2016 Post-Project Monitoring Report: Long Reach Lane at Long Marsh, Harpswell

Year 3 of 5

Compensation for the Martin's Point Bridge Project, Falmouth-Portland (PIN 16731.00)

March 2017

Prepared For:

MAINE DEPARTMENT OF TRANSPORTATION
Division of Field Services and Mitigation
16 State House Station
Augusta, Maine 04333

Prepared By:

Matthew Craig
CASCO BAY ESTUARY PARTNERSHIP
University of Southern Maine
PO Box 9300, 34 Bedford Street
Portland, Maine 04104-9300

Casco Bay Estuary Partnership

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. OVERVIEW

In 2012, the Maine Department of Transportation (MDOT) proposed a mitigation project at Long Reach Lane in Harpswell (Figure 1) to compensate for the functional impacts to marine wetlands associated with the construction of the Martin's Point Bridge between Falmouth and Portland. The mitigation project took place in January and February 2014, and resulted in the successful replacement of a 36" (7.1 ft^2 flow area) round concrete pipe beneath Long Reach Lane with a larger 6' x 12' concrete box culvert (72 ft^2 flow area) in February 2014 (photo MDOT, below).

This report primarily presents the results of pre-project monitoring, which occurred during the 2013 growing season, and Year 3 of post-project monitoring, which occurred during the 2016 growing season, at the Long Marsh mitigation site. Year 1 & 2 post-project data from 2014 and 2015 are included in some instances, for context.

1.1 Project Monitoring

The Casco Bay Estuary Partnership (CBEP), which is hosted by the University of Southern Maine, was contracted by MDOT to conduct monitoring within the Project Area for one year pre-project, and five years post-project. CBEP, one of 28 National Estuary Programs nationwide, has focused on assessment, restoration, and monitoring at tidal marshes since 2009.

The *Martin's Point Bridge Wetland Mitigation Plan* (*Plan;* MDOT 2012) describes the mitigation site Project Area as the marsh area upstream (south) of Long Reach Lane, and north of a bedrock feature locally known as "the narrows" (Figure 1). The *Plan* also states:

> In "*…the Marsh area south of the narrows … there are three large established patches of Phragmites that makes up approximately 7% of this portion of the marsh surface area. This area is outside of the project area."* (MDOT, Section J)

To monitor ecosystem change in response to the mitigation project, CBEP established 10 monitoring Stations at Long Marsh, spaced so that they were evenly distributed. Station 1 was located outside the Project Area, immediately to the north of Long Reach Lane, and Stations 2-10 were located within the Project Area, south of Long Reach Lane and north of the narrows (Figure 2). CBEP also established two monitoring Stations south of the Project Area, Stations 11 and 12.

The *Plan* specifies parameters for pre- and post-project monitoring:

- Hydrology signal – using continuous water level recorders deployed upstream and downstream of Long Reach Lane.
- Pore water and surface water salinity.
- Vegetation – abundance (percent cover) of halophytic, brackish, freshwater, and invasive plant species.
- Channel morphology – cross sectional area.
- Erosion – post-project visual surveys within the construction area.
- Photo stations.

1.2 Summary of Mitigation Goals and Performance Standards

The stated objective of the mitigation project was to eliminate the tidal restriction created by Long Reach Lane in Harpswell (MaineDOT 2012). The following performance standards were established for this objective:

1) *Tide curve data upstream of the crossing will be 80% or greater than that of the downstream area after crossing construction…The intention is that 80% (as opposed to 100%) removal will give us a comfortable operating margin, accounting for potential uncertainty in the model. If this standard is not met, the opening size will be enlarged to meet this standard. There may be a phase delay associated with this site after construction which will not be remediated.*
2) *All the constructed features such as slopes, soils, substrates within the mitigation site will be stabilized and free from erosion.* (MDOT 2012, Section I)

In addition, the *Plan* laid out a set of mitigation goals:

1) *Vegetation in the upstream marsh will transition from a salt marsh – brackish – freshwater system to predominately salt tolerant species. After the culvert replacement it is expected that a salinity gradient will limit freshwater species establishment. These species will be confined to the marsh edge fringe where overtopping does not occur and will include at a minimum the southernmost 30 acres of the marsh.*
2) *Invasive species, namely* Phragmites australis *(Common Reed) and* Lythrum salicaria *(Purple Loosestrife) will be monitored and controlled using integrated pest management techniques. The goal will be to eliminate the establishment of Common Reed and Loosestrife in the marsh*

restoration area. The project enhancement and restoration area does not support any Common Reed or Purple Loosestrife. (MDOT 2012, Section J)

Monitoring efforts to date indicate that site conditions within the Project Area continue to adjust in response to the new culvert, in ways that are consistent with the mitigation project objective, performance standards, and goals. Table 1 summarizes the status of tidal hydrology, erosion, and other monitored parameters in the third growing season post-project (2016), based on a comparison with pre-project monitoring data collected in 2013, and describes whether the status is consistent with pre-defined standards and goals for the mitigation site.

The performance standard for hydrology was met in 2014 as reported in Section 3.1 of the Year 1 post-project report (CBEP 2015). The performance standard for erosion control was met 2015, with the slopes, soils, and substrates within at the project site stable.

For the remaining monitoring parameters, response to the modified hydrology beneath Long Reach Lane is presumed to be ongoing, with Year 3 post-project data indicating that changes in site conditions are 'on-track' in that they are consistent with the objective and goals for the mitigation site over the 5-year post-project monitoring period.

Table 1. Summary of Performance Standards and Monitoring Parameters

Performance Standard/ Monitoring Parameters	2016 Findings	Meet Standard?*
Hydrology signal	*N/A*	Yes[1]
Erosion control	*Slopes, soils, substrates at the Project Site are stable*	On-track
Pore water salinity	*Pore water salinity levels generally remained higher throughout the Project Area over 2013*	On-track
Vegetation community	*Halophytic vegetation abundance increased in the Project Area; brackish and freshwater vegetation abundance decreased, with extensive dead cat tail stands*	On-track
Channel morphology	*Channel cross sectional area continued to increase throughout Project Area*	On-track
Invasive species	Two new, small patches of *Phragmites australis* were observed within the Project Area.	Remedial action taken

***** *Hydrology signal and erosion control are the only two performance standards. Assessment of other monitoring parameters provided for context.*
[1] *Summarized in Year 1 post-project report.*

1.3 Remedial actions

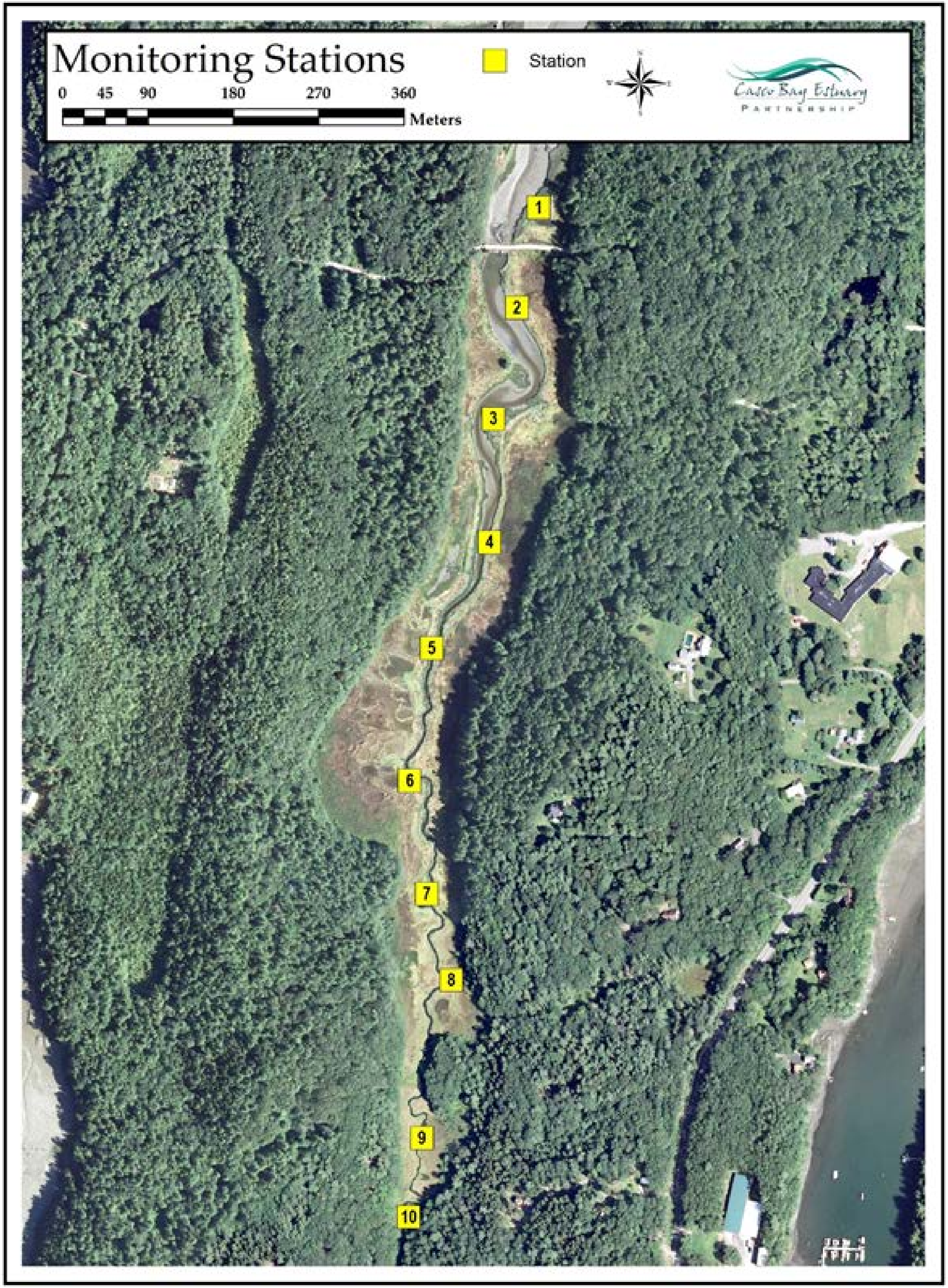
During an invasive species meander survey in early August, CBEP's seasonal field crew observed a small new patch of *Phragmites australis* in a southeastern portion of the Project Area, approximately 15m away from the upland edge of the marsh at Station 9. At subsequent site visits, the patch was estimated to include 390 stems in an area of approximately 100m^2. The patch was located amongst standing dead alder, cattails, and white pine, in an ecologically disturbed area of the marsh that now experiences regular tidal inundation, post-project (photo below). CBEP contacted Deane Van Dusen of MDOT to report the discovery. Van Dusen subsequently applied a mixture of Glyphosate and Imazapyr as a control agent in a fall application. Monitoring and spot treatment will continue in Years 4 and 5.

1.4 Erosion

The mitigation site is stable. As expected, the creek channel continues to widen and deepen within the Project Area in response to the changed hydrology resulting from the new culvert beneath Long Reach Lane. Other than this morphological response of the channel to the increased tidal exchange, and the associated sediment movement within and out of the system, the slopes, soils, and substrates adjacent within the construction area at Long Reach Lane were stable and no remedial actions were deemed to be necessary. CBEP will continue to closely monitor the stability of soil conditions at the Long Reach Lane construction site in Years 4-5.

Figure 1. Project Area map.

Figure 2. Monitoring Station location map. Long Reach Lane is visible between Station 1 and Station 2. Stations 2-10 lie within the Project Area.



2. METHODS

Monitoring methods are based on protocols and methods laid out in Sections K and L of the *Mitigation Plan*, and which generally align with protocols set forth in the *Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine* for the selected parameters (Neckles & Dionne 1999). Parameters were monitored in association with designated Stations unless otherwise noted (Table 2).

Table 2. Monitoring parameters by Station.

Station	Hydrology Signal**	Pore Water Salinity	Surface Water Salinity**	Vegetation	Channel Morphology	Plant Species of Concern
1	X	X		X	X	X
2	X	X	X	X	X	X
3				X	X	X
4		X		X	X	X
5				X	X	X
6		X*		X	X	X
7				X	X	X
8		X	X	X	X	X
9			X	X	X	X
10		X	X	X	X	X

* At Station 6, two pore water wells were monitored.
** Continuous monitoring of surface water hydrology and salinity limited to pre-project and Year 1 post-project.

2.1 Hydrology signal

Surface water hydrology was monitored in 2013 and 2014, but not in 2015 or 2016.

2.2 Pore water salinity

CBEP constructed wells from 2" PVC consistent with established protocols for monitoring pore water salinity (Neckles and Dionne 1999). Pore water wells were installed at Stations 1, 2, 4, 6, 8, and 10 approximately 10 meters from the tidal creek channel edge. A map is provided in Appendix A. An additional pore water well (6a) was installed approximately 10 m from the upland edge at Station 6 (s). Two wells are located beyond the Project Area (St. 11 & 12). Simultaneous surface water samples are taken from the tidal creek where vegetation transects intersect with the marsh channel. Water samples are collected using a syringe with a tube for extension into wells and the tidal creek, and sampled within two hours of predicted low tide. Salinity readings are read from a handheld refractometer that is calibrated with de-ionized water. Observations are recorded on a site-specific data sheet.

2.3 Surface Water Salinity

Surface water salinity was monitored in 2013 and 2014, but not in 2015 or 2016.

2.4 Vegetation

CBEP established vegetation transects at each Station in the Project Area. An additional two vegetation transects were established at Stations to the south of the Project Area (St. 11 & 12). Transects were set to allow for representative sampling of established marsh areas and adequate sampling intensity. Vegetation data are collected in meter-square plots located every 10-15 meters along the length of each transect. The number of plots collected along each transect varies from 10 to 12, with most transects having 11 plots. Observers replicate transect locations year over year by extending a tape measure from a PVC stake marking the channel edge (e.g., 1C) to another PVC stake located at the upland edge (e.g., 1U; see map, Appendix A). Transects run perpendicular to the tidal creek toward the upland edge, with 0' (zero) starting at the channel. Data collected in each plot includes: (1) a list of the well represented (>10% coverage) species in the plot; (2) percent coverage by those species; (3) overall percent coverage for the plot; and, (4) general hydrologic conditions. Data for each plot was recorded on a separate data sheet. All project vegetation data are entered into a Microsoft Access database and subsequently proofed by a second reviewer. Species identification and nomenclature follows Haines & Vining 1998. Alternative nomenclature is tracked within a database of plant species developed and maintained by CBEP.

2.5 Channel Morphology

CBEP established channel cross section transects at each Station (map, Appendix A). An additional cross section transect was established beyond the Project Area at Station 11. In addition, CBEP surveyed a longitudinal profile of the channel bottom from Station 1 to Station 3 (approximate). Cross sectional areas are surveyed in identical locations from stakes on the east and west side of the channel (e.g., XS1E, and XS1W; Figure 5) proximate to where vegetation transects originate at the marsh channel. Elevations are surveyed at regular increments or where elevation grade changes are evident, using an auto level on a tripod and a stadia rod, and tied to local benchmarks with known elevations relative to NAVD 88. Cross section and longitudinal profile data are recorded onto project-specific data sheets and entered into the *Reference Reach Spreadsheet* (Mecklenburg 2006) to standardize and quantify survey data. The spreadsheet is used broadly in among natural resource managers as a tool for quantifying channel morphology (Alex Abbott, personal communication).

2.6 Plant species of concern

Once per field season, an intensive meander survey for invasive plant species is conducted throughout the Project Area. Incidental observations of invasive plants during other monitoring activities are also documented. During the meander survey, invasive plant species are identified, photographed, described in field notebooks, geo-referenced, and flagged if possible. Any indication that invasive plant species of concern are establishing or expanding within the Project Area is immediately communicated to MDOT, with recommendations for control measures, if needed.

2.7 Erosion

CBEP conducts regular visual surveys within the construction area to check for signs of erosion along the road bank, or structural failure within or adjacent to the culvert. Observations of erosion would be recorded and findings would be photographed, georeferenced, flagged, and immediately reported to MDOT if needed.

2.8 Photographic documentation

CBEP established a series of photo stations associated with the construction area, channel cross sections, and vegetation transects in order to provide a visual record of changes at and adjacent to the mitigation site and the Project Area during the monitoring period. Photos are taken annually at a minimum at each photo station.

2.9 Wildlife use

CBEP records incidental observations or signs of wildlife within or adjacent to the Project Area during each site visit.

2.10 Additional data

Additional data are being collected at Long Marsh by CBEP and other researchers:

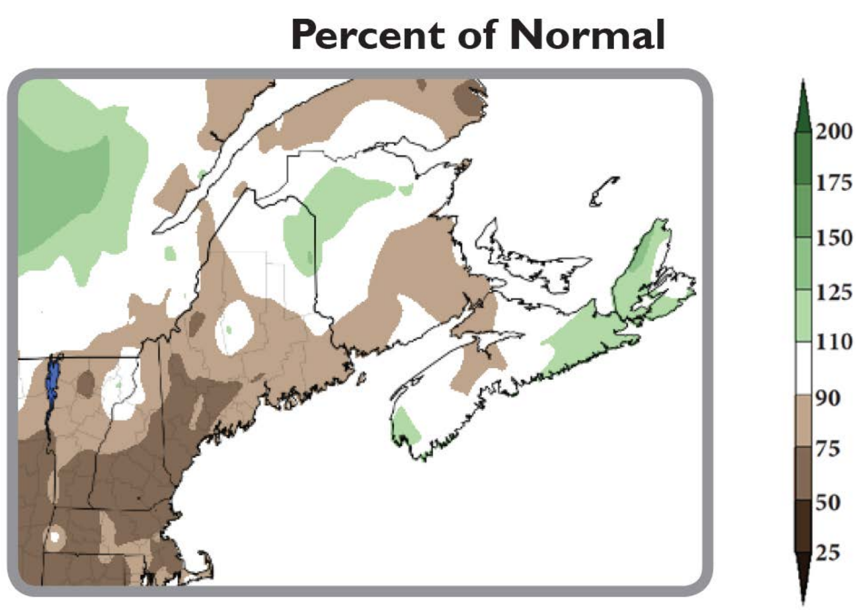
- Additional field observational data, such as dead vegetation, etc., was periodically collected during the course of field sampling activities, recorded in field notebooks, and photographed, by CBEP staff.
- As part of broader CBEP monitoring of tidal marshes in Casco Bay, two additional Stations were established outside of the Project Area, to the south of "the narrows," and as time allowed, CBEP collected data on the core parameters at these Stations. Parameters monitored included vegetation transects, pore water and surface water salinity, surface water hydrology, and channel cross sections. These data were collected at no cost to DOT, but are available separately from this report upon request.

- Dr. Beverly Johnson, working with undergraduate students from Bates College, is collecting methane measurements as part of an ongoing research study. These data were not included in this report.
- Project SHARP (Saltmarsh Habitat & Avian Research Program), of which the University of Maine's School of Biology and Ecology is a collaborator, has a long-term bird monitoring station on Long Marsh, located within the Project Area.

3. RESULTS & DISCUSSION

This section presents monitoring results from monitoring of pore water salinity, vegetation, channel morphology, plant species of concern, wildlife use, erosion, and photo documentation. The Year 3 report draws primarily from 2013 and 2016 monitoring results, but data from 2014-15 monitoring are provided for context in some areas.

The Eastern Casco Bay region experienced drought conditions during most of the 2016 growing season, beginning in the spring. Unusually warm temperatures during the 2015-2016 winter, combined later drought conditions, suggest that generally, marshes were likely to receive high salt delivery early in the growing season. Across all monitoring sites, CBEP documented elevated salinity readings in surface and pore water measurements.



Above: Map illustrating percent of normal precipitation levels in the Gulf of Maine region from March – May 2016. Source: Gulf of Maine Council Climate Network: http://www.gulfofmaine.org/2/wp-content/uploads/2016/06/GOM-Spring-2016.pdf

3.1 Hydrology Signal

Not monitored in 2015. Refer to the 2014 monitoring report for hydrology data and analysis.

3.2 Pore Water Salinity

During the 2016 field season, CBEP staff collected seven sets of pore water salinity samples at Stations 1, 2, 4, 6, 6a, 8, 10, and 11 (Table 3). Prior to monitoring, pore water wells were re-located and their condition assessed following a winter with heavy ice buildup and ice movement on the marsh surface.

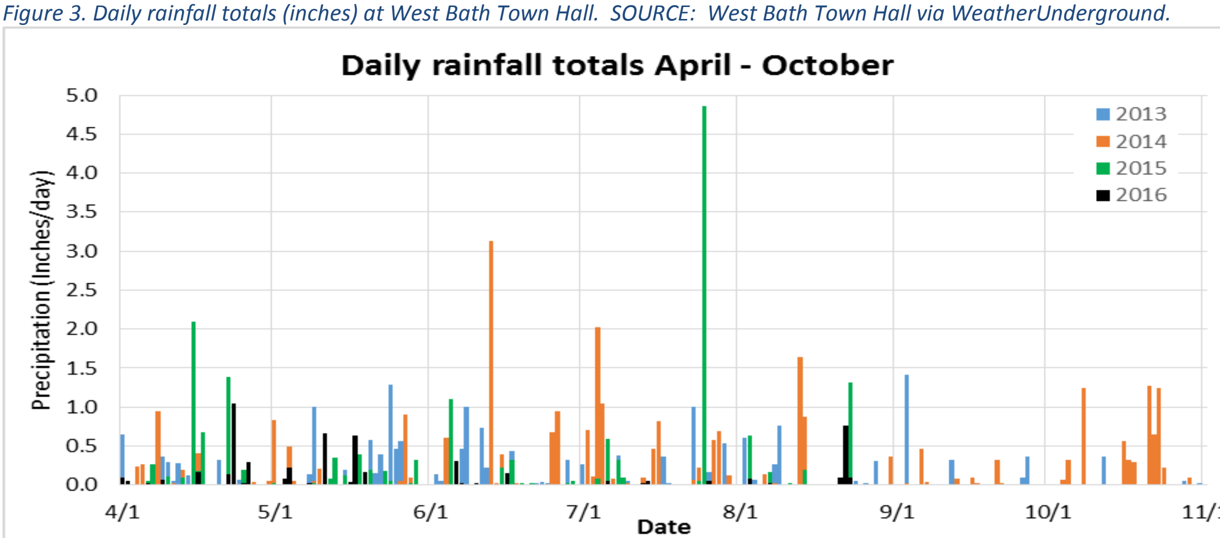
Table 3. Pore water salinity sampling dates.

Year	April	May	June	July	August	September	October
2013		5/21		7/1, 7/25	8/29	9/25	10/21
2014	4/23, 4/25	5/21	6/6, 6/24	7/8	8/28	9/17	10/28
2015	4/28	5/8	6/12	7/9	8/13	9/18	10/23
2016	4/27	5/17	6/15	7/15	8/24	9/22	10/24

Pore water salinity levels in the marsh are influenced by a number of factors, including tide height, precipitation, local soil conditions and runoff from adjacent uplands. Although more salt is being delivered via tidal exchange into the Project Area following replacement of the Long Reach Lane culvert, it is useful to consider pore water data in the context of seasonal precipitation trends since rainfall appears to impact pore water salinity levels at Stations with groundwater seeps from the adjacent upland.

The West Bath Town Hall hosts a weather station that collects and records precipitation totals for the Maine Department of Marine Resources' use in determining rainfall closures for local shellfish beds. These data are posted online at The Weather Underground and can be downloaded into Excel. Graphical display of daily precipitation data over the 2013-2016 monitoring seasons illustrates variations in rainfall patterns from year to year (Fig. 3). 2013 was relatively dry in comparison to 2014, while 2015 was closer to normal. 2016 was consistently drier than prior years, consistent with drought conditions. Heavy rains in 2014 (3.13" on 6/13; 3.89" 7/2-7/5), and 2015 (4.86" on 9/30) affected subsequent pore water salinity readings.

Figure 3. Daily rainfall totals (inches) at West Bath Town Hall. SOURCE: West Bath Town Hall via WeatherUnderground.



In both 2014 and 2015, precipitation for June was higher than normal, but about average in 2013 (Table 4). September rainfall was higher than normal in 2015, but because most of the rain fell at the end of the month, this spike did not affect the September pore water sample. In 2016, just .8 inches of rain fell from August 1 to September 30. The low rainfall is evident in elevated pore water salinity readings.

Table 4. Comparison of monthly precipitation with historic levels. Shown are monthly rainfall totals (inches) at West Bath Town Hall weather station.

Year	March	April	May	June	July	August	Sept.	Oct.	Cum.
2013	1.9	2.4	5.3	3.6	3.3	2.0	3.7	1.5	23.7
2014	4.2	2.7	3.4	6.0	7.2	2.9	1.3	4.5	32.1
2015	1.3	3.3	2.2	6.7	1.7	2.1	6.1	3.0	26.4
2016	4.53	2.7	1.8	2.7	2.2	0.6	.2	2.1	16.7
Normal*	*3.7*	*4.1*	*3.6*	*3.4*	*3.1*	*2.9*	*3.1*	*3.9*	*27.8*

*Historic 'normal' monthly rainfall at Portland Jetport (1961-1990).

Although recent studies incorporating more recent data than the "normal" rainfall totals shown in Table 4 suggest that precipitation totals may be increasing in spring, summer, and fall seasons (Wake *et. al*., 2009), the Portland Jetport data still provides a useful baseline to show that 2014 rainfall totals were higher than normal, particularly in June and July, and that rainfall in September 2015 was nearly double normal levels. Looking only at freshwater inputs during the monitoring season (and excluding precipitation from the preceding winters), the 2014 monitoring season was generally a wetter one at Long Marsh than either 2013 or 2015, particularly during the typically hottest and driest summer months. In contrast, 2016 was exceptionally dry.

Despite above normal rainfall in 2014, pore water salinity levels were generally higher throughout the Project Area post-project (2014-16) than in 2013, consistent with what we would expect to find resulting from improved tidal exchange (Table 5). At Station 1, which can be considered a reference site, mean pore water salinity has been consistently lower post-project.

Table 5. Mean, minimum and maximum pore water salinity (‰) for the 2013 – 2016 monitoring seasons.

Station	Mean				Minimum				Maximum			
	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
1	22.7	14.5	15.4	20.9	9	4	5	10	29	25	29	32
2	23.0	30.6	27.0	33.4	13	25	14	29	30	35	33	39
4	19.8	25.7	26.4	30.8	5	16	20	25	30	30	33	34
6	21.6	29.2	28.1	30.7	10	25	22	28	33	33	32	35
6a	8.6	24.7	23.7	27.2	2	10	20	20	15	29	28	33
8	27.2	28.4	23.5	27.0	20	23	14	19	33	32	31	34
10	25.4	27.0	24.6	25.3	17	24	20	15	30	32	30	32
11	8.6	18.0	22.5	19.1	2	12	15	11	14	25	28	30

Figure 4 plots pore water salinity levels at Stations 1-11 per visit per year. Each point represents the mean of three readings taken per a given sample. Pre-project samples are shown in blue, and post-project samples in orange, differentiated by symbols. Station 11 is outside the Project Area but included for context.

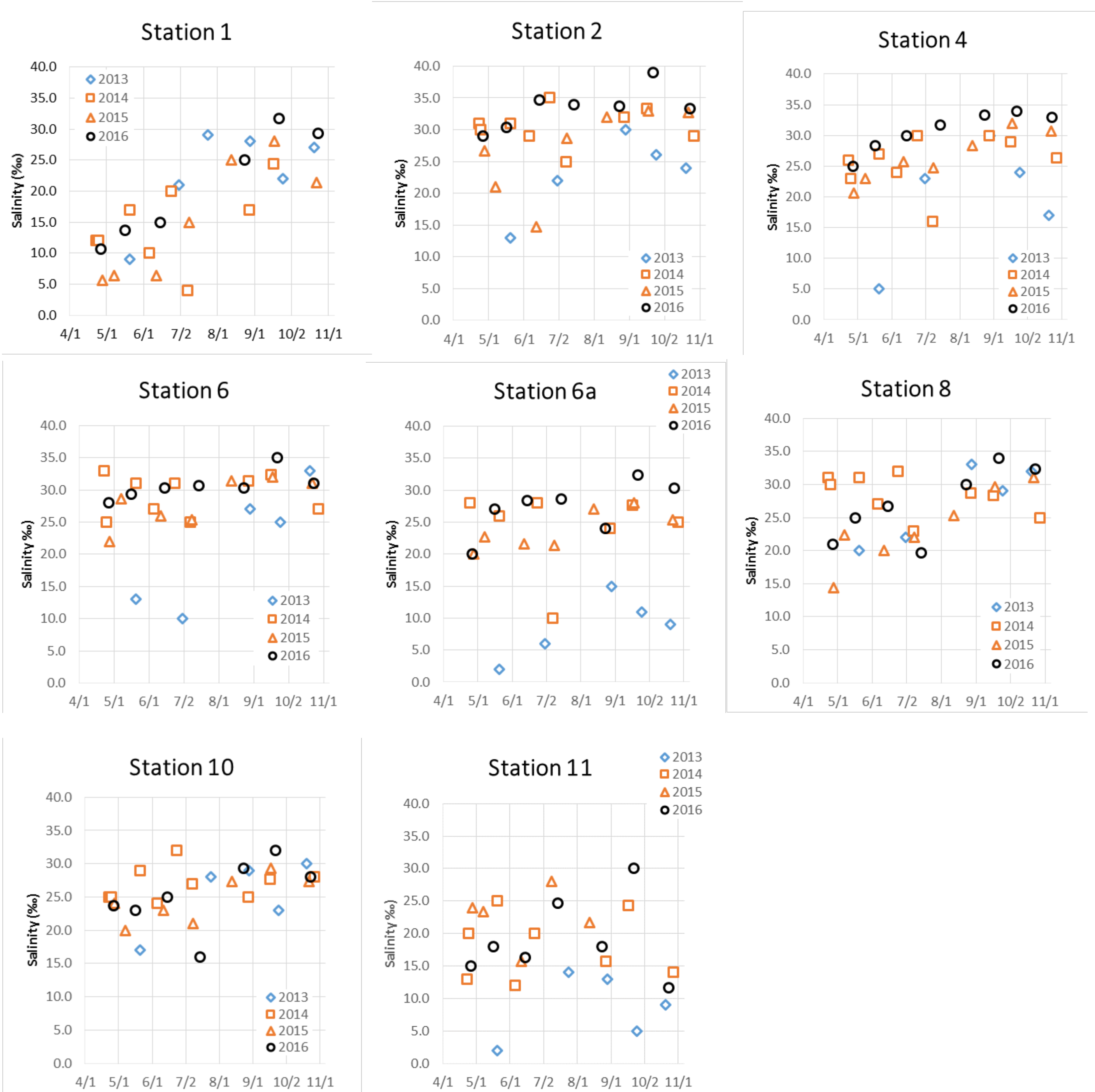


Figure 4. Plotted pore water salinity Stations 1, 2, 4, 6, 6a, 8, 10 and 11.

Across all Stations in the Project Area, mean pore water salinity increased from 20.9 ppt. pre-project (2013) to 28.2 ppt. post-project (2014-2016). The greatest changes in pore water salinity has been observed at Station 6a, which of the stations in the Project Area, is furthest from the main channel. At 6a, mean pore water salinity increased from 8.6 ppt. in 2013 to 25.2 ppt. from 2014-2016 (Table 5, Figure 5).

Figure 5 graphically illustrates mean, minimum, and maximum pore water salinity levels per Station. Post-project readings have yet to drop below 10 ‰ in the Project Area. The largest increases from pre-project levels are at Station 6a, located approximately 5m from the upland edge, and at Station 11, which is south of the narrows and outside the Project Area. The abrupt increase at Station 6a is consistent with the results of vegetation monitoring, which documented that freshwater species present in 2013 were dead in 2014, and the vegetation community remains in transition. The increase at Station 11, which is adjacent to stands of invasive *Phragmites australis*, documents that the effect of the improved tidal exchange extends well south of the Project Area and the Narrows, into the southern reach of the marsh.

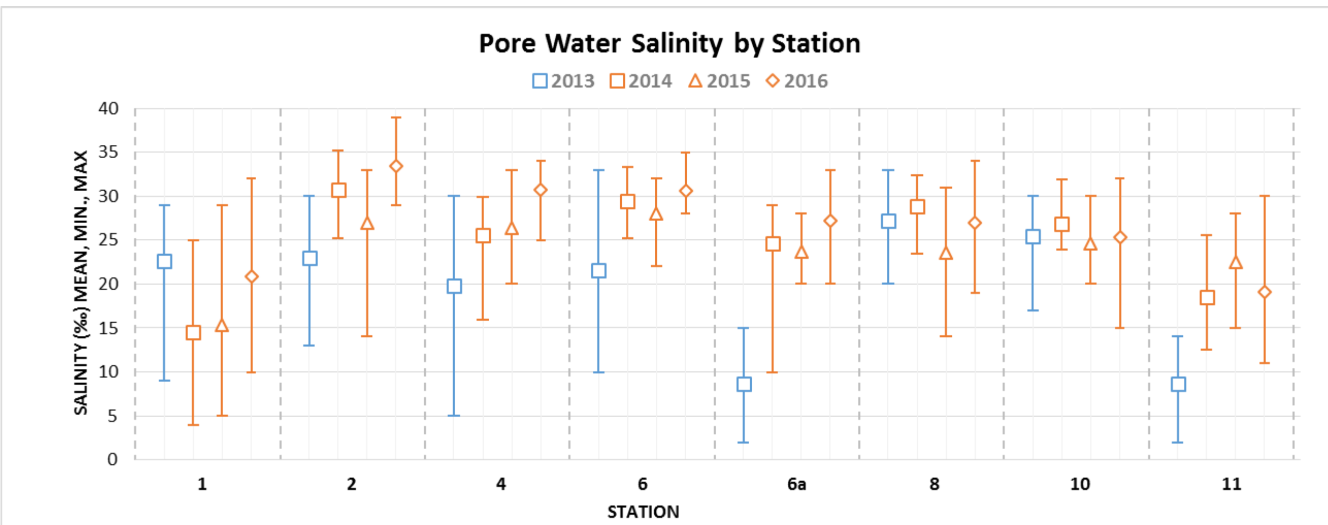


Figure 5. Mean (symbol), minimum (low bar), and maximum (high bar) pore water salinity (‰) for 2013-15.

Even with higher than normal precipitation in 2014, mean pore water salinity, including all observations within the Project Area (excluding Station 1 and Station 11), was higher in 2014 (mean = 27.4‰) and in 2015 (mean = 25.5‰) than in 2013 (mean = 20.3‰). In 2016, consistent with drought conditions, mean pore water salinity in the Project Area rose to 29.1‰, with individual readings approaching 40‰ at Station 2, which is adjacent to a large pool. The high readings are consistent with hypersaline conditions that result from evaporation. Combined, mean pore water salinity in the Project Area is 28.2‰ post-project.

Figure 6 plots salinity measurements in the Project Area with linear trendlines for each year of data points. Based on trendlines, pore water salinity may be higher post-project earlier in the growing season than pre-project due to the increased tidal exchange and freshwater drainage out of the marsh. In 2013, pore water salinity at Stations 2-10 trended upward over the course of the summer into fall, whereas in 2014, pore water salinity at Stations 2-10 was consistent, other than the July samples, across the season. In 2015, pore water was lower than in 2014 early in the season, possibly reflecting the influence of snow and ice melt, but increased to higher levels later in the season. The similarity in slope of the lines in 2013, 2015 and 2016 is interesting as an illustration of the effect of tidal restoration, which in this visualization, has increased pore water salinity throughout the Project Area by at least 5‰.

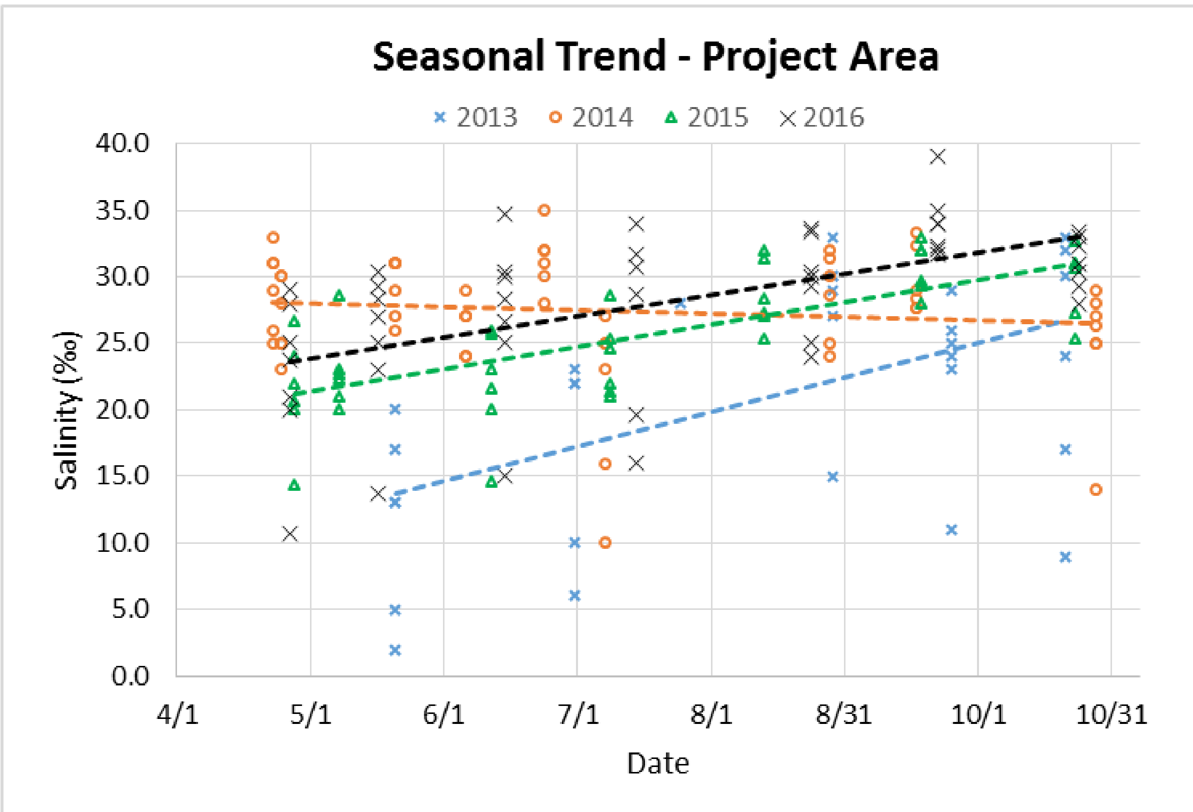


Figure 6. Year over year plot with trend lines of pore water salinity levels in the Project Area (excluding Station 1 & Station 11).

Overall, post-project pore water salinity is higher within the Project Area in years 1-3 as compared with pre-project levels in 2013. Pore water salinity was also observed to be higher earlier in the growing season in 2014-2016 than in 2013, consistent with expectations that the marsh is draining more quickly through the new culvert. This is illustrated by the dip and recovery of pore water salinity levels following heavy rain events in late June and early July 2014 and October 2015, following a 5" rain event on 9/30/15.

These data indicate that the change in tidal hydrology is delivering more salt water onto the high marsh, and that freshwater drains from pore water more quickly, resulting in higher salt content in the root zone, which influences the vegetation community. Pore water salinity levels appeared to be higher throughout the spring and summer in 2014, 2015, and 2016 than in 2013, which, over time, we expect to gradually influence the vegetation community. These data suggest that the vegetation community in the Project Area is likely to continue shifting toward more salt tolerant plant communities and salt marsh, from brackish and freshwater communities, in the years to come.

3.3 Surface Water Salinity

Continuous surface water salinity monitoring was not conducted in 2016. See Year 1 Post-Construction report for results.

3.4 Vegetation

CBEP collected vegetation data on July 7-8 & 11 in 2016. A total of 108 plots were sampled, including 8 plots at Station 1 and 100 plots at Stations 2-10. An additional 22 plots were monitored at Stations 11 and 12 outside of the Project Area. Plot locations were at identical distances along each transect for most stations, but at Station 1, the transect markers were lost and the transect location was different in 2013 than in 2014 - 2016.

A total of 41 species were identified across all Stations in 2016, including Stations 11-12, and including plots with overhanging trees near upland transitions. Of the 41, a total of 27 species were identified in Stations 1-10. The number of unique plant species throughout the twelve monitored stations declined from 67 in 2013 to 52 in 2014, 51 in 2015, and 41 in 2016. The decline was primarily in the presence of glycophytic and brackish species (Table 11, App. B).

To track changes in vegetation community type, we are using a salinity index developed by University of Southern Maine graduate student Shri Verrill (unpublished thesis 2017), and subsequently modified by CBEP Director Curtis Bohlen. The index references a standard field guide (Tiner 2009) to assign salinity index scores, with freshwater plants = 1, brackish plants = 2, and halophytic plants = 3. In 2017, Bohlen adjusted the scores used for prior monitoring reports, resulting is minor changes to distribution of cover classes. Figures 7 and 8 have not been updated with the modified scores from last year's report. The Figures illustrate a general pattern of transitions throughout the Project Area toward salt tolerant (brackish and halophytic) species. Closer to the project site (St. 2 & 3), a rapid transition to salt marsh is evident, with similarities to the reference site (St. 1), and similar distribution shifts are occurring at Stations 5-8. At the furthest end of the Project Area, St. 10, a similar immediate shift is evident closer to the channel, but less so away from the channel. The effects of the mitigation project clearly extend beyond the Project Area, as a marked shift toward halophytic plants is evident at Station 11, adjacent to invasive *Phragmites australis* stands, in the first several plots away from the channel. Station 12 appears to not yet have been affected by the change in hydrology.

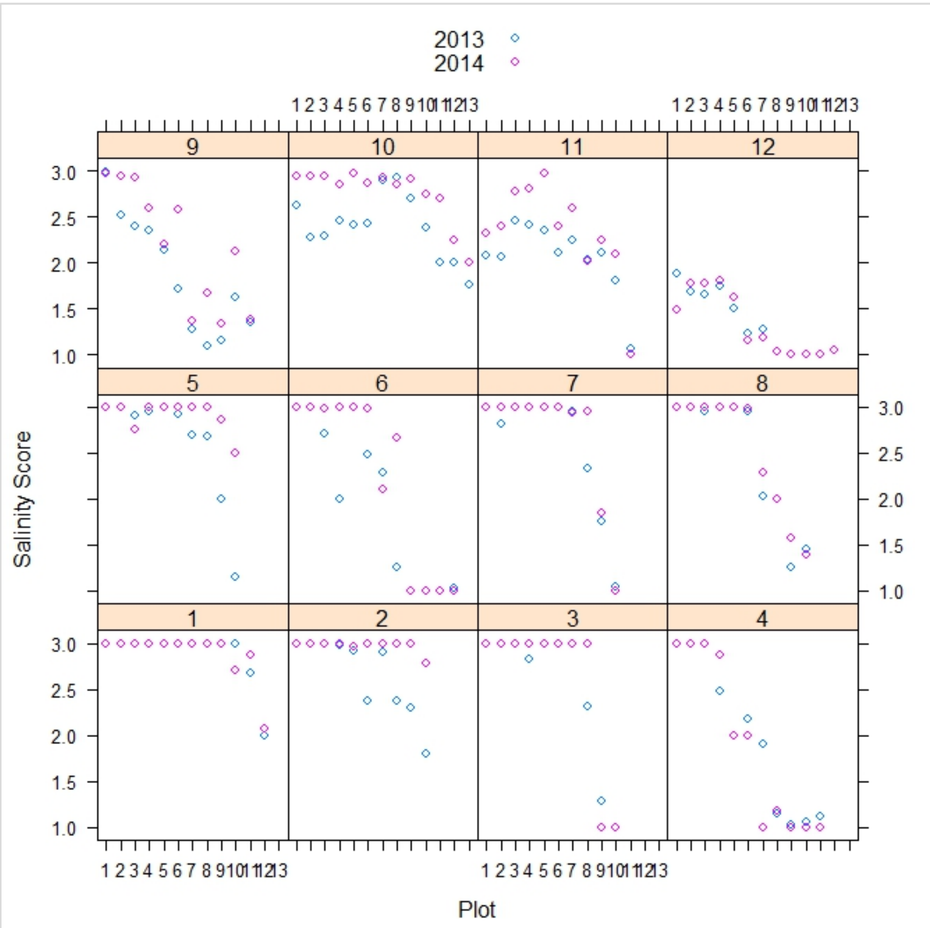


Figure 7. Salinity index scores of vegetation plots, 2013 to 2014.

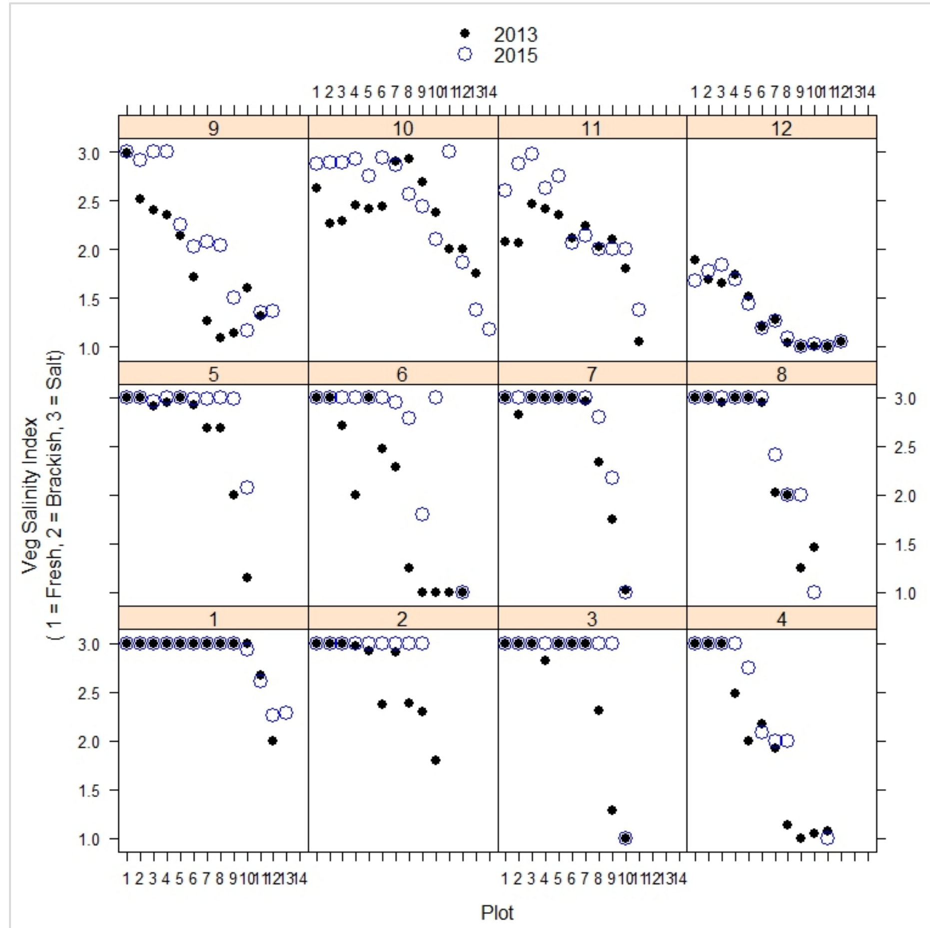
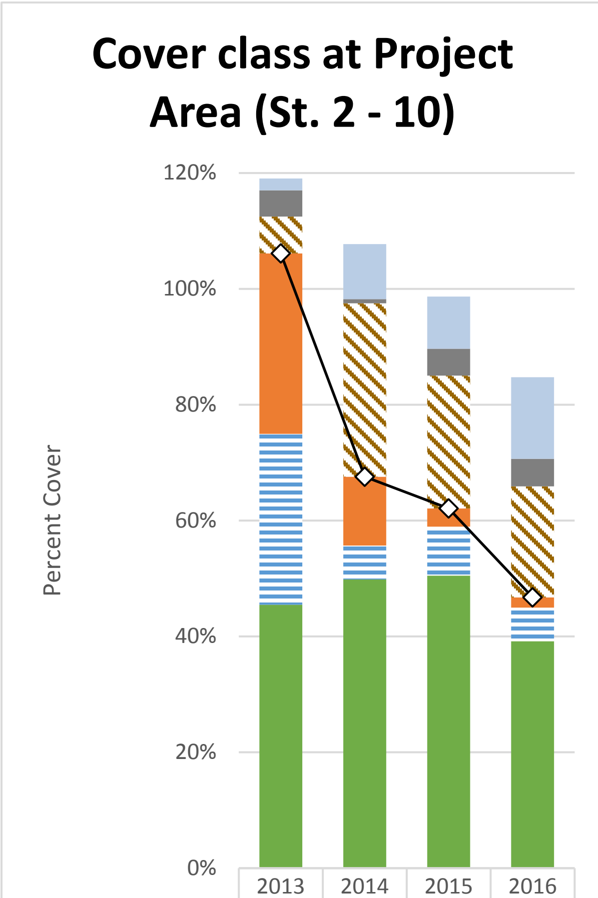
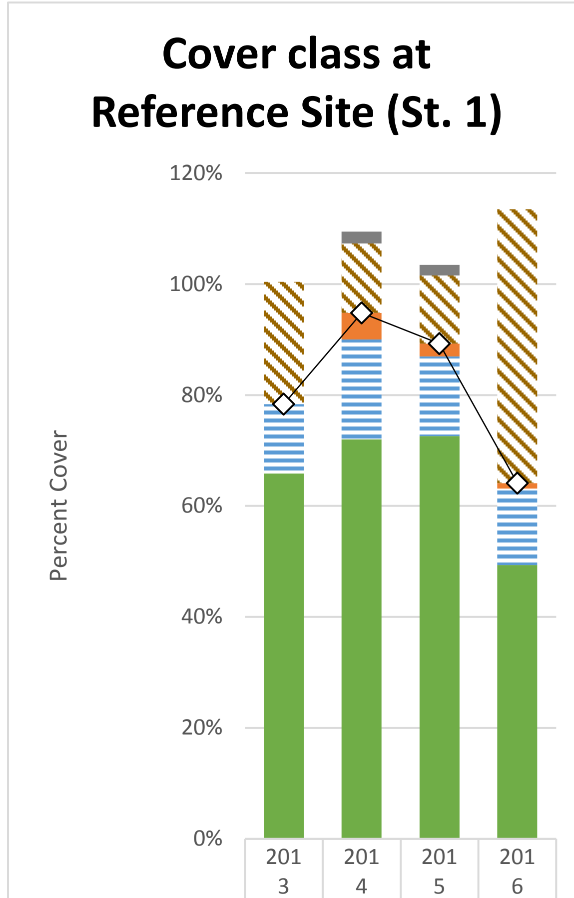


Figure 8. Salinity index scores of vegetation plots, 2013 to 2015.



	2013	2014	2015	2016
Pool/panne	2.0%	9.5%	9.0%	14.1%
Bare	4.5%	0.7%	4.6%	4.7%
Litter	6.4%	30.0%	22.9%	19.1%
Glycophytes	31.2%	11.9%	3.2%	1.8%
Brackish	29.5%	5.8%	8.4%	5.8%
Halophytes	45.5%	49.9%	50.5%	39.2%
Total cover	106.1%	67.6%	62.1%	46.8%

Figure 9. Comparison of mean percent cover of plots within the Project Area (Stations 2-10).



	2013	2014	2015	2016
Pool/panne				
Bare		2.1%	1.9%	
Litter	22.1%	12.5%	12.3%	49.4%
Glycophytes		4.8%	2.3%	1.0%
Brackish	12.5%	18.0%	14.3%	13.8%
Halophytes	65.8%	72.0%	72.6%	49.4%
Total cover	78.3%	94.8%	89.2%	64.1%

Figure 10. Comparison of mean percent cover of plots within the Reference area (Station 1).

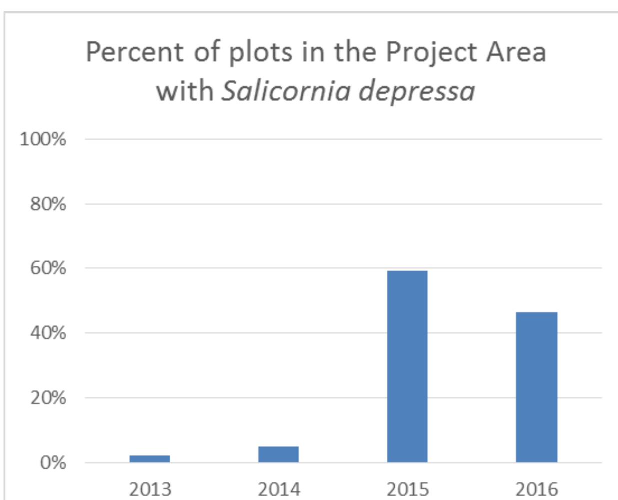
Figure 9 compares yearly mean percent cover types of plots within the Project Area (Stations 2-10) from 2013 to 2016. Overall, 2016 data suggest a decrease in general plant cover on the marsh across all community types. Halophytic species cover increased from pre-project levels of 27.7% in 2013 to 49% during the second growing season post-project; however, a decline in halophytic species coverage to 39% is apparent in 2016. Plot coverage by glycophytes declined from over 31% in 2013 to just 1.8% in 2016, and coverage by brackish plants decreased from over 29% in 2013 to nearly 6% in 2016. Litter (standing dead plant matter) remains prevalent within plots, consistent with the loss of freshwater and brackish species over pre-project levels. The decline in brackish and glycophytic species is consistent with increased salt delivery into the marsh, and improved freshwater drainage out of the marsh. The continued declines in these community types in 2016 is also consistent with drought conditions and elevated pore water salinity levels.

The observed decline in halophytic plant cover within the Project Area in 2016 is a departure from increases observed in 2014 and 2015 and is lower on a percentage basis than pre-project levels from 2013. The cause of this decline is not clear, but in the context of declines in glycophytic and brackish community cover, it could be cause for concern if halophytic species cover continues to decline. Overall living plant cover has steadily declined within the Project Area since the project was implemented (Figure 9). Figure 10 compares mean percent cover of plots in the Project Area with plots at Station 1, which can be considered a reference site due its proximity downstream from the project site, in 2016. The transect location for 2016 was in a physically different location than in prior years due to the prevalence of wrack and litter on the marsh surface downstream of Long Reach Lane. Comparison with prior results is therefore complicated by a shorter transect length and fewer plot samples over prior samples. With this caveat, it is interesting to note the apparent decline in the cover of halophytes at Station 1 in 2016, which appears to mirror the decline in halophytic plant cover within the Project Area. Future monitoring results may provide clues as to whether the drought, and the corresponding elevated pore water salinities observed at Long Marsh in 2016, affected the abundance of halophytes and plant cover, generally.

(This paragraph, and Table 12, were not updated in 2016). Table 12 (Appendix B) shows graphed percent cover for each community type against distance from the creek channel, by Station, in 2013, 2014, and 2015. Proximity to the creek channel appears to be associated with community type as shown by the prevalence of salt marsh community assemblages in proximity to the creek channel, even near the “narrows” at Station 10, in all years. The 2013 vegetation data show that community type shifted markedly moving toward the upland edge, so that brackish and freshwater assemblages were increasingly abundant at distances of 100 feet or more from the creek edge, particularly at the higher Stations. In 2014 and 2015, a change in this pattern is evident, with salt tolerant plants increasing in abundance in plots further away from the creek channel, and brackish and freshwater-grouped plants showing a marked decrease in area covered. This decrease is often associated with an increase in litter, which includes standing dead vegetation. The percent of plots covered by litter is particularly high at transects 4 and 6, which pass through large cattail stands. This illustrates a trend in evidence around the perimeter of much of the Project Area, where cattail stands died off in response to the higher tidal inundation, with mostly dead stands remaining (Table 9, vegetation transect photo stations). This trend is likely to continue as the energy stores of individual plants are depleted. Over the next few years, as light availability increases on the marsh surface within former cattail stands, salt tolerant and brackish plant community cover is anticipated to increase.

As with pore water salinity, Long Marsh's vegetative community year-3 post-project shows a marked change consistent with what we would expect in response to the new culvert, which increased tidal exchange. Together, the salinity and vegetation data indicate that the vegetation community within the Project Area is shifting in response to the new tidal hydrology. Effects of increased tidal elevation and duration of inundation are evident in the plant community shifts at Stations furthest from the construction site, in plant community shifts mid-way through the transects and at approaching the upland edge, and widespread increase in litter as a result of dead freshwater loving and brackish plants. Viewed at the scale of the Project Area, the shift in community type is particularly evident in looking at living cattail plants (Figure 11), which declined from 8.34 acres in 2013 to .64 acres in 2015. Standing dead cattails covered much of the remaining 7.7 acres in 2015. Remaining cattail stands appear to be associated with freshwater seeps from adjacent uplands.

The expansion in halophytic species cover which was observed in 2014 and 2015 was reversed in 2016, as cover of salt-tolerant plants fell to the lowest levels of the four monitoring years. The cause of this decline is not clear, but colonization / new plant growth within bare areas, and areas with standing dead plant matter, is proceeding slower than we expected it would, based on anecdotal observation. One exception however is the halophytic species *Salicornia depressa*, which appears far more abundant following tidal restoration. This early successional species has proliferated within the Project Area following tidal restoration (chart below), but has not been recorded in plots at Station 1 in any of the four years.



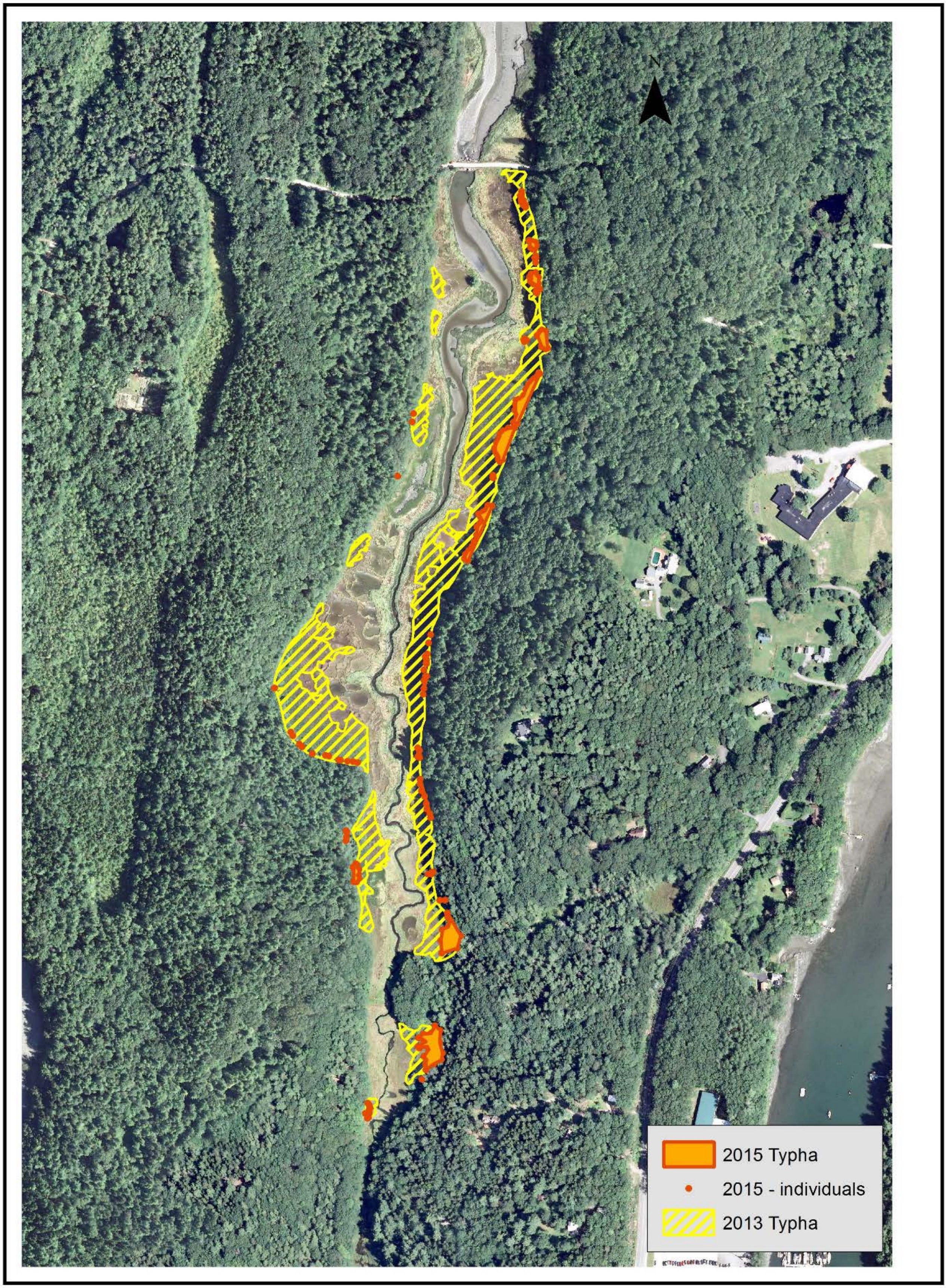


Figure 11. Map of Typha spp. stand extent in 2013 and 2015 (CBEP).

3.5 Channel Morphology

CBEP surveyed channel cross sections at each Station, as well as a longitudinal profile through the project site, in 2013, 2014, 2015, and 2016 (Table 6).

Table 6. Channel morphology survey dates.

Location	2013	2014	2015	2016
Station 1	7/25	6/17	7/23	6/16
Station 2	7/31	6/17	7/23	7/15
Station 3	8/5	6/18	6/25	6/16
Station 4	8/5	6/18	6/25	6/16
Station 5	8/5	6/18	6/25	6/14
Station 6	8/5	6/18	6/25	6/14
Station 7	8/5	6/18	6/25	6/14
Station 8	8/5	6/18	6/25	6/14
Station 9	7/25	7/8	6/25	6/8
Station 10	7/25	7/8	6/25	6/8
Longitudinal Profile	8/30; 12/10	8/5	7/23	6/14

Longitudinal profiles for 2013 and 2016 are graphed in Figures 12 and 13, with elevations in feet relative to NAVD 88. Mean high water (MHW, 4.12' NAVD) at the Portland Tide Station is shown for context. Although transect lengths and the location of start and end points differed (the 2013 transect is longer), the location of channel cross sections at Stations 1 – 3 are shown for context, allowing for comparison year to year. The 2013 profile illustrates mudflat downstream of the road, rip-rap at the base of the outlet, the invert of the original round pipe, a deep scour pool hidden beneath water impounded upstream, and acculated sediment upstream of the scour pool. Upstream of the scour pool, sediment elevations level off consistent with the invert of the culvert.

View of channel and scour pool upstream of culvert inlet.

The 2016 profile shows mudflat downstream of the road, with elevations comparable to 2013. Rip-rap at the base of the outlet remains, but the new culvert invert is lower. A series of sediment deposits are evident upstream of the culvert inlet, resulting in a series of shallow ripples and pools in the former upstream scour pool. A head cut is migrating up the channel, which is being tracked using stakes at the channel edge. Upstream of the head cut, the channel bottom levels off, but at an elevation over a foot deeper than prior to the project, indicating significant movement of fine sediments.

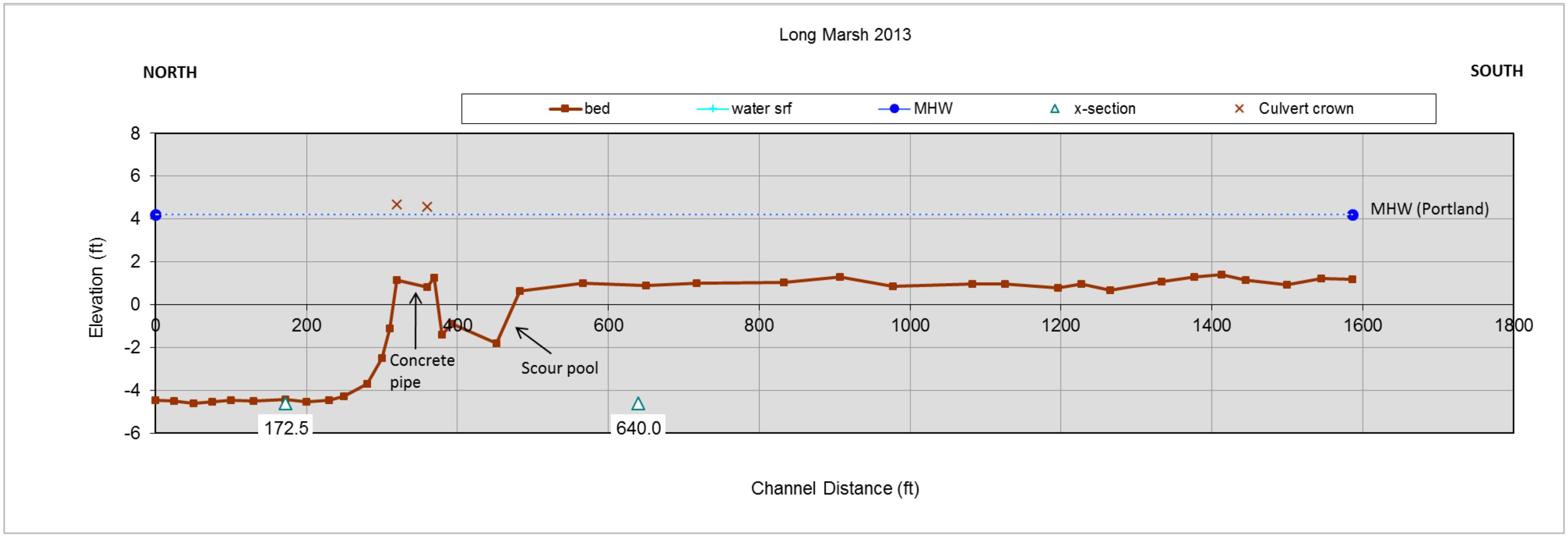


Figure 12. Longitudinal channel profile, 2013. Elevations shown in NAVD 88. (Mecklenburg 2006).

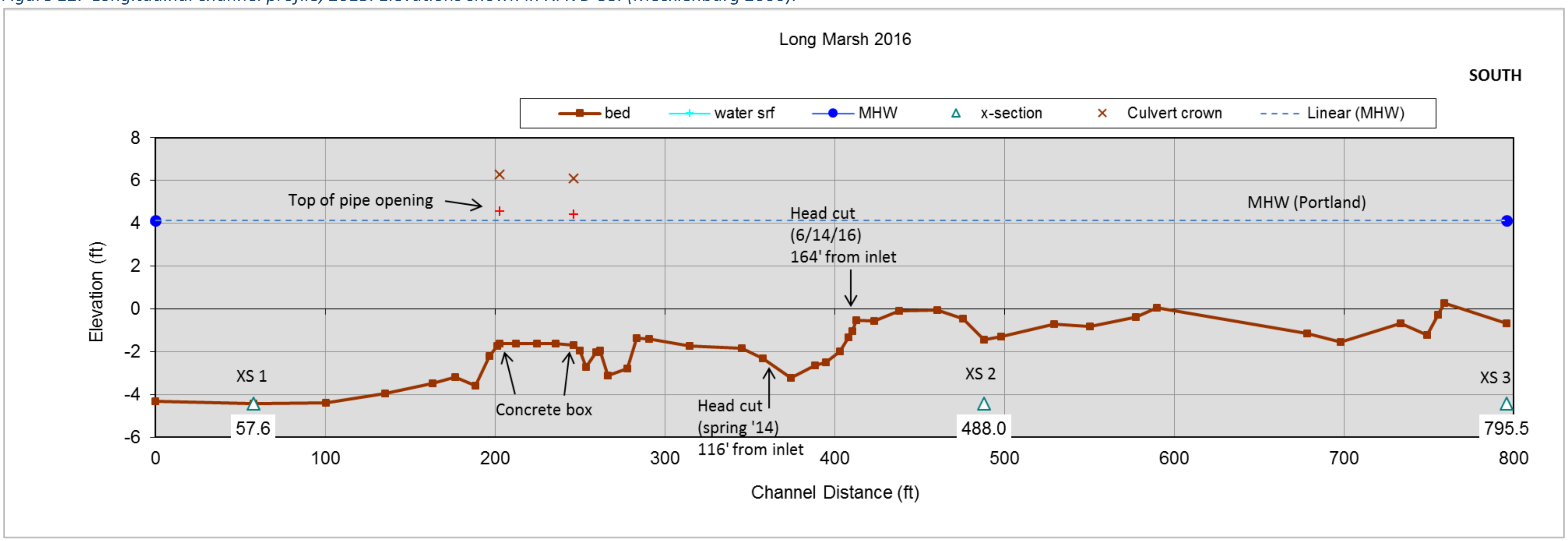


Figure 13. Longitudinal channel profile, 2016. Elevations shown in NAVD 88. (Mecklenburg 2006).

Figures 14 and 15 plot channel cross sections at Stations 1-10, with MHW (4.12' NAVD) at the Portland Tide Station for context. MHW was used in the Reference Reach Spreadsheet (Mecklenburg 2006) to calculate channel dimensions and cross sectional area, allowing for a standardized comparison of change in channel characteristics from one year to the next, which is particularly useful for looking at channel evolution in relation to increased inundation of the marsh surface. At each Station, the west side of the marsh is shown on the left side (0') of the transect. Elevations at Stations 1-5 are shown in feet relative to NAVD 88; elevations other Stations are approximated in NAVD. At most Stations, transects begin and end at fixed points that are higher than MHW, with the exception of Station 7. The location of cross section transects was identical each year, but slight differences in transect length occur due to conditions in the field, such as wind.

Channel response to increased tidal exchange was not always captured in surveys. A long and expanding rill along the east side of the channel near Station 4 (left, view N) could indicate future dimensions under the new hydrologic regime. The same site is shown in 2016 (right, view S). Standing water in the rill co-occurs with an abrupt transition from low marsh to high marsh.

Channel cross section observations:

St. 1 - Due to heavy wrack accumulation and loose peat deposition on the marsh surface at this station, we could not locate the stake, XS1E, marking the eastern start of the transect; therefore, the transect may have been in a slightly different location in 2016. A 3.7% increase in cross sectional area was observed this year whereas previously, cross sectional area has been nearly identical year to year. Surveys continue to show linear bank sloughing on the western channel edge at approximately 50 feet along the transect. Where sloughing had previously been documented on the eastern bank, at approximately 175' on the transect, the channel edge is now steeper and slightly wider.

St. 2 – Down cutting continues, with a V-shaped channel expanding between exposed mudflats with deep unconsolidated fine sediments. In 2016, maximum channel depth grew by .8' over 2015, and overall, is now 2.9' deeper than pre-project. Cross sectional area increased by 8.4% (26.5 ft^2) over 2015. The mudflats are popular for shellfish harvest; softshell clams, quahogs, and an occasional native oyster have been observed.

St. 3 – The transect length in 2016 was more than 20' shorter than in prior years and no corresponding explanation is provided for this discrepancy in the data sheets. A wider U-shaped channel pattern between narrower adjacent mudflats is present compared with St. 2. Maximum channel depth increased by .8' in 2016 over 2015, while cross sectional area increased by 13.3% (17.8 ft^2).

St. 4 – The V-shaped thalweg is widening into a U-shape. Maximum channel depth is now 3.2' deeper than in 2013, and cross sectional area increased by 18.5% (16.2 ft^2) over 2015. The mudflats adjacent to the thalweg are not present at this station, or at stations further upstream. However, the photos on the preceding page illustrate a rill that pools water parallel to the eastern bank has formed. The rill may indicate the future channel bank on the east side.

St. 5 – The creek channel is considerably smaller here, and further upstream, than at the downstream stations, and this is reflected in the lower cross sectional area (68 $ft.^2$) in 2016, and a relatively lower change from 2015 of 4.3%. The U-shaped channel is 2.7' deeper than in 2013 the channel depth has dropped by about two feet since 2013. Angular features seen in 2014 are becoming more rounded into a U-shape.

St. 6 – Maximum depth increased by .7', while cross sectional area increased by 7.4 % over 2015. The U-shaped channel is deepening and a remnant plane/toe of peat is exposed on the south side.

St. 7 - Maximum depth increased by .7', while cross sectional area increased by 6.5% over 2015. The U-shaped channel is deepening.

St. 8 - Maximum depth increased by 1.0', while cross sectional area increased by 17.2% over 2015. The U-shaped channel is deepening, but is approximately 1 foot higher than St. 7.

St. 9 & 10 – These stations are upstream of the "old road bed" crossing. Compared with other stations in the Project Area, the channel in this reach has experienced relatively little change. Sediment transport downstream is limited by the rock pile. Maximum channel depth was measured to have increased at Station 10 from 1.9' in 2015 to 3.62 feet in 2016, but this may be partially attributed to the presence of unconsolidated organic material, and consequently, the lack of a stable base to hold the stadia rod at a constant depth.

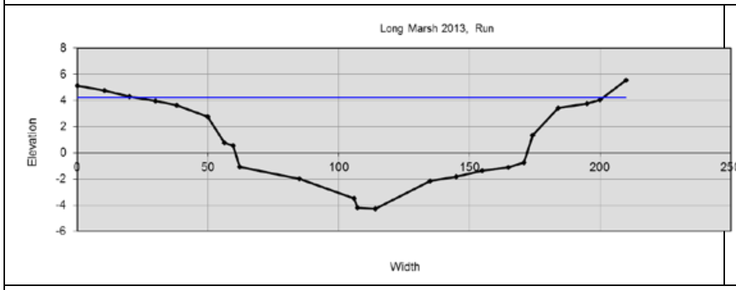
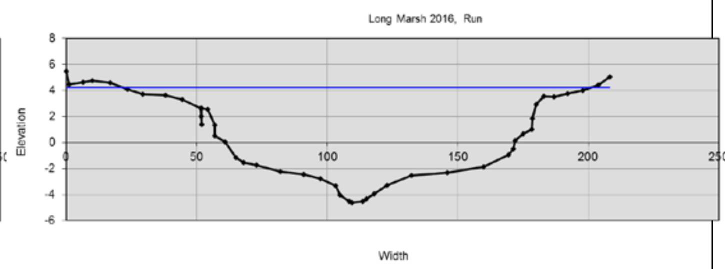
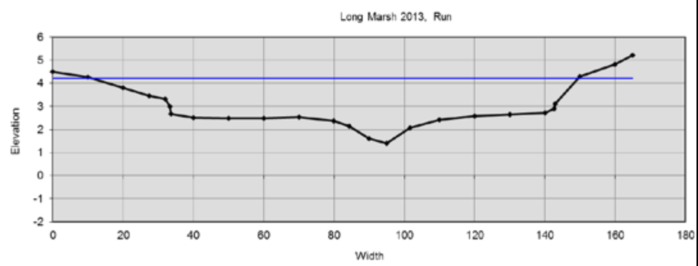
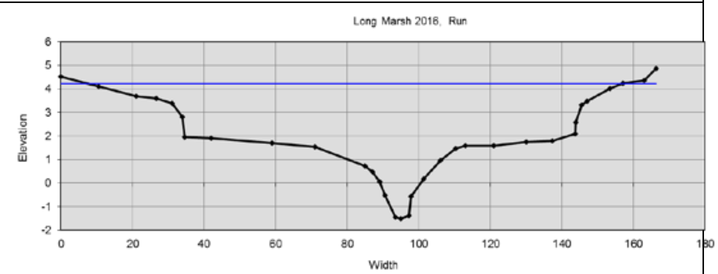
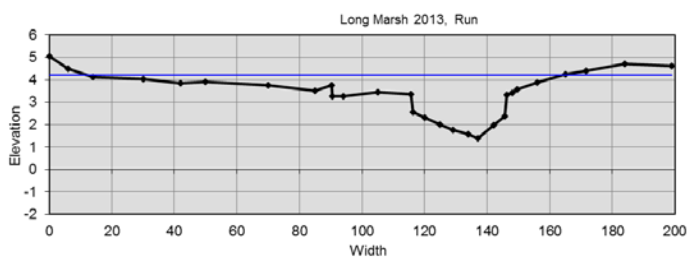
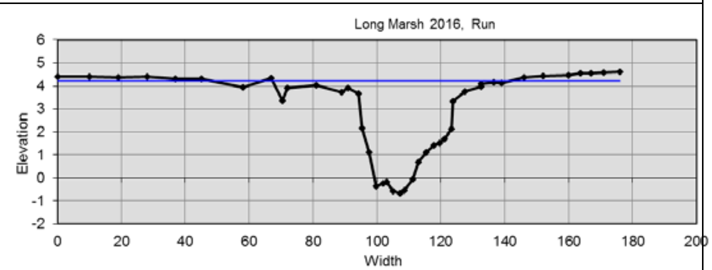
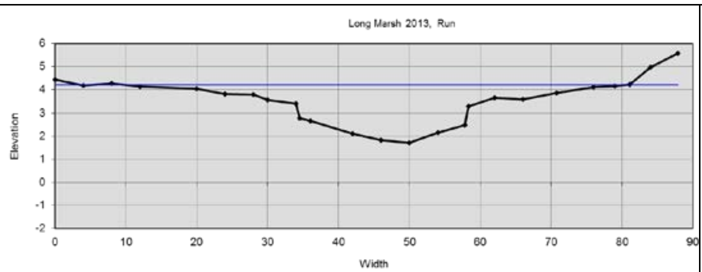
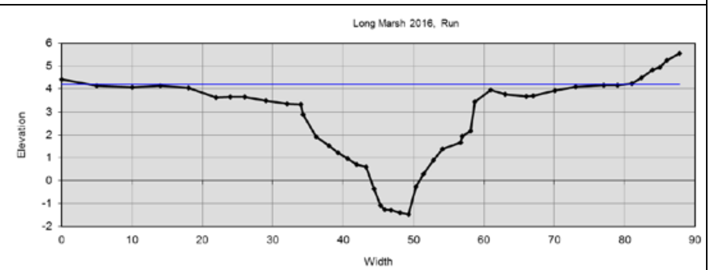
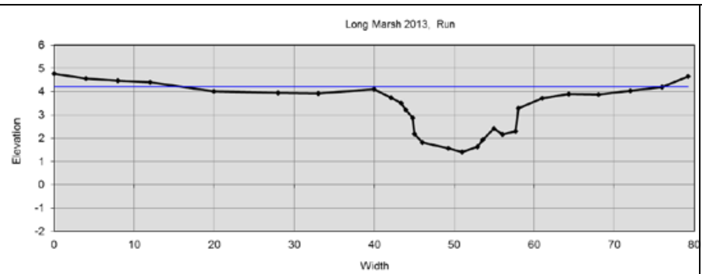
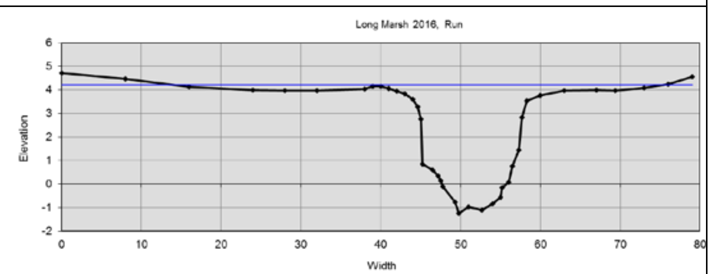
Pre-Project (2013)	Post-Project (2016)
Station 1	
	
Station 2	
	
Station 3	
	
Station 4	
	
Station 5	
	

Figure 14. Plotted channel cross sections (Stations 1-5).

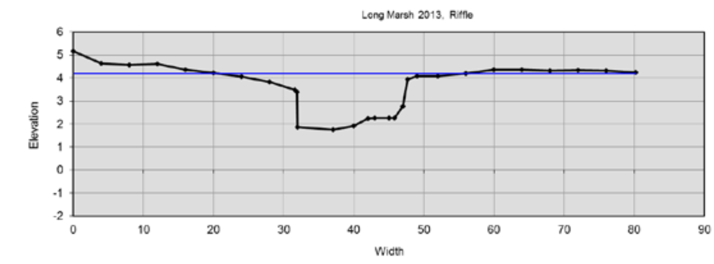
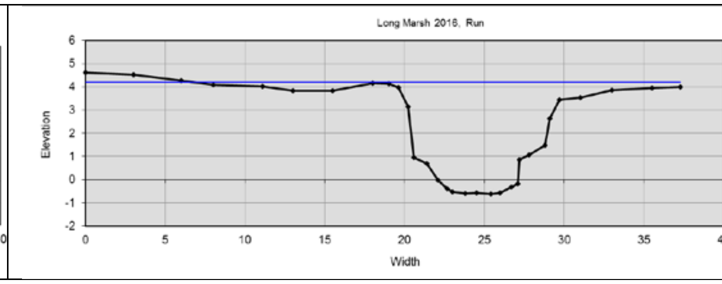
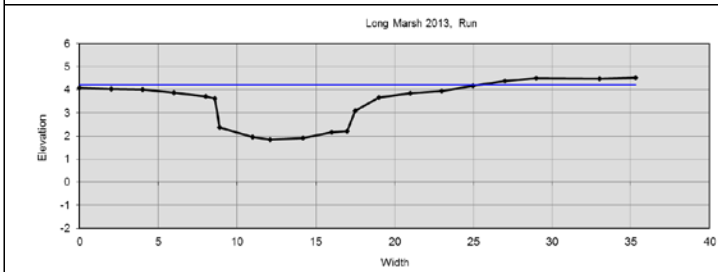
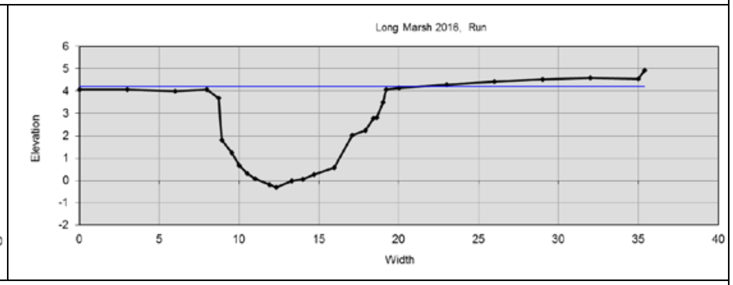
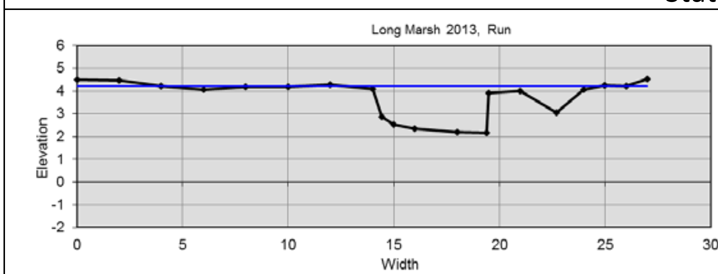
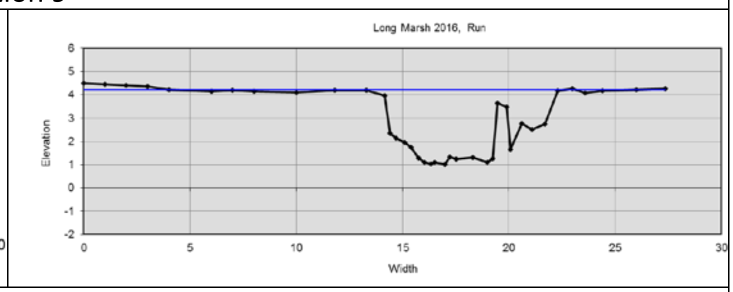
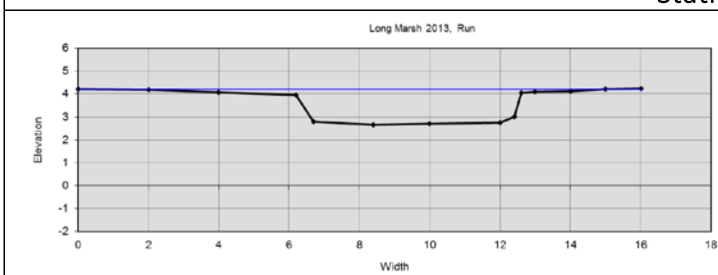
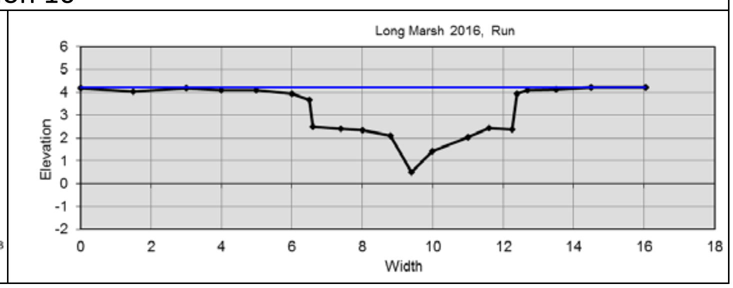
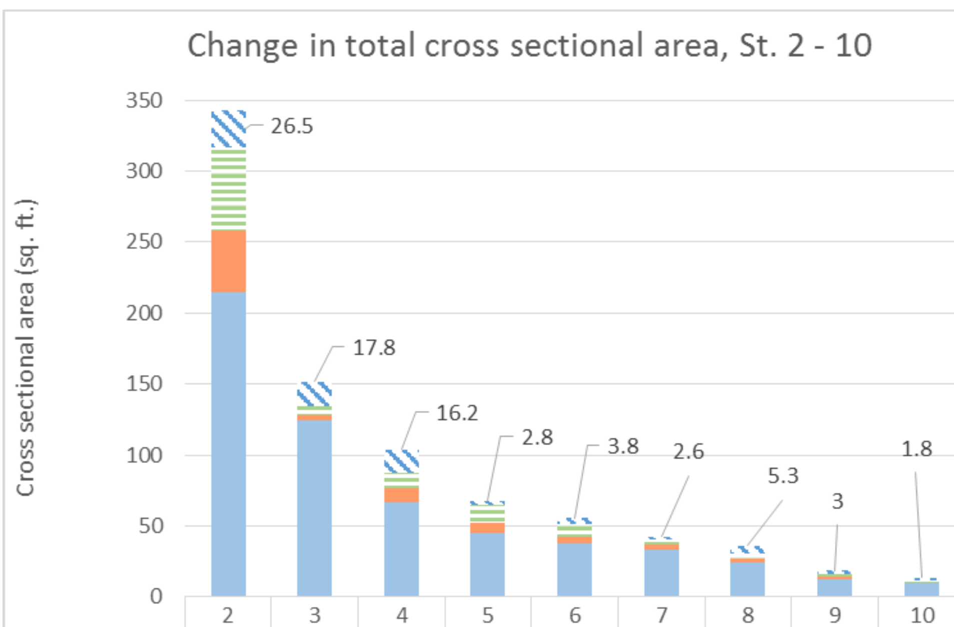
Pre-Project (2013)	Post-Project (2016)
Station 6	
	
Station 7	
	
Station 8	
	
Station 9	
	
Station 10	
	

Figure 15. Plotted channel cross sections (Stations 6-10).

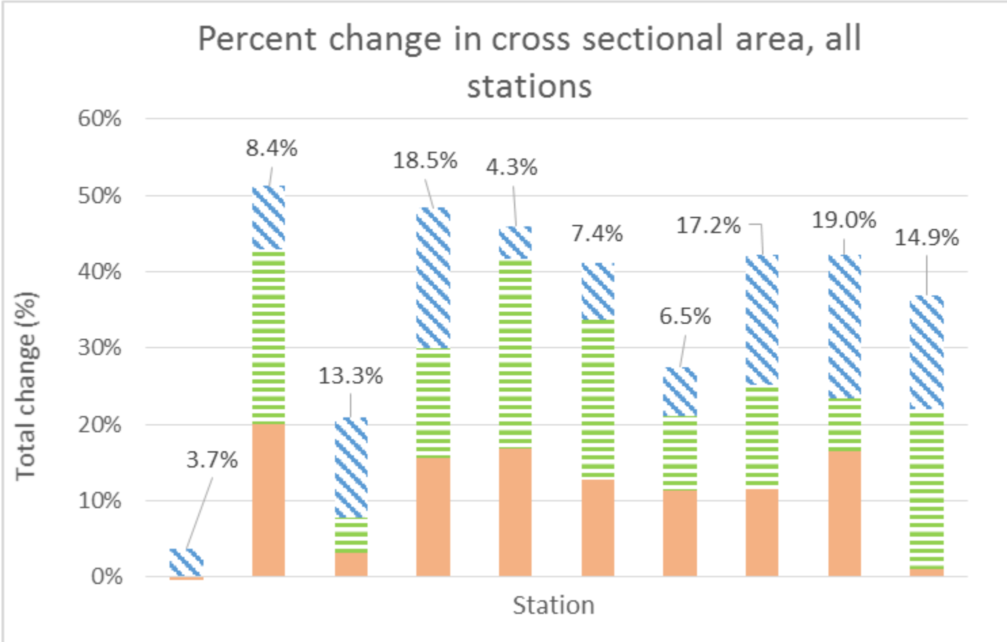
Photos from cross section surveys are included in Section 3.7. At most stations, photos were taken looking upstream, downstream, and from each channel bank, providing a visual record over time. Quantitative metrics of the cross sections are graphed in Figures 16-17. Cross sectional area has increased at each station within the Project Area for each year of post-project monitoring (Fig. 16). In terms of total area, the greatest increases continue to occur closer to the culvert (stations 2-4). In terms of percentage change (Fig. 17), all stations in the Project Area have had at least a 20% total increase in area, and all but two (Stations 3 and 7) have had at least a 40% total increase in area. Cross section area of Stations 9 and 10 remain the smallest (about ½ that of Station 8), likely due to the presence of the historic ford across the channel upstream of Station 8, which acts as a grade control for the upstream channel depth. The cross sectional area at Station 2 has experienced the highest rate of change post-project, both in absolute and relative (percentage) terms. While this is likely due in part to higher water velocities nearer to the culvert, it also suggests that the upstream channel may still be in earlier stages of response to the new hydrology.

The maximum post-project channel depth has increased at every station in the Project Area for each year of monitoring, and all stations except for St. 9 & 10 have deepened by at least two feet (Fig. 18). Elevations are approximate relative to NAVD 88. The culvert invert is shown for reference. Maximum depths at St. 2, 4 & 5 are within .5’ of the invert elevation.



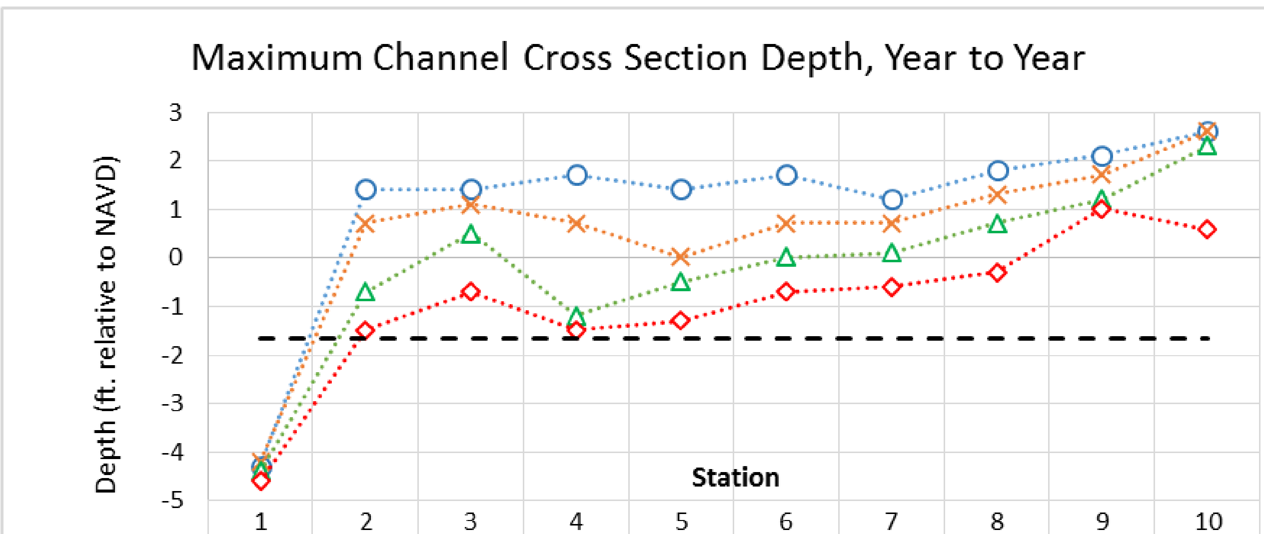
	2	3	4	5	6	7	8	9	10
2015-6	26.5	17.8	16.2	2.8	3.8	2.6	5.3	3	1.8
2014-5	58.9	5.9	11	13	9	3.6	3.7	1	2.1
2013-4	43.0	3.8	10.3	7.5	4.8	3.7	2.8	2.1	0.1
Base (2013)	214.9	124.3	66.3	44.7	37.9	32.9	24.4	12.7	9.9

Figure 16. Change in total cross sectional area in the Project Area. Labelled are changes from 2015. (Mecklenburg 2006).



	1	2	3	4	5	6	7	8	9	10
2015-6	3.7%	8.4%	13.3%	18.5%	4.3%	7.4%	6.5%	17.2%	19.0%	14.9%
2014-5	0.0%	22.8%	4.6%	14.4%	24.9%	21.1%	9.8%	13.6%	6.8%	21.0%
2013-4	-0.5%	20.0%	3.1%	15.5%	16.8%	12.7%	11.2%	11.5%	16.5%	1.0%

Figure 17. Year over year percent change in cross sectional area by station. Labelled are percent change from 2015.



	1	2	3	4	5	6	7	8	9	10
2013	-4.3	1.4	1.4	1.7	1.4	1.7	1.2	1.8	2.1	2.6
2014	-4.19	0.71	1.11	0.71	0.01	0.71	0.71	1.31	1.71	2.61
2015	-4.4	-0.7	0.5	-1.2	-0.5	0.0	0.1	0.7	1.2	2.3
2016	-4.59	-1.49	-0.69	-1.49	-1.29	-0.69	-0.59	-0.29	1.01	0.59
Invert	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65

Figure 18. Maximum channel depth by station, with approximate elevations relative to NAVD.

3.6 Plant Species of Concern

Incidence of invasive plant species were documented during vegetation transect surveys, meander surveys of the high marsh and marsh perimeter, and incidental observations during the course of monitoring in 2013, 2014, 2015, and 2016. The meander surveys did not cover the forested area upslope of the upland edge, an area which is determined to be outside of the Project Area, which is notable due to the fact that invasive plants and shrubs appear to be abundant in the adjacent forest based on incidental anecdotal observations. Two invasive plant species were located within the Project Area in 2016: purple loosestrife, and common reed.

Purple Loosestrife (*Lythrum salicaria*) has been observed within the Project Area during each year of monitoring, however frequency has declined to a single individual observed in both 2015 and 2016 at the upland edge of the vegetation transect at Station 9. This site lies in the middle of a cattail stand with a freshwater seep from the adjacent uplands. Meander surveys of other transitional areas confirmed that increased tidal inundation had eliminated virtually all of the loosestrife in the Project Area by the 2015 growing season.

One of two small adjacent Phragmites patches found in the Project Area during 2016 meander surveys.

Invasive Common Reed (*Phragmites australis*) was found in the Project Area for the first time in 2016. During an invasive species meander survey in early August, CBEP's seasonal field crew observed a small new patch of *Phragmites australis* in a southeastern portion of the Project Area, approximately 15m away from the upland edge of the marsh near Station 9. At subsequent site visits, the patch was estimated to include 390 stems in an area of approximately $100m^2$. The patch was located amongst standing dead alder, cattails, and white pine, in an ecologically disturbed area of the marsh that now experiences regular tidal inundation, post-project. CBEP contacted Deane Van Dusen of MDOT to report the discovery. Van Dusen subsequently applied a mixture of Glyphosate and Imazapyr as a control agent in a fall application. Monitoring and spot treatment will continue in Years 4 and 5. Invasive *Phragmites* continues to grow in three distinct patches downstream (south) of Station 10 (visible on Figure 1). Anecdotal observations suggest that these stands are stressed by increased salt water delivery south of the "narrows". These stands were likely the source of the cloned Phragmites found in 2016.

3.7 Photo Stations

Photographic documentation is being used to visually record conditions at fixed locations at the road crossing, and at each Station. Table 7 shows photo stations associated with the road crossing, before and after construction.

At most Stations, photographs were taken during cross section surveys looking upstream, downstream, and from each channel bank, providing a visual record of each Station (Table 8). At some Stations, additional photos were taken showing views to the upland edge.

During vegetation surveys, photographs were taken from the 0’ (creek channel) looking to the end of the transect (upland edge), and from the upland edge looking back at the creek channel. Many of the post-project photographs, including those from 2016, clearly show standing dead vegetation in the background, particularly white pine, cattails and alder (Table 9).

Table 7. Photo stations at the construction site, 2013 and 2016.

Pre-Project (2013)	**2016**
View Downstream (North)	
	
View to Outlet (South)	
	
View to Inlet (North)	
	
View Upstream (South)	
	

Table 8. Photos stations at channel cross section transects, 2013 and 2016.

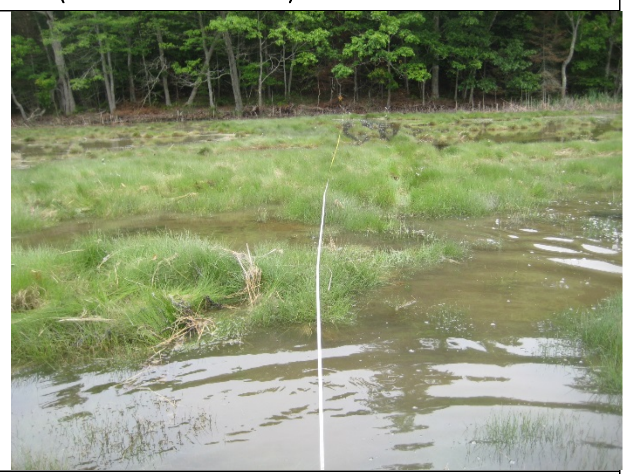
PRE-PROJECT (2013)	**2016**
Station 1 Cross Section (view north)	
	
Station 2 Cross Section (view upstream)	
	
Station 3 Cross Section (view west)	
	

Pre-Project (2013)	**2016**
Station 4 Cross Section (view north)	
	
Station 5 Cross Section (view south)	
	
Station 6 Cross Section (view east/upstream)	
	

<table>
<tr><th>Pre-Project (2013)</th><th>2016</th></tr>
<tr><td colspan="2">Station 7 Cross Section (view south)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 8 Cross Section (view east/upstream)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 9 Cross Section (view south)</td></tr>
<tr><td></td><td></td></tr>
</table>

PRE-PROJECT (2013)	2016
Station 10 Cross Section (view south)	
	

Table 9. Photo stations at vegetation transects, 2013 and 2016.

Pre-Project (2013)	**2016**
Station 1 Vegetation Transect (view from channel)	
	
Station 2 Vegetation Transect (view from channel)	
	
Station 2 Vegetation Transect (view from upland)	
	

<table>
<tr><th>PRE-PROJECT (2013)</th><th>2016</th></tr>
<tr><td colspan="2">Station 3 Vegetation Transect (view from channel)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 3 Vegetation Transect (view from upland)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 4 Vegetation Transect (view from channel)</td></tr>
<tr><td></td><td></td></tr>
</table>

<table>
<tr><th>Pre-Project (2013)</th><th>2016</th></tr>
<tr><td colspan="2">Station 5 Vegetation Transect (view from channel)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 6 Vegetation Transect (view from channel)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 7 Vegetation Transect (view from channel)</td></tr>
<tr><td></td><td></td></tr>
</table>

<table>
<tr><th>Pre-Project (2013)</th><th>2016</th></tr>
<tr><td colspan="2">Station 7 Vegetation Transect (view from upland)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 8 Vegetation Transect (view from channel)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 9 Vegetation Transect (view from channel)</td></tr>
<tr><td></td><td></td></tr>
</table>

2014	2016
Station 10 Vegetation Transect (view from channel)	
	

3.8 Wildlife use

CBEP documented incidental observations of wildlife use of the Project Area and the immediate upland edge but generally, time and energy was focused on monitoring core parameters. Observations are listed in Table 10. In 2016, CBEP observed that extensive areas of the marsh adjacent to the tidal creek were being used by mating horseshoe crabs. The crabs were observed as far south as Station 8, and in considerable numbers. Over 30 mating pairs were observed in an informal tally.

Table 10. Incidental observations of fish and wildlife during monitoring (2013 – 2016).

Common name	Scientific name	Notes
Great blue heron	*Ardea herodias*	Pannes; outlet
Snowy egret	*Egretta thula*	Pannes; outlet
Bald eagle	*Haliaeetus leucocephalus*	2013 nest in pine
Glossy ibis	*Plegadis falcinellus*	Pools St. 1 & 2 (2015)
Osprey	*Pandion haliaetus*	
Greater yellowlegs	*Tringa melanoleuca*	Pannes; outlet
Sandpipers	*Scolopacidae spp.*	Pannes
Black duck	*Anas rubripes*	Creek channel
Mallard	*Anas platyrhynchos*	Creek channel
Canada goose	*Branta canadensis*	Creek channel
Belted Kingfisher	*Megaceryle alcyon*	
Black-crowned night heron	*Nycticorax nycticorax*	Pannes
Mink	*Neovison vison*	
Fisher	*Martes pennanti*	Found dead in spring trap
White-tailed deer	*Odocoileus virginianus*	
Coyote	*Canis latrans*	

Black bear	*Ursus americanus*	
Moose	*Alces alces*	
Raccoon	*Procyon lotor*	Tracks in channel flats
Soft shell clam	*Mya arenaria*	Upstream flats
Quahog	*Mercenaria mercenaria*	Upstream flats
Ribbed mussel	*Geukensia demissa*	
Mud snail	*Hydrobiidae sp.*	
Macoma clams	*Macoma sp.*	
Horseshoe crab	*Limulus polyphemus*	
Silverside	*Menidia menidia*	
Mummichog	*Fundulus heteroclitus*	
Green crab	*Carcinus maenas*	
American eel	*Anguilla rostrate*	
Moon jelly	*Aurelia spp.*	High marsh, 2014

4. MANAGEMENT RECOMMENDATIONS

Monitoring in 2016 documented that the marsh's vegetation communities, channel morphology, and habitat continues to adjust to the increased tidal exchange beneath Long Reach Lane. The discovery of invasive *Phragmites* within the Project Area reinforces the importance of monitoring of core parameters during the ongoing transition. CBEP will continue to intensively monitor the marsh for *Phragmites*, and continued spot treatment with herbicides is recommended on an as-needed basis.

5. REFERENCES

Abbott, A. Personal communication, 2/2015. Contractor with the US Fish and Wildlife Service, Gulf of Maine Coastal Program, Falmouth, Maine.

CBEP 2015. *2014 Post-Construction Monitoring Report: Long Reach Lane at Long Marsh. Year 1 of 5.* Maine Department of Transportation.

Gulf of Maine Council Climate Network. June 2016. *Quarterly Climate Impacts and Outlook, March-May 2016.* http://www.gulfofmaine.org/2/wp-content/uploads/2016/06/GOM-Spring-2016.pdf

Haines, A. and T.F. Vining. 1998. *Flora of Maine: A Manual for Identification of Native and Naturalized Vascular Plants of Maine.* V.F. Thomas Co., Bar Harbor.

Konisky, R., D.M. Burdick, M. Dionne, and H.A. Neckles. 2006. *A Regional Assessment of Salt Marsh Restoration and Monitoring in the Gulf of Maine.* Restoration Ecology, 14:4 (516-525).

Maine Department of Transportation, 2012. *Wetland Mitigation Plan: Martin's Point Bridge, Falmouth-Portland. PIN 16731.00.*

Mecklenburg, D., 2006. *The Reference Reach Spreadsheet: Version 4.3 L.* Ohio Department of Natural Resources.

Neckles, H., and M. Dionne, Eds., 1999. *Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine.* Wells National Estuarine Research Reserve. https://www.pwrc.usgs.gov/resshow/neckles/Gpac.pdf.

Tiner, R. 2009. *Field Guide to Tidal Wetland Plants of the Northeastern United States and Neighboring Canada: Vegetation of Beaches, Tidal Flats, Rocky Shores, Marshes, Swamps, and Coastal Ponds.* University of Massachusetts Press.

Verrill, S. 2014. *Shifting vegetation zones in response to culvert enlargement at a tidally restricted salt marsh in Harpswell, Maine.* (Unpublished master's thesis). University of Southern Maine, Portland.

Wake, C., E. Burakowski, K. Hayhoe, C. Watson, E. Douglas, J. VanDorn, V. Naik, and C. Keating, 2009. *Climate Change in the Casco Bay Watershed: Past, Present, and Future.* Casco Bay Estuary Partnership. http://www.cascobayestuary.org/wp-content/uploads/2014/08/2009_cbep_climate_change_report.pdf

APPENDIX A – MONITORING STATION MAPS


Vegetation
0 45 90 180 270 360
Meters
Transect Location
C = channel; U = upland
1C
1U
2C
2U
3C
3U
4C
4U
5U
5C
6C
6U
7C
7U
8U
8C
9C
9U
10C
10U


Channel Cross Sections
0 45 90 180 270 360
Meters
Stake
Casco Bay Estuary
PARTNERSHIP
XS1W
XS1E
XS2E
XS2W
XS3W
XS3E
XS4W
XS4E
XS5W
XS5E
XS6E
XS6W
XS7W
XS7E
XS8E
XS8W
XS9W
XS9E
XS10E
XS10W


Pore Water Salinity
0 45 90 180 270 360
Meters
Well
Casco Bay Estuary
PARTNERSHIP
1S
2S
4S
6S
6aS
8S
10S

APPENDIX B – VEGETATION

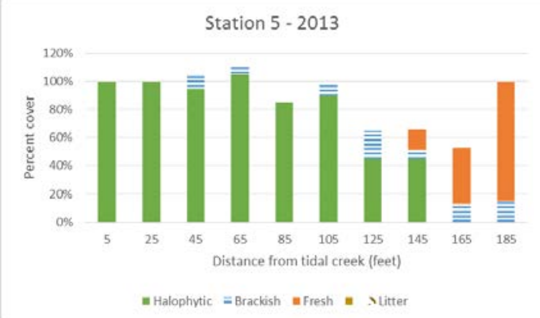
Table 11. List of observed plant species and associated community types. Groupings based on Salinity Index Scores developed by Verrill and Bohlen 2017, after Tiner 2009.

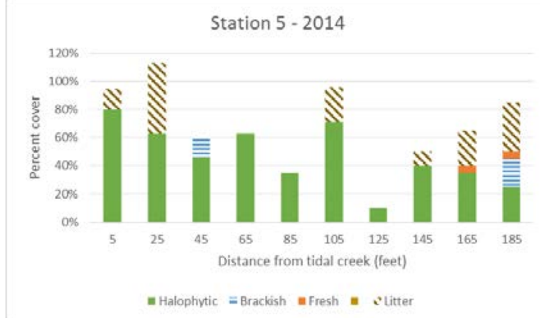
Latin Name	Common Name	Community Group	2013	2014	2015	2016
Abies balsamea	Balsam Fir	Fresh	X*			
Acer rubrum	Red Maple	Fresh		X	X	X
Agrostis stolonifera	Creeping Bent Grass	Brackish	X	X	X	X
Alnus incana	Speckled Alder	Fresh	X	X	X	X
Atriplex prostrata	Orach	Halophyte	X	X	X	X
Bolboschoenus maritimus	Alkali Bulrush	Brackish	X	X	X	X
Calamagrostis Canadensis	Bluejoint Grass	Fresh	X	X	X*	
Calystegia sepium	Hedge Bindweed	Brackish	X			
Carex crinata	Fringed Sedge	Fresh	X			
Carex hystericina	Bottlebrush Sedge	Fresh	X*	X*	X*	
Carex lacustris	Lake Sedge	Fresh	X	X		
Carex lurida	Shallow Sedge	Fresh	X*			
Carex nigra	Smooth black sedge	Fresh				X
Carex paleacea	Chaffy Sedge	Brackish	X			
Carex scoparia	Broom Sedge	Fresh	X	X*	X*	X*
Carex stipata	Stalk-Grain Sedge	Fresh	X		X	
Carex utriculata	Common Beaked Sedge	Fresh		X	X*	X*
Cladium mariscoides	Smooth Sawgrass	Fresh	X*	X*	X*	X*
Distichlis spicata	Salt Grass	Halophyte		X	X	X
Dryopteris cristata	Crested Wood Fern	Fresh	X			
Dulichium arundinaceum	Three Way Sedge	Fresh	X*		X*	
Eleocharis sp.	Sedge		X*		X	
Eleocharis palustris	Common spikerush	Fresh				X*
Elymus pycnanthus	Tick Quackgrass	Brackish	X		X	
Elymus repens	Creeping Wild Rye	Fresh	X	X		X
Equistem pratense	Horsetail	Fresh	X	X		
Euthamia graminifolia	Flat-Top Goldentop	Brackish	X			
Festuca rubra	Red Fescue	Brackish	X	X	X	X
Galium asprellum	Rough Bedstraw	Fresh		X		
Galium trifidum	Threepetal Bedstraw	Fresh	X	X*	X*	X*
Glaux maritima	Milkwort	Halophyte		X		
Glyceria canadensis	Rattlesnake Mannagrass	Fresh	X			X
Hordeum jubatum	Foxtail Barley	Halophyte	X	X		
Hypericum mutilum	St. John's Wort	Fresh	X	X	X*	X*
Ilex verticillata	Winterberry	Fresh	X	X*	X*	
Impatens capensis	Jewelweed	Fresh	X	X*	X*	
Juncus arcticus	Arctic Rush	Halophyte	X	X	X	X
Juncus gerardii	Black Grass	Halophyte	X	X	X	X
Lemma minor	Duckweed	Fresh				X*
Lycopus americanus	Cut-Leaf Water Horehound	Fresh	X			
Lycopus uniflorus	Northern Bugleweed	Fresh	X*	X*	X*	X*
Lysimachia terrestris	Swamp Candle	Fresh	X	X	X	X*
Lythrum salicaria	Purple Loosestrife	Fresh	X	X	X	X
Onoclea sensibilius	Sensitive Fern	Fresh	X	X*	X*	X*
Osmunda cinnamomea	Cinnamon Fern	Fresh		X		
Osmunda regalis	Royal Fern	Fresh	X*			
Panicum dichotomiflorum	Panic Grass	Fresh	X	X*		
Persicaria sagittata	Tearthumb	Fresh	X	**X**	X	
Populus tremuloides	Poplar	Fresh				X
Proserpinaca palustris	Marsh Mermaidweed	Fresh	X*	X	X*	
Puccinellia tenella	Alkali Grass	Halophyte	X*			
Quercus rubra	Northern Red Oak	Fresh	X*	X	X	X
Ribes hirtellum	Currant	Fresh	X			
Rosa palustris	Swamp Rose	Fresh	X			
Rubus hispidus	Blackberry	Fresh	X*	X		

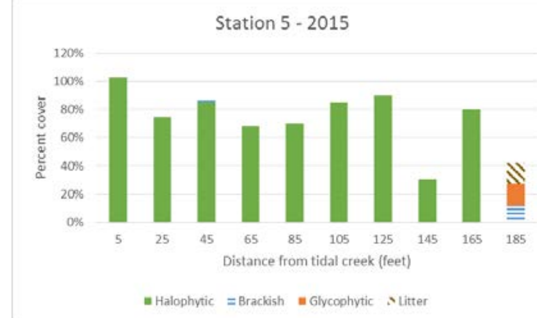
Ruppia maritima	Widgeon Grass	Halophyte	X	X	X	X
Salicornia depressa	Common Glaswort	Halophyte	X	X	X	X
Schoenoplectus acutus	Hardstem Bulrush	Brackish	X	X	X	X
Schoenoplectus pungens	Three-Square Bulrush	Brackish	X	X	X	X
Scirpus sp.	Sedge		X			
Scutellaria galericulata	Hooded Skullcap	Fresh	X	X	X	
Solidago altissima	Tall Goldenrod	Fresh	X	X	X	
Solidago sempervirens	Seaside Goldenrod	Halophyte	X	X	X	X
Spartina alterniflora	Smooth Cordgrass	Halophyte	X	X	X	X
Spartina patens	Salt Hay	Halophyte	X	X	X	X
Spartina pectinata	Freshwater Cordgrass	Brackish	X	X	X	X
Spirea alba	White Meadowsweet	Fresh	X	X	X	
Spirea tomentosa	Steeplebush	Fresh	X		X*	X*
Symphyotricum novi-belgii	Aster	Brackish	X		X*	
Thelypteris palustris	Eastern Marsh fern	Fresh	X	X*	X*	X*
Toxicodendron radicans	Poison Ivy	Fresh	X	X	X	X
Triglochin maritima	Seaside Arrowgrass	Halophyte	X	X	X	X
Typha angustifolia	Narrow-Leaf Cattail	Brackish	X	X	X	X
Typha latifolia	Broad-Leaf Cattail	Fresh	X	X	X	X
Typha x glauca	hybrid cattail	Brackish	X*	X*	X*	
Vaccinium macrocarpon	Large Cranberry	Brackish	X*	X*	X*	X*
Viola pallens	violet	Fresh	X		X	

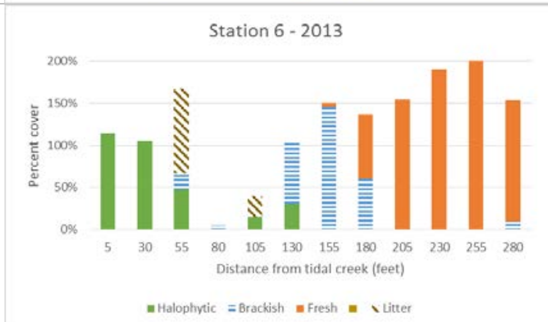
*Denotes species was only observed at Stations 11 or 12.

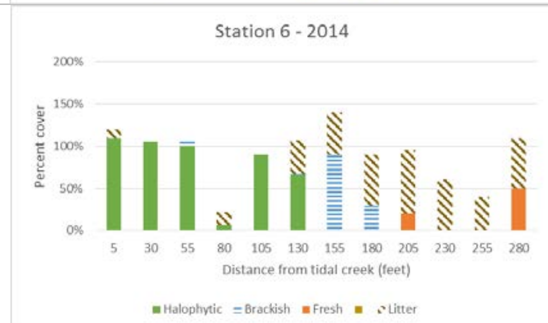
Table 12. Bar graphs of community type (% cover) for Stations 1-10, by transect distance, 2013 - 2015.

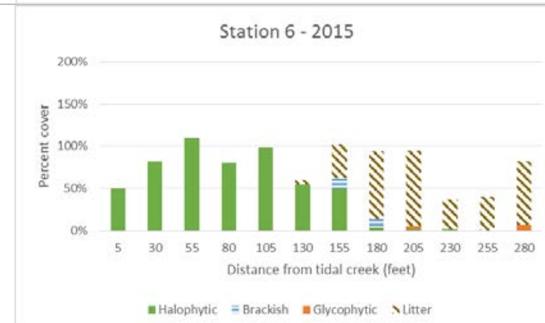

Station 5 - 2013
120%
100%
80%
60%
40%
20%
0%
Percent cover
5 25 45 65 85 105 125 145 165 185
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter

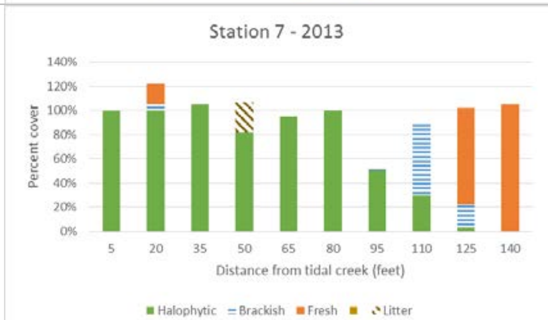

Station 5 - 2014
120%
100%
80%
60%
40%
20%
0%
Percent cover
5 25 45 65 85 105 125 145 165 185
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter

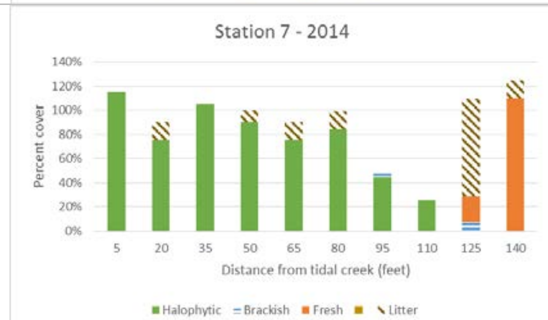

Station 5 - 2015
120%
100%
80%
60%
40%
20%
0%
Percent cover
5 25 45 65 85 105 125 145 165 185
Distance from tidal creek (feet)
Halophytic Brackish Glycophytic Litter

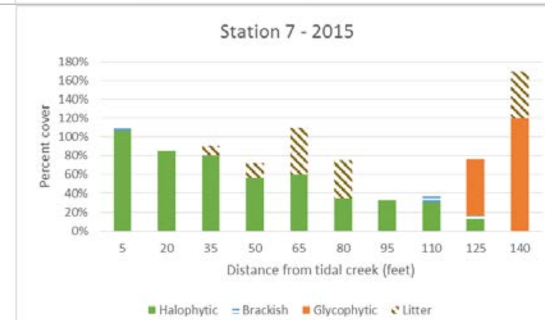

Station 6 - 2013
200%
150%
100%
50%
0%
Percent cover
5 30 55 80 105 130 155 180 205 230 255 280
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter

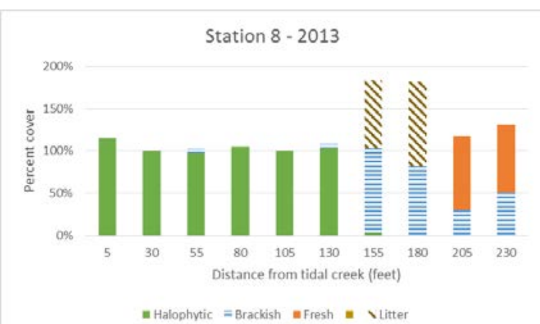

Station 6 - 2014
200%
150%
100%
50%
0%
Percent cover
5 30 55 80 105 130 155 180 205 230 255 280
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter

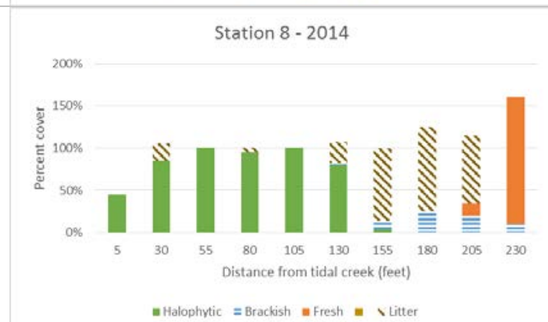

Station 6 - 2015
200%
150%
100%
50%
0%
Percent cover
5 30 55 80 105 130 155 180 205 230 255 280
Distance from tidal creek (feet)
Halophytic Brackish Glycophytic Litter

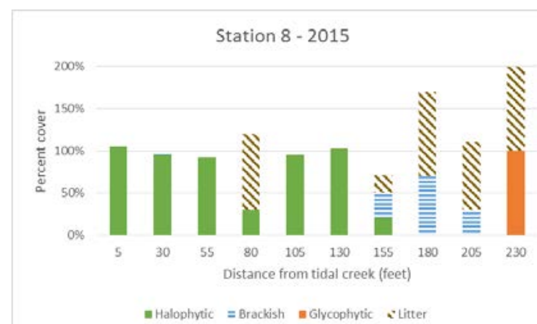

Station 7 - 2013
140%
120%
100%
80%
60%
40%
20%
0%
Percent cover
5 20 35 50 65 80 95 110 125 140
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter

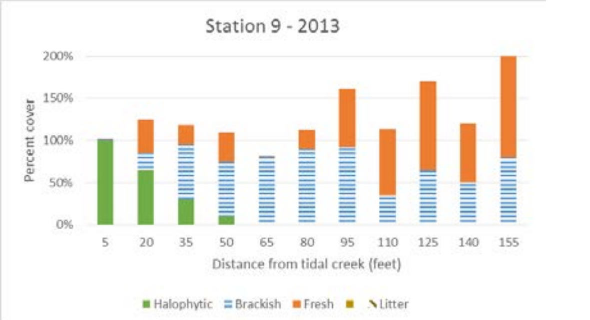

Station 7 - 2014
140%
120%
100%
80%
60%
40%
20%
0%
Percent cover
5 20 35 50 65 80 95 110 125 140
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter

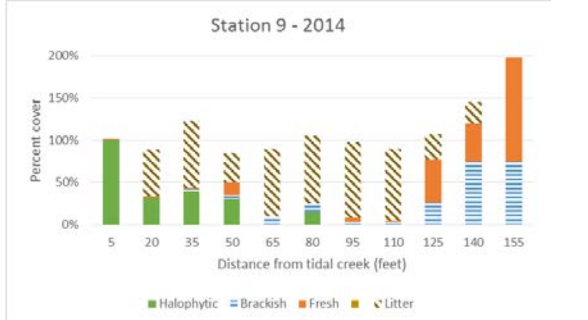

Station 7 - 2015
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
Percent cover
5 20 35 50 65 80 95 110 125 140
Distance from tidal creek (feet)
Halophytic Brackish Glycophytic Litter

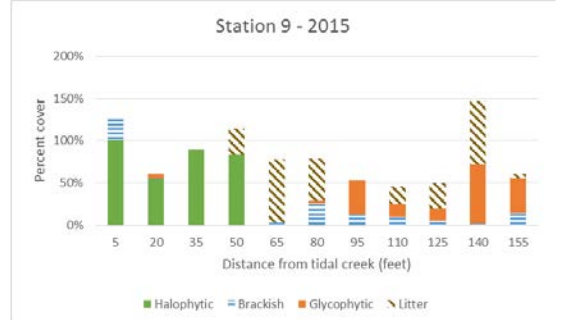

Station 8 - 2013
200%
150%
100%
50%
0%
Percent cover
5 30 55 80 105 130 155 180 205 230
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter

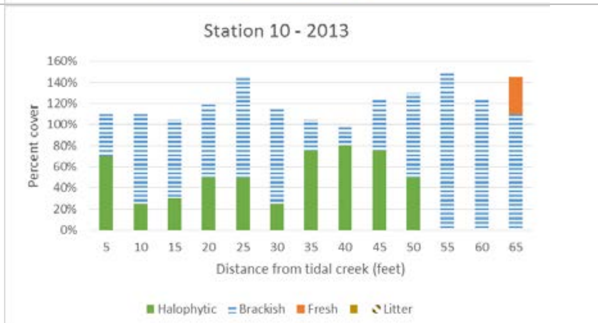

Station 8 - 2014
200%
150%
100%
50%
0%
Percent cover
5 30 55 80 105 130 155 180 205 230
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter

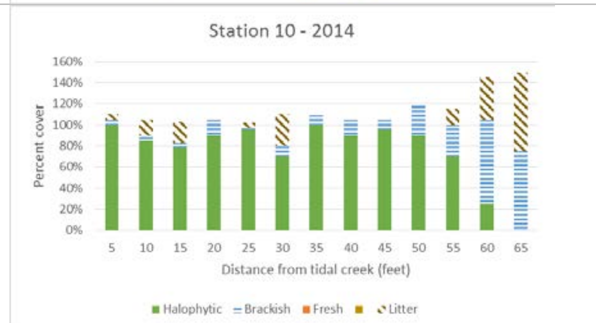

Station 8 - 2015
200%
150%
100%
50%
0%
Percent cover
5 30 55 80 105 130 155 180 205 230
Distance from tidal creek (feet)
Halophytic Brackish Glycophytic Litter

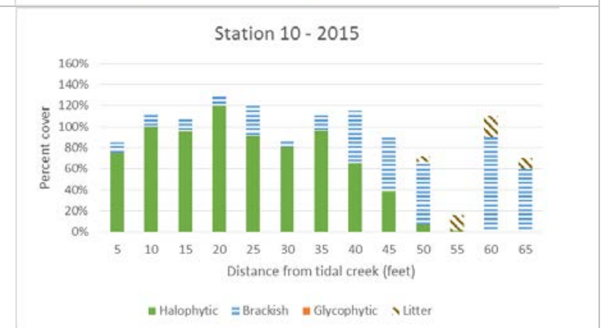

Station 9 - 2013
200%
150%
100%
50%
0%
Percent cover
5 20 35 50 65 80 95 110 125 140 155
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter


Station 9 - 2014
200%
150%
100%
50%
0%
Percent cover
5 20 35 50 65 80 95 110 125 140 155
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter


Station 9 - 2015
200%
150%
100%
50%
0%
Percent cover
5 20 35 50 65 80 95 110 125 140 155
Distance from tidal creek (feet)
Halophytic Brackish Glycophytic Litter


Station 10 - 2013
160%
140%
120%
100%
80%
60%
40%
20%
0%
Percent cover
5 10 15 20 25 30 35 40 45 50 55 60 65
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter


Station 10 - 2014
160%
140%
120%
100%
80%
60%
40%
20%
0%
Percent cover
5 10 15 20 25 30 35 40 45 50 55 60 65
Distance from tidal creek (feet)
Halophytic Brackish Fresh Litter


Station 10 - 2015
160%
140%
120%
100%
80%
60%
40%
20%
0%
Percent cover
5 10 15 20 25 30 35 40 45 50 55 60 65
Distance from tidal creek (feet)
Halophytic Brackish Glycophytic Litter