MAYO CREEK SALT MARSH RESTORATION
CULVERT DESIGN ALTERNATIVES

Prepared For:
Mayo Creek Restoration Committee
John Riehl, Chair
300 Main Street
Wellfleet, MA 02667

Prepared By:
Woods Hole Group, Inc.
81 Technology Park Drive
East Falmouth, MA 02536

December 2016

Mayo Creek Salt Marsh Restoration
Culvert Design Alternatives

December 2016

Prepared for:
Mayo Creek Restoration Committee
John Riehl, Chair
300 Main Street
Wellfleet, MA 02667

Prepared by:
Woods Hole Group
81 Technology Park Drive
East Falmouth MA 02536
(508) 540-8080

Table of Contents

List of Figures

List of Tables

1.0 INTRODUCTION

The Town of Wellfleet, Massachusetts, working through the Wellfleet Restoration Committee, is conducting further analysis to evaluate the restoration of Mayo Creek Salt Marsh (Figure 1). This current analysis follows up on an initial feasibility study and hydrodynamic model development conducted in 2011 (Woods Hole Group, 2011). Currently, Mayo Creek is connected to Wellfleet Harbor through a 2-foot diameter pipe culvert under Commercial Street. The culvert is equipped with a duckbill valve that prevents incoming tide from entering the former tidal creek; while still allowing freshwater discharge (e.g. precipitation) to exit the marsh when the tide is low in Wellfleet Harbor. Relatively small water surface elevation fluctuations occur in the creek as a result of periodic interruption of the discharge flow as the duckbill valve is closed by high tides in Wellfleet Harbor. Existing tidal fluctuations in the marsh are also caused by leaking around the culvert through the Commercial Street embankment. The elevation of the culvert combined with the unidirectional influence of the duckbill valve has reduced the tidal range as well as the mean water level in the creek to such a degree that normal tidal inundation of the surrounding marsh area no longer occurs. This study utilizes the model developed for Mayo Creek in the initial feasibility study and evaluates targeted solutions that optimize the tide range with limitations applied to the Mean High Water (MHW) to avoid potential surface water flooding, and to the Mean Tide Level (MTL) to avaoid potential groundwater increases. As such, the newly proposed culvert should increase the tidal range within Mayo Creek without increasing Mean Tide Level (MTL), which currently resides at -1.7 ft NAVD88, or having a Mean High Water (MHW) that exceeds the elevation of surrounding infrastructure. The lowest lying existing structure is at 1.3 ft NAVD88, however the next set of structures are at an elevation of 2.1 ft NAVD88. Therefore, since theere is only one structure at 1.3 ft both the 1.3 and 2.1 MHW limiting conditions will be evaluated.

This report describes the application of the Mayo Creek analytical estuarine culvert model. It presents the results from the model with different proposed culvert designs, to identify a feasible option for marsh restoration with minimal impacts to the infrastructure. The report is divided into the following sections:

- Section 1.0 Introduction
- Section 2.0 Previous Work
- Section 3.0 Culvert Design Assessment
- Section 4.0 Conclusion and Recommendations

Section 2.0 describes the model and how the model was implemented for this area, including input parameters and calibration, and is essentially a recast of the work presented in Woods Hole Group (2011). Section 3.0 lays out the different culvert designs that were investigated and the results produced by the hydrodynamic model. Section 4.0 summarizes the results and gives recommendations for the culvert sizing and components that could be considered to advance restoration of the Mayo Creek system.

Figure 1. Location map of Mayo Creek. The magenta outline shown on the inset of the map indicates the extent of the modeling domain and encompasses the area less than 10 feet in elevation (NAVD, 1988).

2.0 PREVIOUS WORK

An analytical estuarine culvert model for Mayo Creek was developed by Woods Hole Group in 2011 to conduct initial assessments of potential marsh restoration options. During that model development, hypsometric curves were created for Mayo Creek that were also applied in this study. A hypsometric curve, which defines the relationship between the land elevation and wetted area, was developed using topographic and bathymetric elevations for the marsh system. These data were acquired using Light Detection and Ranging (LiDAR) and Real Time Kinematic (RTK) techniques. The elevations were transformed into hypsometric curves for both the upper and lower basins of the marsh system (Figure 2 and Figure 3). The lower basin starts at the Commercial Street culvert and extends to Chequessett Neck Road. The upped basin is constrained by Chequessett Neck Road and Old Chequessett Neck Road. The flow from Wellfleet Harbor and between basins was characterized using a head-loss relationship for the flow through a circular pipe culvert. This allowed for the determination of how the water elevations change as a function of time in each basin.

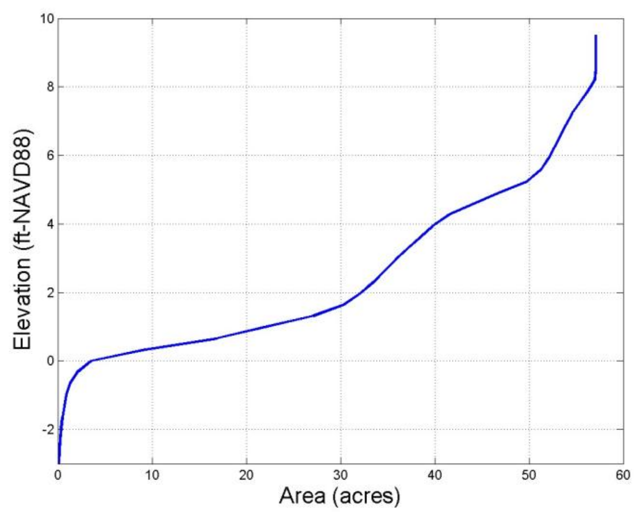

Figure 2. Hypsometric curve for Mayo Creek lower basin.

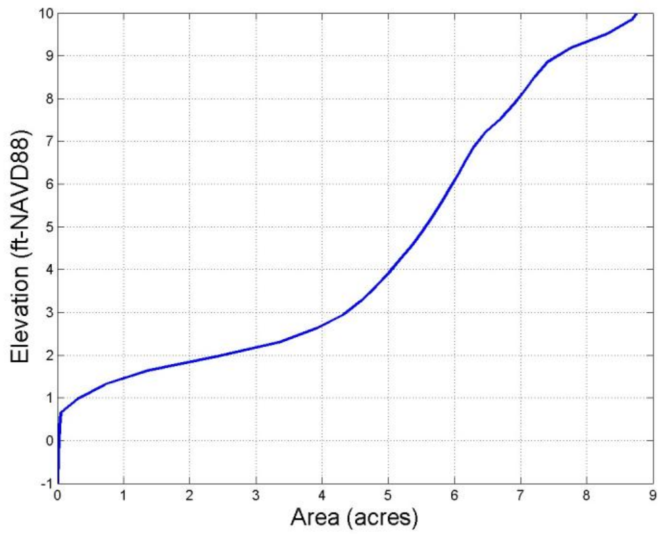

Figure 3. Hypsometric curve for Mayo Creek upper basin.

The boundary conditions for this area were characterized by tidal data measured in Wellfleet Harbor for the period of 3/19/10 to 4/24/10, and rainfall conditions acquired at the Provincetown Airport. Water elevations were also recorded during the same time period inside the lower basin. Using a portion of the collected data, the model was calibrated for existing conditions. The model was then validated for another period using the collected data. The model development process and other information about the previous study can be found in the Woods Hole Group 2011 study.

The validated analytical estuarine culvert model was used in the current study to assess different culvert scenarios, maximizing the tidal range while maintaining a MTL of -1.7 ft NAVD88 and also limiting MHW to a maximum elevation of 2.1 or 1.3 ft NAVD88.

3.0 CULVERT DESIGN ASSESSMENT

The ultimate goal of the restoration of the Mayo Creek system is to improve the health of the marsh by increasing the tide range and, therefore, the intertidal area within the marsh. As discussed in 2011 Woods Hole Group study, the current intertidal zone is limited to the banks of the perennial stream (Figure 4), and the tidal range is less than 2 feet (compared to nearly 10 feet in Wellfleet Harbor).

Figure 4. Mayo Creek Basin with contours of MHW, MLW, and Spring High tide under existing conditions (does not consider rainfall). From Woods Hole Group, 2011.

While in the previous study (Woods Hole Group, 2011) various new culvert sizes were considered, these previous alternatives were not evaluated with respect to the surrounding infrastructure, which had not been surveyed at the time. The previous study was more focused on what level of restoration could be attained unencumbered by any infrastructure restrictions. However, in this evaluation, limiting factors were applied to account for the lowest elevation of surrounding residences in the area and the effect MTL might have on the ground water table. The lowest single infrastructure asset surrounding Mayo Creek has an elevation of 1.3 ft NAVD88, while the next lowest structure is 2.1 ft NAVD88. Due to these upper limitations for the water surface elevation (both MTL and MHW), it was critical to reduce Mean Low Water (MLW) in the system as much as possible in order to maximize tidal exchange, range, flushing ability, and also improve drainage capacity. Therefore, the analysis for the optimum culvert design started with determining the lowest MLW level that could be achieved. As a starting point, invert elevations for the Commercial Street culvert were investigated.

3.1 CIRCULAR CULVERT DESIGN

The invert elevations of the Commercial Street culvert are currently -4.73 and -3.59 ft NAVD88 downstream and upstream, respectively. Each invert was changed within the range of -2 ft to -5 ft NAVD88 using 0.5-foot increments. The invert elevation could not be raised higher than -2 feet NAVD88 due to potential interference with existing piped infrastructure (water main). This resulted in 49 different invert combinations to determine the maximum drainage producing the lowest MLW. Through these series of runs, it was determined that an invert elevation of -3.8 ft NAVD88 at both ends of the a newly installed culvert produced the lowest MLW for the current culvert size (2-foot diameter).

The effect of changing the culvert size was then evaluated by adjusting the culvert diameter from 0.5 ft to 5 ft. Figure 5 shows the comparison of water levels for different culvert diameters with invert elevations set at -3.8 ft. The lowest MLW that could be achieved was -3.55 ft using a 3.5-foot diameter culvert. The culvert that met the not-to-exceed 1.3 ft MHW criteria was with a 2-foot diameter. A 3-foot diameter culvert produced a MHW lower than the 2.1 ft NAVD88 criteria, and gave the second lowest MLW of -3.53 ft. None of the culvert scenarios were able to maintain a MTL of -1.7 feet, however, which is also one of the limiting criteria. This means that it is impossible to maintain the existing MTL with passive flow control (without tidal control measures) and also attain some reasonable restoration.

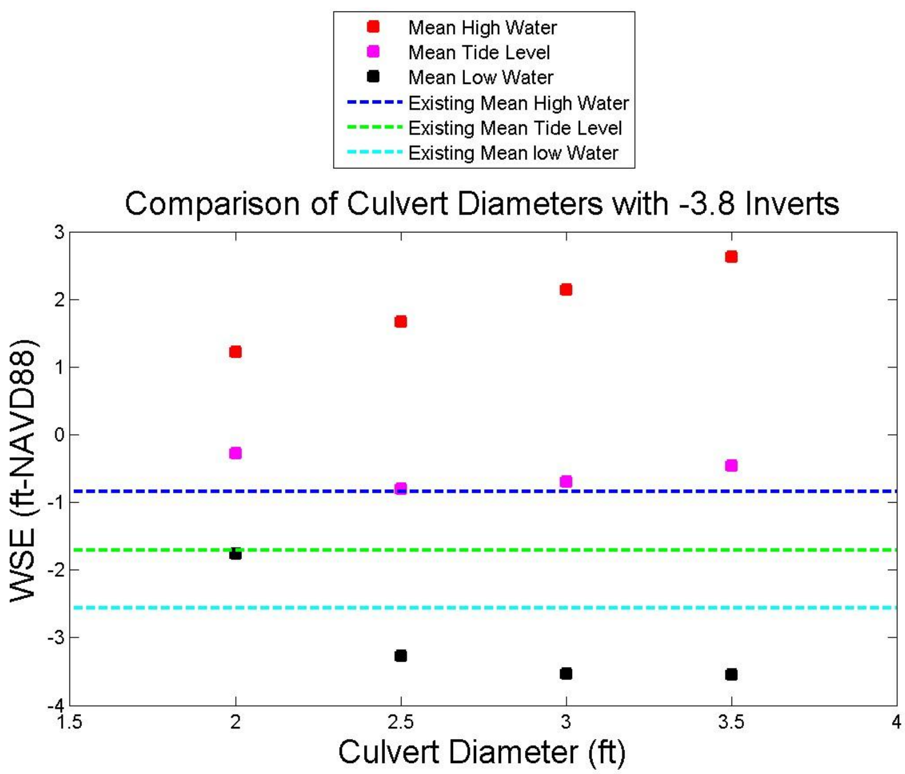

Figure 5. MLW, MTL, and MHW as a function of potential culvert size in the lower Mayo Creek Basin.

While passive control measures (pipes with no tidal control) can produce MHW elevations below the critical infrastructure, the proposed culvert would also need to maintain storm surge levels equivalent to existing conditions (i.e., the proposed new culvert should not allow storm surge flooding above current levels). The evaluated storm scenarios that were evaluated consist of combination surge and precipitation events. These included a 10-year event having 8.34 feet of surge taken from the (USACE, 1988) with a 100-year rainfall of 8 inches (Figure 6), as well as the storm of record for the area, the Blizzard of 1978, with 9.7 feet of surge combined with a 10-year rainfall of 5 inches (Figure 7). The rainfall conditions (NRCC Cornell University, 2016) were distributed over 24 hours using a type 1 rainfall distribution. The rainfall was then multiplied by the area of the Mayo Creek Basin, 65 acres, to determine the total input into the system. Both of these cases were run with the invert elevation of -3.8 ft NAVD88. The culvert sizes were then varied to determine the required culvert size that kept the peak water surface elevation below the critical elevations of 1.3 ft and 2.1 ft. A 1.5 foot diameter culvert kept the peak water surface elevation under 2.1 ft; however, no culvert could keep the peak water surface elevation under 1.3 ft. (Table 1). As such, using a culvert alone (without some sort of tidal control measures) would result in increased flooding during a storm event (compared to existing conditions), or require a reduction in culvert diameter that would inhibit restoration potential. The more appropriate solution requires tidal control to not only maximize restoration during normal tidal conditions, but also limit MTL and peak storm surge levels in Mayo Creek.

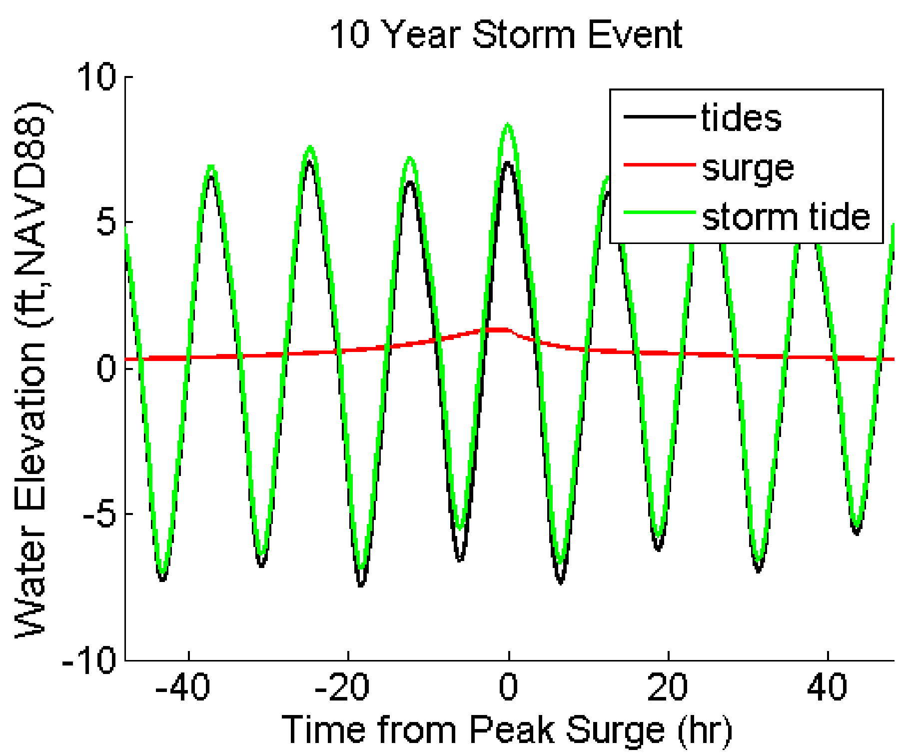

Figure 6. **Storm surge profile for the 10-year storm with tides in Wellfleet Harbor.**

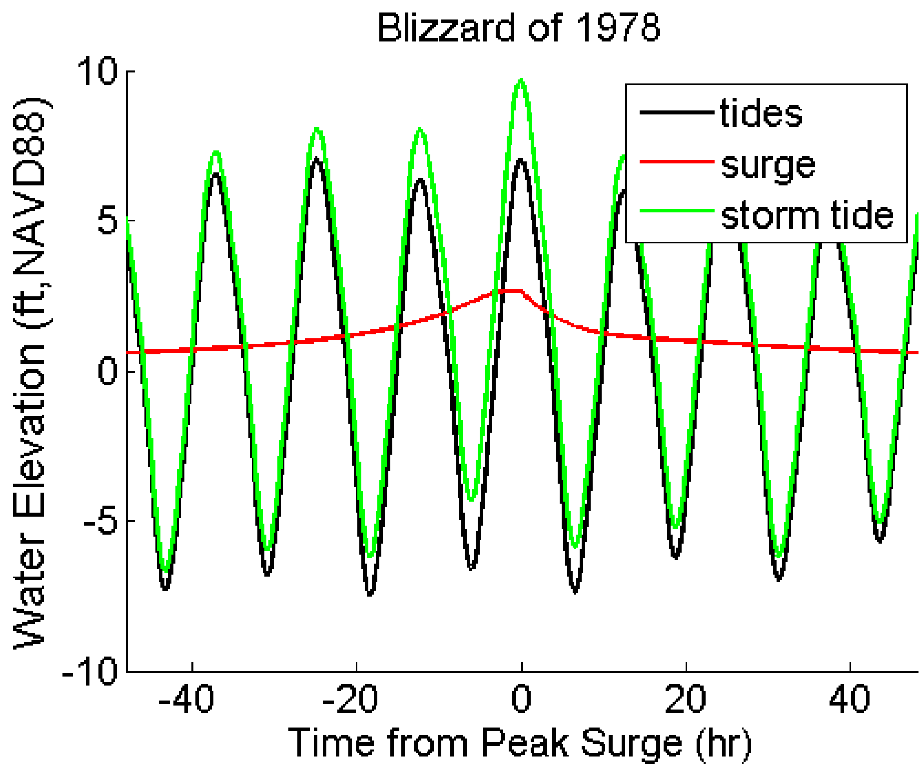

Figure 7. Storm surge profile for the Blizzard of 1978 with tides in Wellfleet Harbor.

Table 1. Peak water levels from the surge/rainfall storm cases for different culvert diameters in the lower basin.

Diameter (ft)	**2.5**	**2**	**1.5**	**1.25**	**1**	**0.75**	**0.5**
10-year storm with 100-year rain peak water level (ft, NAVD)	2.72	2.30	2.09	2.04	2.09	2.27	2.48
100-year storm with 10-year rain peak water level (ft, NAVD)	3.06	2.51	2.11	1.98	1.95	2.07	2.26

Therefore, a self regulating tide gate could be installed on a new larger culvert as an active measure to effectively control MHW and MTL, while still allowing for better drainage (lower MLW) and greater overall tidal range. Using a 3.5 foot diameter culvert, which produced the lowest MLW attainable; simulations were conducted to determine the appropriate set point for the self-regulated gate. A set point is the value of water surface elevation where once reached by the water, the tide gate automatically closes. The culvert was modeled with different tide gate set points in order to find the appropriate value that did not increase MTL above existing conditions. The objective was to find the tide gate set point that met both the MHW and MTL requirements (i.e., limited MHW below the 1.3-foot threshold and maintained MTL at -1.7 ft). By simply closing the gate at the limiting high water values (MHW elevations of 2.1 and 1.3 feet), MTL was higher than existing conditions, as shown in Table 2. However, with a tide gate set point of 0.1 feet NAVD88, MTL was -1.73 ft. For this scenario, MHW is maintained well under the critical levels, MTL is not increased, and the tide range is improved from 1.76 ft to 3.54 ft, as shown in Figure 8.

Table 2. MTL for the different tide gate set point values.

Tide Gate Set Point (ft-NAVD88)	1.3	1.1	0.9	0.7	0.5	0.3	0.1
MTL (ft-NAVD88)	-1.13	-1.23	-1.33	-1.43	-1.53	-1.63	-1.73

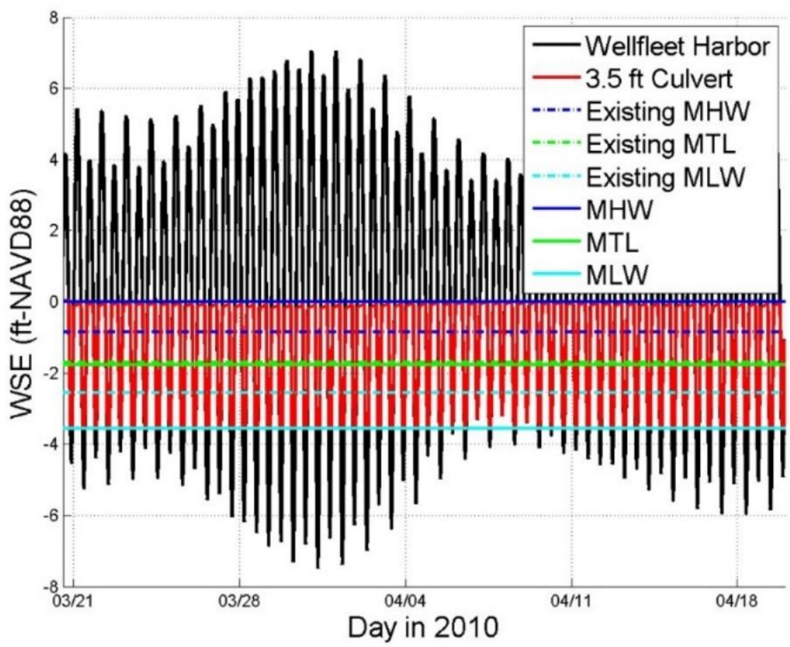

Figure 8. Time series water surface elevation for a 3.5 ft diameter culvert having -3.8 ft NAVD88 invert elevations and tidal control limiting high water to 0.1 feet. Dashed horizontal lines show existing MHW, MLW, and MTL and solid lines showing proposed MHW, MTL, and MLW.

The tide gate scenario using a set point elevation of 0.1 ft NAVD88 and a circular culvert diameter of 3.5 ft allows for the largest tide range while also meeting the MHW and MTL criteria.

Another option for the proposed culvert design is utilization of a box culvert. Box culverts have a larger base than that of a circular culvert and would, in theory, allow the system to drain more efficiently. A box culvert may also prove to be a safer option as it can be designed to allow for adequate head space in case of human entrainment into the culvert.

3.2 BOX CULVERT DESIGN

The same approach used to evaluate the circular culvert design parameters was also used to assess a conceptual box culvert design. First, the invert elevations were varied to determine the lowest MLW that could be achieved within the Mayo Creek system. The invert elevation that produced the lowest MLW for a box culvert was a elevation of -3.6 ft NAVD88, at both the upstream and downstream ends. This invert elevation was then assessed for different culvert widths using a culvert height dimension of 2 feet. Figure 9 shows the results of these model simulations with the lowest MLW (-3.51 ft NAVD88) attained when the culvert width was 4 feet or larger. Increasing the box culvert width beyond 4 feet did not decrease MLW further.

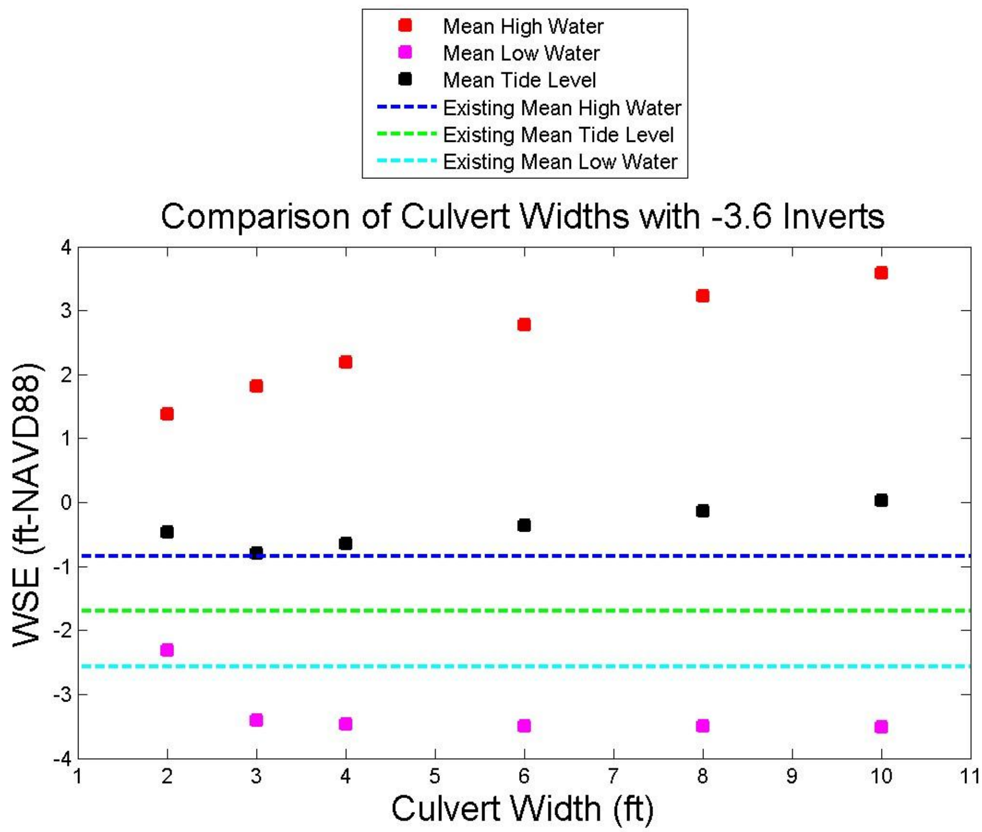

Figure 9. MLW, MTL, and MHW in the lower Mayo Creek Basin as a function of width of box culvert having a height of 2 ft.

A 4’x2’ foot culvert produced water levels with MLW =-3.47, MTL =-0.64, and MHW = 2.18 feet, indicating that the box culvert alone, without any tidal control measures, would result in an increased MTL in the system. The 4’x2’ foot box culvert was then evaluated for the same storm conditions that were used in evaluating the circular culvert scenario. The storm simulations indicated the 4’x2’ box culvert produces a peak elevation over the 2.1-foot limiting criteria, as shown in Figure 10. As for the circular culvert case, the box culvert would also require a self regulated tide gate in order to meet all the requirements:

- Improving the tidal range and intertidal area for restoration,

- Keeping the MTL at or below its existing elevation,
- A MHW elevation not to exceed the limiting elevations of either 1.3 feet or 2.1 feet NAVD88.

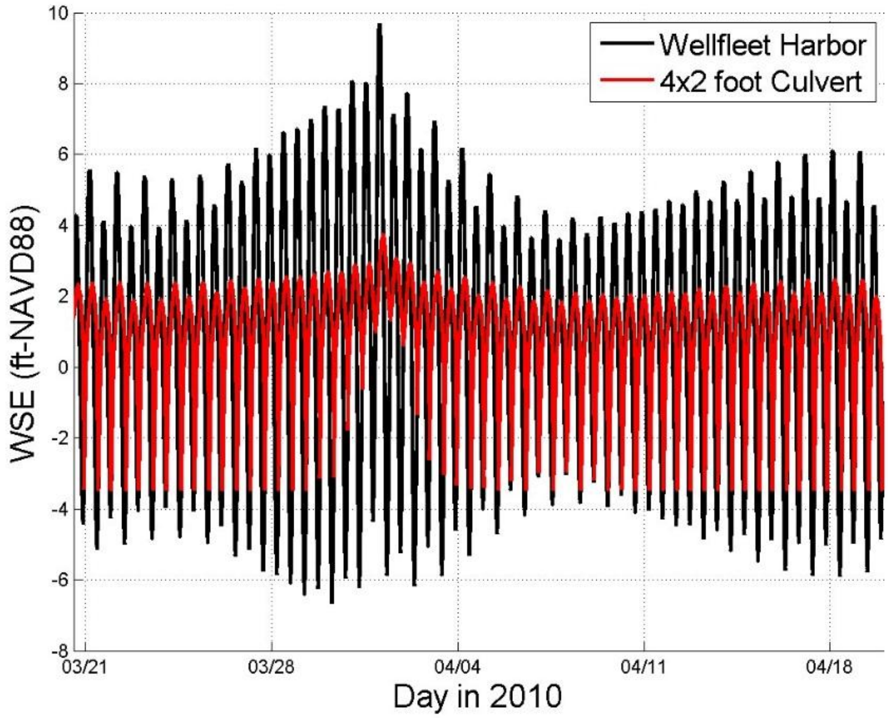

Figure 10. Time series of water surface elevation during storm conditions (100-year surge/10-year precipitation) for a 3.0 ft diameter culvert with invert elevations at -3.8 ft NAVD88.

A self-regulating tide gate was also further evaluated for a box culvert scenario by varying the set point of the gate to ensure the limiting MTL and MHW criteria could be attained. In order to limit the high water within Mayo Creek to a maximum of 2.1 feet NAVD88, the set point on the tide gate would need to be set at 6 feet NAVD88 (the tide gate would close when the water surface elevation in Wellfleet Harbor reached 6 feet NAVD88. Similarly, to keep the maximum water surface elevation in Mayo Creek at 1.3 feet, a set point of 3.6 feet would be required. However, the limiting criteria in this case is the MTL limitation, which would require the tide gate to close when the water surface elevation reached 0.2 feet NAVD88 in Wellfleet Harbor, as shown in Table. 3. With a set point of 0.2 feet, the tide range increases from 1.76 (existing conditions) to 3.47 (Figure 11). This is approximately the same result as the circular culvert produced.

Table 3. Tide gate set point to meet the elevation criteria for a 4'x2' foot box culvert

Tide Gate Set Point (ft-NAVD88)	6	3.6	0.2
MHW	2.1	1.35	0.002
MTL	-0.69	-1.06	-1.73
MLW	-3.47	-3.47	-3.47

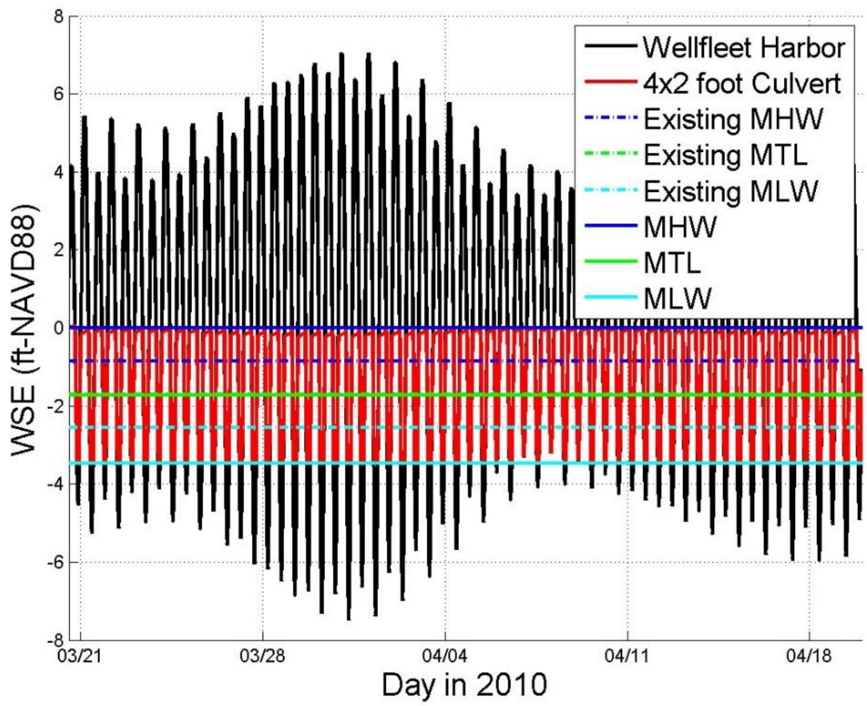

Figure 11. Time series of water surface elevation for a 4'x2' ft box culvert having invert elevations at -3.6 ft NAVD88 and tidal control limiting high water to approximately 0 feet NAVD88. Dashed horizontal lines show existing MHW, MLW, and MTL and solid lines showing proposed MHW, MTL, and MLW.

3.3 EXCAVATED CASE

Due to the long-term restricted nature of Mayo Creek, it is likely that some of the channels in the marsh network have disappeared and/or shoaled over time. The existing marsh system can only drain to a limited elevation partly due to the elevations within the marsh channels and marsh itself, as indicated in the hypsometric curves. Therefore, a scenarios was evaluated that assessed the potential for improved drainage, restoration, and tidal range by cleaning some of the existing channels, as well as adding some additional channel branches throughout the marsh system. While for existing conditions, the lowest MLW that could be achieved by replacing the culvert is -3.5 feet, if the channels were excavated, then it is expected a lower MLW could be attained, therefore also allowing for improved volumetric exchange of salt water. This scenario evaluated excavation of the channels to -5 feet NAVD88 and creation of some additional tidal channels thought the system (Figure 12). All channels were excavated to a depth of -5 feet NAVD88 and a box culvert connection was utilized for this scenario assessment. In reality, channels would be slightly sloped towards the Wellfleet Harbor to promote drainage.

Figure 12. Schematic showing channel lowering (red) and added channels (yellow) for improved drainage.

As for the previous cases, simulations were targeted towards identifying the lowest possible MLW that could be attained under the excavated conditions. Not surprisingly, the culvert invert for these simulations was also set to -5 feet NAVD88 and was again tested for different box culvert widths. The culvert height dimension was set at 2 feet (as before) and the results of the simulations are shown in Figure 13. The lowest MLW attained was -4.5 feet NAVD88 using a 6'x2' foot culvert. The 6'x2' foot culvert also produces a MHW of 2.7 feet, which exceeds the required limit of 2.1 feet NAVD88. Figure 13 also shows that a 4'x2' culvert keeps MHW under 2.1 feet, and a 2'x2' culvert keeps MHW under 1.3 feet. As for the non-excavated cases, there is no culvert dimensions that are able to maintain a MTL at or below the existing elevation of -1.7 feet

NAVD88. As such, tidal control measures would be required to meet all the goals of maintaining MTL, limiting MHW, and increasing tidal range.

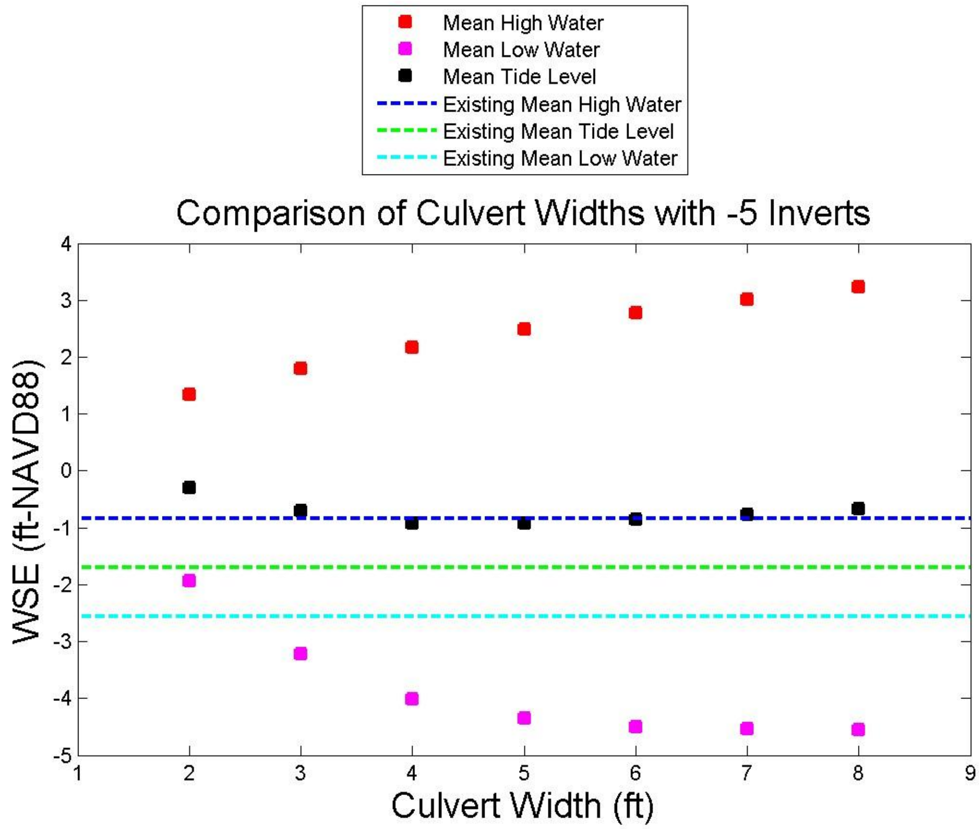

Figure 13. MLW, MTL, and MHW in the lower Mayo Creek Basin as a function of width of box culvert having a height of 2 ft for the excavated scenario.

A self-regulated tide gate was assessed to determine the set point required to maintain MTL at the existing -1.7 feet NAVD88 in Mayo Creek. In order to meet the MTL criteria, the set point would be set at 2.4 feet, indicating the tide gate would close when the Wellfleet Harbor water surface elevation reaches 2.4 feet, as shown in Table 4. This tide gate setting would results in an increased tidal range from 1.76 to 5.68 feet, and produces a higher MHW such that more area would be converted to inter-tidal habitat (as shown in Figure 14). Other set points were evaluated to meet the MHW requirements of 2.1 and 1.3 feet as well; however, these set points elevate MTL (Table 4).

Table 4. Tide gate set point elevations evaluated to meet the elevation criteria for a 6'x2' foot box culvert under the excavated case.

Tide Gate Set Point (ft-NAVD88)	4.4	2.8	2.4
MHW	2.11	1.29	1.11
MTL	-1.23	-1.64	-1.73
MLW	-4.56	-4.58	-4.58

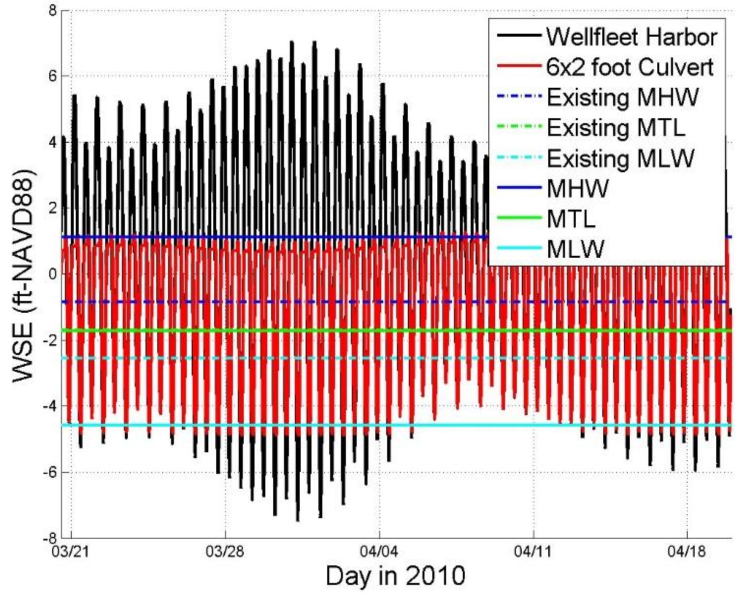

Figure 14. Time series of water surface elevation for a 6'x2' ft box culvert with invert elevations at -5 ft NAVD88 and tidal control limiting high water to 1.1 feet. Dashed horizontal lines show existing MHW, MLW, and MTL and solid lines showing proposed MHW, MTL, and MLW.

3.4 Design Consideration

Low, wide box culverts were originally considered in order to promote drainage and limit the amount of water entering the system. Due to the limitations associated with the restoration of Mayo Creek (i.e., getting low water as low as possible and limiting high water), box culvert simulations focused on these low and wide dimensions. However, as illustrated in the results above, the low, wide box culverts could not meet the required criteria without the inclusion of a tidal control mechanism. As such, the tidal control mechanism becomes the ultimate flow control for the tidal connection (as opposed to the dimensions of the culvert). As such, additional design considerations, beyond just the control of tidal exchange can be included in the overall design layout. For example, box culverts that are only 2 feet high result in fully flowing connections for a portion of the tidal cycle. This would leave no headspace (air gap) open during a portion of the tidal cycle, which could be considered a safety risk for an inadvertent impingent of a human. For example, if a person were to fall into the water on the upstream side of the culvert on an outgoing tide, they could be entrained into the culvert and pinned against a partially closed tide gate. By increasing the height dimension of the culvert, adequate head space could be provided prior to (and after) gate closure. Therefore, the proposed culvert height was increased to 5 feet (4'x5' box culvert) for the non-excavated case with a -3.8 feet NAVD88 invert, and 7 feet (6'x7' box culvert) for the excavated case with a -5 feet NAVD88 invert.

With the self-regulated tide gate included in the design, the larger culvert size will not cause a major change to MHW or MTL, and also provides this added safety consideration. Table 5 provides the new required set point elevations for both the non-excavated and excavated conditions. Changing the size of the culverts also allow for a slight increase in tidal range from 3.47 to 3.52 feet for the existing case and 5.68 to 5.76 feet for the dredged case. These dimensions are the final recommended box culvert dimensions for a new culvert at Mayo Creek.

Table 5. Tide gate set point to meet the MTL of -1.7 ft for both non excavated and excavated cases.

	Non-excavated 4’x5’	Excavated 6’x7’
Tide Gate Set Point (feet- NAVD88)	**0**	**1.4**
MHW	0.03	1.18
MTL	-1.73	-1.7
MLW	-3.49	-4.58

3.5 COMBINATION GATE

While all tidal control measures evaluated above include the use of a self-regulated gate that would automatically close when a specific water level was reached in Wellfleet Harbor, the use of a combination gate (Figure 15) was also considered. This type of gate slides opens to various opening elevations such that there is a limited opening on a incoming tide, but is able to flap completely open during an outgoing tide to allow increased drainage. This allows for a non-linear exchange of water into and out of the system. To model this scenario, the height of the sliding gate was adjusted to maintain the MTL while allowing the full height of the culvert for the drainage of the system. The sliding gate for the non-excavated 4’x5’ foot proposed culvert would require a small 0.15-foot gap at the bottom of the culvert to maintain MTL of -1.7 ft (Table 6). For the excavated case with a 6’x7’ foot box culvert, the sliding gate would require a vertical gap of 0.75 feet. The drawback of using a combination gate for tidal control is that during storm events, the gate would allow additional water in to the system as compared to a self-regulating tide gate. The combination gate would need to be manually closed during an impending storm surge scenario in order to ensure that high water in the Mayo Creek system does not exceed the maximum required water surface elevation. If the combination gate was not manually closed, higher storm surge based water surface elevations could be expected in Mayo Creek.

Figure 15 Golden Harvest GH-50 sluice-flap combination gate.

Table 6. Sliding gate gap to meet the MTL of -1.7 for both non-excavated and excavated cases.

	Non-excavated 4'x5'	Excavated 6'x7'
Sliding Gate Gap (ft)	**0.15**	**0.75**
MHW	0.31	1.21
MTL	-1.76	-1.68
MLW	-3.49	-4.58

4.0 CONCLUSION AND RECOMMENDATIONS

Restoration of the Mayo Creek system will require increased tidal exchange in order to enhance tidal flushing, increase intertidal area, and revitalize ecological resources within the marsh system. Increased tidal exchange was evaluated though the replacement of the existing 2' diameter culvert and duckbill system that is currently limiting tidal exchange at the entrance to Mayo Creek. A hydrodynamic model was utilized to evaluate various proposed connections, including both circular and box culverts with a range of dimensions, inverts, and tidal control measures. Use of tidal control measures and tide gates was attempted to be avoided such that the new proposed connection could be maintained through passive control (natural restriction of the new culvert) of the water levels. However, the strict requirements of limiting the high water levels due to surrounding infrastructure, as well as the desire to maintain the current mean tide level, required the use of tidal control measures if any reasonable restoration was expected. Both the proposed box and circular culverts were unable to increase the tide range while maintaining the required existing MTL. As such, an active tide control solution is required as part of any restoration of the Mayo Creek system, unless the limitations on MHW and/or MTL are modified. Two options were investigated for active tidal control; a self regulating tide gate and a combination tide gate. The installation of a tide gate system also offers additional storm surge protection to the Mayo Creek system, as well as the ability to adjust to future sea level rise and changing climate conditions. However, the inclusion of a tide gate control also requires diligent maintenance of the structure to ensure operability, as well as monitoring to ensure the ecological benefits are continued in the future. A box culvert, as opposed to a circular culvert, is recommended due to slightly improved hydrodynamics as well as the ability to provide a safer tidal connection.

Both a current condition (non-excavated) and enhanced marsh system (excavation and channel creation) condition were also evaluated. The excavated case was evaluated and with the optimized box culvert/tide gate was found to increase the tide range by more than 2 feet compared with the existing channels case and approximately 4 ft more compared with the existing culvert design. This significant improvement in the tide range is primarily driven by being able to get a much lower MLW, which allows MTL to be more easily maintained in Mayo Creek. This excavated scenario and newly proposed culvert/tide gate increases MHW by more than a foot compared to the existing channels case and 2 feet compared with the existing culvert design. This increase allows more of the marsh to be inundated during high tides without affecting existing infrastructure or increasing MTL. It may also be reasonable to install the new box culvert prior to performing any maintenance/excavation work in the Mayo Creek system to observe if the increased tidal exchange allows for any natural flushing of sediment build up in the existing channels. Following the natural flushing, the need for additional excavation could be considered.

Based on our analysis and results, a reasonable solution for the Commercial Street culvert design would be the replacement of the existing culvert with a box culvert fitted with a tidal control mechanism (self-regulating or combination tide gate). This would produce the largest increase in both tidal range and the intertidal area, while maintaining the existing MTL and limiting the MHW level. Figure 16 shows the increase in MHW lines expected for both the non-excavated and excavated channel scenarios coupled with a culvert replacement compared with that of current conditions. Currently, there is a total intertidal area of 2.17 acres. The non-excavate (existing) case with a newly installed 4’x5’ box culvert with tidal control (combination or self regulated gate) provides and intertidal area of 4.57 acres. An excavated case with a 4’x7’ box culvert with tidal control (combination or self regulated gate) provides and intertidal area of 25.7 acres. As shown in Figure 16, the best scenario for maximum restoration given the current limitations to MHW and MTL is to excavate out the existing channels, create some additional drainage channels, and install a 4/x7’ box culvert with appropriate tidal control (self-regulated or combination gate). This scenario results in an increase of 23.5 acres in intertidal area, does not increase MTL, and minimizes the MHW level relative to the surrounding infrastructure. Either a self-regulating of combination gate could be utilized; however, the combination gate would require more manual adjustment, especially to limit high water during storm surge events. Both tide gates would require a maintenance and operational program to be developed and rigorously followed.

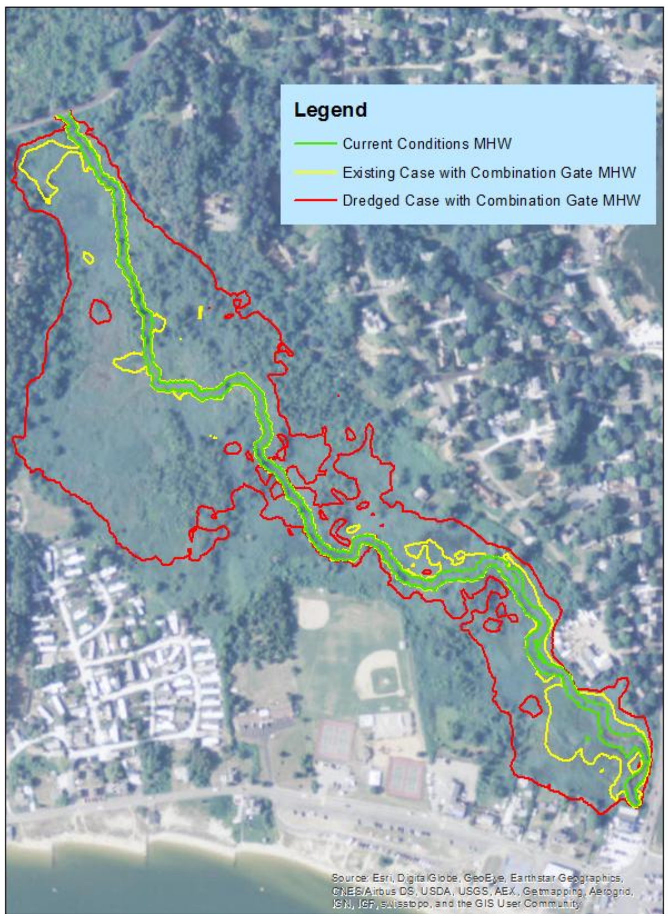

Figure 16. Comparison of MHW lines from the current conditions (green), the non-excavated case (yellow), and the dredged case (red).

5.0 REFERENCES

NRCC Cornell University. 2016. Extreme Precipitation in New York and New England. Technical Documentation and User Manual.

USACE. 1988. Tidal Flood Profiles New England Coastline. Hydraulics and Water Quality Section New England Division.

U.S. Environmental Protection Agency. 1990. Technical Guidance Manual for Performing Waste Load Allocations, Book III Estuaries, Part 2, Application of Estuarine Waste Load Allocation Models. EPA 823-R-92-003.

Woods Hole Group. 2011. Mayo Creek Final Report. Technical Memorandum to Ms. Hillary Greenberg, Health and Conservation Agent, Town of Wellfleet. January 1, 2011