Suffolk County Peconic Estuary Program
Conceptual Habitat Restoration Designs

Narrow River Tide Enhancement and Phragmites Management
Orient, Town of Southold

Prepared For:

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1 EXECUTIVE SUMMARY

The Narrow River *Phragmites* Control and Hydrological Restoration was one of forty-one (41) priority habitat restoration projects identified in the 2017 PEP Habitat Restoration Plan by the PEP Habitat Restoration Workgroup. The marshes in the headwaters of Narrow River are dominated by the invasive plant *Phragmites australis,* including the 113.4-acre Broad Meadows Marsh property (part of New York State's Long Beach Bay State Tidal Wetlands Preserve) and the Town of Southold's 16.4-acre Whitcom Marsh Preserve. Tidal exchange between Narrow River and Broad Meadows Marsh is restricted by an earthen berm with double 2.6-foot culverts located at the downstream end of Broad Meadows Marsh. This earthen berm and the contiguous berms located to the east of Narrow River and surrounding the perimeter of the Latham Farm to the east were constructed in the aftermath of the 1938 Hurricane, with the culverts installed later to allow the marshes to drain. Downstream of the earthen berm, the tidal reaches of Narrow River feature intact and high-functioning tidal marshes that support an important commercial shellfishery, provide estuarine nursery and feeding habitat for finfish species, and provide habitat for overwintering waterfowl, among other ecological benefits.

Narrow River has two culverted crossings in the project area: the double 2.6-foot culverts within the earthen berm and a 1.5-ft culvert that conveys waters under Route 25 from the Town of Southold Whitcom Marsh Preserve to Broad Meadows Marsh. There are also three culverts that convey tributary drainage under Narrow River Road (2 culverts) and Route 25 (1 culvert).

At the downstream end of Broad Meadows Marsh, the double 2.6-foot culverts with flap gates are undersized and restrict tidal flows to the upstream marsh. The tidal range upstream of these culverts is reduced to approximately 1.0-1.5 feet, compared to 2.5-3.5 feet in downstream reaches of Narrow River; and the lowest low tides downstream of the culvert are not matched upstream of the culvert.

The Route 25 culvert (1.5-ft diameter) that conveys the headwaters of Narrow River from Whitcom Marsh Preserve to Broad Meadows Marsh has an upstream invert elevation of 1.0 feet NAVD88, and a downstream invert elevation of -0.1 feet NAVD. This culvert is perched approximately 0.7 feet above the ordinary water level downstream of the culvert. These conditions present a barrier for fish and aquatic organisms at certain periods of low flow. The small size of this culvert restricts water flow, resulting in backwater upstream of the culvert and deposition of sediment, rather than allowing the natural flow of water and sediment to move into the downstream marsh and estuary.

Multiple modifications to the culverts and road crossing infrastructure adjacent to Broad Meadows marsh are recommended to 1) increase salinity and tidal range within Broad Meadows Marsh and 2) improve ecological and hydraulic function of the Route 25 culvert, while minimizing potential flooding hazards to adjacent infrastructure and private property. Removal of the tidal barrier presented by the double culvert and earthen berm could result in ecological recovery of the *Phragmites*-infested marshes through conversion to tidal or brackish marsh.

However, the earthen berm present at the downstream end of Broad Meadows Marsh is critical for preventing the flooding of Narrow River Road, Route 25, and private lands during storm events and will continue to do so under future sea level rise scenarios. Potential impacts to Route 25 are particularly critical as it is the only access route to Orient Point and the Orient Point ferry terminal, and is essential for transit of police, fire, and emergency vehicles and personnel. Accordingly, marsh restoration actions must either maintain the earthen berm or replace the flood protection benefits that it provides by modifying or increasing the resiliency of adjacent roadways and private property to coastal storms and sea level rise.

This study recommends replacement of the double 2.6-ft culverts in the earthen berm with four (4) self-regulating tide gates that would increase the typical tidal range within the marsh, but would block higher tides and storm flows that would inundate roads and property. Self-regulating tide gates are metal gates attached to the downstream end of 5 ft x 5 ft reinforced concrete box culverts. The gates are open for the incoming tide until the water levels exceeds the designed threshold water elevation, at which point the gates close, not allowing continued filling of the marsh upstream of the culverts. As the tides downstream subside, the gates open again to allow the upstream marsh drain. The concrete box culverts and tide gates would be built into a concrete headwall, with approximately 15 feet between each gate.

The existing 1.5-foot culvert pipe under Route 25 is undersized and perched on the downstream end. This study recommends replacement of the culvert with a three or four-sided concrete box culvert to improve fish and aquatic organism passage, passage of terrestrial organisms, and hydrology. The recommended culvert would have natural substrate within the bottom of the culvert for habitat and organism passage and a floodplain bench to provide terrestrial organism passage, reducing possible mortality from crossing the road.

This study and the conceptual plans developed identify general locations and dimensions of the recommendations, concept-level construction costs, and environmental permitting requirements. Detailed engineering and modeling will be necessary during the construction phase to determine final crossing dimensions, grading elevations, and specifications.

This study and development of conceptual plans for modifications to the earthen berm and Route 25 culverts within Narrow River contribute to the implementation of actions identified in the 2001 Peconic Estuary Comprehensive Conservation and Management Plan (CCMP). Specifically, this project contributes to CCMP’s Habitat and Living Resources Actions HLR-7 (Develop and Implement an Estuary-wide Habitat Restoration Plan) and HLR-8 (Develop and Implement Specific Restoration Projects).

2 EXISTING CONDITIONS

2.1 General Site Description and Background

The Hurricane of 1938 (i.e. the Long Island Express) caused major damage to this area of Orient (Town of Southold). The existing berms adjacent to Narrow River and surrounding the perimeter of the Latham Farm were constructed in the aftermath of the 1938 storm without culverts to provide drainage of the headwaters of Narrow River to its tidal reaches. By the 1950s, subsequent hurricane(s) resulted in more flood damage. The various culverts were constructed to allow the impounded marshes by the earthen berms to drain. The existing double culvert at the downstream end of Broad Meadows Marsh was installed in the 1980s (*J. Sepenowski, pers. comm.).*

The marshes on the 113.4-acre Broad Meadows Marsh property (part of New York State's Long Beach Bay State Tidal Wetlands Preserve) and the Town of Southold's 16.4-acre Whitcom Marsh property are dominated by the invasive plant *Phragmites australis*. A LiDAR-based topographical map of Broad Meadows Marsh showing the low-lying farmlands to its east and west, adjacent road infrastructure (Narrow River Road to the west and Route 25 to the north), and peripheral earthen berms is provided on Figure 1. Property boundaries for New York State and Town of Southold parcels are shown on Figure 2. Broad Meadows Marsh is impounded at its downstream end by an earthen berm approximately 230 feet long. The trapezoidal berm is approximately 62 feet wide at its base and 25 feet at the top. The berm is approximately 10.8 feet in height with the top of the berm at El. 6.1 NAVD88, approximately 6.3 feet above mean tide level. This 230-foot long berm adjoins another 5,700 linear feet of berm along the southern margin of Latham Farm. Portions of this earthen berm were breached during Hurricane Sandy in 2012 and subsequently restored pursuant to NYSDEC Permit ID# 1-4738-04295/00001.

Downstream of the 230-linear foot earthen berm are the tidal reaches of Narrow River featuring intact and high-functioning tidal marshes. The Narrow River and its tidal wetlands (as well as the Broad Meadows and Whitcom Marsh complex) border the tidal reach of the Narrow River downstream of the earthen impoundment and are part of the Orient Harbor Significant Coastal Fish and Wildlife Habitat. Orient Harbor and its tributaries are of statewide significance due to the presence of an important commercial shellfishery, habitat provided for overwintering waterfowl, and estuarine nursery and feeding habitat provided for many finfish species.

Removal of the tidal barrier presented by the earthen berm at the downstream end of Broad Meadows Marsh could result in ecological recovery of the *Phragmites*-infested marshes through conversion to tidal or brackish marsh. Alternatives for removal of tidal barriers considered under this conceptual planning assessment include modification of culverts or complete removal of the culvert and earthen dike. *Phragmites* control and wetland restoration in Narrow River was one of forty-one (41) priority habitat restoration projects identified in the 2017 PEP Habitat Restoration Plan by the PEP Habitat Restoration Workgroup. This project was identified as a "high priority" restoration project in the 2017 PEP Habitat Restoration Plan. This study and development of conceptual plans for modifications to the earthen berm and Route 25 culverts within Narrow River contribute to the implementation of actions identified in the 2001 Peconic Estuary Comprehensive Conservation and Management Plan (CCMP), specifically the CCMP's Habitat and Living Resources Actions HLR-7 (Develop and Implement an Estuarywide Habitat Restoration Plan) and HLR-8 (Develop and Implement Specific Restoration Projects).

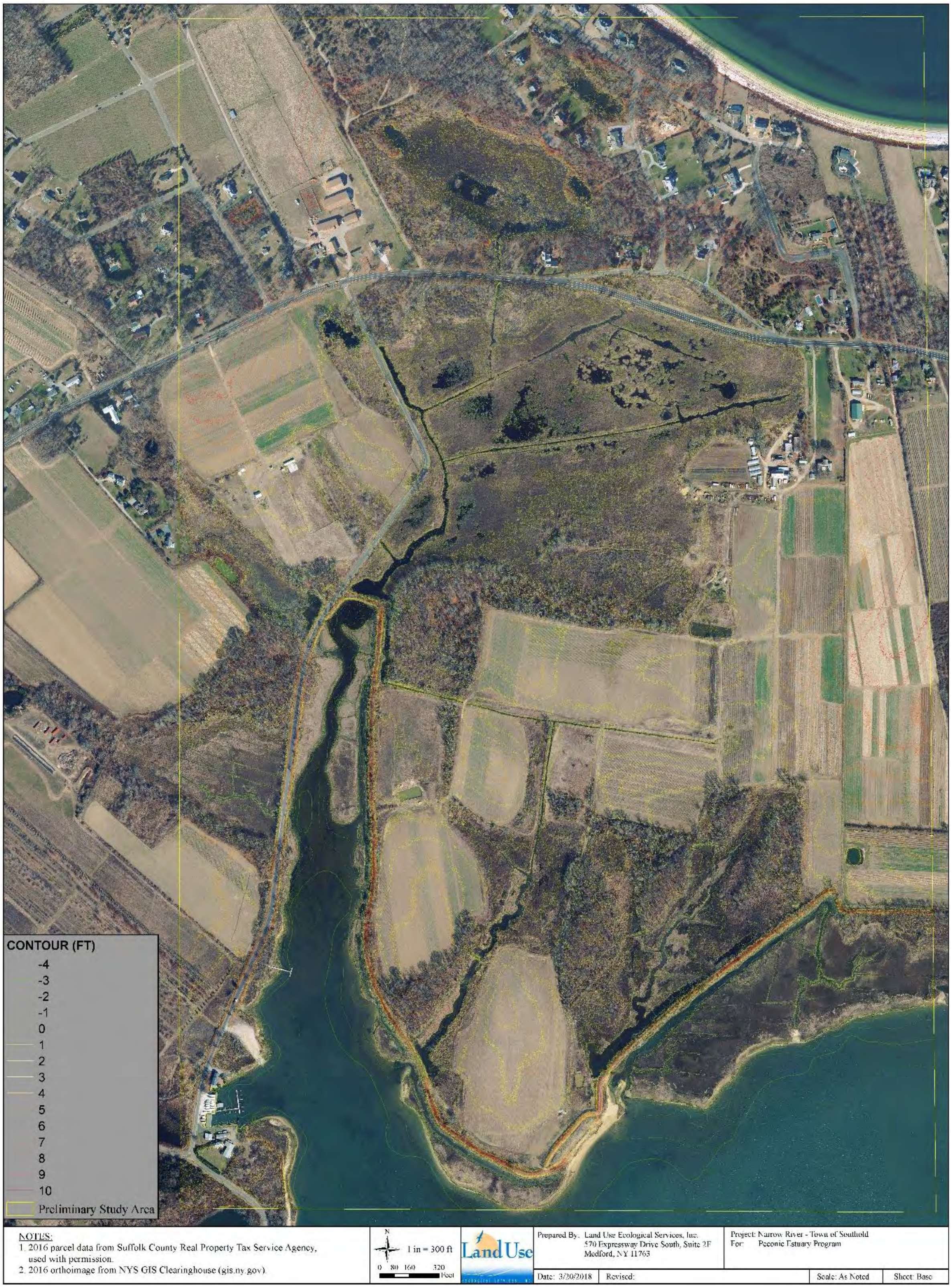


Figure 1: Narrow River topography utilizing 2016 USGS CoNED Topobathymetric Model (1887 - 2016): New England, obtained from the NOAA Data Access Viewer. Contour tool utilized in ArcMap on DEM.

Figure 2: Parcel ownership within the project area. Parcel data obtained from Suffolk County Real Property Tax Service Agency, used with permission.

2.2 Culvert Inventory and Evaluation

Narrow River has two culverted stream crossings within the project area at Route 25 and the earthen berm along with three culverts that convey tributary drainage under Narrow River Road (2 culverts) and Route 25 (1 culvert). The location of all culverts is shown on Figure 3 and the invert elevations and dimensions of each culvert is provided on Table 1.

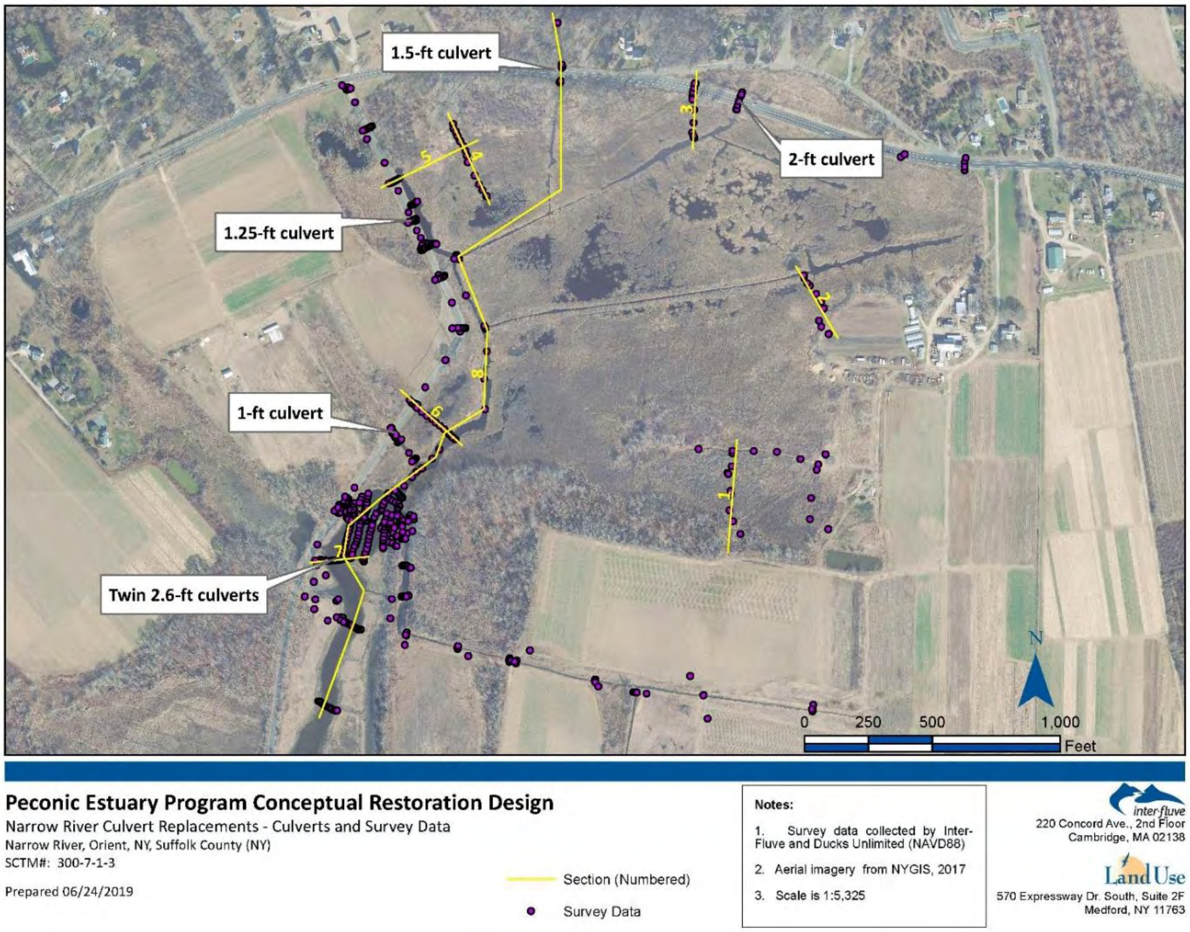


Figure 3: Survey data collected by Inter-Fluve (2018) and Ducks Unlimited (2019). Yellow lines indicate the location of cross sections (1-7) and a longitudinal profile (8) analyzed in figures below.

Route 25 Crossing

The headwaters of Narrow River flow from the Town of Southold Whitcom Marsh Preserve to Broad Meadows Marsh through a 1.5-foot culvert under Route 25 (Figure 4). The culvert slope is currently approximately 2%, with the upstream invert at elevation 1.0 feet and the downstream invert at elevation -0.1 feet NAVD88. Ordinary high water marks were identified at approximately the invert elevation on the downstream side and the culvert is perched approximately 0.7 feet. These conditions present a barrier for fish and aquatic organisms at certain periods of low flow. The small size of this culvert restricts water flow, resulting in backwater upstream of the culvert and deposition of sediment, rather than allowing the natural flow of water and sediment to move into the downstream marsh and estuary. In addition, the elevation and slope of the culvert do not allow tidal fluctuations from entering the upstream channel, maintaining an artificially fresh water system.

Route 25 and Narrow River Road Drainage Culverts

Three smaller culverts ranging in diameter from 1 to 2 feet are located along the edges of the marsh and convey water from the wetlands under Route 25 and the Narrow River Road.

Earthen Berm Crossing

At the downstream end of the project, two 2.6-foot culverts convey flow through an earthen berm, allowing some movement of fresh and tidal water. These culverts have flap gates on the downstream end, but these are likely not functioning as desired due to debris jamming. The upstream invert of the pipes is elevation -2.5 feet and the downstream invert is elevation -2.7 feet, resulting in a 0.4% slope over approximately 47 feet of culvert length. The Cornell Cooperative Extension completed a study on this site that included monitoring water elevations using water level loggers (CCE, 2000). One of the primary findings of this study was that the typical tidal range of 2.5 to 3.5 feet in the tidal reach of Narrow River is reduced to approximately 1.0 to 1.5 feet upstream of these twin culverts. This suggests that the culverts are undersized and unable to convey the full tidal fluctuations in this area. The lowest low tides downstream of the culvert are not matched upstream of the culvert. Since the upstream culvert invert is nearly a foot lower in elevation than MLLW of -1.6 feet, the pipes either get clogged at low tide or are too small to fully flush the low tide out of the upstream marsh before the high tide returns on the downstream side.

Figure 4: Culvert at Route 25 crossing.

Table 1: Narrow River and Broad Meadows Marsh Culvert Inventory

Culvert	Diameter (ft)	Upstream Invert Elevation (ft)	Downstream Invert Elevation (ft)	Slope (%)
Route 25 culvert	1.5	1.0	-0.1	2
Twin culvert at earthen berm	1.6	-2.5	-2.7	0.4
SR 25 culvert #2	2.0	-0.4	-1.5	1.9
NRR culvert #1	1.25	-1.2	-2.0	2.5
NRR culvert #2	1.0	-2.4	-2.6	0.6

2.3 Tides and Tidal Datums

Tidal datums from the nearby NOAA tide gauge at Orient Harbor were obtained and converted to NAVD88 to be consistent with this project's survey data. SHW, MHHW, MHW, MTL, MLW, and MLLW based on the Orient Harbor tide station (Station ID#8511671) are provided in Table 2. The tidal range indicated by this conversion is approximately 3.04 feet, consistent with the range described in the Cornell study (Table 2). Our survey data also corresponded well with the conversion of tidal datums as our surveyed MLLW was -1.8 feet as compared to the datum's -1.6 feet. As described above, the Cornell study recorded water levels downstream and upstream of the earthen berm, finding that the culverts reduced the tidal range by up to 1.5 feet upstream of the berm. Additional long-term monitoring of water levels was not part of this project's scope, but deployment of multiple water level loggers is recommended for the next phase of engineering design and modeling to further understand the existing hydrologic interactions within the site. If the full tidal range were restored to the upstream marsh, the Narrow River Road would be inundated multiple times a day as the road is as low as 0.85 feet NAVD88 in some locations compared to the MHW (1.12 feet) and MHHW (1.44 feet) elevations (Table 2).

Table 2: Tidal elevations at Orient Harbor (NOAA Tide Station ID# 8511671).

Elevation	Orient Harbor NAVD88 (ft)
Mean Spring High Water (SHW)	1.63
Mean Higher High Water (MHHW)	1.44
Mean High Water (MHW)	1.12
Mean Tide Level (MTL)	-0.14
Mean Low Water (MLW)	-1.4
Mean Lower Low Water (MLLW)	-1.6

2.4 Ecological Conditions

Phragmites Marshes

The marshes on the 113.4-acre Broad Meadows Marsh property (part of New York State's Long Beach Bay State Tidal Wetlands Preserve) and the Town of Southold's 16.4-acre Whitcom Marsh property are dominated by invasive *Phragmites australis*. Approximately 55 acres of *Phragmites* monoculture marshes are located in Broad Meadows Marsh upstream of the earthen berm, as shown on Figure 5. There are no significant stands of native tidal wetland communities within Broad Meadows Marsh. The northeastern corner of the Broad Meadows Marsh property consists of successional forests; coastal oak and successional forests border Broad Meadows Marsh to the south. There are large unvegetated mudflats/marsh ponds (up to 0.75 acres) within the Broad Meadows *Phragmites* marsh. The marsh is transected by large marsh channels and ditches, some of which convey water from culverts on Route 25 and Narrow River Road. The largest channel is approximately 90 feet in width with channel depths of approximately 4-7 feet. Marsh elevation transects from adjacent uplands to either open water ditch or marsh pannes are shown in Figure 3. Elevation measurements within the *Phragmites* marshes at Broad Meadows indicate that these marshes typically have a ground surface elevation between -0.25 and 0.15 NAVD88 which is at, or just above, the Mean Tide Level elevation of -0.014 NAVD88 (Figure 6). Some of the *Phragmites*-dominated areas in the southeastern portion of the marsh are interspersed with trailing brambles and successional shrubs; these areas are located at a slightly higher elevation between 0.78 and 1.93 within the (NAVD 1988). The ground surface within the *Phragmites* marshes is typically overlain by several inches of thatch consisting of senesced and partially broken down leaves and shoots. Measurement of the depth of *Phragmites* thatch within Broad Meadows Marsh at approximately 30 locations indicated a mean thatch depth of 3.6 inches.

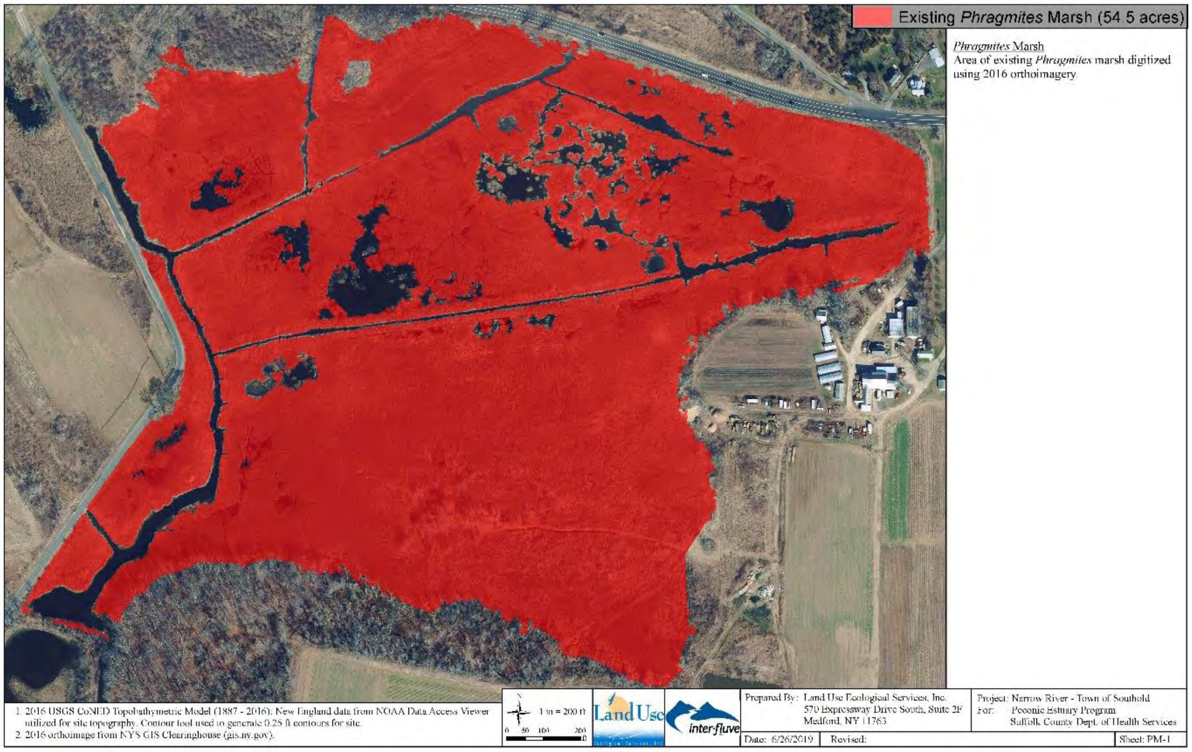


Figure 5. Existing *Phragmites* marsh within the Narrow River project area.

Narrow River Reference Tidal Wetlands and Elevations

There are no areas of native tidal wetland communities within Broad Meadows Marsh. Intact and high-function tidal marshes border the tidal reach of Narrow River downstream of the earthen impoundment. Intertidal marsh, high marsh, and salt shrub communities are present. Representative elevations of native high and low marsh communities were recorded at approximately 30 locations approximately 250 feet downstream of the double culvert. Elevations of these native marsh communities are provided in Table 3. The marsh platform consisting of short-form *Spartina alterniflora* and high marsh species located downstream of the earthen impoundment was typically located at elevations ranging between 0.24 and 1.21 (NAVD 1988).

Table 3: Native Marsh Community Elevations at Narrow River Reference Locations

Marsh Community Type	Elevation Range (NAVD88)[1]
Intertidal Marsh	-0.37 to 1.27
High Marsh	0.92 to 1.43
[1]Elevation Data collected by InterFluve and Ducks Unlimited (April 2019)	

The *Phragmites* marshes located upstream of the earthen impoundment in Broad Meadows Marsh are generally lower in elevation (between El. -0.25 and 0.15), or at the lower portion of the native marsh elevation range, than the intact marshes located downstream of the impoundment (generally between -0.05 and 1.27 NAVD88).

2.5 Endangered and Threatened Species

Consultation with the New York Natural Heritage Program (dated September 25, 2018) indicates the potential for Scotch lovage (*Ligusticum scoticum ssp. scoticum*) to occur in the vicinity of Narrow River. This plant species is listed as endangered in New York State, and has been documented within upland oak-hickory forests adjacent to tidal reaches of Narrow River. Scotch lovage is typically found near headwaters of tidal rivers and high salt marshes and adjacent forest habitats including coastal oak and maritime red cedar forests (NYNHP, 2018). Encroachment of *Phragmites* and succession of high marshes to *Phragmites* stands or upland habits are threats to this species identified by the New York Natural Heritage Program (NYNHP, 2018). Given this species preference for high marsh habitats, Scotch lovage would likely benefit from any restoration efforts to enhance tidal flow to Broad Meadows Marsh and limit *Phragmites* abundance. If final construction plans for this project include any grading, clearing, or ground disturbance within the upland forests (e.g. forests located to the east of the earthen berm on the opposite side of the large drainage ditch), surveys for Scotch lovage should be conducted in potential disturbance areas to verify that no potential impacts to this species shall occur.

3 ANALYSIS OF TOPOGRAPHY AND INFRASTRUCTURE AND FEASIBILITY ASSESSMENT OF TIDAL RE-CONNECTION

Elevation data collected in 2018 and 2019 by Inter-Fluve and Ducks Unlimited was used to generate cross sections and longitudinal profiles, and to evaluate the elevation of culverts, roads, surrounding private property, and marsh surfaces and channels relative to published tidal datums. Elevation data corrected with an RTK GPS in NAD83 New York Long Island State Plane are shown on Figure 3.

3.1 Evaluation of Infrastructure and Site Elevations Compared to Tidal Datum

3.1.1. Route 25 and Culvert

Route 25 is approximately 4 feet higher than the MHHW at Cross Section 3 (Figure 6), but approximately 850 feet further to the east, the road elevation is only 2.5 feet higher than MHHW. The LIDAR topographical data (Figure 1) corresponds well to the collected survey data. The road elevations range from about 4 feet to the east to 6 feet in the middle and about 7 feet near the west end of the road in the study area (Figures 7, 8).

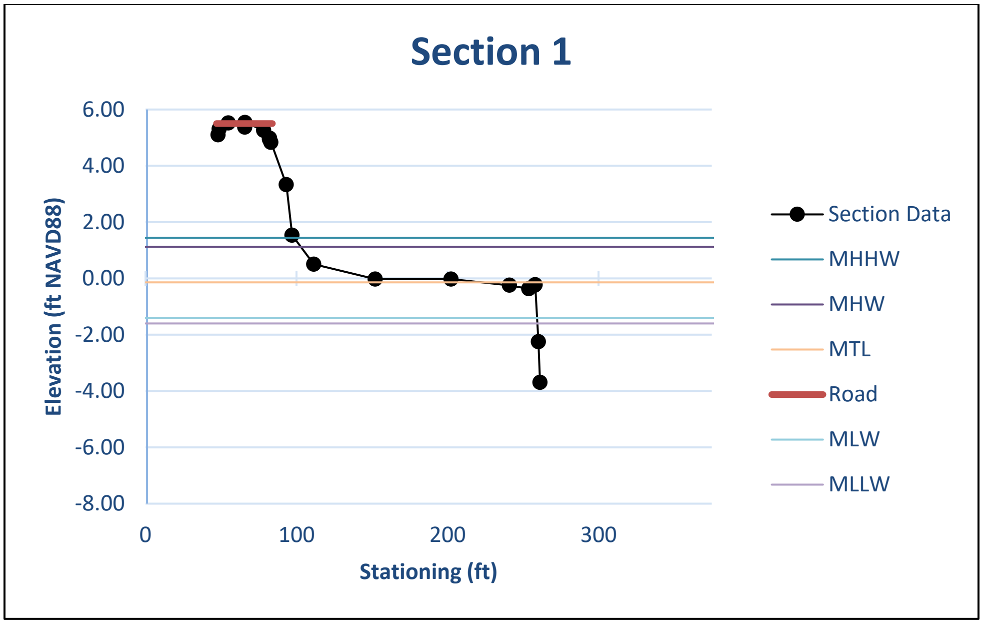


Figure 6: Route 25 is approximately 4 feet higher in elevation than the unimpeded MHHW elevation.

Figure 7: The LiDAR elevation data was evaluated along the edges of the study area with three profiles: 1) Route 25 from W-E; 2) Narrow River Rd from N-S; 3) the eastern and southern property boundary from N-S.

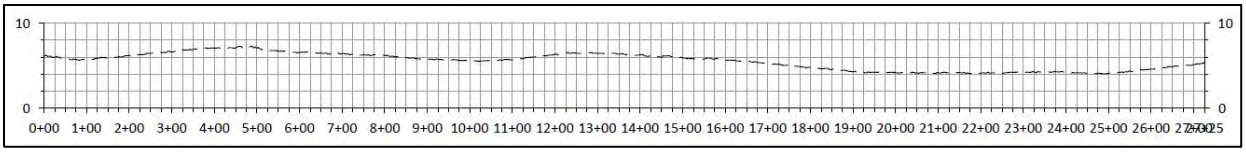
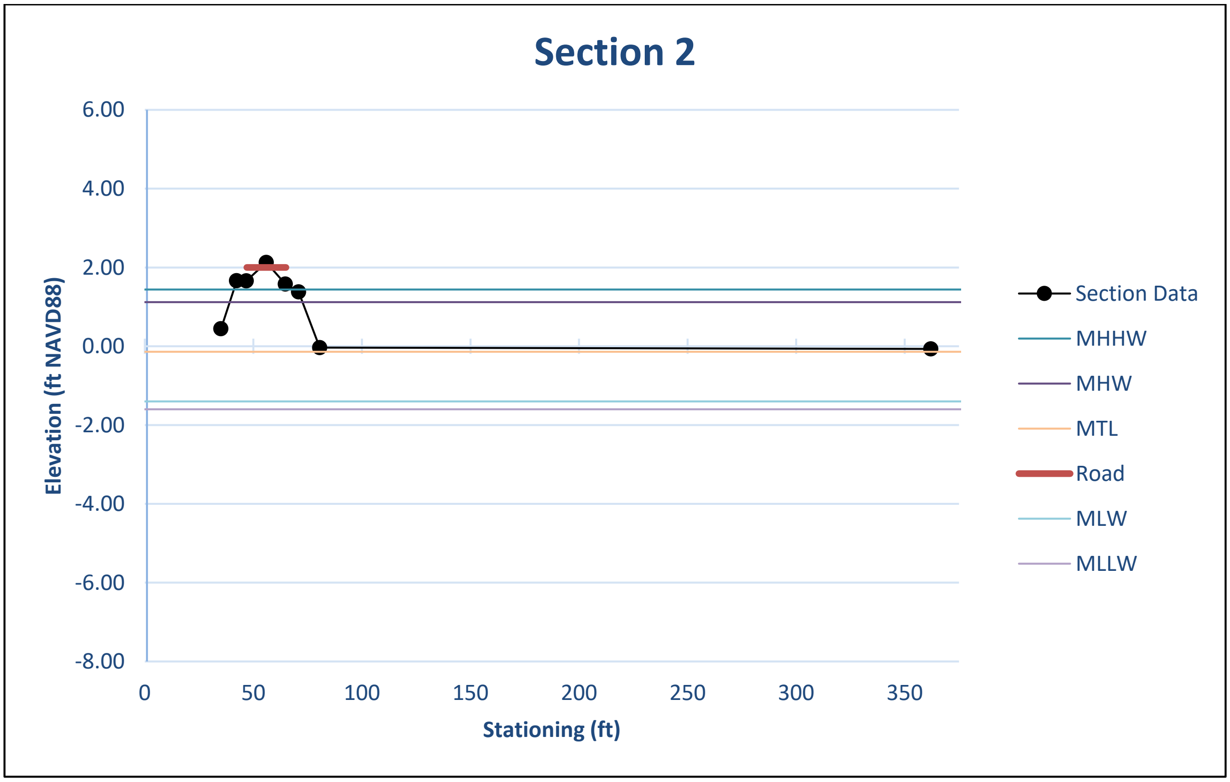


Figure 8: Elevation profile of Route 25 north of the study site. Elevation is in feet on the y-axis and the stationing along the x-axis corresponds to the station numbers indicated on the map above.

3.1.2. Narrow River Road

During the field investigations, low points in Narrow River Road were observed with typical high tide indicators identified. The survey data confirms that the road centerline ranges from approximately 0.85 to 4.0 feet NAVD88 with the lowest section in the location where the road crossed the historical natural alignment of the channel (Figures 9, 10). This area currently has wetlands on both sides of the road with a small culvert conveying flows between. Approximately 300 feet of this road is lower in elevation than the MHHW elevation of 1.44 feet that would be experienced following replacement of the double culverts (Figure 10). This section of the road has already been replaced, though the reason for replacement is unknown (Figure 11).



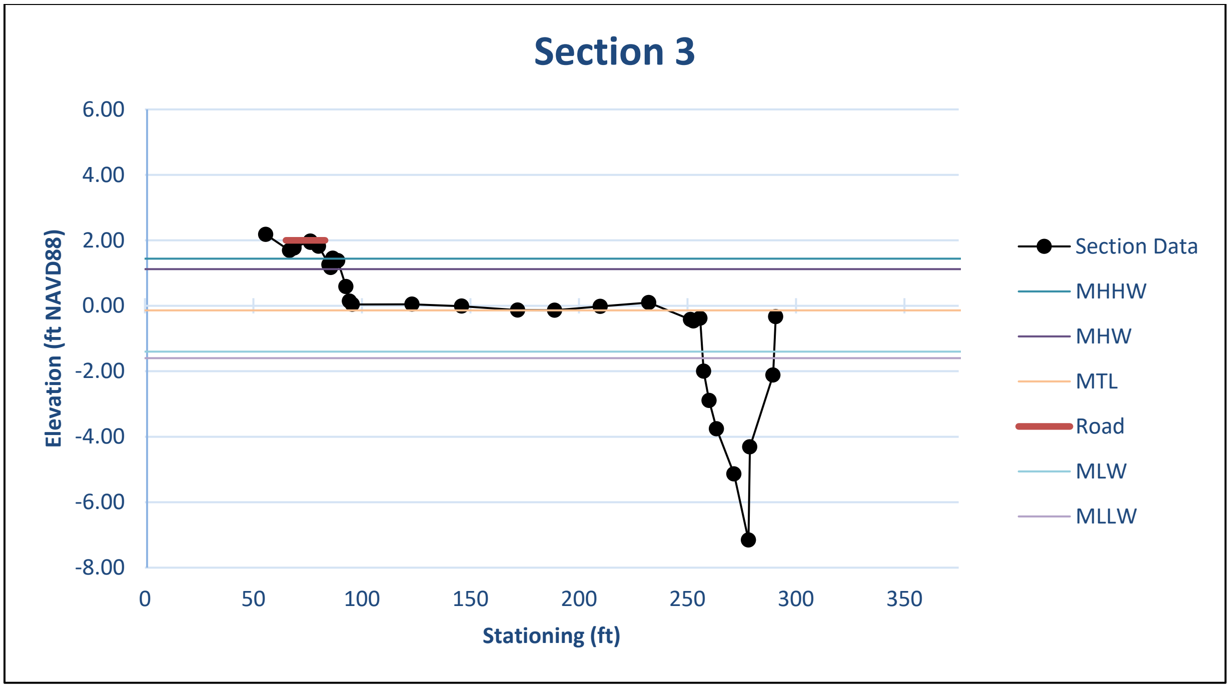


Figure 9: Cross sections indicating that Narrow River Rd in these locations is only 0.5 feet higher than the expected MHHW upon replacement of the double culverts. Other portions of the road are as low as 0.85 feet in elevation.

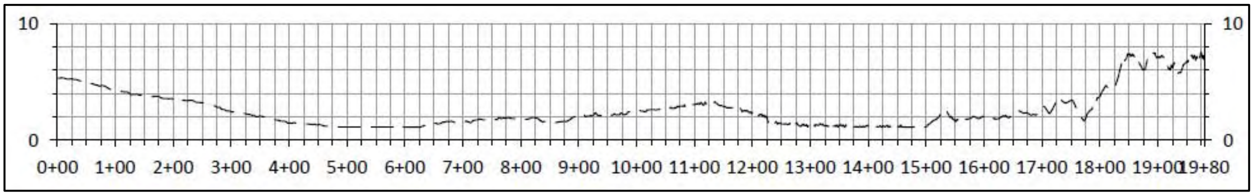


Figure 10: Elevation profile, from north to south, of Narrow River Road extending from Route 25 to downstream of the earthen berm with the double culverts. Elevation is in feet on the y-axis and the stationing along the x-axis corresponds to the station numbers indicated on the map above.

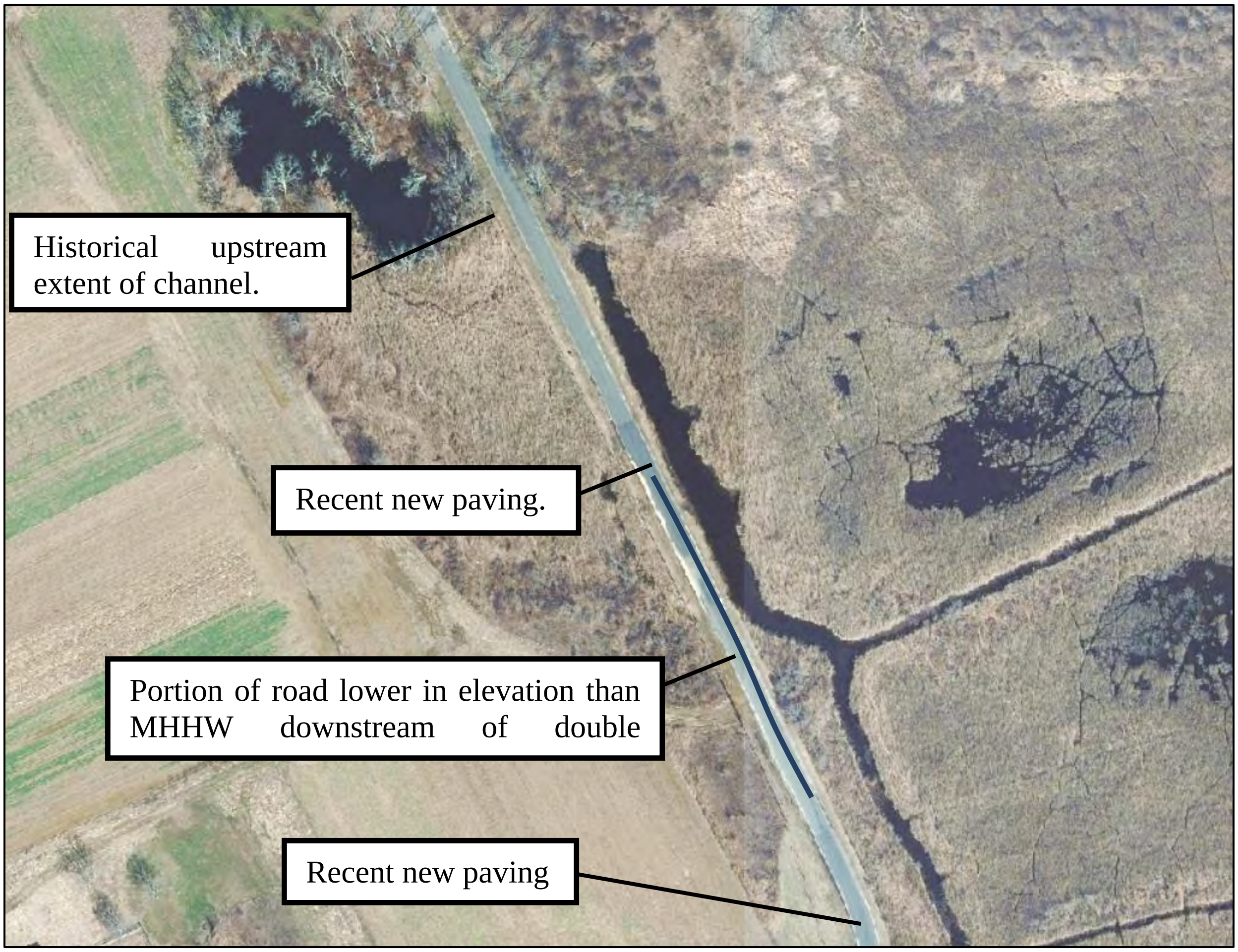
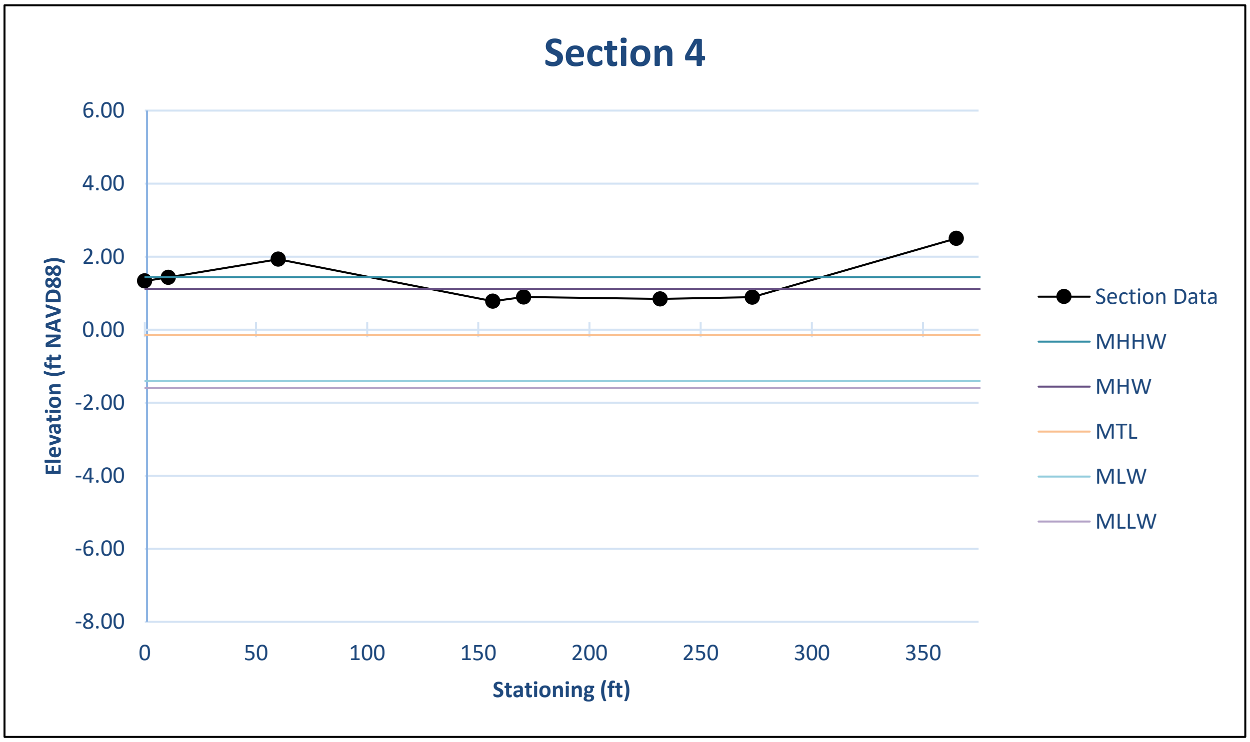


Figure 11: Northern portion of Narrow River Road where the lowest elevations of the road are in the area where the road crosses the historical channel alignment.

3.1.3. Latham Farm

On the eastern side of Broad Meadows Marsh, the fields on the Latham Farm were at approximately elevation 2.5 feet in the areas surveyed, about 1 foot higher than the unimpeded MHHW in the estuary downstream of the double culverts (Figure 12). If the tidal range in the marsh were to be restored, these fields in the area surveyed would still be higher in elevation than the typical daily tidal fluctuations. The SHW, however, is slightly higher at approximately elevation 1.6 feet. We evaluated an elevation profile, derived from available LiDAR data, along the Latham Farm property boundary (Figure 13). We found areas as low as 1.0 feet, but these may be in locations adjacent to higher elevation ground that was not sampled in the profile. So, while it is possible that some areas of the farm are vulnerable to flooding, further survey of the remaining edges of this property should be completed to confirm locations potentially vulnerable to the MHHW or this SHW.



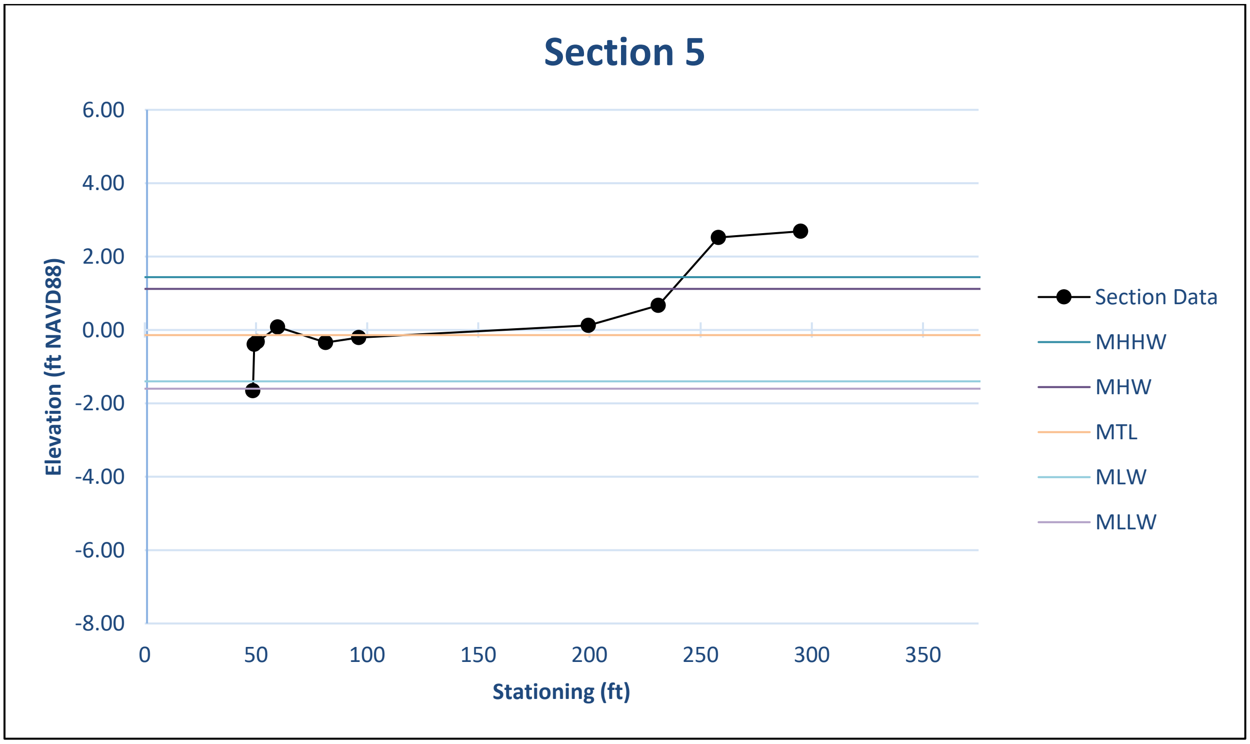


Figure 12: Section 4 and 5 surveyed reflect the elevation in the marsh and edge of farm fields along the southern and eastern edges of the marsh respectively.

3.1.4. Comparison of Infrastructure and Private Property to Tidal Datums

The earthen berm present at the downstream end of Broad Meadows Marsh is critical for preventing the flooding of Narrow River Road under routine tidal conditions, as a low-lying reach of Narrow River Road is lower in elevation than both MHHW and SHW elevations. Route 25 and the perimeter of the Latham Farm are generally higher in elevation than the MHHW and SHW elevations (1.44 and 1.63, respectively), but not substantially, as the lowest points of Route 25 and the Latham Farm perimeter are at elevation 4 feet and 1 foot, respectively.

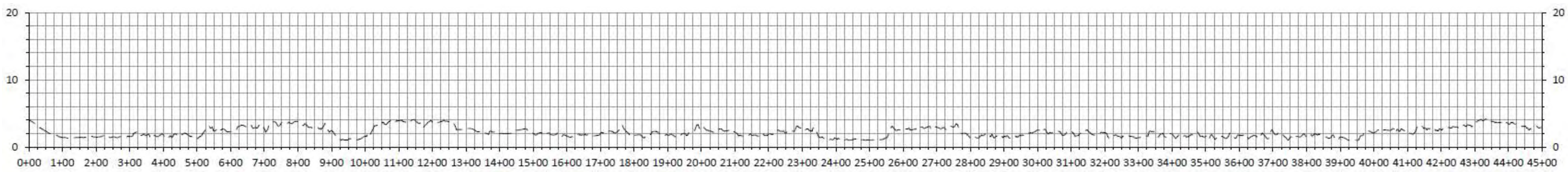


Figure 13: Elevation profile, from northeast to southwest, of the edge of the property east and south of the marsh extending from Route 25 to downstream of the earthen berm with the double culverts. Elevation is in feet on the y-axis and the stationing along the x-axis corresponds to the station numbers indicated on the map above. Elevations are based on LiDAR data as the survey data is sparse along these edges, so the elevations are approximate. Elevations range from approximately 1 foot to 4 feet, suggesting that some areas may be vulnerable to MHW, MHHW, and SHW. Because this profile followed the property boundary, low areas in the profile may have higher elevation areas nearby that would limit flooding impacts to the farm. A more detailed survey of the high points along the farm boundary would be needed to identify potentially-vulnerable locations.

3.2 Storm Surge Vulnerability

The vulnerability of Narrow River Road, Route 25, and surrounding private property to storm surges from hurricanes was assessed by reviewing the National Weather Service SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model projections of storm surge for the Broad Meadows/Narrow River area. Storm surge is the abnormal rise of water generated by a storm, over and above the predicted astronomical tides. The projected storm surge resulting from a Category 1 storm at high tide for the project area is 4 to 8 feet, as shown in Figure 14. Of course, the actual flooding resulting from a storm depends on many factors, such as the track, intensity, size, and forward speed of the hurricane, as well as the characteristics of the coastline where it comes ashore or passes nearby. Additionally, storms more severe than a Category 1 storm would be result in greater storm surge. The existing earthen berm (constructed in the aftermath of the 1938 Hurricane) with an elevation of approximately 6 feet above mean tide level provides necessary storm protection for Narrow River Road, Route 25, and adjacent private property and residences for some hurricanes and lower intensity storm events.

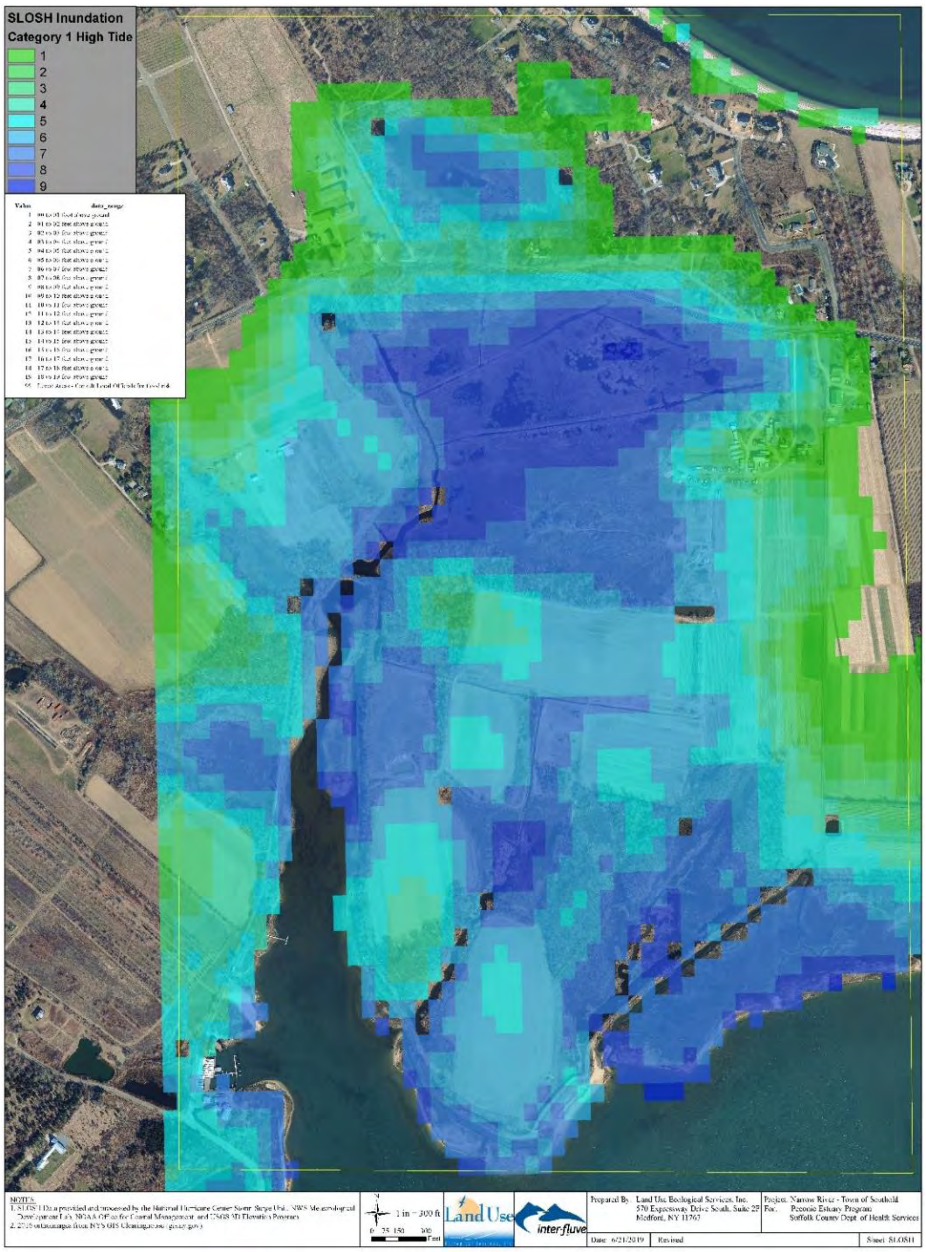


Figure 14: Predicted Storm Surge from Category 1 Hurricane from National Hurricane Center SLOSH Data.

3.3 Sea Level Rise

The vulnerability of Narrow River Road, Route 25, and surrounding private property from storm surges or more routine tidal flooding will increase in coming decades due to sea level rise. Regional projections anticipate sea level to rise by 7-12 inches and 12-23 inches by the 2050s and 2080s, respectively, with greater sea level rise under rapid ice melt scenarios (NYSERDA ClimAID, 2010). Local projections of sea level rise for eastern Suffolk County were reviewed. Sea level rise in the vicinity of the project area is predicted to increase by 24-36 inches under rapid ice melt scenarios by the 2050s, as shown Figure 15 presenting NOAA Sea Level Rise Data.

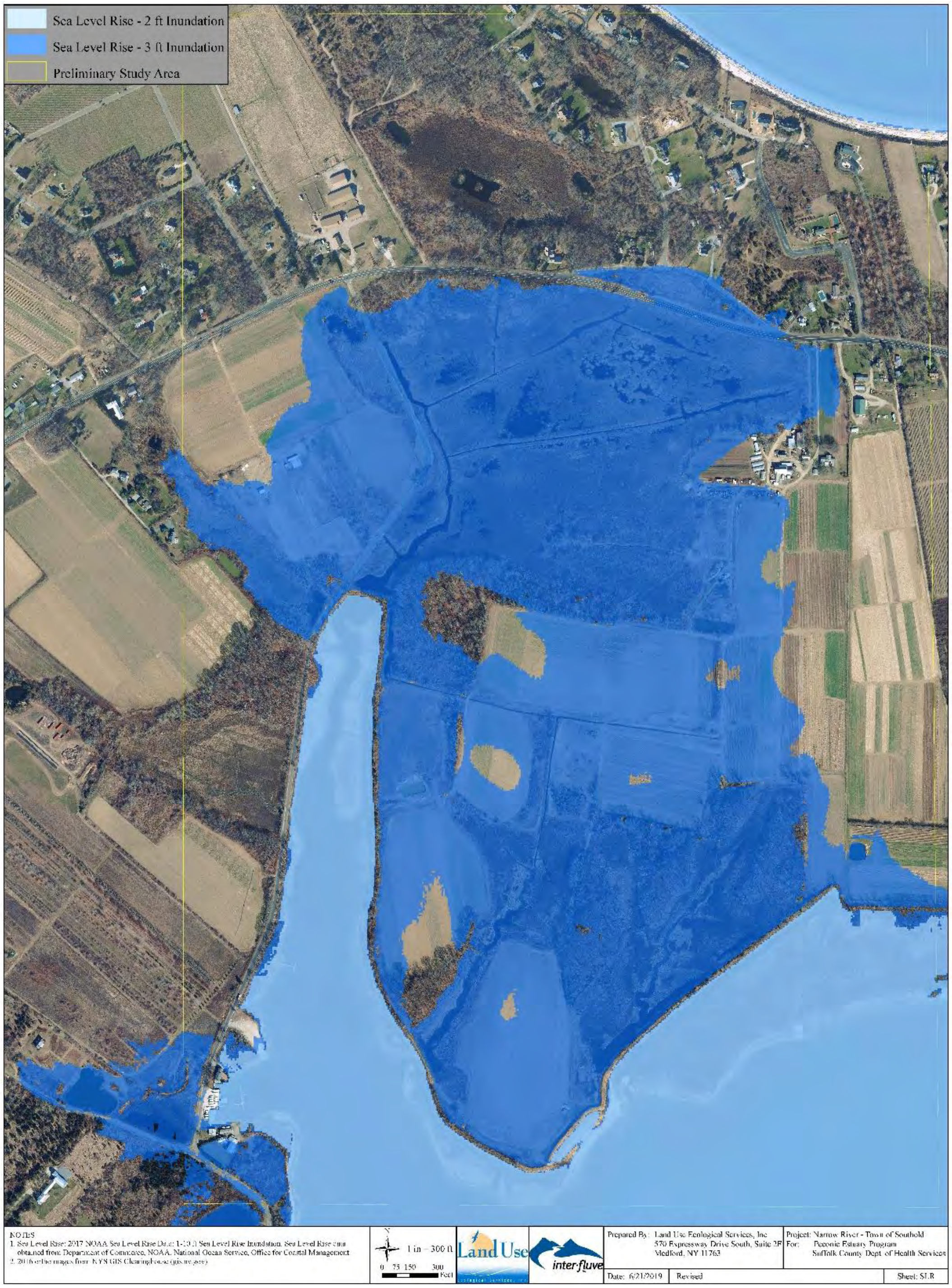


Figure 15: Predicted Sea Level Rise by 2050s from NOAA 2017 Sea Level Rise Data.

3.4 Evaluation of Double Culvert in Earthen Berm

Elevation data collected in 2018 and 2019 by Inter-Fluve and Ducks Unlimited were used to generate longitudinal profiles and cross sections of the earthen berm and double culverts. Survey points close to the center of the channel that depicted the deepest portions of the channel were used to create a longitudinal profile of the channel extending through the earthen berm and double culvert (Figure 16). The data suggest a scour hole immediately downstream of the double culvert as the channel bed is approximately 2 feet lower in elevation (~ -4.5 feet) than the channel further downstream. Upstream of the culverts, the channel bed ranges in elevation from approximately -4 feet to -7 feet.

Existing double culverts at the earthen berm appear to be undersized as indicated by 1) the channel scour observed downstream of the berm and 2) the difference in tidal range between the upstream marsh and the downstream estuary.

Downstream of the berm, the channel bed is more than two feet lower in elevation than the invert of the culverts, with the channel bed further downstream rising to be consistent with the culvert invert. This scour is due to the velocity of the water coming through the undersized culverts and mobilizing the channel bed substrate (Figure 17).

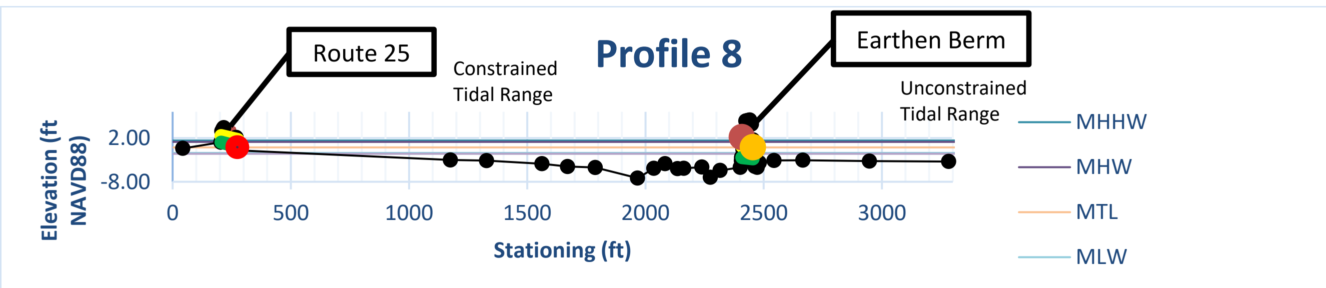


Figure 16: The longitudinal profile of the channel from upstream of Route 25 to downstream of the double culverts.

Figure 17: Scour and erosion upstream and downstream of the double culvert.

As described in the Cornell Cooperative Extension report (CCE, 2000), differences in the tidal amplitude upstream and downstream of the culverts have been observed. Downstream of the culverts, the tidal range is 2.5 to 3.5 feet, while the tidal range within the marsh upstream of the culverts is approximately 1.0 to 1.5 feet. The Cornell study included the deployment of multiple water level loggers upstream and downstream of the culverts to evaluate the water level changes in each area.

Long term monitoring of water levels was not part of this scope, but we do recommend deploying multiple loggers in the next phase of design and modeling. We reviewed the nearby tide gauge at Orient Harbor and converted the tidal datums (SHW, MHHW, MHW, MTL, MLW, and MLLW) to NAVD88 to be consistent with the survey data. The tidal range indicated by this conversion is approximately 3.04 feet, consistent with the range described in the Cornell study. Our survey data also corresponded well with the conversion of tidal datums as our surveyed MLLW was -1.8 feet as compared to the datum's -1.6 feet. While we did not have water level logger data for this study, we do feel confident in the elevations and findings based on the convergence of these findings identified above.

The earthen berm present at the downstream end of Broad Meadows Marsh (top of berm at El. 6.0) is critical for preventing the flooding of Narrow River Road, Route 25, and private lands during storm events and will continue to do so under future sea level rise scenarios.

Accordingly, marsh restoration actions, such as double culvert removal or culvert modifications that would allow the entire tidal range to occur in Broad Meadows Marsh, are not feasible due to the potential for significant adverse flooding impacts to roadways and private property, unless these resources are modified for increased resiliency to coastal storms and sea level rise. Potential impacts to Route 25 are particularly critical as it is the only access route to Orient Point and the Orient Point ferry terminal and essential for transit of police, fire, and emergency vehicles and personnel.

However, the double culverts in the earthen berm are undersized and restrict tidal flows to the upstream marsh. Potential restoration actions include:

- Replacing culverts with one or more self-regulating tide gates that would increase the typical tidal range within the marsh, but would block higher tides and storm flows that would inundate roads and property. If no work is completed to raise Narrow River Road, the low points at elevation 0.85 feet will be inundated during tides between the mean tide line and the mean high water (1.12 feet).

- Removing the berm and culverts in entirety and raising Narrow River Road as well as raising or establishing a berm between the Broad Meadows Marsh and the Latham farm. Raising Narrow River Road an average of 2 feet to be at an elevation of approximately 4 feet would bring it above MHHW and the low point on Route 25. This would provide flood protection to the roads and farms adjacent to the estuary up to approximately elevation 4 feet. Roads (Route 25 and Narrow River Road) and protective berms would need to be raised to an elevation greater than El. 4.0 to provide storm protection equivalent to the existing earthen berm (El. 6.0) and to account for sea level rise.

- Removing the culverts and Narrow River Road and raising or establishing the farm berm. In place of Narrow River Road, an earthen berm could be created at elevation 4 feet that could also provide pedestrian access. This would provide flood protection for the farms to the east and west, restore the native marsh ecosystem, and eliminate the future work required to maintain Narrow River Road. Route 25, Narrow River Road, and protective berms would need to be raised to an elevation greater than El. 4.0 to provide storm protection equivalent to the existing earthen berm (El. 6.0) and to account for sea level rise.

3.5 Feasibility of Marsh Restoration Based on Analysis of Tidal Datums and Marsh Elevation

The surface elevation of the *Phragmites* marshes in Broad Meadows generally corresponds to the MTL elevation (El. -0.14) that would be experienced if the full tidal range observed in Narrow River was reintroduced. Elevation measurements within the *Phragmites* marshes at Broad Meadows indicates that these marshes have a ground surface elevation between -0.25 and 1.930 (NAVD 1988) (Figures 9, 11, and 14). However, the ground surface elevations within the *Phragmites* marsh are typically between -0.25 and 0.15. These observed marsh surface elevations are lower than the elevations of the intact high and intertidal marsh communities observed in Narrow River downstream of the earthen berm. Native high marsh communities were observed at elevations 0.92 and 1.43 and intertidal marsh was observed between elevations -0.05 and 1.27 (NAVD 1988). As shown in Figure 18a, approximately 52% of the existing

Phragmites marsh (55 acres in area) in Broad Meadows is between El. 0.0 and 1.1 consistent with intertidal marshes downstream of the earthen berm and only 24% is between El. 1.1 and 1.5 consistent with native high marsh communities yielding a potential restoration area (based on existing elevations) of 50.9 acres.

The ground surface within the *Phragmites* marshes is typically overlain by several inches of thatch consisting of senesced and partially broken down leaves and shoots. Measurement of the depth of *Phragmites* thatch within Broad Meadows Marsh indicated a mean thatch depth of 3.6 inches. When this *Phragmites* thatch is taken into account, approximately 52% of the existing *Phragmites* marsh in Broad Meadows remains between El. 0.0 and 1.1 consistent with intertidal marshes downstream of the earthen berm and 22% is between El. 1.1 and 1.5 consistent with native high marsh communities. When the *Phragmites* thatch is taken into account, the potential restoration area (based on existing elevations) decreases to 46.2 acres (Figure 18b).

The below figures indicate that a large marsh panne may result after restoration of tidal exchange due to subsidence of existing *Phragmites* marsh and inadequate current marsh elevation. Thin layer deposition or other fill placement may therefore be necessary to establish native marsh communities in the lowest areas of the existing *Phragmites* marsh.

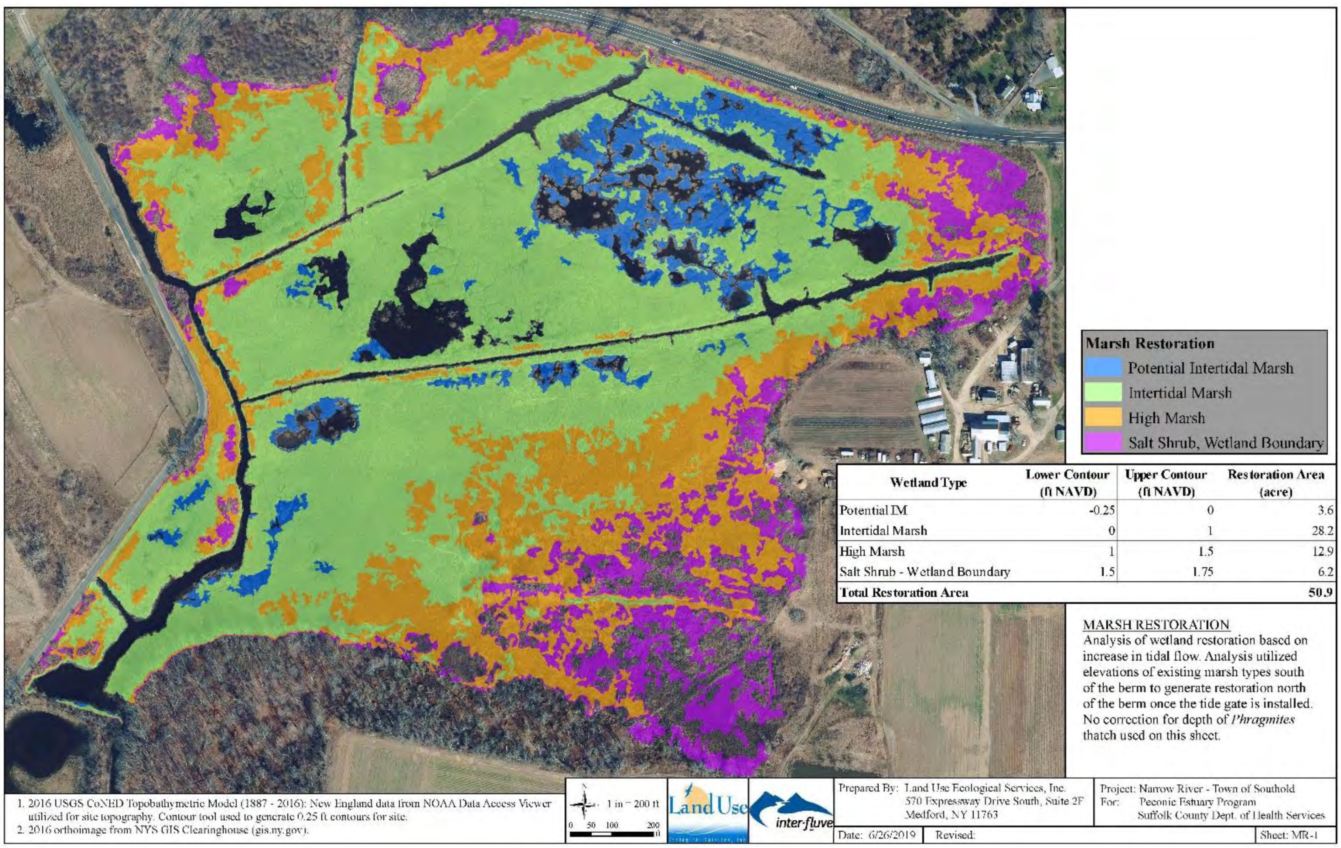


Figure 18a: Existing *Phragmites* Marsh and Percentage at Elevation Consistent with Native Marsh Communities.

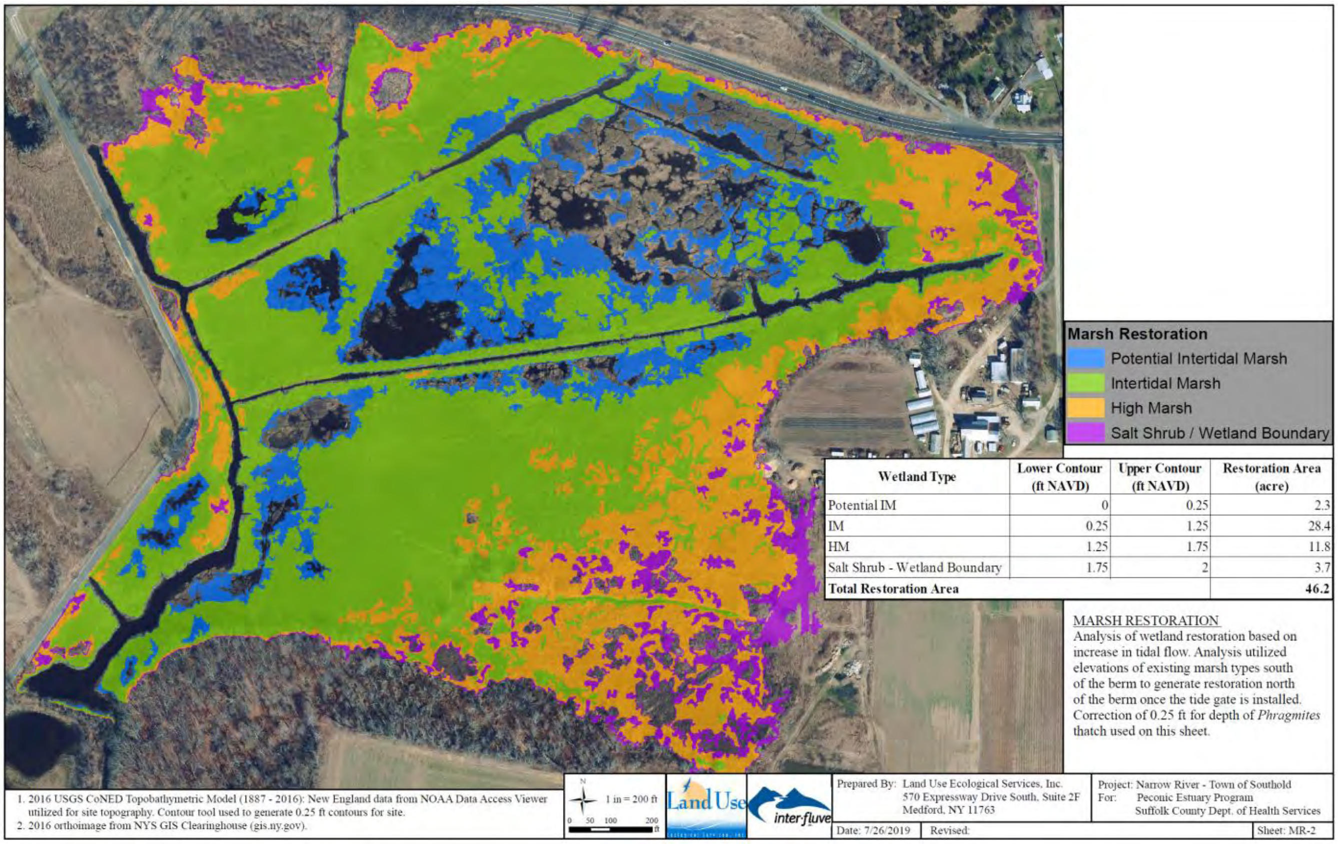


Figure 18b: Existing *Phragmites* Marsh (corrected for 3.6 inches of accumulated thatch) and Percentage at Elevation Consistent with Native Marsh Communities.

4 CONCEPTUAL PLANS FOR BROAD MEADOWS MARSH

Multiple modifications to the road and crossing infrastructure adjacent to the marsh are recommended to 1) increase salinity and tidal range within Broad Meadows Marsh and 2) improve ecological and hydraulic function of the Route 25 culvert, while minimizing potential flooding hazards to adjacent infrastructure and private property. These recommendations are identified on the conceptual plans provided in Figures 18, 19 and Appendix A. The conceptual plans identify general locations and dimensions of the recommendations, concept-level construction costs, and environmental permitting requirements. Detailed engineering and modeling will be necessary during the construction phase to determine final crossing dimensions, grading elevations, and specifications.

4.1 Double Culvert at the Earthen Berm

The twin culverts in the earthen berm are undersized and restrict tidal flows to the upstream marsh. These culverts should be replaced with one or more self-regulating tide gates that would increase the typical tidal range within the marsh, but would block higher tides (above approximately 1.12 feet, MHW) and storm flows that would inundate roads and property. MHHW and SHW would also be blocked as these inundate Narrow River Road and potentially portions of Latham Farm to the east. If measures are taken to protect this infrastructure in other ways, the MHHW and SHW could be allowed into the marsh. As sea levels rise, the tide gates can be managed, but the road and adjacent property elevations would need to be addressed as well. Multiple companies manufacture these tide gates, such as Golden Harvest and Waterman Industries; representative photos, specifications, and constructions costs are based on these manufactured tide gates.

Self-regulating tide gates are metal gates attached to the downstream end of reinforced concrete box culverts. The gates are open for the incoming tide until the water levels exceeds the designed threshold water elevation, at which point the gates close, not allowing continued filling of the marsh upstream of the culverts. As the tides downstream subside, the gates open again to allow the upstream marsh to drain. The concrete box culverts and tide gates are built into a concrete headwall, with approximately 15 feet between each gate. We have assumed four 5x5-foot concrete box culverts and tide gates for this site. The proposed concrete headwall and wingwalls are approximately 95 feet in length under the proposed conditions. The proposed invert culvert elevation will be lower in elevation than the MLLW (-1.6 feet) so as to allow low tides to fully drain through the marsh. We propose placing the culverts at elevation -2.0 feet, with the top of the culverts at 3.0 feet, above the MHHW as well as the SHW (1.63 feet).

The recommended box culvert configuration is based on hydraulic evaluation of multiple box culvert configurations to identify a configuration that would optimize hydraulic conditions at the earthen berm crossing and provide a near “free flowing” connection between the tidal floodplain on either side of the berm. It was assumed that a free-flowing condition was achieved if inflow and outflow through the crossing are primarily controlled by changes in tidal stage, rather than by size and configuration of the culvert opening(s).

Each configuration was analyzed using culvert computations within a two-dimensional (2-D) domain in HEC-RAS (USACE Hydrologic Engineering Center River Analysis System). These computations analyze flow exchange through the crossing in both directions, which allows for effects of floodplain storage to be included in the analysis. Performance was evaluated by examining floodplain inundation stage and timing over a 4-day tide cycle, with tide levels exceeding the estimated MHHW (1.44 ft NAVD88) and MLLW (-1.60 ft NAVD88) within the cycle. A summary of the analysis, assumptions, limitations, and recommendations are provided in Appendix B.

Figure 19: Representative photo of self-regulating tide gates from location (Waterman Industries).

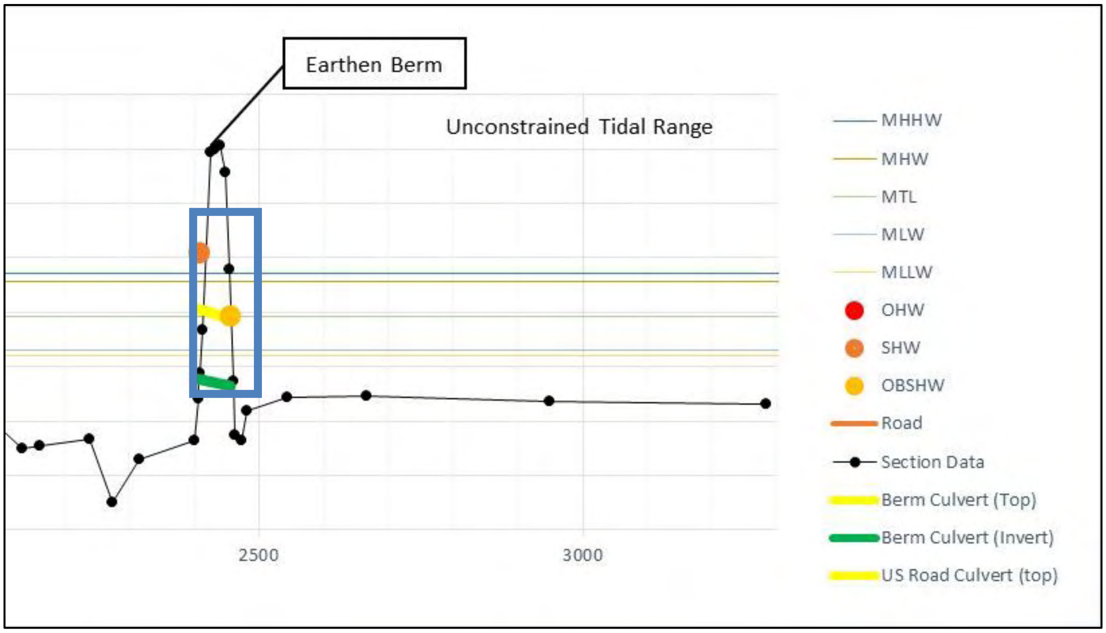


Figure 20: Approximate location of the proposed self-regulating tide gate (blue rectangle).

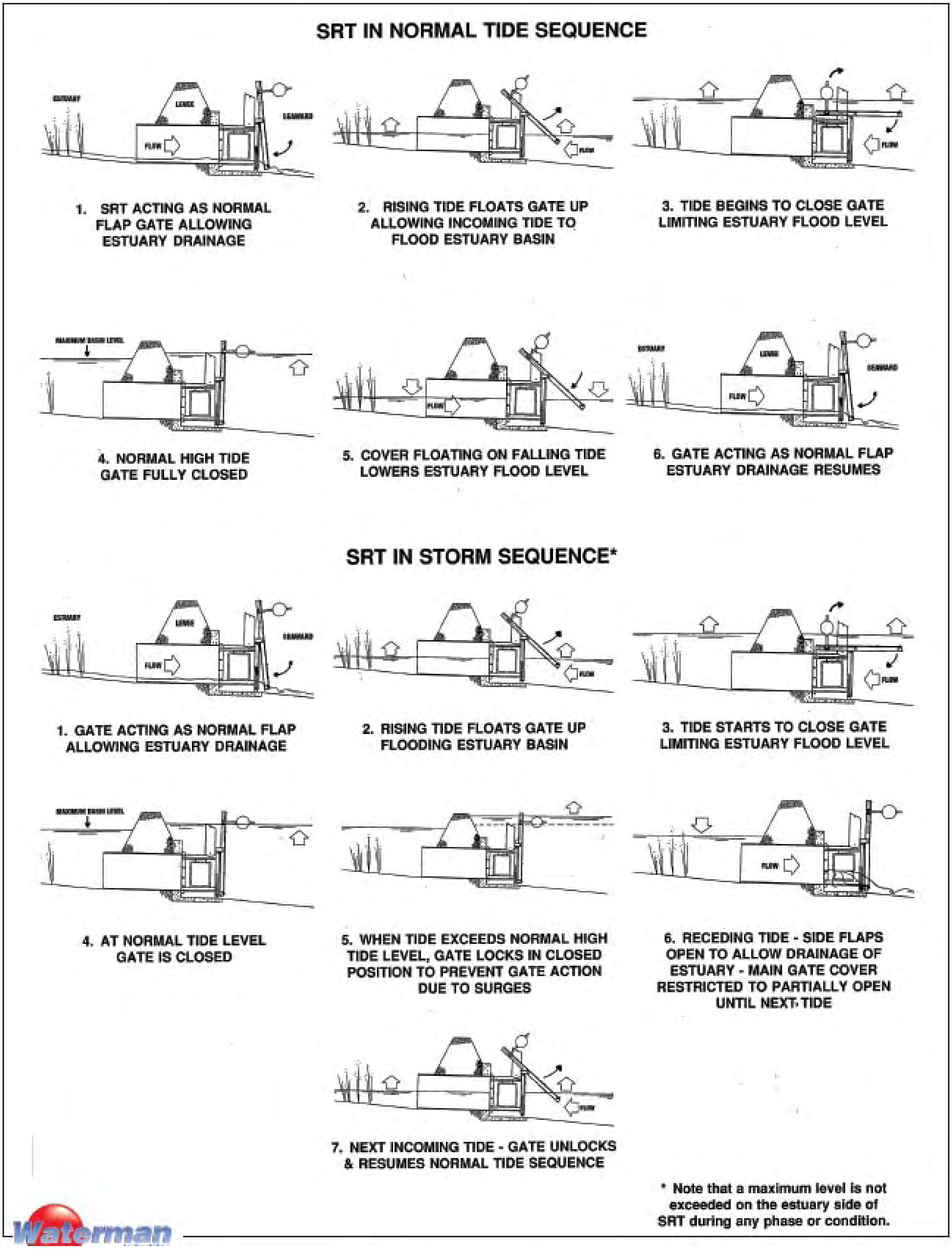


Figure 21: Typical operation of a self-regulating tide gate (Waterman Industries).

4.2 Latham Farm Ditch

A constructed farm ditch is located to the east of the double culvert; this north-south oriented ditch extends from the earthen berm to the farm field to the south. The spoils of this ditch excavation were likely used to construct the earthen berm that also runs north to south immediately to the west of this ditch (Figure 1). This ditch currently serves no purpose except to drain water that collects in the ditch to the east. The following actions are recommended to prevent increased flooding risk to the adjacent farmlands resulting from modification to the double culvert:

- Utilize fill generated by installation of self-regulating tide gates and culverts to fill a portion of the north-south ditch and create a berm that would prevent enhanced tidal flow from flowing towards the farmlands. A flap gate or low-level weir could be installed to allow the stormwater from the farm to drain north into Broad Meadows Marsh.

- Reconstruct the farm crossing to the east – the channel elevations at this crossing acts as a watershed divide, with water in the western ditch being forced to flow west and water in the eastern ditch flowing east. Replacement of this crossing and re-grading the ditch (or removing the ditch if not necessary anymore) would direct water east to reconnect with the historical channel alignment. Since the current north-south ditch is blocked from its historic estuarine connection by a berm, a tide gate, tide valve, or flap gate would need to be installed at this location to allow this drainage to occur.

4.3 Route 25 Culvert

The existing 1.5-foot culvert pipe under Route 25 is undersized and perched on the downstream end. Typical high tides do not extend upstream of Route 25 as ordinary high water marks were observed at approximately the culvert invert elevation on the downstream side of the road. This culvert should be replaced with a three or four-sided concrete box culvert to improve fish and aquatic organism passage, passage of terrestrial organisms, and hydrology. The recommended culvert would be approximately 4 feet in height, with the top of the culvert set to approximately 2.0 feet in elevation, providing two feet of fill and road surface material above (Figures 22, 23). Approximately 1.0 feet of natural channel substrate would be placed on the bottom of the culvert for habitat and organism passage. The width of the culvert would likely be 4 to 6 feet; however, final dimensions would be developed during construction design phase. This recommended width should allow for the design of a floodplain bench to provide terrestrial organism passage, reducing possible mortality from crossing the road (Figure 23). The proposed culvert dimensions should be designed to equal or exceed 1.2 times the bankfull channel width and should account for increased storm frequency and sea level rise. If tidal flows were restored through modifications to the double culvert, the downstream end of the culvert would be backwatered a large percentage of time, as the MHW and MHHW would be expected to extend upstream of Route 25, while low tides would not reach the culvert (Figure 22). Enhancement of tidal flow would allow more fish to move upstream and increase salinity within the *Phragmites*-dominated Whitcom Marsh.

If replacing the culvert under Route 25 is not of interest to the Town or New York State as the owner of the roadway, restoration of Whitcom Marsh through actions at the double culvert and berm can still occur. Some fish would likely be able to migrate upstream through the Route 25 culvert and the upstream wetland would remain freshwater. The Town should consider long-term maintenance and management regarding sea level rise as it will become harder to maintain a freshwater system as sea levels continue to rise. If the state feels the need to replace this culvert in the future as part of regular road infrastructure maintenance, this may be an opportune time to design the new crossing to achieve improved hydrologic and aquatic organism passage.

Whitcom Marsh, located to the north of Route 25, is currently (and historically) a freshwater wetland. The Whitcom Marsh outflow is through a narrow man-made channel flowing to the northern margin of Broad Meadows Marsh. Similar to Narrow River Road and Route 25, the earthen berm shields Whitcom Marsh from tidal influence of Narrow River. Recommended enhancement of tidal flow into Broad Meadows and ecological and hydraulic improvements to the Route 25 culvert could potentially result in tidal waters reaching northward of Route 25 into Whitcom Marsh.

Sea level rise is expected to result in conversion of many coastal freshwater wetlands to more brackish or tidal wetlands on Long Island and elsewhere over the coming decades. If tidal encroachment into Whitcom Marsh is not desired by the Town of Southold or local residents, then the proposed recommended culvert could be set at an equivalent elevation to the existing perched culvert. This alternative would provide limited increased drainage of Whitcom Marsh into Broad Meadows Marsh and minor improvements to the potential for terrestrial and aquatic organisms to pass through the culvert.

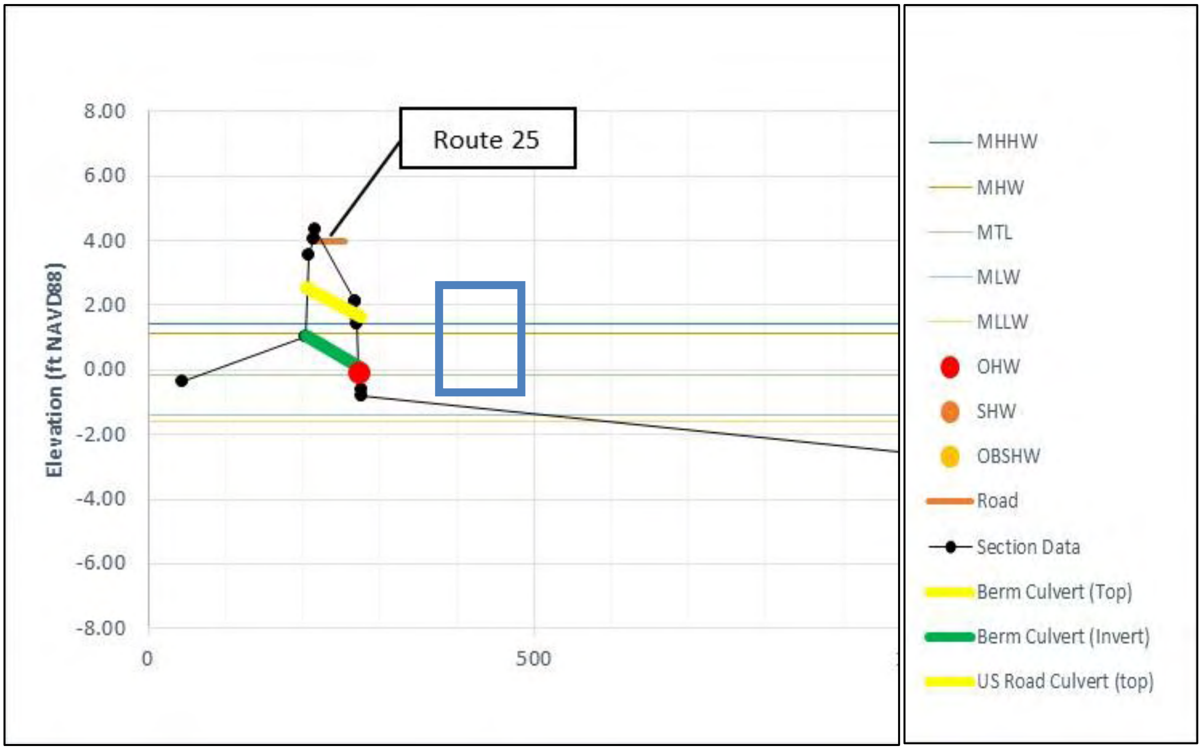


Figure 22: Approximately location of the proposed culvert (blue polygon) under Route 25.

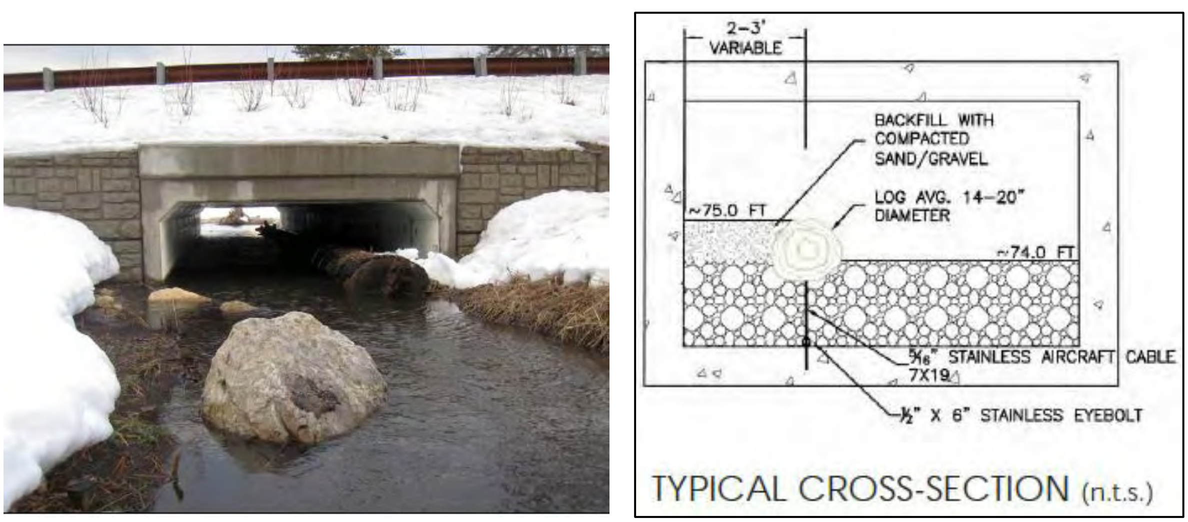


Figure 23: An example of a concrete box culvert with natural channel substrate on the bottom and a floodplain bench built for terrestrial organism passage.

4.4 Narrow River Road

Narrow River Road is currently very low in elevation in many locations, is flooded during storm events, and has had to be replaced due to damage. The road crosses the historical alignment of the channel at the northern end with marshland on both sides. The low elevation of Narrow River Road may constrain the operation and ecological benefits of the recommended self-regulating tide gates. If the natural tidal range is restored, approximately 300 feet of this road will be lower in elevation than the MHHW. Sea levels will continue to rise in the coming decades, suggesting that this road will become even more vulnerable. We provide two possible alternatives to address these concerns:

1. <u>Convert Road to a Recreational Path</u> – Maintaining a paved road in this location could become more burdensome in the future with sea level rise and increased frequency of large storm events. Abandoning this road for vehicular traffic and converting it to pedestrian and/or bike use could eliminate that maintenance expense and provide recreational opportunities for residents. The portion of the road that is higher in elevation at the northern end could be converted to a parking area off of Route 25. Then a combination of a boardwalk and dirt path, depending on proximity to water and wetlands, could be constructed above the projected elevation of the MHHW.

2. <u>Raise the Road Elevation</u> – One option for raising the road would raise approximately 300 feet of road to an elevation of 1.5 feet. This would exceed the existing MHHW elevation and would likely remain above the MHHW in the coming decades. A more substantial option would be to raise the road to the combined elevation (~4 feet) of MHHW and Route 25 low point. Most of Narrow River Road falls below this elevation, and therefore 1,800 feet of road would need to be raised. Depending on actual sea level rise, additional modifications would need to be made to both Narrow River Road and Route 25 in the future, but more regional infrastructure modifications would likely be necessary at this point.

4.5 Construction Costs

Costs here are concept level estimates to provide approximate values for project planning purposes. Actual design and construction costs will vary following a more detailed data collection effort and engineering design. A detailed account of costs is provided in Appendix B. These costs have been based on knowledge of similar projects and construction components. A contingency was added to each estimate to provide the range noted below.

Alternative	Design Cost	Construction Cost	Notes
Route 25: Culvert Replacement	$137-182K	$251-335K	- Proposed culvert is a 4x4-ft concrete box culvert approximately 50 feet in length - Culvert cost is assumed to be $1,200 per linear foot - Assume reconstruction of the road, though no sidewalks or guardrails needed - Assume $25,000 allowance for managing utilities under the road. While it is understood that utilities are under road, we do not know the type of utility or where they are located (above or below the culvert). This cost could be substantially greater if sewer, water, gas and fiberoptic need to be temporarily shut off and redirected during construction. - Assumes active pumping for water control - Assumes traffic is reduced to one lane, but that complete road closure is not possible
Narrow River Road: Raise Road Elevation	$68-80K	$123-165K	- Proposed design includes the raising of the low portions of this road to approximately elevation 1.5 feet - Road reconstruction assumed to be $100 per square yard
Tide Gate Replacement	$230-320K	$765K-1.025M	- Proposed design includes 4, 5x5-foot self-regulating tide gates with 4, 5x5-foot associated concrete box culverts (final number could be updated following more detailed modeling). Self-regulating tide gates = $70,000 each; concrete box culverts = $1,400 per linear foot. - Approximately 15 feet of concrete headwall lies between each culvert and tide gate - Approximately 15 feet of concrete wingwall on each end of the headwall - Assumes concrete headwall and wingwalls only on the downstream side of the berm - Assumes excavated materials will not be disposed of in a landfill but in the open ditch to the east - Passive water control, using the existing culverts until the new ones are finished, but active water management will be necessary to keep water out of the work zone while installing the concrete headwall, wingwalls, culverts and tide gates
Latham Farm Ditch	$24-32K	$80-106K	- Fill ditch and add flag gate or low-level weir
Alternative 1: Remove Earthen Berm and Double Culvert; Raise Narrow River Road	$237-315K	$904-1.2M	- Remove earthen berm and double culverts - Raise low portions of Narrow River Road to approximately El. 4.0. - Raise or provide farm berm to the east of Broad Meadows Marsh to approximately El. 4.0. - Road reconstruction assumed to be $100 per square yard
Alternative 2: Remove Earthen Berm, Double Culverts; Remove Narrow River Road and Replace with Path	$140-$185	$465-$618	- Remove earthen berm and double culverts - Remove portion of Narrow River Road between Earthen Berm and Route 25 - Build recreational path on top of Narrow River Road raised to approximately El. 4.0. - Raise or provide farm berm to the east of Broad Meadows Marsh to approximately El. 4.0.

4.6 Environmental Permitting

Modification of the existing culverts at Route 25 and the earthen berm to enhance tidal inundation, improve marsh habitat conditions through *Phragmites* management and native marsh expansion, and enhance passage for aquatic species would require the following environmental permits:

- United States Army Corps of Engineers:
  - Section 404 of Clean Water Act
  - Section 10 of Rivers and Harbors Act
- New York State Department of Environmental Conservation:
  - Article 24 (Freshwater Wetlands)
  - Article 25 (Tidal Wetlands)
  - Article 15 (Protection of Waters)
- New York State Department of State, Division of Communities and Waterfronts:
  - Consistency Determination under Coastal Zone Management Act
- New York State Department of Transportation
- New York State Office of Parks, Recreation, and Historic Preservation:
  - Review under NYS Historic Preservation Act of 1980 (Section 14.09)
- Town of Southold:
  - Southold Town Trustees
  - Town of Southold Planning Board and Building Department Permits

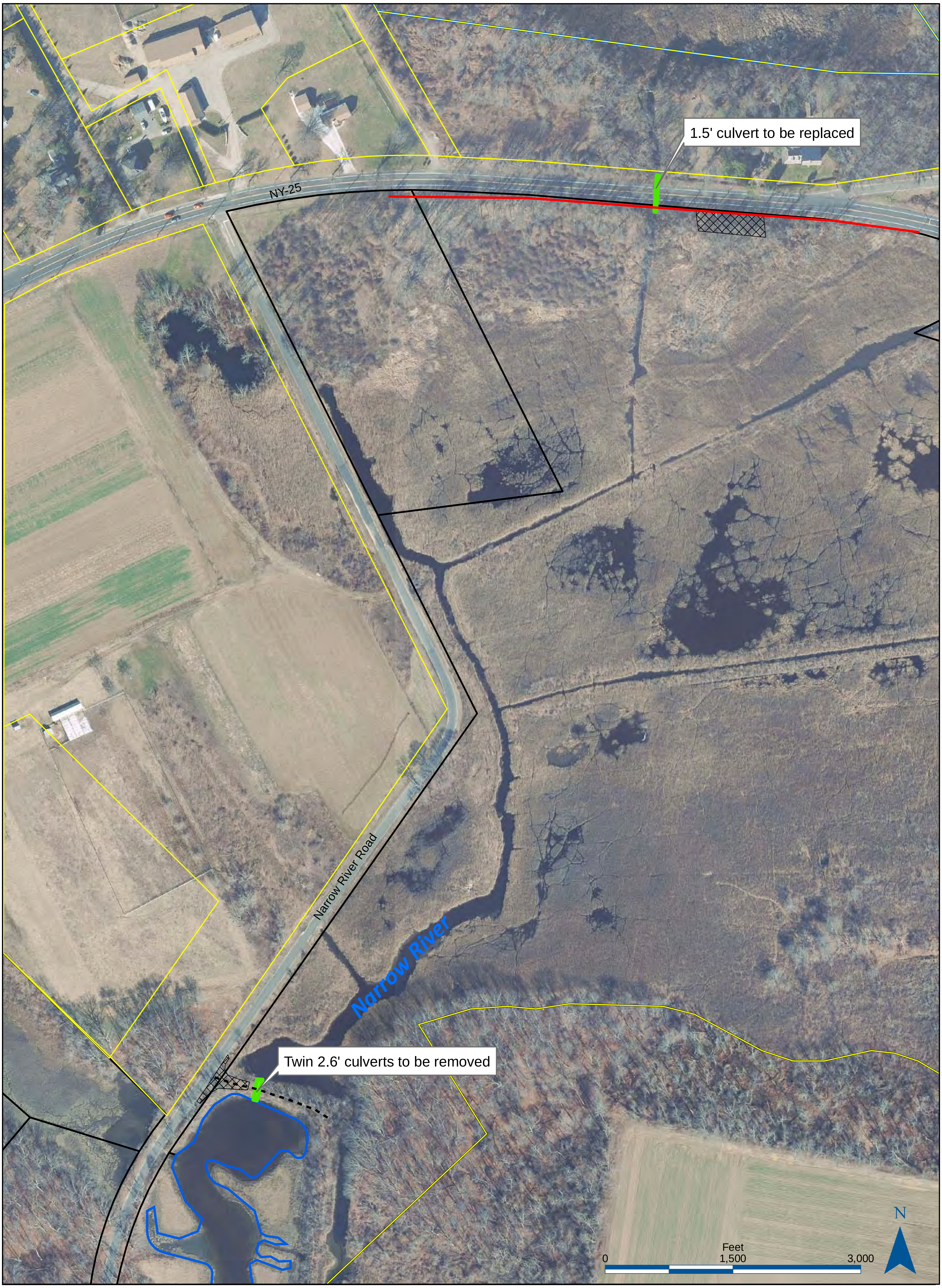
5 LITERATURE CITED

Cornell Cooperative Extension. 2000. Long Beach Bay Tidal Wetland Restoration. Progress Report Submitted to New York State Department of Environmental Conservation. Cornell Cooperative Extension, Riverhead, NY. 75 pgs.

New York Natural Heritage Program. 2018. Scotch lovage (*Ligusticum scoticum ssp. scoticum*) Conservation Guide. New York Natural Heritage Program. Albany, New York.

NYSERDA ClimAID. 2010. Integrated Assessment for Effective Climate-change Adaptation Strategies in New York State. C. Rosenzweig, W. Solecki, A. DeGaetano, M. O'Grady, S. Hassol, P. Grabhorn, Eds. New York State Energy Research and Development Authority, 17 Columbia Circle, Albany, NY 12203.

Appendix A – Conceptual Restoration Plans for Narrow River



Peconic Estuary Assessment

Narrow River Culvert Replacements
Sheet 1 - Overall Location Map
Narrow River, Orient, NY, Suffolk County (NY)
SCTM#: 300-7-1-3

Prepared 07/22/2019

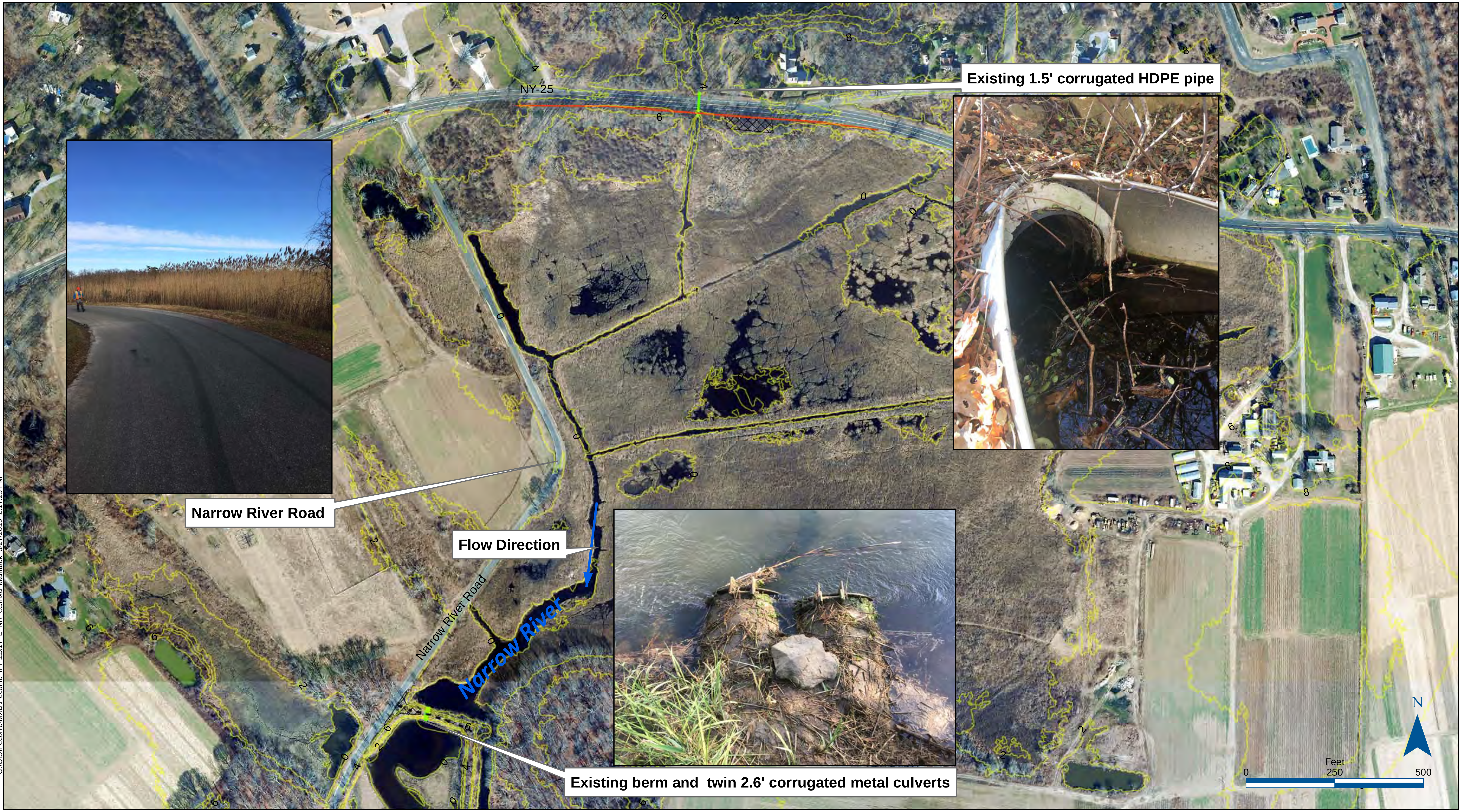
Access
Overhead Electric
Existing Culvert
Staging
Privately-Owned
Town-Owned (Southold)
State-Owned

Notes:

1. Aerial imagery from NYGIS, 2017
2. Datum: 2014 USGS Lidar (NAVD88)
3: Scale is 1:2,000

inter-fluve
220 Concord Avenue, 2nd Floor
Cambridge, MA 02138

Land Use
570 Expressway Drive South, Suite 2F
Medford, NY 11763



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Peconic Estuary Assessment

Narrow River Culvert Replacements

Sheet 2 - Existing Conditions and Site Photos

Narrow River, Orient, NY, Suffolk County (NY)

SCTM#: 30-7-1-3

Prepared 07/22/2019

Contours (2ft)	Existing Culvert
Access	Staging
Overhead Electric	

Notes:

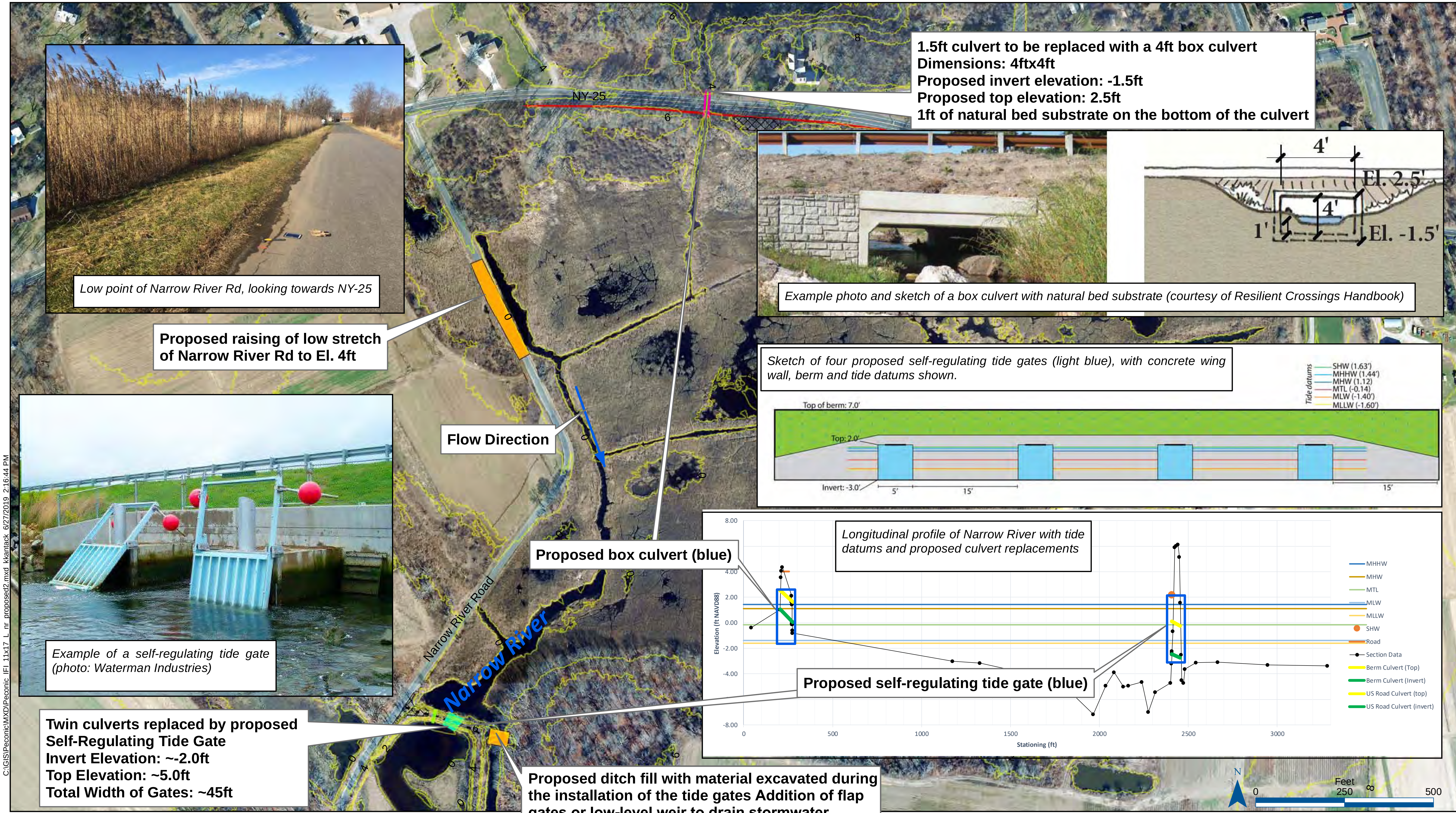
1. Contours (2 ft intervals) created from 2014 Lidar (USGS)
2. Aerial imagery from NYGIS, 2017
3. Scale is 1:3,000

inter-fluve

220 Concord Avenue, 2nd Floor
Cambridge, MA 02138

Land Use

570 Expressway Drive South, Suite 2F
Medford, NY 11763



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Peconic Estuary Assessment

Narrow River Culvert Replacements
Sheet 3 - Conceptual Recommendations
Narrow River, Orient, NY, Suffolk County (NY)
SCTM#: 300-7-1-3

Prepared 07/22/2019

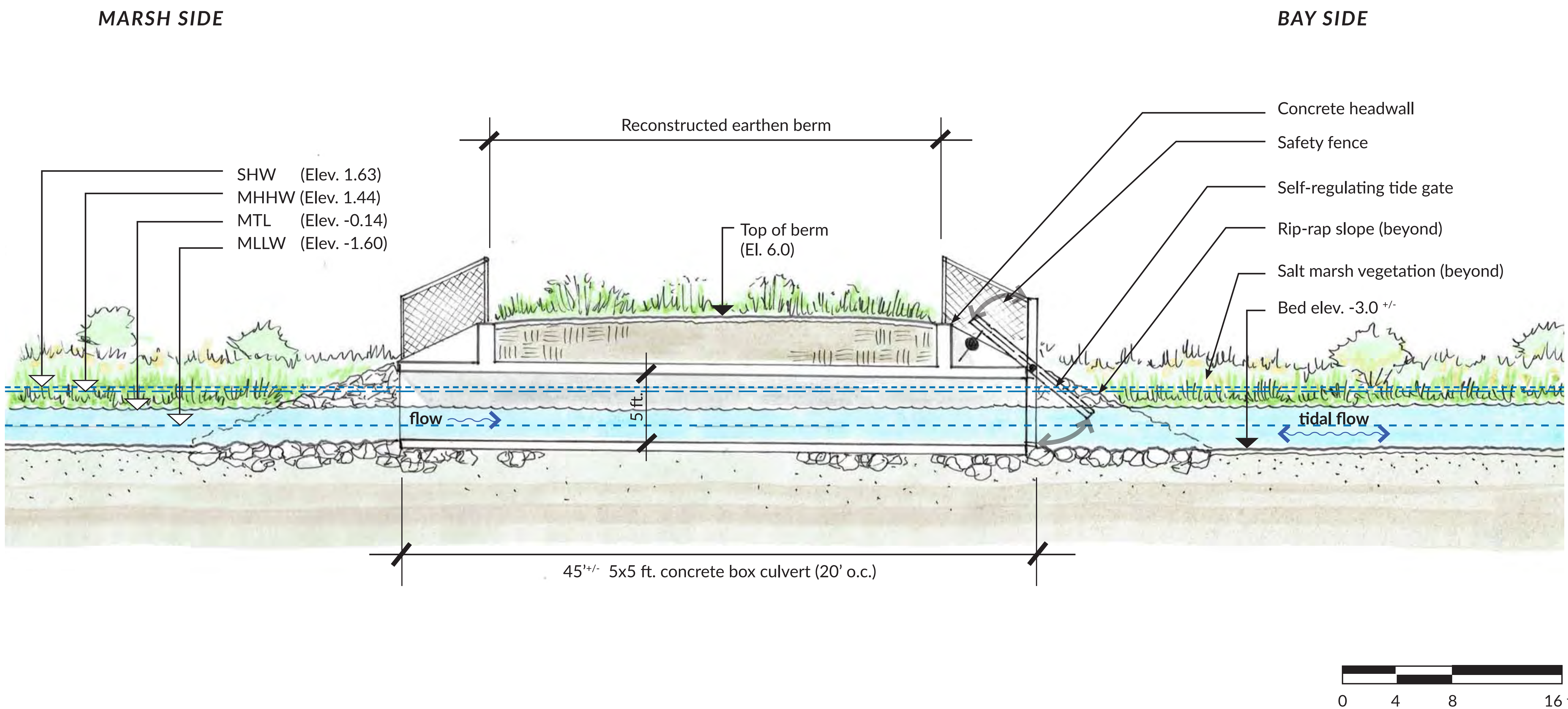
Contours (2ft)	Proposed Culvert	Access
Existing Culvert	Proposed Tide Gate	Overhead Electric
Fill	Staging	

Notes:

1. Contours (2.5 ft intervals) created from 2014 Lidar (USGS)
2. Aerial imagery from NYGIS, 2017
5. Scale is 1:3,000

inter-fluve
220 Concord Ave., 2nd Floor
Cambridge, MA 02138

Land Use
570 Expressway Dr. South, Suite 2F
Medford, NY 11763



C1

PECONIC ESTUARY PROGRAM July 1, 2019

Conceptual Section:
Double Culvert Replacement with Self-Regulating Tide Gate

BROAD MEADOWS MARSH (ORIENT, NY)

Land Use inter·fluve LVB LVBrown Studio LLC

Appendix B – Hydraulic Analysis of Earthen Berm Culverts

Appendix B – Hydraulic Analysis of Earthen Berm Culverts

Overview

In an effort to optimize the hydraulic conditions at the earthen berm crossing, multiple box culvert configurations were analyzed to determine a configuration that would provide a near "free flowing" connection between the tidal floodplain on either side of the berm. The analysis assumed that a free-flowing condition was achieved if inflow and outflow through the crossing are primarily controlled by changes in tidal stage, rather than by size and configuration of the culvert opening(s).

Each configuration was analyzed using culvert computations within a two-dimensional (2-D) domain in HEC-RAS. HEC-RAS is the USACE Hydrologic Engineering Center's River Analysis System (https://www.hec.usace.army.mil/software/hec-ras/), and is designed to perform hydraulic computations for flow in open channels, floodplains, and alluvial fans. Computations analyze flow exchange through the crossing in both directions, which allows for effects of floodplain storage to be included in the analysis. Performance was evaluated by examining floodplain inundation stage and timing over a 4-day tide cycle, with tide levels exceeding the estimated MHHW (1.44 ft NAVD88) and MLLW (-1.60 ft NAVD88) within the cycle. The analysis discussed herein is preliminary in nature, and assumptions, limitations, and recommendations for future analyses are discussed in the following sections.

Hydrologic Inputs

The tidal stage hydrograph used as the model input was taken from the Orient Harbor gage (NOAA Station ID 8511671) and converted to NAVD88 using survey information obtained by Inter-Fluve in 2018. The gage data were assumed to directly apply to the project site, although some scaling may be warranted in future analyses. The input hydrograph is displayed in Figure 1.

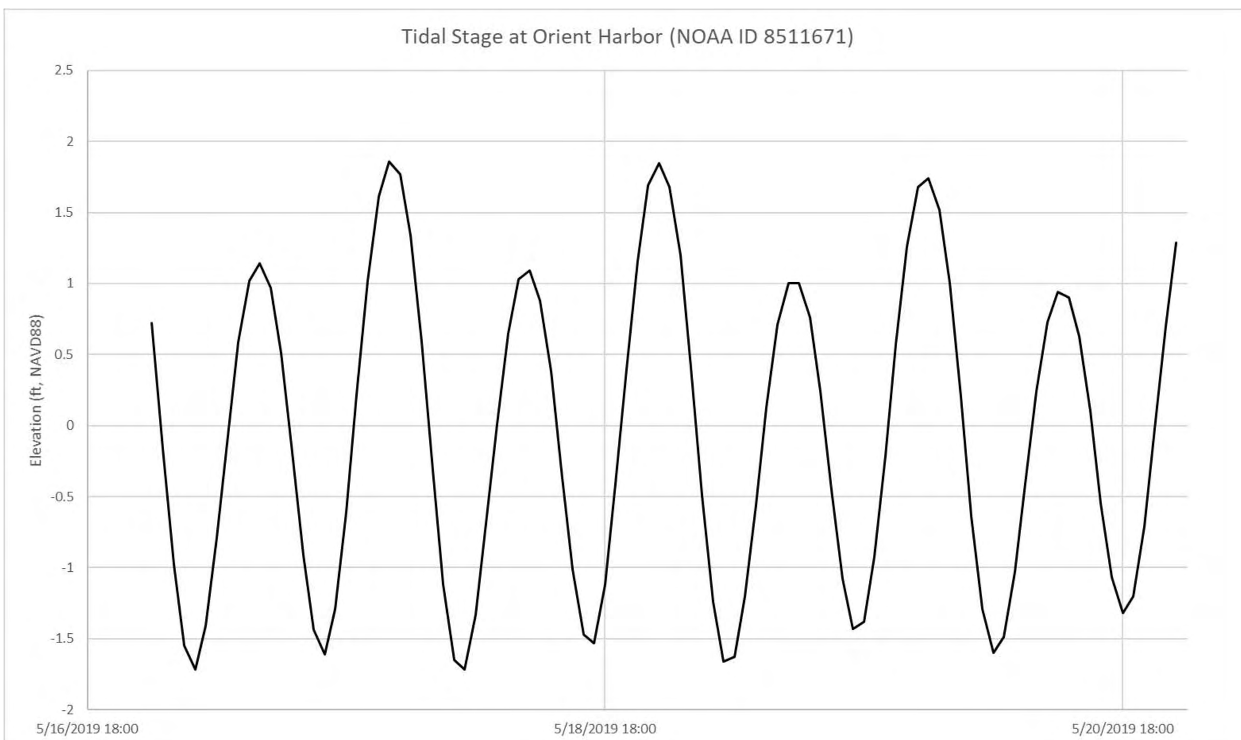


Figure 1. Input tidal hydrograph used for the culvert analysis.

Hydraulic Model Setup

A 2-D hydraulic computational domain was delineated for the project site, extending from approximately 250 ft south of the crossing location to Route 25 to the north. The model domain was bounded by high ground to the east and west where feasible. The underlying terrain consisted of LiDAR data collected by U.S. Geological Survey in 2016, and survey bathymetry collected by Ducks Unlimited in 2019 in the vicinity of the crossing. Future analyses may warrant supplementing the LiDAR surface with the complete bathymetry survey, in order to appropriately represent the storage volume and conveyance pathways within the project site.

Hydraulic roughness was applied as a single value for the entire model domain, using a value of 0.04 (agricultural fields). A single, higher roughness value of 0.12 was also checked to test the sensitivity of the model to the roughness parameter, and the results were not substantially different between the two analyses. However, using a spatially varying roughness layer will be likely provide a higher resolution to future analyses.

The culvert configurations were input directly in to the 2-D connection editor in HEC-RAS, assuming 5-foot wide by 5-foot high box culverts, spaced 15 feet apart. Culvert parameterization is a key component of the hydraulic analysis, and the following assumptions should be refined as the design progresses:

- The culvert slopes were assumed to be flat, with invert elevations of approximately -2.46 ft NAVD88 on both sides of the crossing.
- An entrance loss coefficient of 0.4 was assumed, which is within the typical range for box culvert inlet conditions.
- A culvert length of 42 feet was assumed, which is relatively consistent with existing conditions.

In addition to parameter refinements, adjustments to the location, length, orientation, and spacing of the culverts will likely be required in future analyses. Further, future culvert analyses should consider the entrance/exit losses in both directions to ensure that the culvert losses associated with the multi-directional flow of a tidal hydrograph are appropriately represented by the specified flow direction in the model.

Results

Existing conditions were analyzed using the available survey information to inform the culvert configuration, and the results were checked against anecdotal observations to ensure that the model was representing site conditions reasonably well. The existing conditions results demonstrate that there is a reduction in the peak of the higher high stage of approximately 0.5 feet, with a lag on the ebb of the higher high tide (Figure 2). These results are consistent with observations; however, further verification of the model results should be conducted for different tide cycles and with the full bathymetric surface incorporated into the hydraulic model.

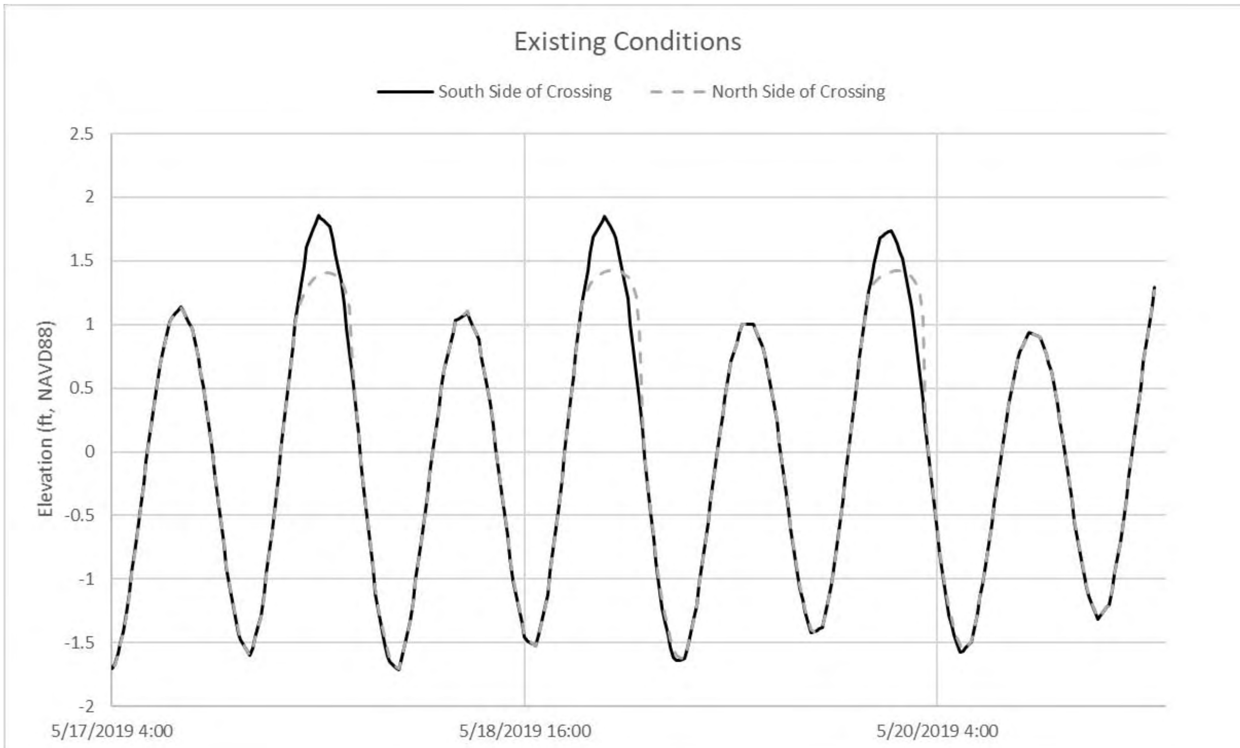


Figure 2. Analysis results for existing conditions.

The culvert-sizing analysis focused on changing the number of box culvert cells at the crossing location, until the computed hydrograph on both sides of the culvert was similar in magnitude and timing. The computed hydrographs are presented in Figure 3. The results demonstrate that four 5ftx5ft box culvert cells will allow for a nearly free-flowing condition with the assumed configuration, under the tidal conditions analyzed.

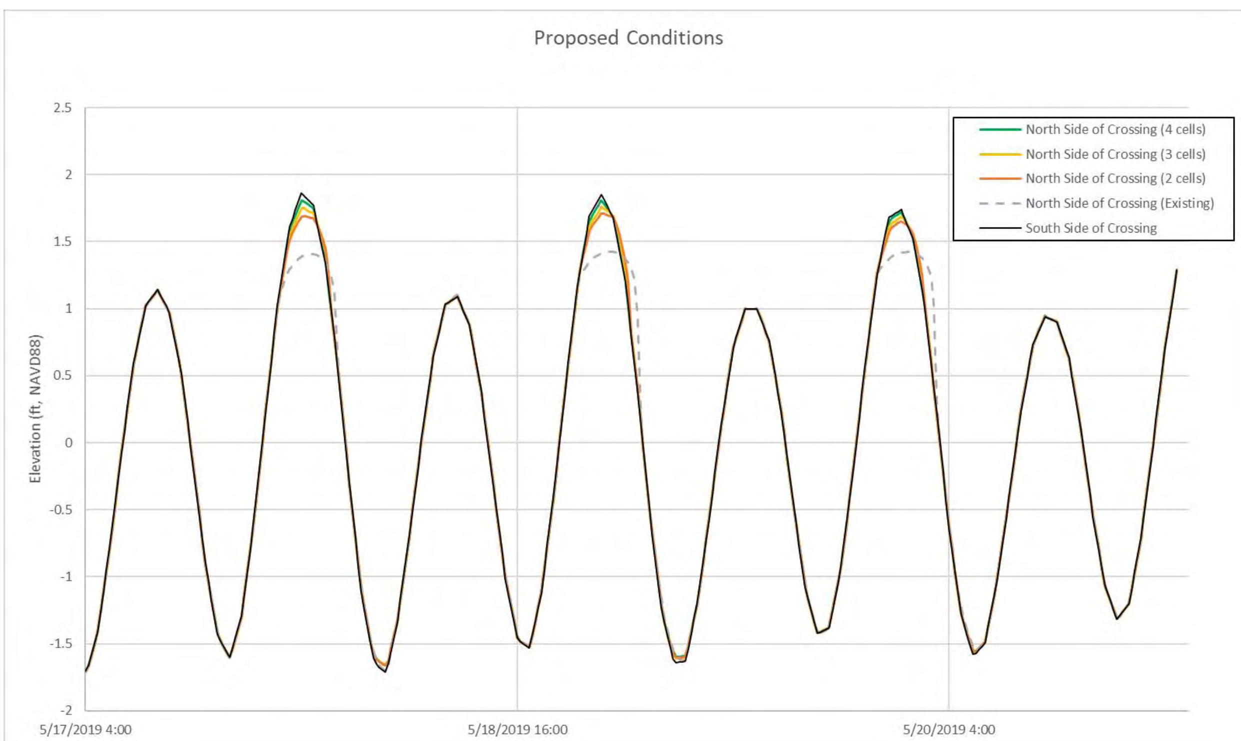


Figure 3. Summary of analysis results for proposed conditions.

Summary

The results of the preliminary analysis suggest that a near free-flowing condition can be achieved for the tidal hydrograph analyzed using four 5 ft x 5 ft box culverts to convey tidal flows through the earthen berm. The preliminary hydraulic analysis is somewhat limited by the terrain model, hydraulic roughness delineation, and culvert parameterization. The digital terrain model primarily consists of LiDAR data, and the bathymetry of Narrow River is only incorporated in the immediate vicinity of the crossing. A single roughness coefficient was used for the entire model domain, as sensitivity analysis on the existing hydraulic model suggests that the hydraulic computations are not substantially influenced by the roughness coefficient assigned to the project area. However, incorporation of bathymetry into the terrain model for the project area and a spatially varying roughness layer could potentially improve the accuracy of the analysis with respect to peak timing and attenuation. Basic assumptions were made for the layout and configuration of the proposed crossing, and refinement of the culvert computation parameters may be warranted as the design progresses.

Appendix C – Estimate of Construction Costs Based on Conceptual Plans

Narrow River

Cost Estimate Based on Conceptual Design Phase

No.	Bid Item	Unit	Unit Price	Quantity	Subtotal	Notes
1	Mobilization & Demobilization	LS	$113,900	1	$113,900	
2	Access & Traffic Control	LS	$60,000	1	$60,000	
3	Erosion & Pollution Control	LS	$25,000	1	$25,000	
4	Flow Management	LS	$60,000	1	$60,000	Pumping for upstream culvert, Isolation for tide gate installation
5	Clearing & Grubbing	LS	$10,000	1	$10,000	
6	Demolition	LS	$15,000	1	$15,000	Roadway surfaces and old culverts
7	Excavation (cut)	CY	$25	1,190	$29,750	
8	Import structural fill for Narrow River Rd	CY	$65	230	$14,950	
9	Road reconstruction	SF	$15	6,500	$97,500	Includes Rt 25 and Narrow River Road
10	Self-Regulating Tide Gate	EA	$70,000	4	$280,000	Golden Harvest GR-35, 5'x5'
11	Cast-in-place retaining wall for SRTG	SF	$135	600	$81,000	75 LF x 8 ft high; Assuming dowstream side of berm only
12	Precast box culvert - Route 25	LF	$1,200	50	$60,000	4'x4' precast box culverts
13	Precast box culverts - SRTG	LF	$1,400	180	$252,000	5'x5' precast box culverts with average length of 45 LF
14	Utility coordination/relocation	LS	$25,000	1	$25,000	
15	Planting	LS	$15,000	1	$15,000	
				CONSTRUCTION SUBTOTAL	$1,139,100	
				30% Construction Contingency	$341,800	
				3% Escalation, assuming 2020 construction	$44,500	
				CONSTRUCTION TOTAL with Contigency & Escalation	**$1,525,400**	
				PROJECT DELIVERY (design, permitting, construction support)	$341,800	30% of Construction Subtotal
				30% Project Delivery contingency	$102,600	
				PROJECT DELIVERY TOTAL with Contigency	**$444,400**	
				GRAND TOTAL with all contingencies	**$1,969,800**	