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MEMORANDUM

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TO Maraspin Creek Project Team

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Maraspin Creek, Barnstable, MA–
Existing Culvert Sizing and Hydrologic & Hydraulic Assessment

1. Summary

On behalf of the Town of Barnstable, Woods Hole Group conducted a Hydrologic and Hydraulic (H&H) Assessment of Maraspin Creek. The primary purposes of the work were to evaluate the influence on coastal flooding and/or salt marsh habitat of the existing culvert under Commerce Road. The H&H assessment involved: 1) collecting field measurements of water levels, salinity, and temperature throughout the tidally-influenced salt marsh system; 2) surveying the channels and hydraulic structures; 3) developing a calibrated and validated tidal hydraulics model for Maraspin Creek to characterize existing flow conditions; 4) utilizing the model to simulate a range of tides and coastal storms; and 5) evaluating whether the existing culvert (2.5-foot diameter pipe) at Commerce Road is restricting flow to the upstream marsh area for purposes of habitat restoration, and/or causing flood impacts to developed areas adjacent to Maraspin Creek, such as the Blish Point Community.

The H&H assessment focused on evaluating the hydraulic structures located within Maraspin Creek, considering Maraspin Creek as the sole source of flood water. It did not include direct flooding from the bay side, localized precipitation-based runoff and flooding, or backup from stormwater outfalls. These additional flood sources are potentially significant to Blish Point flooding.

Results of the assessment and methods applied are detailed in this Memorandum. Some of the pertinent results include:

- During typical tides, high tide elevations do not significantly change throughout the system, indicating the hydraulic structures (bridge at Millway and culvert at Commerce Road) are not substantially restricting flow.
- During extreme coastal storm events, the bridge at Millway does not restrict the incoming surge; however, the culvert at Commerce Road does restrict surge elevations upstream of the culvert.

- Looking at a potential future condition with a moderate 2-foot increase in sea level, the bridge at Millway does not restrict high tide elevations in Maraspin Creek during typical tides; however, the culvert at Commerce Road does become restrictive in this scenario.
- Model simulations show a larger 5-foot diameter pipe culvert is required at Commerce Road to not restrict flow during extreme coastal storm events and during typical tides with an increased sea level.
- A larger non-restrictive culvert at Commerce Road is shown to increase flooding upstream of Commerce Road during coastal storm events and with an increased sea level; however, the modest increase in storage volume does not reduce flooding impacts downstream of Commerce Road.

In summary, the existing culvert at Commerce Road restricts flow during coastal storms and during typical tides with sea level rise. A larger culvert that does not restrict flow would have benefits in allowing for potential migration and expansion of salt marsh upstream of Commerce Road with future increases in sea level. However, the storage capacity of the marsh area upstream of Commerce Road is not sufficient to alleviate flooding in Maraspin Creek and the adjacent Blish Point community during these scenarios.

Additional alternatives are being further investigated including a reduced opening at the bridge under Millway to restrict storm surge into Maraspin Creek, and potential for an increased berm/road elevation adjacent to Blish Point to prevent overtopping of floodwater from Maraspin Creek.

2. Introduction

Maraspin Creek is a tidally-influenced salt marsh system located in Barnstable, MA. Tidal flow is conveyed within the marsh from Barnstable Harbor through two roadway crossings: a bridge under Millway, and a culvert under Commerce Road (Figure 1). A 2.5-foot diameter pipe culvert exists under Commerce Road, which was thought could be restricting flow into the upstream marsh leading the upstream portion being primarily a freshwater wetland system. An initial data collection and modeling effort was completed to investigate the existing conditions within the marsh and effects of the culvert under Commerce Road on the system both upstream and downstream. The model was also developed to evaluate potential alternatives for replacing the culvert under Commerce Road.

Concerns also exist for the portion of Maraspin Creek between Millway and Commerce Road due to flooding of adjacent properties in Blish Point which occurred during recent extratropical storm events (e.g., January and March storms of 2018). This data collection and modeling evaluation helped to better understand the overall system dynamics, and whether replacing the culvert at Commerce Road has potential benefits of restoring salt marsh habitat upstream of the roadway in normal tidal conditions, and/or changing the coastal storm flood risk in the system. Specifically, the investigation evaluated potential for increased flooding upstream of the Commerce Road culvert and potential for reduced flooding between Millway and Commerce Road in Blish Point, adjacent to Maraspin Creek.

3. Analytical Culvert Estuarine Model

Maraspin Creek was evaluated using an analytical hydraulic model to simulate tidal and storm surge propagation in the Maraspin Creek system. The model was applied specifically to simulate the effect of the Millway and Commerce Road culverts on the tidal attenuation in the marsh downstream and upstream of Commerce Road, as well as flooding and drainage of the system during storm conditions. The model uses the topography and bathymetry of the area and the boundary conditions described below to determine water levels in Maraspin Creek, downstream and upstream of Commerce Road.

The model is based on conservation of mass principles in propagating water fluxes through flow-control structures into basins described by their hypsometry (elevation-to-area relationship). Hypsometric analysis describes the elevation distribution across an area of land surface. It is an important tool to evaluate areas inundated and the volumetric distribution with respect to specific water levels. The hypsometry for each basin was created using a combination of existing LiDAR and recent Real Time Kinematic (RTK) GPS surveys that are described further below.

Figure 1: Maraspin Creek in Barnstable, MA, showing the two roadway crossings.

3.1. Model Description

The technical approach utilized by the hypsometric model involves a simple procedure for calculating the tidal response in a marsh connected to the ocean by a fully or partially-full opening. The assumptions are that the sea level in the marsh is independent of position, and that the flow through the culvert is described by a standard hydraulic head-loss relationship, depending on the type of flow control structure and depth of flow.

For Maraspin Creek, the flow control structures include the bridge structure, the existing circular pipe culvert and any alternative culvert configuration (alternative condition). The hydraulic computations for the marsh system are based on the mass conservation equation for the water in each marsh basin:

$$A_{marsh} \frac{dh_{marsh}(t)}{dt} Q_{culvert} \qquad (1)$$

where t is time
A_{marsh} is the surface area of the marsh basin
$h_{marsh}(t)$ is the time-varying water surface elevation in the basin
$Q_{culvert}(t)$ is the volume flow rate

Given the assumption of a horizontal sea surface within the marsh, the conservation-of-mass equation for the water in the marsh is

$$A(h_{marsh}) \frac{dh_{marsh}}{dt} = Q_{culvert} + Q_{gw} + Q_{rain} \qquad (2)$$

$$Q_{culvert} = -au \qquad (3)$$

The surface area of the marsh A is prescribed as a function of marsh h through the measured hypsometric relationship; $a(t)$ is the cross-sectional area of flow in the culvert; and $u(t)$ is the average flow velocity in the culvert. Velocity is defined as positive when flowing from the marsh toward the ocean (i.e., downstream). Q_{gw} and Q_{rain} are volumetric flow rates into the marsh resulting from groundwater input and surface water runoff, respectively. For circular pipe culverts, it is straightforward to calculate the relevant geometric parameters required to determine the velocity (cross-sectional area , the wetted perimeter P, and hydraulic diameter).

The quadratic head-loss relationship for the flow through a circular pipe culvert(s) is:

$$h_{marsh} - h_{ocean} = \left(K_{entrance} + K_{exit} + \frac{fl}{d_h}\right) \frac{u|u|}{2g} \qquad (4)$$

where g is the acceleration due to gravity, entrance K and exit K are the dimensionless head-loss coefficients for the entrance and exit to the culvert, respectively, *l* is the length of the culvert, d_h is the hydraulic diameter, and *f* is the empirical Darcy-Weisbach friction factor.
The solution of (4) for the velocity is

$$u = 2g \left(\frac{|h_{marsh} - h_{ocean}|}{K_{entrance} + K_{exit} + \frac{fL}{d_h}} \right)^{1/2} \frac{(h_{marsh} - h_{ocean})}{|h_{marsh} - h_{ocean}|} \qquad (5)$$

The friction factor, f varies depending on roughness and flow velocity in the pipe and is calculated iteratively using the manning's n equation. The above equations are solved in time by means of standard first-order finite difference approach. Results of the computations include the water level time series in the marsh, time dependent water surface area in the marsh, and discharge volume through the culvert.

To account for potential overtopping of barriers that separate basins in the model, an additional overtopping flow can be specified in the model once a certain water elevation is reached. This flow is incorporated into the model using equations for a broad crested weir (Equation 6 and 7).

$$Q_{weir} = CLH^{\frac{3}{2}} \quad (6)$$

$$C = \frac{2^{\frac{3}{2}}}{3} g^{\frac{1}{2}} \quad (7)$$

Where Q_{weir} is the flow over the barrier, L is the length of the road section over which water is flowing, H is the head difference between the water and the road, and g is the force of gravity.

3.2. Model Configuration

This section presents site-specific data for Maraspin Creek, and describes how these data were used to develop and parameterize the model. The required data include topographic/bathymetric data to define the model hypsometry, as well as tidal data and rain flow input to the model. Site specific tidal data for Maraspin Creek were collected in the Fall of 2018 together with supplemental topographic/bathymetric data to support this study.

3.2.1.Topography/Bathymetry

The Maraspin Creek system can be defined by two separate basins. The first basin is upstream of Millway and downstream of Commerce Road (downstream basin), and the second basin is upstream of the Commerce Road (upstream basin). For the downstream basin, surveyed elevations were collected along Commerce Road, in the channel at the culvert, and around Millway bridge in 2018 (Figure 2). Upstream of Commerce Road, channel elevations in close proximity to the culvert were also surveyed. Additional elevations were surveyed including the inverts of the culvert under Commerce Road and controlling elevations for the Millway Bridge opening.

The channel inverts for the Millway bridge are -3.5 feet on the downstream harbor side and -1.6 feet on the upstream creek side, relative to NAVD88. The inverts for the culvert under Commerce Road are 2.0 feet downstream and 3.7 feet upstream. Topographic elevations for the remaining areas within Maraspin Creek were defined using a 2016 USGS Digital Elevation Model (DEM) (USGS, 2017).

The basin elevations were derived from combining the elevations from the survey and USGS DEM (Figures 3 and 4). These elevations were then used to develop hypsometric curves used as input to the model and shown in Figure 5. In developing the hypsometry for the downstream basin, the storage volume of the Blish Point development north of Commerce Road was evaluated. Surveyed and LiDAR elevations along the berm/Commerce Road on the northern side of the downstream Maraspin Creek basin indicate the critical elevation when a flood pathway would develop from Maraspin Creek into the Blish Point development north of Commerce Road is 9 feet NAVD88. For perspective, the storage volume in Blish Point for a representative water surface elevation of 9 feet

NAVD88 is approximately 2% of the downstream Maraspin Creek basin volume and thus, was considered insignificant and not included.

Although more detailed elevation data could be incorporated into the analysis to describe the intricate undulations of the roadway, adjacent berm, and private properties/driveways, RTK surveyed elevations inside the channel matched the USGS DEM well, which gave further confidence in the LiDAR elevation data set used for the defining the hypsometry of the Maraspin Creek basins (Figure 5).

Figure 2: Maraspin Creek elevation survey of Millway Bridge, Maraspin Creek channel, and Commerce Road.

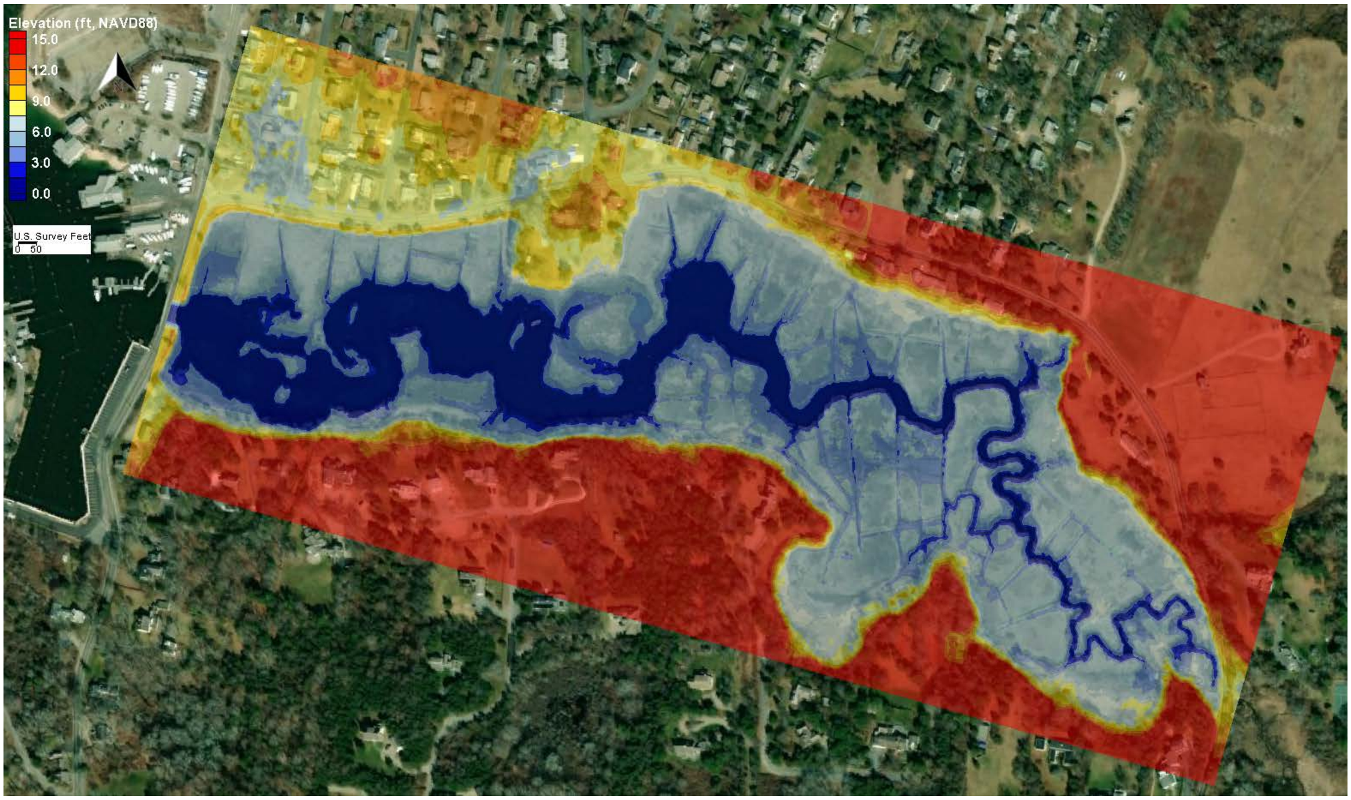


Figure 3: Combined elevations from the surveyed areas and LiDAR used to make the downstream hypsometry.

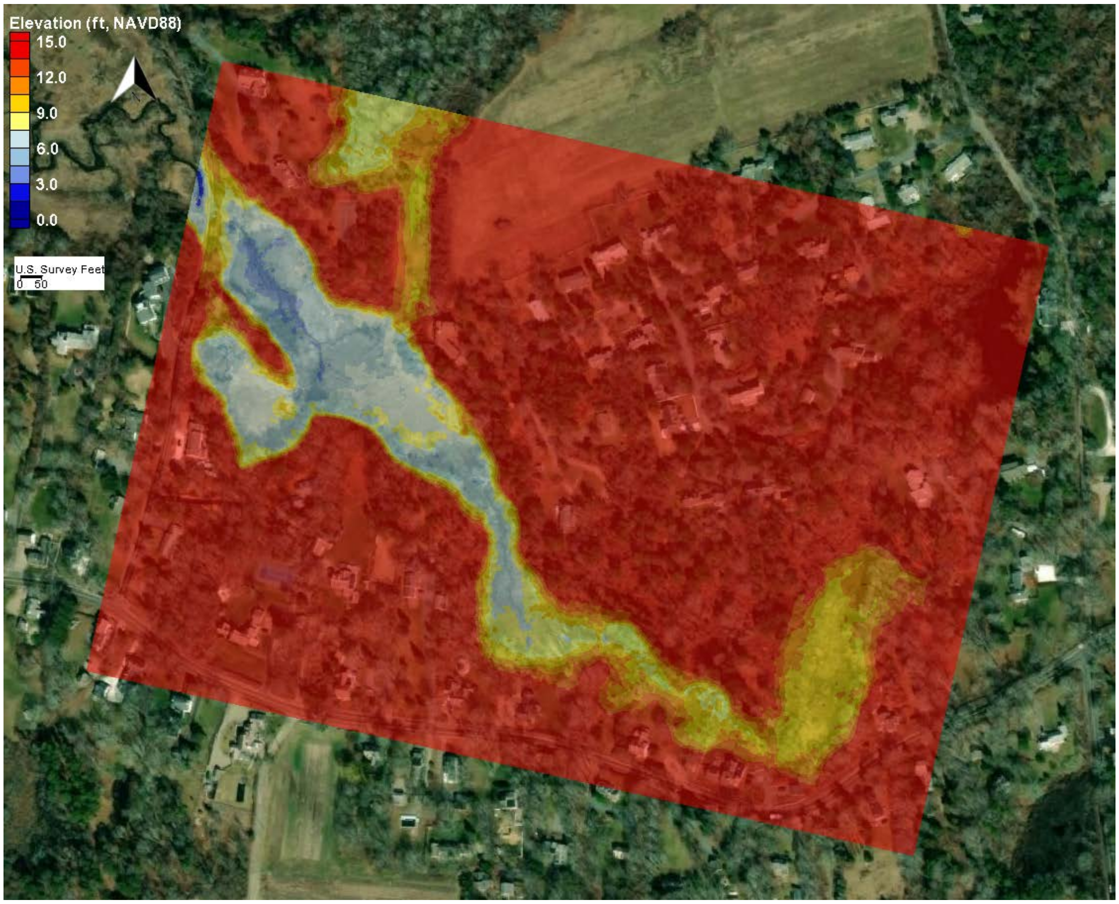


Figure 4: Combined elevations from the RTK elevation and LiDAR elevations to make the upstream hypsometry.

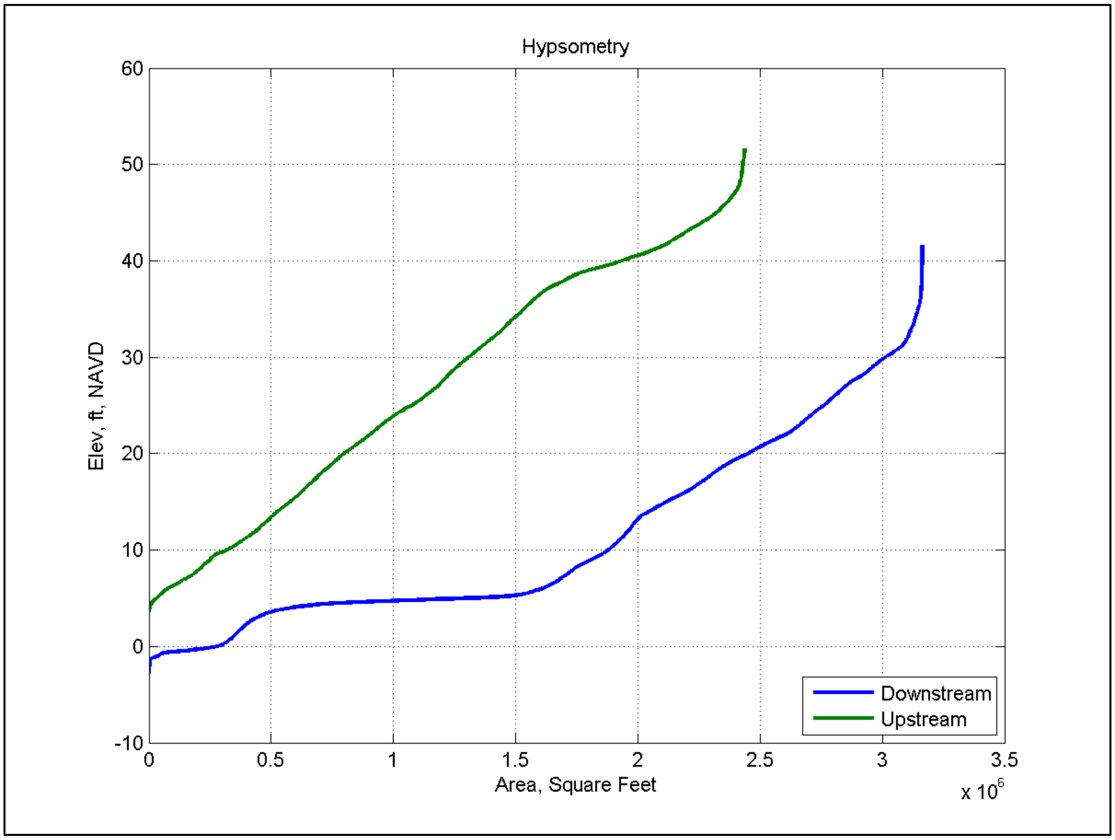


Figure 5: Downstream and upstream basin hypsometry created from the combined elevations of the area.

3.2.2.Boundary Conditions

3.2.2.1. Tidal boundary conditions

Measurements of water level and salinity were collected in Maraspin Creek during September and October 2018, and 100% data return was achieved. These measurements serve as both a tidal boundary condition for the model and points used to calibrate the model to existing conditions.

Figure 6: Water level recording stations throughout Maraspin Creek system.

Water elevations were recorded at four locations including Barnstable Harbor, upstream of Millway bridge, as well as up- and downstream of Commerce Road (Figure 6). The Barnstable Harbor water levels were used for the tidal boundary condition of the model. The month of water level data collected in 2018 is shown in Figure 7 (top panel) together with salinity (upper-mid panel), temperature (lower-mid panel), and precipitation (lower panel) over the same period. Precipitation (rainfall) data were obtained from the Hyannis Airport station. The effect of rainfall can be primarily seen in the salinity data and the upstream water level signal (station MC4). This time period shows the occurrence of both spring and the neap tidal cycles, and the attenuation that occurs within the Creek between the downstream and upstream locations.

Some general observations about the system from the data:

- There is a substantial reduction in the tide range from the Harbor, through Maraspin Creek and upstream of the Commerce Road culvert.
- The tide range reduction is primarily associated with an increase in the low tide elevation and mean water level. The increasing low tide elevation is likely due to a combination of an increase in the marsh creek bed elevation upstream, as well as freshwater inflow providing a net flow out of the marsh.
- High tide elevations are not restricted substantively, suggesting the bridge and culvert are not providing a substantial constraint on flow at regular high tides.
- There is a substantial spring-neap modulation of the tide range including higher high and lower low tides with the new and full moon phases in the fortnightly cycle.
- Salinity levels decrease with distance upstream in the system.

- The overall salinity level in the system decreases during substantial rainfall events (e.g. just prior to October 14)

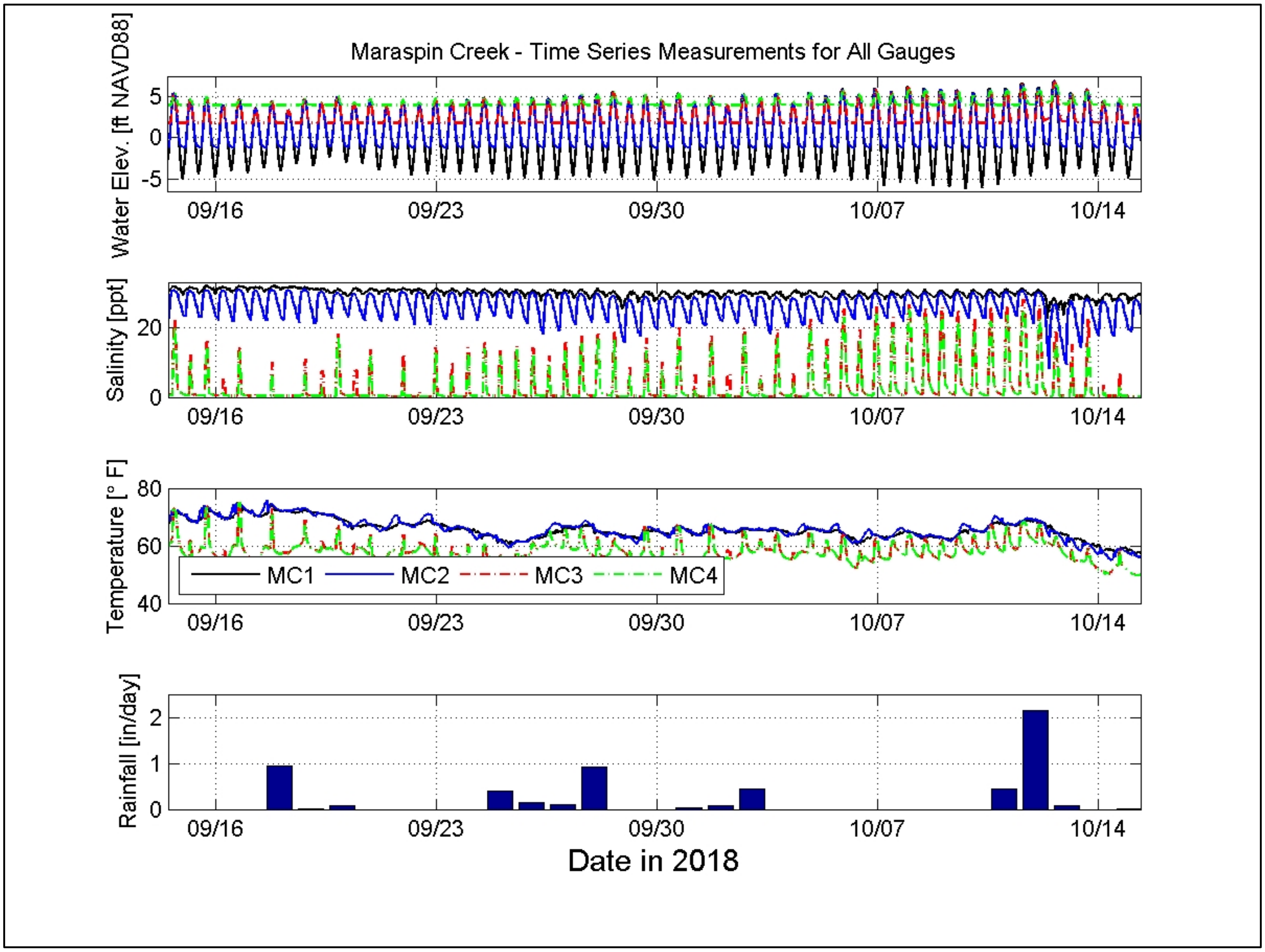


Figure 7: Water level, salinity, temperature, and rainfall measurements in 2018

3.2.2.2. Upstream Boundary Condition

The next step in developing model boundary conditions was to determine the upstream input condition attributed to baseflow and surface water runoff from rainfall during the observed time period. The upstream boundary condition was specified as an input flow or discharge representing combined contributions from groundwater and surface water runoff feeding Maraspin Creek.

To develop the upstream inflow associated with surface water runoff, hourly rainfall data were collected from Hyannis Airport. The established rational method was then used to establish the surface water discharge, Q, using the following equation:

$$Q = CIA \qquad (8)$$

where C is a dimensionless runoff coefficient, I is the rainfall intensity, and A is the area of the watershed. The watershed areas for the Maraspin Creek basins were defined using USGS Streamstats. The areas of the watershed were determined to be 135 acres for downstream, and 415 acres upstream (Figure 8). Based on the defined watersheds and land use data sourced from the USGS 2011 National Land Cover Database, composite values for C were determined to be 0.23 and 0.18 for the downstream and upstream watersheds, respectively. A time-varying input flow rate was determined for the upstream and downstream basins using the rainfall data.

Since the measured water level data showed a higher mean water elevation in the upstream marsh in comparison to the downstream water level, there is likely a contribution from baseflow attributed to groundwater. To determine an appropriate groundwater baseflow rate, the model was run with various baseflow rates in the upstream basin until the modeled water levels were consistent with the observations. This resulted in a groundwater baseflow rate of 1 cubic feet per second. This constant baseflow was added to the model with the time-varying precipitation flow rate discussed above.

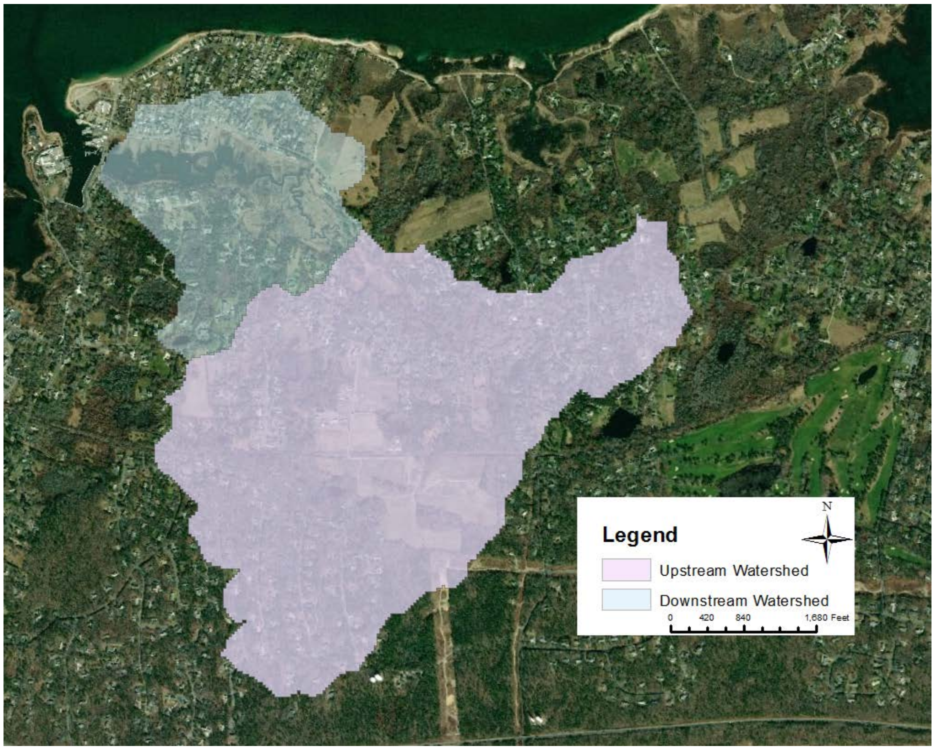


Figure 8: Watershed areas obtained from USGS for Maraspin Creek.

3.2.2.3. Coastal Storm Surge Events

Boundary conditions were also developed for model simulations of coastal storm surge events. The extreme storm surge elevations used in this study are from the latest 2014 FEMA Flood Insurance Study for Barnstable County and are shown in Table 1. These peak water levels were superimposed onto a typical tidal signal to develop a storm surge hydrograph using methods detailed in the 2004 Federal Highway Administration Hydraulic Engineering Circular No. 25. The storm surge hydrograph developed using this procedure for a 100-year storm event is shown in Figure 9. A comparison between the 100-year storm and winter storm Grayson (at Boston) which occurred in January of 2018 is shown in Figure 10. Grayson was a significant storm event for the area, as indicated by the peak water level near a 50-year return period level (2% chance of occurrence in any given year). Grayson's surge elevation was only 0.1 ft less than a 50-year event.

Table 1: Storm Return Frequency Water Levels for Barnstable Harbor

Return Period (years)	**Water Level (ft, NAVD88)**
	Source: FEMA (2014)
100	10.1
50	9.8
10	8.8

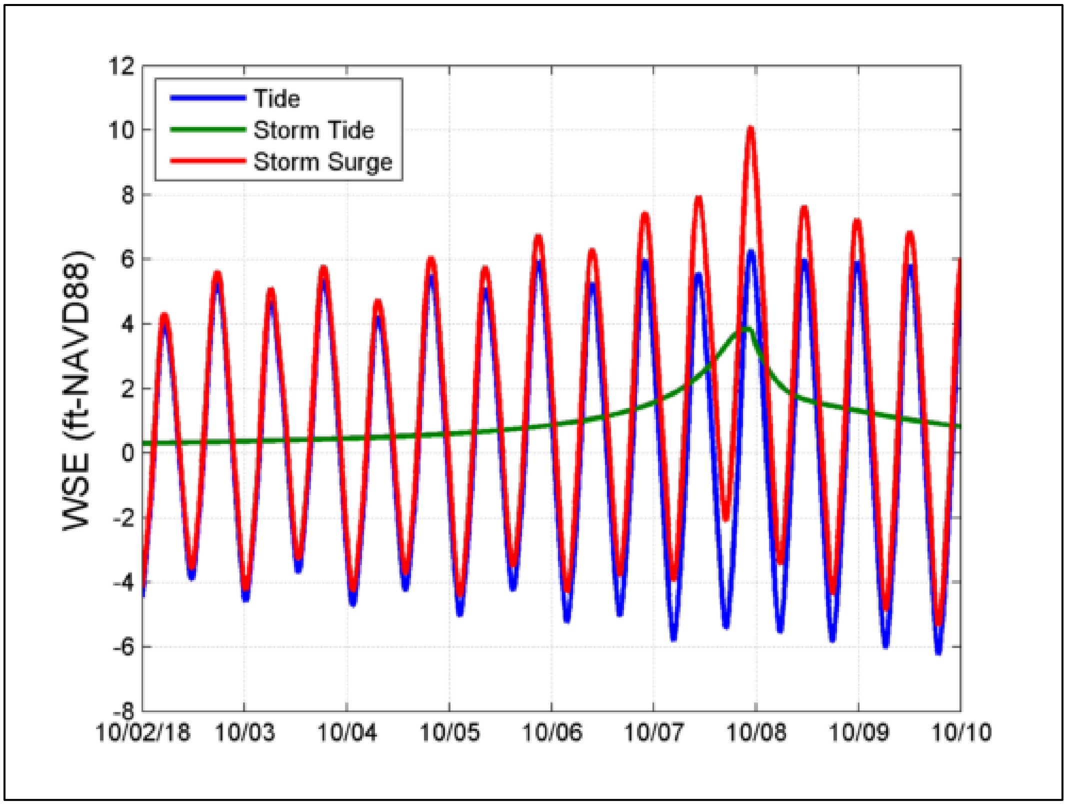


Figure 9: Storm surge hydrograph developed for the 100-year event.

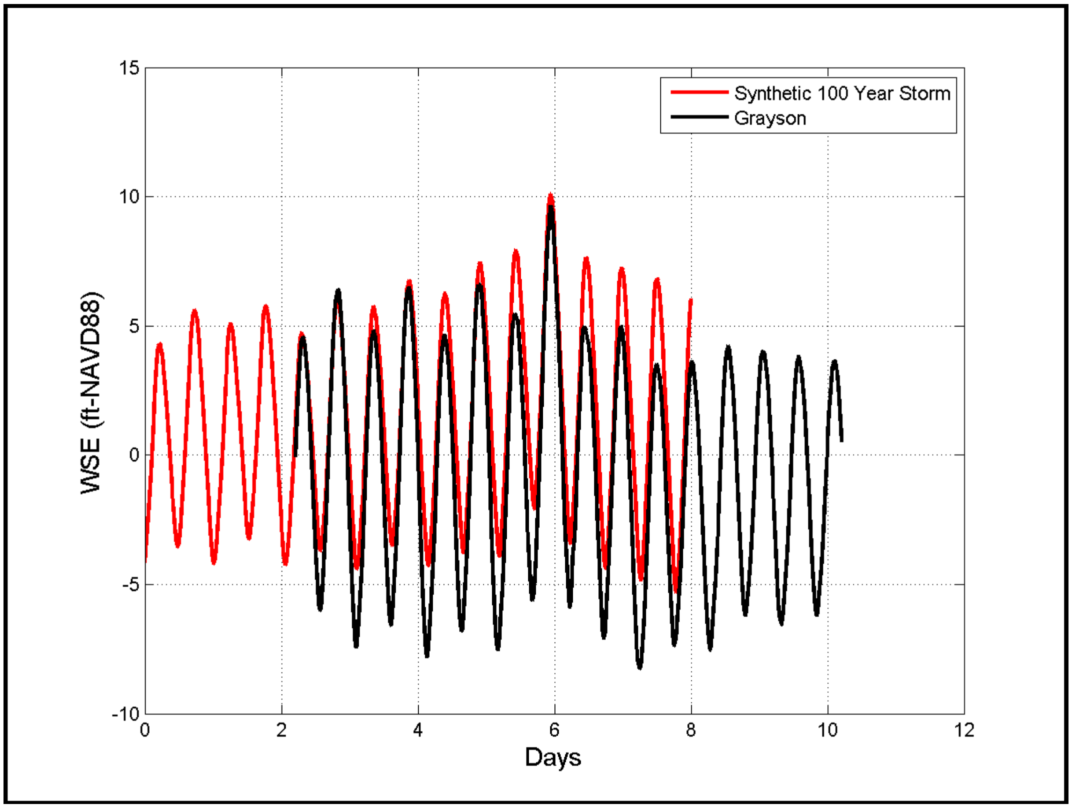


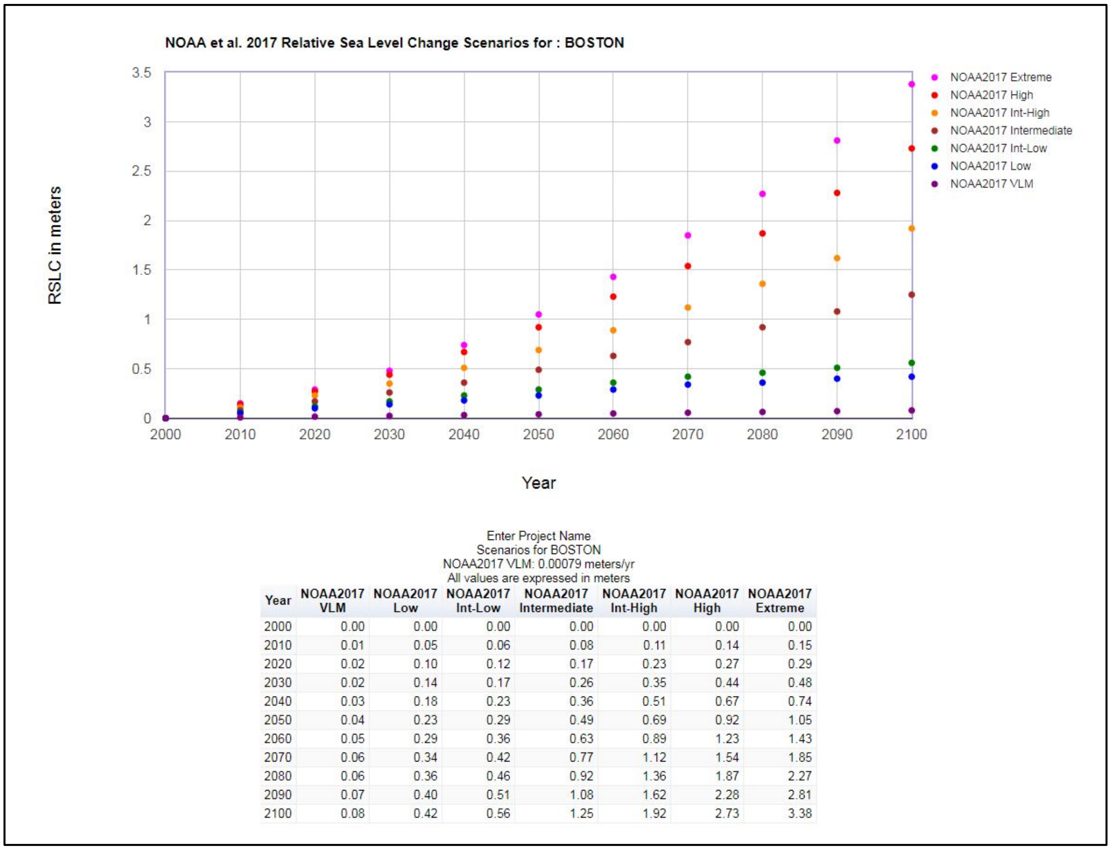
Figure 10: Comparison between synthetic 100-year event and winter storm Grayson.

3.2.2.4. Sea Level Rise

In considering a culvert replacement at Commerce Road, sea level rise (SLR) projected to occur over the expected design life of the structure should be evaluated. Projections of SLR for the Barnstable area were obtained from the latest 2017 NOAA Technical Report NOS CO-OPS 83 - *Global and Regional Sea Level Rise Scenarios for the U.S.* with values at Boston, MA from NOAA-derived curves shown in Table 2 and Figure 11.

Table 2: Projected sea level rise at Boston, MA from the year 2020 based on the latest NOAA data.

Year	NOAA Low (ft)	NOAA Int Low (ft)	NOAA Int (ft)	NOAA Int High (ft)	NOAA High (ft)	NOAA Extreme (ft)
2050	0.43	0.56	1.05	1.51	2.13	2.49
2070	0.79	0.98	1.97	2.92	4.17	5.12
2100	1.05	1.44	3.54	5.54	8.07	10.14



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Scenarios for BOSTON
NOAA2017 VLM: 0.00079 meters/yr
All values are expressed in meters

Year	NOAA2017 VLM	NOAA2017 Low	NOAA2017 Int-Low	NOAA2017 Intermediate	NOAA2017 Int-High	NOAA2017 High	NOAA2017 Extreme
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.01	0.05	0.06	0.08	0.11	0.14	0.15
2020	0.02	0.10	0.12	0.17	0.23	0.27	0.29
2030	0.02	0.14	0.17	0.26	0.35	0.44	0.48
2040	0.03	0.18	0.23	0.36	0.51	0.67	0.74
2050	0.04	0.23	0.29	0.49	0.69	0.92	1.05
2060	0.05	0.29	0.36	0.63	0.89	1.23	1.43
2070	0.06	0.34	0.42	0.77	1.12	1.54	1.85
2080	0.06	0.36	0.46	0.92	1.36	1.87	2.27
2090	0.07	0.40	0.51	1.08	1.62	2.28	2.81
2100	0.08	0.42	0.56	1.25	1.92	2.73	3.38

Figure 11: Sea level rise scenarios for Boston, MA (NOAA, 2017)

Upon review of the different projections and scenarios, the NOAA Intermediate and Intermediate High scenarios would be recommended for design as they have lower probabilities of being exceeded, ranging from 0.4% to 17% based on (NOAA, 2017). When incorporating sea level rise into a project design, the anticipated project design life needs to be taken into consideration. Given that the culvert replacement is a structural solution, the 2070 scenario should be considered with a typical expected culvert design life on the order of 50 years. This would give sea level increases of 1.97 feet for the Intermediate scenario and 2.92 feet for the Intermediate-High scenario. For the purposes of this evaluation and potential design of a culvert, the Intermediate scenario was chosen as a representative sea level increase (17% probability of being exceeded).

3.3. Model Calibration and Validation – Typical Tides

Model calibration and validation refers to a comparison of model results with measured data, and refining the model within reason to optimize the match. It is critical that the model's skill at predicting measured events is well-understood so uncertainties in using model output for design or planning purposes are clear. No model is perfect; however, greater confidence is attached to models with proven ability to reproduce field measurements.

After completion of model setup, the model was calibrated to measured data collected within the Maraspin Creek system. The primary parameters for calibrating the model are the manning's n values used for the bridge and the culvert under Commerce Road. The manning's n specified for the bridge was chosen to be 0.03, representative of natural rock channels. The Commerce Road culvert is a 2.5-foot diameter corrugated pipe; however, a visual inspection of the pipe revealed a depression under the road causing the pipe to be further constricted. The manning's n was increased from the initial value of 0.024 to 0.05 to represent the damaged condition of the pipe.

The tidal elevations used to calibrate the model were the field measurements from September to October 2018. The model was run for the entire data collection period to allow for model comparisons during the spring and neap tidal cycle, and to include multiple rain events.

Figure 12 shows a comparison of modeled (red line) and measured (blue line) water levels in the downstream Maraspin Creek marsh at station MC-2. The comparison shows the downstream marsh water levels produced by the model are similar to the observed data. High tides match almost exactly, which is key for this model application focused on understanding flood potential at high water. At lower tide elevations, the marsh drains slightly more in the model than what was measured resulting in lower simulated low tides. This is due to small scale constrictions within channels of the downstream basin (e.g., localized shoals, bank slumps, etc.), which cannot be fully accounted for in the analytical model. Exact match at low tide is not essential for this application. The large opening of the Millway bridge is shown to not restrict tidal flow and allows for a transparent tidal signal from Barnstable Harbor during high tides (Figure 12).

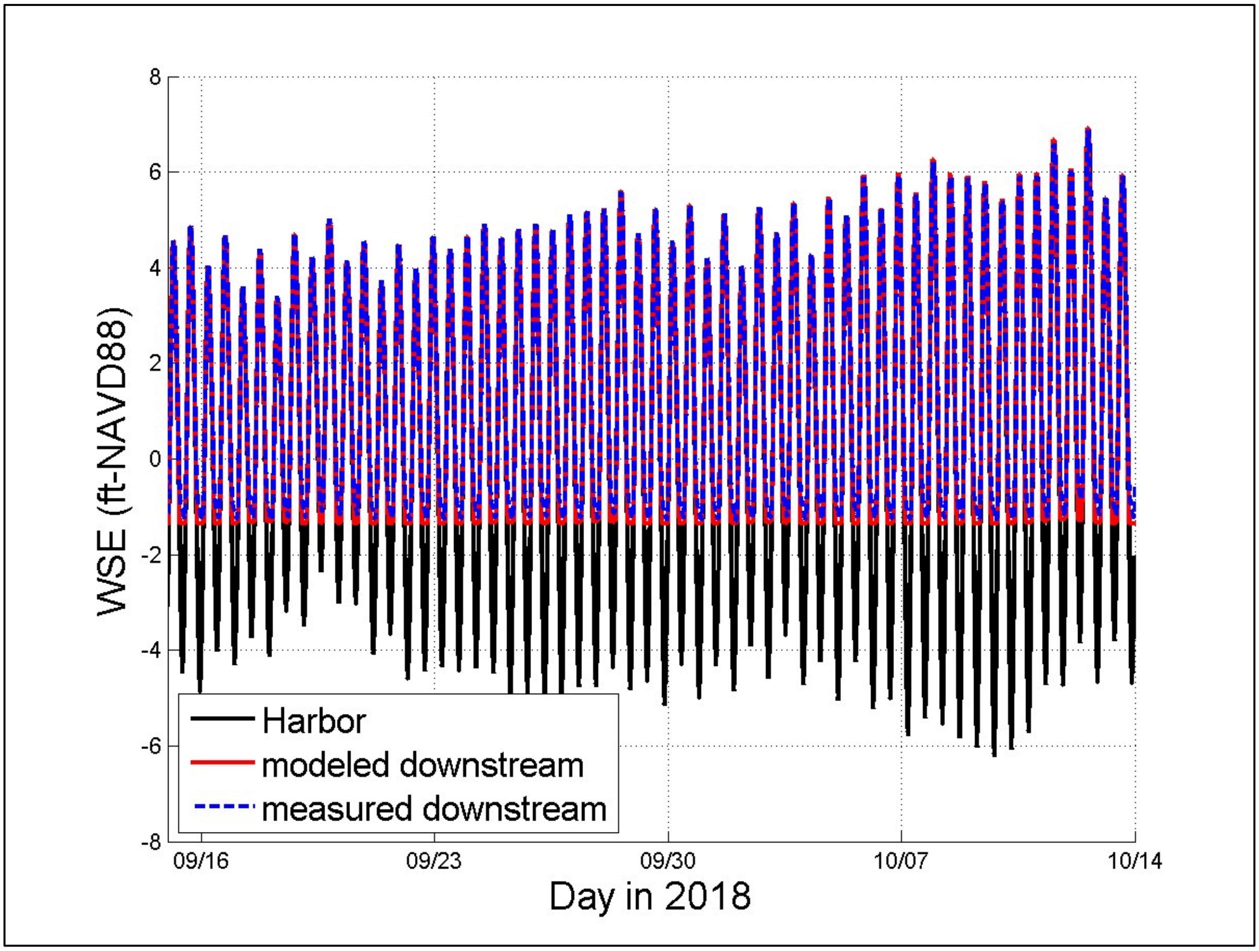

Figure 12: Downstream comparison (station MC-2) between 2018 modeled and measured data

The model results for the upstream basin at station 4 show good agreement with measurements through most of the tidal cycles (Figure 13). Figure 14 shows a one-week timeframe of the upstream basin results to give a more detailed view of the model comparisons with measurements. The model captures the peak elevations, as well as the shape and phase of the tidal cycle. Additionally the culvert at Commerce Road is not shown to significantly limit high tide elevations in the upstream marsh during typical tide conditions. Peak tide elevations are slightly lower in the upstream marsh during spring high tides, suggesting limited culvert flow constriction at these higher high tides.

The modeled low tides are very close to the measured elevations, which are limited by the invert elevation of the culvert in combination with the baseflow in the upstream basin. Overall the upstream and downstream comparisons show the model is well-calibrated and validated for neap and spring tides, and can be applied with confidence for evaluation of the Maraspin Creek system.

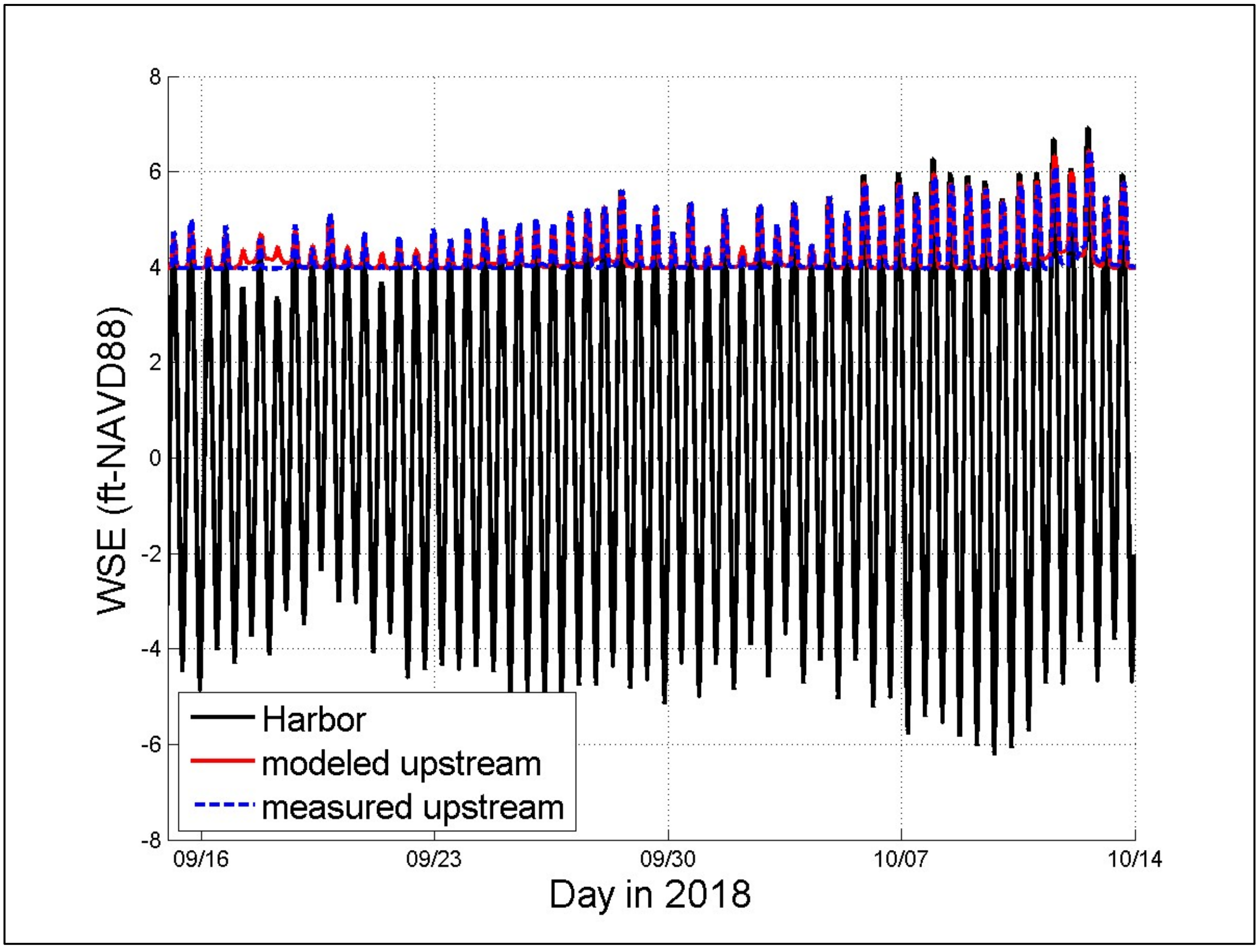

Figure 13: Upstream comparison (station MC-4) between 2018 modeled and measured data

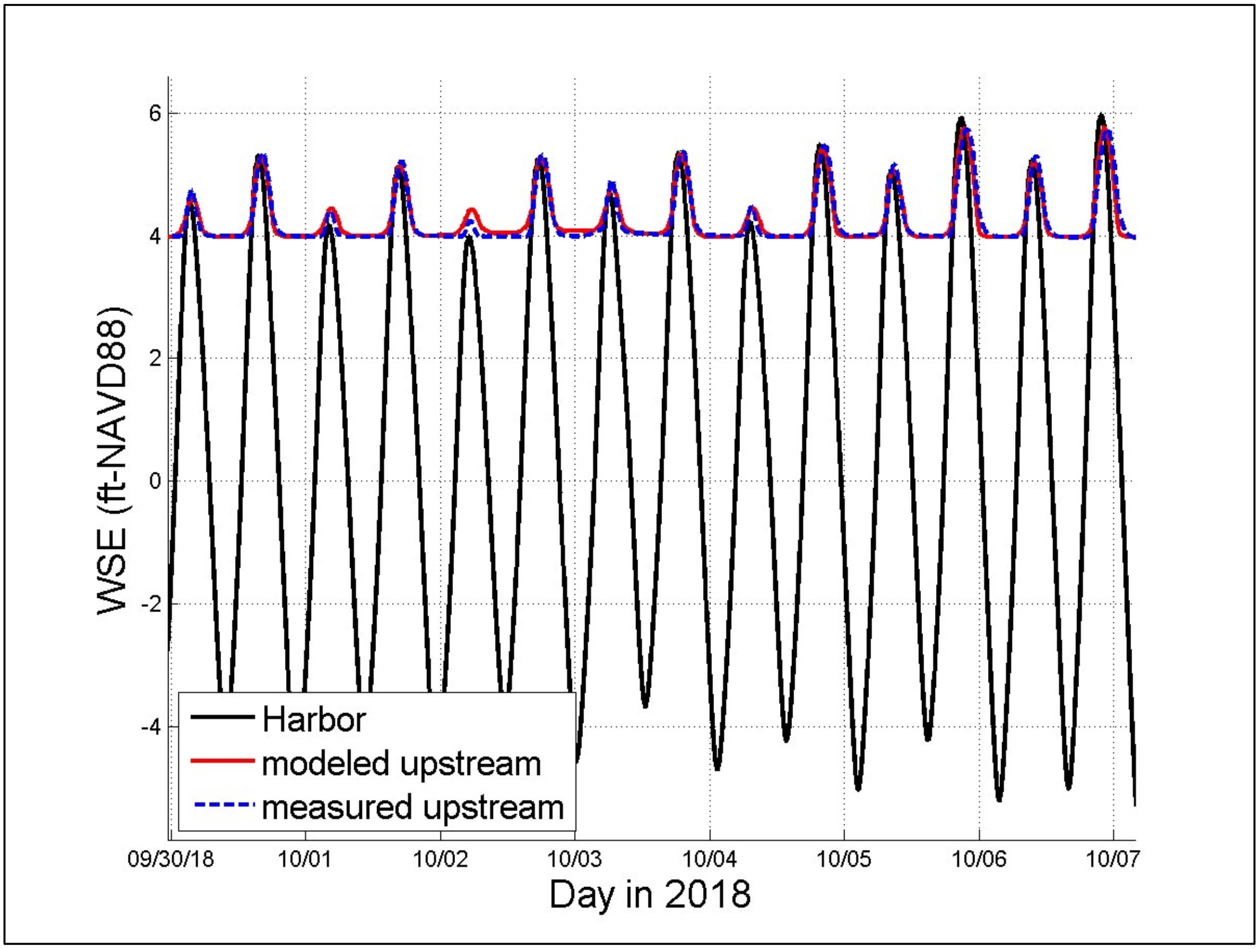

Figure 14: One-week view of the upstream comparison (station MC-4) between 2018 modeled and measured data

3.4. Existing Condition Model Results - Coastal Storm Surge Events

Once the model was calibrated and validated for the typical spring-neap tidal conditions, simulations of Maraspin Creek/existing conditions were conducted for coastal storm surge events. These simulations indicate whether the culvert under Commerce Road restricts flow to the upstream marsh during more extreme high water levels. The coastal storm surge simulations included the 10-year, 50-year, and 100-year return period storm events.

Figure 15 shows results of the 10-year storm simulation with time series of the modeled upstream basin (green line) and downstream basin (red line) water levels along with Barnstable Harbor (black line). During the peak of the storm, the water level in the downstream basin matches that of Barnstable Harbor; however, the upstream peak water level is lowered by nearly two feet at the storm peak (e.g., ,difference between red and green line around October 8 on Figure 15). In a 10-year storm, Commerce Road is not overtopped and the model results indicate the culvert restricts flow to the upstream marsh.

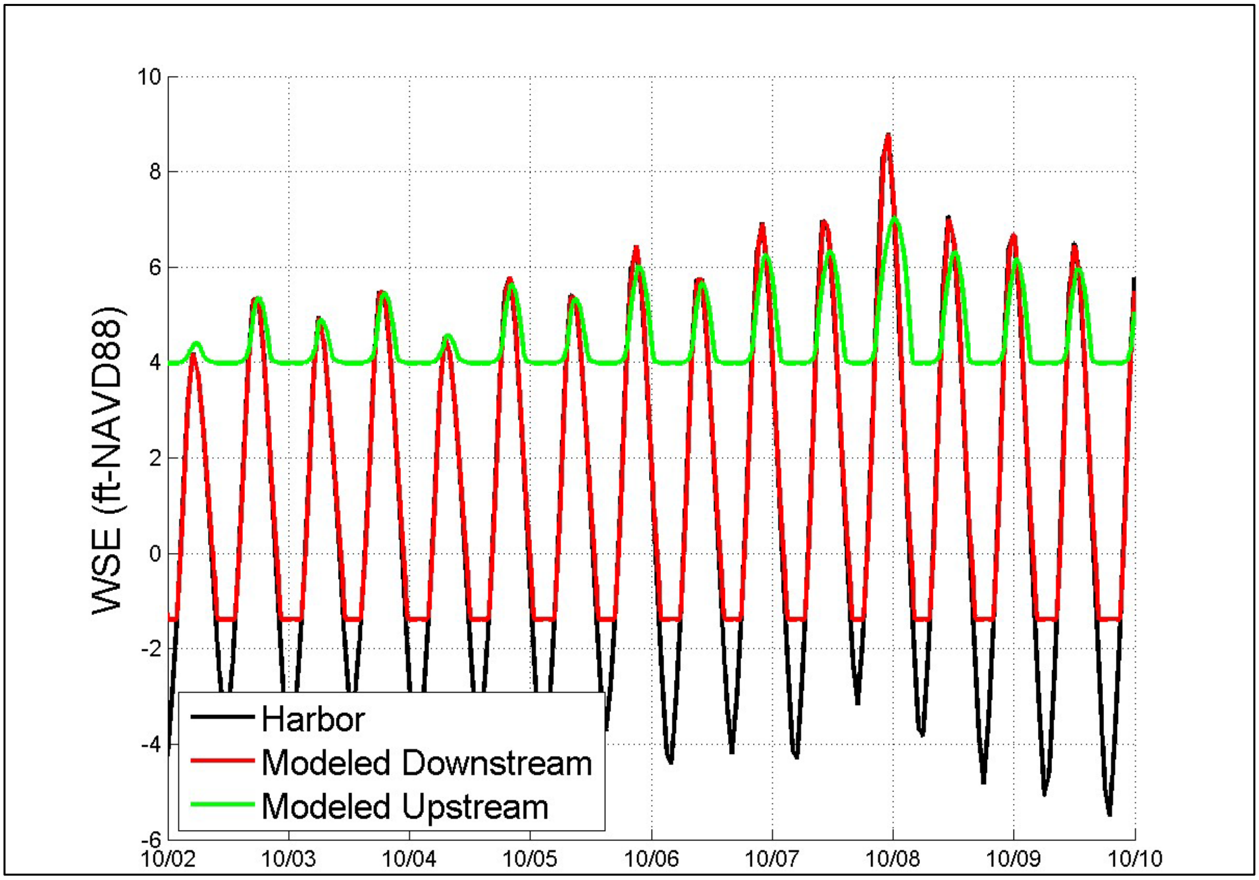

Figure 15: 10-Year storm comparison between harbor, downstream, and upstream water levels

Similar time-series of modeled water levels from the 50-year and 100-year storm simulations are shown in Figures 16 and 17. Again the peak water level in the downstream basin reaches the peak water level that exists in Barnstable Harbor for both storms, so the Millway Bridge is still not a restriction to storm surge entering Maraspin Creek.

In comparison to the 10-year event, peak upstream water levels for the 50- and 100-year events are closer to those in the downstream basin. During the 50- and 100-year events water starts to overtop Commerce Road during the peak of the storm. With water flowing both over the roadway and through the culvert, the water level upstream reaches higher levels, but it’s still lower than the peak surge level downstream of Commerce Road.

Using the maximum water surface elevations for the downstream and upstream basins, the maximum inundation extents for the storms were mapped using the DEM for Maraspin Creek and the surrounding area (Figures 18 through 20). In a 10-year event, the flooding extent in the downstream basin is confined to the marsh system due to the berm/road elevation on the northern side which helps to limit the flooding extent into the Blish Point community.

Figures 19 and 20 show that, under existing conditions, a portion of the Blish Point neighborhood north of Maraspin Creek adjacent to the downstream basin is impacted by flooding from the Creek during both a 50- and 100-year storm event. It should be noted that these flooding extents are based on Maraspin Creek being the sole source of flood water. This does not include direct flooding from the bay side, localized precipitation-based runoff and flooding, or backup from stormwater outfalls. These additional flood sources are potentially significant to Blish Point flooding. In particular, when the surge level in Maraspin Creek reaches an elevation above the storm water drainage pipe outfalls, precipitation-based runoff will not drain into the Creek and will subsequently accumulate within low-lying areas of Blish Point.

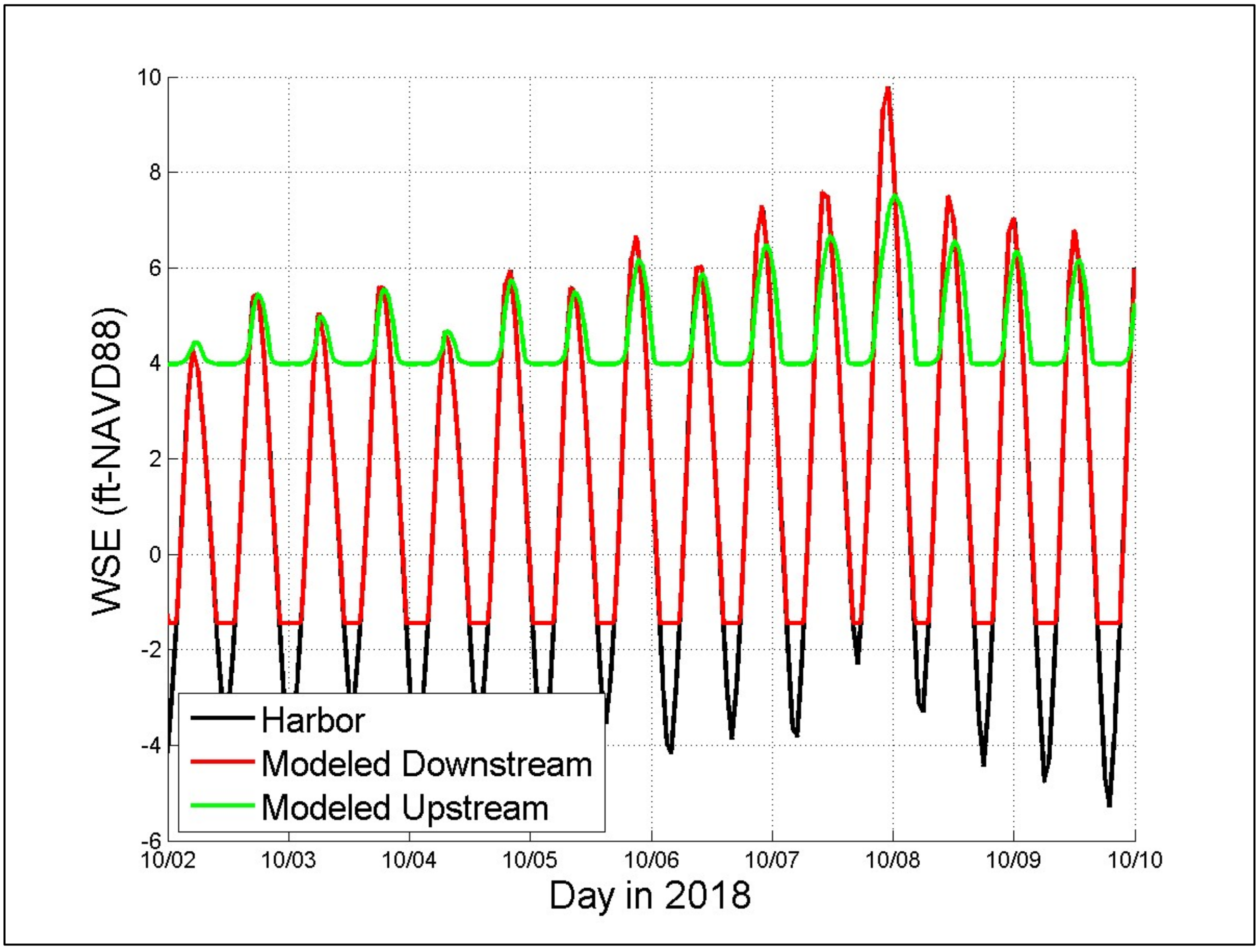

Figure 16: 50-year storm comparison between harbor, downstream, and upstream water levels

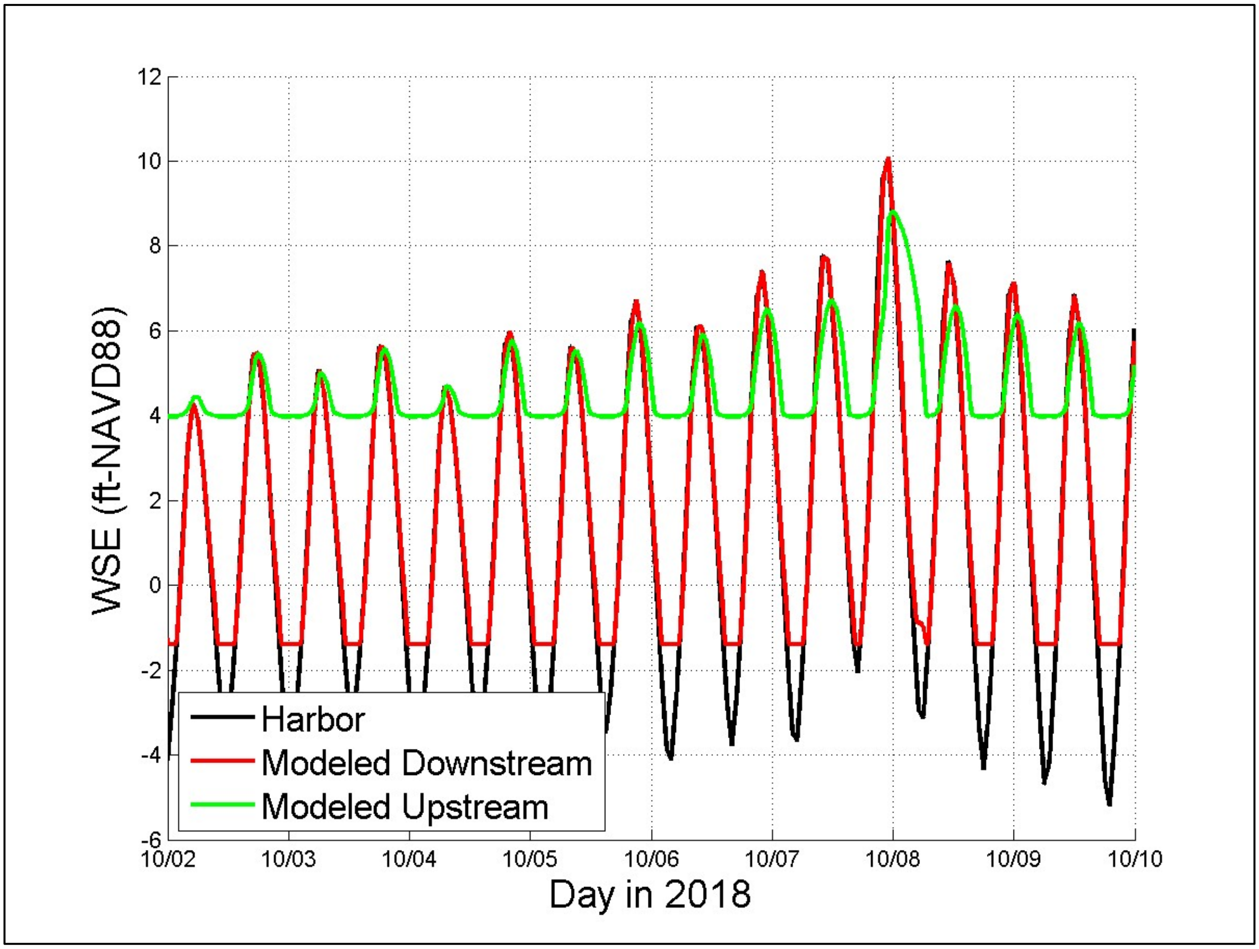

Figure 17: 100-Year storm comparison between harbor, downstream, and upstream water levels

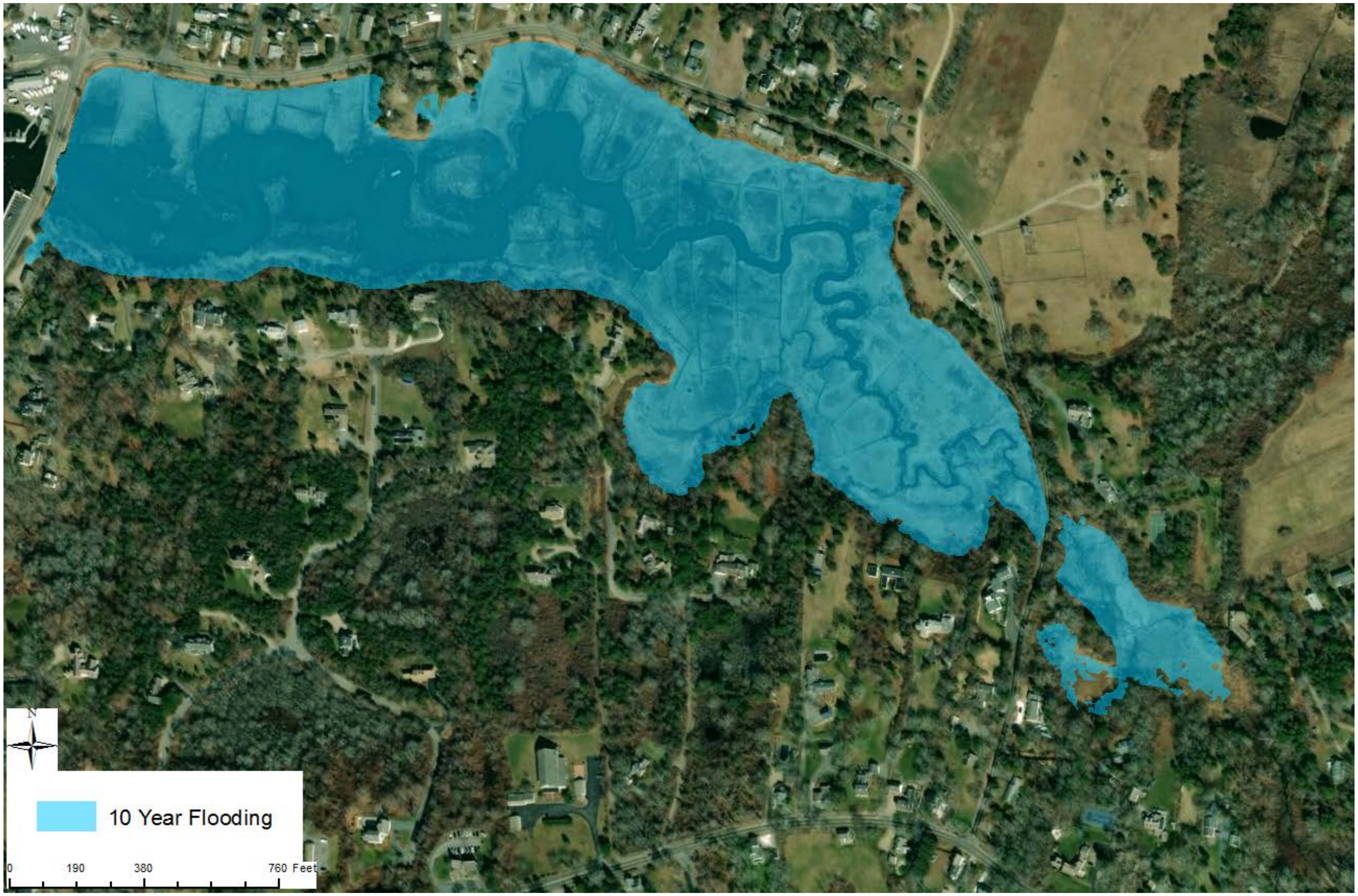

Figure 18: 10-Year storm flooding extent for existing conditions

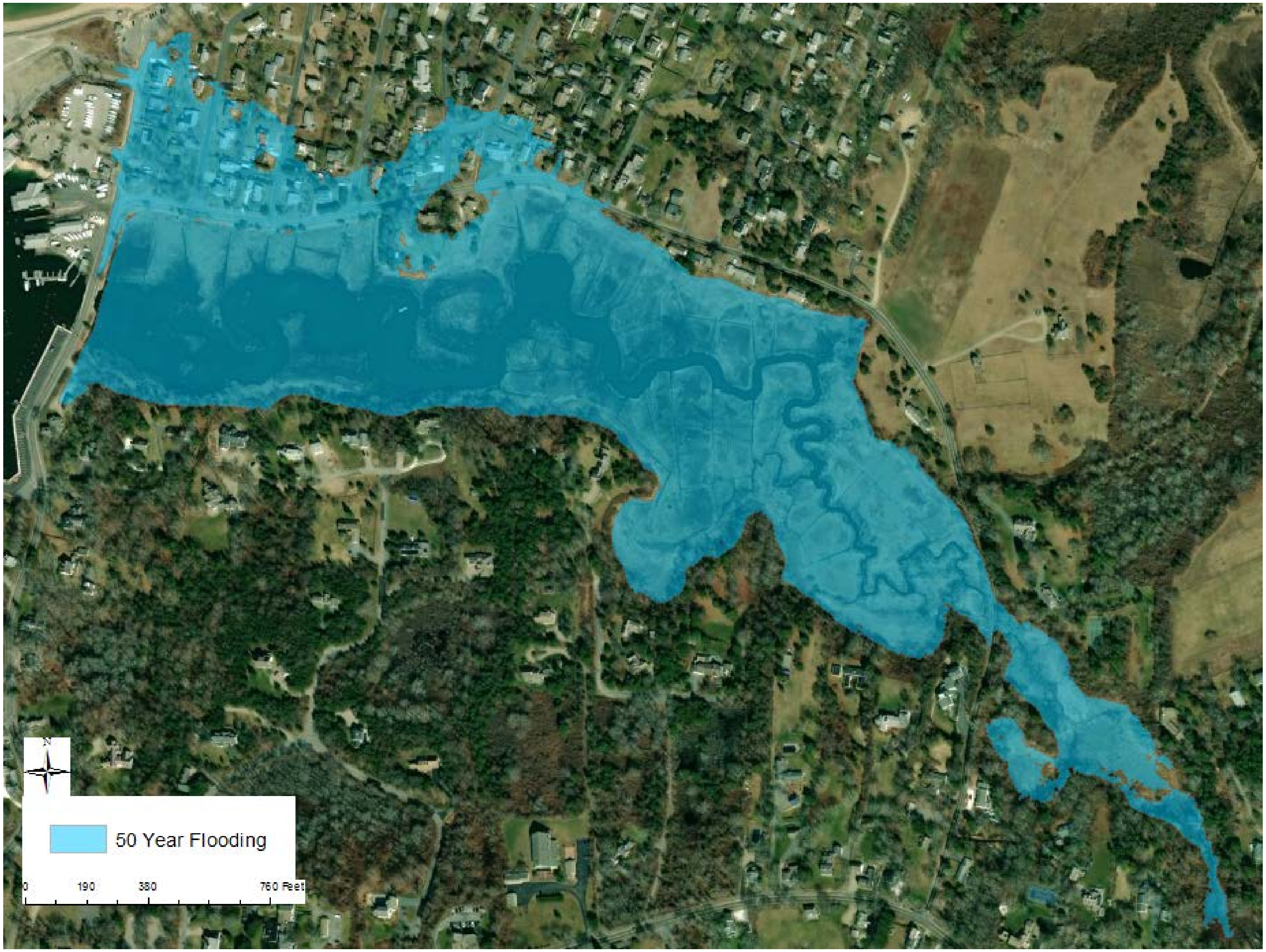

Figure 19: 50-Year storm flooding extent for existing conditions

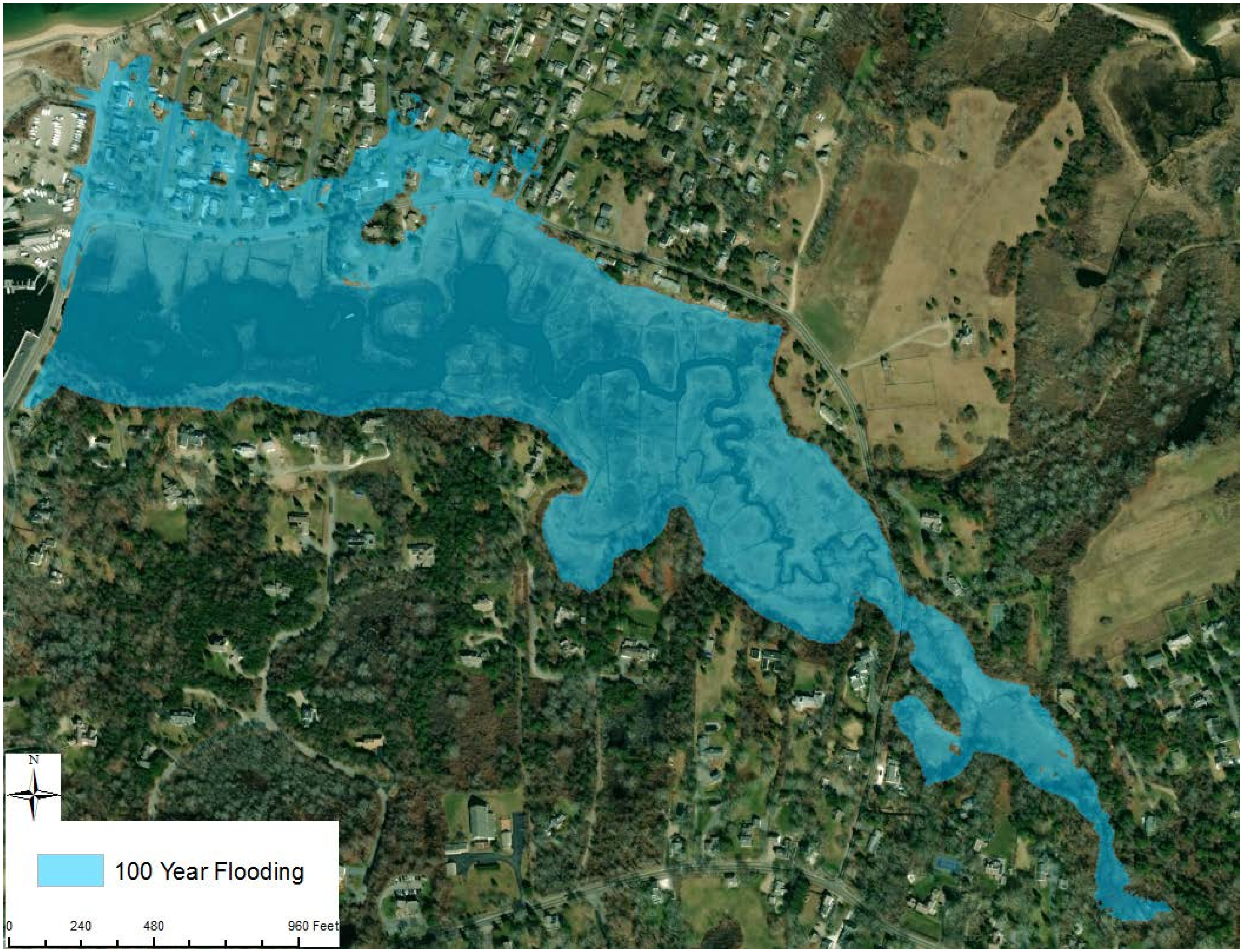

Figure 20: 100-Year storm flooding extent for existing conditions

3.5. Existing Condition Model Results – Typical Tides with SLR

The model of existing conditions was also simulated for typical tides (using the 2018 measurements) together with a selected scenario of projected sea level rise, approximately 2 feet by the year 2070 (further detailed in Section 3.2.2.5). For this simulation, the tidal boundary was adjusted by increasing the mean sea level by 2 feet. This simulation will give insight into whether the existing culvert at Commerce Road will pose as more of a restriction with an increased sea level.

The modeled time series of water elevation from this simulation are shown in Figure 21. The model results indicate that with an increased sea level, the culvert at Commerce Road does restrict tidal flow with upstream high tide elevations being 0.5 to 1.7 feet lower than the downstream high tide elevations. The low tide elevations on the upstream side of the culvert remain restricted by the invert elevation of the culvert, as is the case with the current sea level. The bridge at Millway is not shown to restrict tidal flow from the harbor up into Maraspin Creek even with a moderate increase in sea level.

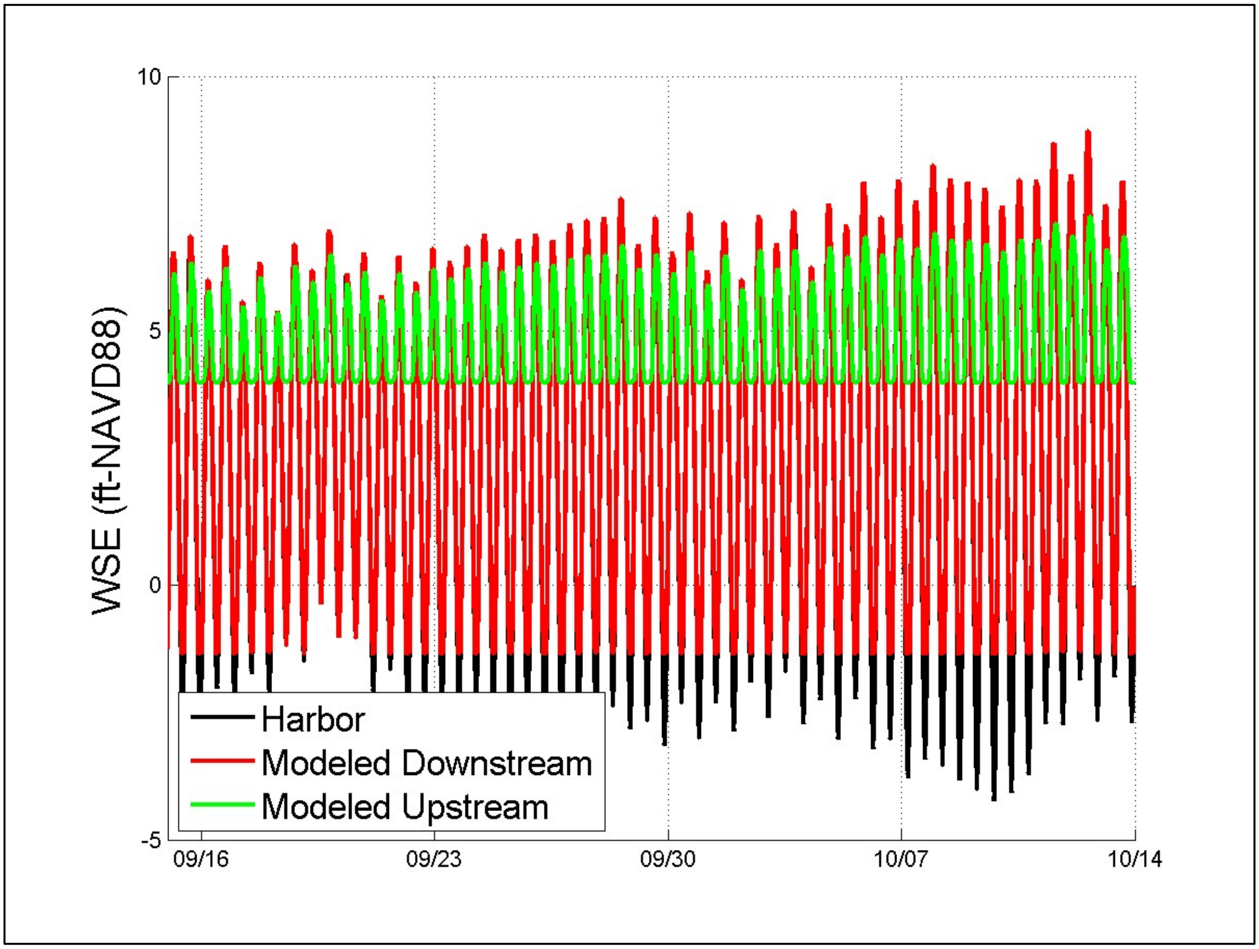

Figure 21: Typical tides with SLR comparison between harbor, downstream, and upstream water levels

3.6. Initial Alternative Culvert Model Results –Coastal Storm Surge Events

One purpose of this investigation is to understand potential to restore tidal flow to the Maraspin Creek upstream of Commerce Road. There is interest in the potential to restore salt marsh habitat, need to mitigate flooding of the roadway, and possibilities for expanding the stormwater storage capacity to potentially alleviate flooding in the system, including Blish Point. Restoring flow upstream of Commerce Road may have a potential negative impact, however, in increased flooding upstream, which also can be evaluated with the model developed herein. To determine what size culvert would be required to relieve the restriction at Commerce Road during extreme coastal surge events, a 100-year storm was simulated with an increased culvert opening at Commerce Road, and the roadway elevation increased so there would not be overtopping. These model runs showed that a 5-foot diameter pipe culvert at Commerce Road would be required to relieve the restriction and allow peak water levels in the upstream marsh to match the downstream peak water level even during an extreme storm.

The time series of modeled water levels from this simulation are shown in Figure 22. For a 5-foot diameter pipe culvert simulation, the upstream peak water level equals the peak elevation in the downstream basin. The peak water elevation in the downstream basin remains at 10.1 feet, and would therefore have same flooding impacts as for existing conditions. Thus, the storage capacity of the marsh area upstream of Commerce Road is not sufficient to alleviate flooding in Maraspin Creek or the adjacent Blish Point community during severe storms. The maximum inundation extent in the upstream basin during a 100-year storm with a 5-foot diameter pipe culvert at Commerce Road is shown in Figure 23. This indicates the flooding upstream of Commerce Road would still be confined to the marsh area and would have limited impact to adjacent properties. Also shown is the continued flooding downstream in Blish Point, even with the expanded culvert at Commerce Road.

3.7. Initial Alternative Culvert Model Results – Typical Tides with SLR

A 5-foot diameter pipe culvert at Commerce Road was also simulated for typical tides with a 2-foot increase in sea level. The times series of model results shown in Figure 24 indicate that a larger 5-foot pipe would not substantially restrict tidal flow to the upstream marsh under this scenario. During the highest spring tides, the high tide elevations upstream of the culvert are slightly lower (approximately 0.2 feet) than those on the downstream side of the culvert. This indicates that a 5-foot diameter pipe (or equivalent) would be required at Commerce Road to maintain full tidal flow upstream of Commerce road with an increased sea level, assuming a 50-year design life. This would allow for potential migration and natural expansion of the salt marsh system to occur with projected increases in sea level.

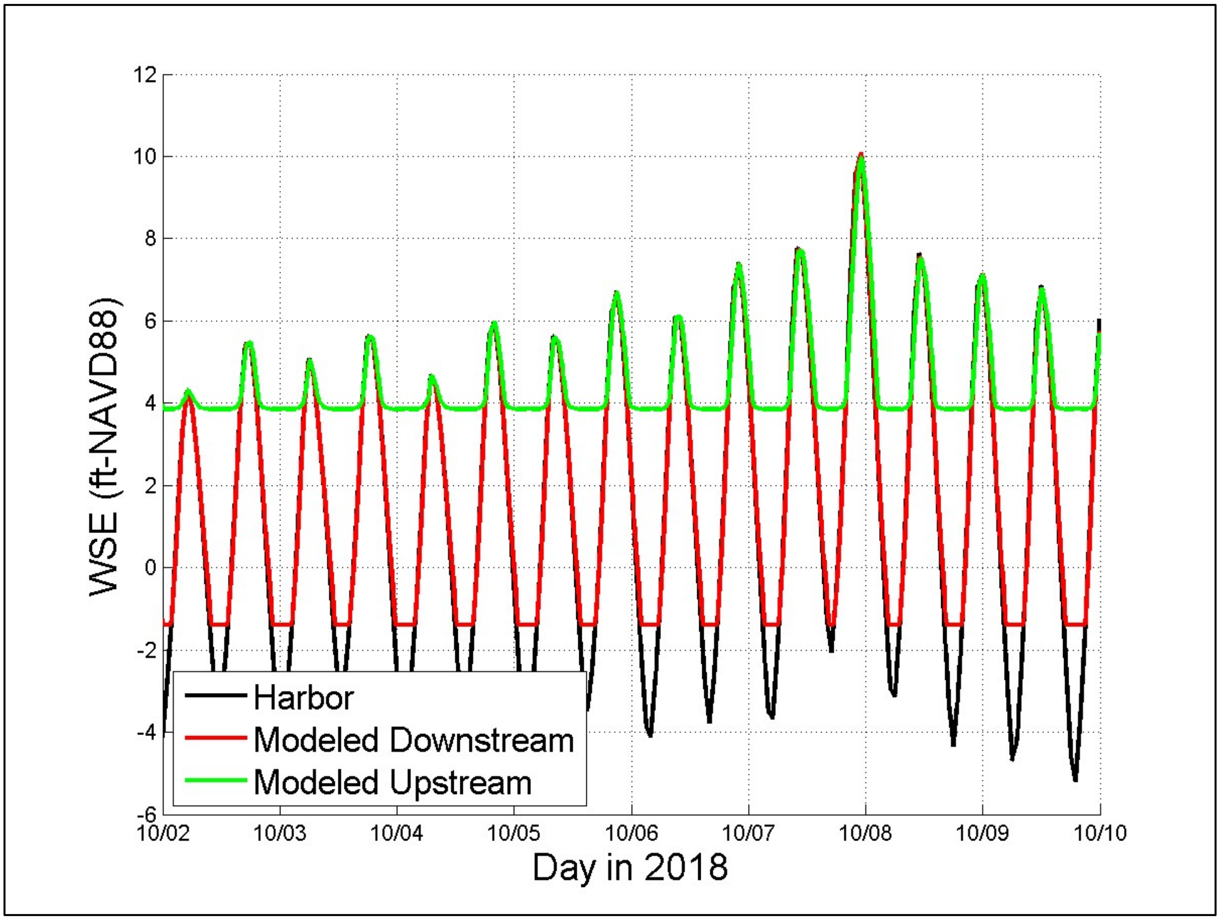

Figure 22: 100-year storm results with a 5-foot diameter pipe culvert at Commerce Road and elevated roadway

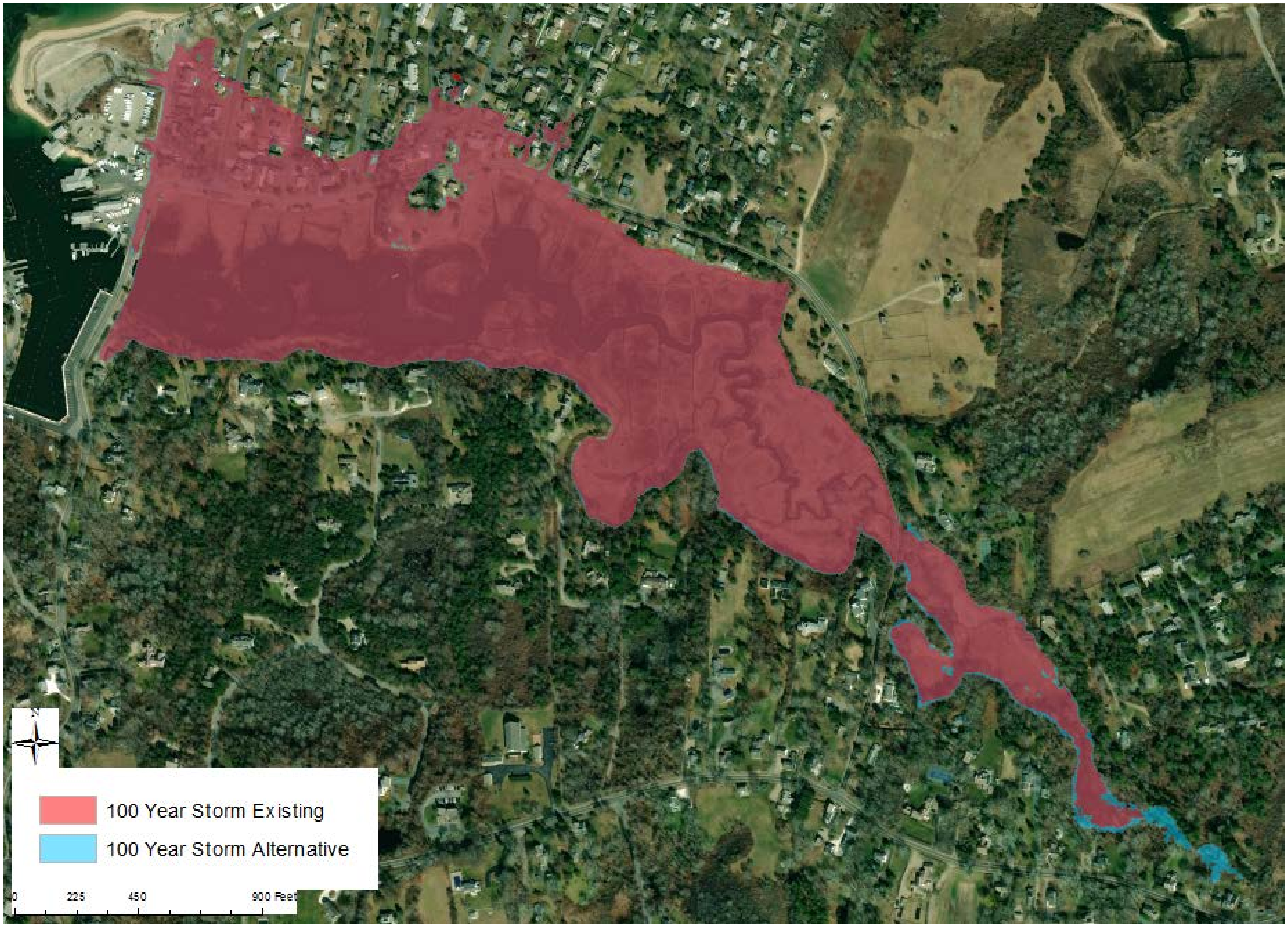

Figure 23: 100-Year storm flooding extent for the alternative, and existing culverts

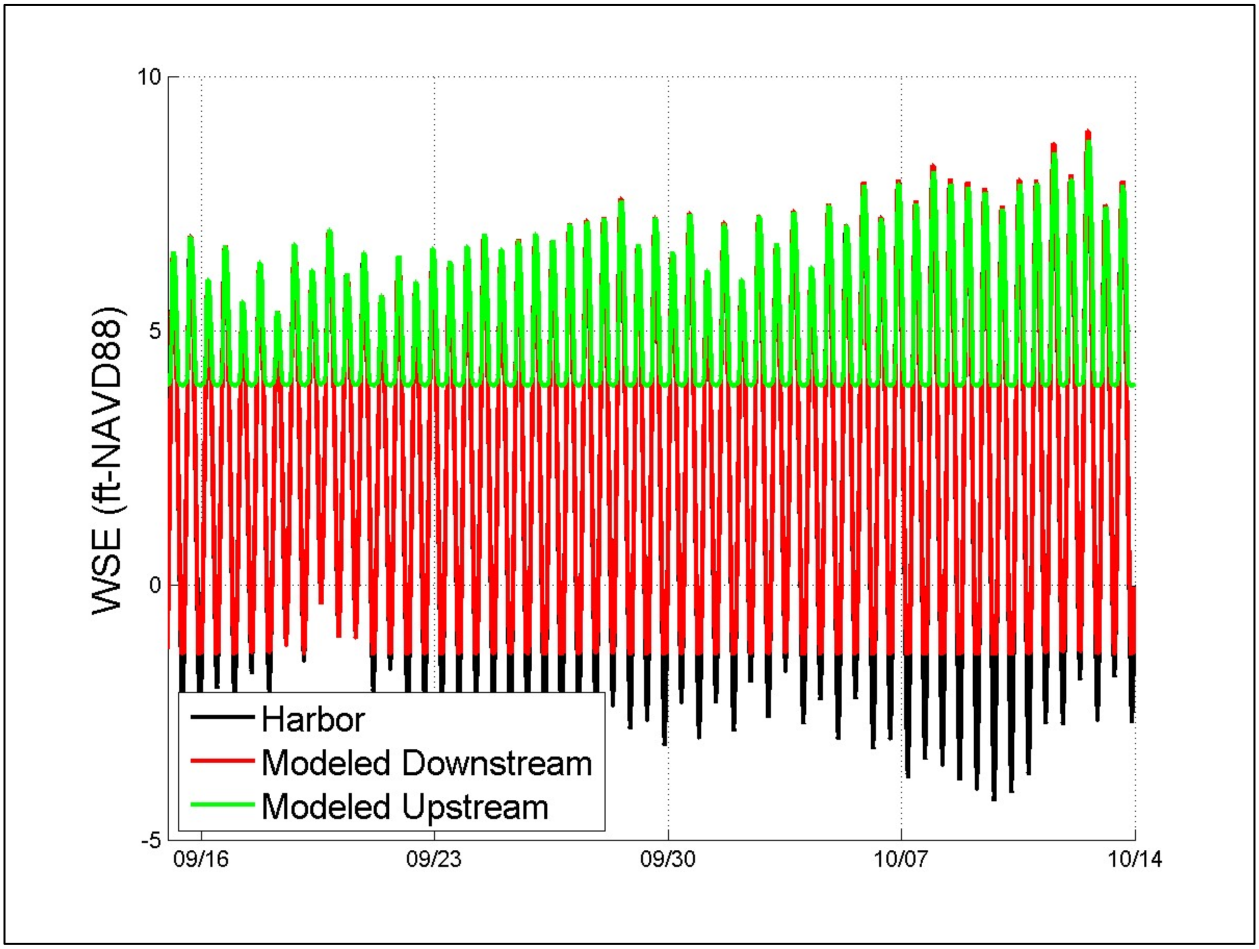

Figure 24: Typical tides with SLR results with a 5-foot diameter pipe culvert at Commerce Road

4. Summary and Next Steps

An H&H study of Maraspin Creek was conducted to better understand the system's hydraulics under typical tide and extreme coastal storm conditions. The study included field data collection of tides, salinity, and temperature data throughout the marsh system, as well as development of a hydraulics model calibrated and validated using the measurements. The model was then applied to simulate existing conditions and an initial alternative culvert configuration at Commerce Road to gain insight into how the system's hydraulics would change with an increased culvert opening. The study also took into account projected SLR over the expected design life for a replacement hydraulic structure. The following summarizes some of the study observations and results:

- There is a substantial reduction in the tide range from the Harbor, through Maraspin Creek and upstream of the Commerce Road culvert. The tide range reduction is primarily associated with an increase in the low tide elevation and mean water level. The increasing low tide elevation is likely due to a combination of an increase in the marsh creek bed elevation upstream, as well as freshwater inflow providing a net flow out of the marsh.

- The high tide elevations do not significantly change throughout the system, indicating the hydraulic structures (bridge at Millway and culvert at Commerce Road) are not substantially restricting flow during typical tidal cycles.
- Model simulations of existing conditions in coastal storm surge events show the adjacent Blish Point neighborhood is impacted by flooding from Maraspin Creek in a 50-year storm or greater, or when water levels exceed 9 feet NAVD88. The bridge at Millway does not restrict storm surge from entering Maraspin Creek in these scenarios; however, the culvert at Commerce Road does restrict flow to the upstream marsh. Commerce Road starts to overtop when water levels in the downstream basin exceed 9 feet NAVD88.
- Model simulations of existing conditions for typical tides with a moderate 2-foot increase in sea level show the culvert at Commerce Road becomes restrictive and limits high tide elevations in the upstream marsh. This would limit future potential migration and expansion of salt marsh habitat.
- Model simulations of an alternative culvert configuration at Commerce Road indicate a 5-foot diameter pipe culvert (or equivalent) would be required to not restrict flow to the upstream marsh in coastal storm events having a 100-year (or less) return period, and in typical tide conditions with a 2-foot increase in sea level. The increased culvert size would cause increased flooding in the upstream basin during coastal storm events; however, the inundation extent is shown to be within the existing wetland/forested area, providing habitat restoration potential.
- The existing culvert at Commerce Road is shown to restrict flow to the upstream marsh during coastal storm events and with increased sea level; however, an increased opening does not reduce flooding impacts downstream of the culvert in the adjacent Blish Point neighborhood. The storage capacity of the marsh area upstream of Commerce Road is not sufficient to alleviate flooding in Maraspin Creek or the adjacent Blish Point community during severe storms

Working in consultation with the Town, next steps in the study will explore different alternatives that may work in combination with, or as standalone alternative to, a culvert replacement at Commerce Road. These alternatives will likely include modifying the Millway opening such that it restricts storm surge from entering Maraspin Creek, and possibly increasing the berm/road elevation adjacent to Blish Point. These alternatives will be simulated for a range of storm events to identify potential benefits and adverse impacts.

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