ellisville Harbor to support entry into the Estuaries Project and thereby allow full evaluation of protective measures, the Towns received DEP 604(b) funding support for collection, processing and analyses of water samples from the overall embayment system. A locus map is provided as Figure 1.

Samples and field data were collected from 15 marine and 4 stream sample stations in the Plymouth/Kingston/Duxbury System and 6 marine and 2 stream sample stations in the Ellisville Harbor System, during 6 sample rounds from June through mid-September, 2003 and 2004. Marine stations were sampled at approximately two-week intervals during the falling tide (targeting the 2 hours before and after mid-ebb) during the early morning hours (6-9 A.M.). Streams with tidal influence were sampled at ebb slack tide, independent of time of day. Sampling was conducted June through mid-September in order to focus on what is typically the period of poorest nutrient related water quality. Sample stations were located by Global Positioning System (GPS, see detail below) and on-shore landmarks during an initial survey with SMAST staff.

At each marine sampling location (PDH 1-15, EVH 3-8), a water samples were collected for dissolved oxygen by Winkler titration (Hach or YSI 85 meter, see detail below) and temperature. Salinity/specific conductance were measured in the Coastal Systems Laboratory. Sampling teams with SMAST Staff aboard used the YSI for profiling of D.O. and temperature and specific conductance, the other teams collected water with a Niskin sampler for D.O. by Winkler Titration and temperature by dial thermometer (Surface and Bottom). A Secchi Disk was used to determine

light penetration at each site. Water samples for nutrients and chlorophyll a were collected using a 2.2 liter Niskin Sampler at mid water depth, generally 1.5 to 5 m in Plymouth/Duxbury Harbor System and 0.5 – 1.0 m in the Ellisville Harbor System. Both systems have significant tidal ranges relative to their high tide water depths, which maintains a vertically well mixed watercolumn

At each stream sampling location (PDH 16-19, EVH 1-2), weekly water quality samples were collected for approximately 16 months. Water samples were collected by SMAST Staff at slack low tide. Whole water samples and filtered samples (0.45 um) were collected at each stream. The stream gauges were downloaded at 0.5-1.0 month intervals.

SMAST received all water samples within 6 hrs of their collection and conducted chemical analyses: nitrate+ nitrite, ammonium, particulate and dissolved organic nitrogen, and ortho-phosphate, chlorophyll *a* and pheophytin, particulate carbon for all samples and total phosphorus for stream samples. The School for Marine Science & Technology Coastal Systems Analytical Facility (Dr. Brian Howes, Program Manager and Sara Sampieri, Analytical Facility Manager, 508-910-6352) performed all chemical assays under their laboratory SOP and Quality Assurance Plan procedures. Bacterial assays were by the Barnstable County Department of Health and Environment Laboratory.

The estuarine watercolumn and stream data have been incorporated into this report. The discussion includes the sampling undertaken, discussion of nutrient related water quality spatial distribution (Section 3.1), flow and nutrient levels in freshwater inputs (Section 3.2). The raw data is presented in the attached appendices and in electronic format.. It is important to note that the major focus of this effort is to support future MEP analysis, which will include a complete water quality and habitat quality assessment. However, based upon the available data is was possible to provide a preliminary assessment of the current status of both the Plymouth Harbor/Duxbury Harbor/Kingston Bay System, and Ellisville Harbor System relative to nutrients.

South Coastal Basin Estuaries Monitoring DEP #2003-04/604

Towns of Plymouth, Kingston, and Duxbury

Figure 1 – Locus map depicting Plymouth Harbor, Duxbury Harbor, Kingston Bay and Ellisville Harbor

2.0 METHODS:

Sampling and analysis of both estuarine and stream sites followed the Sampling and Analysis Plan (SAP) developed for this project and approved by DEP and EPA.

2.1 Lab analyses:

Marine (M) and stream (S) water samples collected under the 604(b) grant were analyzed at the Coastal Systems Analytical Facility for the following constituents:

- Nitrate + Nitrite (M,S)
- Ammonium (M,S)
- Ortho-phosphate (M,S)
- Total phosphorus (S)
- Particulate Carbon (M,S)
- Particulate Nitrogen (M,S)
- Dissolved Organic Nitrogen (M,S)
- Chlorophyll *a* & pheophytin *a* (M,S)
- Specific Conductance (M,S)

Carbon-clean glass fiber filters were used for particulate analysis and nitrocellulose filters for chlorophyll *a* analysis. Dissolved nutrient samples were filtered in the field (0.45um) using cellulose acetate filters. Laboratory analytical standards were met for each batch of samples assayed. Samples were received at the analytical facility within 6 hours of collection and were accompanied by a Chain of Custody Form.

2.2 Field Data Collection:

Dissolved oxygen was assayed in the field by 2 methods: (1) field teams with SMAST Staff used an YSI 85 meter and probes (for temperature also) following the calibration procedures specified by the manufacturer and specified in the SAP and (2) other field teams used the Winkler titration method (Hach, 0.5 mg/L) on samples collected by Niskin sampler, with temperature by dial thermometer. Measurements were collected from surface (0.15 m depth) and bottom waters (0.5 m off bottom). In both cases, water samples were collected for laboratory analysis of salinity. Additionally, sampling teams made measurements of Secchi depth, Wind Speed (Beaufort Scale), tide stage, rainfall.

2.3 Personnel:

The field portion of the estuarine water quality monitoring effort relied upon teams of samplers from the Towns of Plymouth, Kingston and Duxbury. The sampling teams will be trained and supervised by SMAST personnel under the direction of Jen Antosca (field oversight) or Dale Goehringer (logistics coordination). Each Town has assigned a point of contact responsible for coordinating a team of samplers tasked to sample designated stations as follows:

- Town of Duxbury – Ron Maribett (with field assistance from Jen Antosca - SMAST)

- Town of Kingston – Pine DuBois
- Town of Plymouth – Wendy Garpow (with field assistance from P. Henderson-SMAST)

Sampling personnel were trained by, SMAST Technical Staff to assure that the sample collection and handling procedures are followed. In addition, SMAST Staff generally partnered with the volunteer teams in the field. All personnel were provided with a copy of the relevant pages of the SAP and field SOP's. Chain of Custody Forms and procedures were followed for all sampling events. This project would not have been possible, but for the efforts of these volunteers, and they deserve credit for the successful completion of the full sampling schedule.

2.4 Materials:

Niskin Samplers for collection of estuarine watercolumn samples and Sampling Kits for each field team (data and COC forms, thermometers, field filters, Hach D.O. Kits, Secchi Disk and misc. supplies) were provided by SMAST. Sampling Teams for each event also received a cooler with the necessary number of high density polyethylene (HDPE) bottles (1 L) for whole water samples for particulate and chlorophyll *a* assays and 60 milliliter polyethylene bottles (HCl leached) for dissolved nutrients. The YSI 85 meters were supplied and maintained by SMAST.

2.5 Estuarine and Stream Sample Locations:

All portions of the overall Plymouth/Kingston/Duxbury embayment system (PDH 1-15) and the Ellisville Harbor System (EVH 3-8) designated as estuarine were tidal. Only the stream gauging/water quality sampling stations (PDH 16-18, EVH 1-2) were fresh water (<0.2 ppt). All estuarine samples were collected from boats, while stream samples were collected from the center of the channel by wading upgradient to the site. The sample station locations are shown in Figures 2 and 3. Two of the stations in Plymouth Harbor (PDH1, PDH3) were selected to coincide with sample sites used in the Eel River Study for the Plymouth WWTF discharge siting.

The estuarine sampling stations in Plymouth Harbor/Duxbury Harbor/Kingston Bay are shown in Figure 2 and included:

- The head of Plymouth Harbor: PDH-1
- Within the breakwater: PDH-2
- The main channel to the breakwater: PDH-3
- Between High Cliff and White Flat: PDH-4
- The entrance to Goose Point Channel: PDH-5
- In the main channel at its entrance: PDH-6
- Off Rocky Nook: PDH-7
- In north tributary channel off Goose Point: PDH-8
- The mouth of the Jones River: PDH-9
- The mouth of Kingston and Duxbury Bays off Duxbury Pier Lighthouse: PDH-10

- In the entrance to the main channel (Cowyard): PDH-11
- Northeast of Clarks Island: PDH-12
- In the central portion of Duxbury Bay: PDH-13
- South of Long Point in open water: PDH-14
- At the mouth of Back River: PDH-15

Each of the major surface fresh water inflows to the Plymouth Harbor/Duxbury Harbor/Kingston Bay Estuarine System were gauged and sampled just prior to discharge to estuarine waters. The fresh water stream sites shown in figure 2 were:

- Jones River at Rt. 3A: PDH-16
- Town Brook at Rt. 3A: PDH-17
- Eel River down-gradient at Plymouth Harbor: PDH-18
- Eel River upgradient, at Old Sandwich Rd: PDH-19

The Eel River was gauged at 2 locations. The down-gradient site was at the mouth just prior to discharging into Plymouth Harbor (PDH-18). The gauging location is non tidal and also being used as a weekly water quality sampling station. The second gauging location was further up in the Eel River watershed down gradient of Russell Mill Pond where the Eel River crosses under Old Sandwich Road. This gauging location is operated by the Massachusetts Riverways Program (PDH-19). Weekly water quality samples were also be collected from this gauging location. The Jones River was gauged at the pump station just prior to the Jones River crossing under Route 3A in Kingston. The gauging location was non-tidal and had weekly water quality samplings. The Town Brook (PDH-17) was gauged south of Arms House Pond just prior to the Town Brook crossing under Route 3A (Sandwich Road) in Plymouth. The gauging location was non-tidal and had weekly water quality samplings.

The Ellisville Harbor Estuarine System is a separate embayment located south of the Plymouth/Kingston/Duxbury embayment system. Ellisville Harbor is located in the Town of Plymouth east of Route 3A and discharges to Cape Cod Bay (Figure 1). The tide range is between 8 to 10 feet. The Ellisville Harbor system is shallow, being less than 6 feet throughout. Samples were collected from the estuarine waters (EVH 2-8) and major streams discharging to this system (EVH1-2). Sampling locations are shown in Figure 3 and were as follows:

- Stream to headwaters of Ellisville Harbor: EVH-1
- Stream from cranberry bog to mid region of Ellisville Harbor: EVH-2.
- Main salt marsh tidal channel, inner: EVH-3.
- Main salt marsh tidal channel, middle: EVH-4.
- Main salt marsh tidal channel, open basin: EVH-5.
- Main salt marsh tidal channel, new tidal inlet: EVH-6.
- Main salt marsh tidal channel, old tidal inlet: EVH-8.
- Offshore Reference Station: EVH-7

Table 1 - Summary Table of Parameters to be Analyzed for Marine and Freshwater Samples

Location	Station I.D.	Dissolved Nutrients	Particulate Nutrients	Chlorophyll /Pheophytin	Total P	Field Parameters
MARINE						
Plymouth Harbor	PDH 1 – 5	X	X	X		X
Kingston Bay	PDH 6 – 10	X	X	X		X
Duxbury Harbor/Bay	PDH 11 – 15	X	X	X		X
Ellisville Harbor	EVH 3 – 8	X	X	X		X
FRESH						
Jones River	PDH16	X	X		X	
Town Brook	PDH17	X	X		X	
Eel River	PDH18-19	X	X		X	
Ellisville Crk	EVH 1	X	X		X	
Ellisville Bog	EVH2	X	X		X	

Dissolved parameters: (measured in the lab) nitrate+nitrite, ammonium, dissolved organic nitrogen, specific conductance, salinity, and orthophosphate.

Particulate parameters: particulate carbon and particulate nitrogen

Total P (Total phosphorus): this analysis will be performed on samples from selected stations as identified

Field parameters: Dissolved oxygen, temperature, Secchi depth

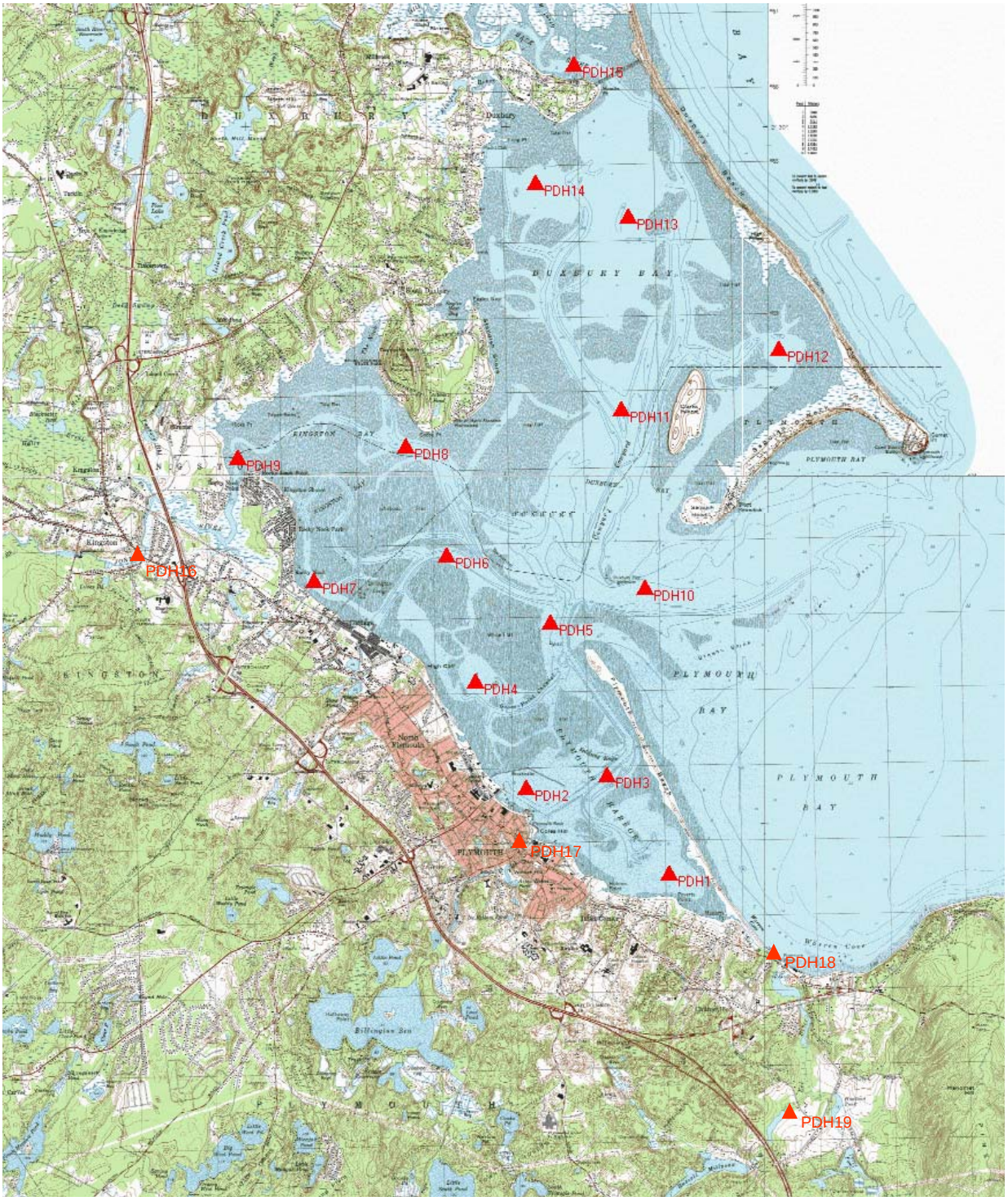

Figure 2 - Plymouth Harbor, Duxbury Harbor, Kingston Bay estuarine sampling station locations occupied in summers 2003 and 2004.

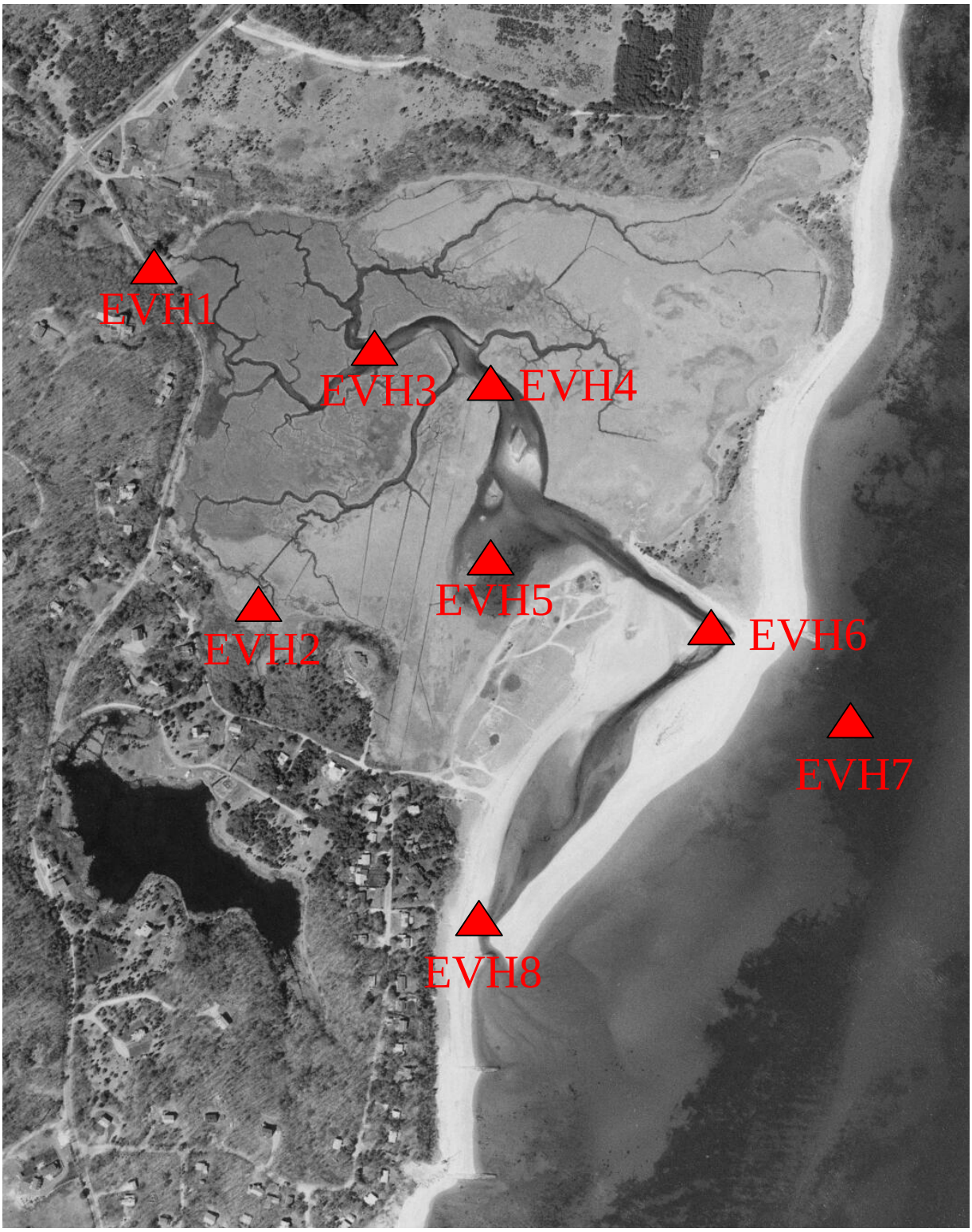

Figure 3 - Ellisville Harbor estuarine sampling stations occupied in summers 2003 and 2004.

3.0 RESULTS AND DISCUSSION

Surface and groundwater flows are pathways for the transfer of land-sourced nutrients to coastal waters. Fluxes of primary ecosystem structuring nutrients, nitrogen and phosphorus, differ significantly as a result of their hydrologic transport pathway (i.e. streams versus groundwater). In sandy glacial outwash aquifers, such as the south coast of Falmouth, phosphorus is highly retained during groundwater transport as a result of sorption to aquifer mineral. Since throughout southeastern Massachusetts "rivers" are primarily groundwater fed, watersheds tend to release little phosphorus to coastal waters. In contrast, nitrogen, primarily as plant available nitrate, is readily transported through these oxygenated groundwater systems. The result is that terrestrial inputs to coastal waters tend to be higher in plant available nitrogen than phosphorus (relative to plant growth requirements). However, coastal estuaries and salt ponds tend to have algal growth limited by nitrogen availability, due to their flooding with low nitrogen coastal waters. The Plymouth Harbor/Duxbury Harbor/Kingston Bay and Ellisville Harbor Systems which exchange tidal waters with Cape Cod Bay follow this general pattern, although their upper-most reaches can have excess inorganic nitrogen levels due to localized loading of nitrates at their headwaters (see below). The lower reaches of these estuaries are nitrogen limited based upon their inorganic N to P ratios (<<16) and these regions would be expected to expand inland if nitrogen loading in the upper reaches were to be reduced. However, the primary nutrient of eutrophication in these systems is nitrogen, similar to most other estuaries in Massachusetts.

Nutrient related water quality decline represents one of the most serious threats to the ecological health of the nearshore coastal waters. Coastal salt ponds and embayments, because of their shallow nature and large shoreline area, are generally the first indicators of nutrient pollution from terrestrial sources. By nature, these systems are highly productive environments, but nutrient over-enrichment of these systems world-wide is resulting in the loss of their aesthetic, economic and commercially valuable attributes.

Each embayment system maintains a capacity to assimilate watershed nitrogen inputs without degradation. However, as loading increases a point is reached at which the capacity (termed assimilative capacity) is exceeded and nutrient related water quality degradation occurs. As nearshore coastal salt ponds and embayments are the primary recipients of nutrients carried via surface and groundwater transport from terrestrial sources, it is clear that activities within the watershed, often miles from the water body itself, can have chronic and long lasting impacts on these fragile coastal environments.

Protection and restoration of coastal embayments from nitrogen overloading has resulted in a focus on determining the assimilative capacity of these aquatic systems for nitrogen. This effort is ongoing throughout southeastern Massachusetts (e.g. Massachusetts Estuaries Project). The general approach focuses on changes in nitrogen loading from watershed to embayment, and determination of the changes in habitat health for incremental increases or decreases in nitrogen inputs, hence nitrogen concentrations within the receiving waters. The MEP approach depends upon estimates of nitrogen inputs and embayment recycling of nitrogen, circulation within the embayment; and assessments of habitat quality. The MEP approach requires a sound baseline

(not less than 3 years) of nitrogen related water quality monitoring. This latter monitoring is partially fulfilled for the Plymouth Harbor/Duxbury Harbor/Kingston Bay and Ellisville Harbor Systems by the present effort. However, determination of the "allowable N concentration increase" or "threshold nitrogen concentration" will require the MEP assessment, modeling and analysis (i.e. the "MEP approach").

The following assessments are based upon the initial 2 summers of watercolumn monitoring and are likely to need refinement as additional water quality data is collected and with the "higher level" analysis by the MEP. However, some general conclusions relative to estuarine water quality (Section 3.1) and major stream inputs (Section 3.2) can be made at this time. Note also that the following is meant to be a brief analysis focusing on the nutrient related health of these 2 important coastal systems, Plymouth Harbor/Duxbury Harbor/Kingston Bay and Ellisville Harbor.

3.1 Estuarine Water Quality Monitoring Data

Overall, the Plymouth Harbor/Duxbury Harbor/Kingston Bay and Ellisville Harbor Systems appear to support moderate to high nitrogen related habitat quality relative to their specific resource conditions. Both systems were confirmed to be nitrogen limited based upon the elemental ratio method (Redfield Ratio of N/P <16). The average ratio of inorganic nitrogen to inorganic phosphorus (N/P) was 4-7 for the stations internal to Ellisville Harbor (the offshore station was 3). Similarly, the Plymouth Harbor/Duxbury Harbor/Kingston Bay System showed N/P ratios of 2-6 (Table 2). While this is only an approximate method, it is consistent with other studies concluding nitrogen limitation in estuaries throughout the region and in Cape Cod Bay proper. In addition, it is consistent with established theories of nitrogen limitation in temperate estuaries. The conclusion supports the targeting of nitrogen as the key nutrient for management of the habitat quality of these estuarine systems.

Plymouth Harbor/Duxbury Harbor/Kingston Bay System: The Plymouth Harbor/Duxbury Harbor/Kingston Bay is an open embayment with relatively deep waters (2-8 m at mid tide) and high salinity waters throughout (Table 2). The lack of a strong salinity gradient results from the relatively low freshwater inflow and the high tidal flushing of this semi-enclosed basin. Only the stations directly influenced by the Jones River (PDH-9), Eel River (PDH-1) and Town Brook (PDH-2) showed discernable dilution of salinity. However, even at these stations the extent of dilution from offshore boundary waters (PDH-10) was < 1ppt.

Since nitrogen enters these systems primarily in freshwater inputs, it is not surprising that nitrogen levels also generally showed only a low to moderate enhancement over the boundary waters, generally TN 0.31 – 0.42 mg/L in the main basin. Only the Jones River influenced station and the northern-most basins showed moderately high values of total nitrogen (TN), 0.46-0.55 mg/L. The elevated nitrogen levels are ultimately the result of nitrogen entering the tidal waters from both groundwater and surface water inflows. This is supported by the generally higher levels of TN in regions associated with river inflows. The lack of a strong relationship in TN at all stream sites relates to their differences in flow rates (Jones River > Eel River > Town Brook), nitrogen levels (see Section 3.2) and the location of the sampling stations relative to the

point of river discharge (Figure 2). The northern basin (PDH-15, 14) also supported high total nitrogen levels also associated with the interplay of watershed nitrogen inputs and tidal flushing. However, this region also likely has significant salt marsh influences and possibly high sediment nitrogen release, both of which would tend to elevate summer nitrogen levels. However, this hypothesis will have to be examined by the direct methods used by MEP.

Associated nitrogen related health parameters followed the above pattern seen in the TN levels. In general oxygen levels were relatively high, average of lowest 20% of observations > 6 mg/L in all but the northern basin and mouth of the Jones River, and > 5 mg/L at all sites.
The sites with the highest TN levels tended to have the lowest dissolved oxygen levels. This pattern was also repeated in the phytoplankton pigments. The boundary waters (PDH-10) showed low TN, high dissolved oxygen and low concentrations of chlorophyll a pigments. The main basins of the estuary also generally supported low levels of chlorophyll a pigments, 3-5 ug/L. Only the mouth of the Jones River sub-estuary (PDH-9) and the northern most basin (PDH-15) showed moderate levels of chlorophyll a pigments (~7.5 ug/L), consistent with their TN and dissolved oxygen levels.

These data can be used to generate a Bay Health Index as developed and refined by the Buzzards Bay Project, Coalition for Buzzards Bay's Bay Watcher Program and SMAST. The concept is to integrate the basic water quality monitoring parameters (dissolved inorganic nitrogen, total organic nitrogen, chlorophyll a pigments, Secchi depth and lowest 20% of D.O. measures) into a single index that can be plotted to show the spatial pattern of nitrogen related water quality within an embayment. The reference values used in the index are shown in Table 3.

Using the Bay Health Index for the Plymouth Harbor/Duxbury Harbor/Kingston Bay System bring forward the individual spatial pattern discussed above (Figure 4). In general, the southern, central and outer northern basins show a high level of nitrogen related water quality. This pattern is consistent with the structure of the watershed and the high tidal flushing of estuarine waters resulting, in part from the large tide range (3 m). The slightly impaired waters in the region nearest the Jones River discharge and the inner regions of the northern basin most likely result from their lower flushing rates and from nitrogen loads. In the region of the Jones River discharge the nitrogen loading is almost certainly from the river discharge (see below), while in the northern basin (PDH 14, 15) it is likely from the salt marshes and sediment coupled with watershed inputs. These assessments require additional habitat parameters before habitat impairments can be firmly documented, however, these data indicate that additional sampling in the basin between PDH 9 and PDH 8 (in the region of the Jones River) may be warranted. In addition, these data indicate that MEP analysis of this system should focus on restoration of these inner basins and protection of the greater region of the System.

Ellisville Harbor System: Ellisville Harbor is primarily a tidal salt marsh system with an open basin in its lower third and a tidal inlet which is susceptible to occlusion and migration, resulting from coastal sediment transport processes. The Ellisville Harbor System was altered just prior to the initiation of the water quality monitoring effort. The historic inlet (adjacent EVH-6) was opened and the recent inlet (at EVH-8) became isolated with the channel forming a restricted basin. The opening of the historic tidal inlet made Station EVH-6 the most seaward waters of the main channel. The restoration of the historic channel had profound positive influences on the

salt marsh system of Ellisville Harbor. Prior to opening the restriction of the tidal flows had resulted in the death of much of the salt marsh grasses in the upper third of this wetland. With the restoration of tidal flows, the wetland grasses showed an immediate regrowth and rapid recolonization. This wetland response is being followed by wetland scientists within the Coastal Systems Program at SMAST as part of a research effort.

The Ellisville Harbor System, as a salt marsh, supports tidal channels that are relatively shallow, generally < 1 m, (Table 2). Similar to Plymouth Harbor to the north, the system has relatively low freshwater inputs relative to its flushing rate and therefore maintains high salinity waters throughout (Table 2). The lack of a strong salinity gradient results from the relatively low freshwater inflow at the systems head and the inflow of freshwater at mid system, plus the discharge of groundwater along the length of the marsh. Only station EVH-8, which is now located in a stranded basin at the old inlet site shows a significant dilution of offshore water salinity. The boundary marine station (EVH-7) and stream stations (EVH 1,2) had salinities of 30.4 and 0.1 ppt, respectively. The marine boundary station had salinities similar to the boundary station in Plymouth Harbor (30.8 ppt).

Since nitrogen enters this system primarily in freshwater inputs, it is not surprising that nitrogen levels also generally showed only an enhancement over the boundary waters, generally TN 0.44 – 0.71 mg/L in the main marsh regions and 0.35 mg/L, offshore (Table 2). The relatively high TN levels within the Harbor waters results form both watershed loading and tidal flushing and the fact that salt marshes are naturally nitrogen enriched systems. This is supported by the generally moderate TN levels in the more open basins (EVH-4,5,6) of 0.44-0.49 mg/L and the high level in the central region of the salt marsh (EVH-3) of 0.71 mg/L.

The upper salt marsh region is also likely enhanced by the nitrogen from the 2 freshwater streams (major to this system, but not large), which had TN levels of 0.61-0.8 mg/L TN. While these nitrogen levels are moderate to high for embayments, they may not represent impairment in a salt marsh dominated system, like Ellisville Harbor. These results indicate that it is unlikely that water column data alone will be sufficient to determine the quality of the Ellisville Harbor System and that determination of the level of health or impairment will require the direct methods used by MEP.

Even so, it is useful to examine the associated nitrogen related health parameters. These associated parameters generally showed a similar pattern seen in the TN levels. In general oxygen levels were relatively low, average of lowest 20% of observations 4.5-5.5 mg/L in all but the offshore station which was fully oxygenated (8 mg/L). The sites with the highest TN levels tended to have the lowest dissolved oxygen levels, such that there was a gradient in improving oxygen status moving from the inner marsh to the tidal inlet and then offshore. This pattern was also repeated in the phytoplankton pigments. The boundary waters (PDH-10) showed low TN, high dissolved oxygen and low concentrations of chlorophyll a pigments. The inner marsh regions supported high chlorophyll a pigments, 8.7-18.5 ug/L, while the outer basin and tidal inlet had low levels of chlorophyll a, <4 ug/L. All Harbor sites were higher than the offshore waters.

These data can be used to generate a Bay Health Index as developed and refined by the Buzzards Bay Project, Coalition for Buzzards Bay's Bay Watcher Program and SMAST. The concept is to integrate the basic water quality monitoring parameters (dissolved inorganic nitrogen, total organic nitrogen, chlorophyll a pigments, Secchi depth and lowest 20% of D.O. measures) into a single index that can be plotted to show the spatial pattern of nitrogen related water quality within an embayment. The reference values used in the index are shown in Table 3.

Using the Bay Health Index for the Ellisville Harbor System brings forward the individual spatial pattern discussed above (Figure 5). In general, there is a strong gradient in nitrogen related water quality from the high nitrogen-chlorophyll and low oxygen inner regions to the low nitrogen-chlorophyll and high oxygen outer basin and tidal inlet. The offshore station show highest quality. This pattern is consistent with the structure of the watershed and the potentially restricted tidal flushing of this estuary. The low Index scores may be the result of the systems function as a salt marsh rather than an open embayment, but it is also possible that the levels of the various indicators may suggest impairment of even a salt marsh system or of the lower more open basin. This determination requires additional habitat assessments impairments can be firmly documented, however, these data are cause for concern for the health of this system. In addition, these data indicate that MEP analysis of this system should focus on both the status of the salt marsh and lower basin regions, as the Index scores were poor to moderate from the innermost reach to the tidal inlet.

Overall, it appears that the MEP analysis is warranted for both estuarine systems monitored and that water quality monitoring needs to continue for a minimum of 1 year to develop the needed baseline.

Table 2 - Summary of average levels of primary nutrient related water quality parameters measured in the summers of 2003 and 2004 in Ellisville Harbor and Plymouth-Duxbury Harbor Systems by volunteers from Kingston, Duxbury and Plymouth and SMAST Coastal Systems Staff. Raw data is presented in Appendix B.

Station	Total Depth (m)	Salinity (ppt)	20% Low * DO mg/L	PO4 (mg/L)	NH4 (mg/L)	NOx (mg/L)	DON (mg/L)	PON (mg/L)	DIN (mg/L)	TN mg/L	DIN/DIP Ratio	Total Chl a ug/L
Ellisville Harbor												
EVH 1	0.15	0.1	ND	0.013	0.081	0.066	0.373	0.08	0.147	0.61	24	6.3
EVH 2	0.13	0.1	ND	0.040	0.067	0.179	0.409	0.14	0.247	0.80	14	7.6
EVH 3	1.70	28.8	4.5	0.021	0.038	0.011	0.307	0.35	0.049	0.71	5	18.5
EVH 4	0.89	28.9	4.5	0.019	0.026	0.011	0.262	0.17	0.036	0.47	4	8.7
EVH 5	0.61	27.2	5.3	0.019	0.045	0.019	0.294	0.13	0.064	0.49	7	3.8
EVH 6	1.01	27.9	5.5	0.020	0.037	0.017	0.296	0.09	0.054	0.44	6	3.1
EVH 7	2.39	30.4	8.0	0.013	0.014	0.003	0.247	0.08	0.018	0.35	3	1.6
EVH 8	0.69	20.4	2.0	0.042	0.071	0.145	0.337	0.32	0.217	0.87	11	8.5
												0.0
Plymouth-Duxbury Harbor												
PDH 1	2.12	29.8	7.3	0.018	0.034	0.005	0.251	0.12	0.039	0.41	5	4.2
PDH 2	4.43	30.1	6.0	0.016	0.015	0.003	0.200	0.10	0.018	0.31	2	5.3
PDH 3	5.11	30.5	6.3	0.016	0.013	0.002	0.206	0.09	0.015	0.31	2	3.7
PDH 4	2.93	30.5	7.8	0.014	0.020	0.003	0.212	0.08	0.022	0.32	3	3.9
PDH 5	5.37	30.3	7.9	0.015	0.022	0.002	0.234	0.08	0.023	0.34	4	3.4
PDH 6	8.64	30.5	7.4	0.013	0.024	0.001	0.205	0.08	0.025	0.31	4	3.1
PDH 7	3.17	30.5	7.3	0.014	0.027	0.008	0.214	0.09	0.035	0.34	6	4.5
PDH 8	5.39	30.9	7.4	0.012	0.017	0.003	0.241	0.09	0.020	0.35	4	3.7
PDH 9	2.67	29.9	5.9	0.017	0.030	0.019	0.256	0.16	0.049	0.46	6	7.5
PDH 10	6.11	30.8	7.2	0.012	0.009	0.002	0.199	0.06	0.011	0.27	2	2.7
PDH 11	7.16	30.6	6.7	0.012	0.011	0.001	0.222	0.09	0.012	0.32	2	4.1
PDH 12	2.16	30.9	6.9	0.012	0.020	0.002	0.297	0.10	0.021	0.42	4	4.1
PDH 13	2.56	30.5	5.7	0.017	0.014	0.003	0.199	0.10	0.018	0.32	2	4.6
PDH 14	2.22	30.3	6.2	0.017	0.040	0.002	0.304	0.12	0.042	0.46	6	4.8
PDH 15	2.98	30.3	5.0	0.026	0.036	0.005	0.333	0.18	0.040	0.55	3	7.9

* Average of the lowest 20% of recorded values.

Table 3 - Reference values used in the Bay Health Index. Scores are generated for each parameter and the mean score computed. In some cases where Secchi data is not available, the mean of the other 4 parameters may be used. Index values of >65 indicate high quality, 35-65 moderate quality and <35 fair/poor quality (described in Howes et al. 1999 and also at www.savebuzzardsbay.org.)

Score	Secchi Depth M	Oxygen Saturation %	Inorganic N mg/L	Total N mg/L	Total Chlorophyll a Pigments ug/L
0%	0.6	0.40	0.140	0.600	10.0
100%	3.0	0.90	0.014	0.280	3.0

The relationship between 0% to 100% for each parameter is logrithmc.

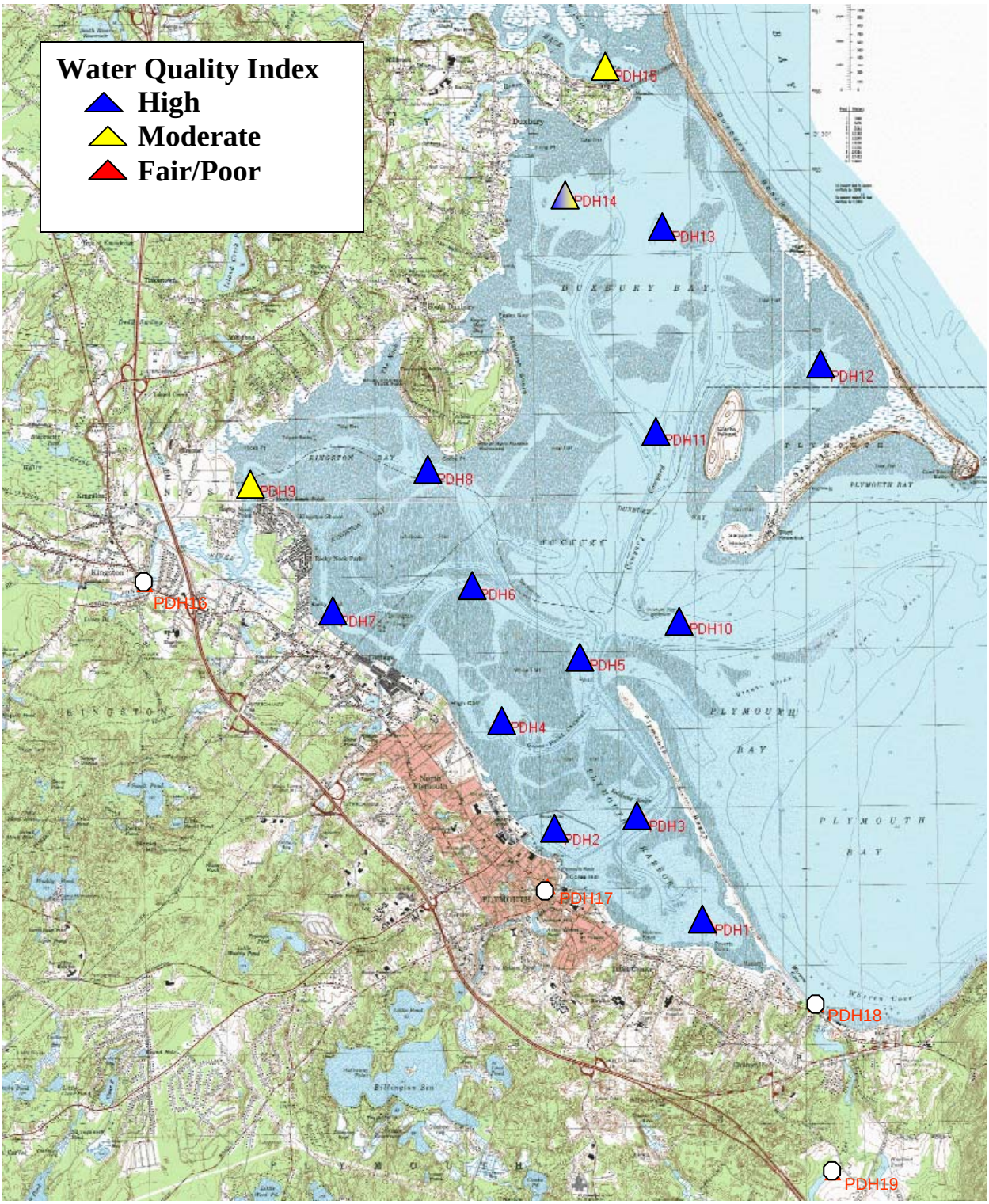

Figure 4 - Nutrient Related Water Quality of Plymouth-Duxbury Harbor based upon monitoring data from stations in Figure 3. The Health Index was developed for Buzzards Bay and is described in Howes et al. 1999 and also at www.savebuzzardsbay.org. Triangles show estuarine stations and white circles, stream stations.

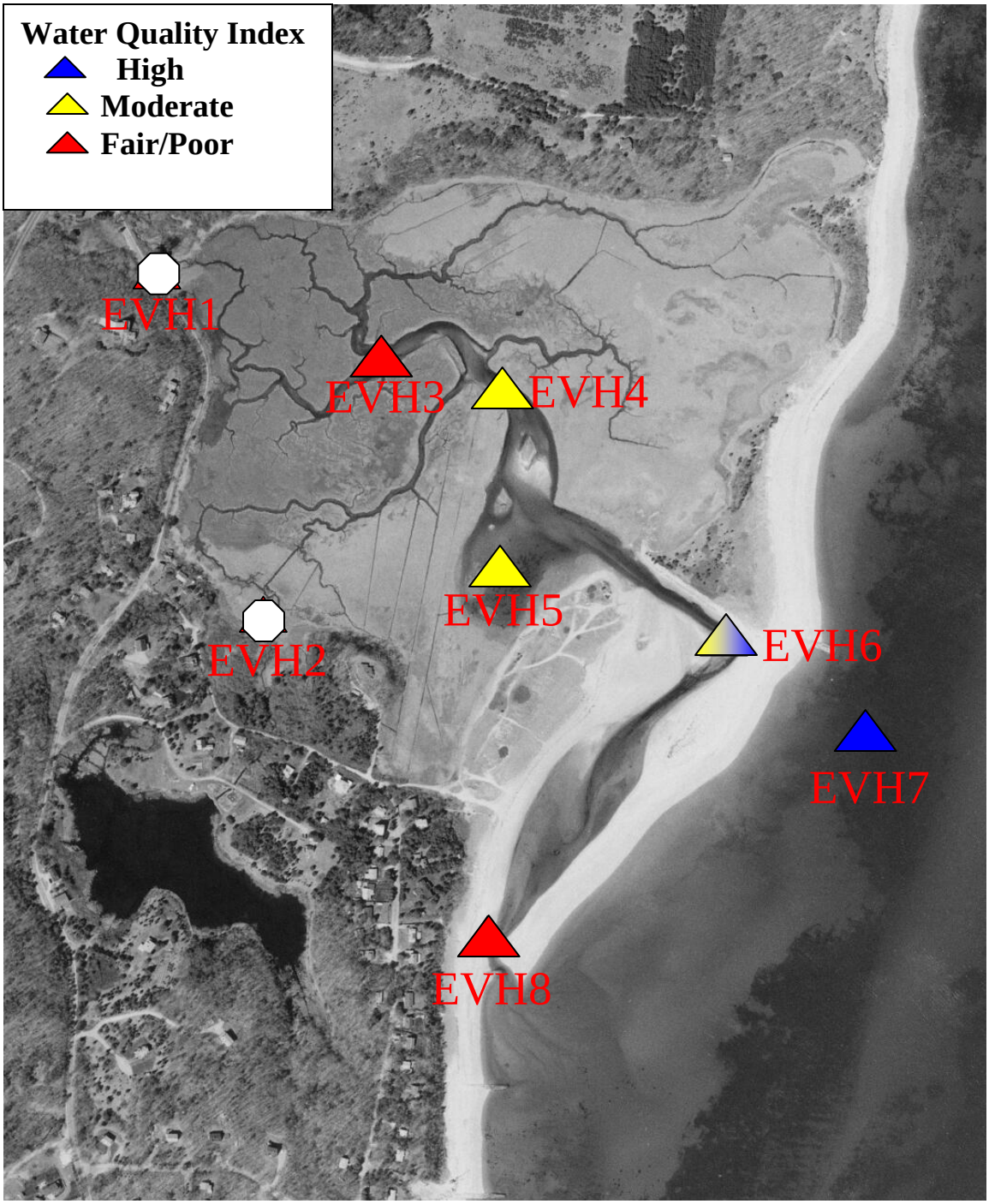

Figure 5 - Nutrient Related Water Quality of Ellisville Harbor based upon monitoring data from stations in Figure 3. The Health Index was developed for Buzzards Bay and is described in Howes et al. 1999 and also at www.savebuzzardsbay.org. Triangles show estuarine stations and white circles, stream stations. Note that the index focuses on embayments and Ellisville Harbor is primarily a salt marsh system and therefore likely has higher habitat health than indicated by the index.

3.2 Stream Discharge and Water Quality Monitoring Data

With regard to the stream gaging and stream water quality monitoring component of the 604(b) grant objectives for the Plymouth-Kingston-Duxbury Harbor Project, the stream related tasks where initiated to ultimately generate the data necessary to support critical elements of the Massachusetts Estuaries Project (MEP) Linked Watershed- Embayment Modeling Approach. The MEP is structured to generate site specific embayment nutrient thresholds that serve as targets for watershed wide nutrient load reductions that would be protective or restorative of the habitat quality in any given embayment. As such, MEP modeling and prediction of change in coastal embayment nitrogen related water quality is based, in part, on determination of the inputs of nitrogen from the surrounding contributing land or watershed. This watershed nitrogen input parameter is the primary term used to relate present and future loads (build-out, sewering analysis, enhanced flushing, pond/wetland restoration for natural attenuation, etc.) to changes in water quality and habitat health. Therefore, in the context of the MEP nutrient threshold analysis, nitrogen loading is the primary threshold parameter for protection and restoration of estuarine systems. Though the complete nitrogen land use load analysis (watershed-wide) undertaken by the MEP has many more dimensions than those just mentioned, a critical element of the MEP land use load analysis rests on the accurate determination of stream discharges and the associated attenuated nitrogen loads to the embayment being analyzed. The 604(b) grant project for the Plymouth-Kingston-Duxbury Harbor embayment system has allowed for the development of daily stream flow values and associated N-loads based on the stream gaging and weekly stream water quality data collection undertaken as part of the 604(b) grant. This effort has yielded a significant data set directly applicable to the objectives to be met by the MEP in the Plymouth-Kingston-Duxbury Harbor embayment system.

Surfacewater transport and Nitrogen Load Determination

Measured rates of nitrogen loading from streams discharging to the Plymouth-Kingston-Duxbury Harbor embayment system (Jones River, Town Brook, and Eel River) as well as the Ellisville Harbor embayment system (stream from Savery Pond and creek from abandoned cranberry bog) being investigated under this 604(b) grant were based on long term measurements of stage in each of the mentioned surfacewaters as well as collection of weekly water quality sampling at each gage location. Ultimately, this data will be merged with the MEP nutrient threshold analysis which is based upon the delineated watersheds to the stream gages and the embayment itself and the watershed specific land-use coverages which enable the development of watershed wide theoretical nitrogen loads specific to the land use characteristics of the watershed.

If all of the nitrogen applied or discharged within a watershed (based on MEP land use analysis) reaches an embayment the watershed land-use loading rate represents the nitrogen load to the receiving waters. This condition exists in watersheds where nitrogen transport from source to estuarine waters is through groundwater flow in sandy outwash aquifers. The lack of nitrogen attenuation in these aquifer systems results from the lack of biogeochemical conditions needed for supporting nitrogen sorption and denitrification. However, in most watersheds in southeastern Massachusetts, nitrogen passes through a surface water ecosystem (pond, wetland, stream) on its path to the adjacent embayment. Surface water systems, unlike sandy aquifers, do

support the needed conditions for nitrogen retention and denitrification. The result is that the mass of nitrogen passing through lakes, ponds, streams and marshes (fresh and salt) is diminished by natural biological processes that represent removal (not just temporary storage). However, this natural attenuation of nitrogen load is not uniformly distributed within the watershed, but is associated with ponds, streams and marshes. In the cases of the Plymouth-Kingston-Duxbury Harbor embayment system watersheds, most of the freshwater flow and transported nitrogen passes through a surface water system and frequently multiple systems prior to entering the estuaries, producing the opportunity for significant nitrogen attenuation.

Failure to determine the attenuation of watershed derived nitrogen overestimates the nitrogen load to receiving estuarine waters. If nitrogen attenuation is significant in one portion of a watershed and insignificant in another the result is that nitrogen management would likely be more effective in achieving water quality improvements if focused on the watershed region having unattenuated nitrogen transport (other factors being equal). In addition to attenuation by freshwater ponds, attenuation in surface water flows is also important. An example of the significance of surface water nitrogen attenuation relating to embayment nitrogen management was seen in the Agawam River, where >50% of nitrogen originating within the upper watershed was attenuated prior to discharge to the Wareham River Estuary (CDM 2001). Similarly, MEP analysis of the Quashnet River indicates that in the upland watershed, which has natural attenuation predominantly associated with riverine processes, the integrated attenuation was 39% (Howes et al. 2004). In addition, a preliminary study of Great, Green and Bournes Ponds in Falmouth, measurements indicated a 30% attenuation of nitrogen during stream transport (Howes and Ramsey 2001). An example where natural attenuation played a significant role in nitrogen management can be seen relative to West Falmouth Harbor (Falmouth, MA), where ~40% of the nitrogen discharge to the Harbor originating from the groundwater effluent plume emanating from the WWTF was attenuated by a small salt marsh prior to reaching Harbor waters. Similarly, the small tidal basin of Frost Fish Creek in the Town of Chatham showed ~20% nitrogen attenuation of watershed nitrogen load prior to discharge to Ryders Cove. Clearly, proper development and evaluation of nitrogen management options requires determination of the nitrogen loads reaching an embayment, not just loaded to the watershed. As such, the 604(b) grant has developed the necessary stream flows and nitrogen loads to be able to do the comparison with the MEP developed land use based load values and obtain a percent attenuation for nitrogen flowing to the embayment system.

Given the importance of determining accurate nitrogen loads to embayments for developing effective management alternatives and the potentially large errors associated with ignoring natural attenuation, direct integrated measurements of nitrogen loading and stream flow was undertaken as part of the 604(b) grant objectives. These measurements were conducted in each of the 3 major surface water flow systems discharging to the Plymouth-Kingston-Duxbury Harbor embayment system (e.g. the Jones River discharging to Kingston Bay, Town Brook discharging to Plymouth Harbor, Eel River discharging to Plymouth Harbor). Additionally, stream gaging was undertaken in the Ellisville Harbor embayment system (e.g. creek discharging from Savery Pond to the head of Ellisville Harbor, creek from abandoned bog to Ellisville Harbor). The location of the stream gages placed in each of the surface water systems mentioned above are depicted below (Figures 6 – 10).

Quantification of watershed based nitrogen attenuation is contingent upon being able to compare nitrogen load to the embayment system directly measured in freshwater stream flow (or in tidal marshes, net tidal outflow) to nitrogen load as derived from the detailed land use analysis (MEP analysis). Measurement of the flow and nutrient load associated with the Jones River (at Route 3A/53 and Brook Street), Town Brook (immediately upgradient of Sandwich Street bridge in downtown Plymouth) and Eel River (immediately down gradient of the Route 3A bridge) provide a direct integrated measure of all of the processes presently attenuating nitrogen in the sub-watersheds upgradient from the gauging sites. Flow and nitrogen concentration were measured at the gages on the Jones River, Town Brook and the Eel River for 21 months of record. Flow and nitrogen concentration were measured at the gage on the creek from Savery Pond to Ellisville Harbor River for 23 months of record and data is still being collected on the creek discharging from the abandoned cranberry bog flowing into Ellisville Harbor. The gage on the creek from the abandoned bog to Ellisville Harbor was deployed after all the other gages as that small surface water flow was identified in the winter time after all the ground cover had been thinned back to reveal the small creek. That gage, which is certainly needed for the MEP nutrient analysis is outside the scope of the 604(b) grant and as such will not be reported as part of the grant as the data set is not completed.

During the study period, velocity profiles were completed on each river every month to two months in order to ultimately develop a rating curve (stage – discharge relation) that could be utilized to convert measured stream stages into daily flows. The summation of the products of stream subsection areas of the stream cross-section and the respective measured velocities represent the computation of instantaneous stream flow (Q).

Determination of stream flow was calculated and based on the measured values obtained for stream cross sectional area and velocity. Stream discharge was represented by the summation of individual discharge calculations for each stream subsection for which a cross sectional area and velocity measurement were obtained. Velocity measurements made across the entire stream cross section were not averaged and then applied to the total stream cross sectional area.

The formula that was used for calculation of stream flow (discharge) is as follows:

$$Q = \Sigma(A * V)$$

where by:

Q = Stream discharge (m^3/s)
A = Stream subsection cross sectional area (m^2)
V = Stream subsection velocity (m/s)

Thus, each stream subsection will have a calculated stream discharge value and the summation of all the sub-sectional stream discharge values will be the total calculated discharge for the stream.

Periodic measurement of flows over the entire stream gauge deployment period allowed for the development of a stage-discharge relationship (rating curve) that could be used to obtain flow

volumes from the detailed record of stage measured by the continuously recording stream gauges. Water level data obtained every 10-minutes was averaged to obtain hourly stages for a given river. These hourly stages values where then entered into the stage-discharge relation to compute hourly flow. Hourly flows were summed over a period of 24 hours to obtain daily flow and further, daily flows summed to obtain annual flow.

In the case of tidal influence on stream stage (Jones River and Eel River), the diurnal low tide stage value was extracted on a day by day basis in order to resolve the stage value indicative of strictly freshwater flow. The two low tide stage values for any given day were averaged and the average stage value for a given day was then entered into the stage – discharge relation in order to compute daily flow. A complete annual record of stream flow (365 days) was generated for each of the surfacewater discharges flowing into the Plymouth-Kingston-Duxbury Harbor embayment system as well as Ellisville Harbor.

Figure 6 – Location of stream gages in the project study area.

Figure 7 – Stream gage location on the Jones River relative to USGS long term stream gaging station.

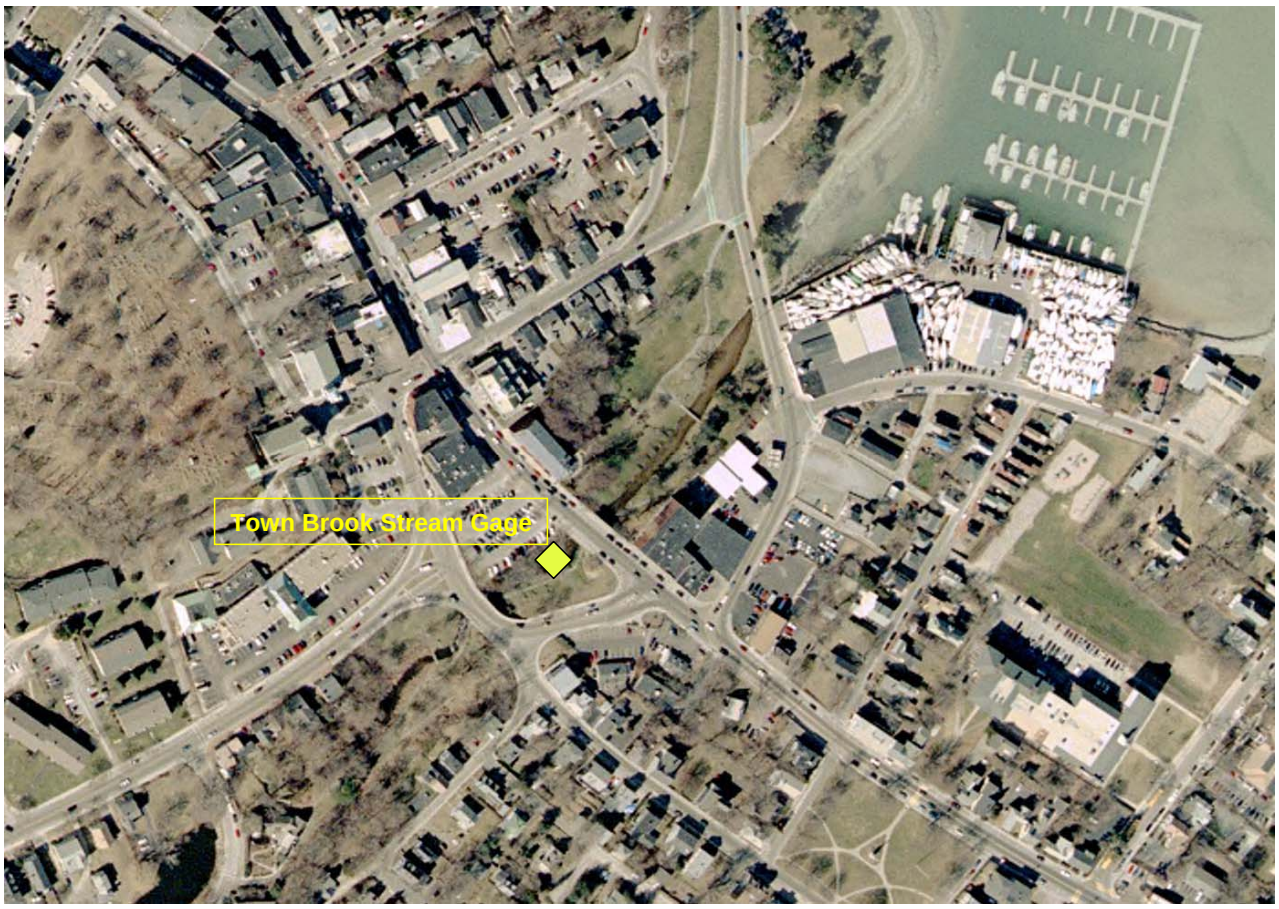

Figure 8 – Location of stream gage deployed in Town Brook.

Figure 9 - Location of stream gage deployed in the Eel River.

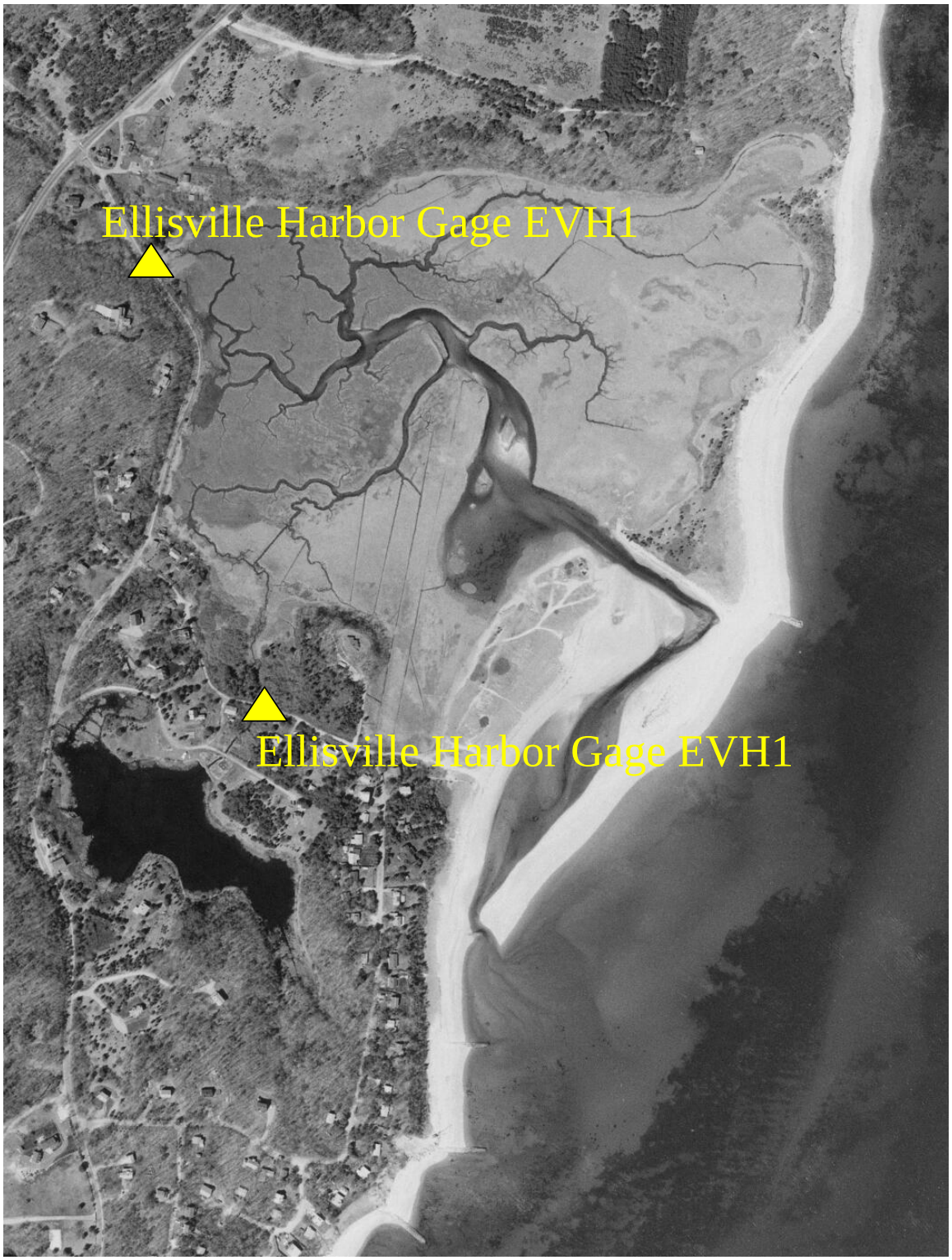

Figure 10 – Location of Stream gages deployed in the Ellisville Harbor embayment system.

The annual flow record for each surface water flow was merged with the nutrient data sets generated through the weekly water quality sampling to determine nitrogen loading rates to the tidally influenced portion of the Plymouth-Kingston-Duxbury Harbor embayment system as well as Ellisville Harbor. Nitrogen discharge from a given stream was calculated using the paired daily discharge and daily nitrogen concentration data to determine the mass flux of nitrogen through the gaging sites.

For a given gaging location, weekly water samples were collected (at low tide for a tidally influenced stage) in order to determine nutrient concentrations from which nutrient load was calculated. In order to pair daily flows with daily nutrient concentrations, interpolation between weekly nutrient data points was necessary. These data are expressed as nitrogen mass per unit time (kg/d) and can be summed in order to obtain weekly, monthly, or annual nutrient load to the embayment system as appropriate. Ultimately, by comparing these measured nitrogen loads based on stream flow and water quality sampling to predicted loads based on the land use analysis to be performed by the MEP, the degree to which natural biological processes within the watershed to each embayment reduces (percent attenuation) nitrogen loading will be determined.

Surface water Discharge and Watershed Nitrogen Load: Jones River to Kingston Bay

Stream gaging on the Jones River provides for a direct measurement of the nitrogen loading to the Plymouth-Kingston-Duxbury Harbor embayment system. The combined rate of nitrogen attenuation by watershed-wide biological processes will be determined in the future by comparing the present predicted nitrogen loading (to be determined by the MEP) to the sub-watershed region contributing to the Jones River above the gauge site and the measured annual discharge of nitrogen to the tidal portion of the Jones River as determined under the 604(b) grant.

At the Jones River gauge site, a continuously recording vented calibrated water level gauge was installed to yield the level of water in the freshwater portion of the Jones River that carries the flows and associated nitrogen load to Kingston Bay. As the Jones River is tidally influenced upgradient of the Route 3A/53 bridge, the gage was located such that it be above the influence of saltwater at low tide. In this manner, flow measurements conducted at low tide would be a measure of freshwater being discharged from the Jones River at the gage. To confirm that freshwater was being measured at low tide, salinity measurements were conducted on the weekly water quality samples collected from the gauge site. Average low tide salinity was determined to be 0.1 ppt therefore, the gauge location was deemed acceptable for making freshwater flow measurements. Additionally, daily flows calculated using the rating curve developed under the 604(b) grant were confirmed relative to a historical record of daily flows developed by the US Geological Survey at a USGS maintained gaging station approximately 1 km upgradient of the gage deployed by the 604(b) project. As depicted in Figure 9 predicted daily flows developed under the 604(b) grant agree within 14 percent of the USGS daily flows for the overlapping period of record. Additionally, predicted daily flows agree favorably with measured flows used in the development of the rating curve. Calibration of the gauge was checked monthly. The gauge on the Jones River was installed on July 3, 2003 and operated continuously for 21 months such that two summer seasons would be captured in the flow record. The gage was retrieved

from the field in February 2005. During the period of deployment there was one period of instrument failure (November 24, 2003 to January 12, 2004) during which time invalid stage data was generated by the instrument. Since no stage data was generated during that period it was not possible to calculate daily flows for that period using the rating curve discussed above. As a result of the excellent agreement between the flow record developed under the 604(b) grant and the USGS flow record upgradient of the gage, it was decided to utilize the USGS daily flows in order to fill the gap in the daily flow record develop under the 604(b) grant project. The 12-month uninterrupted record used in this analysis encompasses the summer 2004 field season and extends from September of 2003 to the end of August 2004 (one complete hydrologic year).

River flow (volumetric discharge) was measured at low tide every 4 to 6 weeks using a Marsh-McBirney electromagnetic flow meter. A rating curve was developed for the Jones River gage based upon these flow measurements and measured water levels at the gage site. The rating curve was then used for conversion of the continuously measured stage data to obtain daily freshwater flow volume. Before using the continuously measured stage data to determine volumetric flow, tidal influence on stage was filtered out of the record by examining stage at ebb slack tide. Based on the daily flows obtained from the Jones River stage record, measured flows, and the rating curve, the annual freshwater flux was determined to be 37,829,207 m^3/yr with an average daily discharge of 103,642 m^3/d to the embayment system (Figure 11). Water samples were collected weekly for nitrogen analysis. Integrating the flow and nitrogen concentration datasets will allow for the future determination of nitrogen mass discharge to the estuarine portion of Kingston Bay.

Total nitrogen concentrations within the Jones River outflow were relatively high, average of 1.01 mg N L^{-1}, where as Nitrate + Nitrite (NOx) was on average 0.493 mg N L^{-1}. In the Jones River, nitrate was the predominant form of nitrogen (50 %), indicating that groundwater nitrogen (typically dominated by nitrate) discharging to the freshwater ponds and to the river was not completely taken up by plants within the pond or stream ecosystems. Dissolved inorganic nitrogen (DIN) was the next most abundant nitrogen specie with an average of 0.521 mg N L^{-1} (51 % of the Total Nitrogen pool) followed by dissolved organic nitrogen (DON) with an average concentration of 0.413 mg N L^{-1} (41 % of the Total Nitrogen pool). Figures 12 and 13 depicts the daily freshwater flow in the Jones River relative to the concentrations of Total Nitrogen (TN) and Nitrate + Nitrite (NOx) as determined from the weekly water quality sampling at the gage as supported by the 604(b) grant.

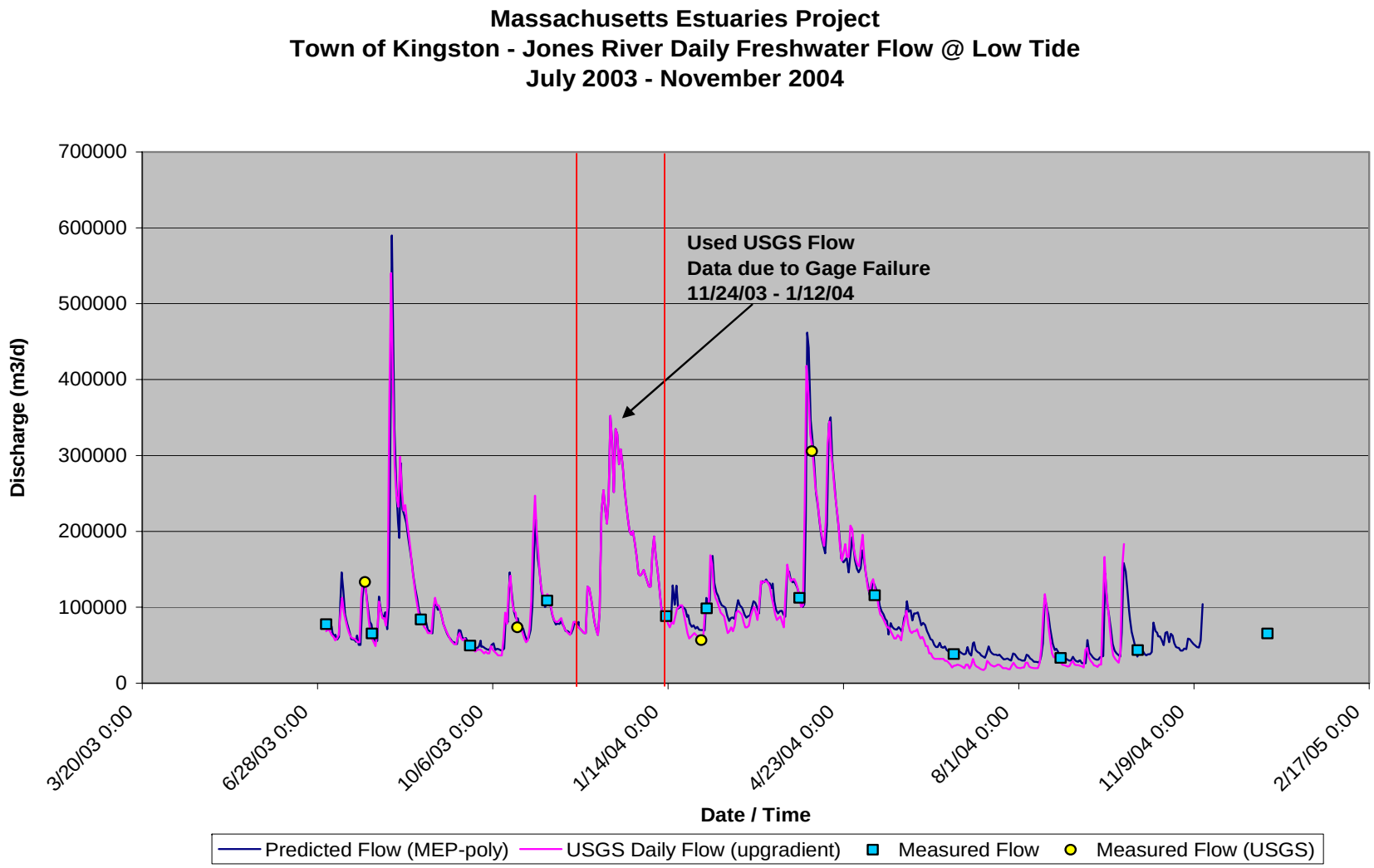

Figure 11 – Predicted daily discharge for the Jones River discharging to Duxbury Harbor

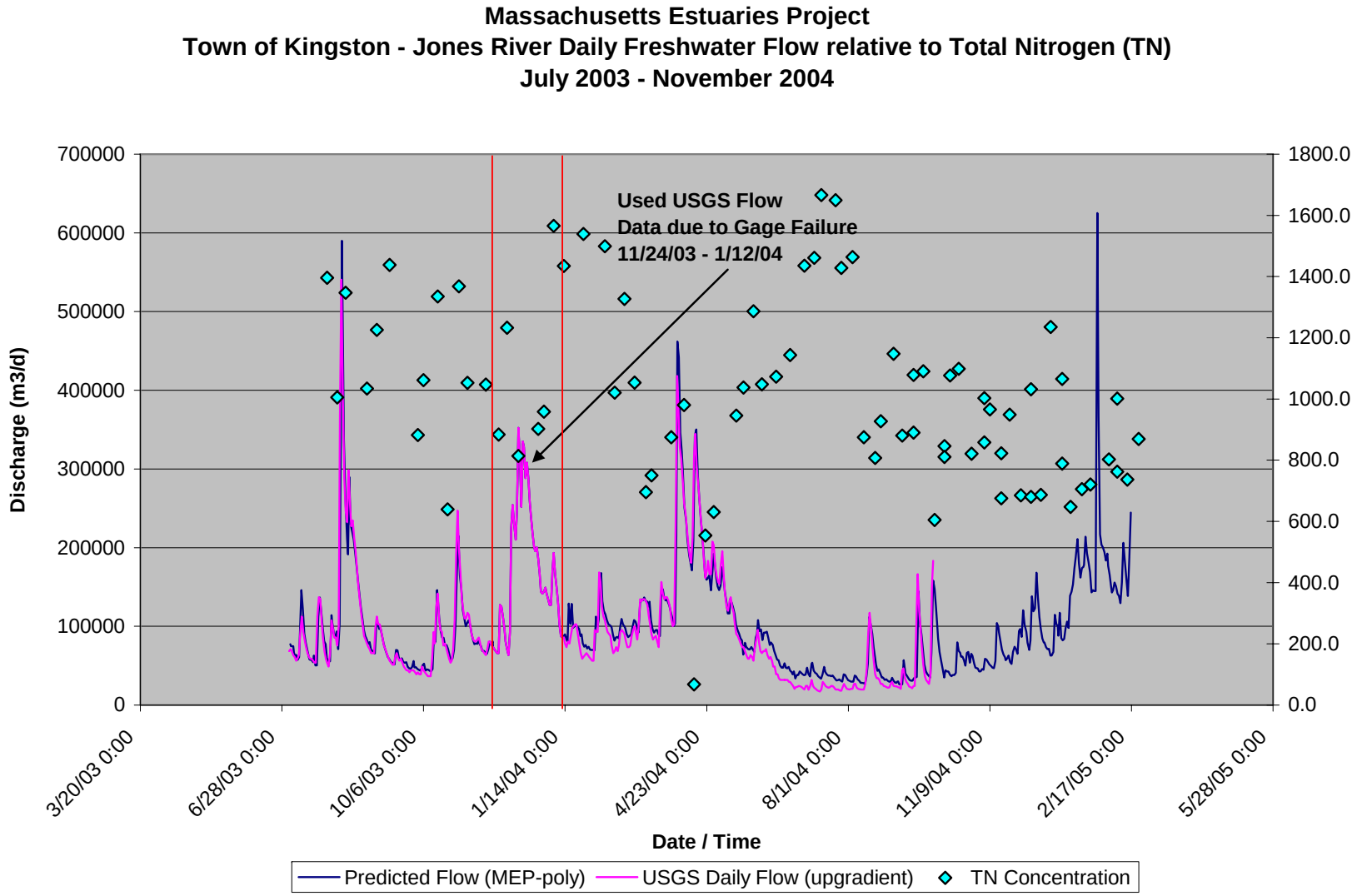

Figure 12 - Predicted daily discharge and Total Nitrogen (TN) concentrations for the Jones River discharging to Duxbury Harbor

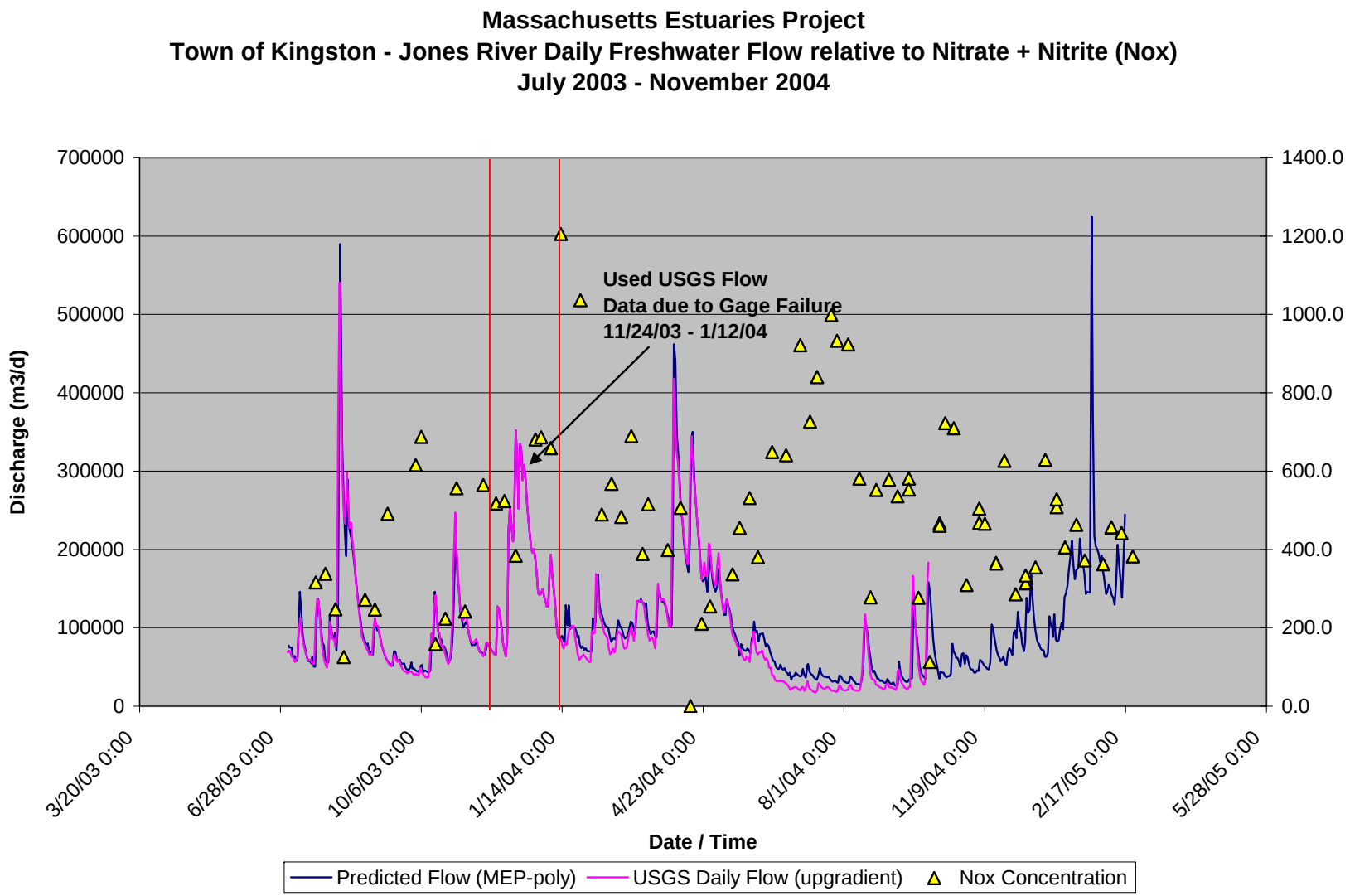

Figure 13 – Predicted daily discharge and Nitrate + Nitrite (NOx) concentrations for the Jones River discharging to Duxbury Harbor.

Surface water Discharge and Watershed Nitrogen Load: Town Brook to Plymouth Harbor

Stream gaging on Town Brook provides for a direct measurement of the nitrogen loading to the Plymouth-Kingston-Duxbury Harbor embayment system. The combined rate of nitrogen attenuation by watershed-wide biological processes will be determined in the future by comparing the present predicted nitrogen loading (to be determined by the MEP) to the sub-watershed region contributing to Town Brook above the gauge site and the measured annual discharge of nitrogen from Town Brook as determined under the 604(b) grant.

At the Town Brook gauge site, a continuously recording vented calibrated water level gauge was installed to yield the level of water in the freshwater portion of Town Brook that carries the flows and associated nitrogen load to Plymouth Harbor. As Town Brook is controlled through a weir installed where the brook passes under Water Street, the gage could only be located upgradient of the control structure and immediately upgradient of the Sandwich Street bridge. While this gage location enabled stage measurements to be made in the absence of tidal influence, the stage and flow records were significantly influenced by the extent to which the control structure was manipulated. To confirm that freshwater was being measured at low tide, salinity measurements were conducted on the weekly water quality samples collected from the gauge site. Average low tide salinity was determined to be 0.1 ppt therefore, the gauge location was deemed acceptable for making freshwater flow measurements.

Based on flow measurements taken throughout the gage deployment period and the detailed stage record, a rating curve relating stage to flow was developed in order to determine predicted daily flows in Town Brook. Predicted daily flows agree favorably with measured flows used in the development of the rating curve. Calibration of the gauge was checked monthly. The gauge on the Town Brook was installed on July 3, 2003 and operated continuously for 21 months such that two summer seasons would be captured in the flow record. The gage was retrieved from the field in February 2005. During the period of deployment there was one period of instrument failure (January 6, 2004 to February 8, 2004) during which time invalid stage data was generated by the instrument. Since no stage data was generated during that period it was not possible to calculate daily flows for that period using the rating curve discussed above. As a result it was decided to utilize linear interpolation between predicted daily flows in order to fill the gap in the daily flow record develop under the 604(b) grant project. The 12-month uninterrupted record used in this analysis encompasses the summer 2004 field season and extends from September of 2003 to the end of August 2004 (one complete hydrologic year).

River flow (volumetric discharge) was measured at low tide every 4 to 6 weeks using a Marsh-McBirney electromagnetic flow meter. A rating curve was developed for the Town Brook gage based upon these flow measurements and measured water levels at the gage site. The rating curve was then used for conversion of the continuously measured stage data to obtain daily freshwater flow volume. Based on the daily flows obtained from the Town Brook stage record, measured flows, and the rating curve, the annual freshwater flux was determined to be 19,322,561 m^3/yr with an average daily discharge of 52,939 m^3/day to Plymouth Harbor (Figure

14). Integrating the flow and nitrogen concentration datasets discussed below will allow for the future determination of nitrogen mass discharge to the estuarine portion of Plymouth Harbor.

Water samples were collected weekly for nitrogen analysis. Total nitrogen concentrations within the Town Brook outflow were relatively high, 1.277 mg N L^{-1}, where as Nitrate + Nitrite (NOx) was 0.67 mg N L^{-1}. In the Town Brook, nitrate + nitrite and dissolved inorganic nitrogen were the predominant forms of nitrogen (52 % and 57 % respectively), indicating that groundwater nitrogen (typically dominated by nitrate) discharging to the freshwater ponds and to the river was not completely taken up by plants within the pond or stream ecosystems. Dissolved organic nitrogen (DON) was clearly a less abundant nitrogen specie with an average of 0.369 mg N L^{-1} (29 % of the Total Nitrogen pool) followed by dissolved organic nitrogen (PON) with an average concentration of 0.185 mg N L^{-1} (14 % of the Total Nitrogen pool). Figures 15 and 16 depict the daily freshwater flow in the Jones River relative to the concentrations of Total Nitrogen (TN) and Nitrate + Nitrite (NOx) as determined from the weekly water quality sampling at the gage as supported by the 604(b) grant.

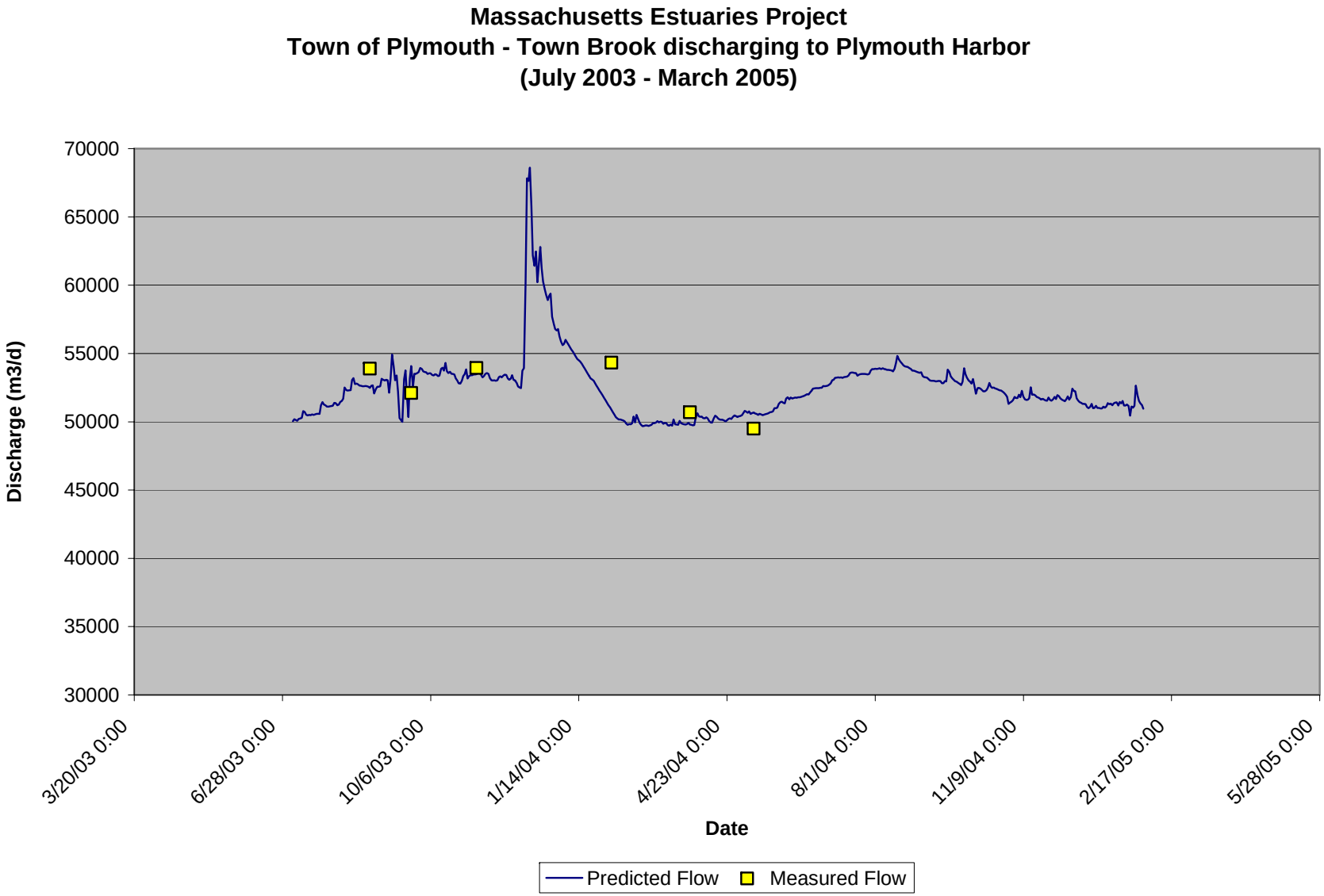

Figure 14 - Predicted daily discharge for Town Brook discharging to Plymouth Harbor.

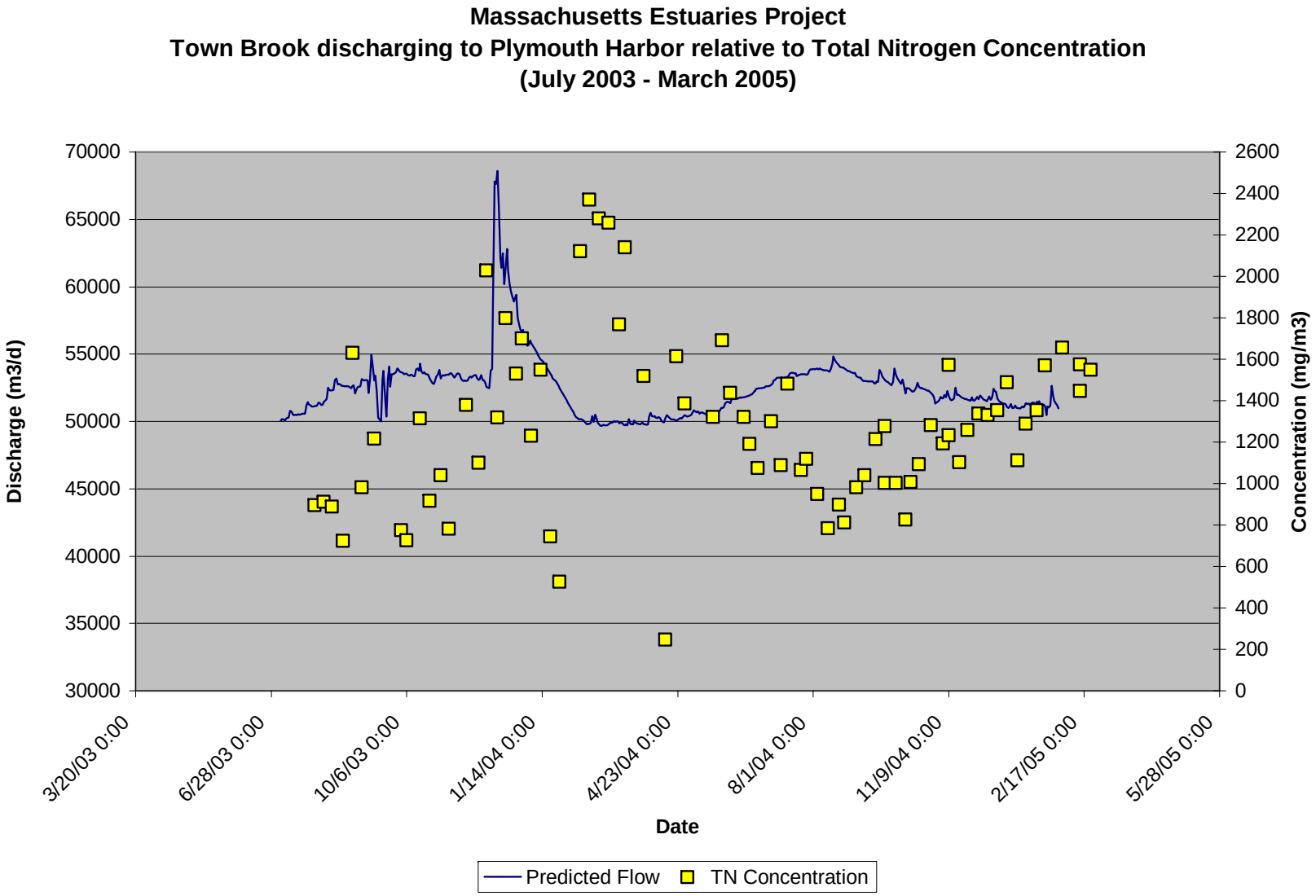

Figure 15 - Predicted daily discharge for Town Brook relative to Total Nitrogen (TN) concentrations.

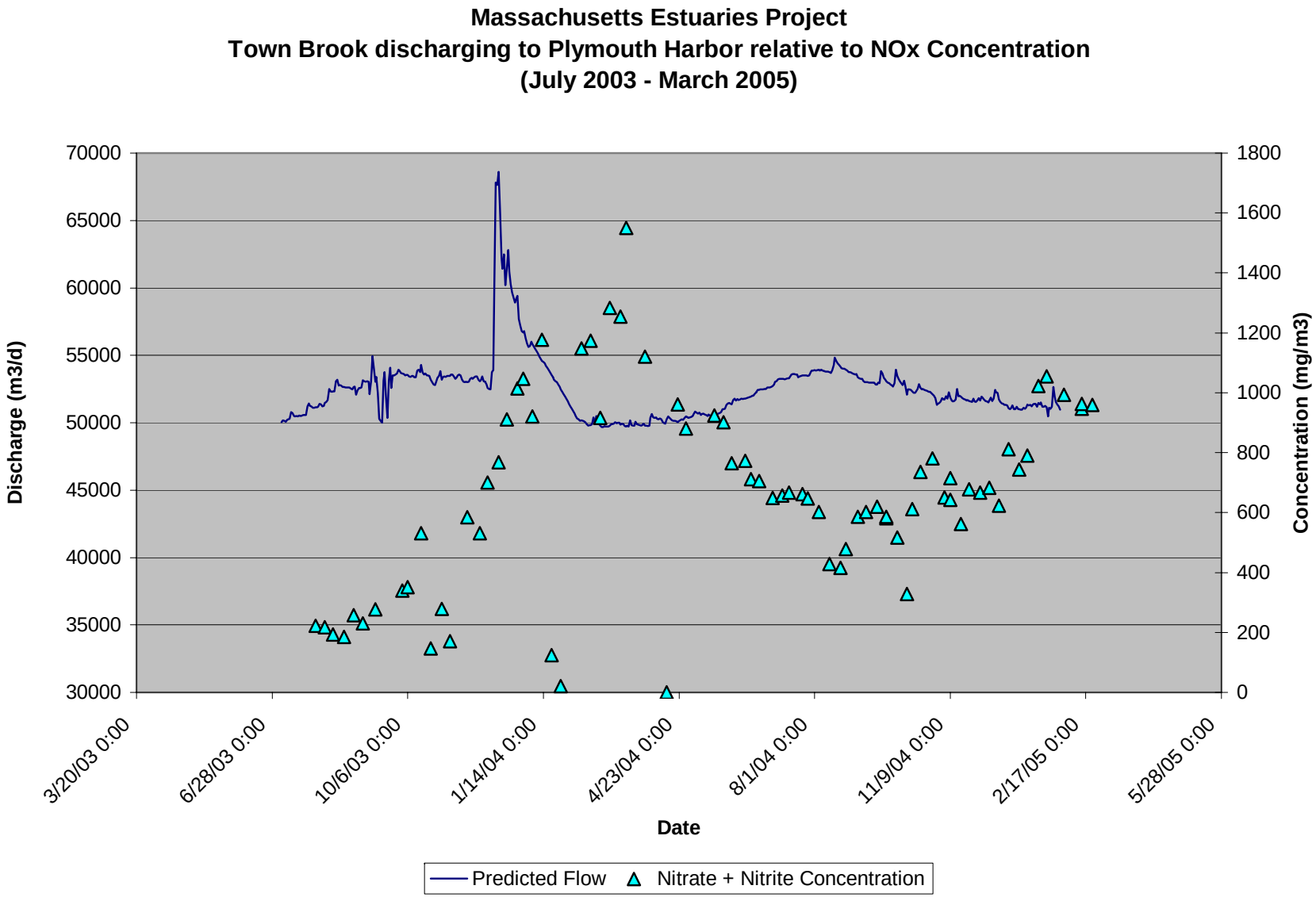

Figure 16 - Predicted daily discharge for Town Brook relative to Nitrate + Nitrite (NOx) concentrations.

Surface water Discharge and Watershed Nitrogen Load: Eel River to Plymouth Harbor

Stream gaging on the Eel River provides for a direct measurement of the nitrogen loading to the Plymouth-Kingston-Duxbury Harbor embayment system. The combined rate of nitrogen attenuation by watershed-wide biological processes will be determined in the future by comparing the present predicted nitrogen loading (to be determined by the MEP) to the sub-watershed region contributing to the Eel River above the gauge site and the measured annual discharge of nitrogen to the tidal portion of the Eel River as determined under the 604(b) grant.

At the Eel River gauge site, a continuously recording vented calibrated water level gauge was installed to yield the level of water in the freshwater portion of the Eel River that carries the flows and associated nitrogen load to Kingston Bay. As the Eel River is tidally influenced down gradient of the Route 3A bridge, the gage was located such that it be above the influence of saltwater at low tide. In this manner, flow measurements conducted at low tide would be a measure of freshwater being discharged from the Eel River at the gage. To confirm that freshwater was being measured at low tide, salinity measurements were conducted on the weekly water quality samples collected from the gauge site. Average low tide salinity was determined to be 0.1 ppt therefore, the gauge location was deemed acceptable for making freshwater flow measurements. Additionally, daily flows calculated using the rating curve developed under the 604(b) grant were confirmed relative to measured flows at the stream gage. Predicted daily flows agree favorably with measured flows used in the development of the rating curve. Calibration of the gauge was checked monthly. The gauge on the Eel River was installed on July 3, 2003 and operated continuously for 21 months such that two summer seasons would be captured in the flow record. The gage was retrieved from the field in February 2005. During the period of deployment there was one period of instrument failure (December 6, 2003 to January 6, 2004) during which time invalid stage data was generated by the instrument. Since no stage data was generated during that period it was not possible to calculate daily flows for that period using the rating curve discussed above. It was decided to utilize a linear interpolation between the dates during which the instrument failed in order to fill the gap in the daily flow record developed under the 604(b) grant project. The 12-month uninterrupted record used in this analysis encompasses the summer 2004 field season and extends from September of 2003 to the end of August 2004 (one complete hydrologic year).

River flow (volumetric discharge) was measured at low tide every 4 to 6 weeks using a Marsh-McBirney electromagnetic flow meter. A rating curve was developed for the Eel River gage based upon these flow measurements and measured water levels at the gage site. The rating curve was then used for conversion of the continuously measured stage data to obtain daily freshwater flow volume. Before using the continuously measured stage data to determine volumetric flow, tidal influence on stage was filtered out of the record by examining stage at ebb slack tide. Based on the daily flows obtained from the Eel River stage record, measured flows, and the rating curve, the annual freshwater flux was determined to be 25,178,656 m^3/yr yielding a daily discharge of 68,983 m^3/day (Figure 17). Water samples were collected weekly for nitrogen analysis. Integrating the flow and nitrogen concentration datasets will allow for the future determination of nitrogen mass discharge to the estuarine portion of Plymouth Harbor.

Total nitrogen concentrations within the Eel River outflow were relatively high, on average 0.603 mg N L^{-1}, where as average Nitrate + Nitrite (NOx) concentration was 0.140 mg N L^{-1} (23 % of the Total Nitrogen pool). Additionally, particulate organic nitrogen (PON) with an average concentration of 0.120 mg N L^{-1} represented 20 % of the total nitrogen pool. In the Eel River, dissolved organic nitrogen (DON) with an average concentration of 0.310 mg N L^{-1} was the predominant form of nitrogen (51% of the Total Nitrogen pool), indicating that groundwater nitrogen (typically dominated by nitrate) discharging to the freshwater ponds and to the river was significantly taken up by plants within the pond or stream ecosystems prior to discharging to the Plymouth Harbor system. Figures 18 and 19 depict the daily freshwater flow in the Eel River relative to the concentrations of Nitrate + Nitrite (NOx) and Total Nitrogen (TN) as determined from the weekly water quality sampling at the gage as supported by the 604(b) grant.

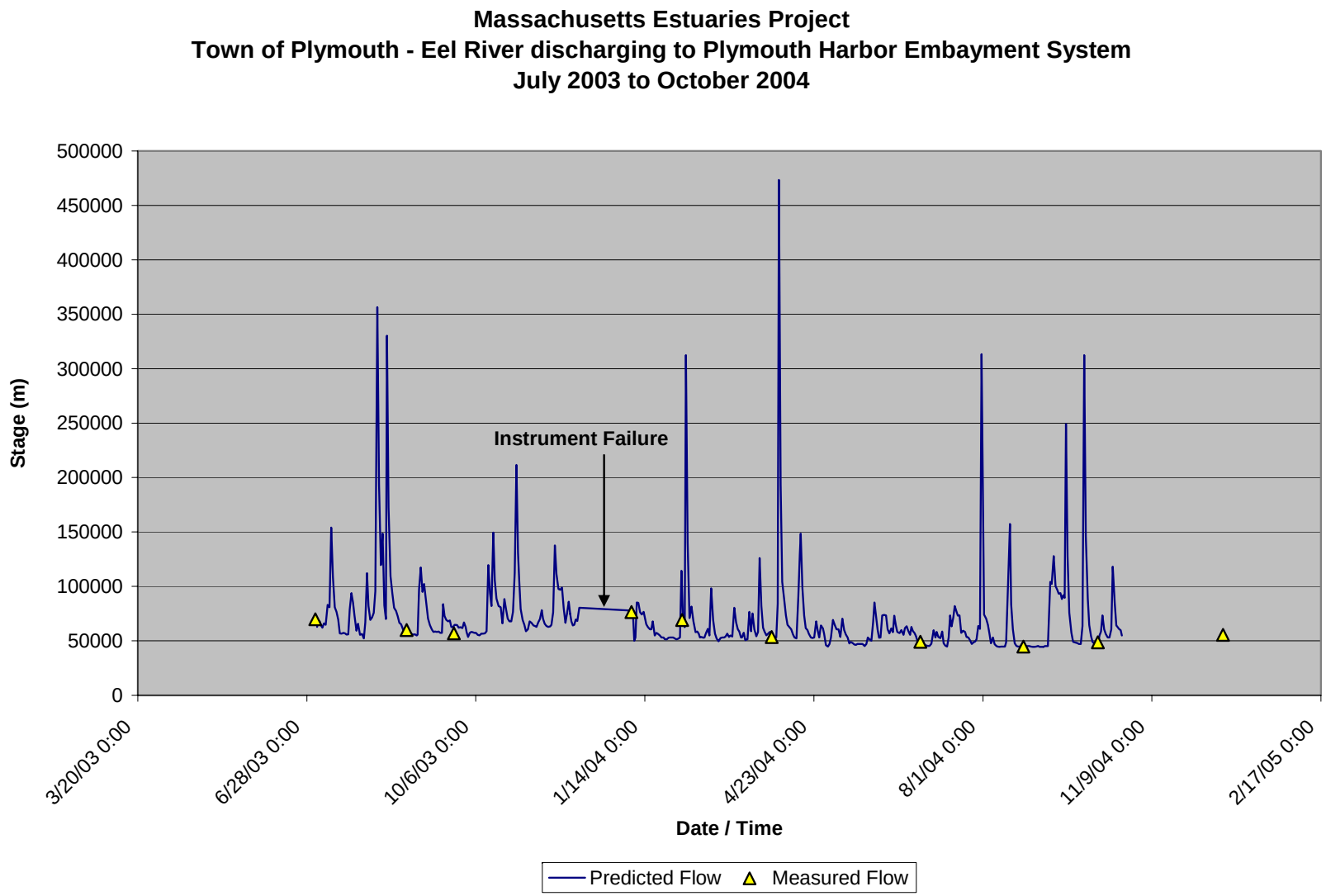

Figure 17 – Predicted daily discharge in the Eel River discharging to Plymouth Harbor.

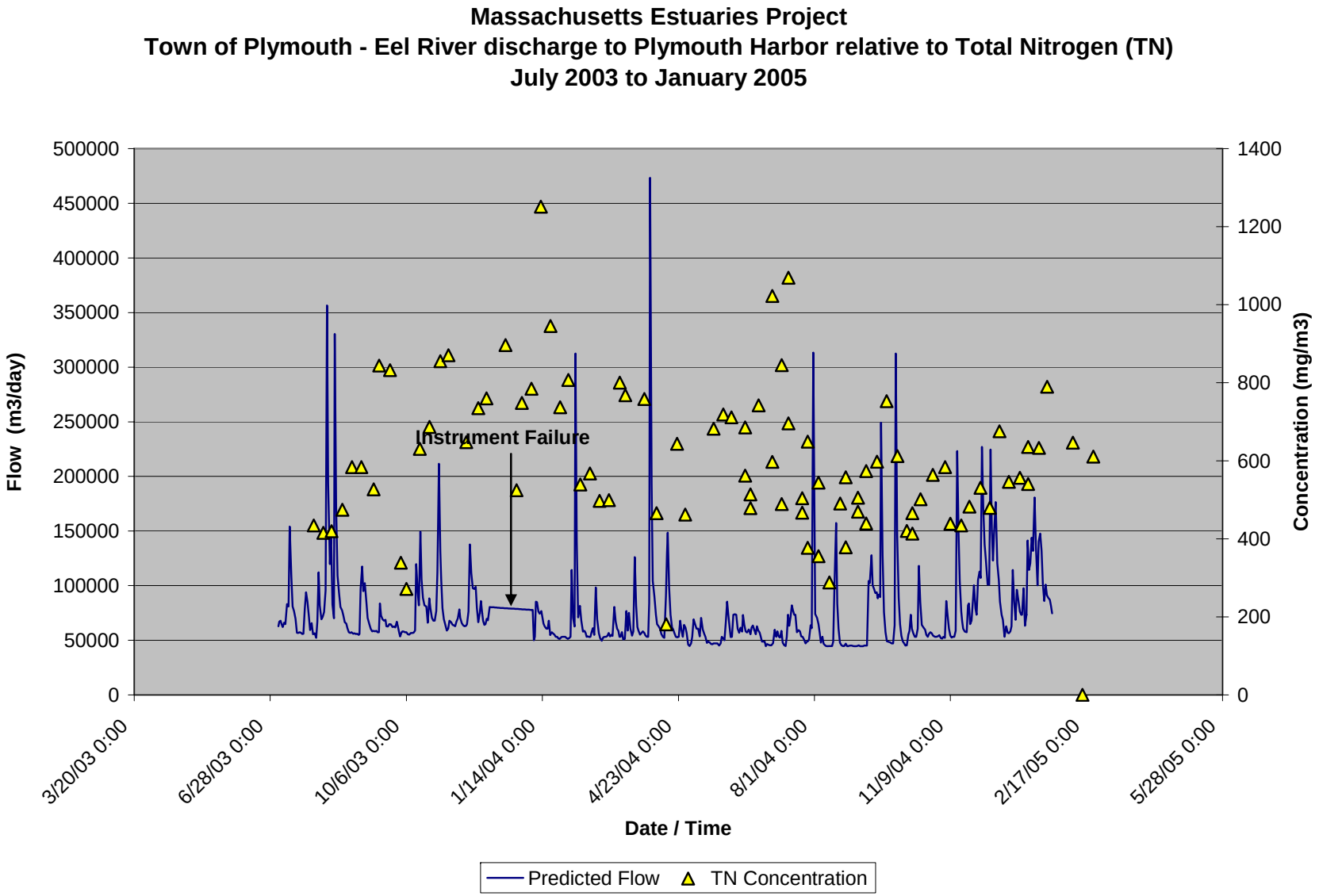

Figure 18 - Predicted daily discharge for Eel River relative to Total Nitrogen (TN) concentrations

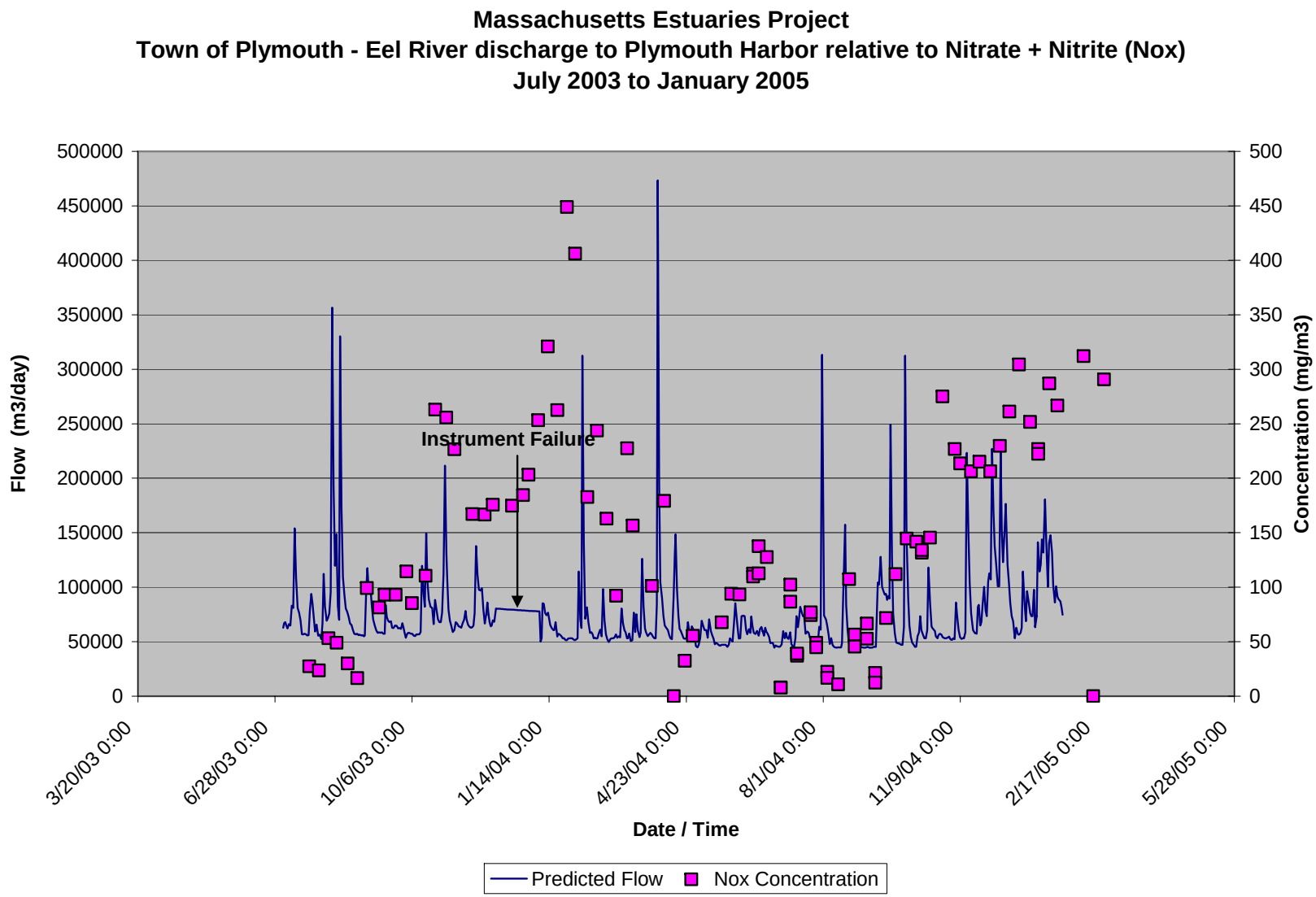

Figure 19 - Predicted daily discharge for Eel River relative to Nitrate + Nitrite (NOx) concentrations.

Surface water Discharge and Watershed Nitrogen Load: Savery Pond Creek to Ellisville Harbor

Stream gaging on the Savery Pond Creek to Ellisville Harbor provides for a direct measurement of the nitrogen loading to the Ellisville Harbor embayment system. The combined rate of nitrogen attenuation by watershed-wide biological processes will be determined in the future by comparing the present predicted nitrogen loading (to be determined by the MEP) to the sub-watershed region contributing to the Savery Pond Creek above the gauge site and the measured annual discharge of nitrogen to the tidal portion of the Ellisville Harbor system as determined under the 604(b) grant.

At the Savery Pond Creek gage site, a continuously recording vented calibrated water level gage was installed to yield the level of water in the freshwater portion of the Savery Pond Creek that carries the flows and associated nitrogen load to the head of Ellisville Harbor. As the creek is not tidally influenced upgradient of Ellisville Road where it passes over the creek, the gage was located such that it maintain high enough velocities during low flow periods to be able to make accurate flow determinations. Despite that consideration there were still periods during the hydrologic year when flow was to low to be able to accurately measure velocities from which flow could be calculated. To confirm that there was not tidal influence at the gage stage was checked over multiple tidal periods and salinities where measured for indication of freshwater flow at the gage. Salinity measurements were conducted on the weekly water quality samples collected from the gauge site. Average salinity was determined to be 0.1 ppt therefore, the gage location was deemed acceptable for making freshwater flow measurements. As a further safety measure, velocity measurements were taken at low tide despite the lack of a tidal signal. This was motivated by the need to make measurements at low tide for both the Eel River gage location as well as the Jones River. Additionally, daily flows calculated using the rating curve developed under the 604(b) grant were confirmed relative to measured flows used in the development of the rating curve. As depicted in Figure 18, predicted flows agree well with measured flows obtained during the deployment period. Calibration of the gauge was checked monthly. The gage on the Savery Pond Creek was installed on July 3, 2003 and operated continuously for 21 months such that two summer seasons would be captured in the flow record. The gage was retrieved from the field in February 2005. During the period of deployment there was one period of instrument failure (November 28, 2004 to December 22, 2004) during which time invalid stage data was generated by the instrument. Since no stage data was generated during that period it was not possible to calculate daily flows for that period using the rating curve discussed above. It was decided to utilize a linear interpolation between the dates during which the instrument failed in order to fill the gap in the daily flow record developed under the 604(b) grant project. The 12-month uninterrupted record used in this analysis encompasses the summer 2004 field season and extends from September of 2003 to the end of August 2004 (one complete hydrologic year).

River flow (volumetric discharge) was measured at low tide every 4 to 6 weeks using a Marsh-McBirney electromagnetic flow meter. A rating curve was developed for the Jones River gage based upon these flow measurements and measured water levels at the gage site. The rating curve was then used for conversion of the continuously measured stage data to obtain daily

freshwater flow volume. Before using the continuously measured stage data to determine volumetric flow, tidal influence on stage was filtered out of the record by examining stage at ebb slack tide. Based on the daily flows obtained from the Savery Pond Creek stage record, measured flows, and the rating curve, the annual freshwater flux was determined to be 292,192 m^3/yr yielding a daily discharge of 801 m^3/day (Figure 20). Water samples were collected weekly for nitrogen analysis. Integrating the flow and nitrogen concentration datasets will allow for the future determination of nitrogen mass discharge to the estuarine portion of Ellisville Harbor.

Total nitrogen concentrations within the Savery Pond Creek outflow were relatively high, on average 0.799 mg N L^{-1}, where as Nitrate + Nitrite (NOx) was on average 0.05 mg N L^{-1}. In the creek, dissolved and particulate forms of nitrogen where the predominant form of nitrogen (47% and 38% respectively of the Total Nitrogen pool), indicating that groundwater nitrogen (typically dominated by nitrate) discharging to the freshwater ponds and to the river was significantly taken up by plants within the pond or stream ecosystems prior to discharging to the head of the Ellisville Harbor system. Figures 21 and 22 depict the daily freshwater flow in the Savery Pond Creek relative to the concentrations of Total Nitrogen (TN) and Nitrate + Nitrite (NOx) as determined from the weekly water quality sampling at the gage as supported by the 604(b) grant.

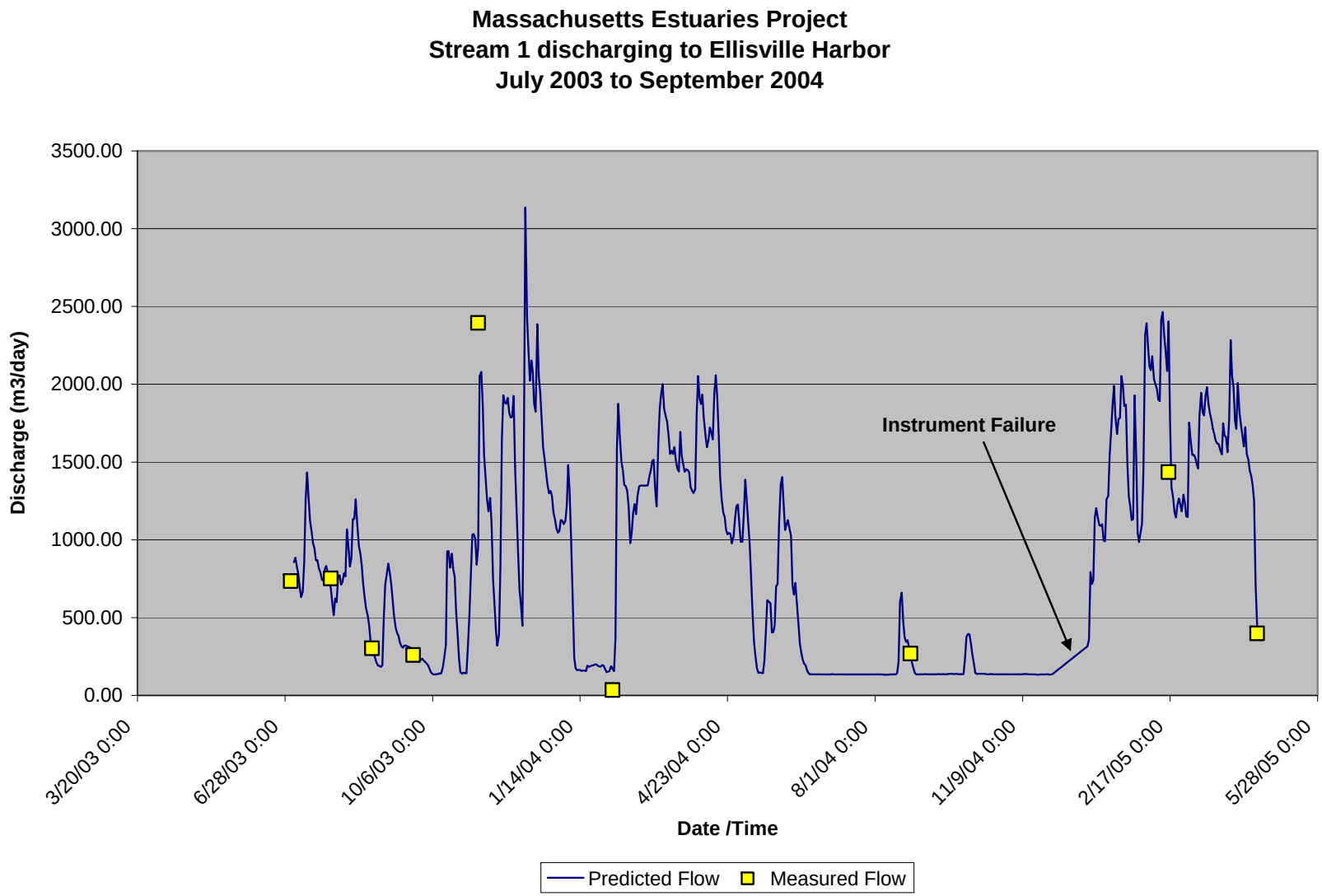

Figure 20 – Predicted daily discharge for the stream flowing from Savery Pond to the head of the Ellisville Harbor system.

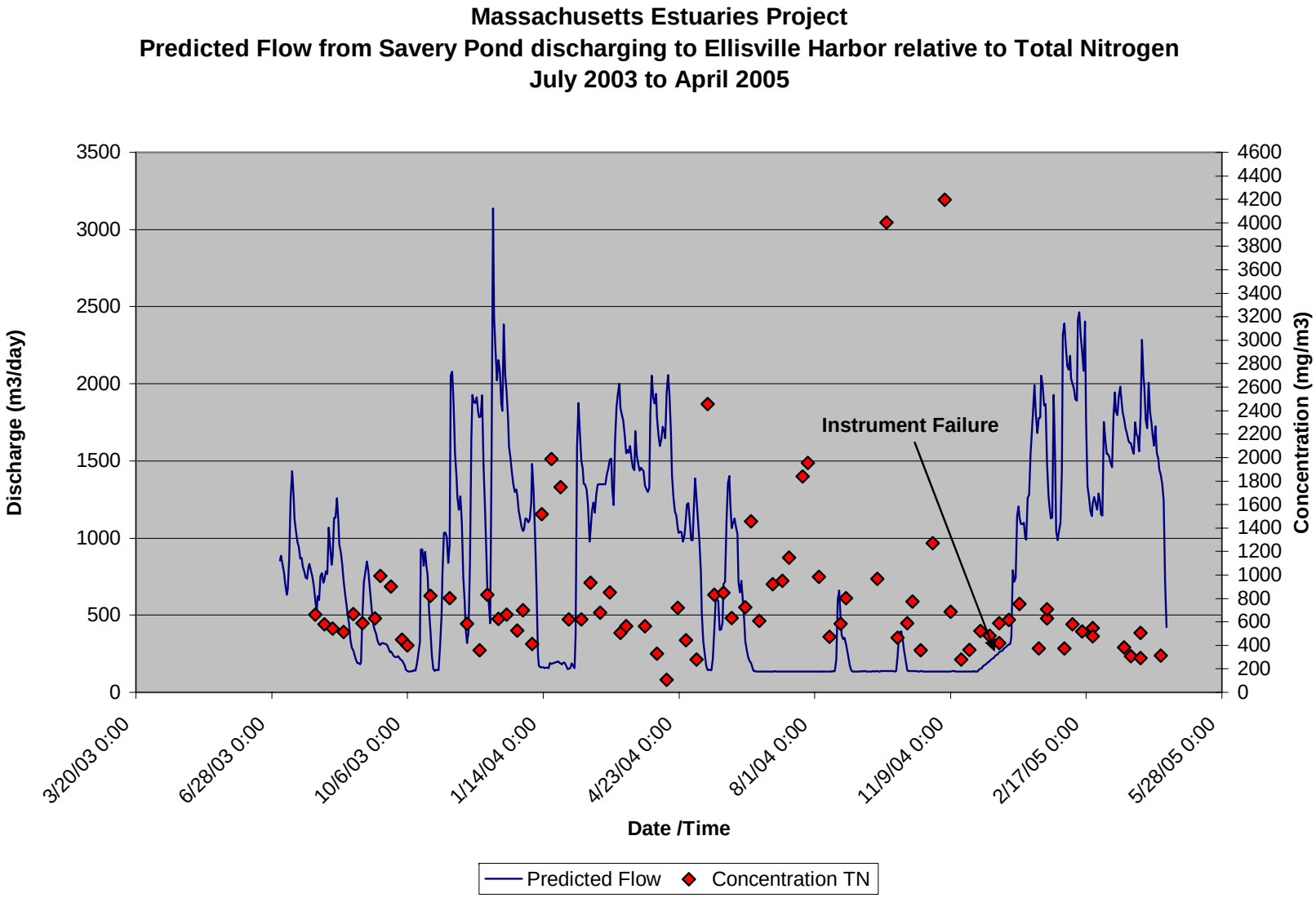

Figure 21 – Predicted daily discharge relative to Total Nitrogen (TN) concentrations for the stream flowing from Savery Pond to the head of the Ellisville Harbor system

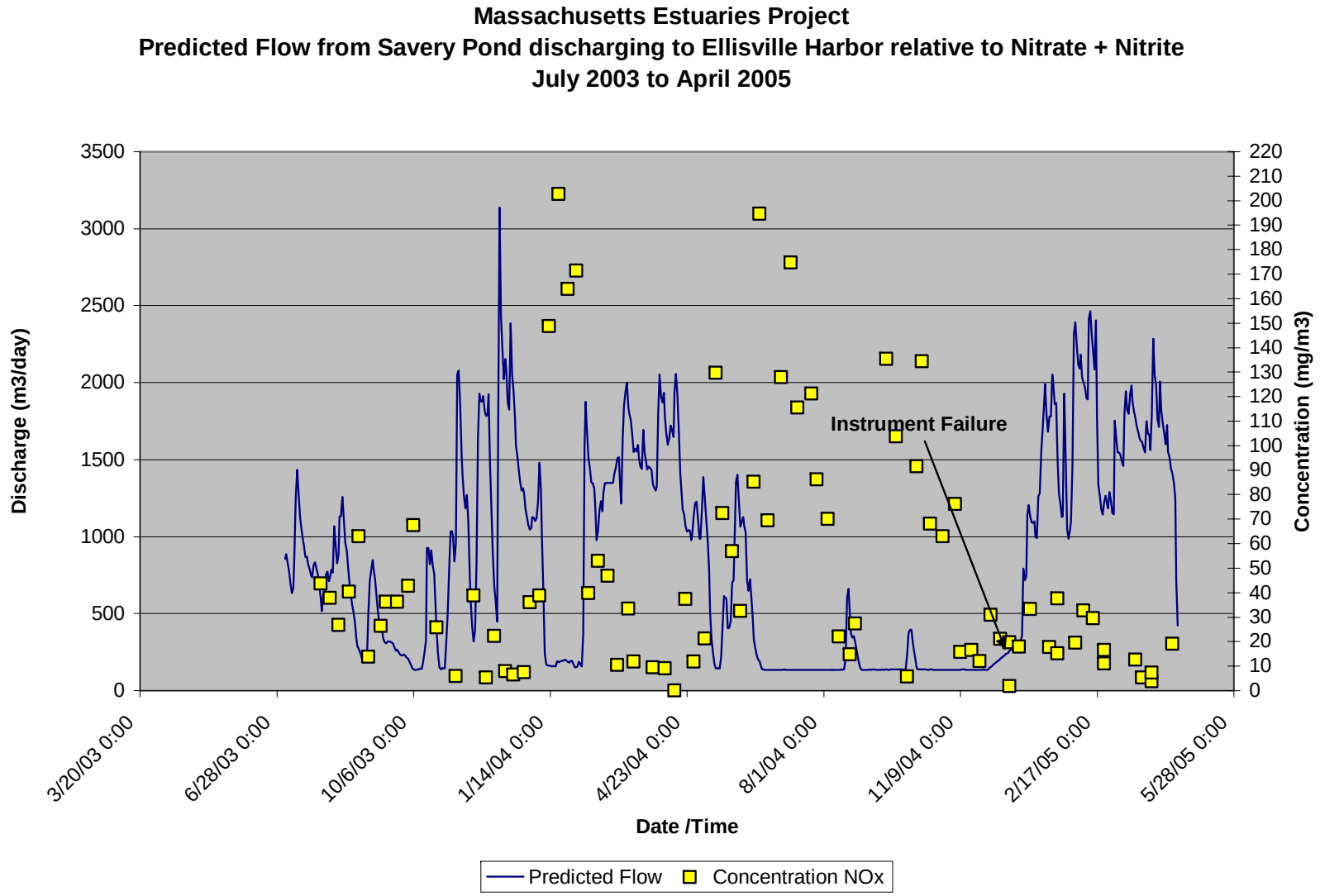

Figure 22 – Predicted daily discharge relative to Nitrate + Nitrite (NOx) concentrations for the stream flowing from Savery Pond to the head of the Ellisville Harbor system.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Overall, it appears that the Massachusetts Estuaries Project (MEP) analysis is warranted for both estuarine systems (Plymouth-Kingston-Duxbury embayment and Ellisville Harbor embayment) monitored under this 604(b) project and that water quality monitoring needs to continue for a minimum of 1 year to develop the needed baseline to invoke the MEP nutrient threshold analysis.

With regards to the specifics of each embayment monitored under the 604(b) grant certain water quality characteristics have become apparent as follows:

- The Plymouth Harbor/Duxbury Harbor/Kingston Bay and Ellisville Harbor systems appear to support moderate to high nitrogen related habitat quality relative to their specific resource conditions.

- Both systems were confirmed to be nitrogen limited based upon the elemental ratio method (Redfield Ratio of N/P <16). The average ratio of inorganic nitrogen to inorganic phosphorus (N/P) was 4-7 for the stations internal to Ellisville Harbor (the offshore station was 3). Similarly, the Plymouth Harbor/Duxbury Harbor/Kingston Bay System showed N/P ratios of 2-6.

- Only the stations directly influenced by the Jones River (PDH-9), Eel River (PDH-1) and Town Brook (PDH-2) showed discernable dilution of salinity by freshwater. Since nitrogen enters these systems primarily in freshwater inputs, nitrogen levels also generally showed only a low to moderate enhancement over the boundary waters, generally TN 0.31 – 0.42 mg/L in the main basin. Only the Jones River influenced station (PDH-9) and the northern-most basins showed moderately high values of total nitrogen (TN), 0.46-0.55 mg/L. The elevated nitrogen levels are ultimately the result of nitrogen entering the tidal waters from both groundwater and surface water inflows. This is supported by the generally higher levels of TN in regions associated with river inflows.

- In general oxygen levels were relatively high, average of lowest 20% of observations > 6 mg/L in all but the northern basin and mouth of the Jones River, and > 5 mg/L at all sites. The sites with the highest TN levels tended to have the lowest dissolved oxygen levels. This pattern was also repeated in the phytoplankton pigments. The mouth of the Jones River sub-estuary (PDH-9) and the northern most basin (PDH-15) showed moderate levels of chlorophyll a pigments (~7.5 ug/L), consistent with their TN and dissolved oxygen levels.

- In general, the southern, central and outer northern basins show a high level of nitrogen related water quality. The slightly impaired waters in the region nearest the Jones River discharge and the inner regions of the northern basin most likely result from their lower flushing rates and from nitrogen loads. In the region of the Jones River discharge the nitrogen loading is almost certainly from the river discharge while in the northern basin (PDH 14, 15) it is likely from the salt marshes and sediment coupled with watershed inputs.

- Using the Bay Health Index for the Plymouth Harbor/Duxbury Harbor/Kingston Bay System, the southern, central and outer northern basins show a high level of nitrogen related water quality. This pattern is consistent with the structure of the watershed and the high tidal flushing of estuarine waters resulting, in part from the large tide range (3 m).

- The slightly impaired waters in the region nearest the Jones River discharge and the inner regions of the northern basin most likely result from their lower flushing rates and from nitrogen loads. In the region of the Jones River discharge, the nitrogen loading is almost certainly from the river discharge while in the northern basin (PDH 14, 15) it is likely from the salt marshes and sediment coupled with watershed inputs.

- Similar to Plymouth Harbor to the north, the Ellisville Harbor system has relatively low freshwater inputs relative to its flushing rate and therefore maintains high salinity waters throughout. The lack of a strong salinity gradient results from the relatively low freshwater inflow at the systems head and the inflow of freshwater at mid system, plus the discharge of groundwater along the length of the marsh.

- The upper salt marsh region is likely enhanced by the nitrogen from the 2 freshwater streams (major to this system, but not large), which had TN levels of 0.61-0.8 mg/L TN. While these nitrogen levels are moderate to high for embayments, they may not represent impairment in a salt marsh dominated system, like Ellisville Harbor.

- Since nitrogen enters this system primarily in freshwater inputs, it is not surprising that nitrogen levels also generally showed only an enhancement over the boundary waters, generally TN 0.44 – 0.71 mg/L in the main marsh regions and 0.35 mg/L, offshore.

- In general oxygen levels in Ellisville Harbor were relatively low, average of lowest 20% of observations 4.5-5.5 mg/L in all but the offshore station which was fully oxygenated (8 mg/L). The sites with the highest TN levels tended to have the lowest dissolved oxygen levels, such that there was a gradient in improving oxygen status moving from the inner marsh to the tidal inlet and then offshore. This pattern was also repeated in the phytoplankton pigments.

- The low Bay Health Index scores may be the result of the systems function as a salt marsh rather than an open embayment, but it is also possible that the levels of the various indicators may suggest impairment of even a salt marsh system or of the lower more open basin. This determination requires additional habitat assessments so impairments can be firmly documented, however, these data are cause for concern for the health of this system. In general, there is a strong gradient in nitrogen related water quality from the high nitrogen-chlorophyll and low oxygen inner regions to the low nitrogen-chlorophyll and high oxygen outer basin and tidal inlet.

5.0 DATA QUALITY ASSURANCE AND CONTROL

The lab data included in this report were reviewed by Drs. Brian Howes and Dr. David White (SMAST QA Officer) to assure that the data meets SMAST Quality Assurance requirements. Samples were cross-checked to Chain-of-Custody forms to confirm sample numbers, id's etc. Lab results were scrutinized both for each station over the course of the sampling program and for all stations within the embayment system during each sampling round. The data were compared to identify suspicious outliers. Possible causative factors for data outliers include: proximity to a fresh water discharge; location within a poorly circulated recess of the estuary; recent rainfall; handling or collection errors; and lab error as indicated by blind duplicate results for that date. After examination, no sample results were excluded from the database. Assays and pre-assay procedures were performed within the appropriate time intervals post-collection. All "missing" samples are the result of either, samples not being collected or analytical machine error, where the full sample was lost and therefore could not be re-analyzed. Although these "errors" did occur, they represented far less than 1% of the data.

The data are included in the Appendices below.

APPENDIX – A

FIELD SAMPLING PROTOCOL (NUTRIENTS)

MEP FIELD SAMPLING PROTOCOLS: NUTRIENTS

Nutrient Sample Collection Overview (MEP QAPP Appendix B-1, H)

The goal of the Water Quality Monitoring Program is to provide needed data with which to evaluate overall water quality conditions in nearshore waters and harbors. These waters are most likely to be impacted by excessive nutrient loading originating from local land use. Because of the value of this data, it is very important that measurements are made using the protocol provided and that collections occur during the last three hours of an outgoing tide. Through training sessions, hands-on instruction and sampling tips, we will provide you with the information necessary to ensure efficiency and accuracy in the measurements. Please call (Paul Henderson) 508-910-6352) if you have any questions and note any problems on the data sheet.

In addition to nutrient sample collection and filtering, the following measurements need to be taken at each station: dissolved oxygen (milligrams per liter), water temperature, water clarity (Secchi disk) and total depth. Samples collected for nutrients will be analyzed at the SMAST laboratory for:

Ammonium	Nitrate+Nitrite	Particulate Organic Nitrogen
Ortho-Phosphate	Chlorophyll a & pheophytin a	Particulate Organic Carbon
Dissolved Organic N	Total Phosphorus (streams)	Specific Conductance / Salinity

Arriving On Station

The on-shore landmarks will be used to approximate sample station location, with final sample station determined by GPS. However, it is anticipated that, for the stream stations and nearshore marine stations, that landmarks or navigational bouys will provide sufficient location information once sampling is underway. All stations will be located by GPS so that future sampling programs can easily return to them. The boat will be anchored so that it remains in a fixed position while samples are collected and profile readings taken. The boat should approach the sample location moving into the current to minimize sediment disturbance for all sample stations but particularly for shallow stations (anticipated water depth less than 1 meter).

5.3 Order of Data Collection on Station

In order to avoid bottom disturbance, the following data collection order will be followed:

Use Secchi disk to determine light penetration and to determine exact depth from stern of boat and wait until after touching bottom (5 minutes) before proceeding
Collect meter data in vertical profile using depth information to collect data to within 0.5 meters of the bottom (from side or bow of boat)
Collect water samples (from the side or bow of boat)

General Information and Weather Conditions (Appendix A also MEP QAPP Append B-1 H)

The following parameters will be recorded on the data sheet:

*Time of nearest low tide from tide table and whether the tide is ebbing (approaching low) or flooding (approaching high)
*Wave conditions - see Beaufort scale
*Wind direction - the direction the wind is coming from
*Weather conditions
*Rainfall in last 24 hours. (collected by SMAST from KPYM weather station located at Plymouth Municipal Airport, Lat. 41 54 31N Lon. 070 43 41 W 43min.)
* Any unusual natural or man-made conditions.
*Fill out each field data sheet with the pond, station number, time, cloud cover and wind direction and speed and wave height if it has changed from the previous station.

Secchi Depth / Total Depth (Appendix A also MEP QAPP Append B-1 H)

These readings should be taken over the shaded side of the boat and without the aid of polarizing sunglasses.

Step 1. Lower Secchi disk into water slowly from shady side of a boat, dock or pier until it just disappears from view. Raise and lower slightly to insure the proper average depth of disappearance.

Step 2. Read depth on tape where it intersects the water surface, record on data sheet. *Note: Sometimes the Secchi disk will hit the bottom before it disappears — in this case write "visible on bottom" or "vis/btm" on disk depth on data sheet.*

Step 3. Lower Secchi disk slowly until it touches bottom, record station total depth.

Dissolved Oxygen, Field Data Collection with YSI-85 Multi-Parameter Meter

The meter is calibrated each day on shore before starting the sampling. Calibration is described in Appendix B. Once calibrated, the meter should be left on throughout the course of the sampling day. If turned off, it must be re-calibrated for Dissolved Oxygen prior to proceeding with data collection. The meter provides readings of four parameters with six pieces of information: dissolved oxygen percent saturation, dissolved oxygen milligrams per liter, conductivity, specific conductivity, salinity and temperature. When arriving on station, once the boat is secured with the anchor, remove the probe from its protective housing and place it into the surface water to allow it to equilibrate with the surface water temperature. Water depth will initially be determined with a Solinst depth-sounding device to avoid disturbance of the sediment. After meter readings and water sample collection, the Secchi readings will be taken and the marked cable used to determine the exact depth.

The meter data should be collected in the same order as listed above at each depth interval. Record the data on the field data sheets. The meter cable is marked in one-meter intervals. At each depth, the probe should be moved in an up and down manner over a distance of several inches to circulate pond water over the probe. Wait to record data until the reading for each parameter has stabilized. Data should be collected at the surface (at a depth of 6 inches) and then at one-meter intervals to the bottom reading at less than one-half meter above the sediment. If the water depth is one meter or less, readings should be taken at the surface and at one-half meter and near the bottom.

If the D.O. reading from the YSI 85 is less than 5 mg/L, collect a water sample for dissolved oxygen by Winkler analysis.

When the data collection is completed, retrieve the probe and insert it in the protective housing. Do not shut the meter off until the last station readings are completed.

Dissolved Oxygen, Water Sampling and Processing

Note to YSI meter Teams: If the D.O. reading from the YSI 85 is less than 5 mg/L, collect a water sample for dissolved oxygen by Winkler analysis, that sample will be collected first. All other Teams collect Winkler D.O. samples at each location.

First: Following the protocol below, fill glass O_2 reagent bottle from blue oxygen kit:

Step 1. Label one 300 mL glass Winkler bottle with station I.D., date, and depth.
Step 2. Using Niskin Bottle collect sample from depth and bring to surface.
Step 3. Remove glass stopper from 300 mL Winkler bottle
Step 4. Lower rubber tube from Niskin Bottle to the bottom of the glass reagent bottle from the blue oxygen kit.
Step 5. Drain ¾ of the Niskin Bottle through the glass Winkler bottle, overflowing the glass bottle.
Step 6. Gently tap glass bottle to insure that no bubbles stick to sides.
Step 7. As volume reaches ¾ of the Niskin, slowly remove the rubber tube from the glass bottle and then carefully insert glass stopper so as not to trap any bubbles. Dropping glass stopper in from above works best.

Now: Continue the dissolved oxygen analysis instruction below:

Step 8. Open Reagent packet #1 (use the scissors in your kit);
Step 9. Open Reagent packet #2
Step 10. Remove glass stopper from glass oxygen reagent bottle;
Step 11. Pour Reagent #1 into bottle and then add reagent packet #2 to bottle.
Step 12. Replace glass stopper, careful not to trap bubbles.
Step 13. Shake bottle vigorously holding bottle and stopper (some reagent may stick to bottom of bottle…this is O.K.).
Step 14. Let stand 2 minutes, shake again.

After a total of 5 minutes (when the chemical floc has settled the second time and there is a clear division), open Reagent packet #3, remove glass stopper, add powder to bottle, replace stopper (no bubbles), shake vigorously until water in bottle becomes clear (no #3 particles). *THE SAMPLE IS FIXED NOW CAN BE FIELD TITRATED.*

Step 15. Using small clear plastic tube and square glass bottle from oxygen kit, rinse tube with sample and discard. Then place two tube-fulls of sample in glass jar. When filling tube with sample make sure there is no bulge on top of vial.

Step 16. Using the eyedropper in the brown plastic bottle in kit (do not get on hands). **Hold the dropper vertically**, add 1 drop to the square glass jar and swirl. Continue to add drop by drop and swirl each time(about 10 seconds between drops) until the yellow color goes away. **DO NOT ADD DROPS TOO FAST!** At the point you think color is gone add one more drop to check; often the eye is fooled by the color (hold up to white background to check).

Step 17. Record the number of drops to turn clear; don't count the extra drop added as a check unless it was needed (1 drop = 0.5 mg O_2/Liter). Surface samples usually take 14-15 drops to turn clear. Collect and save oxygen waste in a waste bottle, which will be collected at the end of the final sampling. Rinse glass bottle, plastic tube, and dropper with distilled or tap water when done.

Nutrient & Chlorophyll Sample Collection Protocol (MEP QAPP App. B-1, H)

Sample collection should proceed in the up-current or up-wind direction from the meter readings and only after any suspended bottom sediments have settled. You will perform each of these steps at each station in your embayment beginning in the inner portion and moving outward (toward the inlet). Samples are collected by Niskin Bottle. A surface sample will be collected at every station at 15 cm below the surface at pre-selected depths where required with the bottom sample 50 cm above sediment surface (be sure not to hit the bottom).

MAKE SURE ICE IS IN COOLER

a) Label one 1 liter nutrient (white) bottle and one 1 liter chlorophyll (brown) bottle with station I.D., date, depth, and time of collection).

b) Lower Niskin Bottle to 15 cm below the surface and pull stopper, bring to surface, shake and dump to rinse bottle; reset and repeat. If a sample is collected for dissolved oxygen Winkler analysis, that sample will be collected first and processed as in Section 5.7, above.

c) Add about 50 mL to 1L nutrient (white) bottle, cap, shake and dump out, repeat. Then fill bottle to shoulder then put in cooler, and shut cooler lid.

d) Repeat rinse and filling procedure with 1 liter brown Chlorophyll bottle, cap and put in cooler. Shut cooler.

PUT NUTRIENT AND CHLOROPHYLL SAMPLES IN COOLER IMMEDIATELY

e) Move to next station, repeat.

Note: Surface samples can be taken by hand if desired. If taking samples by hand you must hold the open bottle in an inverted vertical position while submerging to the desired depth and then tip upright to fill.

FIELD SAMPLE PROCESSING (on station filtering)

Samples will be prepared for dissolved nutrient analyses by filtration. This process will be done by sampling teams in the field.

Dissolved Nutrient Analyses (MEP QAPP Appendix B-1, H)

Samples for dissolved nutrient analyses will be filtered through a 0.25-micron cellulose acetate filter 47 millimeters in diameter into a 60 cc acid-leached plastic bottle.

- TO BE DONE AS SOON AS POSSIBLE AFTER COLLECTION (<1 hr)
- Filtered samples are to be shipped in the small white 60 cc plastic bottle (these bottles are acid leached and provided by SMAST)

Procedure (MEP QAPP Appendix B-1, H):

1. Remove white 1 liter sample bottle from cooler, one station bottle at a time.
2. Label a 60cc bottle with identical station information:
    a. Embayment abbreviation name
    b. Station ID
    c. Sample Depth (in meters)
    d. Date (mo/dy/yr)

    1. Place filter (using provided forceps) in clear plastic filter holder. (white filter, not the blue paper).
    2. Vigorously Shake 1-liter nutrient (white) sample bottle (in case of particulate settling) and fill 60cc syringe with water from bottle by removing plunger and pouring in, replace plunger.
    3. Attach filter (cup side up) to syringe (most filter holders have an arrow drawn on side indicating the direction of flow) and push through and discard the first approx. 30 cc of water through the filter.
    4. Push next 20 cc – 30 cc of water through the filter into the small 60 cc sample bottle, replace cap, shake and discard water.
    5. Now refill syringe, **attach to filter** (cup side up) and collect all water through the filter into the now rinsed bottle until bottle is full to shoulder, **taking care that no unfiltered water drips into sample**, Fill bottle to top leaving only a small (2-3 ml) bubble, cap and put on ice.
    6. Cap 1-liter nutrient (white) sample bottle with the remaining water, check label and put on ice. The bottle must be at least ¾ full to be used for analysis.
    7. Remove used white filter paper and discard.

    8. Repeat steps a) through h) for each 1 liter nutrient (white) sample bottle.

The samples must remain in the dark and cold. Keep cooler lid closed.

SHIPPING AND HANDLING

All samples will be transported by SMAST personnel involved in the field program. The SMAST person transporting the samples will check the Chain of Custody and verify that the samples are as stated before accepting them for transport. Samples will be transported the same day as collection to arrive within 8 hours of collection in the case of morning sampling and the following morning within 12 hours of collection in the case of afternoon sampling. After collection, samples will be kept continuously on ice or in refrigeration. Samples will be shipped in heavy-duty styrofoam coolers with ice or cold packs adequate to maintain cold internal temperatures. All shipments will be accompanied by a Chain of Custody (sample in Appendix B).

APPENDIX – B

CHAIN OF CUSTODY AND FIELD DATA SHEETS

COASTAL SYSTEMS GROUP
Chain of Custody Record

Personnel Contacts

RECEIVED		RECEIVED	
name		name	
date	time	date	time
COLLECTED		**CONTACT**	
name		name	
date	local	phone/address	

Sample Notes

Special notes/ Sample Handling	Total number of samples

Sample Status

Sample ID	NH4	PO4	NO3/NO2	TDN	POC/N	TSS	CHLA	TP	Salinity	pH	Alkalinity				

Kingston/Duxbury/Plymouth Harbor
Citizen Water Quality Monitoring Program – Water Sampling Data Sheet 2003
General Conditions

_____ Station ID. Embayment _____

_____ Sample Date Volunteers Names _____

_____ Beaufort Scale (Force# 0 - 12)

_____ E / F Ebb (outgoing) or Flood (incoming) tide

Time of nearest LOW tide _____am / pm (refer to your tide table)

#_____ Weather Conditions: (choose one) 1. Cloudless 2. Pt. Cloudy 3 Overcast 4. Rain 5. Fog/Haze 6. Drizzle 7. Intermit. Rain

#_____ 24 hour Precipitation (choose one) 1 None 2 Light 3 Heavy

_____ Wind direction (ie. SE, NW)

Secchi Depth _____(m)Disappearance/descending
_____(m)Reappearance/ascending
_____(m) Average

_____(meter) Total water depth at station

Observations: Birds _____ # , _____type; Moorings _____ #
Swimming _____yes/ no ; Shellfishing _____ yes / no

Please continue comments on back

Depth Specific Parameters

	SURFACE **15 cm below**		MID ½ of total depth		BOTTOM 50 cm from bottom	
Collection Time						
Collection Depth				Meters		
Dissolved Oxygen		# of Drops				# of Drops
Temperature Reading				°C		

Did you collect a 1 L Brown, 1 L Clear and 60cc bottle at each nutrient depth?
Return data sheet with samples to Coastal Systems Program, SMAST c/o Dr. Brian Howes, 706 S. Rodney French Blvd., New Bedford, MA 02744.

Ellisville Harbor
Citizen Water Quality Monitoring Program – Water Sampling Data Sheet 2003
General Conditions

_____ Station ID. Embayment _____

_____ Sample Date Volunteers Names _____

_____ Beaufort Scale (Force# 0 - 12)

_____ E / F Ebb (outgoing) or Flood (incoming) tide

Time of nearest LOW tide _____am / pm (refer to your tide table)

#_____ Weather Conditions: (choose one) 1. Cloudless 2. Pt. Cloudy 3 Overcast 4. Rain 5. Fog/Haze 6. Drizzle 7. Intermit. Rain

#_____ 24 hour Precipitation (choose one) 1 None 2 Light 3 Heavy

_____ Wind direction (ie. SE, NW)

Secchi Depth _____(m)Disappearance/descending
_____(m)Reappearance/ascending
_____(m) Average

_____(meter) Total water depth at station

Observations: Birds _____ # , _____type; Moorings _____ #
Swimming _____yes/ no ; Shellfishing _____ yes / no

Please continue comments on back

Depth Specific Parameters

	SURFACE **15 cm below**		MID 1/2 of total depth		BOTTOM **30 cm from bottom**	
Collection Time						
Collection Depth				Meters		
Dissolved Oxygen		# of Drops				# of Drops
Temperature Reading				°C		

Did you collect a 1 L Brown, 1 L Clear and 60cc bottle at each nutrient depth?
Return data sheet with samples to Coastal Systems Program, SMAST c/o Dr. Brian Howes, 706 S. Rodney French Blvd., New Bedford, MA 02744.

APPENDIX – C

EQUIPMENT TO BE USED AND CALIBRATION

GPS Station Location:
Garmin Global Positioning Units will be used to locate all sample stations by each team. Location measurements will proceed only with at least 5 satellites available to assure accuracy. The goal will be a minimum of six satellites using the High Precision setting. Station locations will be corrected with the download data available at the National Geodetic Survey CORS site (continuously operating reference system). Corrected station locations are expected to be accurate within 3 meters and probably within 1 meter.

YSI 85 Field Meter
The YSI-85 model field monitoring equipment will be maintained and checked as per manufacturers' instruction. The probe is a non-detachable, combination sensor that reads conductivity, dissolved oxygen and temperature. As suggested, the probe and its storage cell will be rinsed with clean tap water after each use.

It will be the responsibility of SMAST Laboratory Manager to check the calibration status of any meter prior to using the instrument and to check its calibration periodically during use. A log documenting problems experienced with the instruments and corrective measures taken will be maintained by the Sampling Coordinator.

All equipment to be utilized during the field analysis and laboratory analysis will be checked, prior to its use, to see that it is in operating condition. This includes checking the manufacturer's operating manuals and the instructions with each instrument to ensure that all maintenance items are being observed.

The meter will be auto-calibrated for dissolved oxygen before each sampling event following manufacturers recommended procedures. The accuracy of dissolved oxygen readings will be checked by collection of samples for Winkler method DO determination at two-week intervals.

The accuracy of the instrument will be checked with a standard conductivity solution each week and the instrument will be calibrated by two-point calibration using lab standard solutions should the instrument error reading of the standard solution exceed 5 percent. Any deviation from these recommendations due to specific peculiarities with certain instruments will be documented in the field logbooks and the monitoring program of the grant work plan. Instruments will be left on for the duration of the sampling round, at station and en route. All standards will be traceable to a nationally recognized standard and documented in field logbooks. A monthly two-point calibration will be performed for the dissolved oxygen probe. Temperature will be calibrated quarterly, by validating the temperature in a known temperature water bath.

CALIBRATION OF DISSOLVED OXYGEN PROBE

The probe is equipped with a polargraphic Clark-type sensor. A new dissolved oxygen membrane will be installed at the beginning of the field season and at 8-week intervals as per the manufacturer’s recommendations outlined below:

1. Before departing from the shore, turn the meter on by pressing the ON/OFF button, and then press MODE button until dissolved oxygen is displayed in mg/l or %. Allow the readings of dissolved oxygen and temperature to stabilize for 15 minutes.

2. The meter has two buttons with arrows; one pointing up and the other pointing down. Push both buttons simultaneously. The screen will read "0", press "enter" if at sea level to set altitude. If above sea level, use the arrow keys to set the altitude in units of 100 feet (i.e. 12 is 1200 feet). For work on all coastal ponds the altitude will be set at zero. When correct altitude is shown, press ENTER.

3. The YSI 85 will now display CAL in the lower left of the display screen. The calibration value should be displayed in the lower right of the screen and the current % reading shows in the main display of the screen. This reading should be within the range of 99 to 101 percent. When the current reading display is stable, press ENTER button. The display will then read SAVE and return automatically to the Normal Operation Mode.

CALIBRATION OF CONDUCTIVITY METER

1. Turn the instrument on and allow it to go through its self-test procedure.
2. Select a calibration standard appropriate to the expected conductivity in the pond to be sampled:
    a. For seawater a 50 mS/cm will be used.
    b. For fresh water, a 1mS/cm standard will be used.
    c. For brackish water, a 10mS/cm standard will be used.
3. Place at least three inches of calibration fluid in a clean glass beaker.
4. Use the MODE button to advance the display to conductivity.
5. Insert the probe deep enough into the standard solution so the oval hole on the side of the probe is completely covered. Suspend the probe ¼ inch from the bottom of the beaker. Do not rest it on the bottom of the beaker.
6. Allow at least 60 seconds for the temperature reading to stabilize.
7. Move the probe vigorously from side to side to dislodge any air bubbles from the electrodes.
8. Press the UP and DOWN arrows simultaneously. The CAL symbol will appear.
9. Use the UP or DOWN arrow buttons to adjust the reading on the display to match the value of the calibration standard.
10. Once the display reads the exact value of the calibration solution, press the ENTER button once. The display screen will then read SAVE indicating the calibration has been accepted.

The YSI 85 is designed to retain its last conductivity calibration permanently. Before each use, the instrument will be checked against the appropriate standard and corrected as needed to maintain accuracy within +/- 5 percent.

DISSOLVED OXYGEN MEMBRANE CAP REPLACEMENT

The membrane cap will be replaced annually at the beginning of field season and again at 8-week intervals or as needed based on inspection of the membrane for defects.

1. Unscrew and remove the probe sensor guard.
2. Unscrew and remove the old membrane cap.
3. Thoroughly rinse the sensor tip with distilled water.
4. Prepare the KCl electrolyte according to the directions provided by the manufacturer with the solution .
5. Hold the membrane cap and fill at least ½ full with electrolyte solution.
6. Screw the membrane cap onto the probe moderately tight. A small amount of electrolyte should overflow.
7. Screw the probe sensor guard on moderately tight.

APPENDIX – D

NUTRIENT WATER QUALITY DATA

(Data Transmitted Electronically as Excel Files)

APPENDIX – E

BACTERIAL DATA

Coastal Systems Group
SMAST
Umass Dartmouth
706 Rodney French Blvd
New Bedford, MA 02747
Project: Plymouth/Kingston/Duxbury
Bacteria Data 2003-present
Created 7/8/05 JLA
ND= No Data

Project	Date	Station	Fecal Coliform (CFU/100mL)	
			Fresh	Marine
Plymouth/Kingston/Duxbury	7/10/2003	PDH1		10
Plymouth/Kingston/Duxbury	7/10/2003	PDH2		10
Plymouth/Kingston/Duxbury	7/10/2003	PDH3		10
Plymouth/Kingston/Duxbury	7/10/2003	PDH4		5
Plymouth/Kingston/Duxbury	7/10/2003	PDH5		ND
Plymouth/Kingston/Duxbury	7/10/2003	PDH6		5
Plymouth/Kingston/Duxbury	7/10/2003	PDH7		5
Plymouth/Kingston/Duxbury	7/10/2003	PDH8		10
Plymouth/Kingston/Duxbury	7/10/2003	PDH9		50
Plymouth/Kingston/Duxbury	7/10/2003	PDH10		10
Plymouth/Kingston/Duxbury	7/10/2003	PDH11		<5
Plymouth/Kingston/Duxbury	7/10/2003	PDH12		<5
Plymouth/Kingston/Duxbury	7/10/2003	PDH13		<5
Plymouth/Kingston/Duxbury	7/10/2003	PDH14		<5
Plymouth/Kingston/Duxbury	7/10/2003	PDH15		<5
Plymouth/Kingston/Duxbury	7/10/2003	EVH1	55	
Plymouth/Kingston/Duxbury	7/10/2003	EVH2	35	
Plymouth/Kingston/Duxbury	7/10/2003	EVH3		110
Plymouth/Kingston/Duxbury	7/10/2003	EVH4		240
Plymouth/Kingston/Duxbury	7/10/2003	EVH5		150
Plymouth/Kingston/Duxbury	7/10/2003	EVH6		70
Plymouth/Kingston/Duxbury	7/10/2003	EVH7		ND
Plymouth/Kingston/Duxbury	7/10/2003	EVH8		ND
Plymouth/Kingston/Duxbury	7/21/2003	PDH1		5
Plymouth/Kingston/Duxbury	7/21/2003	PDH2		15
Plymouth/Kingston/Duxbury	7/21/2003	PDH3		10
Plymouth/Kingston/Duxbury	7/21/2003	PDH4		5
Plymouth/Kingston/Duxbury	7/21/2003	PDH5		10
Plymouth/Kingston/Duxbury	7/21/2003	PDH6		10
Plymouth/Kingston/Duxbury	7/21/2003	PDH7		10
Plymouth/Kingston/Duxbury	7/21/2003	PDH8		20
Plymouth/Kingston/Duxbury	7/21/2003	PDH9		10
Plymouth/Kingston/Duxbury	7/21/2003	PDH10		ND
Plymouth/Kingston/Duxbury	7/21/2003	PDH11		5

Project	Date	Station	Fecal Coliform (CFU/100mL)	
			Fresh	Marine
Plymouth/Kingston/Duxbury	7/21/2003	PDH12		10
Plymouth/Kingston/Duxbury	7/21/2003	PDH13		10
Plymouth/Kingston/Duxbury	7/21/2003	PDH14		10
Plymouth/Kingston/Duxbury	7/21/2003	PDH15		30
Plymouth/Kingston/Duxbury	8/3/2003	EVH1	10	
Plymouth/Kingston/Duxbury	8/3/2003	EVH2	15	
Plymouth/Kingston/Duxbury	8/3/2003	EVH3		200
Plymouth/Kingston/Duxbury	8/3/2003	EVH4		235
Plymouth/Kingston/Duxbury	8/3/2003	EVH5		25
Plymouth/Kingston/Duxbury	8/3/2003	EVH6		85
Plymouth/Kingston/Duxbury	8/3/2003	EVH7		5
Plymouth/Kingston/Duxbury	8/3/2003	EVH8		85
Plymouth/Kingston/Duxbury	8/5/2003	PDH6		5
Plymouth/Kingston/Duxbury	8/5/2003	PDH7		5
Plymouth/Kingston/Duxbury	8/5/2003	PDH8		10
Plymouth/Kingston/Duxbury	8/5/2003	PDH9		25
Plymouth/Kingston/Duxbury	8/5/2003	PDH10		5
Plymouth/Kingston/Duxbury	8/5/2003	PDH11		5
Plymouth/Kingston/Duxbury	8/5/2003	PDH12		5
Plymouth/Kingston/Duxbury	8/5/2003	PDH13		10
Plymouth/Kingston/Duxbury	8/5/2003	PDH14		10
Plymouth/Kingston/Duxbury	8/5/2003	PDH15		5
Plymouth/Kingston/Duxbury	8/6/2003	PDH1		5
Plymouth/Kingston/Duxbury	8/6/2003	PDH2		60
Plymouth/Kingston/Duxbury	8/6/2003	PDH3		10
Plymouth/Kingston/Duxbury	8/6/2003	PDH4		15
Plymouth/Kingston/Duxbury	8/6/2003	PDH5		10
Plymouth/Kingston/Duxbury	8/18/2003	EVH1	25	
Plymouth/Kingston/Duxbury	8/18/2003	EVH2	40	
Plymouth/Kingston/Duxbury	8/18/2003	EVH3		100
Plymouth/Kingston/Duxbury	8/18/2003	EVH4		215
Plymouth/Kingston/Duxbury	8/18/2003	EVH5		20
Plymouth/Kingston/Duxbury	8/18/2003	EVH6		75
Plymouth/Kingston/Duxbury	8/18/2003	EVH7		10
Plymouth/Kingston/Duxbury	8/18/2003	EVH8		90
Plymouth/Kingston/Duxbury	8/19/2003	PDH1		5
Plymouth/Kingston/Duxbury	8/19/2003	PDH2		5
Plymouth/Kingston/Duxbury	8/19/2003	PDH3		5
Plymouth/Kingston/Duxbury	8/19/2003	PDH4		10
Plymouth/Kingston/Duxbury	8/19/2003	PDH5		5
Plymouth/Kingston/Duxbury	8/19/2003	PDH6		5
Plymouth/Kingston/Duxbury	8/19/2003	PDH7		5
Plymouth/Kingston/Duxbury	8/19/2003	PDH8		10
Plymouth/Kingston/Duxbury	8/19/2003	PDH9		60

Project	Date	Station	Fecal Coliform (CFU/100mL)	
			Fresh	Marine
Plymouth/Kingston/Duxbury	8/19/2003	PDH10		5
Plymouth/Kingston/Duxbury	8/19/2003	PDH11		10
Plymouth/Kingston/Duxbury	8/19/2003	PDH12		5
Plymouth/Kingston/Duxbury	8/19/2003	PDH13		5
Plymouth/Kingston/Duxbury	8/19/2003	PDH14		5
Plymouth/Kingston/Duxbury	8/19/2003	PDH15		35
Plymouth/Kingston/Duxbury	9/1/2003	EVH1	5	
Plymouth/Kingston/Duxbury	9/1/2003	EVH2	25	
Plymouth/Kingston/Duxbury	9/1/2003	EVH3		65
Plymouth/Kingston/Duxbury	9/1/2003	EVH4		530
Plymouth/Kingston/Duxbury	9/1/2003	EVH5		5
Plymouth/Kingston/Duxbury	9/1/2003	EVH6		20
Plymouth/Kingston/Duxbury	9/1/2003	EVH7		10
Plymouth/Kingston/Duxbury	9/1/2003	EVH8		10
Plymouth/Kingston/Duxbury	9/3/2003	PDH1		8
Plymouth/Kingston/Duxbury	9/3/2003	PDH2		36
Plymouth/Kingston/Duxbury	9/3/2003	PDH3		14
Plymouth/Kingston/Duxbury	9/3/2003	PDH4		2
Plymouth/Kingston/Duxbury	9/3/2003	PDH5		<2
Plymouth/Kingston/Duxbury	9/3/2003	PDH6		10
Plymouth/Kingston/Duxbury	9/3/2003	PDH7		32
Plymouth/Kingston/Duxbury	9/3/2003	PDH8		56
Plymouth/Kingston/Duxbury	9/3/2003	PDH9		4
Plymouth/Kingston/Duxbury	9/3/2003	PDH10		2
Plymouth/Kingston/Duxbury	9/3/2003	PDH11		4
Plymouth/Kingston/Duxbury	9/3/2003	PDH12		4
Plymouth/Kingston/Duxbury	9/3/2003	PDH13		4
Plymouth/Kingston/Duxbury	9/3/2003	PDH14		<2
Plymouth/Kingston/Duxbury	9/3/2003	PDH15		6
Plymouth/Kingston/Duxbury	9/17/2003	PDH1		82
Plymouth/Kingston/Duxbury	9/17/2003	PDH2		44
Plymouth/Kingston/Duxbury	9/17/2003	PDH3		18
Plymouth/Kingston/Duxbury	9/17/2003	PDH4		6
Plymouth/Kingston/Duxbury	9/17/2003	PDH5		2
Plymouth/Kingston/Duxbury	9/17/2003	PDH6		22
Plymouth/Kingston/Duxbury	9/17/2003	PDH7		18
Plymouth/Kingston/Duxbury	9/17/2003	PDH8		4
Plymouth/Kingston/Duxbury	9/17/2003	PDH9		384
Plymouth/Kingston/Duxbury	9/17/2003	PDH10		2
Plymouth/Kingston/Duxbury	9/17/2003	PDH11		4
Plymouth/Kingston/Duxbury	9/17/2003	PDH12		<2
Plymouth/Kingston/Duxbury	9/17/2003	PDH13		2
Plymouth/Kingston/Duxbury	9/17/2003	PDH14		4
Plymouth/Kingston/Duxbury	9/17/2003	PDH15		12

Project	Date	Station	Fecal Coliform (CFU/100mL)	
			Fresh	Marine
Plymouth/Kingston/Duxbury	9/28/2003	EVH1	2	
Plymouth/Kingston/Duxbury	9/28/2003	EVH2	42	
Plymouth/Kingston/Duxbury	9/28/2003	EVH3		154
Plymouth/Kingston/Duxbury	9/28/2003	EVH4		160
Plymouth/Kingston/Duxbury	9/28/2003	EVH5		30
Plymouth/Kingston/Duxbury	9/28/2003	EVH6		40
Plymouth/Kingston/Duxbury	9/28/2003	EVH7		2
Plymouth/Kingston/Duxbury	9/28/2003	EVH8		146
Plymouth/Kingston/Duxbury	7/11/2004	EVH1	<10	
Plymouth/Kingston/Duxbury	7/11/2004	EVH2	130	
Plymouth/Kingston/Duxbury	7/11/2004	EVH3		20
Plymouth/Kingston/Duxbury	7/11/2004	EVH4		20
Plymouth/Kingston/Duxbury	7/11/2004	EVH5		10
Plymouth/Kingston/Duxbury	7/11/2004	EVH6		<10
Plymouth/Kingston/Duxbury	7/11/2004	EVH7		<10
Plymouth/Kingston/Duxbury	7/11/2004	EVH8		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH1		40
Plymouth/Kingston/Duxbury	7/12/2004	PDH2		10
Plymouth/Kingston/Duxbury	7/12/2004	PDH3		30
Plymouth/Kingston/Duxbury	7/12/2004	PDH4		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH5		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH6		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH7		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH8		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH9		40
Plymouth/Kingston/Duxbury	7/12/2004	PDH10		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH11		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH12		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH13		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH14		<10
Plymouth/Kingston/Duxbury	7/12/2004	PDH15		<10
Plymouth/Kingston/Duxbury	7/14/2004	Jones River	1380	
Plymouth/Kingston/Duxbury	7/14/2004	Town Brook	1470	
Plymouth/Kingston/Duxbury	7/14/2004	Eel River 1	60	
Plymouth/Kingston/Duxbury	7/14/2004	Eel River 2	70	
Plymouth/Kingston/Duxbury	7/14/2004	Ellisville	100	
Plymouth/Kingston/Duxbury	7/14/2004	Ellisville 2	1470	
Plymouth/Kingston/Duxbury	7/27/2004	Jones River	320	
Plymouth/Kingston/Duxbury	7/27/2004	Town Brook	20	
Plymouth/Kingston/Duxbury	7/27/2004	Eel River 1	<10	
Plymouth/Kingston/Duxbury	7/27/2004	Eel River 2	100	
Plymouth/Kingston/Duxbury	7/27/2004	Ellisville	40	
Plymouth/Kingston/Duxbury	7/27/2004	Ellisville 2	90	
Plymouth/Kingston/Duxbury	7/27/2004	PDH1		90

Project	Date	Station	Fecal Coliform (CFU/100mL)	
			Fresh	Marine
Plymouth/Kingston/Duxbury	7/27/2004	PDH2		30
Plymouth/Kingston/Duxbury	7/27/2004	PDH3		10
Plymouth/Kingston/Duxbury	7/27/2004	PDH4		<10
Plymouth/Kingston/Duxbury	7/27/2004	PDH5		<10
Plymouth/Kingston/Duxbury	7/27/2004	PDH6		<10
Plymouth/Kingston/Duxbury	7/27/2004	PDH7		<10
Plymouth/Kingston/Duxbury	7/27/2004	PDH8		<10
Plymouth/Kingston/Duxbury	7/27/2004	PDH9		90
Plymouth/Kingston/Duxbury	7/27/2004	PDH10		<10
Plymouth/Kingston/Duxbury	7/27/2004	PDH11		<10
Plymouth/Kingston/Duxbury	7/27/2004	PDH12		<10
Plymouth/Kingston/Duxbury	7/27/2004	PDH13		<10
Plymouth/Kingston/Duxbury	7/27/2004	PDH14		280
Plymouth/Kingston/Duxbury	7/27/2004	PDH15		<10
Plymouth/Kingston/Duxbury	7/27/2004	EVH1	ND	
Plymouth/Kingston/Duxbury	7/27/2004	EVH2	90	
Plymouth/Kingston/Duxbury	7/27/2004	EVH3		10
Plymouth/Kingston/Duxbury	7/27/2004	EVH4		10
Plymouth/Kingston/Duxbury	7/27/2004	EVH5		40
Plymouth/Kingston/Duxbury	7/27/2004	EVH6		30
Plymouth/Kingston/Duxbury	7/27/2004	EVH7		10
Plymouth/Kingston/Duxbury	7/27/2004	EVH8		600
Plymouth/Kingston/Duxbury	8/9/2004	PDH1		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH2		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH3		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH4		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH5		10
Plymouth/Kingston/Duxbury	8/9/2004	PDH6		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH7		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH8		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH9		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH10		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH11		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH12		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH13		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH14		<10
Plymouth/Kingston/Duxbury	8/9/2004	PDH15		<10
Plymouth/Kingston/Duxbury	8/9/2004	EVH1	ND	
Plymouth/Kingston/Duxbury	8/9/2004	EVH2	10	
Plymouth/Kingston/Duxbury	8/9/2004	EVH3		10
Plymouth/Kingston/Duxbury	8/9/2004	EVH4		90
Plymouth/Kingston/Duxbury	8/9/2004	EVH5		80
Plymouth/Kingston/Duxbury	8/9/2004	EVH6		20
Plymouth/Kingston/Duxbury	8/9/2004	EVH7		<10

Project	Date	Station	Fecal Coliform (CFU/100mL)	
			Fresh	Marine
Plymouth/Kingston/Duxbury	8/9/2004	EVH8		20
Plymouth/Kingston/Duxbury	8/12/2004	Jones River	90	
Plymouth/Kingston/Duxbury	8/12/2004	Town Brook	290	
Plymouth/Kingston/Duxbury	8/12/2004	Eel River 1	<10	
Plymouth/Kingston/Duxbury	8/12/2004	Eel River 2	20	
Plymouth/Kingston/Duxbury	8/12/2004	Ellisville	20	
Plymouth/Kingston/Duxbury	8/12/2004	Ellisville 2	20	
Plymouth/Kingston/Duxbury	8/25/2004	PDH1		20
Plymouth/Kingston/Duxbury	8/25/2004	PDH2		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH3		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH4		10
Plymouth/Kingston/Duxbury	8/25/2004	PDH5		10
Plymouth/Kingston/Duxbury	8/25/2004	PDH6		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH7		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH8		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH9		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH10		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH11		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH12		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH13		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH14		<10
Plymouth/Kingston/Duxbury	8/25/2004	PDH15		<10
Plymouth/Kingston/Duxbury	8/25/2004	EVH1	110	
Plymouth/Kingston/Duxbury	8/25/2004	EVH2	20	
Plymouth/Kingston/Duxbury	8/25/2004	EVH3		150
Plymouth/Kingston/Duxbury	8/25/2004	EVH4		170
Plymouth/Kingston/Duxbury	8/25/2004	EVH5		40
Plymouth/Kingston/Duxbury	8/25/2004	EVH6		10
Plymouth/Kingston/Duxbury	8/25/2004	EVH7		10
Plymouth/Kingston/Duxbury	8/25/2004	EVH8		40
Plymouth/Kingston/Duxbury	9/7/2004	PDH1		20
Plymouth/Kingston/Duxbury	9/7/2004	PDH2		<10
Plymouth/Kingston/Duxbury	9/7/2004	PDH3		<10
Plymouth/Kingston/Duxbury	9/7/2004	PDH4		<10
Plymouth/Kingston/Duxbury	9/7/2004	PDH5		30
Plymouth/Kingston/Duxbury	9/7/2004	PDH6		30
Plymouth/Kingston/Duxbury	9/7/2004	PDH7		<10
Plymouth/Kingston/Duxbury	9/7/2004	PDH8		<10
Plymouth/Kingston/Duxbury	9/7/2004	PDH9		10
Plymouth/Kingston/Duxbury	9/7/2004	PDH10		<10
Plymouth/Kingston/Duxbury	9/7/2004	PDH11		<10
Plymouth/Kingston/Duxbury	9/7/2004	PDH12		<10
Plymouth/Kingston/Duxbury	9/7/2004	PDH13		<10
Plymouth/Kingston/Duxbury	9/7/2004	PDH14		<10

Project	Date	Station	Fecal Coliform (CFU/100mL)	
			Fresh	Marine
Plymouth/Kingston/Duxbury	9/7/2004	PDH15		<10
Plymouth/Kingston/Duxbury	9/9/2004	EVH1	ND	
Plymouth/Kingston/Duxbury	9/9/2004	EVH2	80	
Plymouth/Kingston/Duxbury	9/9/2004	EVH3		120
Plymouth/Kingston/Duxbury	9/9/2004	EVH4		195
Plymouth/Kingston/Duxbury	9/9/2004	EVH5		160
Plymouth/Kingston/Duxbury	9/9/2004	EVH6		170
Plymouth/Kingston/Duxbury	9/9/2004	EVH7		ND
Plymouth/Kingston/Duxbury	9/9/2004	EVH8		<10
Plymouth/Kingston/Duxbury	6/15/2005	PDH11		<4
Plymouth/Kingston/Duxbury	6/15/2005	PDH12		<4
Plymouth/Kingston/Duxbury	6/15/2005	PDH13		<4
Plymouth/Kingston/Duxbury	6/15/2005	PDH14		<4
Plymouth/Kingston/Duxbury	6/15/2005	PDH15		<4
Plymouth/Kingston/Duxbury	6/15/2005	PDH9		80
Plymouth/Kingston/Duxbury	6/15/2005	PDH7		4
Plymouth/Kingston/Duxbury	6/15/2005	PDH6		<4
Plymouth/Kingston/Duxbury	6/15/2005	EVH1	4	
Plymouth/Kingston/Duxbury	6/15/2005	EVH2	112	
Plymouth/Kingston/Duxbury	6/15/2005	EVH3		44
Plymouth/Kingston/Duxbury	6/15/2005	EVH4		264
Plymouth/Kingston/Duxbury	6/15/2005	EVH5		76
Plymouth/Kingston/Duxbury	6/15/2005	EVH6		36
Plymouth/Kingston/Duxbury	6/15/2005	EVH7		10
Plymouth/Kingston/Duxbury	6/15/2005	EVH8		500
Plymouth/Kingston/Duxbury	6/16/2005	PDH1		80
Plymouth/Kingston/Duxbury	6/16/2005	PDH2		8
Plymouth/Kingston/Duxbury	6/16/2005	PDH3		<4
Plymouth/Kingston/Duxbury	6/16/2005	PDH4		<4
Plymouth/Kingston/Duxbury	6/16/2005	PDH5		4
Plymouth/Kingston/Duxbury	6/16/2005	Ellisville	68	
Plymouth/Kingston/Duxbury	6/16/2005	Ellisville 2	<4	