Tidal Restriction Restoration at Wallace Shore Road

2017 Monitoring Report:
Year 3 of 5, Post-Project

Prepared For:

MAINE NATURAL RESOURCE CONSERVATION PROGRAM
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Casco Bay Estuary
PARTNERSHIP

Contents

1. Overview

Project Name:	Tidal Restriction Restoration at Wallace Shore Road
MNRCP ID:	2013-CIM-Wallace Shore Rd-CBEP
Project Location:	Appletree Marsh, Harpswell
Project Sponsor:	Casco Bay Estuary Partnership (CBEP)
Contractor and/or Consultant:	Shaw Brothers Construction; Wright Pierce
Start and Completion Dates:	12/15/2014 – 12/29/2014.
Corps and DEP Permit Numbers:	Corps Permit #: NAE-2014-01922; State ID#: NRPA/PBR #58778

1.1 Project Summary

The primary objective of this project was to reestablish natural hydrology, and specifically, to restore natural tidal variability into the Appletree Marsh adjacent to Wallace Shore Road in Harpswell (Fig. 2, following page). Two existing culverts were replaced according to amended designs provided with permit applications: A 3.3' box culvert was replaced with a 15' open bottom span concrete box culvert, and a 18" HDPE culvert was replaced with a 5' pre-cast concrete culvert (Fig. 1). At the 15' open bottom box, remnant slugs of fill from the original crossing structure were dredged from the channel immediately adjacent to the crossing in order to promote the free exchange of water into and out of the marsh.

Figure 1. Installation of open bottom concrete box culvert IN December 2014 at the lower site (9079, left) and embedded concrete round pipe at the upper site (9078, right).

Engineering services were provided by Wright Pierce, construction services were provided by Shaw Brothers, and the Cumberland County Soil and Water Conservation District administered the construction contract. The project was managed by the Casco Bay Estuary Partnership. Construction activities began on 12/15/14 at the north (secondary) culvert and concluded on 12/24/2014 at the primary crossing. Finishing road work was completed on 12/29/2014 following a break from 12/24 – 12/28/2014 over the holidays.

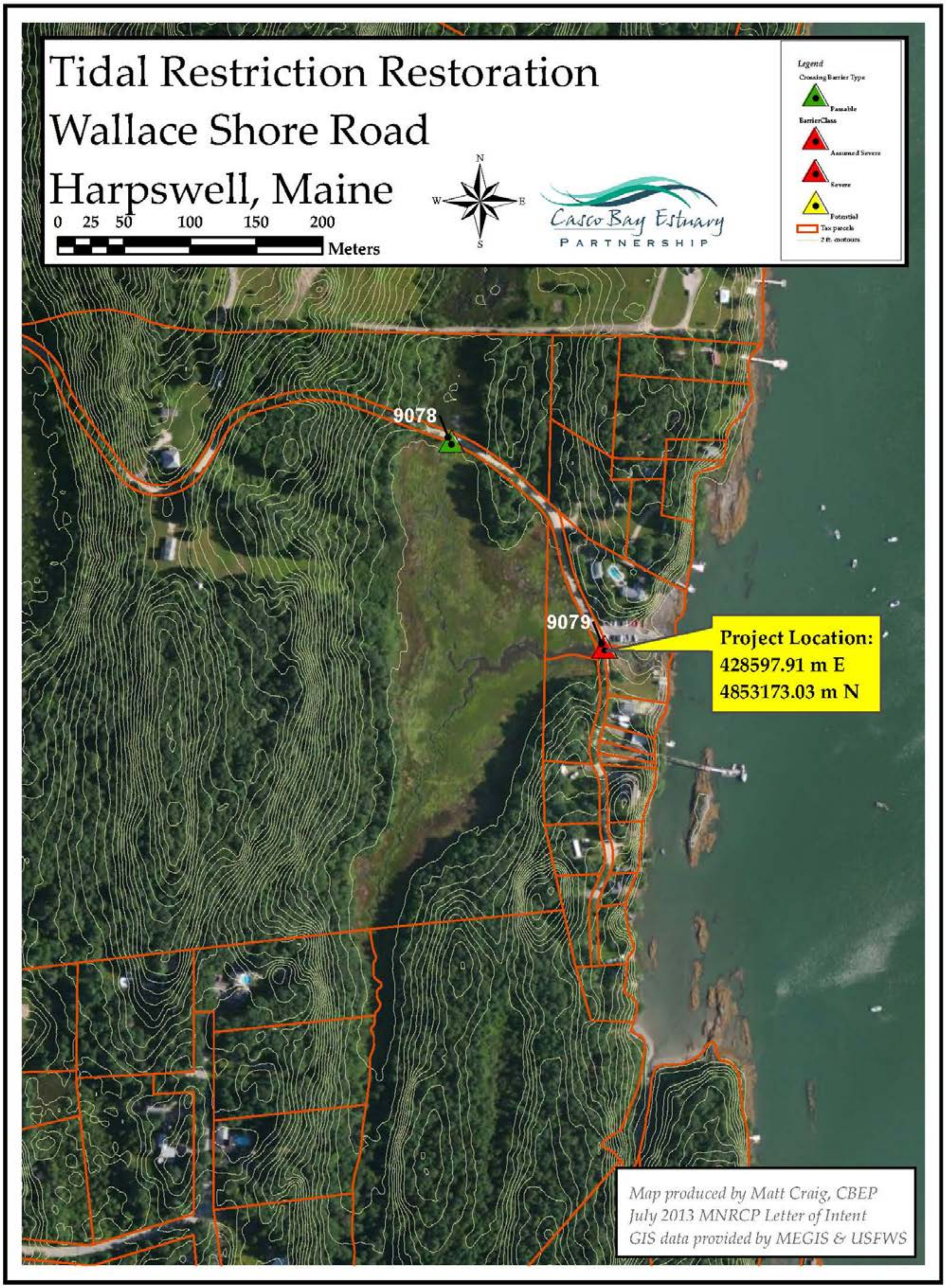

Figure 2. Map of project locations, parcels, and topography.

1.2 Project Monitoring

A monitoring plan was incorporated into the *Wallace Shore Road Restoration Work Plan.* CBEP is conducting pre- and post- project monitoring in the wetland adjacent to the project area (crossings 9079 and 9078). Following one season of collecting pre-project data, CBEP is collecting five years of post-project data.

The *Restoration Work Plan* summarizes the project goal to increase tidal exchange at two road/stream crossings where privately owned Wallace Shore Road crosses a tidal wetland in Harpswell. To monitor ecosystem change in response to the tidal restoration project, CBEP established 10 monitoring Stations at Appletree Marsh, spaced so that they were evenly distributed. Station 1 was located downstream of the primary crossing (9079), immediately to the north of Wallace Shore Road; Stations 2-9 are located in the marsh between the two road crossings, and Station 10 is located upstream of the secondary road crossing (9078; Fig. 3).

The *Restoration Work Plan* described the current (pre-construction) condition of the marsh and incorporated data on channel morphology, surface water hydrology and salinity, pore water salinity, vegetation, species of concern and other parameters. This report summarizes monitoring results from Year 3 post-project and where illustrative, provides a comparison with pre-construction data in the *Restoration Work Plan.* Parameters include:

- 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.

Monitoring is intended to document changes in the marsh following the restoration of tidal exchange at the two road crossings. Monitoring is designed to detect changes such as:

- Channel depth within the construction area compared with the longitudinal profile of the channel's gradient outside the area of impact.
- Halophytes as a percentage of overall species composition.
- Pore water salinity variability in response to tidal cycles.
- Surface water salinity upstream of Wallace Shore Road variability in response to tidal cycles.

NOTE: This Year 3 Post-Project Monitoring Report updates the previous monitoring reports dated March 2016 and January 2017. Where practical, references to previous reports are provided to minimize unnecessary redundancy and emphasize Year 3 results in the context of prior data.

Monitoring Stations
Tidal Restriction Restoration Project
Wallace Shore Road, Harpswell, Maine

Data available from:
Casco Bay Estuary Partnership
Matt Craig
(207) 228-8359
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Figure 3. Map of monitoring stations.

2. Performance Standards/Requirements

The *Restoration Work Plan* defines performance standards for this project as follows (p. 26-7):

- Erosion control: All the constructed features such as slopes, soils, and substrates within the mitigation site will be stabilized and free from erosion, with erosion control materials removed once the site is stable.
- Invasive species: Invasive *Phragmites australis* is not introduced to the site, or if invasive *Phragmites australis* does colonize the project area, it is eliminated.
- Hydrology signal: Tidal restriction at the primary crossing, defined as the difference between highest observed water (HOW) downstream and upstream, will be less than or equal to .3' by the conclusion of the five year post-construction monitoring period.

3. Monitoring Results

This section describes the current conditions on the site focused on the condition of the mitigation project to replace two road crossings and restore tidal hydrology, as well as conditions in the marsh, in order to substantiate the success and/or potential challenges associated with the project. For full photo documentation, see Appendix A.

3.1 Monitoring Dates

This report summarizes data presented in previous reports, as well as data gathered over the course of 8 distinct visits to the site during the 2017 field season.

Table 1. List of 2017 monitoring and site visits.

Date	Name*	Activity
5/3/2017	MC	Pore water salinity samples; maintain monitoring stations
6/1/2017	TT	Pore water salinity samples
6/19/2017	TT	Pore water salinity samples
6/29/2017	TT, Em	Channel morphology (cross sections)
7/13/2017	CB, TT	Vegetation monitoring
7/14/2017	CB, TT	Vegetation monitoring
7/17/2017	MC, TT	Channel morphology (longitudinal profile); pore water salinity samples
8/17/2017	TT	Pore water salinity samples; invasive species meander survey
* MC = Matt Craig, CBEP Habitat Program Manager; TT = Tristan Taber, CBEP Field Technician; Em = Emelie, USFWS Gulf of Maine Coastal Program Intern; CB = Curtis Bohlen, CBEP Director		

3.2 Erosion Control

No erosion issues were observed at the project sites (road/stream crossings) in 2017, and no structural maintenance needs were identified. Ecosystem monitoring documented channel scour and sediment movement in response to the new road/stream crossings. The changes are consistent with the geomorphic response anticipated to result from increased tidal exchange and drainage. Results of Year 3 monitoring of channel response are presented in Section 3.9, Channel Morphology.

3.2.1 Status of Performance Standards

Table 2. Summary of Performance Standards and Monitoring Parameters

Performance Standard/ Monitoring Parameters	2017 Findings (Year 3 post-project)	Meet Standard?
Erosion control	*Slopes, soils, substrates within the mitigation site are stable.*	On-track
Invasive species	*Approximately 8* Phragmites *plants were observed within the project area during meander survey.*	Requires further investigation
Hydrology signal	*No update from previous reports*	Yes
Pore water salinity*	*Mean pore water salinity levels and maximum pore water salinity remained elevated over pre-project levels*	On-track
Vegetation community*	*Changes in the plant community indicate continued adjustment to the new hydrology and higher salinity levels*	On-track
Channel morphology*	*Channel conditions continue to adjust to post-project hydrology*	On-track

* *Hydrology signal, invasive species, and erosion control are the three core performance standards defined by the Restoration Work Plan.*

3.3 Corrective Actions

Table 3. List of corrective actions taken during the monitoring period.

Date	Observation	Corrective Action
8/17/2017	CBEP identified several flowering *Lythrum salicaria* plants during the invasive species meander survey.	Heads were hand clipped, stored in plastic bags, transported off site, and incinerated.
8/17/2017	CBEP field technician observed approximately 8 *Phragmites plants during invasive species meander survey.*	None taken. Requires follow up field identification by MNAP or other qualified botanist to determine whether the plants are native or invasive. See Sect. 3.10.

3.4 Vegetation

Although there are no performance standards associated with changes to the vegetative community, CBEP is monitoring vegetation at ten transects throughout the five year post-project period. Vegetation transects were established and surveyed on 7/15 and 7/17/14, on 7/14 and 7/16/15, 7/11 and 7/13/16, and 7/13 – 7/14/17. Approximately 110 plots are sampled along ten transects (12 plots along Station 1a and 1b, and 98 plots along transects at Stations 2-10). Plot locations are meant to be replicated annually using a tape reel, but actual plot locations likely vary year to year. Selected photos from 2017 vegetation monitoring are included within appendices.

A combined total of 84 plant species were identified across all Stations over the four years of monitoring (Table 4). Species richness within the monitored plots across all stations decreased markedly in 2016 and continued dropping in 2017. Sixty-one (61) species were observed in 2014, 68 in 2015, 35 in 2016 and 31 in 2017. Three species were observed in 2017 that were not recorded in prior years: *Plantago maritima, Ranunculus cymbalaria,* and *Solanum dulcamara.*

Table 4. Plant species observations and community type. Groupings based on Tiner 2009 and Verrill 2016.

Latin Name	Common Name	Community Group	2014	2015	2016	2017
Acer rubrum	Red Maple	Fresh	✓	✓	✓	✓
Agrostis stolonifera	Creeping Bent Grass	Brackish	✓	✓	✓	✓
Alnus incana	Speckled Alder	Fresh	✓	✓	✓	
Argentia anserina	Common Silverweed	Brackish	✓	✓	✓	✓
Atriplex prostrata	Orach	Brackish	✓	✓	✓	✓
Betula populifolia	Gray birch	Fresh	✓		✓	✓
Bolboschoenus maritimus	Alkali Bulrush	Brackish	✓	✓	✓	✓
Calamagrostis Canadensis	Bluejoint Grass	Fresh		✓	✓	
Calla palustris	Wild Calla	Fresh	✓	✓		
Carex hystericina	Bottlebrush Sedge	Fresh	✓			
Carex lacustris	Lake Sedge	Fresh	✓	✓		
Carex scoparia	Broom Sedge	Fresh	✓	✓	✓	
Carex trisperma	Three-Seeded Sedge	Fresh	✓	✓		
Carex utriculata	Common Beaked Sedge	Fresh		✓		
Carex spp.	Unk. Sedge	Fresh	✓	✓		
Drosera rotundifolia	Sundew	Fresh	✓			
Dryopteris cristata	Crested Wood Fern	Fresh		✓		
Eleocharis sp.	Sedge	Brackish			✓	
Elymus pycnanthus	Tick Quackgrass	Fresh	✓	✓		✓
Elymus repens	Creeping Wild Rye	Fresh	✓	✓	✓	✓
Epilobium leptophyllum	American Marsh Willow-Herb	Fresh	✓	✓		
Festuca rubra	Red Fescue	Brackish	✓	✓	✓	✓
Galium asprellum	Rough Bedstraw	Fresh				
Galium palustre	Marsh Bedstraw	Brackish	✓	✓		
Galium trifidum	Threepetal Bedstraw	Fresh	✓	✓		
Glaux maritima	Milkwort	Brackish		✓		✓
Glyceria canadensis	Rattlesnake Mannagrass	Fresh			✓	
Glyceria grandis	American Manna Grass	Fresh	✓	✓		
Hypericum mutilum	St. John's Wort	Fresh	✓	✓		
Ilex verticillata	Winterberry	Fresh	✓	✓	✓	
Impatens capensis	Jewelweed	Fresh	✓	✓		
Juncus arcticus	Arctic Rush	Brackish	✓	✓	✓	✓
Juncus gerardii	Black Grass	Salt	✓	✓	✓	✓
Juniperus communus	Common Juniper	Fresh	✓	✓		
Lemna minor	Duckweed	Fresh	✓			
Limonium carolinianum	Sea Lavender	Salt	✓	✓	✓	✓
Lycopus americanus	American Water Horehound	Fresh	✓			
Lycopus uniflorus	Northern Bugleweed	Fresh	✓	✓		
Lysimachia terrestris	Swamp Candle	Fresh	✓	✓	✓	
Lythrum salicaria	Purple Loosestrife	Fresh	✓	✓		
Onoclea sensibilius	Sensitive Fern	Fresh	✓	✓		
Osmunda regalis	Royal Fern	Fresh	✓	✓		
Persicaria sagittata	Tearthumb	Fresh	✓			

Phragmites americanus	American Reed	Brackish	✓			
Picea glauca	White Spruce	Fresh	✓	✓		
Picea rubens	Red Spruce	Fresh		✓		✓
Pinus strobus	White pine	Fresh		✓		
Plantago maritima	Seaside plantain	Salt				✓
Populus grondidentata	Poplar	Fresh		✓	✓	
Populus tremuloides	Quaking Aspen	Fresh	✓	✓	✓	✓
Proserpinaca palustris	Marsh Mermaidweed	Fresh	✓	✓		
Puccinellia tenella	Alkali Grass	Brackish		✓		
Quercus rubra	Northern Red Oak	Fresh	✓	✓	✓	✓
Ranunculus cymbalaria	Alkali buttercup	Brackish		✓		✓
Rosa palustris	Swamp Rose	Fresh		✓		
Rubus hispidus	Bristly Blackberry	Fresh	✓	✓		
Rubus sp.	Blackberry	Fresh		✓		
Rumex pallidus	Seabeach Dock	Brackish	✓	✓		✓
Ruppia maritima	Widgeon Grass	Salt	✓	✓		
Salicornia depressa	Common Glaswort	Salt		✓	✓	✓
Schoenoplectus pungens	Three-Square Bulrush	Fresh	✓	✓	✓	✓
Scirpus cyperinus	Woolgrass	Fresh	✓			
Scirpus sp.	Sedge	Brackish		✓		
Scutellaria galericulata	Hooded Skullcap	Fresh	✓	✓		
Solanum dulcamara	Bittersweet nightshade	Fresh				✓
Solidago altissima	Tall Goldenrod	Fresh	✓	✓		
Solidago sempervirens	Seaside Goldenrod	Brackish	✓	✓	✓	✓
Sparganium americanum	American Bur-Reed	Fresh	✓	✓		
Spartina alterniflora	Smooth Cordgrass	Salt	✓	✓	✓	✓
Spartina patens	Salt Hay	Salt	✓	✓	✓	✓
Spartina pectinata	Freshwater Cordgrass	Brackish	✓	✓	✓	✓
Spirea tomentosa	Steeplebush	Fresh				
Sphagnum spp.	Unk. Sphagnum moss	Fresh		✓		
Spirea alba var. latifolia	White Meadowsweet	Fresh	✓	✓	✓	
Suaeda maritima	Herbacious Seepweed	Salt	✓	✓	✓	✓
Symphyotricum novi-belgii	Aster	Brackish	✓	✓	✓	✓
Taraxacum officinale	Common Dandelion	Fresh			✓	
Thelypteris palustris	Eastern Marsh fern	Brackish		✓		
Toxicodendron radicans	Poison Ivy	Brackish			✓	
Triglochin maritimum	Seaside Arrowgrass	Salt	✓	✓	✓	✓
Typha angustifolia	Narrow-Leaf Cattail	Brackish	✓	✓	✓	
Typha latifolia	Broad-Leaf Cattail	Fresh	✓	✓	✓	✓
Typha x glauca	Hybrid Cattail	Brackish		✓		✓
Vaccinium corymbosum	High Bush Blueberry	Fresh	✓			
Vaccinium macrocarpon	Large Cranberry	Brackish	✓	✓		
Viola pallens	Smooth White Violet	Fresh		✓		
Total species N			**61**	**68**	**35**	**31**

3.4.1 Community Type

Figure 5 graphs relative abundance of glycophytic, brackish, and halophytic vegetation across all plots for each station. Other cover classes including water, bare, litter, woody debris, panne, and overhanging canopy were recorded but are not included in the graphs so as to emphasize shifts in associated plant community groups.

St. 1 downstream from site 9079 serves as a reference area for the project. Mean relative abundance of associated vegetative communities (2014-17) at St. 1 has been 80.6% halophytic, 11.9% brackish, and 1.4% glycophytic. At stations 2-4 immediately upstream of 9079, a mix of community types was observed in the first three years of monitoring but no brackish species were observed at St. 2-3 in 2017, while the relative abundance of halophytes at St. 2 increased in 2017 over prior years.

At St. 5-7 in the southern lobe of the marsh, previously observed glycophytes were not found in 2017, while the relative abundance of halophytes increased markedly over prior years, particularly at St. 6 and 7. The relative abundance of brackish species at these stations remained consistent compared with prior years. Beyond transect 7 to the south, a stand of alders and other woody shrubs has died and salt tolerant vegetation is extending under the standing litter.

At St. 8 in the northern lobe of the marsh, freshwater vegetation remains abundant along the upland edge but brackish species were absent in 2017. Further north at St. 9, downstream of crossing 9078, the abundance of halophytic plants increased markedly over prior years, with fewer brackish and glycophytic species observed. In 2017, virtually no living cattails remained at the outlet of crossing 9078.

Within the cattail stand upstream of crossing 9078 (St. 10), the abundance of *T. latifolia* has steadily decreased to the point where none were observed within plots in 2017. At the same time, the abundance of brackish *T. x glauca* and *T. angustifolia* increased in 2017, with salt-tolerant *Rumex pallidus* observed for the first time within two plots at St. 10.

The abrupt transition in vegetation (e.g., from salt marsh to cattail stand) remains evident upstream and downstream of the road at crossing 9078. However, at St. 10 the relative abundance of glycophytes decreased from 63% in 2015 to just 11% in 2016. This shift was accompanied by a decline in species richness from 27 species in 2014-15 to 5 in 2016 and 2 in 2017.

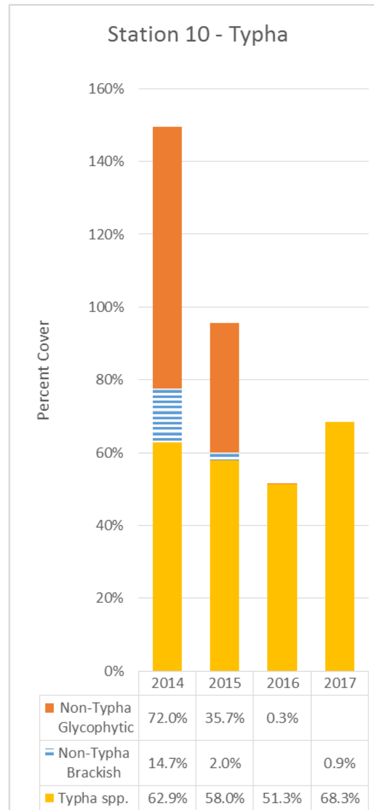


Figure 4. Typha abundance in St. 10 as compared with other species.

Overall, the marsh's vegetation community is continuing to shift from a mix of glycophytes/brackish/halophytes toward a salt marsh, with brackish species increasing in relative abundance away from the road - at the southern and northern lobes of the marsh - and along the base of the hill along the western edge of the marsh. This community shift is consistent with the increased frequency, extent and duration of inundation of the marsh by tidal water following tidal restoration in 2014, as well as the improved drainage of freshwater out of the marsh.

Figure 5. Relative abundance (percent cover) of glycophytic, brackish, and halophytic plants at each station.

3.4.2 Plant Survival

If applicable, by species planted, describe the general health and vigor of the surviving plants, the prognosis for their future survival, and a diagnosis of the cause(s) of morbidity or mortality. Outline any plans for replanting if recommended.

Not applicable. No vegetation was planted as part of this project.

3.5 Fish and Wildlife

CBEP incidentally recorded use of the marsh and immediate vicinity (marsh perimeter) by fish and wildlife when on site for other monitoring tasks. Species observed are listed in Table 5. Note: additional data about bird use may be available from Project SHARP (Saltmarsh Habitat Avian Research Program) based at the University of Maine, which has a long-term monitoring station in the middle of the marsh.

Table 5. Incidental fish and wildlife observations at the site during all monitoring years (2014-2017).

Common name	Scientific name	Uses/notes
Great blue heron	*Ardea herodias*	Feeding in pools
Snowy egret	*Egretta thula*	Feeding in pools
Pileated woodpecker	*Hylatomus pileatus*	Feeding at snag
Osprey	*Pandion haliaetus*	Soaring
Greater yellowlegs	*Tringa melanoleuca*	Feeding in pools
Turkey vulture	*Cathartes aura*	
Black duck	*Anas rubripes*	Creek channel
Mallard	*Anas platyrhynchos*	Creek channel
Canada goose	*Branta canadensis*	Creek channel; marsh surface
Salt marsh sparrow	*Ammodramus caudacutus*	
Mink	*Neovison vison*	Feeding in channel
Coyote	*Canis latrans*	Remains (bones)
Silverside	*Menidia menidia*	Creek channel
Mummichog	*Fundulus heteroclitus*	Creek channel
American eel	*Anguilla rostrate*	Creek channel
Red-winged blackbird	*Agelaius phoeniceus*	Roosting in cattails
White-tailed deer	*Odocoileus virginianus borealis*	
Glossy ibis	*Plegadis falcinellus*	Feeding in pools
Bald eagle	*Haliaeetus leucocephalus*	

3.6 Soils Data

If applicable, soils data, commensurate with the requirements of the soils portion of the Corps Wetlands Delineation Manual (Technical Report Y-87-1 and approved regional supplements) New England District data form, should be collected after construction and every alternate year throughout the monitoring period.

Not applicable for this project.

3.7 Hydrology

CBEP collected continuous data on water levels, salinity, and other parameters at the site using In Situ AquaTroll 200 data loggers with vented cables in order to monitor tidal hydrology, which defines a specific performance standard for the project. CBEP has collected four hydrology data sets to date (Table 6). Pre-project data were collected in 2013, and again from 7/9/15 – 7/25/14. The 2013 data were used by the project engineer to characterize local hydrology. Results of the 2014 data are included in this report for comparison of pre- and post- restoration data. Post-project water level data were collected between 4/30/15 – 6/30/15. (An additional data set was collected between 8/18/15 – and 10/18/15, but is not included in this report).

Table 6. Hydrology monitoring deployments.

Dates	St. 1 (Surface Water)	St. 2 (Surface Water)	St. 3 (Groundwater)	St. 10 (Groundwater)
2013 (pre)	5/21 – 6/17*	5/21 – 6/17*		
2014 (pre)	7/9 – 8/26	7/9 – 8/26	7/9 – 8/26*	7/9 – 8/26
2015 (post)	4/30 – 6/30 8/8 – 10/15*	4/30 – 6/30 8/8 – 10/15*		5/8 – 6/30 8/18 – 9/25*

* Data sets not covered in this report.

3.7.1 Stage Height

Pre- and post- project water levels are plotted in Figures 6 and 7, with Station 1 downstream of the primary crossing #9079, Station 2 upstream of 9079, and Station 10 upstream of the secondary crossing #9078. Station 1 and Station 2 plot surface water elevations, and Station 10 plots groundwater/surface water elevations through a piezometer due to the lack of a channel. Both graphs clearly show spring/neap tide cycles.

Figure 6 illustrates the effect of tidal restriction upstream of 9079 (St. 2), with lower maximum height during spring tides and impounded water during low tide. At Station 10, water levels were generally flat and unaffected by tides, with exception of a peak associated with a > 2.5" rain event over two days in mid-August. Salinity data recorded simultaneously (see Table 8; Figure 14) confirm that tidal water did not reach the Station 10 logger during the 2014 peak.

Figure 7 illustrates the effect of the two new crossings on site hydrology and water levels. At high tide, surface water elevations are virtually identical at St. 1 and St. 2, while the surface water level upstream of 9079 fell by over 1.5 feet, allowing for complete drainage of the upstream marsh at low tide. Groundwater levels at Station 10 fell by about .5 feet, indicating improved drainage through the new embedded round pipe at 9078. The new culvert is also providing two-way flow into the upstream wetland for likely the first time in several decades. During a spring tide event in May 2015, water levels at Station 10 clearly rose and fell with the tides, confirming that tide water is now accessing the cattail stand upstream of 9078 during astronomical high tides.

Figures 8 and 9 illustrate the instantaneous difference in water levels upstream and downstream of 9079 in 2014 (Fig. 8) and 2015 (Fig. 9). The difference is calculated as the water elevation at St. 1 – the elevation at St. 2, so that a positive number would indicate tidal restriction. In 2014, instantaneous water levels differed by as much as .85 feet during a spring tide, with a difference in range of approximately 4 feet over a single spring tide cycle due to water levels at low tide typically at least 3 feet higher upstream than downstream.

In 2015, the instantaneous difference in water level at high tide was negligible, with a maximum difference of .093 feet during a spring tide event. This affirms that the project has met its hydrological performance standard: *Tidal restriction at the primary crossing ≤ .3' at Highest Observed Water.* The remaining difference in instantaneous water level at low tide is a result of the higher channel bottom elevations at Station 2 and grade controls formed by the movement of coarse grained sediments out of the system in response to the new hydrology.

Figures 10 and 11 illustrate that the effect of tidal restriction on the timing of hydrology has been eliminated as well. The obvious lag in upstream water levels in 2014 (60 minutes to reach high water, Fig. 9) is no longer evident in 2015

(Fig. 10). Figure 10 also illustrates the increase in water levels at Station 10, that are clearly associated with the diurnal high tide during the May spring tide cycle.

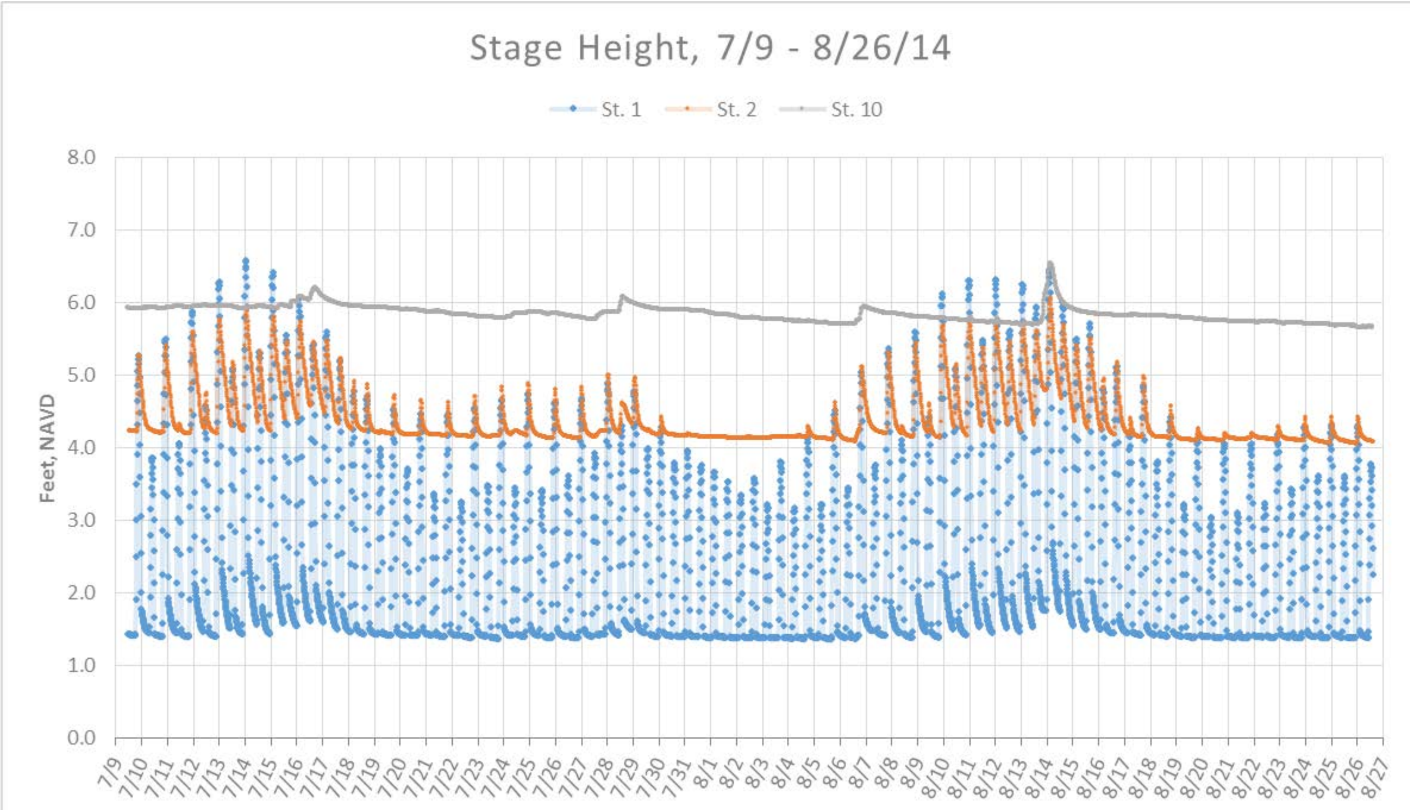


Figure 6. Pre-project water levels (2014).

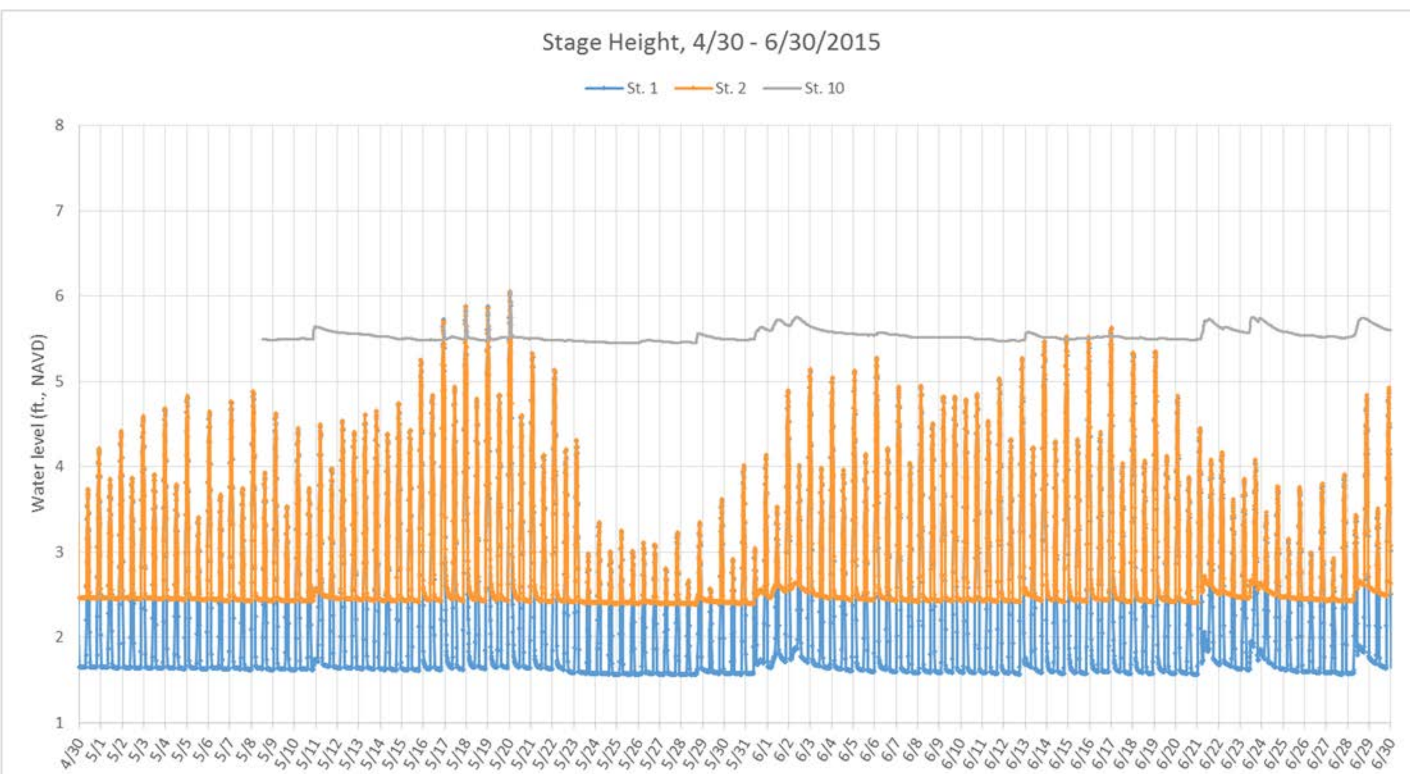


Figure 7. Post-project water levels (2015).

3.7.2 Instantaneous Difference in Stage Height

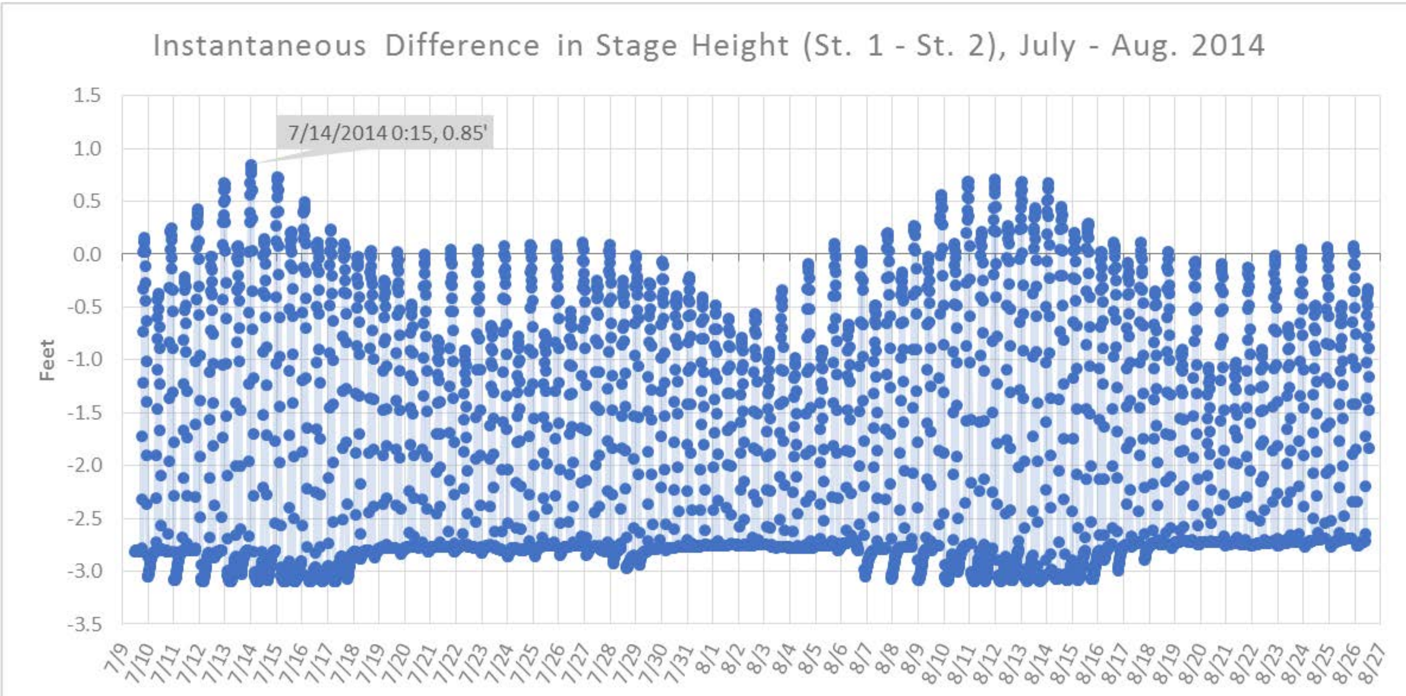


Figure 8. Instantaneous difference in stage height, pre-project (2014).

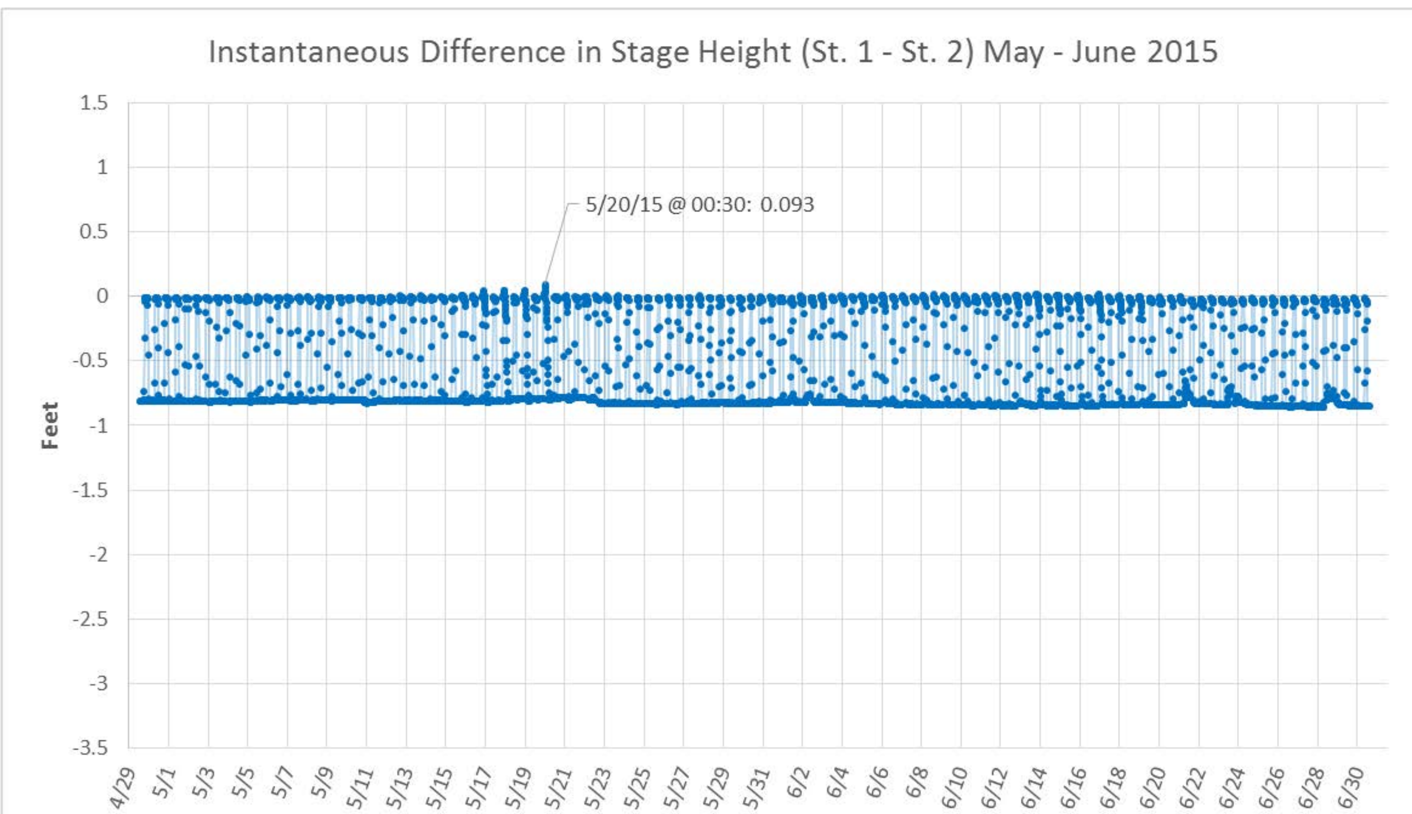


Figure 9. Instantaneous difference in stage height, post-project (2015).

3.7.3 Tidal Metrics

Tidal metrics were developed for the surface water hydrology data sets, as well as for the Portland Tide Station data during the deployment period presented for reference. Tables 7 and 8 summarize pre- and post-project tidal metrics at Station 1 and Station 2 for Mean Water Level (MWL), Highest Observed Water (HOW), Mean Higher High Water (MHHW), and Mean High Water (MHW). (Low-tide metrics were not evaluated due to the fact that the site sits in the upper end of the tide range and the wetland is primarily influenced by inundation at the upper end of the tide cycle). Elevations are provided in NAVD. NOTE: the tables summarize tidal metrics for the deployment period and should not be interpreted as datums for the site.

Over 4,600 data points were collected for the 2014 data set, and over 5,900 data points for the 2015 data set. Despite the longer deployment in 2015, the observed tidal metrics were lower across each elevation. The lower observations for MWL, MHHW, MHW, and HOW in 2015 are partially explained by the fact that the 2014 and 2015 data sets captured quite different spring tide events, based on comparison with Portland data. Another cause for this difference may be that fewer data points were collected during the neap tide phase in 2014, skewing the metrics higher. Other regional/Gulf of Maine circulation changes may also be at play.

For the pre-project data set, HOW was 6.584 at Station 1 (7/14/14), and 60 minutes later, HOW was 5.911 at Station 2, a difference of .673'. Post-project, HOW for the data set was observed to be 6.052 feet at Station 1 on 5/20/15, and 6.045 feet at Station2, with HOW occurring simultaneously. Based on the data, the project appears to have relieved the tidal restriction at the primary crossing (9079).

Portland's tide data is useful as a reference. Comparison of the 2014 and 2015 Portland Tide Station data shows that HOW was 6.783 feet during the 2014 deployment period, but just 6.203 feet during the 2015 deployment period. The 2014 data set captured unusually high tides that happened to occur during the deployment period. Comparison with epochal elevations on the Portland Tide Station Datum suggest that the 2015 data set is more representative of typical elevations at the Portland Tide Gauge, with the epochal datum MHW of 4.21 feet NAVD (compared with 4.365 at Portland, 4.245 at St. 1, and 4.262 at St. 2 for the 2015 deployment period). In contrast, MHW was 4.778' at Portland for the 2014 deployment period and 4.532 at St. 1, considerably higher than normal.

Table 7. Pre-restoration tidal metrics for the 7/9 – 8/26/2014 data set (elevations in NAVD).

7/9 – 8/26/14 (4,617 obs.)	Portland	St. 1	St. 2	Difference (St.1 - St. 2)	Difference (Portland – St. 1)
Mean water level	-0.060	2.296	4.410	-2.113	-2.357
HOW	6.783	6.584	5.911	0.673	0.199
MHHW	5.234	4.957	4.967	-0.010	0.276
MHW	4.778	4.532	4.734	-0.202	0.246

Table 8. Post-restoration tidal metrics for the 4/30 – 6/30/2015 data set.

4/30 – 6/30/2015 (5,955 obs.)	Portland	St. 1	St. 2	Difference (St.1 - St. 2)	Difference (Portland – St.1)
Mean water level	-0.290	2.281	2.841	-0.560	-2.571
HOW	6.203	6.052	6.045	0.007	0.151
MHHW	4.748	4.618	4.633	-0.015	0.131
MHW	4.365	4.245	4.262	-0.017	0.120

3.7.4 Highest Observed Water

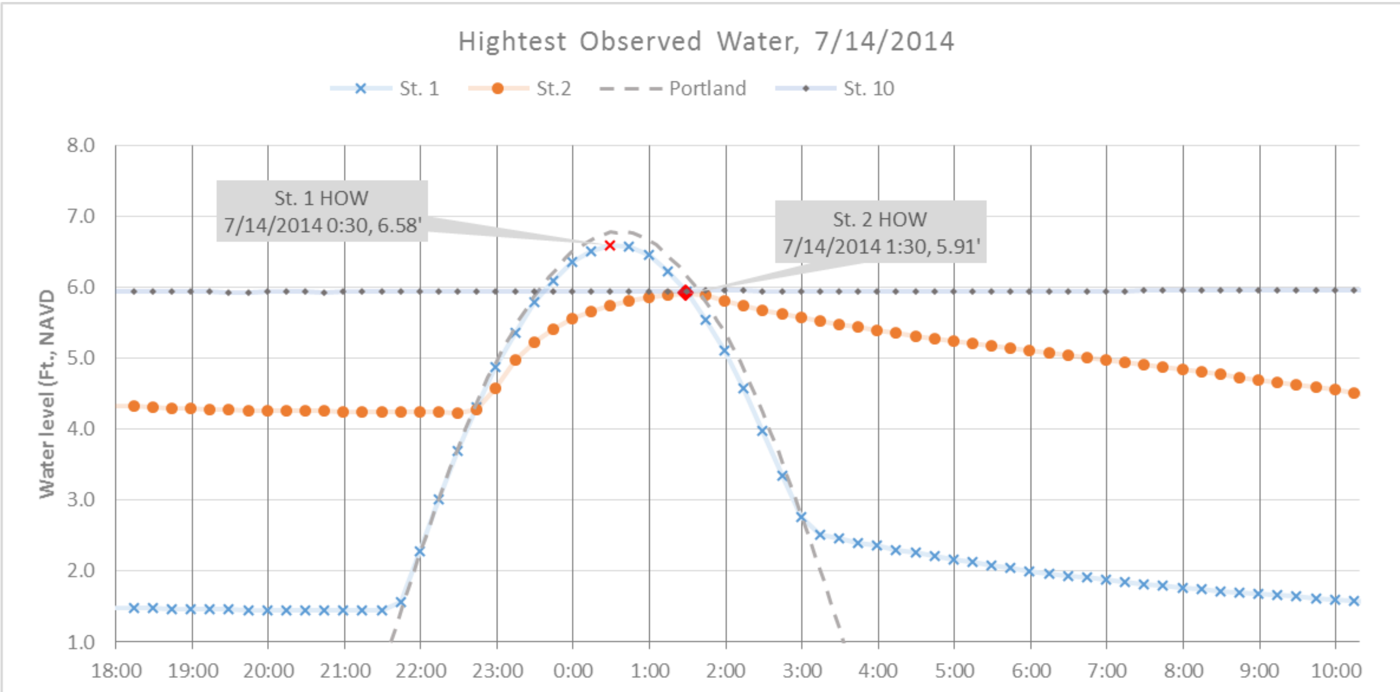


Figure 10. Highest observed water for the 2014 deployment period.

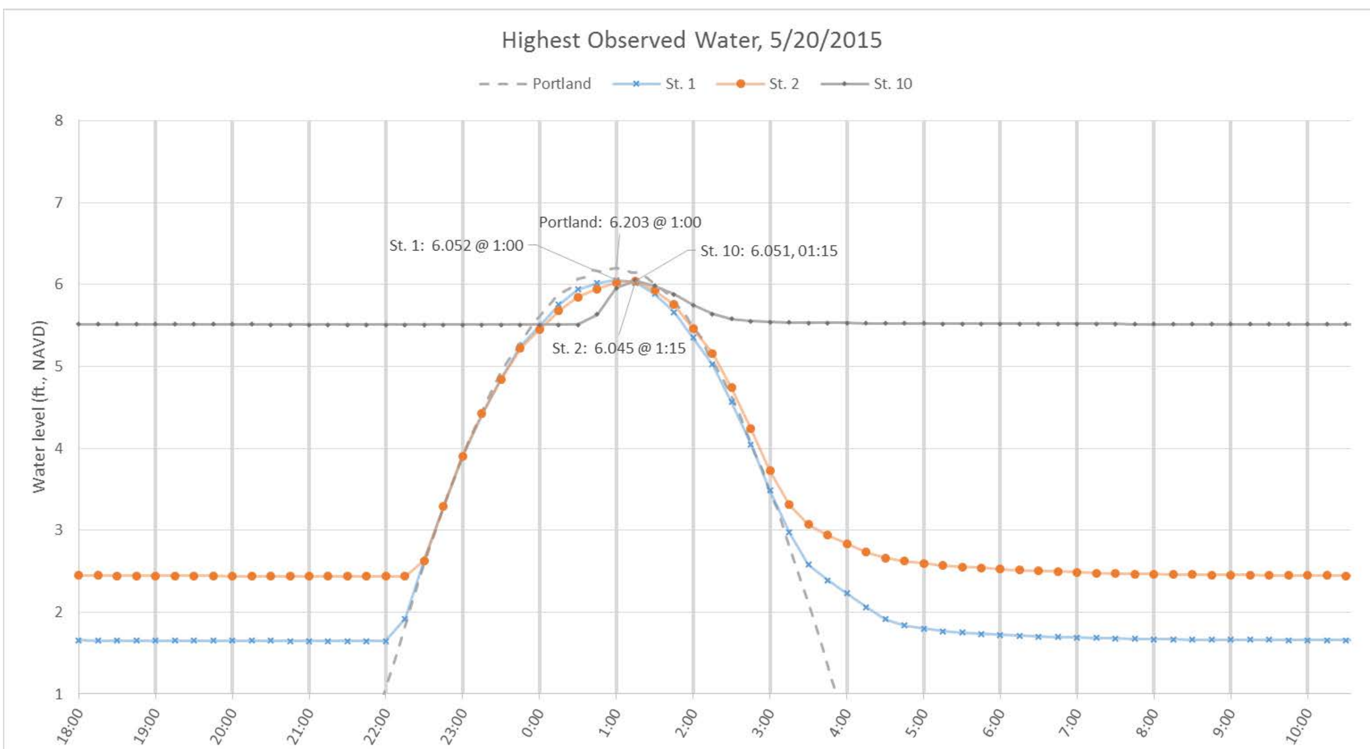


Figure 11. Highest observed water for the 2015 deployment period.

3.7.5 Corresponding High Tide Heights

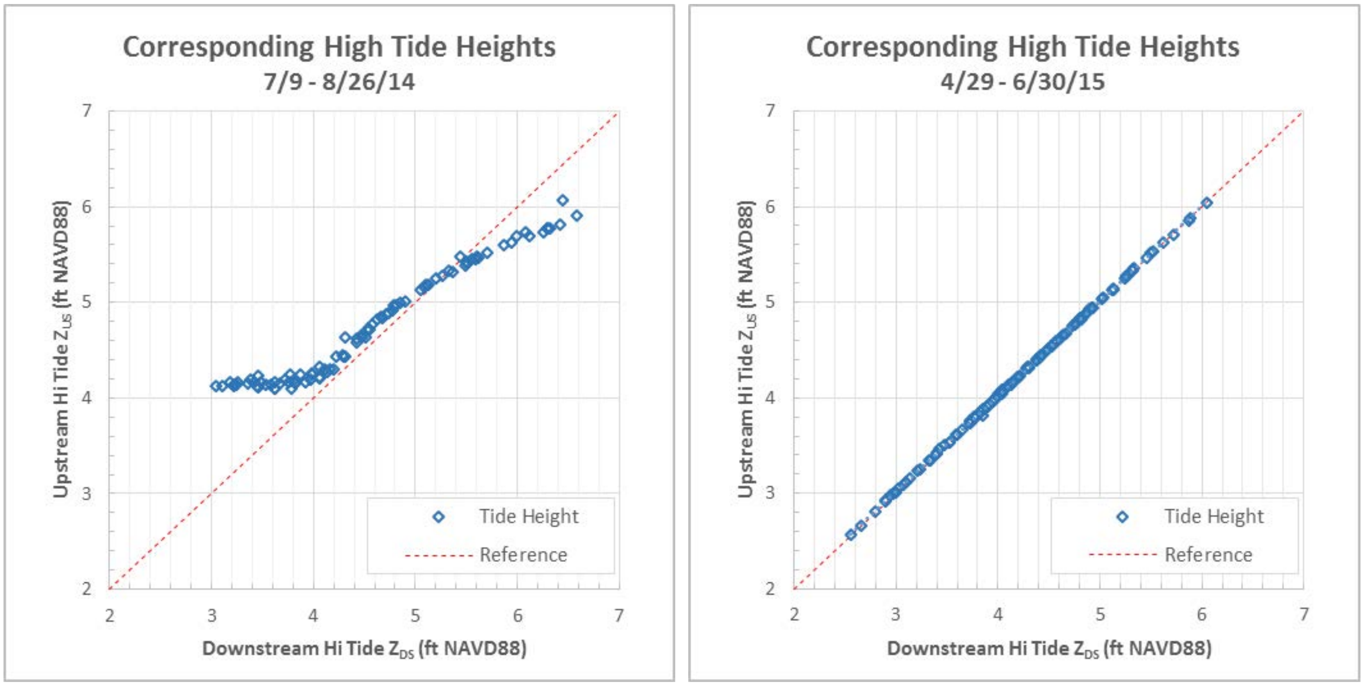


Figure 12. Plotted high tide heights upstream and downstream of 9079 pre- (L) and post- (R) project.

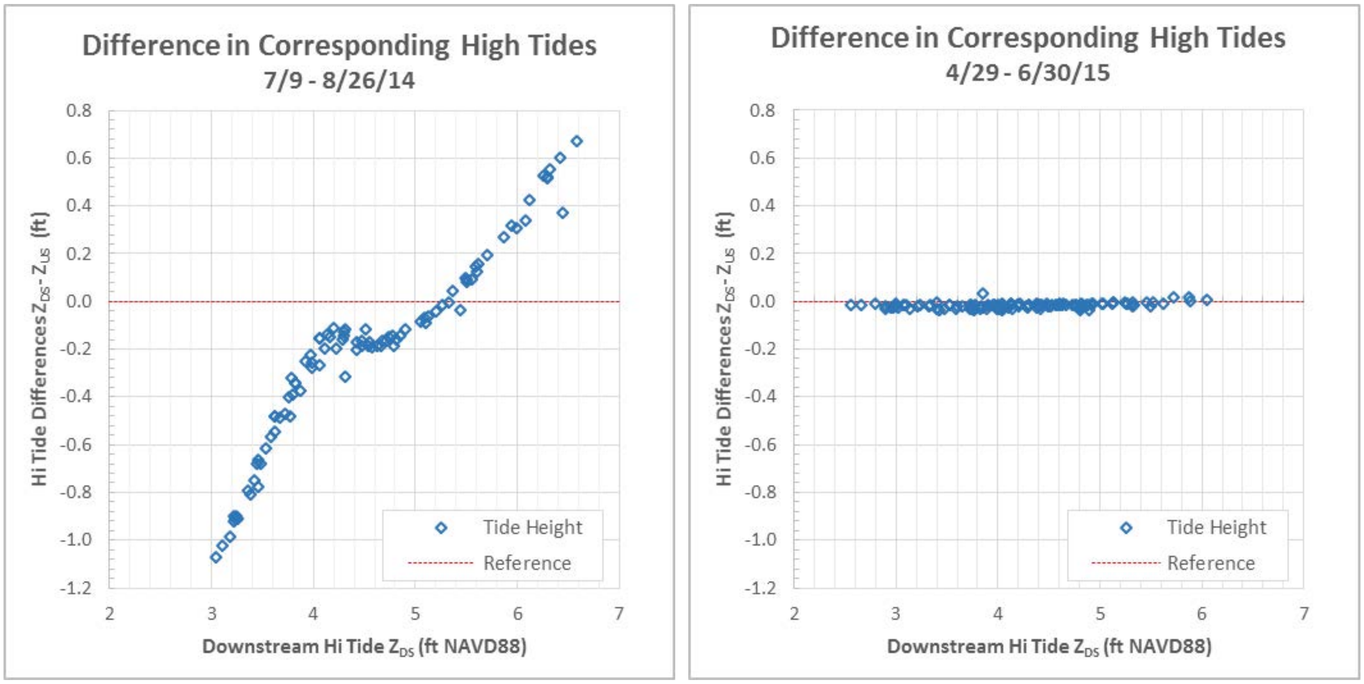


Figure 13. Difference in corresponding high tide heights pre- (L) and post- (R) project.

3.8 Salinity

CBEP monitored surface water salinity at Stations 1 and 2, groundwater salinity at Station 10, and pore water salinity at Stations 1, 3, 4, 6, 7, 8, 9, and 10.

3.8.1 Surface water salinity

Continuous surface salinity data was recorded using In Situ AquaTroll 200 loggers in conjunction with water level monitoring at Station 1 and Station 2. Fig. 14 illustrates the effect of the original crossing on salinity in the upstream surface water, which was much less variable than the surface water downstream except during rain storms. This may be explained by a combination of factors including impoundment of high salinity water upstream, stratification of water in the impoundment, and the fact that at low tide, enough groundwater was seeping into the channel to temporarily affect salinity levels in the shallow remnant pool. Fig. 15 illustrates that the new structure at 9079 has resulted in a similar level of variability in surface water salinity upstream and downstream of the crossing. [Note: manufacturer recommendations for salinity sensor calibration every three weeks were not performed in order to maintain continuous water level monitoring. Both data sets appear to show drift downward in salinity over the deployment].

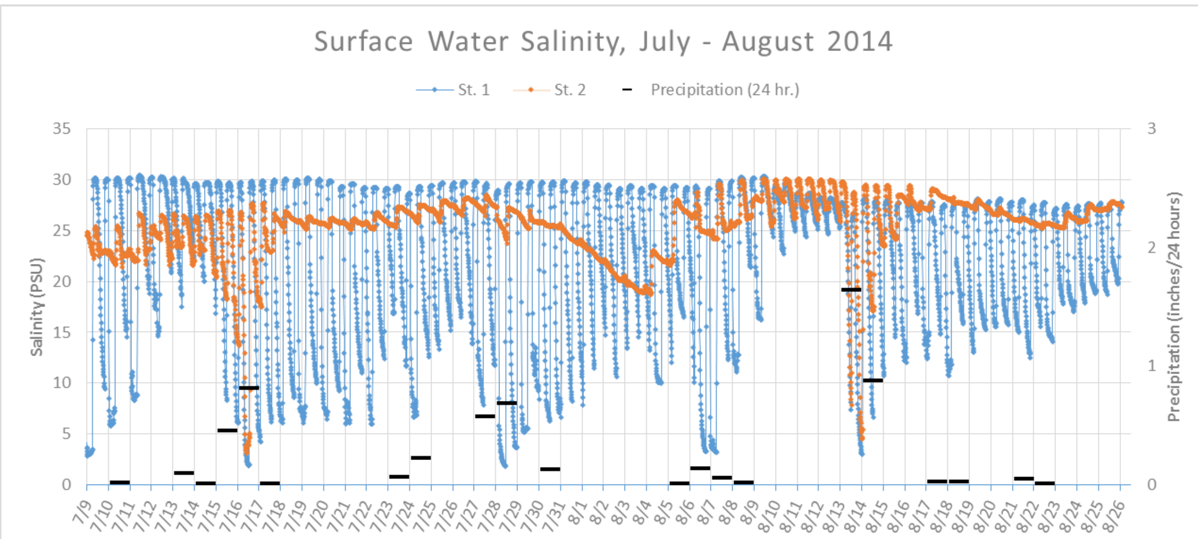


Figure 14. Pre-project surface water salinity, 2014.

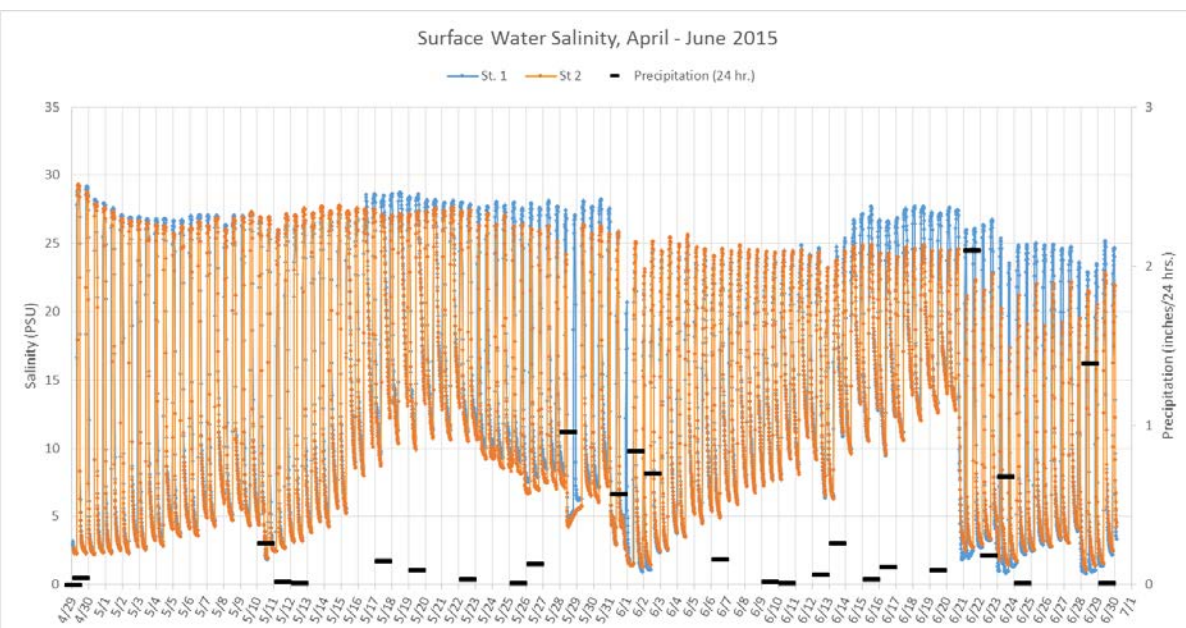


Figure 15. Post-project surface water salinity, 2015.

Tables 9 and 10 summarize the mean, minimum, and maximum salinity levels for surface water at Stations 1 and 2, and groundwater at Station 10. Mean salinity levels were higher at Stations 1 and 2 in 2014 (Table 9) than at the same locations in 2015 (Table 10). In 2014, salinity levels at Station 10 were near zero for the deployment period, but in 2015, salinity levels reached a high of 10.1 PSU (standard salinity units), despite the fact that overall site salinity was lower downstream, and there was a much lower documented HOW in 2015 than in 2014 (see Section 3.8.3). Figure 16 plots pre- and post- project salinity at Station 10 with water levels at Station 2 to illustrate the effect of high water levels on salinity upstream. Spring tides did not affect salinity levels at Station 10 in 2014, but did in 2015, indicating that tidal water moved upstream of 9078.

Table 9. Pre-project summary statistics for salinity (2014).

Location	MIN	MAX	MEAN
St. 1	1.9	30.4	21.4
St. 2	3.1	30.0	25.4
St. 10	0.0	0.7	0.2

Table 10. Post-project summary statistics for salinity (2015).

Location	MIN	MAX	MEAN
St. 1	0.8	29.2	13.7
St. 2	1.1	29.3	12.5
St. 10	0.0	10.1	4.2

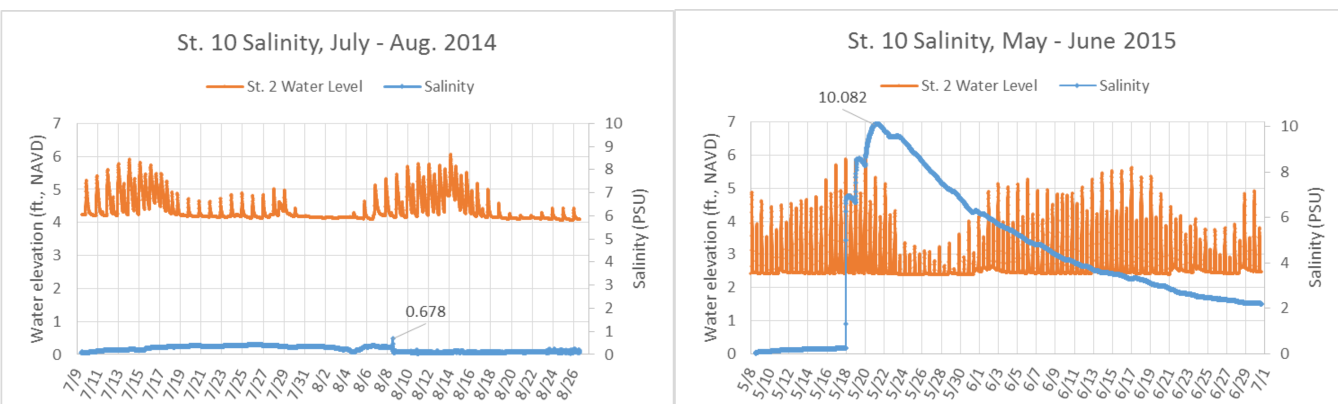


Figure 16. Comparison of pre- and post- project salinity levels at St. 10 with water levels at St. 2.

3.8.2 Pore water salinity

CBEP collected pre- and post-project pore water salinity samples from using wells constructed with PVC piping consistent with specifications provided in the *Restoration Work Plan*, which allow for samples in the root zone of salt marsh vegetation of 15-25 cm below the marsh surface. Sampling protocols call for samples to be collected at least once per month during the growing season (April – October), with samples collected using a catheter and surgical tubing, and measurements made using a calibrated hand-held refractometer. At Stations 3, 4, 6, 8, and 9, multiple wells were installed along the vegetation transect to document pore water salinity levels at various distances from the creek channel and upland edge, with lower alphabetical order (e.g., 3a, 3b) generally associated with closer proximity to the channel

Pre- and post- pore water salinity values at each well are presented in Fig. 17. Pore water salinity levels were generally as high throughout the marsh in 2017 as in 2016. At several stations, values were higher in 2017 than in any prior year of monitoring. Looking at the four years of data (pre- and post), maximum observed pore water salinity values were observed at 8 of 15 wells. This includes the two highest values observed at Station 1, the project reference site. Elevated values at the reference site are consistent with recent drought conditions in 2016 and 2017 throughout the Casco Bay region. Pore water values at Station 10 were notably higher in 2017 than in prior years, and for a longer time period.

Fig. 18 plots pore water salinity values at the project reference site (St. 1) and separately, within the project area (St. 2 – 10). Reference values are aggregated into one data set, while project area values are classified as pre- or post-project values. Trendlines were added to illustrate shifts between pre- and post- project salinity values within the project area. Polynomial trendlines were used to best fit with the downward trend in salinity values in the fall. No effort was made to account for changes in precipitation year to year. The trendlines illustrate a shift toward higher pore water salinity values throughout the project area. This shift is consistent with observed changes in the vegetation community, with the elimination of salt-intolerant plants and the increase in halophytes. The distribution and trends within the post-project data for the project area approach values observed within the project reference site.

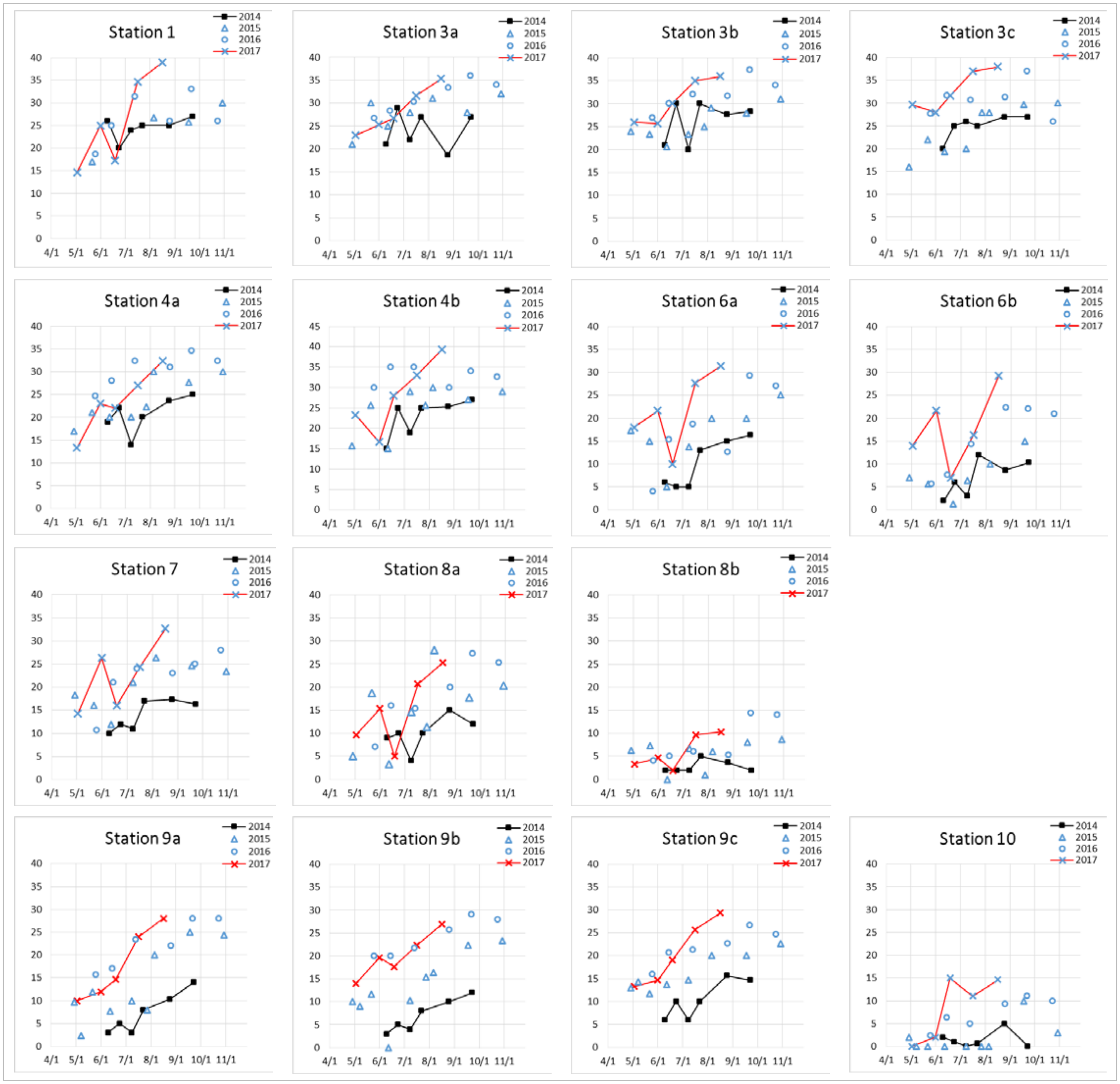


Figure 17. Graphs of pre- and post- project pore water salinity levels at individual wells.

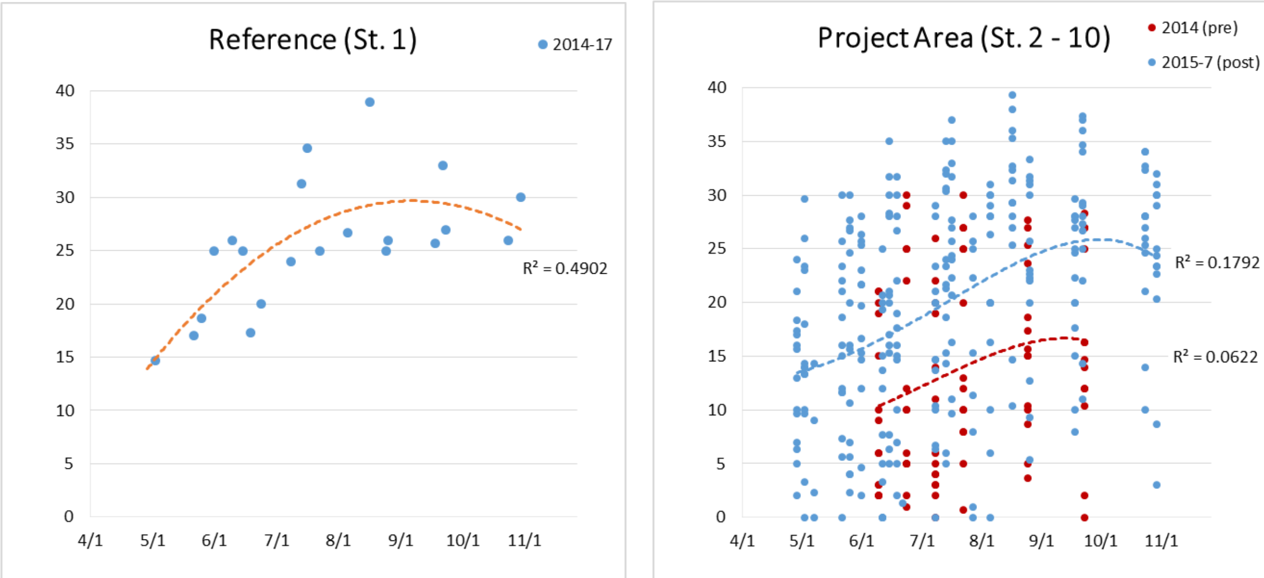


Figure 18. Plotted pore water salinity values with best fit polynomial trendlines for the project reference site (l) and the project area (r).

3.9 Channel Morphology

CBEP staff surveyed channel cross sections at Stations 1-9, as well as longitudinal profile through the construction areas, pre-project and again in 2015, 2016, and 2017. Data were entered into the *Reference Reach Spreadsheet*[1] for comparison. Fig. 19 plots the longitudinal profile of 9079 based on data collected in 2012. The profile illustrates the perched crossing (9079) at 200 feet, with accumulated sediment 50 feet upstream of the culvert outlet functioning as a grade control that impounded surface water upstream. Fig. 20 plots the profile of the channel approaching 9078 from downstream.

The 2015 longitudinal profile of the tidal creek from the bay through both project areas (9079 and 9078) is shown in Fig. 21, with elevations in feet, NAVD based on benchmark data provided by Wright Pierce. Mean high water (MHW, 4.12' NAVD) for the Portland datum is shown for context.

The channel bottom at 9079 is consistent with the channel grade upstream and downstream, and the accumulated sediment upstream is no longer evident. A series of shallow pools remains immediately downstream of 9079, and has formed immediately upstream in response to gradual movement of sediment. A small head cut was observed a little more than 400' upstream from the bay, with the channel bottom relatively flat until getting shallower between Station 8 and 9. The channel bottom at 800' (Fig. 21) has dropped by approximately 1' from the 2012 survey (50', Fig. 20). Further upstream, the channel becomes extremely shallow approaching 9078, where the slug of coarse-grained sediments (evident in both Fig. 20 and 21) sits on the marsh surface, resulting in a very shallow braided channel below the outlet of 9078. The sand is believed to have been deposited in this location during a culvert blow-out prior to any discussions about a restoration project. Local residents described a portion of the road bed washing onto the downstream marsh along with the culvert. Immediately upstream of the slug, and immediately downstream of the culvert outlet, is the area excavated during culvert installation. Here, water is pooled behind this grade control through the culvert into the excavated area upstream, above which a defined channel is no longer visible. This issue is discussed further in Section 4.2. The 2015 profile ends at the next culvert upstream (9076) beneath Shore Road.

[1] Mecklenburg, D. 2006. *The Reference Reach Spreadsheet*. Ohio Department of Natural Resources. http://water.ohiodnr.gov/portals/soilwater/data/xls/Example_of_Reference_Reach_Survey_4_0_T.xls

A 2016 longitudinal profile was surveyed by seasonal CBEP field staff, but errors are evident in the data set and cannot be verified or corrected. The plot is necessarily omitted from this report. A longitudinal profile will be surveyed in 2017.

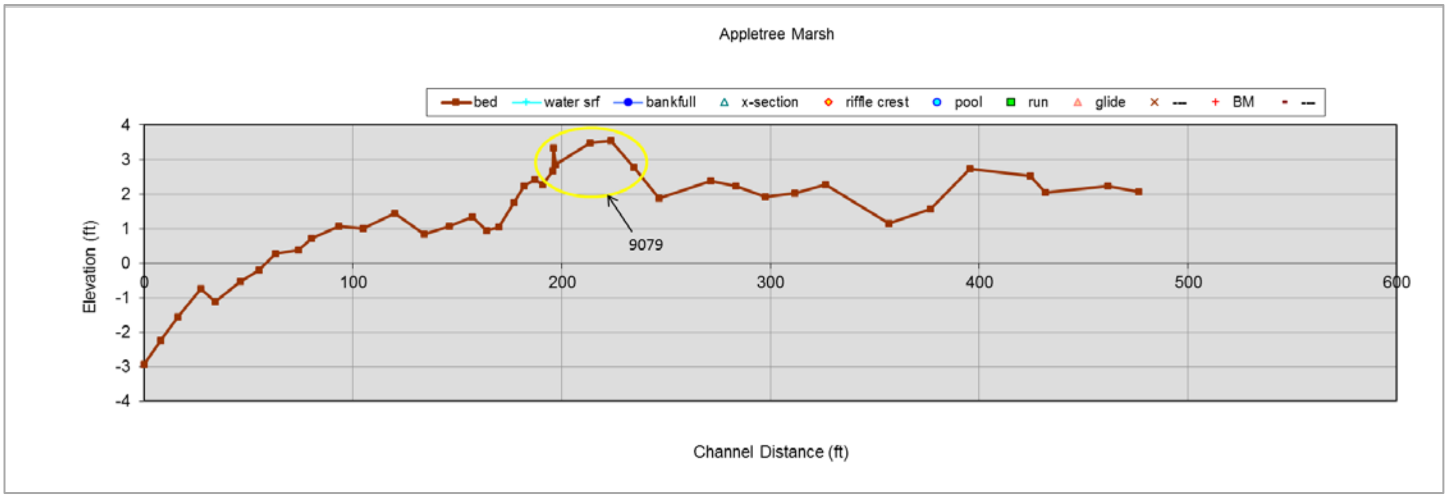


Figure 19. Pre-project longitudinal profile of 9079 (2012). Mecklenburg 2006.

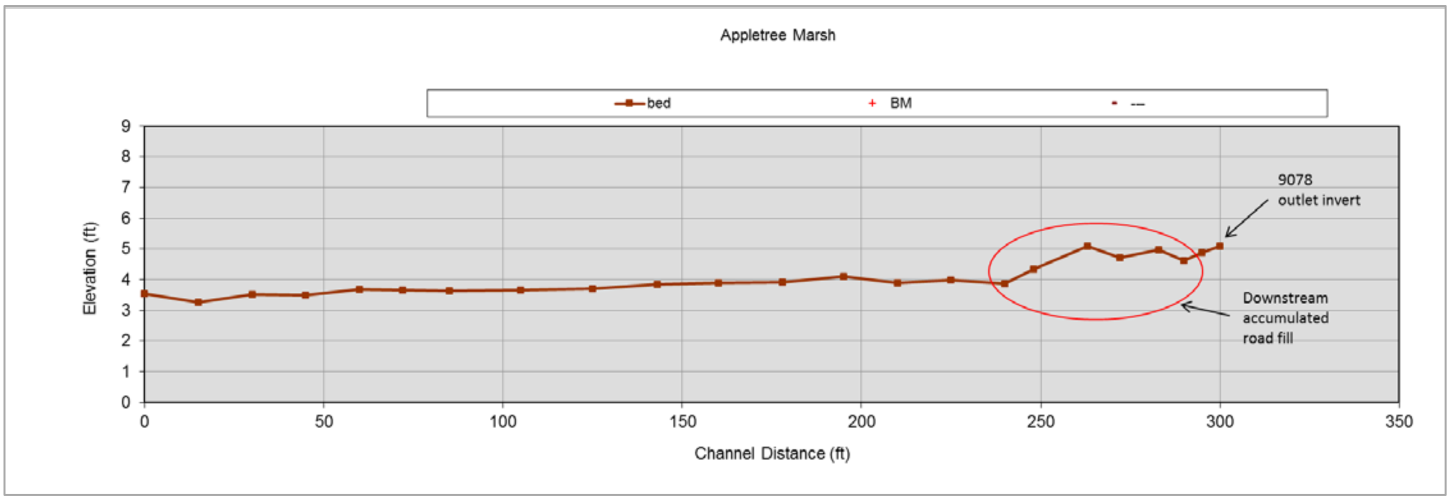


Figure 20. Pre-project longitudinal profile of 9078 (2012, downstream only). Mecklenburg 2006.

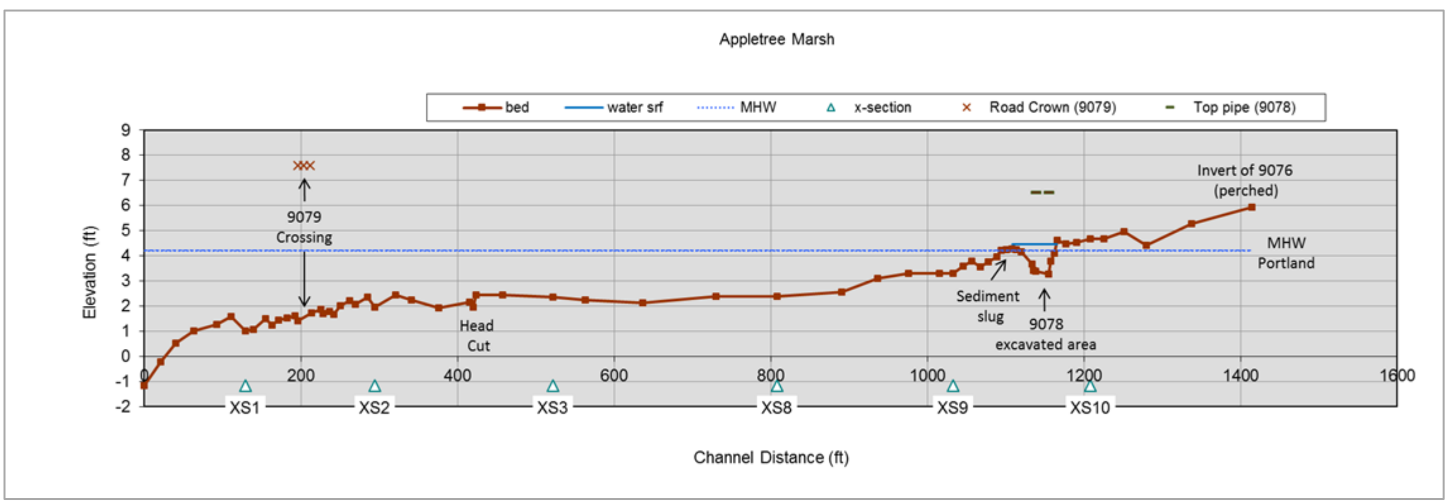


Figure 21. Post-project longitudinal profile of the tidal creek (2015). Mecklenburg 2006.

Fig. 22 plots pre- (2014) and post- (2017) project channel cross section profiles side by side using the *Reference Reach Spreadsheet* developed by Mecklenburg. Cross sections for St. 1, 9 and 10 are not shown.

Bank-full width (indicated by a blue line) was approximated using channel characteristics (elevation breaks, observations/notes) to calculate channel dimensions and cross sectional area, allowing for a roughly standardized year over year comparison of change in channel characteristics, which is useful for considering channel evolution in relation to increased inundation of the marsh surface. Elevations are approximate in feet relative to NAVD.

Generally, the plots illustrate dynamic ongoing changes to channel dimensions in response to increased tidal exchange and improved drainage out of the wetland. Cross sectional area has increased across all stations from pre-project levels, and at stations 2-9, the maximum channel depth has increased. At many stations, the channel has v-shaped angular shape, suggesting active scour and sediment mobility.

In 2015, the greatest percent increase in channel cross sectional area from pre-project occurred at Station 4 (57.6%). By volume, the greatest increase was measured at Station 3 (6.9 $ft.^2$). In 2017, although cross sectional area more than doubled at Stations 8 and 9, the northern lobe of the marsh, the channels were relatively small by comparison to begin with. The greatest total change in area was at Station 3, which increased by 7.4 $ft.^2$, indicating continued active channel response to the altered hydrology.

Selected photographs from the cross section surveys are included in the appendices. At most Stations, photographs were taken looking upstream, downstream, and from each channel bank, providing a visual record. At some Stations, additional photos were taken showing views to the upland edge.

Additional photos and cross section graphs for Stations 1, 2, and 10 are available upon request to CBEP.

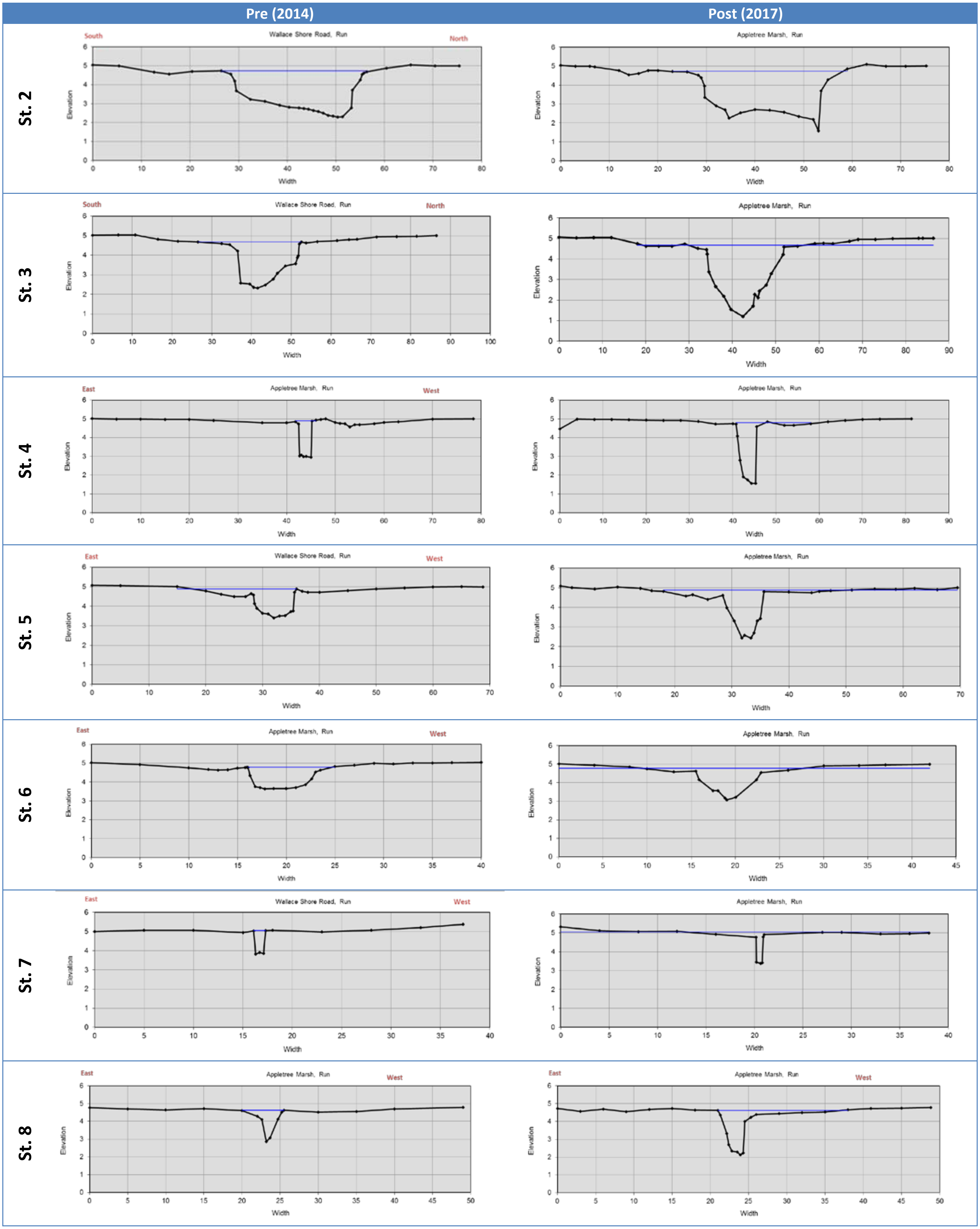


Figure 22. Comparison of pre- and post- project cross section profiles at Stations 2 - 8. Mecklenburg 2006.

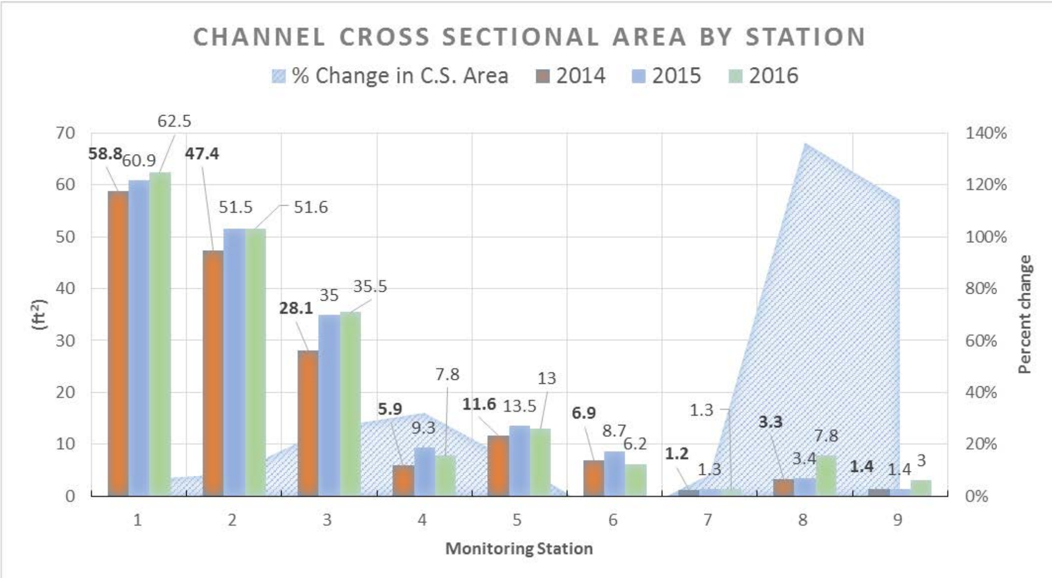


Figure 23. Comparison of channel cross sectional area pre- and year 1 post-project.

3.10 Plant Species of Concern

Monitoring for plant species of concern occurs annually through meander surveys, as well as opportunistically during vegetation surveys and other field work. Invasive species monitoring is limited to the project area, which is the marsh area affected by the 2014 tidal restoration work. CBEP did not document the presence of invasive plants in the forested area upslope of the upland edge, but they appear to be abundant under the forest canopy in some places. Neither did the surveys cover adjacent freshwater wetlands to the north and south of the wetland area influenced by the tidal restoration project.

In 2017, a meander survey for species of concern was conducted on August 8 by CBEP's seasonal field staff Tristan Taber. Fig. 24 maps observations. As in previous years, the survey documented a handful of individual *Lythrum salicaria* plants around the perimeter of the marsh. This year, loosestrife was found almost exclusively in ditches outside of the project area on the opposite side of Wallace Shore Road. The number and distribution of loosestrife plants continued to decline over prior years. All *Lythrum* plants were carefully hand-pulled and rooted prior to going to seed, then bagged and destroyed offsite.

Pre-project site assessment by MNAP (K. Puryear 2013) identified *Phragmites americanus* near the upland edge of Station 8. For the first time since 2013, *Phragmites* was again documented within the project area in 2017. Approximately 8 plants were observed near the upland edge of Station 8 (photo, above). CBEP was unable to determine whether the plants were native (*P. americanus*) or invasive (*P. australis*). CBEP requests assistance of MNAP staff to conclusively determine whether this is a native or invasive stand in order to inform management response in 2018.

Overall, the continued decline in plant species of concern is consistent with the droughts, improved freshwater drainage out of the marsh, and increased salt delivery via tidal restoration. Monitoring for invasive plants will continue in 2018.

Figure 24. 2017 observations of plant species of concern.

4. Summary and Conclusions

4.1 General Site Conditions

The December 2014 project successfully replaced road/stream crossing infrastructure at two locations on Wallace Shore Road (site 9079 and 9078) with the goal, as stated in the *Restoration Work Plan*, of restoring tidal exchange and increasing freshwater drainage, thereby improving overall hydrology, at the adjacent E2EM1P estuarine and marine wetland. General site conditions are on track with the performance standards defined by the *Restoration Work Plan*:

- All the constructed features such as slopes, soils, and substrates within the mitigation site are stable and free from erosion during the monitoring period.
- Invasive *Phragmites australis* has not been introduced to the site.
- The tidal restriction at the primary crossing, defined as the difference between highest observed water (HOW) downstream and upstream, is less than or equal to .3' based on 2015 hydrology monitoring.

Based on review of hydrology data (Section 3.8), the overarching project goal has been achieved. Data collected through monitoring of other ecological parameters, including vegetation, channel morphology, and pore water salinity, indicates that the wetland has begun to adjust to the abrupt change in hydrology (Sections 3.5, 3.9, 3.10), which is presumed to be an ongoing process. Indications of improved bidirectional flow include channel scour, lower water levels, and higher pore water salinity levels. While some parameters, such as tidal hydrology and pore water salinity, show a short-term/immediate response to the new culverts, other parameters, particularly vegetation communities and channel morphology, are responding gradually and less abruptly. The ecological response to the new hydrology is an ongoing process that will be monitoring and reported for Years 3 – 5.

4.2 Recommendations for Adaptive Management

None in 2017.

5.0 References

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

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, Amherst.

Verrill, S. 2017 (projected). *Shifting vegetation zones in response to culvert enlargement at a tidally restricted salt marsh in Harpswell, Maine.* (Unpublished master's thesis in progress). University of Southern Maine, Portland.

Appendix A – Photographs

Representative photos are required to support the findings and recommendations, for each restoration/enhancement site. Photos should be taken from the same locations for each monitoring event and must be dated and clearly labeled. A map, or maps, showing photo locations must be included and clearly labeled with the direction from which the photo was taken. Photos may be included in this appendix or in the body of the report.

CBEP staff photo-documented conditions on the marsh and at the two project areas (crossing #9079 & #9078) on multiple occasions pre-project, and at least once during years 1 and 2 post-project. A subset of these photos are organized in a set of three tables, which also include the subject, direction and date of each photo, within Appendix A. Maps showing the location of the photo stations, which include the project areas (sites 9079 and 9078), and the cross section and vegetation monitoring stations (Stations 1 – 10) are provided in the main body of the report.

Tables 11 and 12 compare pre-project and 2016 comparisons of conditions at the two project locations, 9079 and 9078. Additional photos (for example of the road approach, or certain details) are available upon request.

Table 13 presents pre/post photos at cross sections survey locations (Stations 1 – 9). Additional photos showing alternate views of the cross section surveys may be available. Photographs for Station 10 are presented in Table 14, for the vegetation surveys.

Table 14 presents pre/post photos along the transects at vegetation monitoring stations (Stations 1 – 10). Additional photos showing photos in the opposite direction (e.g., from the upland toward the channel) are available for each Station.

Table 11. Photos of project area, crossing #9079 (crossing nearest to bay). Photos reflect conditions at low tide.

Site 9079, Pre-Project	**Site 9079, Post-Project**
View Downstream (Est). Dates (L to R): 7/31/2012; 2017.	
	
View to Outlet (West). Dates (L to R): 7/31/2012; 2017	
	
View to Inlet (East). Dates (L to R): 7/31/2012; 2017	
	
View Upstream (West). Dates (L to R): 7/31/2012; 2017	
	

Table 12. Photos of project area, crossing #9078 (crossing nearest to upland). Photos reflect conditions at low tide.

Site 9078, Pre-Project	**Site 9078, Post-Project**
View Downstream (South). Dates (L to R): 7/23/2012; 2017	
	
View to Outlet (North). Dates (L to R): 7/28/2014; 2017	
	
View to Inlet (South). Dates (L to R): 7/28/2014; 2017	
	
View Upstream (North). Dates (L to R): 7/23/2012; 2017	
	

Table 13. Photos from cross section surveys. Photos reflect conditions at or near low tide.

Pre-Project	**Post-Project**
Station 1 (L – 7/31/2012; R – 2017); view to E/SE. Outlet to bay in the background.	
	
Station 2 (L - 7/25/2014; R – 2017); view to E. Inlet of 9079 in background.	
	
Station 3 (L – 7/9/2014; R – 2017); view to W, looking upstream from 9079.	
	
Station 4 (L – 7/9/2014; R – 2017); view to S, toward St. 5, 6, and 7.	
	

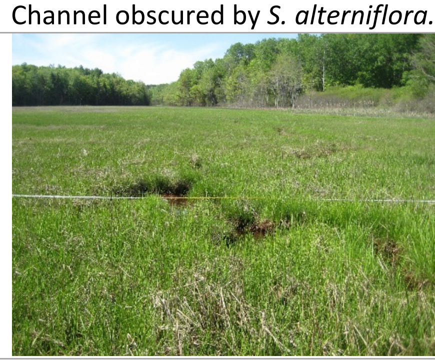
<table>
<tr><th>PRE-PROJECT</th><th>POST-PROJECT</th></tr>
<tr><td colspan="2">Station 5 (L – 7/9/2014; R – 2017); view to N, toward St. 4.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 6 (L – 7/9/2014; R – 2017); view to N, toward St. 4 & 5.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 7 (L – 7/9/2014; R – 2017); view to S. Channel obscured by vegetation.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 8 (L – 7/25/2014; R – 2017); view to S toward St. 4, 5.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 9 (L – 7/25/2014; R – 2016); view to S toward St. 8. Channel obscured by S. alterniflora.</td></tr>
<tr><td></td><td></td></tr>
</table>

Table 14. Photos from vegetation surveys.

<table>
<tr><th>PRE-PROJECT</th><th>POST-PROJECT</th></tr>
<tr><td colspan="2">Transect 1a. (L – 7/15/2014; R - 2017); view S/SW from channel to upland.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 1b. (L – 7/15/2014; R – 2017); view N from channel to upland/gravel parking lot.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 2. (L – 7/15/2014; R – 2017); view N from channel toward upland.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 3. (L – 7/15/2014; R – 2017); view N from channel to upland.</td></tr>
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</table>

<table>
<tr><th>PRE-PROJECT</th><th>POST-PROJECT</th></tr>
<tr><td colspan="2">Transect 4. (L – 7/17/2014; 2017); view E from channel to upland.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 5. (L – 7/17/2014; R – 2017); view E from channel to upland.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 6. (L – 7/17/2014; R – 2017); view E from channel to upland.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Station 7. (L – 7/17/2014; R – 2017); view E from W end of transect.</td></tr>
<tr><td></td><td></td></tr>
</table>

Pre-Project	**Post-Project**
Transect 8. (L – 7/15/2014; 2017). L - view E from upland to channel; R - view W from channel to upland.	
	
Station 9. (L – 7/15/2014; R – 2017). View W from channel to upland.	
	
Station 10. (L – 7/15/2014; R – 2017). View E from W end of transect.	
	

Appendix B – Maps

A map or maps should be attached to each monitoring report showing the boundaries of the restoration/enhancement area(s) relative to other landscape features on the site, habitat types, locations of photographic reference points, transects, sampling data points, and/or other features pertinent to the restoration/enhancement plan and monitoring events. Geographic coordinates are helpful in locating the site(s) for inspection purposes.

All maps are included within the main body of the report. Monitoring stations are georeferenced and GPS coordinates are available upon request to CBEP.

Appendix C – Plans

If alterations were made to the approved restoration/enhancement plan due to conditions found in the field, as-built plans showing appropriate topography for type of restoration, structures including any inlet/outlet structures, grading, etc. must be submitted. These need only be submitted once and may be included in future monitoring reports by reference. If plantings were part of the plan, location and extent of the designed plant community types (e.g., shrub swamp) should be included. Within each community type the plan shall show the species planted—but it is not necessary to illustrate the precise location of each individual plant. There should also be a soil profile description and the actual measured organic content of the topsoil. This should be included in the first monitoring report unless there is grading or soil modifications or additional plantings of different species in subsequent years.

No modifications were necessary due to unforeseen conditions in the field, so the project was constructed within the parameters of the final engineering designs as presented in the *Wallace Shore Road Restoration Work Plan.*

Appendix D – Plant List

As applicable, a vegetative species list of volunteers in each plant community type. The volunteer species list should, at a minimum, include those that cover at least 5% of their vegetative layer.

A comprehensive list of vegetation identified during vegetation surveys is provided in the main body of the report, and a list of invasive plant species observed is provided in Section 3.11. Since this project did not involve planting vegetation, and the community type is already present on the site, the monitoring plan was not designed to document volunteer species within each community type.