Environmental Monitoring Report
Muddy Creek Restoration Bridge Project

Town of Chatham **Town of Harwich**

August 2017

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I. Monitoring Requirements of Permits

The Muddy Creek Restoration Bridge Project is a cooperative effort of the Towns of Chatham and Harwich, Massachusetts in partnership with Massachusetts Division of Ecological Restoration (MassDER), US Fish & Wildlife Service (USFWS), and NOAA Restoration Center. The restoration encompassed the removal of two restrictive box culverts and construction of a new single span bridge with an open channel. The pre-existing stone box culverts were each approximately 2.5-feet wide, 3.75-feet in height, and 100-feet in length. The post restoration hydraulic opening is a trapezoidal channel with a 22-foot wide base and 1.7:1 side slopes. Partial tidal flow was restored through the east (Chatham) side of the channel on February 11, 2016 and the channel was fully open to tidal flow on April 1, 2016. The restoration of tidal flow benefits 55 acres of wetlands upstream of the new bridge and channel, and improves passage for diadromous fish species.

Monitoring requirements for the Muddy Creek Restoration Bridge Project are outlined in permits received from: Massachusetts Department of Environmental Protection (MassDEP), 401 WQ Certificate and Chapter 91 License; Massachusetts Environmental Protection Act (MEPA) Public Benefit Determination and Certificate; Harwich and Chatham Conservation Commissions, Orders of Condition; and US Army Corp of Engineers General Permit[1].

This Environmental Monitoring Report is intended to summarize monitoring activities undertaken by Project Partners, including monitoring activities required under the environmental permits. In accordance with permit requirements, this monitoring report includes the methodologies for the following monitoring activities:

- Analysis of post-construction tidal hydrology relative to pre-restoration condition and project objectives,
- Analysis of Channel Migration,
- Water Quality Monitoring Results (salinity, nutrient parameters, bacterial parameters),
- Survival of restoration plantings w/ recommendations for remediation as needed,
- Assessment of invasive species control,
- Vegetation changes documented through survey of established transects and photo monitoring stations.

Selected initial monitoring results are provided where data are available and analyzed. Photo-monitoring of vegetation and vegetation transects will be undertaken during late summer/fall 2017. Results on vegetation monitoring, and on-going water quality monitoring, will be reported in subsequent reports.

The following monitoring activities are underway:

A. Tidal Hydrology:

- Tide data (water level) readings were collected for a 34-day period from June 22 through July 26, 2016. A Technical Memorandum of tide analysis post-construction is attached as Appendix A. A pre- and post-project comparison shows an increase in tide range of 2.1 feet between Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) which resulted from restoring unrestricted tidal exchange to Muddy Creek. The MHHW elevation in Muddy Creek increased from 1.6 to 2.6 feet, whereas MLLW decreased from 1.0 to -0.1 feet. Mean High tide increased from 1.5 feet pre-construction (2009) to 2.2 feet post-construction (2016), while mean low water dropped from 1.0 feet (2009) to -0.1 feet (2016). All measurements are NAVD88.

[1] The access permit issued by Massachusetts Department of Transportation incorporates the monitoring requirements set forth in these environmental permits.

B. Vegetation:

- Re-survey of vegetation line transects are planned at one, three, and five years post-construction. Pre-project vegetation transects were completed in fall 2015. The first year of post project transect measurements will occur in fall 2017.
- Photo-station monitoring of vegetation conditions is scheduled at the same frequency as the vegetation transect monitoring. Eighteen photo monitoring stations were established pre-construction, and photos were taken in September 2015. Although not required by permit, replicate photos were taken at the eighteen photo monitoring stations six months post–construction, in October 2016. Preliminary photo-monitoring results for some stations are contained in this report for illustrative purposes. Future photo monitoring will coincide with transect readings in years one, three, and five post-construction.
- Restoration plantings will be monitored twice annually (spring and fall) for three years.

C. Channel Dimensions and Migration:

- Channel Bathymetry data was collected along established cross-sections located above and below Route 28 in June, July, September and November 2016 post-construction. These data were compared with pre-construction readings at the same cross-section locations and two new post-construction transects. Channel migration, as measured by top of bank, also was assessed. These data are reported in Appendix A. Additional measurements may be taken following significant winter storm events during the winter of 2017. Channel bathymetry will be re-measured at one and five years post-construction, with increased frequency if necessary to document changes to channel width and depth.

D. Water Quality:

- Nutrient-related parameters (including salinity) and bacteria (Enterococci and Fecal coliform) were monitored pre- and post-construction and data will continue to be collected at the established annual frequency with results compiled and reported annually.

The additional monitoring activities described below are not required by permits, but would enhance the understanding of ecological conditions and responses within the Muddy Creek system. These monitoring activities will be undertaken contingent upon funding.

E. Marsh Plain Elevation

- Permanent plots to be established for the purposes of documenting marsh plain elevation adjustments following restoration. While not a requirement, establishing a protocol to monitor marsh plain development (or subsidence) may prove useful in the future to assess restoration outcomes.

F. Benthic Infauna

- While not a requirement, establishing a protocol to monitor benthic infauna may prove useful in the future to assess restoration outcomes. Pending funding, it is proposed that sediment cores and benthic infauna samples be collected at 1, 3, and 5 year intervals, and that continuous Dissolved Oxygen measurements be taken during the same period as nutrient sampling.

II. Methodologies for Baseline and Post-Construction Monitoring, and Initial Results

A. Hydrology:

Baseline: Tidal hydrology (water level and salinity) was collected over a complete lunar cycle using water-level and conductivity loggers set to record at six minute intervals. Pre-project data were collected by MassDER in July, 2014.

Post-construction: Tidal hydrology data (water levels set to record at 10-minute intervals) were collected during a complete lunar cycle (June 22 through July 26, 2016). Figure 1 shows tide gage deployment locations for pre- and post-construction monitoring. A Technical Memorandum of tide analysis is attached (Appendix A). The data show an increase in tide range of 2.1 feet resulting from the channel opening. The measured increase in tide range matches the predicted increase of 2 feet. Mean High tide increased from 1.5 feet pre-construction (2009) to 2.2 feet post-construction (2016), while mean low water dropped from 1.0 feet (2009) to -0.1 feet (2016). All measurements are NAVD88.

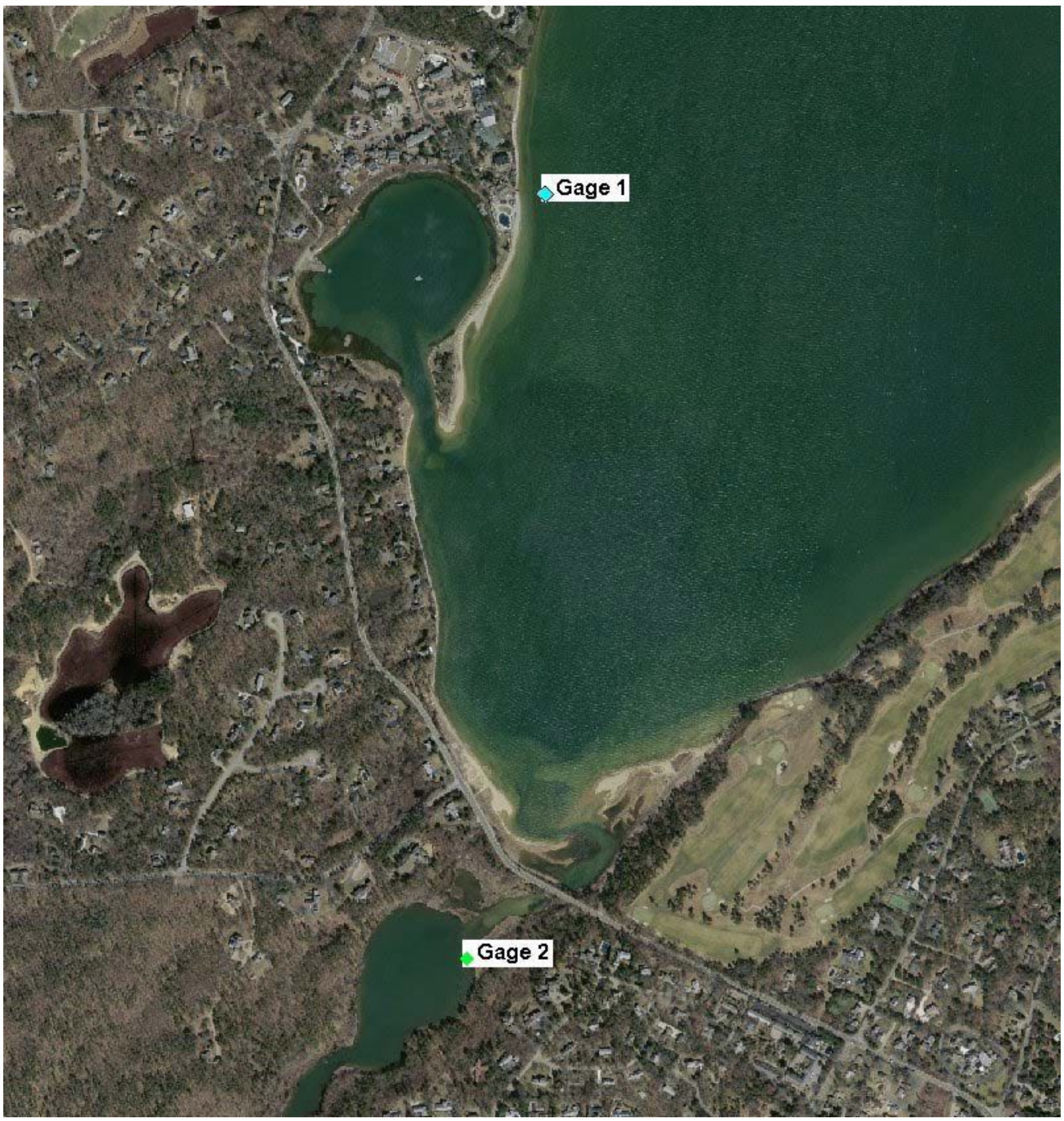

Figure 1: Location of tide monitoring stations.

B. Vegetation:

Pre-Project: Species composition was determined by the line-intercept method (Barbour et al. 1987[2]). Transects were established and surveyed by MassDER during the fall of 2015 and end-points permanently marked with 3.5-foot lengths of ½" PVC pipe set into the marsh. A total of eight transects were established: three transects in the upper basin, one in the middle basin, three in the lower basin, and a single reference transect located downstream of Route 28 Bridge (Figures 2-4), Where applicable, vegetation transects established in 2011 by Baxter & Nye Associates for permitting purposes were re-established. Transect lengths varied, but were generally 50m and were oriented perpendicular to Muddy Creek from the edge of the marsh creek toward adjacent upland.

Post-construction: Transects are scheduled to be revisited 1, 3, and 5 years post-construction. The first full post-construction year of transect measurements will take place in fall 2017. Species composition will be characterized by dividing each transect into one-meter intervals and recording the species of plants present under the line at each meter interval. The number of one meter intervals in which a plant species was present (absolute frequency) will then be divided by the total number of intervals in the transect to derive the percent frequency for that species along each transect. Percent frequency along transects will serve as an indicator of overall vegetation cover.

The heights of *Phragmites australis* will be used as an indicator of its aboveground biomass and overall vigor. The two tallest *P. australis* plants for each five-meter interval where this species occurs along a transect will be measured. Mann-Whitney U tests (Sokal and Rohlf 1995[3]) will be completed on mean *P. australis* heights per transect to determine if there was a difference between heights pre- vs. post-restoration.

The spread or retreat of distinct patches of *P. australis* will be evaluated by recording the distance in meters that the boundary of the *P. australis* patch expanded or declined along the transect relative to the adjacent salt marsh each year.

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[2] Barbour, M. G., J. H. Burk, and W. D. Pitts. 1987. Terrestrial Plant Ecology. Benjamin Cummings Publishing Company, Menlo Park, CA, USA.

[3] Sokal, R. R. and F. J. Rohlf. 1995. Biometry, 3rd ed. W.H. Freeman and Company, New York, NY, USA.

Figure 2: Vegetation transects within the upper basin of Muddy Creek

Figure 3: Vegetation monitoring transects in the middle basin of Muddy Creek

Figure 4: Vegetation monitoring transects within the lower basin of Muddy Creek

Photo Monitoring

Pre-Project: Eighteen photo stations were established and monitored by MassDER and USFWS during fall 2015 as a means to qualitatively assess marsh vegetation change overtime (Figures 5 and 6). Photo stations were marked with PVC pipe or wooden stakes, the location recorded with RTK GPS, and attending photos labeled accordingly: Station ID-(Orientation)-Date. A Site Identification Card (8.5" x 11"), placed in the camera field of view was used to provide a permanent record within each image of the photo location, camera orientation, and date.

Post-construction: Photo monitoring locations are scheduled to be revisited 1, 3, and 5 years post-construction to coincide with vegetation line transect monitoring. However, since the first year of transect monitoring is planned for fall 2017, an additional set of photo monitoring data were collected in the fall of 2016 to capture any early changes in vegetation following the first post-construction growing season. Photo monitoring was conducted on October 24th and 25th at the eighteen photo monitoring stations with 2-4 photos taken at each station. Appendix B contains illustrative monitoring photos.

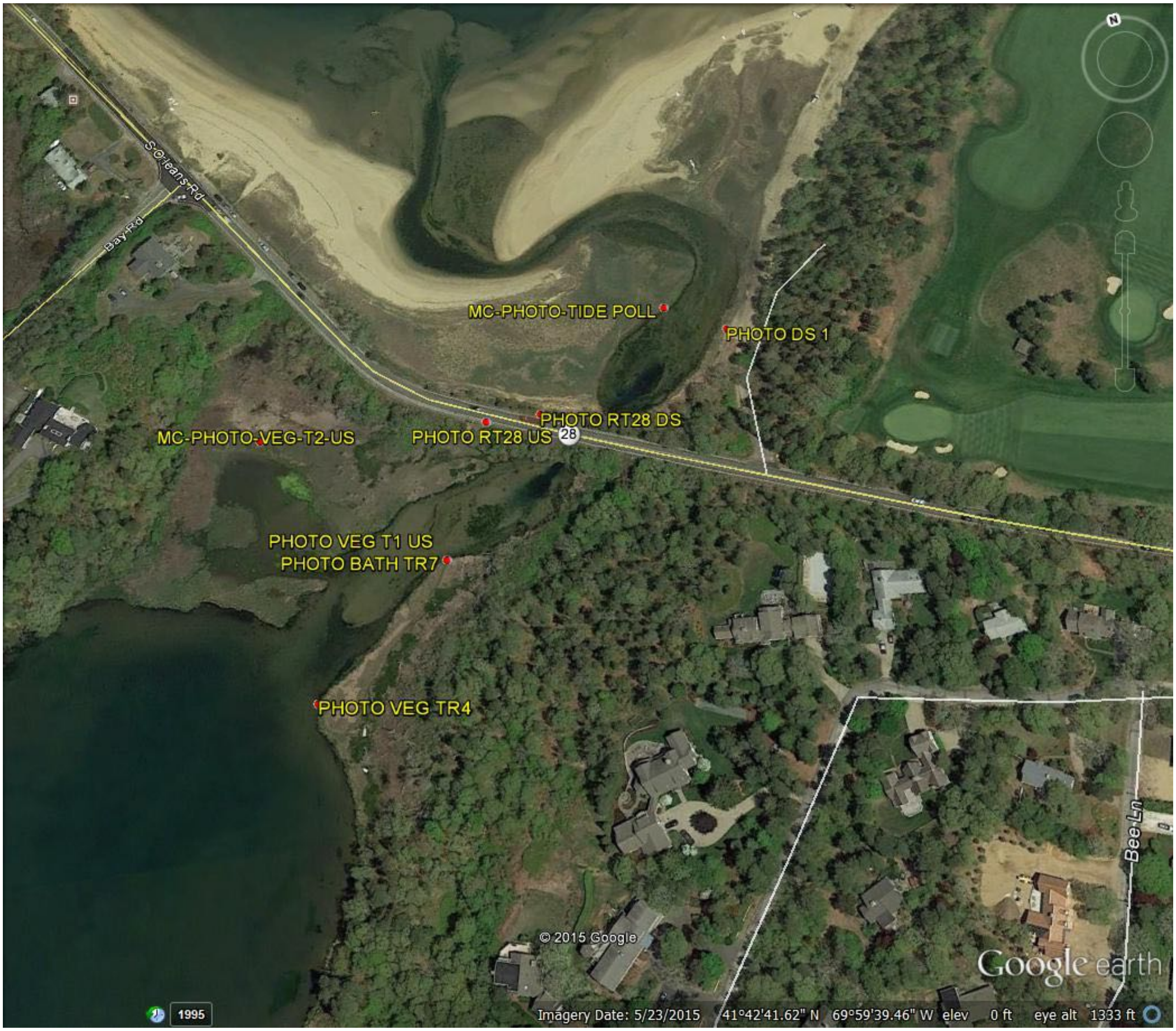


Figure 5: Photo monitoring stations within the lower basin of Muddy Creek

Figure 6: Photo monitoring stations within the upper reaches of Muddy Creek. Not illustrated is the point location on the relic cranberry berm located mid-basin.

C. Channel Bathymetry:

Baseline: Channel bathymetry was collected using an RTK-GPS unit to document pre-construction channel width, depth, and cross-sectional areas up and downstream of Route 28. During the fall of 2015 channel cross-sections were surveyed by MassDER and the USFWS along eight cross-sectional transects – four upstream of Route 28 and four downstream. Transect end-points were permanently marked using PVC pipe set into the marsh. Channel toe and top of bank were surveyed at 25-foot intervals to provide another means to monitor channel migration (Figure 7). Subsequent top of bank measurements did not reveal any significant shift in the channel meander, but did reveal areas where minor bank slumping is occurring (Figure 8). The area around Muddy Creek was flown in October 2015 (Figure 9). In addition, the Town of Chatham frequently conducts aerial photo flights to document coastal erosion.

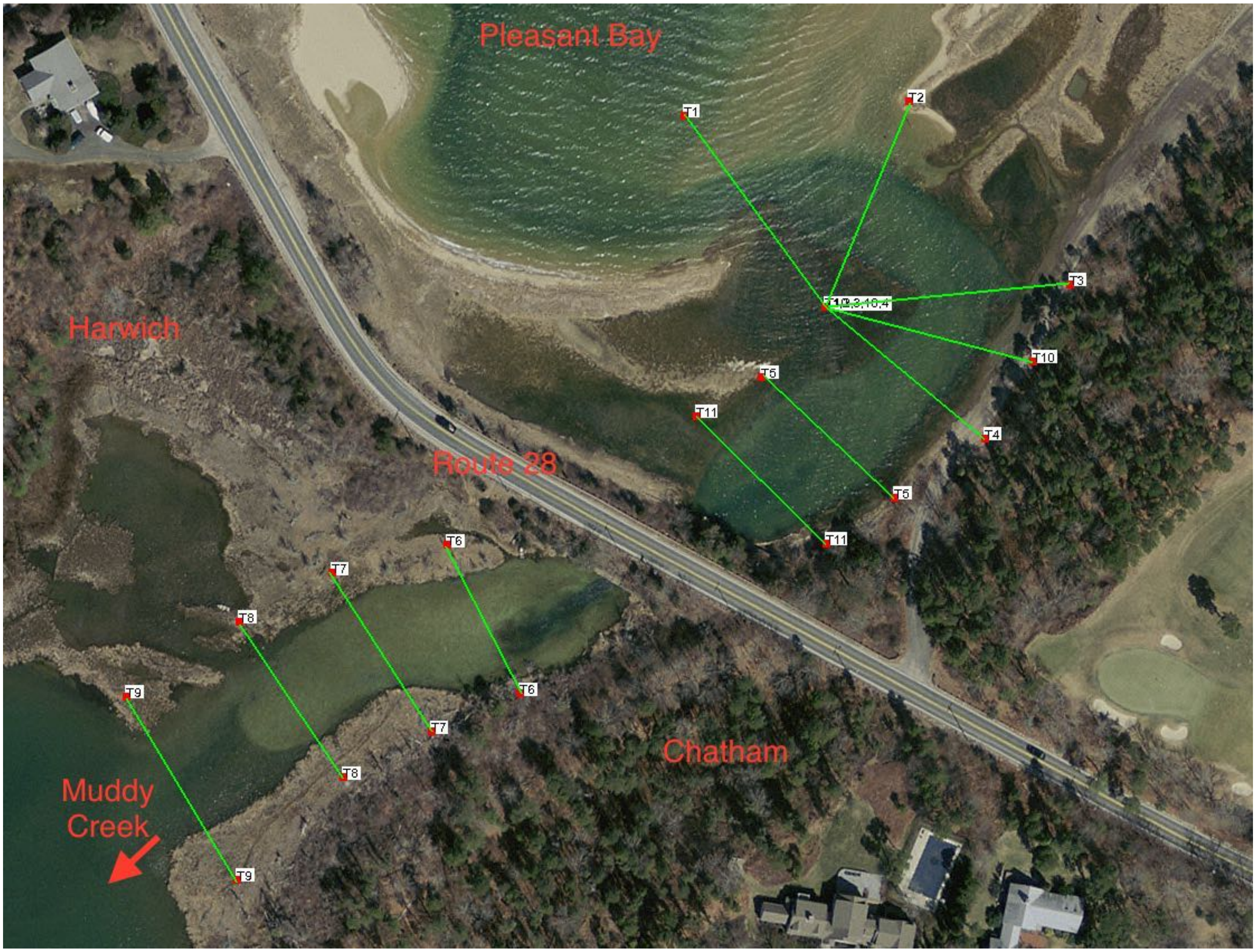


Figure 7: Chanel bathymetry monitoring – transects and planform survey conducted in 2016

(Applied Coastal Research and Engineering, 2016)

Figure 8. Minor bank slumping has been noted over the monitoring period. Areas of bank slumping are shown in red. Blue areas represent marsh plain that was lower than the adjacent marsh plain prior to construction but have not exhibited significant bank slumping (Applied Coastal Research and Engineering, 2016)

Figure 9: Aerial photo of Jackknife and Muddy Creek taken by Greg Berman (WHOI Sea Grant/Barnstable County Extension Service).

Post-construction: Transect measurements along the pre-established eight transects, and two additional transects seaward of Route 28, were taken in June, July, September, and November 2016 by Applied Coastal Research and Engineering using an RTK-GPS unit (Figure 7). A minimum of ten points across the channel, bank-to-bank, were recorded. The additional 2 transects in the vicinity of the Jackknife Beach access road were added, along with additional topographic data associated with the slope adjacent to the roadway. The locations of the additional transects were determined based on observations of bank slumping during the first survey. Measurements of channel bank location, at minimum 25-foot intervals, provided another means to monitor channel migration. A final report on the data collected, in comparison with pre-construction measurements, is found in Appendix A.

D. Water Quality

Pre-Project: Pleasant Bay Alliance has monitored water quality at two monitoring stations in Muddy Creek: one in lower Muddy Creek (PBA 5), and one in Upper Muddy Creek (PBA 5A). A MassDEP approved Quality Assurance Project Plan (QAPP) is in place and includes the following parameters: nitrogen species (DON, PON, DIN, TON, TN), dissolved oxygen, temperature, salinity, phytoplankton pigments, etc.). Sample collection occurs 5 times annually from July through early September. Samples are analyzed by the UMASS Dartmouth School for Marine Science and Technology. This monitoring effort is ongoing and will continue following project completion to document long-term water quality changes.

In the fall of 2015 the Alliance resumed bacterial monitoring at the upper and lower Muddy Creek water quality monitoring stations as well as a station located downstream near Jackknife Beach.

Post-construction: Appendix C contains figures for dissolved oxygen, eutrophication index, total nitrogen, pigment concentrations and salinity for monitoring stations in upper (PBA 5A) and lower (PBA 5) Muddy Creek from 2000-2016. These data include only one post-construction monitoring season.

Initial observations suggest that it is too early to see major changes in water quality due to the bridge:

- TN decreased from the prior year at both 5 and 5A. The change in TN at station 5 doesn't appear significant. TN at station 5A is lowest level observed. There was no significant change in N species breakdown from prior years.
- Pigment concentrations went up at both stations. A similar trend was observed at other Pleasant Bay stations and so it is likely duo to a factor such as weather and is unrelated to the bridge.
- While the range of DO values narrowed, levels were not inconsistent with prior years.
- Salinity was the area where the most significant changes were observed.

The Pleasant Bay Alliance will continue to collect nutrient and bacterial water quality as described above.

E. Marsh Plain Elevation

Although the Project did not have the resources to install horizon markers pre- and immediately post-construction, the Project team is considering the value of installing several horizon markers to monitor long-term sediment marsh surface accretion to evaluate long-term changes to the marsh surface. Methodologies under consideration for establishing and monitoring marker horizons can be found at:
https://www.pwrc.usgs.gov/set/installation/markers.html

F. Benthic Infauna

The project team is considering benthic infauna sampling as a means of gaging restoration resulting from improved ecological conditions (decreased nitrogen concentrations; increased dissolved oxygen, etc.). Benthic infauna monitoring would be conducted by the School for Marine Science and Technology at UMASS-

Dartmouth so that results can be directly compared with benthic infauna sampling taken for the Massachusetts Estuaries Project 2006 Technical Report for Pleasant Bay.

III. Sources

Barbour, M. G., J. H. Burk, and W. D. Pitts. 1987. Terrestrial Plant Ecology. Benjamin Cummings Publishing Company, Menlo Park,CA, USA.

Duncanson, Robert A. Pleasant Bay Citizen Water Quality Monitoring Program Quality Assurance Project Plan. Pleasant Bay Resource Management Alliance Citizen Water Quality Monitoring Program Work Group. April 30, 2001.

Fuss & O'Neill, Inc. (2012). Technical Memorandum: Muddy Creek Wetland Restoration.

Ruthven, Trey. Muddy Creek Post Construction Tidal Monitoring, Chatham and Harwich, Massachusetts. Memorandum to Carole Ridley. September 23, 2016.

Sokal, R. R. and F. J. Rohlf. 1995. Biometry, 3rd ed. W.H. Freeman and Company, New York, NY, USA.

University of Massachusetts Dartmouth (School of Marine Science and Technology) and Massachusetts Department of Environmental Protection (2006). Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Pleasant Bay System, Towns of Orleans, Chatham, Brewster and Harwich, Massachusetts. Massachusetts Estuaries Project. Final Report-May 2006.

IV. Reporting and Data Management

Monitoring reports and data sets are hosted on the Pleasant Bay Alliance website,

http://pleasantbay.org/programs-and-projects/wetlands-protection/muddy-creek-restoration/muddy-creek-restoration-monitoring-results.

V. Appendices

A. Muddy Creek Post-construction Tidal Monitoring, Applied Coastal Research and Engineering

B. Pre and Post-construction Photo Monitoring Images for Select Stations

C. Water Quality Data for Upper (Station 5A) and Lower (Station 5) Muddy Creek

Applied Coastal Research and Engineering, Inc.
766 Falmouth Road
Suite A-1
Mashpee, MA 02649
508-539-3737

MEMORANDUM

Date: **September 23, 2016**

To: **Carole Ridley**

From: **Trey Ruthven**

Subject: **Muddy Creek Post Construction Tidal Monitoring, Chatham and Harwich, Massachusetts**

This summarizes tide data collection upstream and downstream of the new Route 28 Bridge which was constructed to improve tidal circulation within Muddy Creek above the Route 28 causeway. Tide data records were collected at two stations: 1) offshore of Muddy Creek in Pleasant Bay, the gage was located at the Wequassett Resort attached to a wooden pier along the main dock that extends into Pleasant Bay (downstream), and 2) west of Route 28 bridge, in the main body of Muddy Creek (upstream). The locations of the two gage stations are shown in Figure 1. The Temperature Depth Recorders (TDR) used to record the tide data were deployed for a 34-day period beginning June 22, 2016 and ending on July 26, 2016.

The tide gauges used for the study were Brancker XR-420 TG. Data recording was set for 10-minute intervals, with each observation resulting from an average of 60 1-second pressure measurements on 10-minute intervals. These instruments use strain gauge transducers to sense variations in pressure, with resolution on the order of 1 cm (0.39 inches) head of water. Each gauge was calibrated prior to installation to assure accuracy.

Once the data were downloaded from each instrument, the water pressure readings were corrected for variations in atmospheric pressure. Hourly atmospheric readings were obtained from the NOAA recording station in Nantucket Sound (site 44020), interpolated to 10-minute intervals, and subtracted from the pressure readings, resulting in water pressure above the instrument. Further, a (constant) water density value of 1025 kg/m^3 was applied to the readings to convert from pressure units (psi) to head units (for example, feet of water above the tide gauge). The elevation of each gauge was surveyed relative to North American Vertical Datum of 1988 (NAVD88) using an Leica Viva GS08 GNSS receiver RTK network rover coupled with a Leica Viva CS15 3.5G Data Collector system. The geographic locations of the gages are presented in Table 1 in Massachusetts State Plane Coordinates. The survey information was used to provided vertical rectification of the water level to a known vertical datum. The result from each gauge is a time series representing the variations in water surface elevation relative to NAVD88.

Table 1. Location of the tide gages in the Muddy Creek, Chatham and Harwich, MA. Coordinates are Massachusetts State Plane Coordinates, NAD83 (2011), feet.		
Location	Northing (feet)	Easting (feet)
Gage 1 – Pleasant Bay	2,727,152.96	1,067,237.81
Gage 2 – Muddy Creek	2,723,318.20	1,066,842.79

Plots of the tide data from are shown in Figure 2, for the 34-day deployment. The spring-to-neap variation in tide can be seen in this plot. Examining the plot shows that offshore the tide reaches its maximum spring tide range of approximately 4.8 feet on July 6th. Six days later the neap tide range is smaller, approximately 3.3 feet. A visual comparison of the two gage records in Figure 3, shows that there is a reduction in the tide range as the tide propagates from Pleasant Bay into Muddy Creek. The loss of amplitude with distance from the inlet channel through the bridge is described as tidal attenuation. Frictional mechanisms dissipate tidal flow energy, resulting in a reduction of the height of the tide. Tide attenuation is accompanied by a time delay (or phase lag) in the time of high and low tide (relative to the offshore tide). The lag can be visually observed on the flood and ebb tide between Pleasant Bay and Muddy Creek as shown in Figure 3.

Standard tide datums were computed from the 34-day records. These datums are presented in Table 2. For most NOAA tide stations, these datums are computed using 19 years of tide data, the definition of a tidal epoch. For this study, a significantly shorter time span of data was available; however, these datums still provide a useful comparison of tidal dynamics within the system. The Mean Higher High (MHHW) and Mean Lower Low (MLLW) levels represent the mean of the daily highest and lowest water levels. The Mean High Water (MHW) and Mean Low Water (MLW) levels represent the mean of all the high and low tides of a record, respectively. The Mean Tide Level (MTL) is simply the mean of MHW and MLW.

As the tide propagates from the Atlantic Ocean into and through Pleasant Bay and then into Muddy Creek attenuation of the tide occurs. This is observed as a reduction in the tide range and also as a delay in the time of high and low tide during each tide cycle. The tides in the Pleasant Bay and Muddy Creek, are semi-diurnal, meaning that there are typically two tide cycles in a day. There is usually a small variation in the level of the two daily tides. This variation can be seen in the differences between the MHHW and MHW, as well as the MLLW and MLW levels.

Table 2. 2016 Tide datums computed from a 34-day period from the tide records collected in the Muddy Creek, Chatham and Harwich, MA. Datum elevations are given relative to NAVD88.		
Tide Datum	Gage 1 – Pleasant Bay	Gage 2 – Muddy Creek
Maximum Tide	3.7	3.4
MHHW	2.9	2.6
MHW	2.5	2.2
MTL	0.6	1.1
MLW	-1.2	-0.1
MLLW	-1.3	-0.1
Minimum Tide	-1.5	-0.3

To examine the influence the recently constructed Route 28 Bridge has had upon the tides entering and exiting Muddy Creek, the tide datums from the 2009 study which examined various opening alternatives for Muddy Creek are presented in Table 3. The 2009 tidal signal within Pleasant Bay had a slightly larger amplitude range relative to the 2016 dataset. The changes in tidal amplitude are due to differences in tidal forcing over the short monitoring periods, transformation and evolution of the tidal inlets into Pleasant Bay from the Atlantic Ocean, and variability in metrological forcing over the monitoring periods. The key difference upstream of the Route 28 causeway is the significant increase in tidal amplitude from 2009 to 2016, there is approximately a 2.1 foot increase in tidal range within Muddy Creek due to the improved channel opening. A visual comparison also shows the significant increase in amplitude, Figure 3 shows the tidal variations with the new constructed bridge and Figure 4 shows the historic tidal variations with the stone box culverts.

Table 3. 2009 Tide datums for Muddy Creek, Chatham and Harwich, MA. Datum elevations are given relative to NAVD88.		
Tide Datum	Gage 1 – Pleasant Bay	Gage 2 – Muddy Creek
Maximum Tide	4.0	2.0
MHHW	3.3	1.6
MHW	3.0	1.5
MTL	0.9	1.3
MLW	-1.2	1.0
MLLW	-1.4	1.0
Minimum Tide	-1.5	0.7

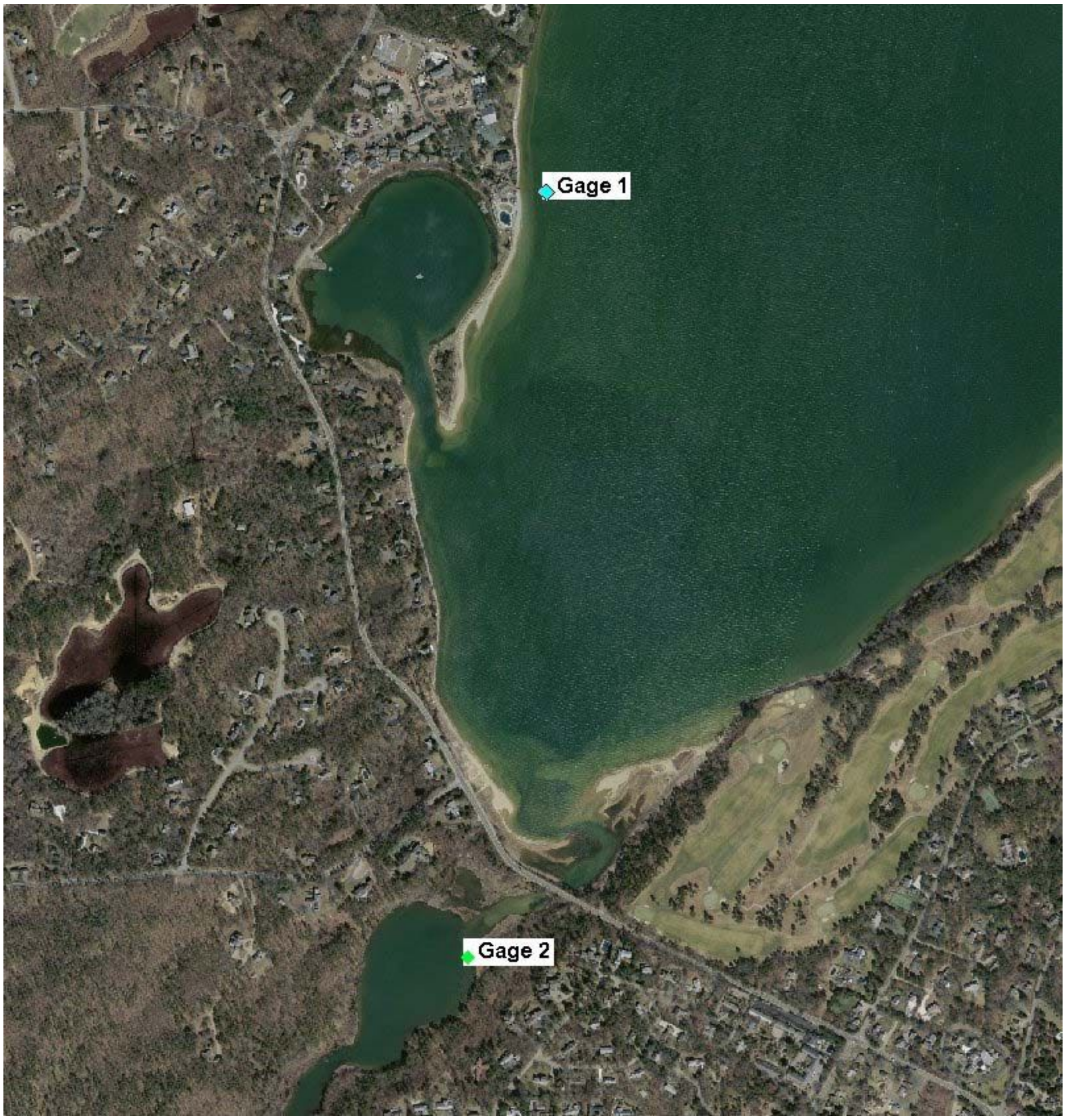


Figure 1. The markers (pink circles) show the locations of the tide recorders deployed for this study.

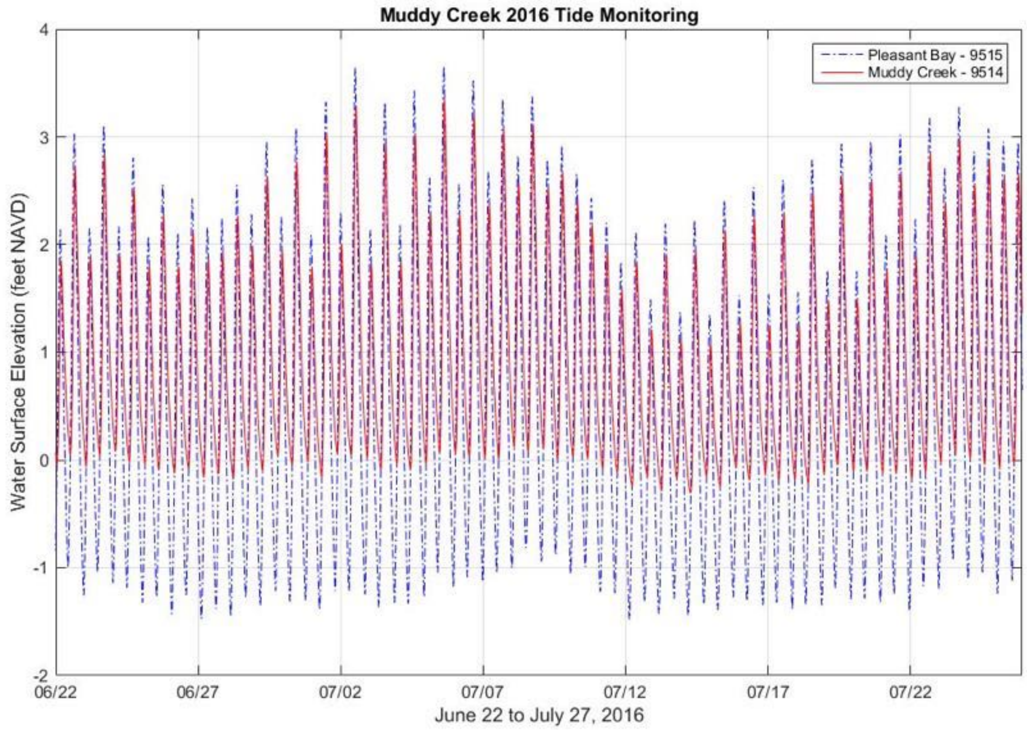


Figure 2. Plots of observed tides for the Muddy Creek, Chatham and Harwich, MA, for the 34-day period between June 1, 2016 and July 16, 2016. The blue line shows tide offshore in Pleasant Bay. The red line shows the tide inside Muddy Creek upstream of the new Route 28 Bridge. All water levels are referenced to the NAVD 88.

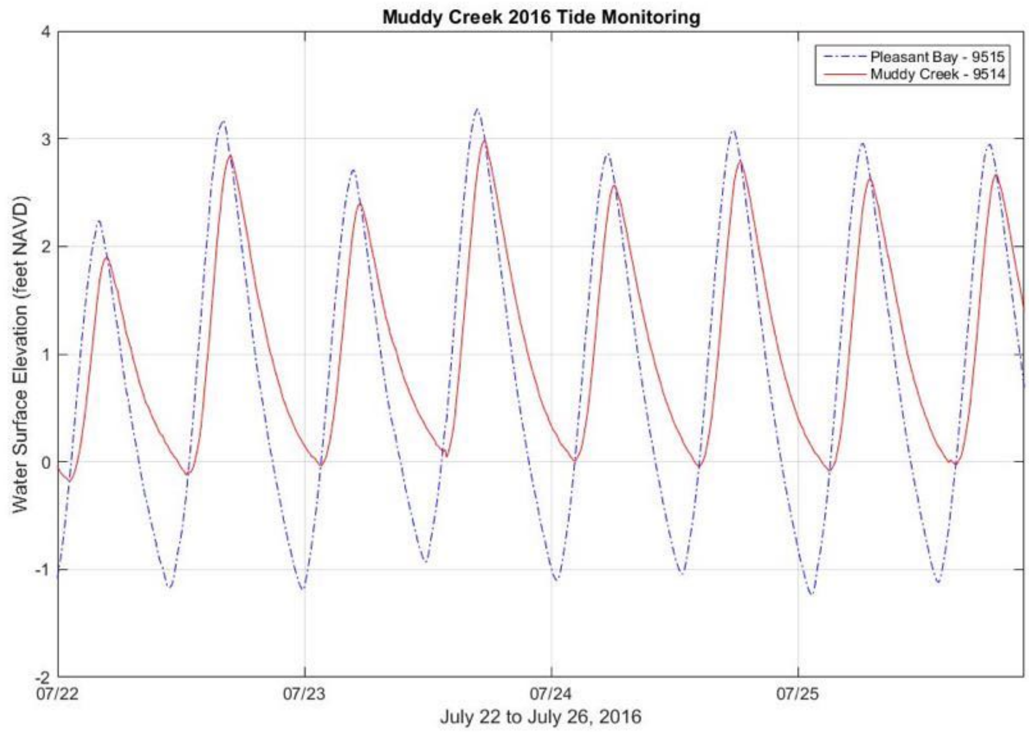


Figure 3. Plot showing three tide cycles offshore in Pleasant Bay and within Muddy Creek upstream of the new Route 28 Bridge.

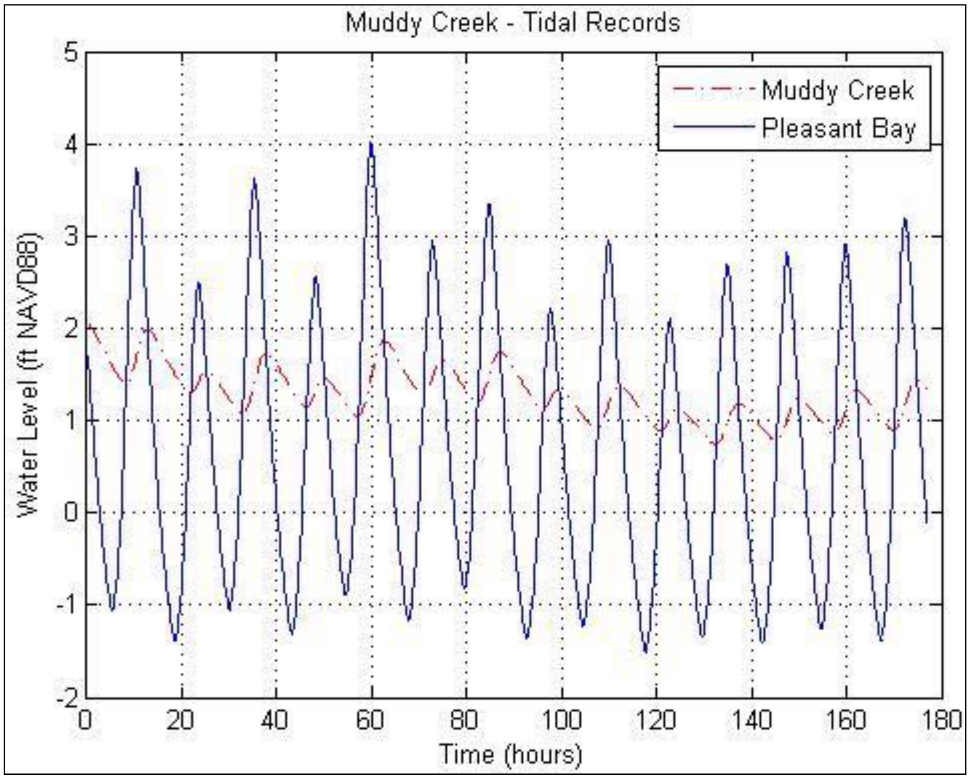


Figure 4. Tide gage records from November 2009 for instruments deployed both upstream and downstream of the Route 28 culvert along Muddy Creek. In 2009, Pleasant Bay was connected to Muddy Creek through a pair of stone box culverts. The stone box culverts were approximately 2.5-feet wide, 3.75-feet in height, and 100-feet in length.

Figure 1 VEGT1 (10°) - Downstream Estuary 09/17/15

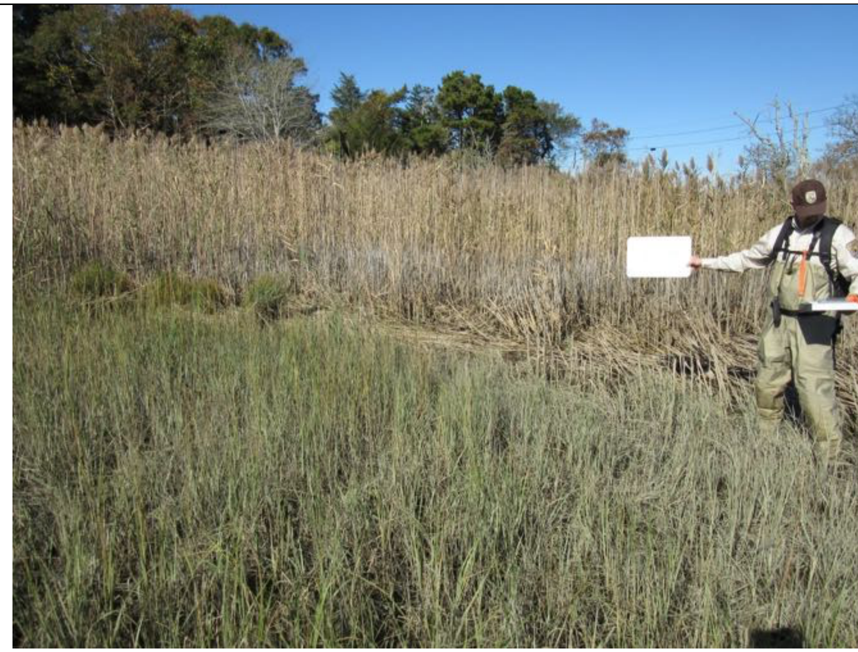


Figure 2 VEGT1 (10°) - Downstream Estuary 10/24/16

Figure 3 MC VEG T4 (140°) - Downstream Estuary 09/16/15

Figure 4 MC VEG T4 (140°) - Downstream Estuary 10/24/16

Figure 5 MC MID1 (270°) 09/17/2015


Figure 6 MC MID1 (270°) 10/26/2016

Figure 7 MC UP Dock (270°) 09/17/2015


Figure 8 MC UP Dock (270°)10/25/2016

Figure 9 MC UP T2 (260°) - Upstream 09/17/15

Figure 10 MC UP T2 (260°) - Upstream 10/25/16

Figure 11 MC UP VEGT3 (40°) Upstream 09/17/15

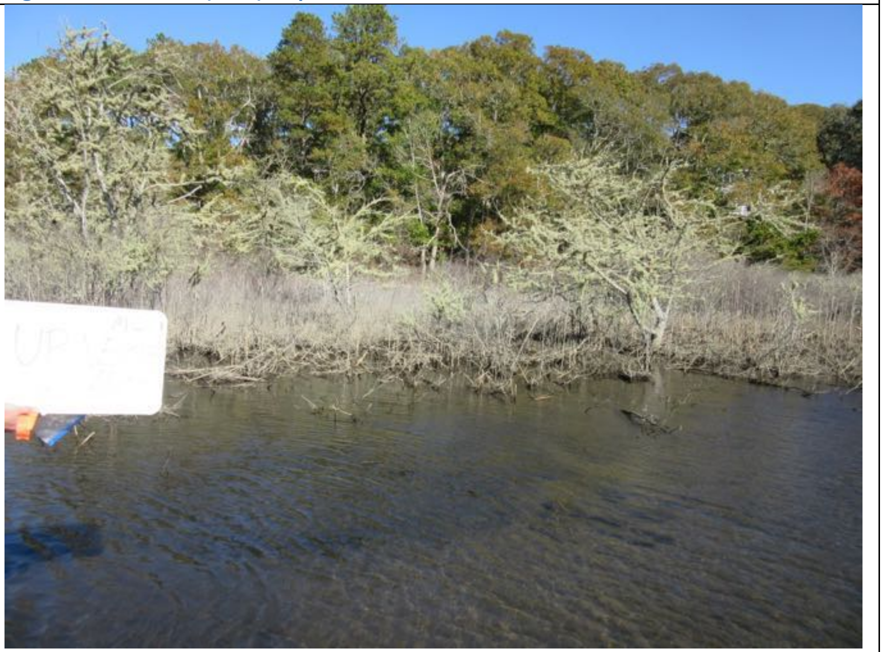
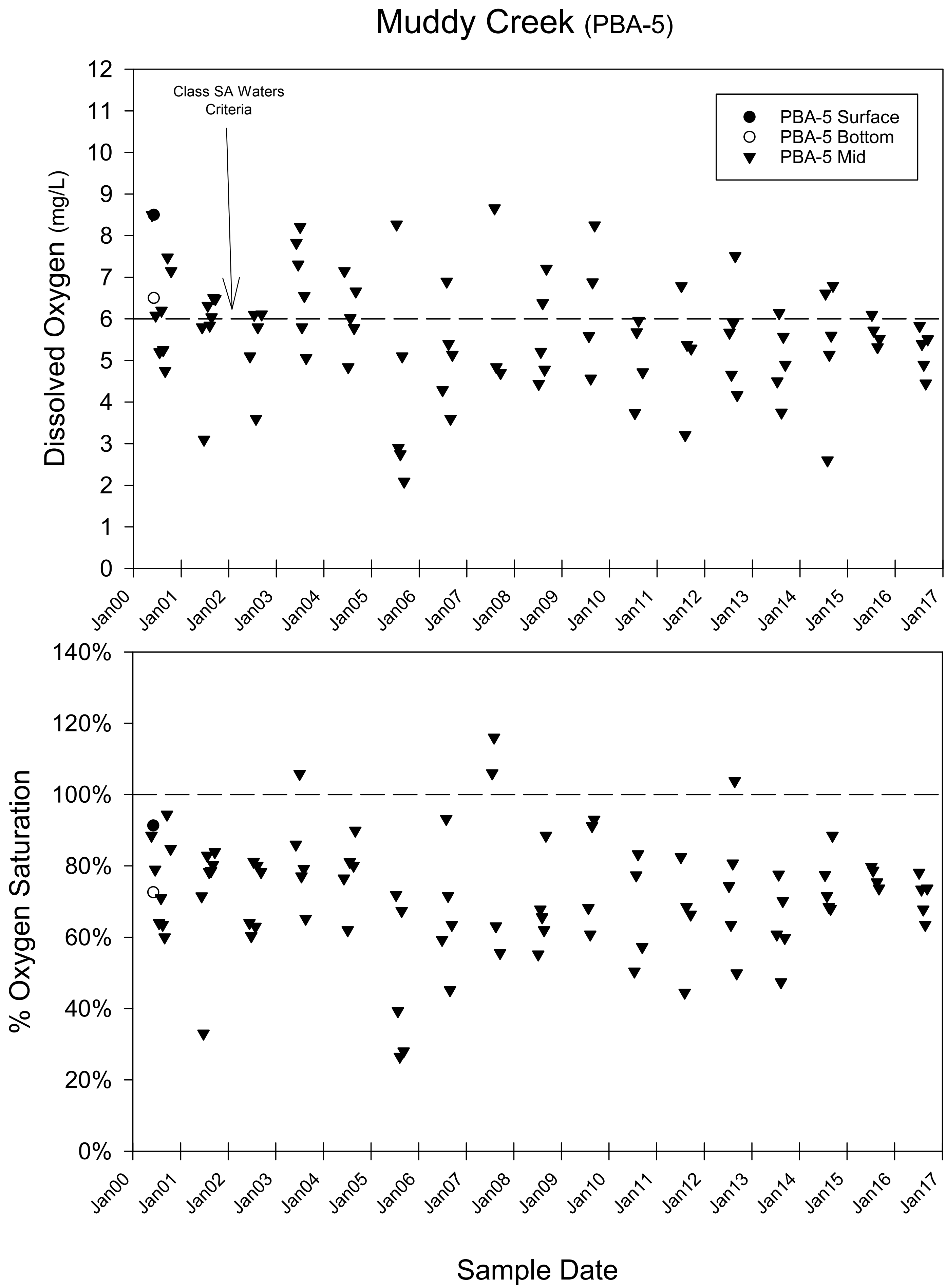


Figure 12MC UP VEGT3 (40°) Upstream10/25/16


Muddy Creek (PBA-5)
Class SA Waters Criteria
PBA-5 Surface
PBA-5 Bottom
PBA-5 Mid
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
% Oxygen Saturation
0%
20%
40%
60%
80%
100%
120%
140%
Jan00
Jan01
Jan02
Jan03
Jan04
Jan05
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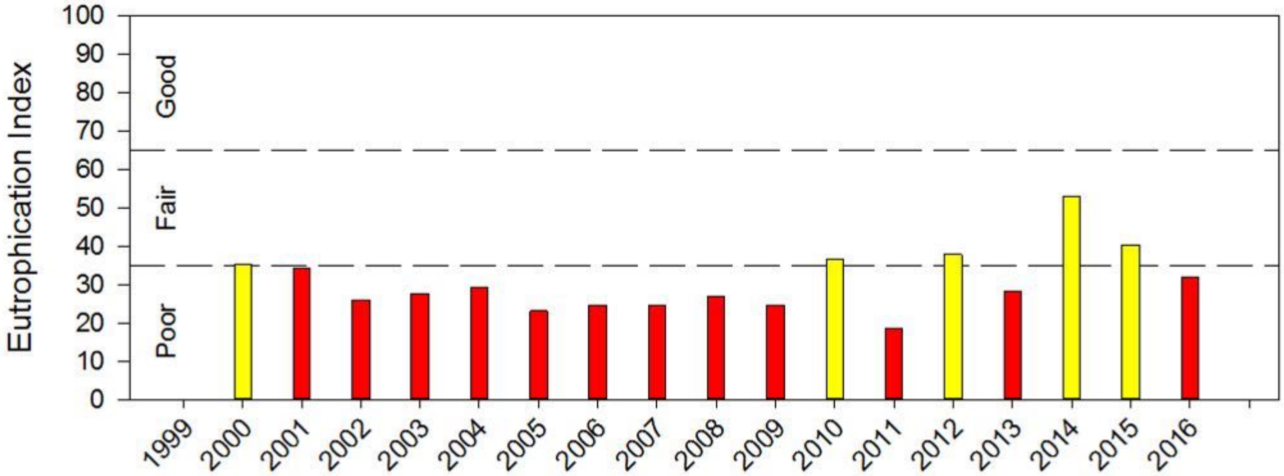
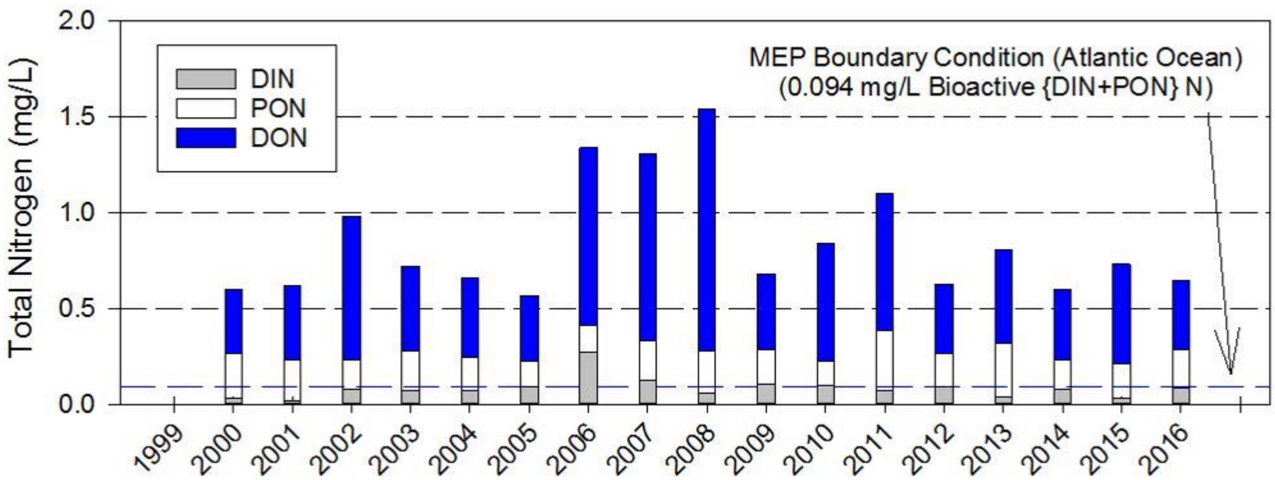
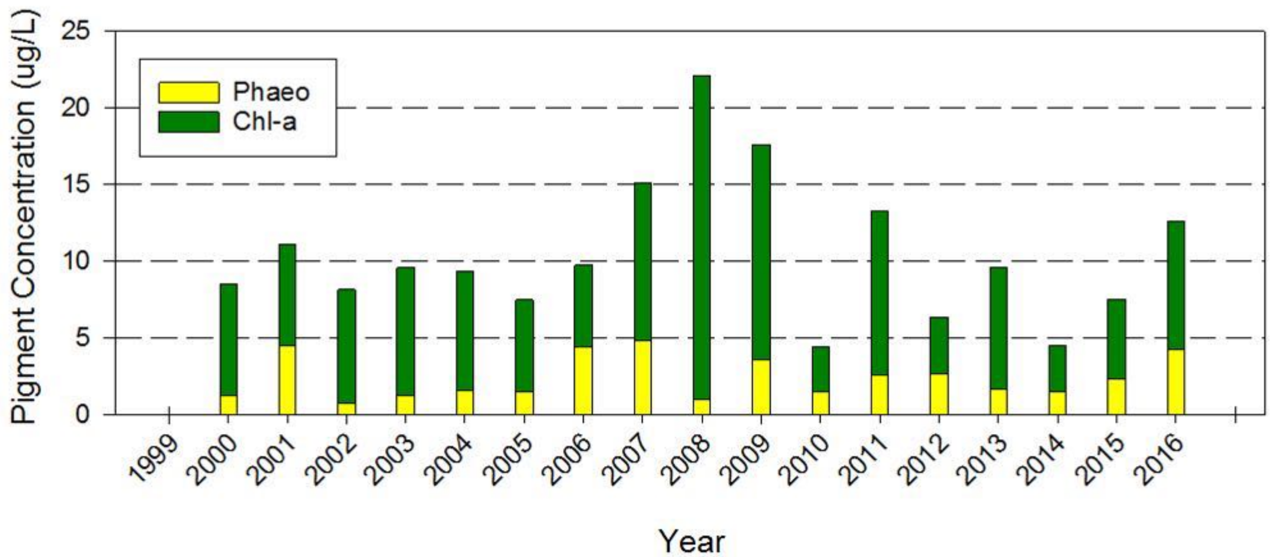
Sample Date

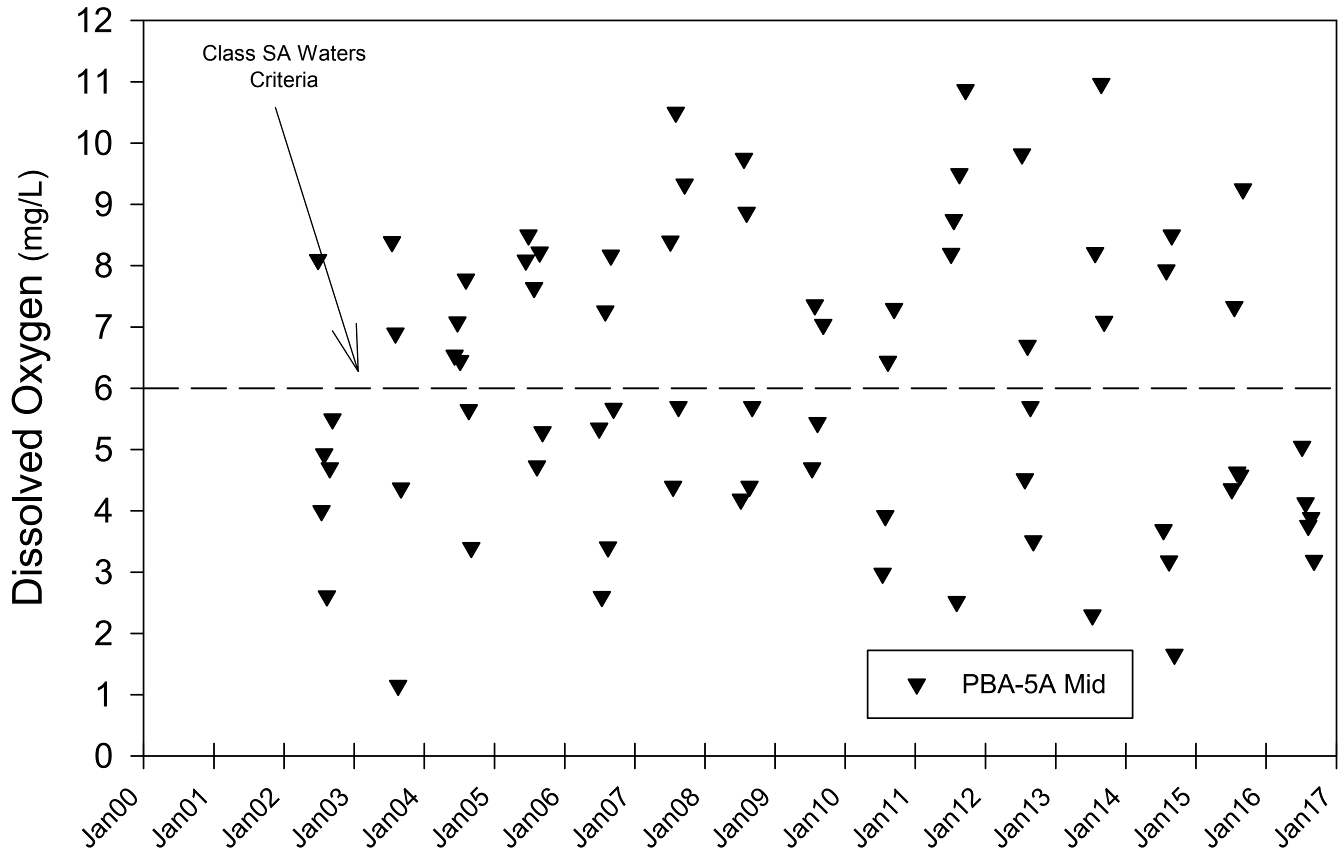
Muddy Creek (PBA-5)

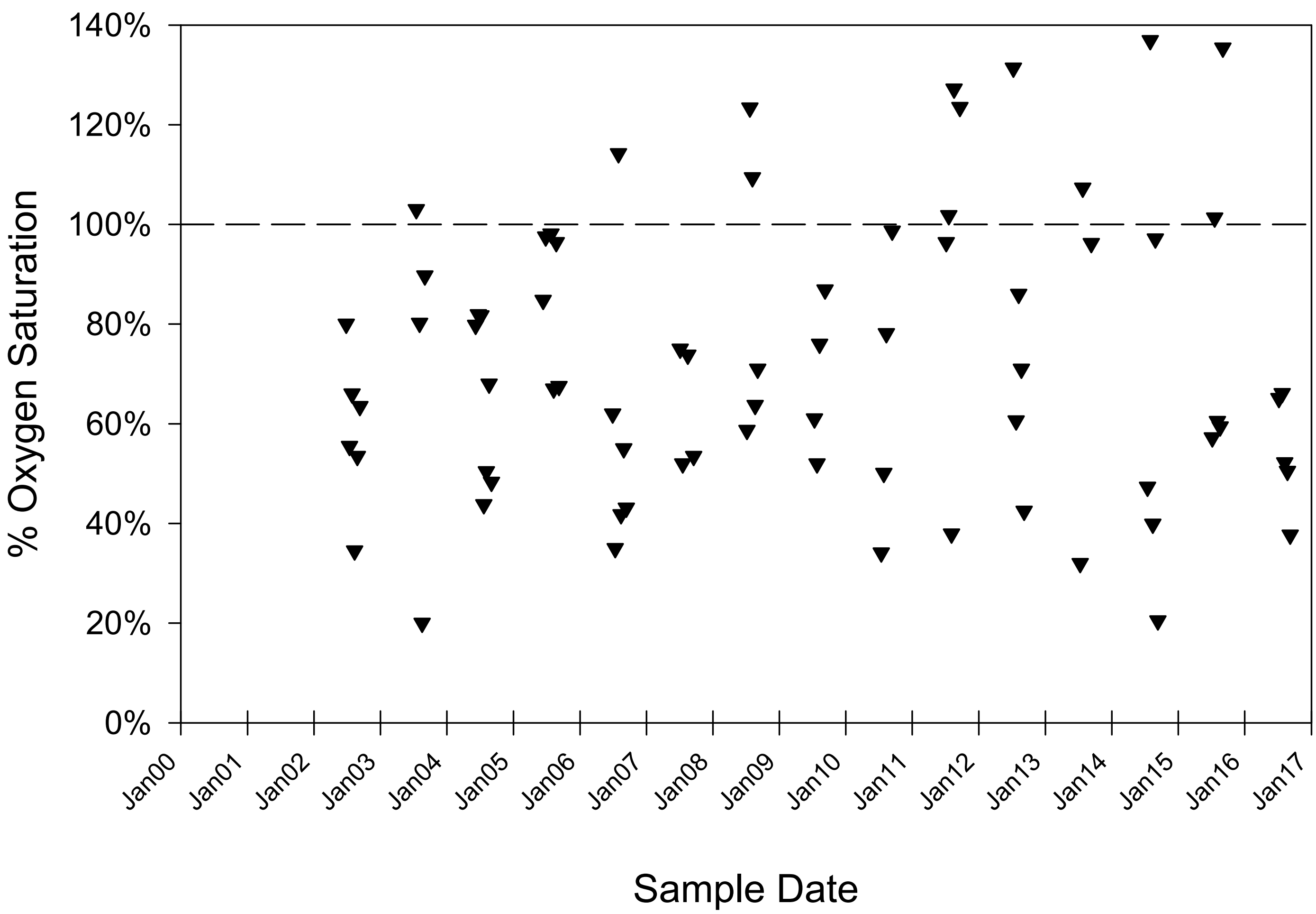




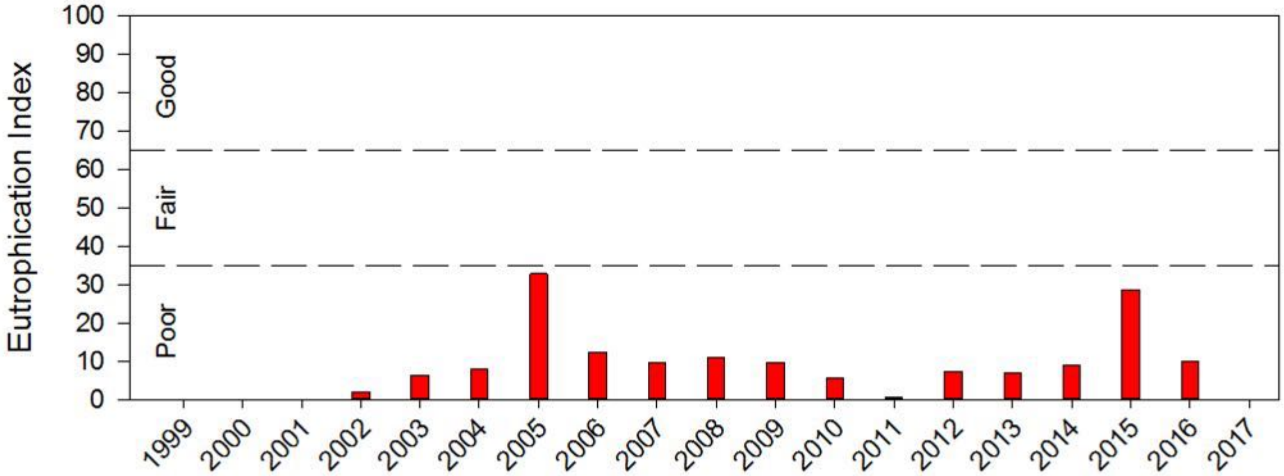


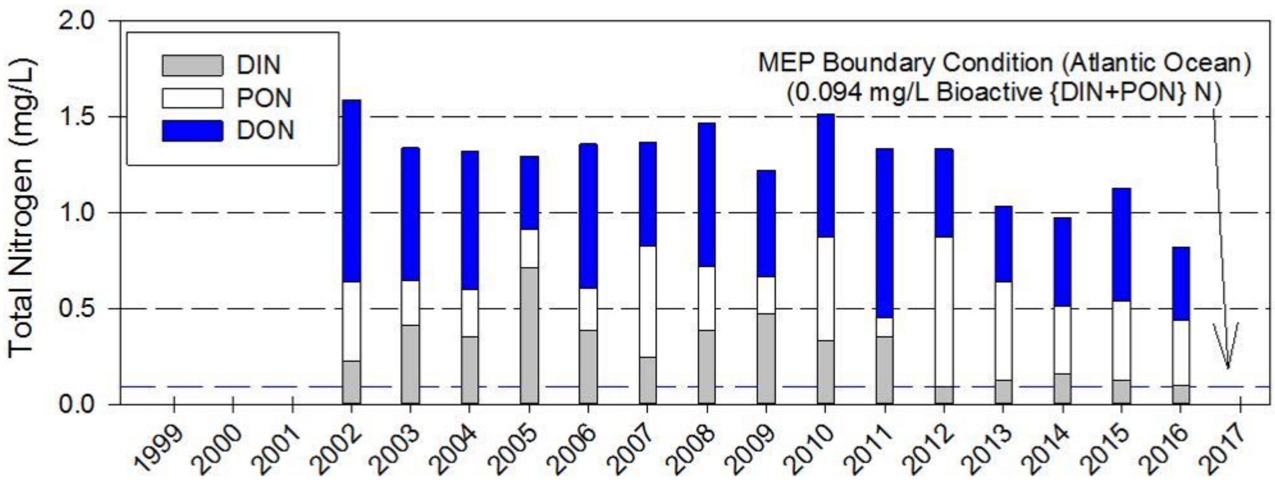
Muddy Creek - Upper (PBA-5A)

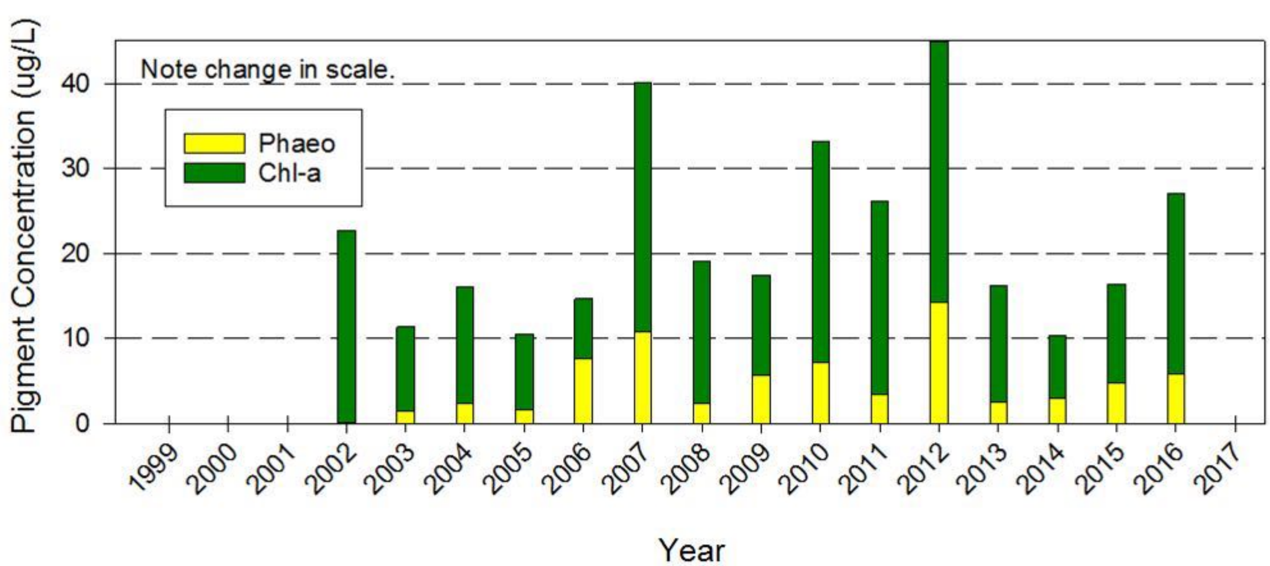


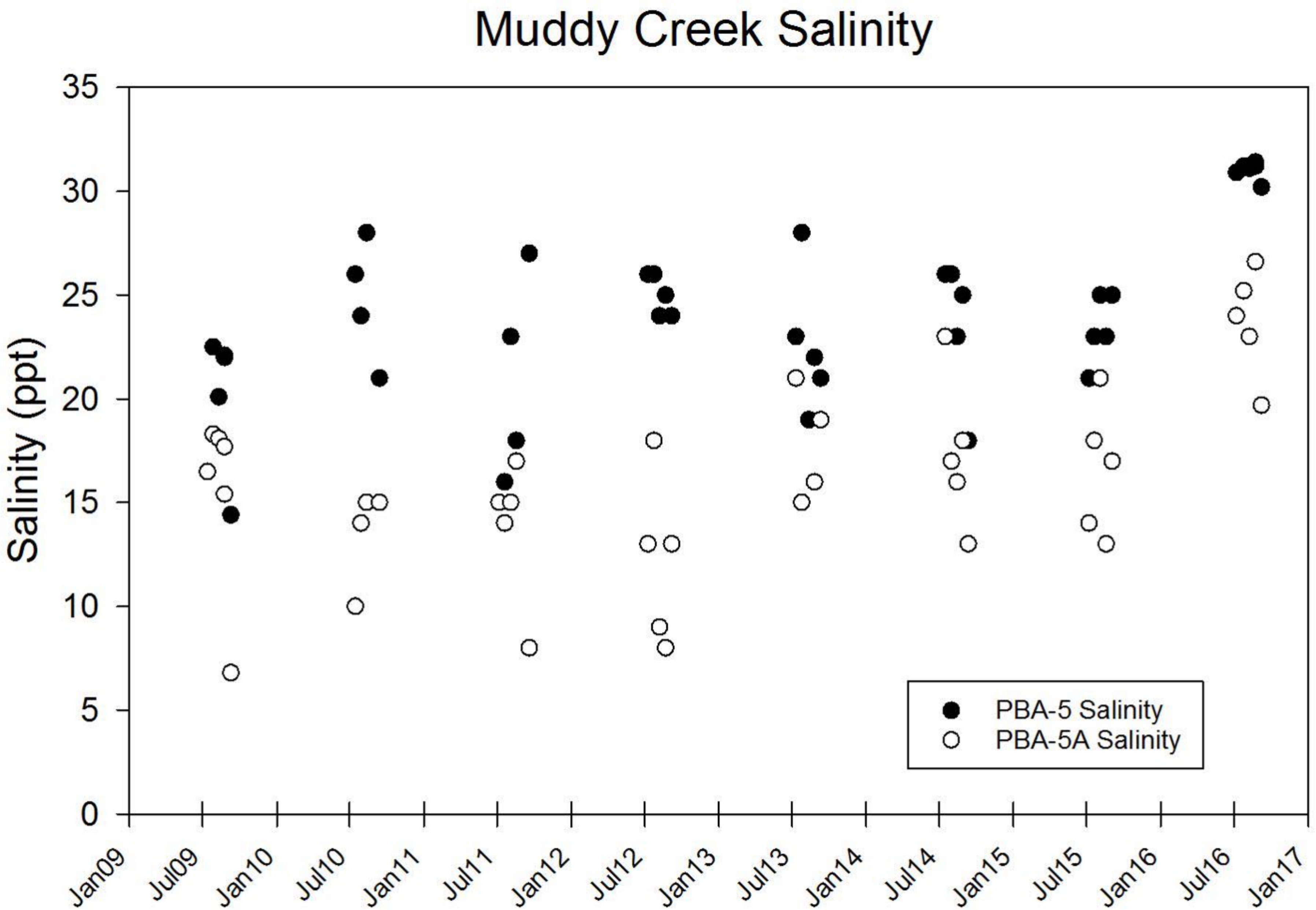


Muddy Creek - Upper (PBA-5A)









Muddy Creek Salinity
Salinity (ppt)
35
30
25
20
15
10
5
0
Jan09
Jul09
Jan10
Jul10
Jan11
Jul11
Jan12
Jul12
Jan13
Jul13
Jan14
Jul14
Jan15
Jul15
Jan16
Jul16
Jan17
PBA-5 Salinity
PBA-5A Salinity