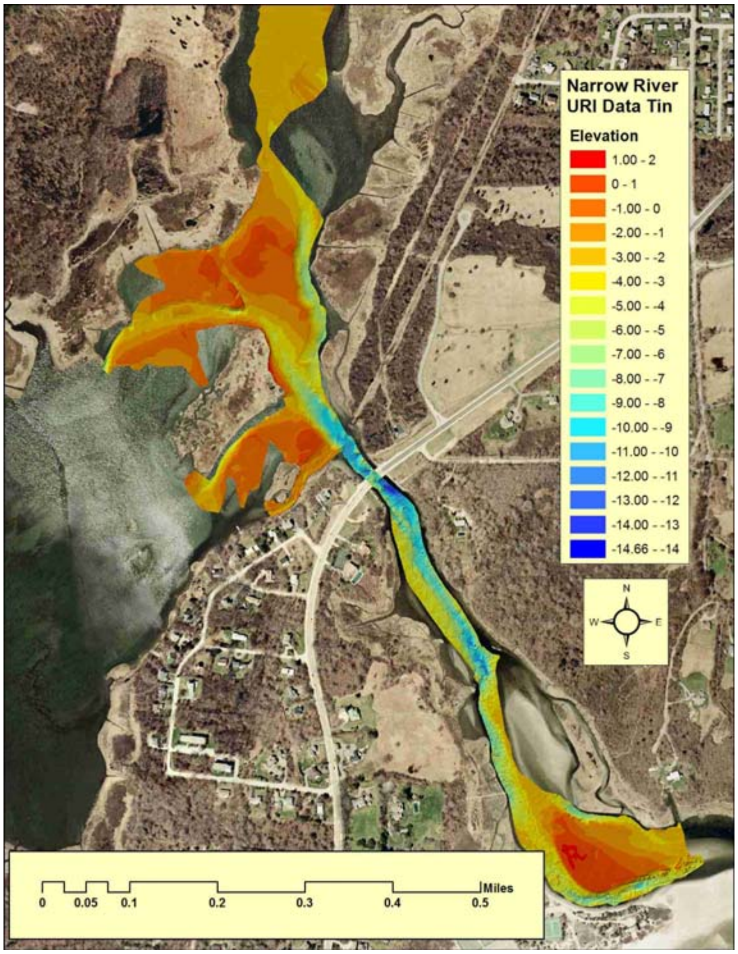
Appendix A

Hydrology and Hydraulics

NARROW RIVER, NARRAGANSETT, RHODE ISLAND

Hydrodynamic Numerical Modeling and Data Collection Report



4/21/2009

U.S. Army Corps of Engineers
New England District - Water Management Section

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1.0 Introduction

As part of the Narrow River Study, the Water Management Section performed a 1-D numerical modeling study to determine the relative impacts of the proposed alternatives and dredging increments on tide range, current speeds, peak volume flows, and most importantly tidal prism/flushing time changes. Additionally, the impacts of these alternatives on storm induced tidal flooding were examined. A total of seven dredging increments were modeled for this study. More were considered, but the results of these seven provided the necessary information.

1.1 Study Location and Setting

The Narrow River, also known as the Pettaquamscutt River, flows south from the outlet of Carr Pond in Narragansett, Rhode Island, through areas known as the upper and lower ponds, under the Bridgetown Road and the Middle Street bridges to a confluence in South Kingstown, RI where Pettaquamscutt Cove (abbreviated as Petta Cove in parts of this report) connects to the river (Figures 1 and 2). The river then passes under Sprauge Bridge (Ocean Road) and through a section known as the "The Narrows," before entering the Atlantic Ocean at the mouth of Narragansett Bay. The inlet has not been modified by jetties or channelized and is free to transform from natural forcing. To the north of the inlet is rocky shoreline and to the south is a sand beach known as Narragansett Beach. The beach is essentially a pocket beach with headlands at both the north and south ends.

The river has a relatively small amount of freshwater input when compared to the tidal flow in the system. The watershed is also relatively small compared to the surface area of water, but fairly developed and steep in many areas. This has caused nutrient loading problems for the Narrow River and bacterial loading problems as well. Presently the tidal river is closed to shell fishing activity due to the bacteria problems from the watershed. Most of the houses are, or will be going to a centralized sewage system.

1.2 Study Alternative Descriptions

Numerous alternatives were investigated during this study. The following alternative descriptions are restated from the main study report.

Alternative A – No Action

If no action were taken to reduce the tidal restriction between Narrow River and Rhode Island Sound, the area would continue to degrade through the accumulation of sediment and smothering of habitats. Currents, including wakes from recreational boats, erode salt marshes lining the estuary. This erosion will continue to reduce the area of salt marsh if no action is taken to manage boat traffic.

Figure 1. Site Locus

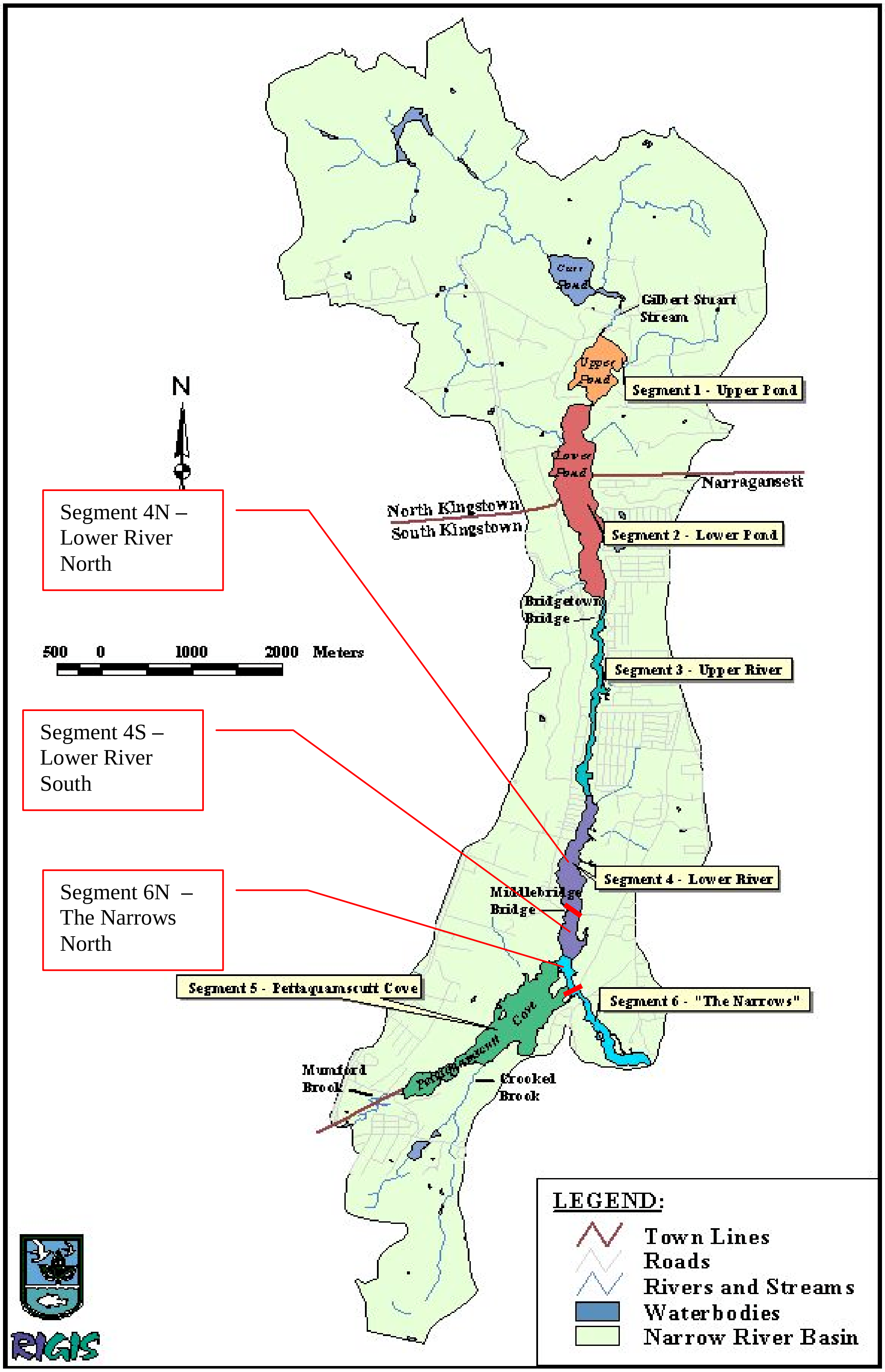


Figure 2. Narrow River Watershed

Alternative B – 9.1 Acre Eelgrass and 10.3 Acre Salt Marsh Restoration

This alternative involves restoring eelgrass (*Zostera marina*) habitats in the portion of Narrow River just south of Middle Bridge (Segment 4S). The sediment in the areas that would be deepened to restore eelgrass in Segments 4S and 5 is primarily composed of detrital organic and inorganic silt with minor amounts of clay. All of the excavated sediment would be used to restore salt marsh in Segment 5 of the Narrow River. The existing bare intertidal and subtidal mud habitats would be replaced by 9.1 acres of eelgrass and 10.3 acres of salt marsh for a total of 19.4 acres of estuarine habitat restored. Only salt marshes that could be restored with coir fiber roll confinement are included in this alternative.

The features of this alternative include:

- restoring 9.1 acres of eelgrass south of Middle Bridge in Segment 4S by dredging 42,000 cy of sediment and seeding,
- restoring 10.3 acres of salt marsh in the Narrow River (Segment 5) by placing 42,000 cubic yards of dredged material into four salt marsh restoration locations (Sedge Island North, Sedge Island South, Sedge Island extension, and Outlet West) and holding the material in place with staked coir fiber rolls.

Alternative C – 19.4 Acre Eelgrass and 15.5 Acre Salt Marsh Restoration

This alterative consists of all of the restoration measures described above for Alterative B but involves restoring additional areas of salt marsh in Segment 5 and Segment 6. The salt marsh edges that face open water at these locations are exposed to swift currents and have a larger drop-off to the toe of the marsh escarpments. Rather than coir rolls, these marsh edges would be protected by constructing shell-filled gabion baskets along the face to reduce erosion and provide hard substrate for oysters, mussels and other estuarine organisms that prefer hard substrates. The existing bare intertidal and subtidal mud habitats would be replaced by 19.4 acres of eelgrass and 15.5 acres of salt marsh for a total of 34.9 acres of estuarine habitat restored.

The features of this alternative include:

- restoring 9.1 acres of eelgrass south of Middle Bridge in Segment 4S by dredging 42,000 cy of sediment,
- restoring 10.3 acres of eelgrass in Pettaquamscutt Cove (Segment 5) by dredging 38,000 cy of sediment,
- restoring 11.5 acres of salt marsh in the Narrow River (Segments 5) by placing 50,000 cubic yards of dredged material into five salt marsh restoration locations (Sedge Island North, Sedge Island South, Sedge Island extension, Pettaquamscutt North, and Outlet West) and holding the material in place with staked fiber rolls,

- restoring 4 acres of salt marsh in the Narrow River (Segments 5 and 6) with shell-filled gabion slope protection and pumping 30,000 cubic yards of dredged material to these five salt marsh restoration locations (Sedge Island Southeast Border, 700 ft. of shoreline protection; Sedge Island East Border, 550 ft. of shoreline protection; Outlet East, 700 ft. of shoreline protection; Inlet North, 1,400 ft. of shoreline protection; Inlet South, 900 ft. of shoreline protection).

Alternative D – 33.9 Acre Eelgrass and 15.5 Acre Salt Marsh Restoration and 3 Acre Salt Marsh Creation

This alterative consists of all of the restoration measures described above for Alterative C, but includes an added 3 acre component of salt marsh creation on the west side of the Narrow River in Segment 4S. The added component of salt marsh creation would allow additional area of eelgrass to be restored. The existing bare intertidal and subtidal mud habitats would be replaced by 33.9 acres of eelgrass and 18.5 acres of salt marsh for a total of 52.4 acres of estuarine habitat restored.

The features of this alternative include:

- restoring 9.1 acres of eelgrass south of Middle Bridge in Segment 4S by dredging 42,000 cy of sediment,
- restoring 24.8 acres of eelgrass in Pettaquamscutt Cove (Segment 5) by dredging 53,000 cy of sediment,
- restoring 11.5 acres of salt marsh in the Narrow River (Segments 5) by placing 50,000 cubic yards of dredged material into five salt marsh restoration locations (Sedge Island North, Sedge Island South, Sedge Island extension, Pettaquamscutt North, and Outlet West) and holding the material in place with staked fiber rolls,
- restoring 4 acres of salt marsh in the Narrow River (Segments 5 and 6) with shell-filled gabion slope protection and pumping 30,000 cubic yards of dredged material to these five salt marsh restoration locations (Sedge Island Southeast Border, 700 ft. of shoreline protection; Sedge Island East Border, 550 ft. of shoreline protection; Outlet East, 700 ft. of shoreline protection; Inlet North, 1,400 ft. of shoreline protection; Inlet South, 900 ft. of shoreline protection),
- creating a 3 acre salt marsh along the western shoreline south of Middle Bridge in Segment 4S by pumping 15,000 cy of dredged material to the salt marsh.

Alternative E – 65.1 Acre Eelgrass and 15.5 Acre Salt Marsh Restoration and 3 Acre Salt Marsh Creation

This alterative consists of all of the restoration measures described above for Alterative D, but includes an added 31.2 acre component of eelgrass restoration with disposal of the dredged material at the Rhode Island Sound Dredged Material Disposal

Site. The existing bare intertidal and subtidal mud habitats would be replaced by 65.1 acres of eelgrass and 18.5 acres of salt marsh for a total of 83.6 acres of estuarine habitat restored. This represents the maximum area of eelgrass restoration in the portion of Pettaquamscutt Cove between Sedge Island and the abandoned stone causeway.

The features of this alternative include:

- restoring 9.1 acres of eelgrass south of Middle Bridge in Segment 4S by dredging 42,000 cy of sediment,
- restoring 56 acres of eelgrass in Pettaquamscutt Cove (Segment 5) by dredging 215,000 cy of sediment and disposing of 162,000 cy of the material at the RISDS,
- restoring 11.5 acres of salt marsh in the Narrow River (Segments 5) by placing 50,000 cubic yards of dredged material into five salt marsh restoration locations (Sedge Island North, Sedge Island South, Sedge Island extension, Pettaquamscutt North, and Outlet West) and holding the material in place with staked fiber rolls,
- restoring 4 acres of salt marsh in the Narrow River (Segments 5 and 6) with shell-filled gabion slope protection and pumping 30,000 cubic yards of dredged material to these five salt marsh restoration locations (Sedge Island Southeast Border, 700 ft. of shoreline protection; Sedge Island East Border, 550 ft. of shoreline protection; Outlet East, 700 ft. of shoreline protection; Inlet North, 1,400 ft. of shoreline protection; Inlet South, 900 ft. of shoreline protection),
- creating a 3 acre salt marsh along the western shoreline south of Middle Bridge in Segment 4S by pumping 15,000 cy of dredged material to the salt marsh.

Alternative F – 65.1 Acre Eelgrass and 11.5 Acre Salt Marsh Restoration

This alterative consists of most of the restoration measures described above for Alterative E, but does not include restoration of salt marsh behind gabion baskets as featured in Alternative C, nor the creation of salt marsh on the south side of the Narrow River in Segment 4S. The existing bare intertidal and subtidal mud habitats would be replaced by 65.1 acres of eelgrass and 11.5 acres of salt marsh for a total of 76.7 acres of estuarine habitat restored.

The features of this alternative include:

- restoring 9.1 acres of eelgrass south of Middle Bride in Segment 4S by dredging 42,000 cy of sediment,
- restoring 56 acres of eelgrass in Pettaquamscutt Cove (Segment 5) by dredging 215,000 cy of sediment and disposing of 207,000 cy of the material at the RISDS,
- restoring 11.5 acres of salt marsh in the Narrow River (Segments 5) by placing 50,000 cubic yards of dredged material into five salt marsh restoration

locations (Sedge Island North, Sedge Island South, Sedge Island extension, Pettaquamscutt North, and Outlet West) and holding the material in place with staked fiber rolls.

Alternative G – 65.1 Acre Eelgrass and 15.5 Acre Salt Marsh Restoration

This alterative consists of all of the restoration measures described above for Alterative F, but also includes restoration of salt marsh behind gabion baskets as featured in Alternative C. The existing bare intertidal and subtidal mud habitats would be replaced by 65.1 acres of eelgrass and 15.5 acres of salt marsh for a total of 80.6 acres of estuarine habitat restored.

The features of this alternative include:

- restoring 9.1 acres of eelgrass south of Middle Bride in Segment 4S by dredging 42,000 cy of sediment,
- restoring 56 acres of eelgrass in Pettaquamscutt Cove (Segment 5) by dredging 215,000 cy of sediment and disposing of 207,000 cy of the material at the RISDS,
- restoring 11.5 acres of salt marsh in the Narrow River (Segments 5) by placing 50,000 cubic yards of dredged material into five salt marsh restoration locations (Sedge Island North, Sedge Island South, Sedge Island extension, Pettaquamscutt North, and Outlet West) and holding the material in place with staked fiber rolls,
- restoring 4 acres of salt marsh in the Narrow River (Segments 5 and 6) with shell-filled gabion slope protection and pumping 30,000 cubic yards of dredged material to these five salt marsh restoration locations (Sedge Island Southeast Border, 700 ft. of shoreline protection; Sedge Island East Border, 550 ft. of shoreline protection; Outlet East, 700 ft. of shoreline protection; Inlet North, 1,400 ft. of shoreline protection; Inlet South, 900 ft. of shoreline protection).

Alternative H – 65.1 Acre Eelgrass and 11.5 Acre Salt Marsh Restoration and 3 Acre Salt Marsh Creation

This alterative consists of most of the restoration measures described above for Alterative F, but also includes the creation of salt marsh on the south side of the Narrow River in Segment 4S. The existing bare intertidal and subtidal mud habitats would be replaced by 65.1 acres of eelgrass and 14.5 acres of salt marsh for a total of 79.6 acres of estuarine habitat restored.

The features of this alternative include:

- restoring 9.1 acres of eelgrass south of Middle Bride in Segment 4S by dredging 42,000 cy of sediment,

- restoring 56 acres of eelgrass in Pettaquamscutt Cove (Segment 5) by dredging 215,000 cy of sediment and disposing of 207,000 cy of the material at the RISDS,
- restoring 11.5 acres of salt marsh in the Narrow River (Segments 5) by placing 50,000 cubic yards of dredged material into five salt marsh restoration locations (Sedge Island North, Sedge Island South, Sedge Island extension, Pettaquamscutt North, and Outlet West) and holding the material in place with staked fiber rolls,
- creating a 3 acre salt marsh along the western shoreline south of Middle Bridge in Segment 4S by pumping 15,000 cy of dredged material to the salt marsh.

Alternative I – Dredging to Restore Flushing

This alternative involves dredging the inlet between Sprague Bridge and Narragansett Bay to improve flushing and restore water quality sufficiently to restore eelgrass and shellfish habitat quality in the estuary. Hydraulic modeling performed for this study identified three increments of dredging:

1) Dredging all shoals between the inlet and Sprague Bridge to -2 feet NGVD (28,000 cy);
2) Dredging all shoals between the inlet and Sprague Bridge to -3 feet NGVD (47,000 cy);
3) Dredging all shoals between the inlet and Sprague Bridge to -4 feet NGVD and dredging channels to -4 ft NGVD from the deep water north of Sprague Bridge to the stone causeway in Pettaquamscutt Cove and to Middle Bridge (68,000 cy).

The dredge would maintain a 50 foot un-dredged buffer between the edge of salt marsh and the beginning edge of dredging. The slope between the buffer and the dredged invert would be 1 vertical to 4 horizontal. The dredged material would be pumped approximately 1 mile to the southern end of Narragansett Beach to restore the beach profile. Sediment samples indicate that the material is almost entirely composed of sand compatible with the sand on Narragansett Beach. The sand would be pumped through a pipeline placed in the water across 150 feet of the Dunes Club beach. The pipeline would be submerged outside the surf zone parallel to Narragansett Beach. The sand would be placed to an upper elevation of 6 ft. NGVD.

1.3 Restoration Measures that can be added to the Alternatives

The restoration measures that follow can be combined with any of the preceding alternatives. Real estate costs would be the same as the costs for those alternatives with which they are combined.

Restoration Measure J – Boat Traffic Control Channel

Several marinas and boat ramps are located on the Narrow River upstream of the restoration focus area south of Middle Bridge. Boat traffic traveling through the shallows from these access points to Narragansett Bay disturbs sediment increasing turbidity and boat wakes contribute to erosion of salt marshes lining the banks of the Narrow River. This alternative consists of relocating the channel closer to its position in 1939, placing the material dredged from the new channel position against the marsh to the south, and constructing and marking a 25 foot wide, 2-foot (NGVD) deep channel to confine boat traffic to a single path as far as possible from the edges of the salt marsh that are subject to erosion. This channel is located in the same place as the area that would be dredged to restore eelgrass south of Middle Bridge. Therefore, if this alternative is implemented along with dredging a short segment of channel to link the eelgrass restoration area to deep water in Segment 6N, the benefits of the channel will have been achieved as well. If this measure were implemented without these other alternatives, the quantity of dredged material would be 4,900 cy. The defined channel would protect the existing salt marshes from erosion and would protect restored eelgrass and shellfish beds from propeller damage and erosion.

Restoration Measure K – Protect Eroding Salt Marshes and Restore Oysters

This alternative involves placing shell slope protection along eroding marsh edges in The Narrows and one section of the lower Narrow River south. The shell would be placed along up to 1,200 feet of marsh edge on the east side of the river just south of Middle Bridge, 800 feet of marsh edge along the east side of The Narrows, between the Sprague Bridge and the elbow where the inlet bends to the north east, and 1,200 feet along the west side of The Narrows just north of the inside of the elbow bend of the inlet. The shell would be placed against the face of the existing marsh and generally have a 1 vertical to 3 horizontal slope. The top layer of shell would be seeded with oyster spat on shell. This alternative would protect 3,200 feet of marsh edge and create approximately 0.6 acres of oyster habitat.

2.0 Tidal Regime

This area of the Atlantic Ocean experiences semi diurnal tides with a Mean Lower Low Water (MLLW) to Mean Higher High Water (MHHW) tide range of 3.5 feet. The Mean High Water Spring (MHWS) tide elevation is 4.00 ft. Predicted tides for Narragansett are provided by NOAA at Narragansett Pier which is approximately one mile south of the Narrow River Inlet. The predicted tides are calculated using correction factors applied to the tides at the NOAA Benchmark in Newport, RI. The correction factors are 0.91 for the high tide and 0.93 for the low tide. In Table 1 a “shifted” Newport Benchmark for Narragansett Pier has been created using these corrections.

Table 1. Tidal Regime outside of the Narrow River

Newport, RI Station 8452660

Tide Reference	Reference Datum (feet)			
	MLLW	MTL	NGVD29	NAVD88
Mean Higher High Water (MHHW)	3.85	1.98	2.67	1.80
Mean High Water (MHW)	3.60	1.73	2.42	1.55
NAVD88	2.05	0.18	0.87	0.00
Mean Tide Level (MTL)	1.87	0.00	0.69	-0.18
NGVD29	1.18	-0.69	0.00	-0.87
Mean Low Water (MLW)	0.14	-1.73	-1.04	-1.91
Mean Lower Low Water (MLLW)	0.00	-1.87	-1.18	-2.05

Narragansett Pier, RI (reference station Newport, RI Station 8452660)
High = 0.91*Newport and -11 minutes
Low = 0.93*Newport and +11 minutes

Tide Reference	Reference Datum (feet)			
	MLLW	MTL	NGVD29	NAVD88
Mean High Water Spring (MHWS)[1]	4.00	2.28	2.97	2.10
Mean Higher High Water (MHHW)	3.50	1.78	2.47	1.60
Mean High Water (MHW)	3.28	1.56	2.25	1.38
NAVD88	1.90	0.18	0.87	0.00
Mean Tide Level (MTL)	1.72	0.00	0.69	-0.18
NGVD29	1.03	-0.69	0.00	-0.87
Mean Low Water (MLW)	0.13	-1.59	-0.90	-1.77
Mean Lower Low Water (MLLW)	0.00	-1.72	-1.03	-1.90

[1] As reported in the Tides and Currents software package

3.0 Previous Studies and Modeling History

The system was modeled in UNET and in June 1993. The Corps issued a report stating that the effects of widening the opening under the Middle Street Bridge would be minimal (less than 0.15 ft difference at the bridge cross-section) at mean spring tides. A replacement bridge was completed in 2003. Applied Science Associates of Narragansett RI completed a study titled “The Effect of Changes in Channel Cross-Section and in Middle Bridge Road Bridge Span Width on Dynamics in the Narrow River Estuary” for the Narrow River Preservation Association in 1995. The Office of Water Resources of the RI DEM completed a study titled “Fecal Coliform TMDL for the Pettaqaumscutt (Narrow) River Watershed, Rhode Island” in 2001.

This hydraulic study creates a HEC-RAS Unsteady Model based on the former UNET model used in the Corps 1993 study with updated bathymetric and tide data collected in 2005.

4.0 Data Collection

As explained in Section 4.1, it was necessary to collect both bathymetric and near shore topographic data along with tide level data in order to properly update the 1-D UNET model developed in 1993 to the HEC-RAS Unsteady Model used for this study.

At first the only data that were collected was in the vicinity of Sedge Island and the area below the Middle Street Bridge. Figure 3 illustrates the area and associated. A USACE New England Survey crew collected cross sectional point information collected in feet-NGVD29.

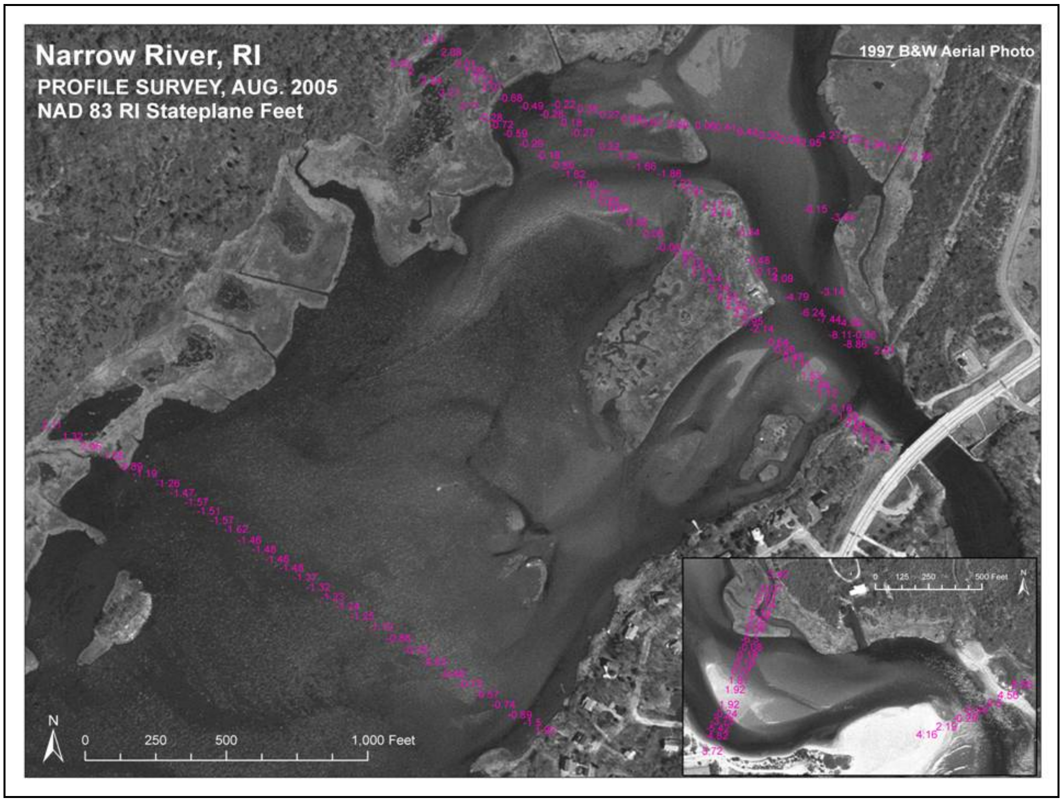


Figure 3. Profile data collection effort August 2005.

Unfortunately, it was determined that these data were not sufficient on their own to update the model since the model was not able to be calibrated to match tide data that were collected in 1993. In trial runs with the model it was determined that the inlet and The Narrows section of the system was critical in controlling water level within the system. Based on that information, it was decided that additional inlet/Narrows section bathymetry data were needed. It was also determined that tidal data would be needed from within the system given the age of the data available, but this effort was postponed until the new bathymetry data were collected. The second set of data that were collected was cross sectional inlet data and scattered XYZ bathymetry data. A map of these data can be seen in Figures 4 and 5. These data were collected under the leadership of Dr. Jon Boothroyd from the University of Rhode Island (URI) during the late fall of 2006 and the late spring of 2007. The second time period was needed to fill in data holes discovered in the first set and to adjust the data following the Patriots Day storm in April 2007. These data were received and entered into the model as cross sections, but the model still would not calibrate. Since it was thought that the bathymetry data were more than adequate to represent the system, it was decided to move forward with the tide data recording effort. In June of 2007 the USACE – New England Survey Section was utilized to install four

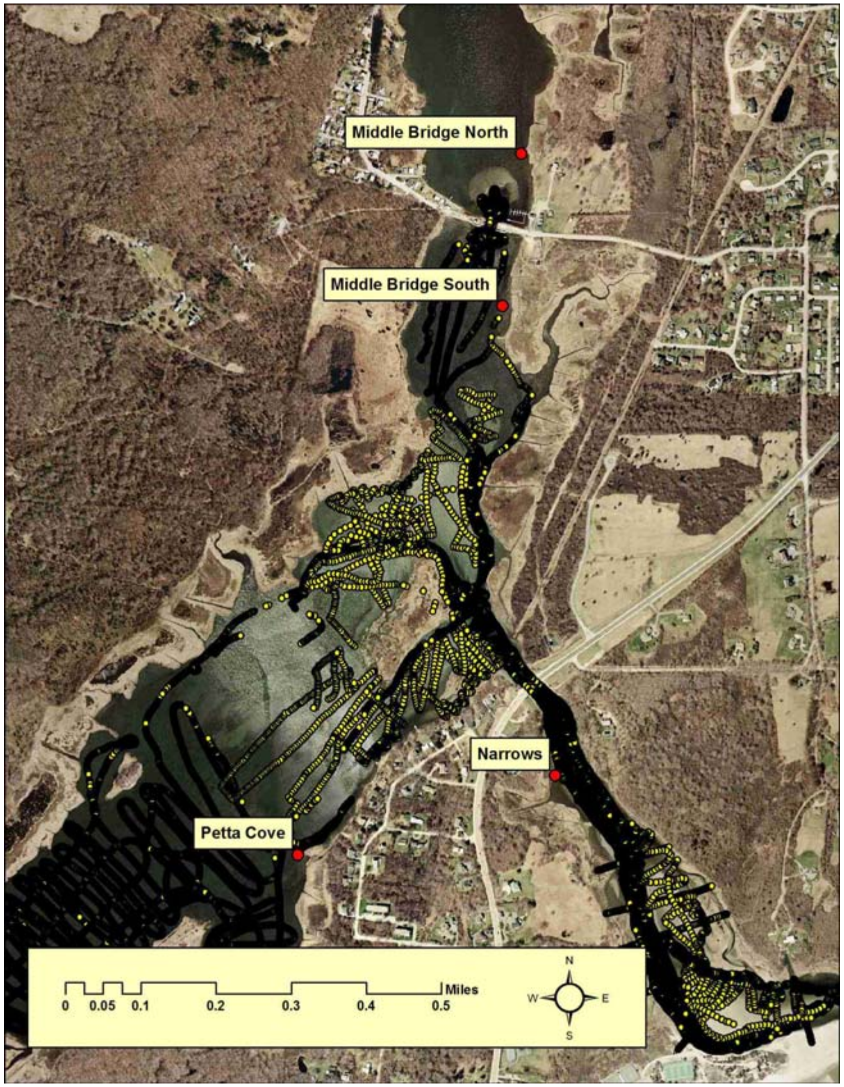


Figure 4. URI XYZ point data and USACE tide board locations

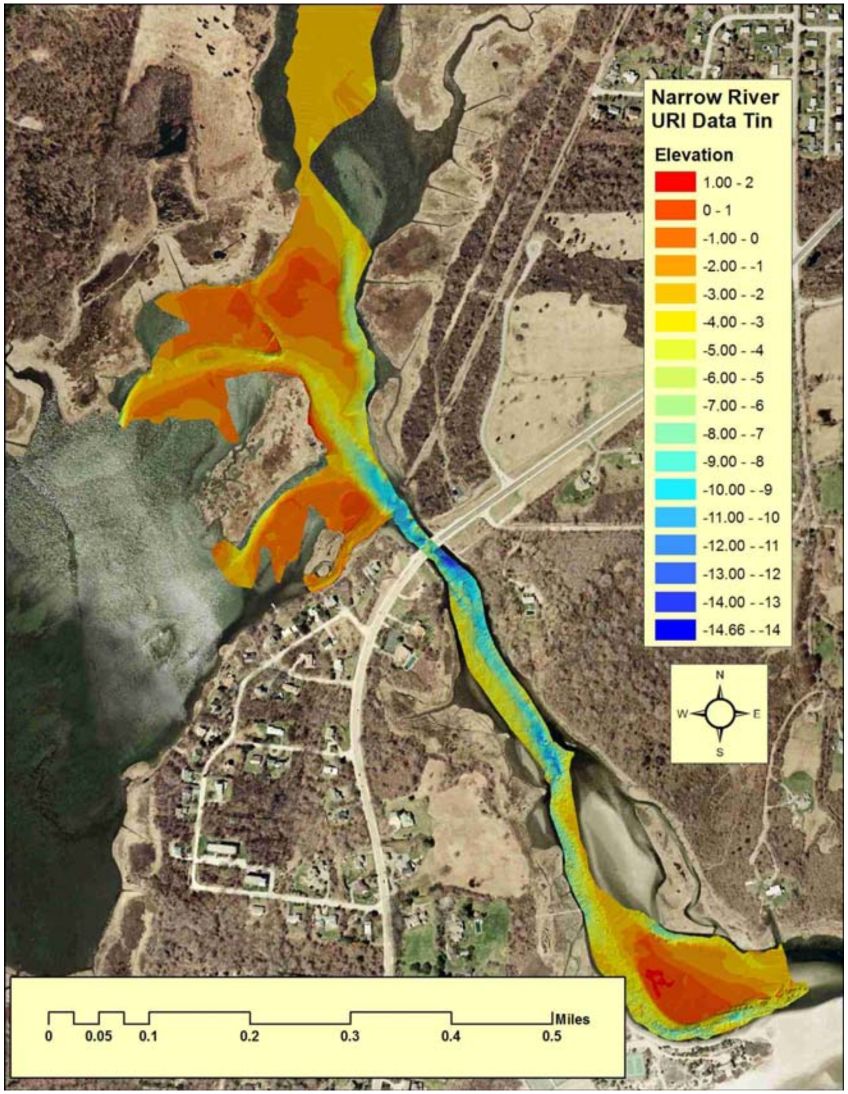


Figure 5. Tin of URI bathymetry data (NGVD29 Ft).

tide boards in the Narrow River system and the tides were read over a complete tide cycle (before low to post high) on June 12, 2007. Tide data were recorded by three Corps employees from the Water Management Section every fifteen minutes. The location of the tide boards can be seen in Figure 4. The plot showing collected data can be seen in Figure 6 with the tabular data provided in Appendix 1.

Since deploying a gage outside of the inlet to record the ocean tide elevations was not practical for this small effort, the tide data recorded by NOAA at the Newport benchmark were used. There is a small published correction factor from Newport to Narragansett (discussed in the Section 2) which was applied to provide ocean tide conditions outside of the Narrow River inlet. It is understood that corrections are only for predicted tides and they do not account for meteorological impacts to the tide data, but this was the best available solution.

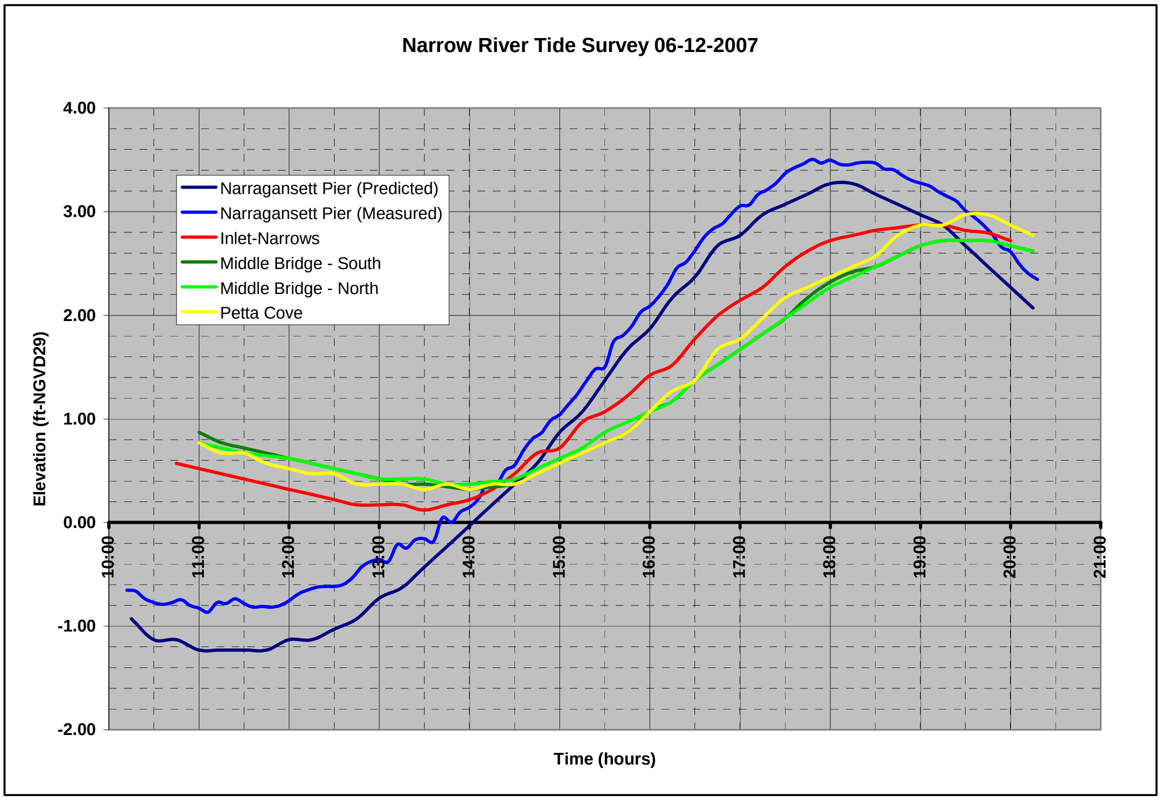


Figure 6. Tide data collected from the Narrow River (06-12-07).

June 12, 2007 Tide Data Discussion

As shown in Figure 6, the low tide elevations are muted by over 1 foot compared to the ocean low tide and lag the ocean tide by over 2 hours. The high tide elevations are also muted, but not as severely with a 0.7 foot reduction, and about a 1.5 hour lag. It is also evident that the inlet is the major cause of tidal range reduction in the system since the tide range and timing within the system is very close amongst the recorded locations. It can also be seen that the ocean tides were running slightly higher than the predicted tides that day and it is thought that this is due a storm that passed a couple of days earlier that was still causing a fairly persistent north west wind. This wind is also believed to be the cause of the Pettaquamscutt Cove tides running slightly higher than the other recorded stations since this wind direction would have a tendency to pile water into the cove.

5.0 Study Model – Existing Conditions

The UNET model used for the 1993 report was reconstructed as a HEC-RAS Unsteady Model in 2006-07. The main alterations to the model setup included cross section changes resulting from bathymetric/topographic data (Section 4.0) collected during this study and the data used to validate the model (Section 4.1). Also, the width of the Middle Street Bridge opening, along with the nearby channel bathymetry were adjusted since the bridge was replaced after the 1993 study. Figure 7 shows many of the model cross sections. In several areas there are more concentrated cross sections in order to represent complex bathymetry areas. However, to avoid cluttering the figure some of the cross sections were omitted for illustration purposes.

The tide signal used for the ocean model boundary condition to drive the model was provided by the Newport, RI NOAA station and transferred to the Narragansett Pier Prediction station. From the NOAA webpage, it was determined the adjustment to Narragansett Pier from Newport was 0.92 and approximately 11 minutes. While it is understood that this correction factor is for predicted tides only and that outside influences from weather are not included in this correction; the use of the correction factors from Newport was the best information available. The model was run from May 15, 2007 to June 15, 2007. This time frame was used since it covered the tidal data collection effort that occurred on June 12, 2007. The June 12th date was ideal for modeling maximum flushing conditions since it was a Spring tide condition.

The original effort to validate the model was unsuccessful since tide data being used were from 1993, and the bathymetry data collected were not sufficient to cover the critical controlling areas. As described in Section 4, due to the poor validation, it was decided more bathymetry data were needed in the inlet/Narrows area of the system along with newer tide data. These data were collected as described in Section 4. Once the new bathymetry data were entered into the model and the model output was compared to the new tide data collected it was found that the model compared very well to the collected data. Since there was only one day of tide data available only one day of comparison could be done. Calibration was not performed in that the friction values were set at the middle value recommended in the HEC-RAS hydraulics manual. As shown in Figures 8-10, collected data matched well with modeled data.

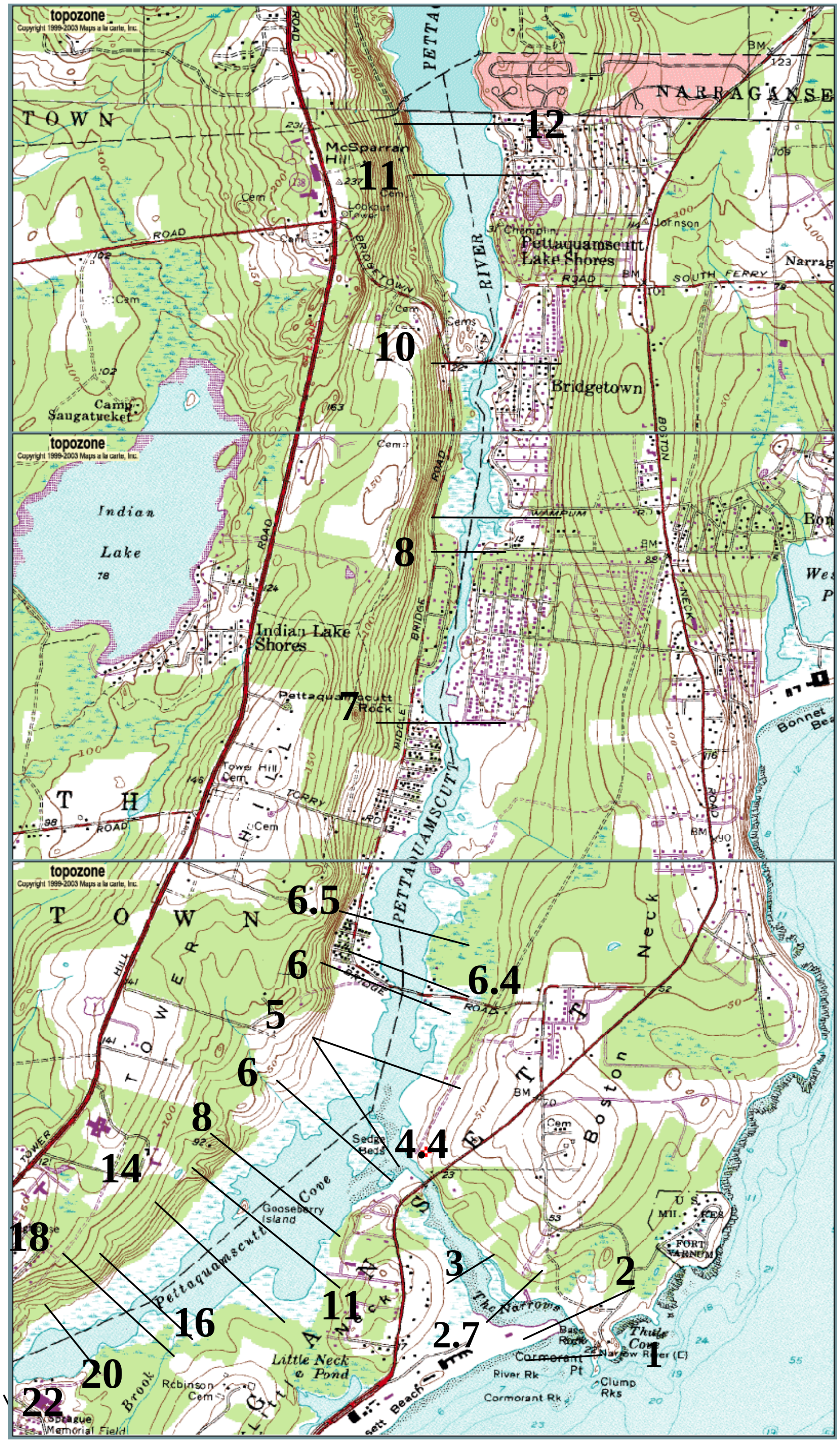


Figure 7. Map Showing Locations of Cross-sections (locations approximate and not all sections are shown).

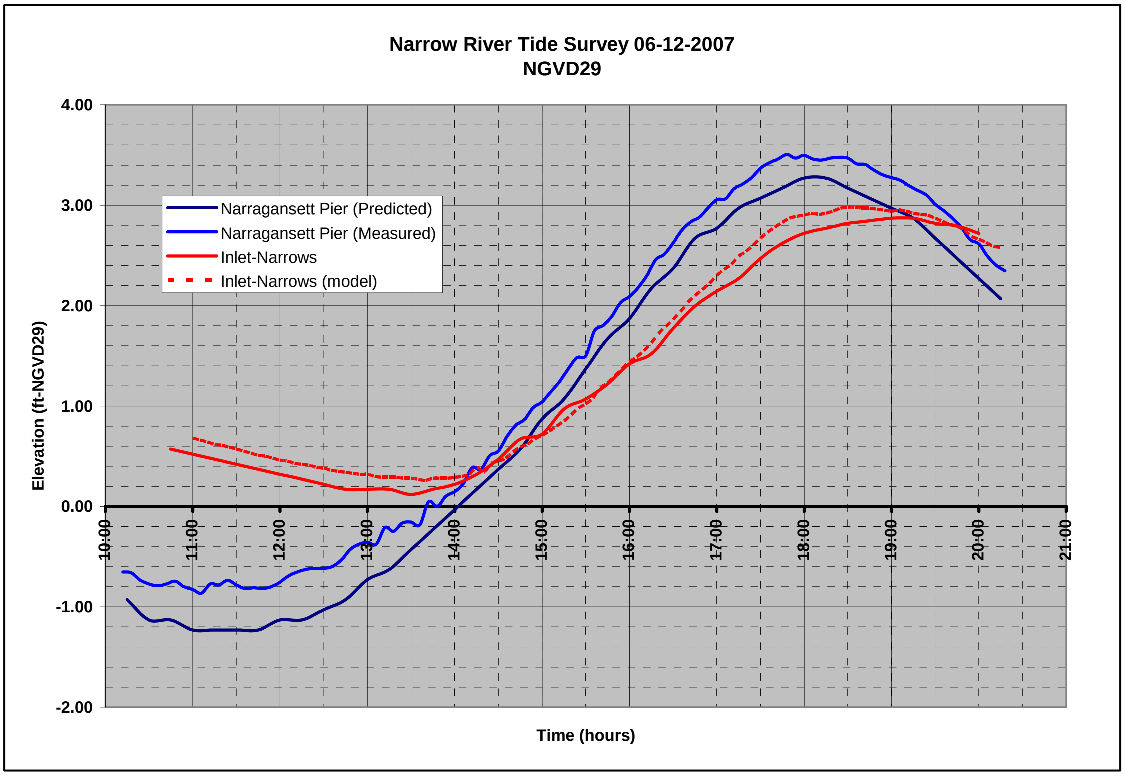
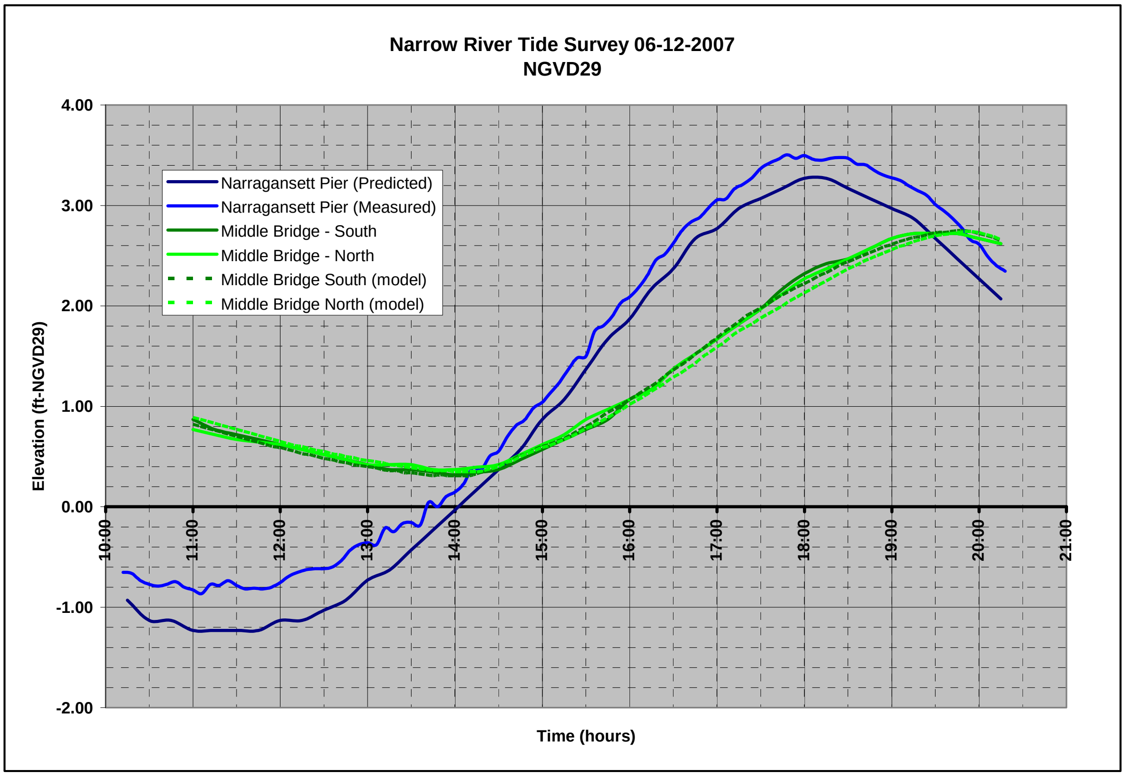


Figure 8. Model comparison at the Narrows to data collected 06/12/07.



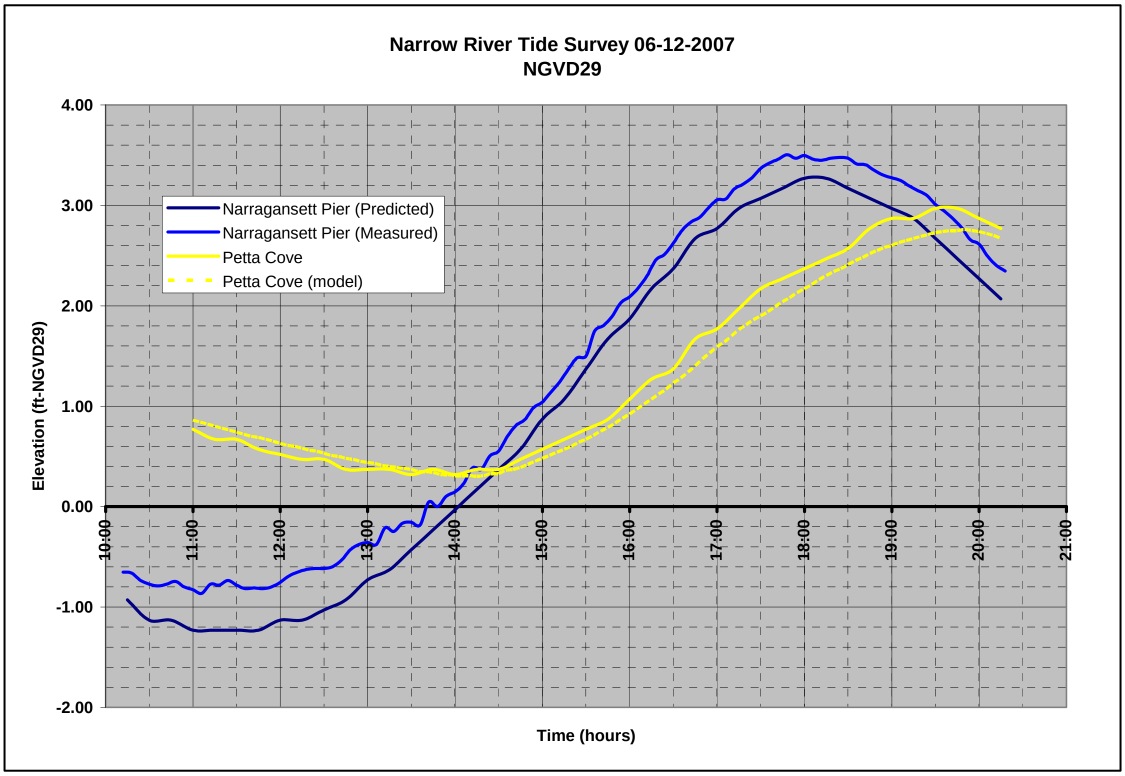


Figure 9. Model comparison at the Middle Bridge to data collected on 06/12/07.
Figure 10. Model comparison at Petta Cove to data collected on 06/12/07.

6.0 Study Model – Alternative Analysis

Once the model was shown to be validated, it was used to represent the existing conditions. In order to determine the hydraulic impacts of the various proposed alternatives a total of seven model dredging increments were looked at. These dredging increments are different than the specific alternatives described in Section 1.2 or the main study report. These model alternatives were formulated to cover the study alternatives and provided the necessary information, but also were used to perform a sensitivity analysis that looked at inlet/Narrows channel depths. The seven dredging options are:

1. -4’ NGVD29 Channel into Petta Cove (40’ wide) and between the Sprague and Middle Bridge (50’ wide)
2. Lowering minimum elevations in Inlet/Narrows to -2’ NGVD29
3. Lowering minimum elevations in Inlet/Narrows to -3’ NGVD29
4. Lowering minimum elevations in Inlet/Narrows to -4’ NGVD29
5. Lowering minimum elevations in Inlet/Narrows to -2’ NGVD29 with Alternative 1.
6. Lowering minimum elevations in Inlet/Narrows to -3’ NGVD29 with Alternative 1.
7. Lowering minimum elevations in Inlet/Narrows to -4’ NGVD29 with Alternative 1.

The modeled channel layout can be seen in Figure 11 and some examples of the existing channel and alternative channel cross sections are shown in Figures 12a-15b. The color shading in the cross sectional figures is depth averaged current speed and is discussed in Section 6.3. The cross sections are always looking up stream (from the ocean).

6.1 Alternatives Analysis – Tide Range/Prism and Flushing Time

The same tide data time series used for the validation was run for each of the alternatives and the output from June 12th was specifically used for comparison. This was done because that was the day tide data was collected, but more importantly that day experienced Spring Tide conditions that were similar to the MHWS tides. This would provide optimum flushing rates. It was found that the installation of channels into Pettaquamscutt Cove and up the Narrow River without dredging the inlet had essentially no impact on tide range, tidal prism, or flushing time. It was shown that the inlet/Narrows must be opened up to beneficially impact tide range, tidal prism, and flushing time. As shown in Figures 16 to 23, it can be seen that as the inlet’s minimum elevations are lowered from existing conditions to -4’ NGVD29 that the tide range and tidal prism increases and flushing times decrease for the Narrow River system. The model stations listed in the figures can be seen in Figure 7. For the flushing time calculations an idealized flushing time was used. More specifically it assumes the water coming into the system mixes well and that there are no pockets of trapped water. It is also assumed once the water exits the system it does not return during the next flood tide.

As shown in Figures 22 and 23, with the inlet/Narrows dredged to a minimum elevation of -4’ NGVD29 there is a noticeable reduction in flushing time. For the inlet only option, the time is reduced by 20% and when the inlet option is put in with the interior channels the time is reduced by 26%. However, this must be kept in context by specifically looking at Figure 22. While the 20% and 26% are significant the actual time is reduced from 1.57 days to 1.25 days and 1.17 days, respectively. The impacts of the flushing will be determined in the Nitrogen Loading model, but they do not appear to be very significant based on the reduction in time.

6.2 System Sub-section Flushing Comparison

In order to have a more refined look at flushing times, specific sections of the system were looked at. When looking at the system, only an average flushing time for the entire system is provided. This means that some areas may be flushing much slower than others, but the overall system seems to be flushing relatively quickly at 1.57 days. The sub regions can be seen in Figure 24. Specifically, Pettaquamscutt Cove (Segment 5), the river starting just south of Middle Bridge (Segments 3 and 4), and the Ponds north of Bridgetown Road (Segments 1 and 2) were looked at.

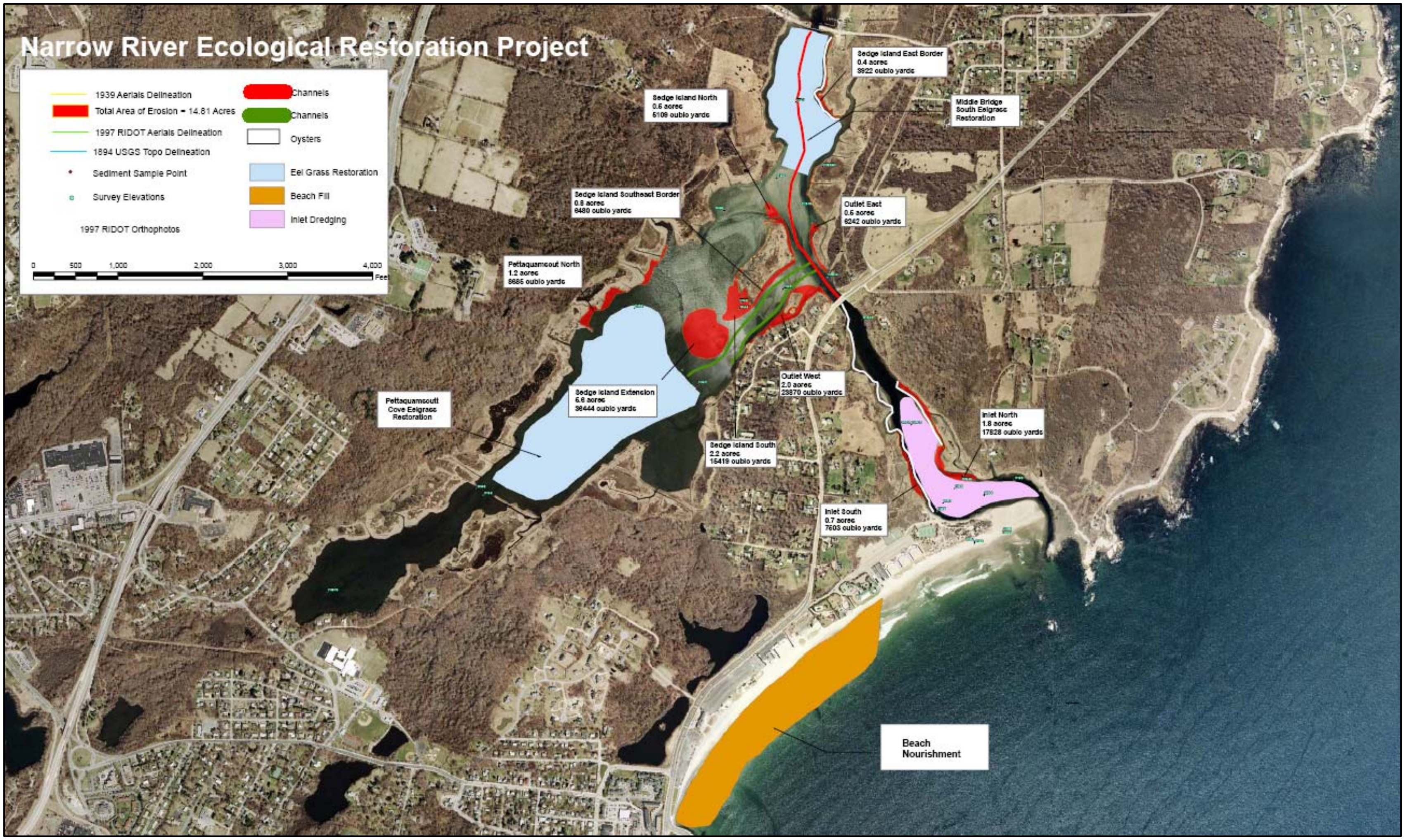


Figure 11. Plan view of modeled channel layouts

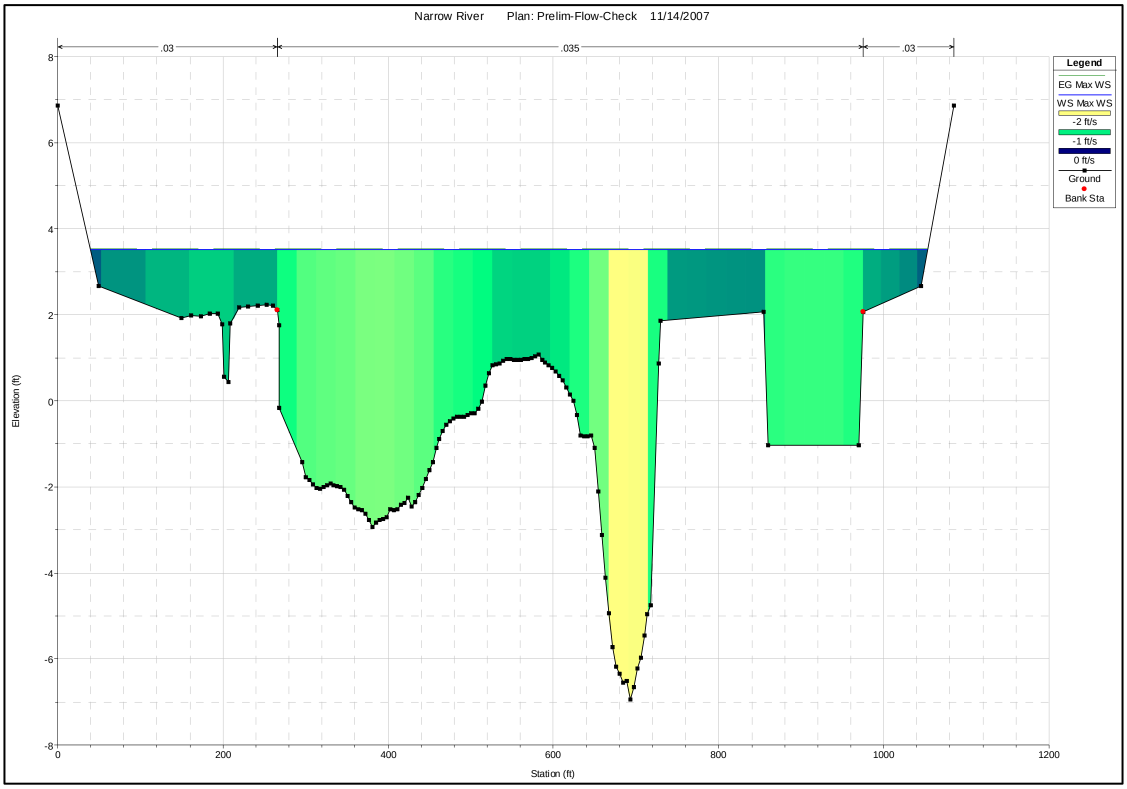


Figure 12a. Existing conditions cross section at model station 2.7 (inlet/Narrows)

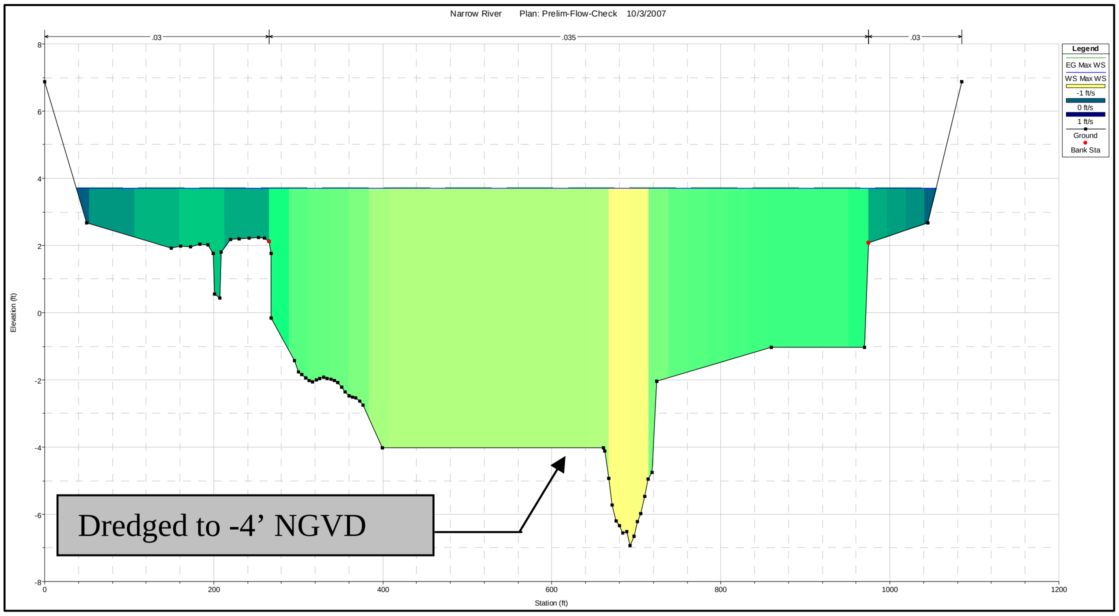


Figure 12b. Dredged condition at model station 2.7 (inlet/Narrows at -4' NGVD29)

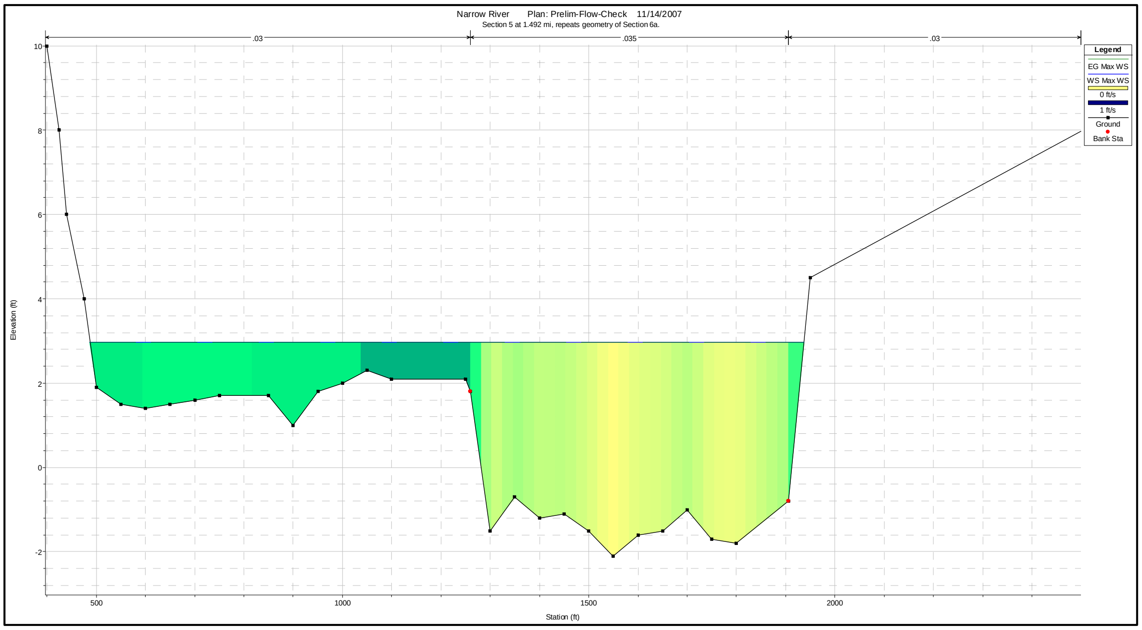


Figure 13a. Existing conditions cross section at model station 5 (Narrow River).

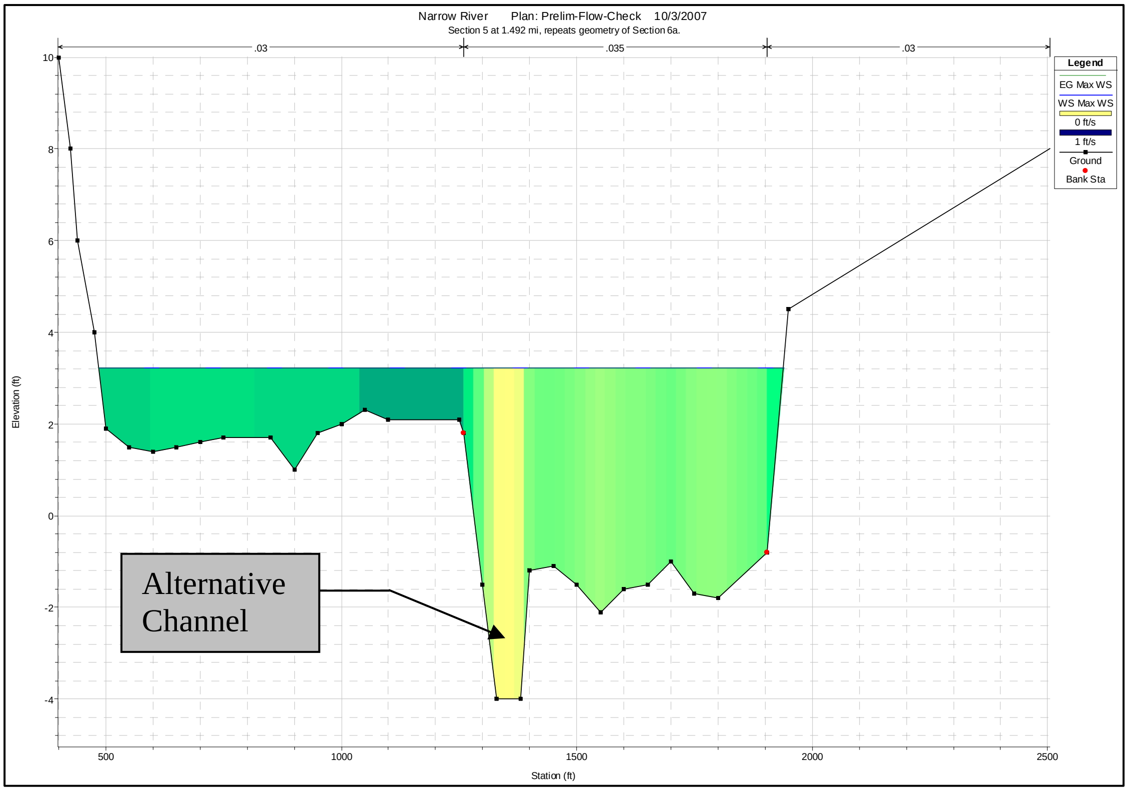


Figure 13b. Dredged channel at model station 5 (Narrow River).

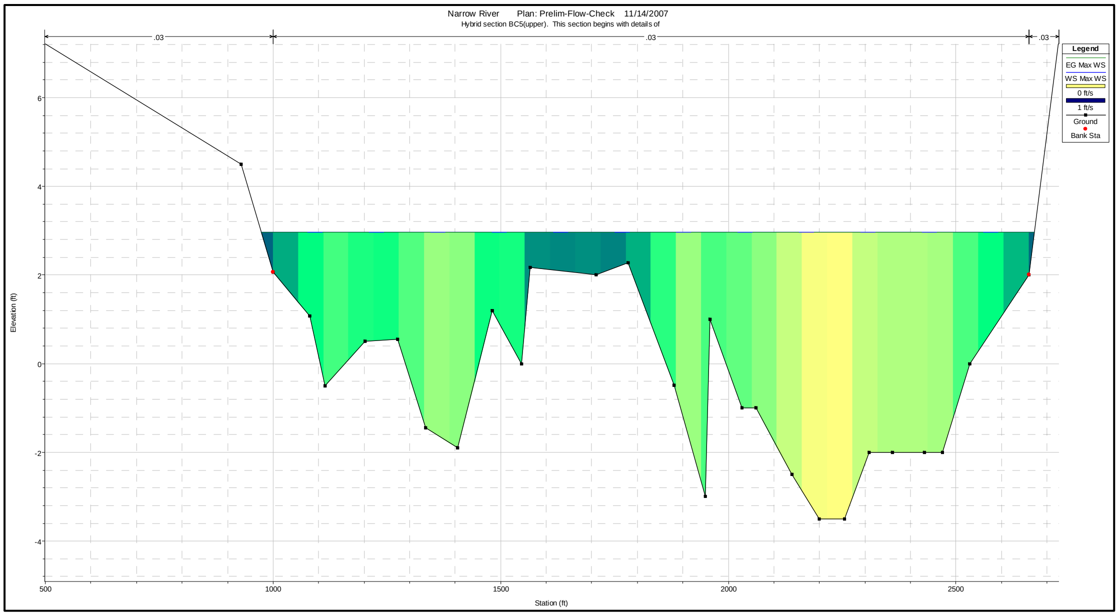


Figure 14a. Existing conditions cross section at model station 4.9 (Pettaquamscutt Cove entrance).

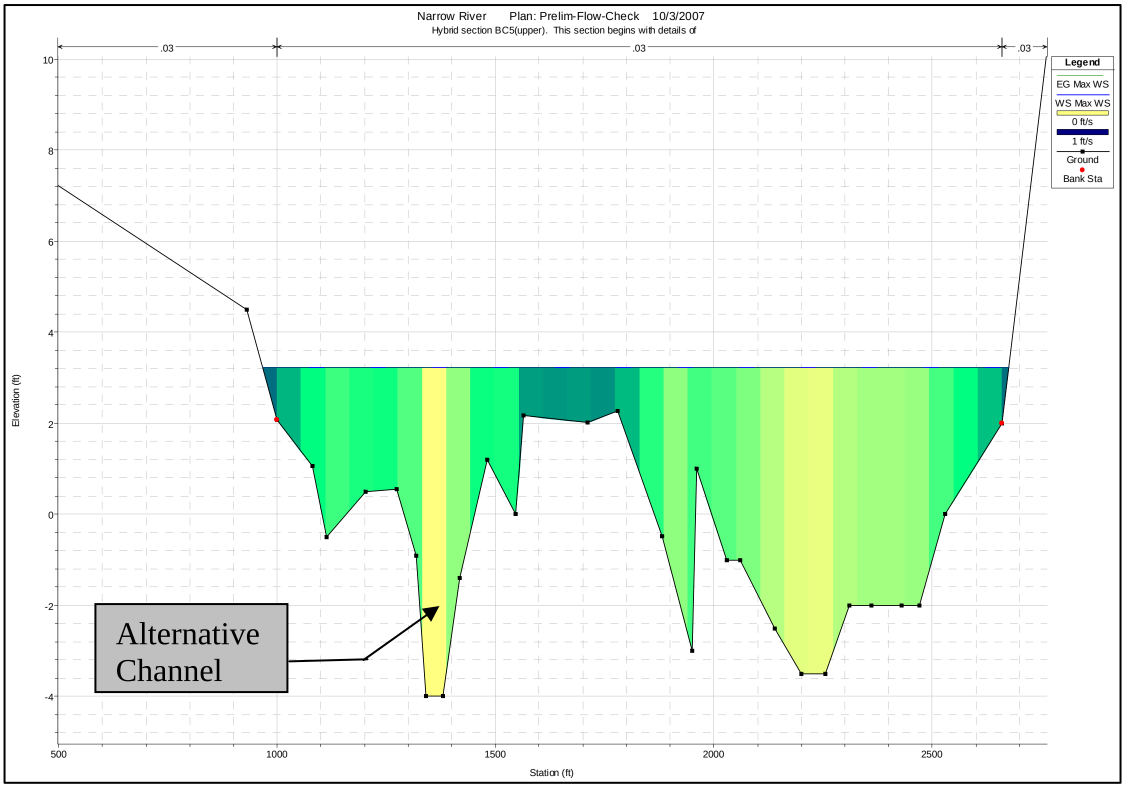


Figure 14b. Dredged channel at model station 4.9 (Pettaquamscutt Cove entrance).

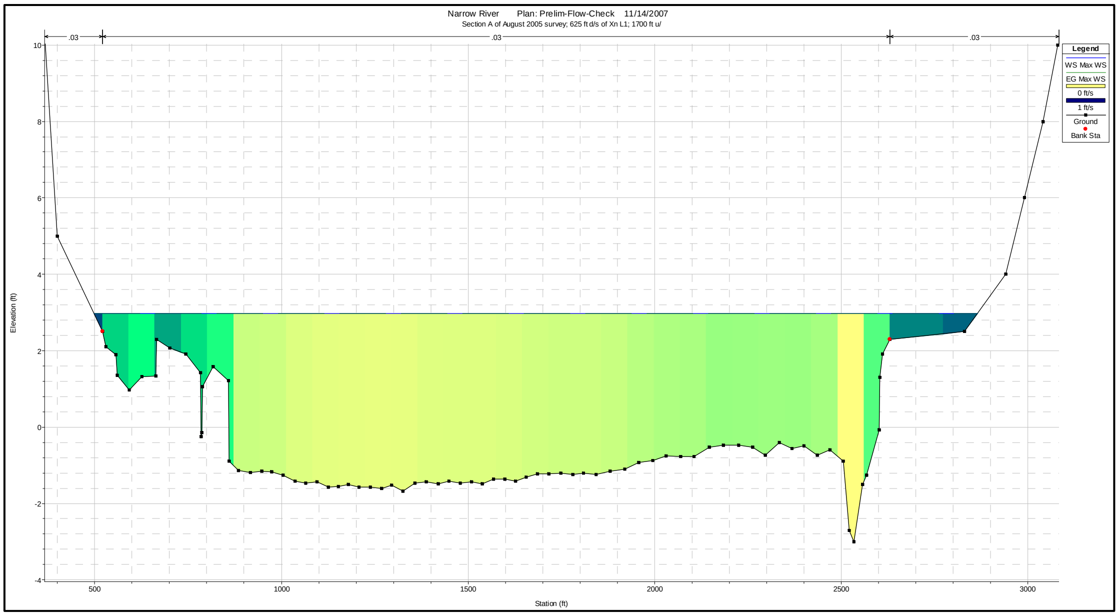


Figure 15a. Existing conditions cross section at model station 8 (Petta Cove)

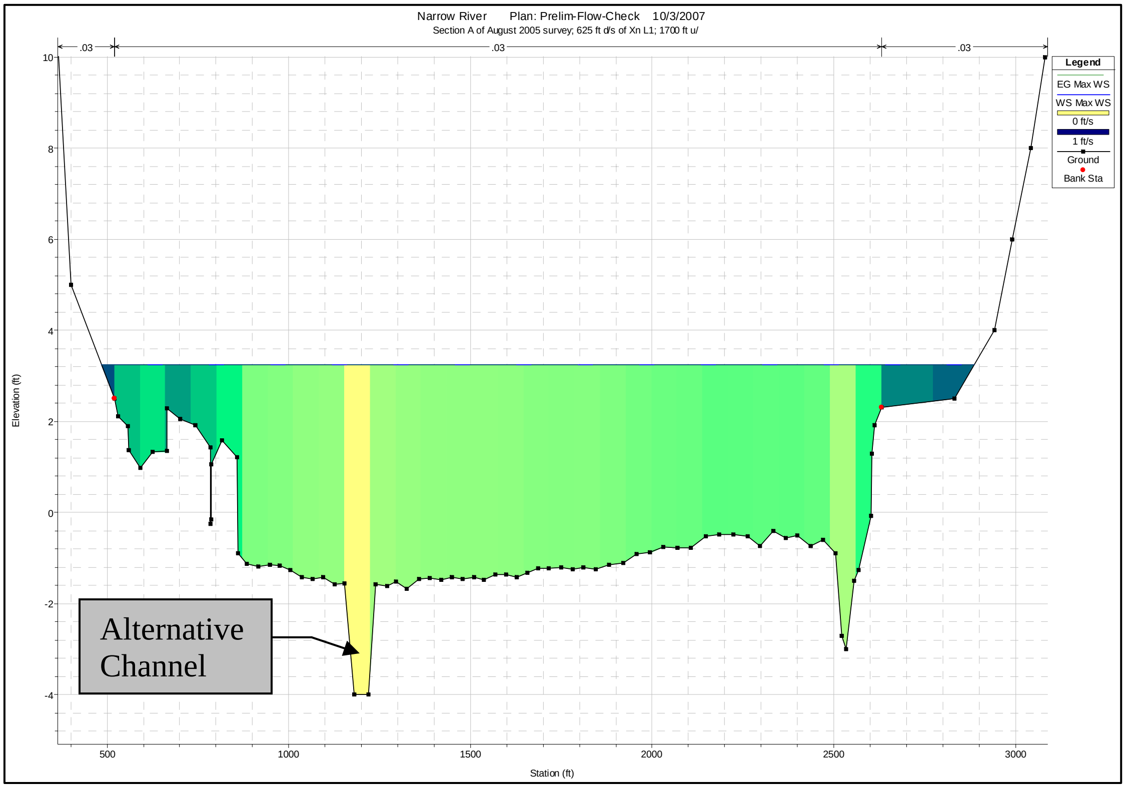


Figure 15b. Dredged channel at model station 8 (Petta Cove).

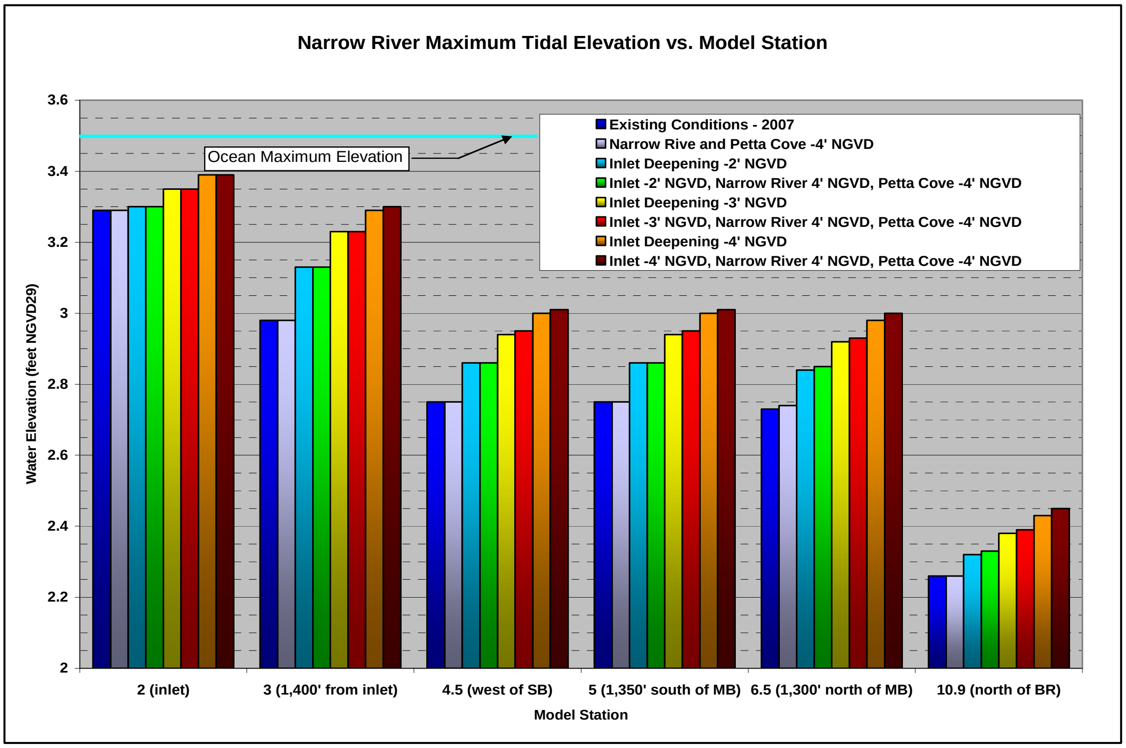


Figure 16. Maximum tide elevation (June 12, 2007) in the Narrow River.

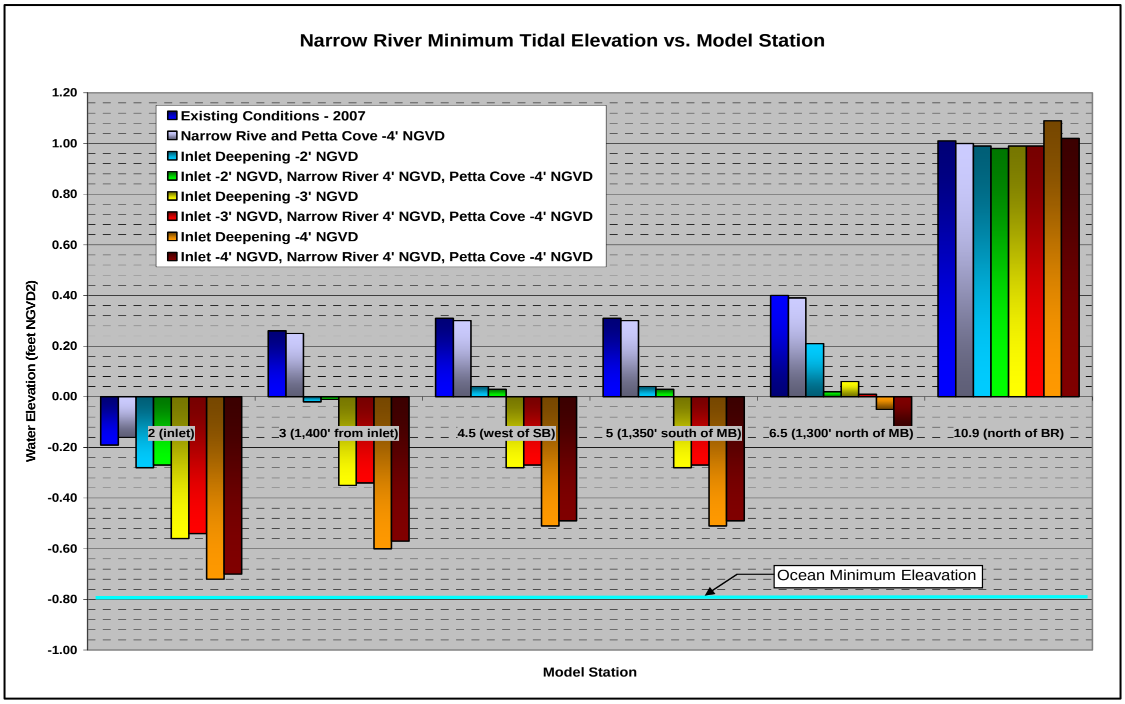


Figure 17. Minimum tide elevation (June 12, 2007) in the Narrow River.

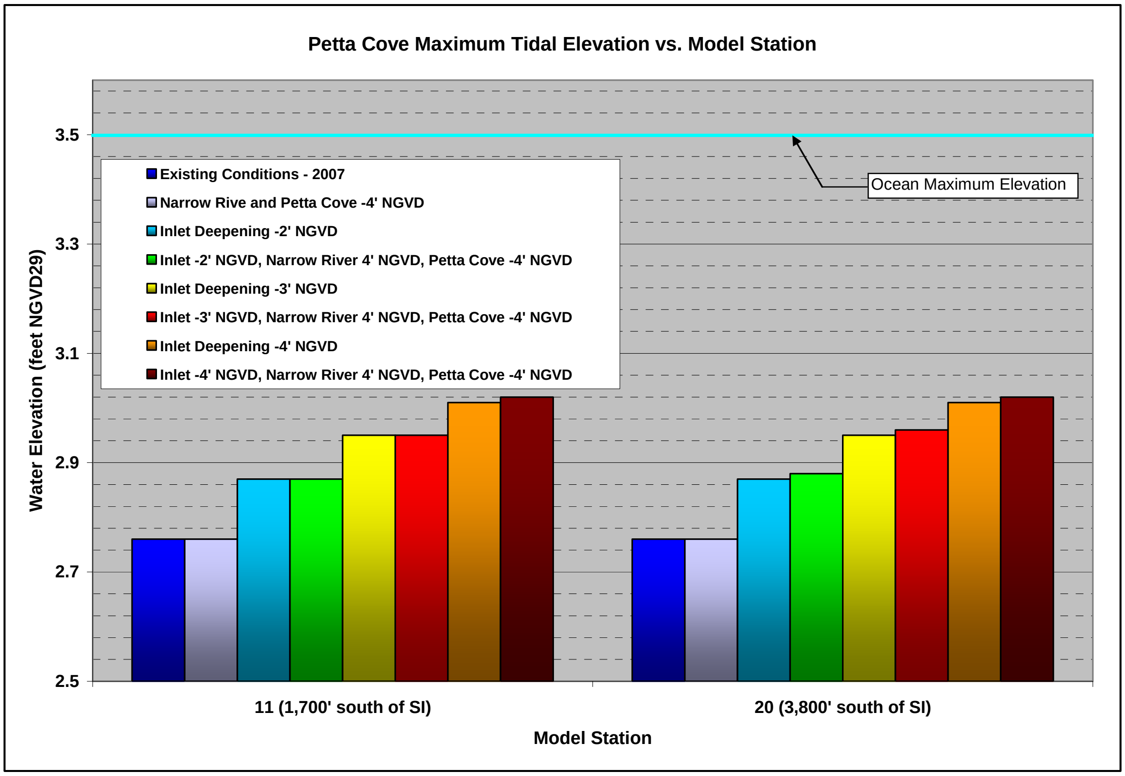


Figure 18. Maximum tide elevation (June 12, 2007) in Petta Cove.

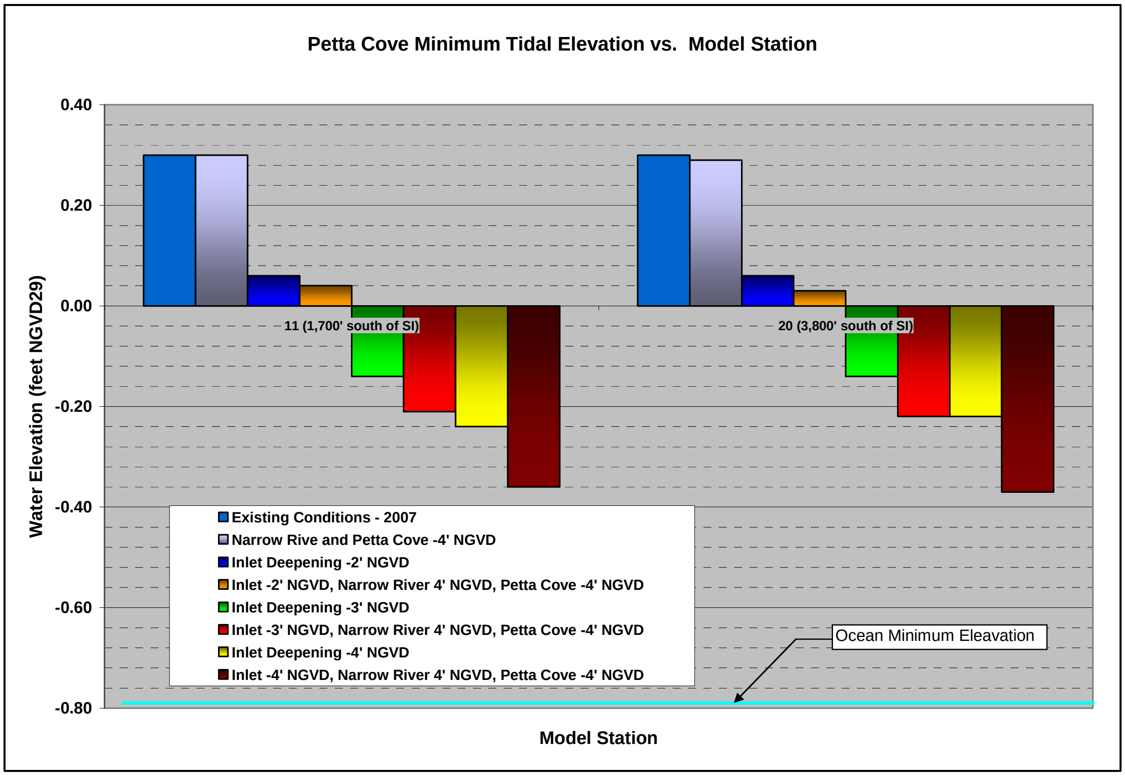


Figure 19. Minimum tide elevation (June 12, 2007) in Petta Cove.

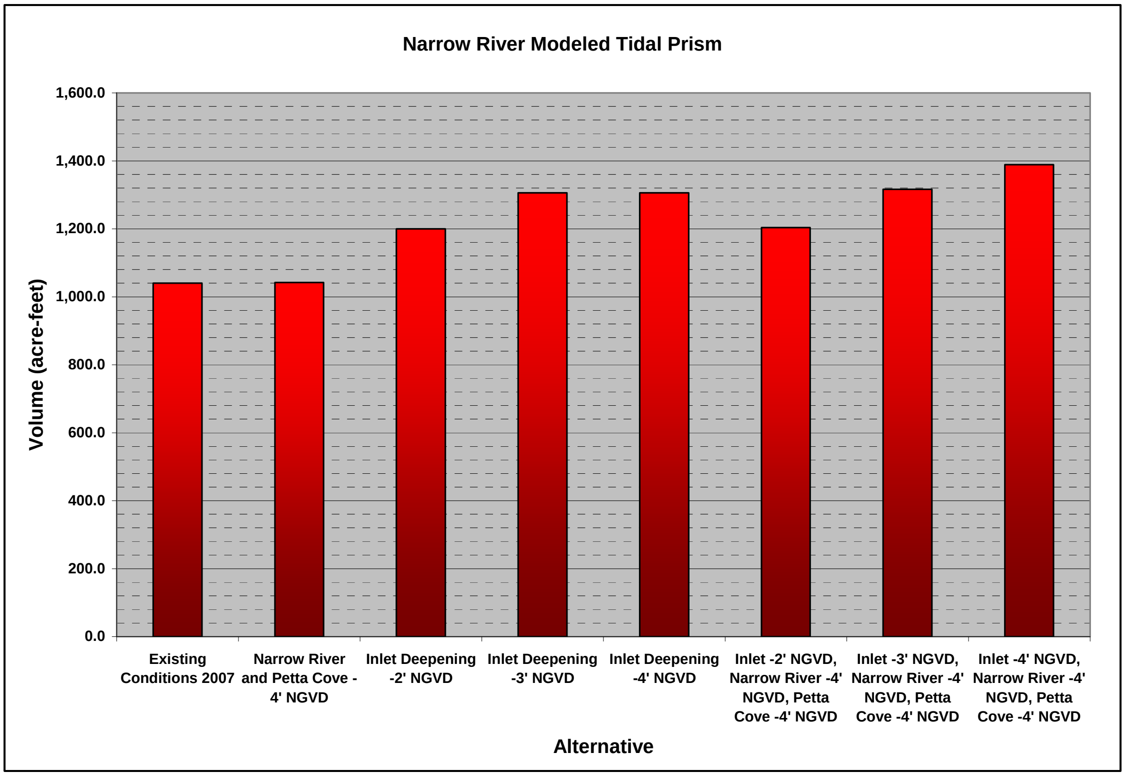


Figure 20. Tidal Prism for existing conditions and each alternative.

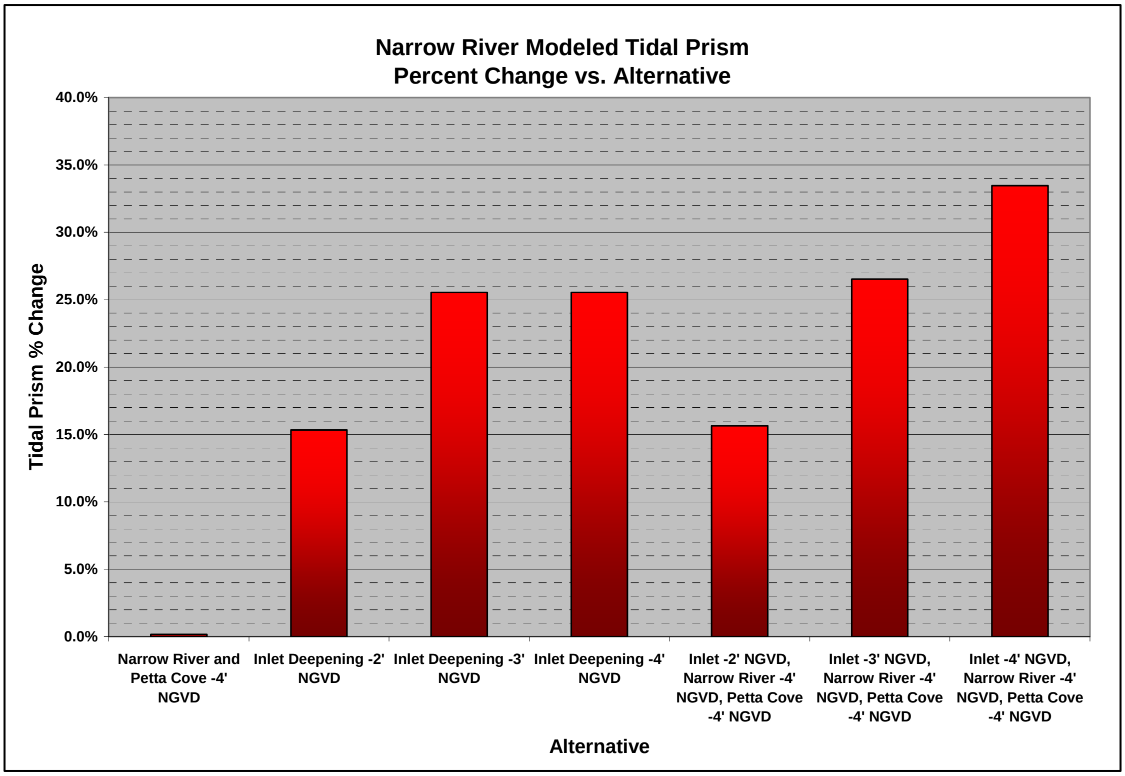


Figure 21.Tidal Prism percentage change versus existing condition.

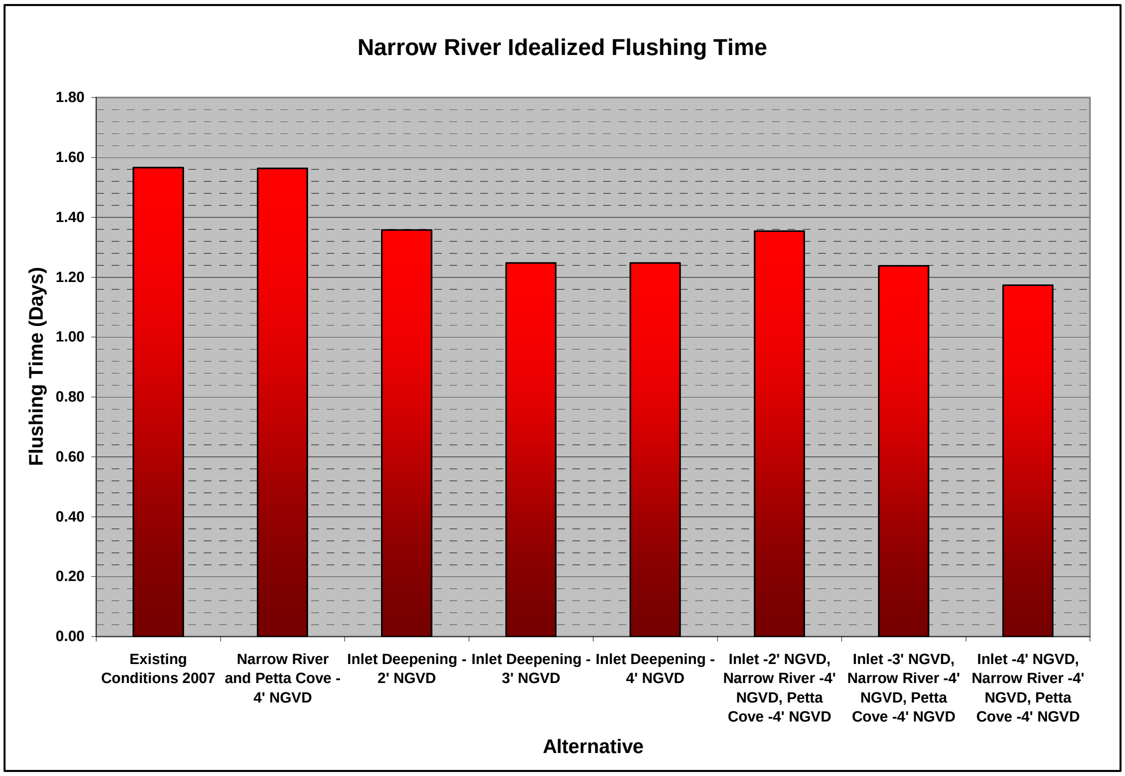


Figure 22. Idealized flushing times for Narrow River System.

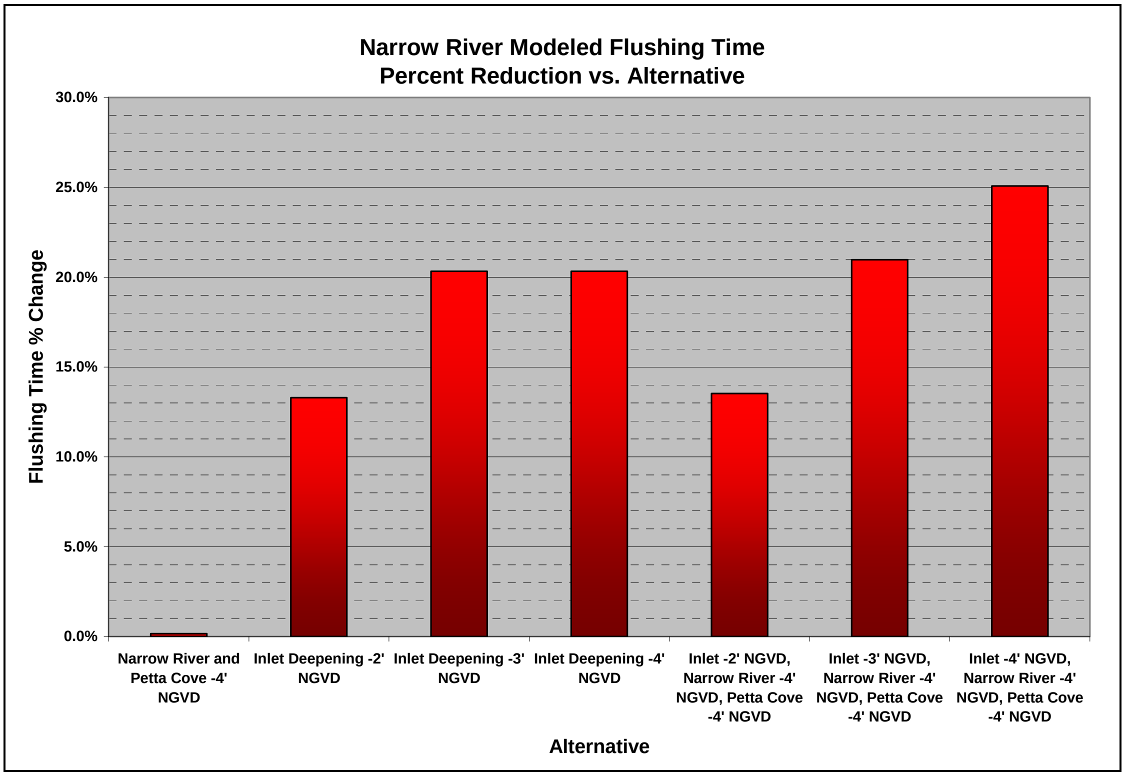


Figure 23. Percentage reduction in idealized flushing time vs. existing conditions.

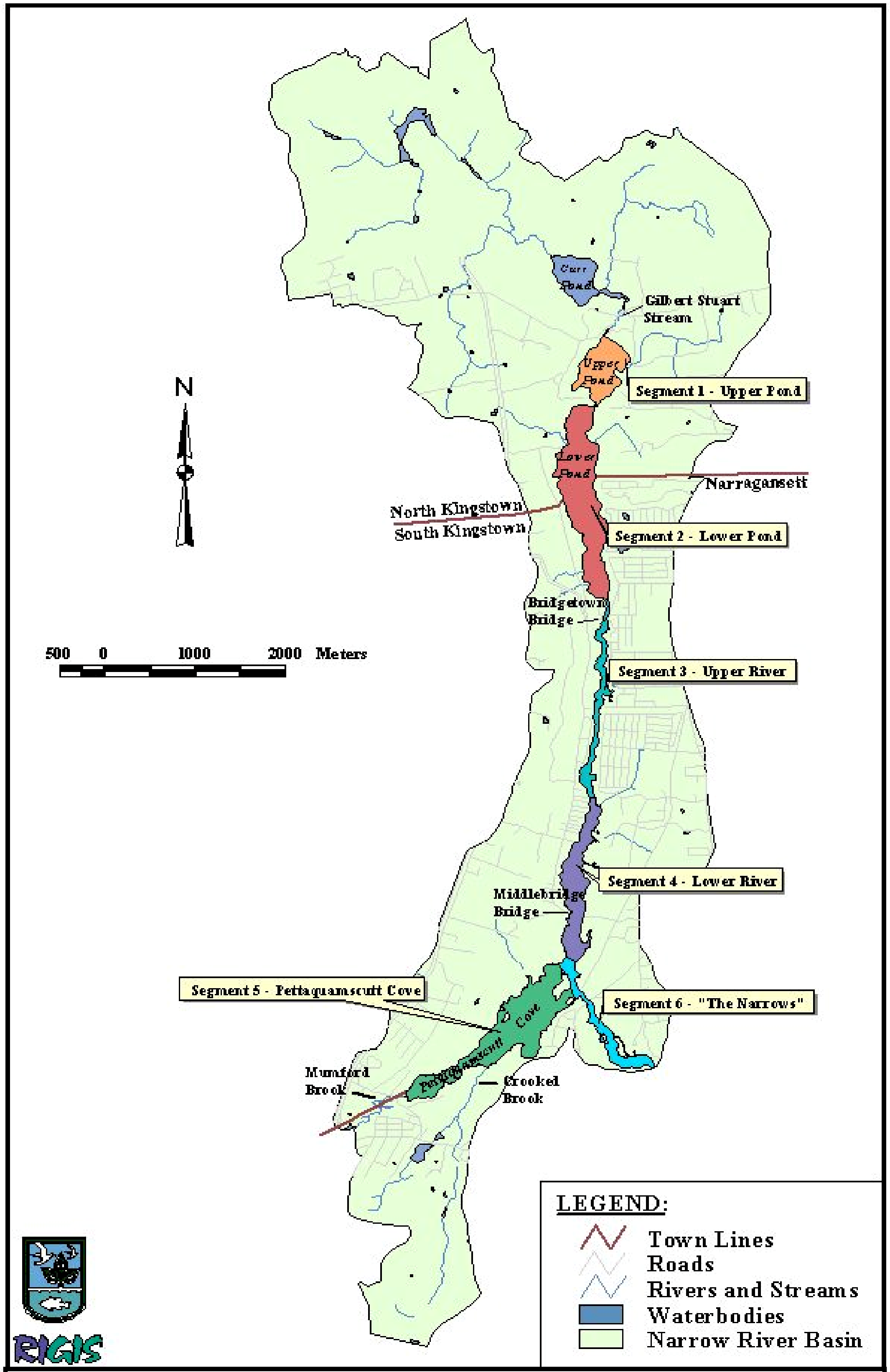


Figure 24. Narrow River sub regions used for flushing time analysis.

As shown in Figures 25 to 30, the findings for each sub region are similar to the analysis for the whole system with the most notable changes occurring with the opening of the inlet. For Pettaquamscutt Cove the flushing time is reduced for the -4' NGVD29 inlet alternative from 0.27 days to 0.17 days. When the -4' NGVD interior channel alternative (Pettaquamscutt Cove and channel to Middle Bridge – Segment 6n) is added the time is unchanged. Looking at the river system starting just below Middle Bridge the findings are similar to the system and the cove in that the flushing time is reduced from time of 3.13 days to 2.56 days when the inlet is opened. Adding the interior channel did not impact flushing time. This reduction represents a decrease in flushing time of just over 18%. It is noteworthy, that the flushing time for the river system (including the ponds) is 3.13 days, while the flushing time for the system is 1.57 days. This is due to the removal of the low flushing times of Pettaquamscutt Cove and the lower river system from the inlet to just south of the Middle Bridge. The question is, is the flushing time for the river below the Bridgetown Road crossing the factor or is it the deeper and restricted ponds to the north. To answer this, just the flushing time for the ponds was looked at. As shown in Figures 29 and 30, the flushing time for the ponds is significantly higher than for the system or the other subparts that were examined. It is apparent that these ponds are the most restricted features in the system and have the longest flushing times. The ponds experience a flushing time reduction from 7.48 days to approximately 6.5 days with the inlet opening alternatives.

It is realized that these times are significantly lower than the times listed in the Special Area Management Plan (SAMP) developed for the Narrow River. This is very likely due the fact that idealized conditions were assumed. It is well documented that the upper ponds are very stratified and that the water at lower elevations has a much longer residence time. In the idealized flushing conditions it is assumed water that leaves the system makes it completely out and does not return and this is not the case in the real world. Also, spring tidal conditions were used in this study. If neap tidal conditions were used, the flushing times would be greater, but still lower than the times reported in the SAM plan.

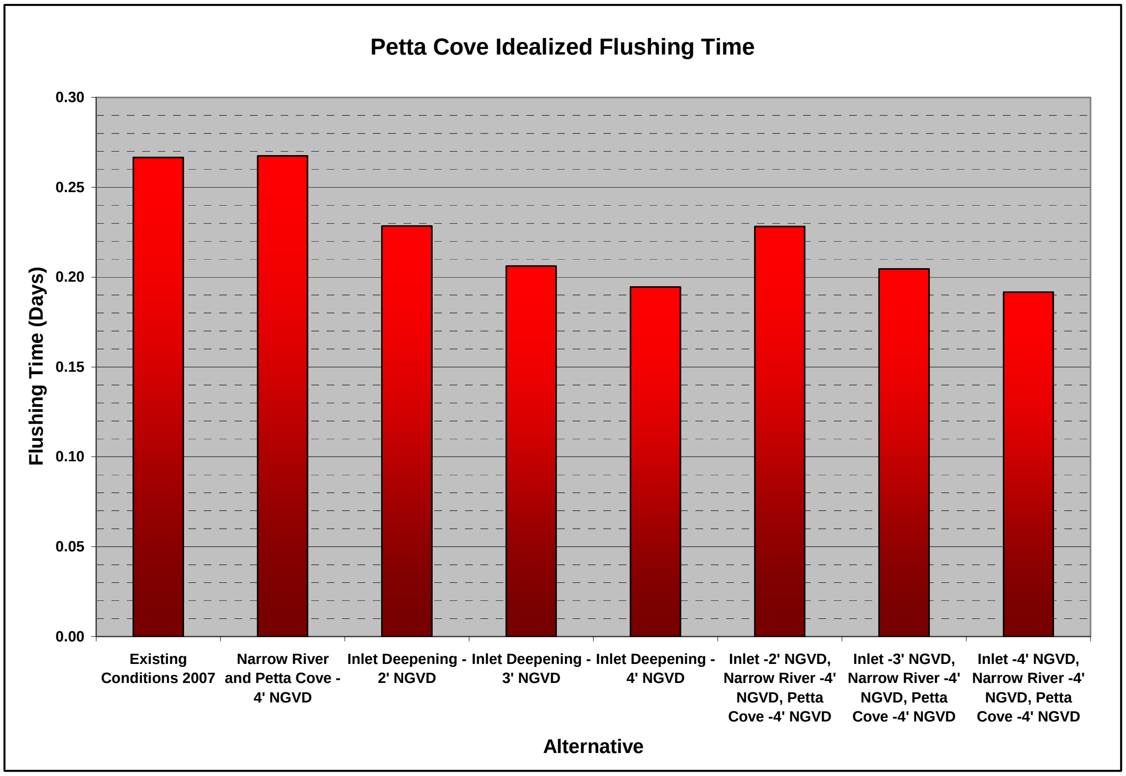


Figure 25. Petta Cove flushing time for existing conditions and alternatives.

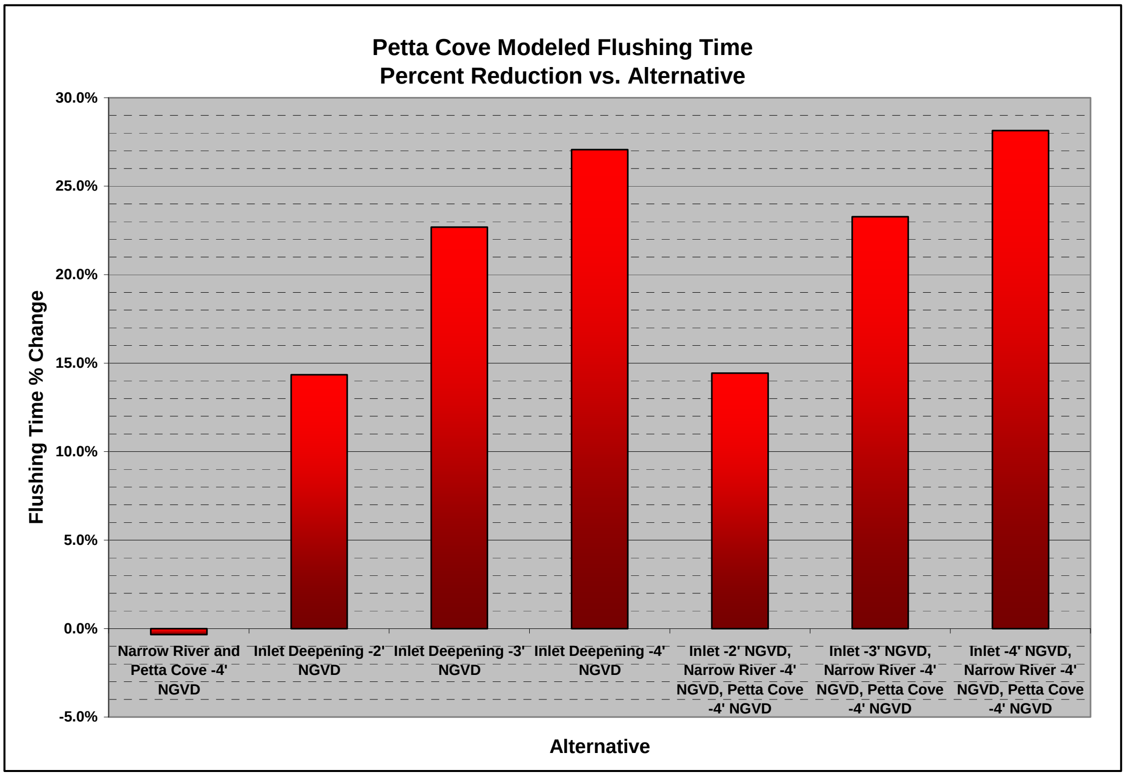


Figure 26. Petta Cove flushing time percent reduction vs. existing conditions.

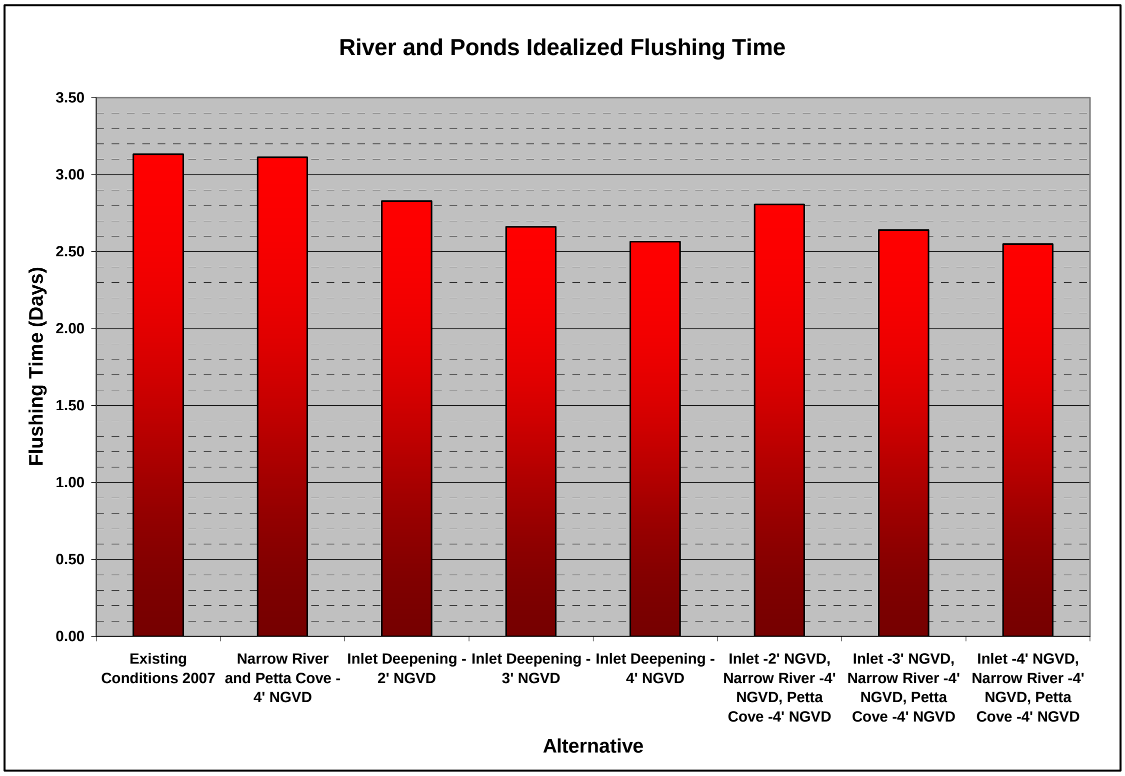


Figure 27. River/Ponds flushing time for existing conditions and alternatives.

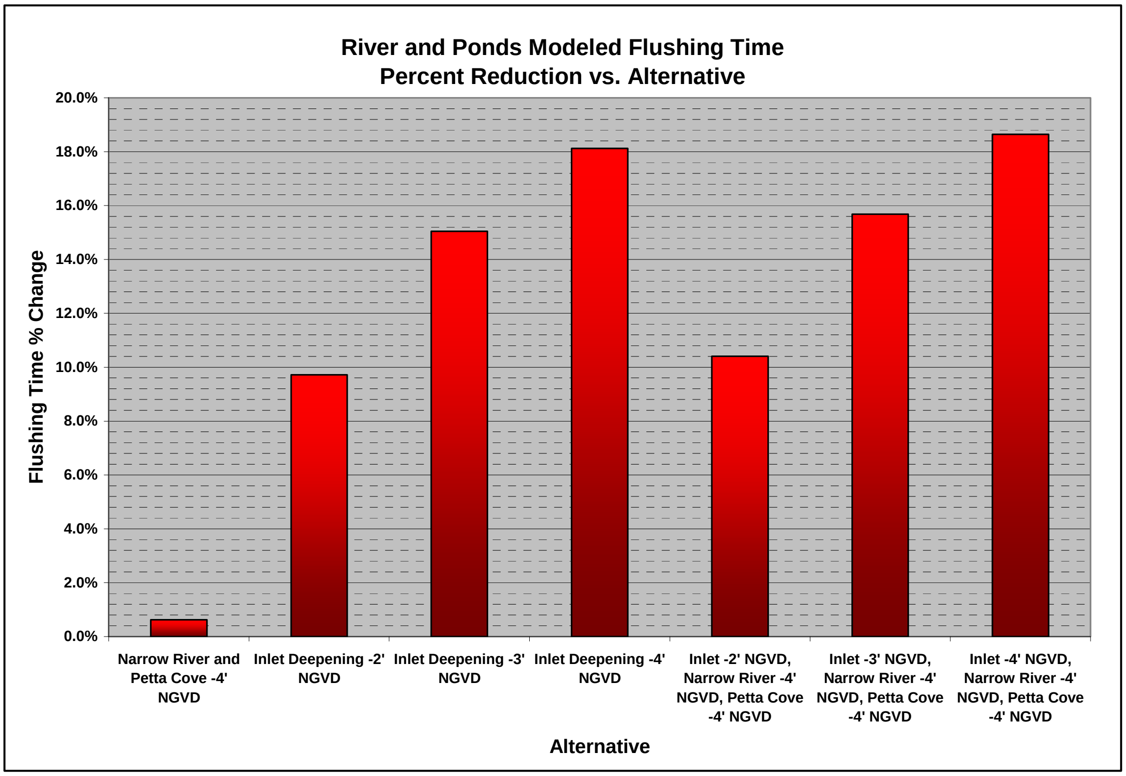


Figure 28. River/Ponds flushing time percent reduction vs. existing conditions.

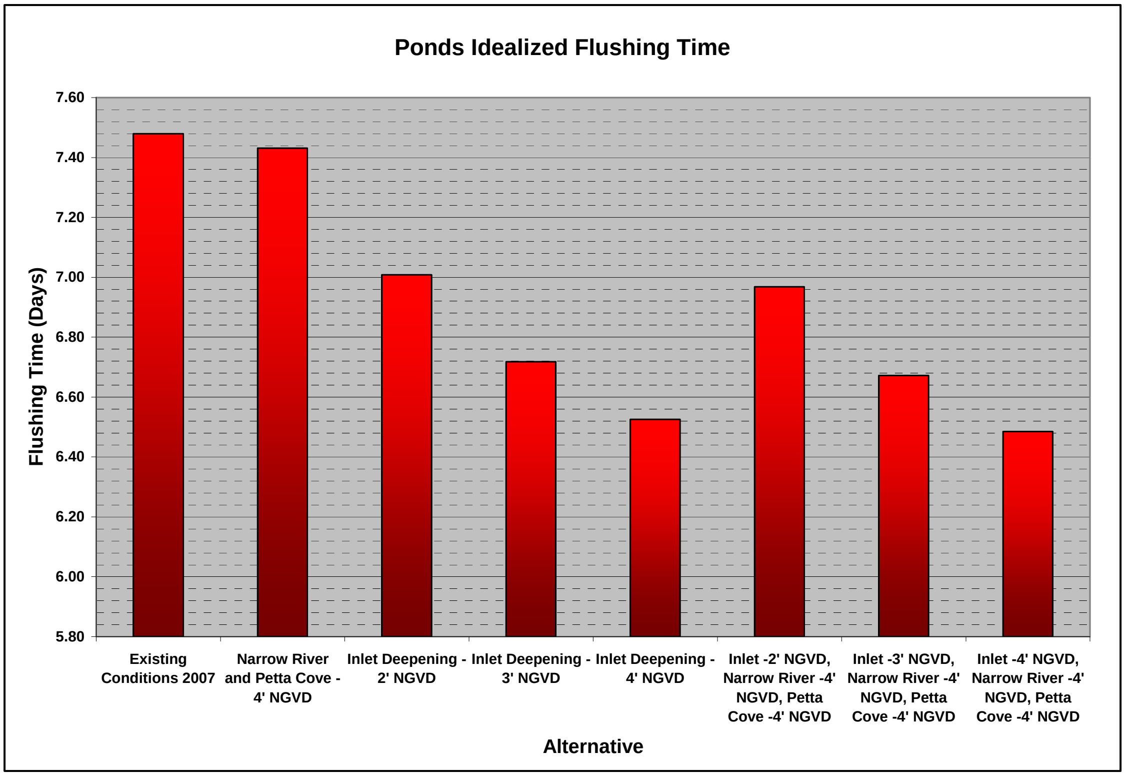


Figure 29. Ponds flushing time for existing conditions and alternatives.

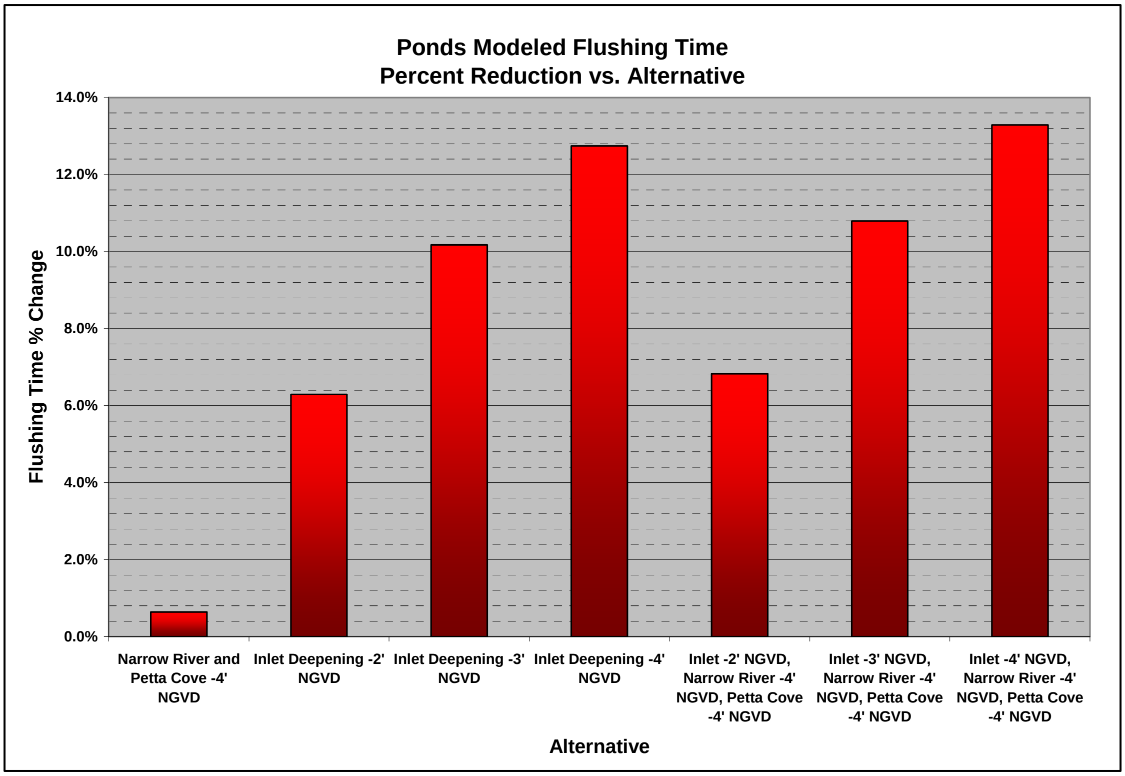


Figure 30. Ponds flushing time percent reduction vs. existing conditions.

6.3 Alternatives Analysis - Current Speed

A concern during the design of several of the alternatives described in Section 1.2 of the main study report was the potential for erosion along marsh banks and restored marsh fronts. To address this issue the maximum current speeds were looked at for the appropriate model cross sections for the existing conditions model and for the maximum alternative model. Additionally, these two models were run for the Patriots Day storm (estimated 10 to 15 year storm) condition to determine a significant storm condition. The model stations looked at were 2.7, 5, 4.7, and 4.9. These cross sections are right in the areas where the alternatives would be constructed. Shown in Figures 31a to 34f are the maximum depth averaged current speeds for these alternatives. As expected the highest current speeds are within the channel thalweg, with the lowest current speeds being along the shallower, higher friction, areas along the banks. Once again the cross sections are always being viewed up stream (from the ocean)

Model Section 2.7 (Narrows/Inlet)

The highest current speeds modeled were 2.15 ft/s in the channel thalweg. That current speed was present during the existing conditions bathymetry with a spring tide and also with a full alternative bathymetry and the Patriot's Day storm. For the full alternative bathymetry and spring tidal conditions, the current speeds drop in the thalweg slightly to between 1.5 and 2.0 ft/s (depending on flood or ebb). Along the marsh edges, the maximum current speed was approximately 0.90 ft/s +/- 0.15 for all the runs.

Model Section 5 (Middle Bridge South to Petta Cove Mouth)

Under existing conditions with a spring tide the maximum speed experienced was 0.85 ft/s. With the full alternative bathymetry in place the current speeds increased in the thalweg to 1.25 ft/s for both the spring tide and Patriots Day storm tide. Along the marsh edges the current speeds increased from about 0.50 ft/s under existing conditions to approximately 0.75 ft/s for the full alternative condition with the Patriots Day storm. For this area it is worth noting that since the relocation of the channel thalweg is being considered, the current speed difference between the channel and the edges is about 0.25 ft/s. This should be considered when designing the exact location of the channel and the proximity of the channel to any marsh faces. If the channel thalweg is relocated away from the bank/marsh face the potential for erosion will be lower. However, picking the location must be done with care since migration of the channel is likely.

Model Sections 4.7 and 4.9 (Entrance to Petta Cove)

For existing conditions the speeds within the channels on either side of Sedge Island were approximately 0.50 ft/s and with the full alternative bathymetry the speeds reached as high as 0.85 ft/s in those channels. Along the marsh fronts the maximum current speeds ranged from 0.10 to 0.40 ft/s. As with model section 5 this area is being considered for channel relocation. If a channel is kept away from the marsh front the erosion potential is low. If a channel is constructed next to a marsh front or meanders post construction to a marsh front then the erosion potential increases significantly.

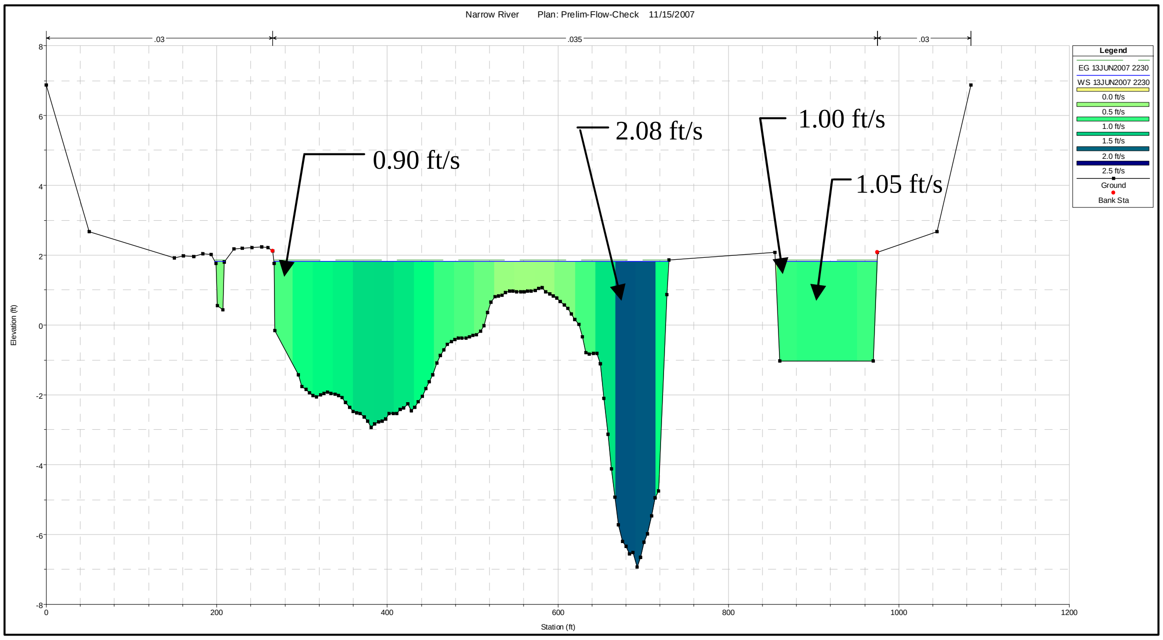


Figure 31a. Existing conditions station 2.7 (inlet/Narrows) peak spring current speeds (ebb tide).

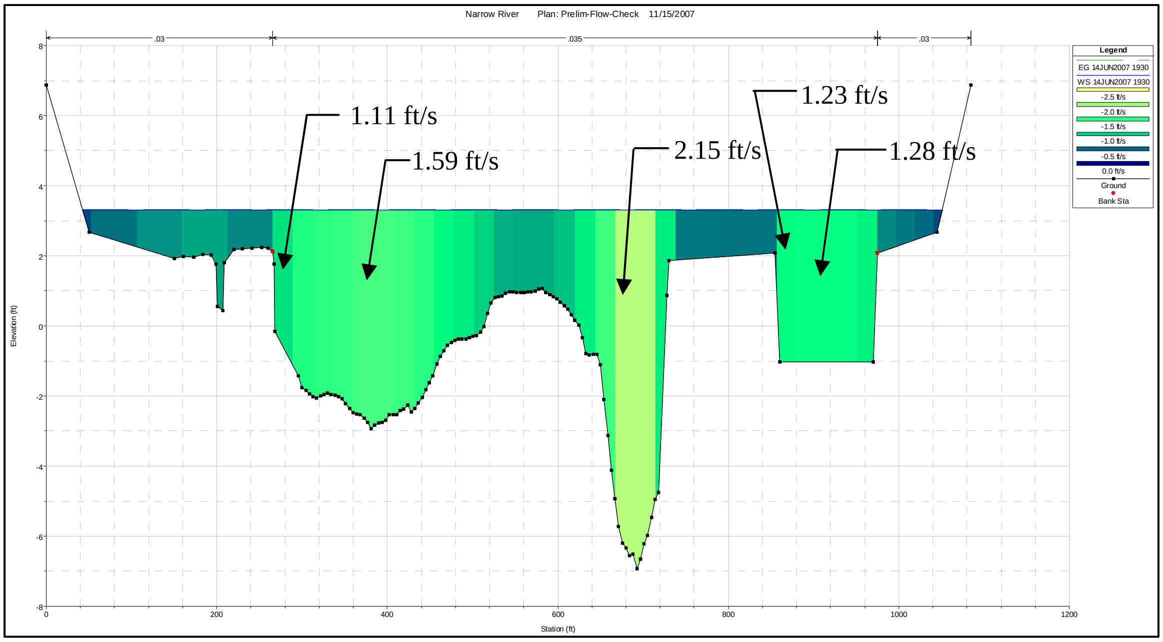


Figure 31b. Existing conditions station 2.7 (inlet/Narrows) peak spring current speeds (flood tide).

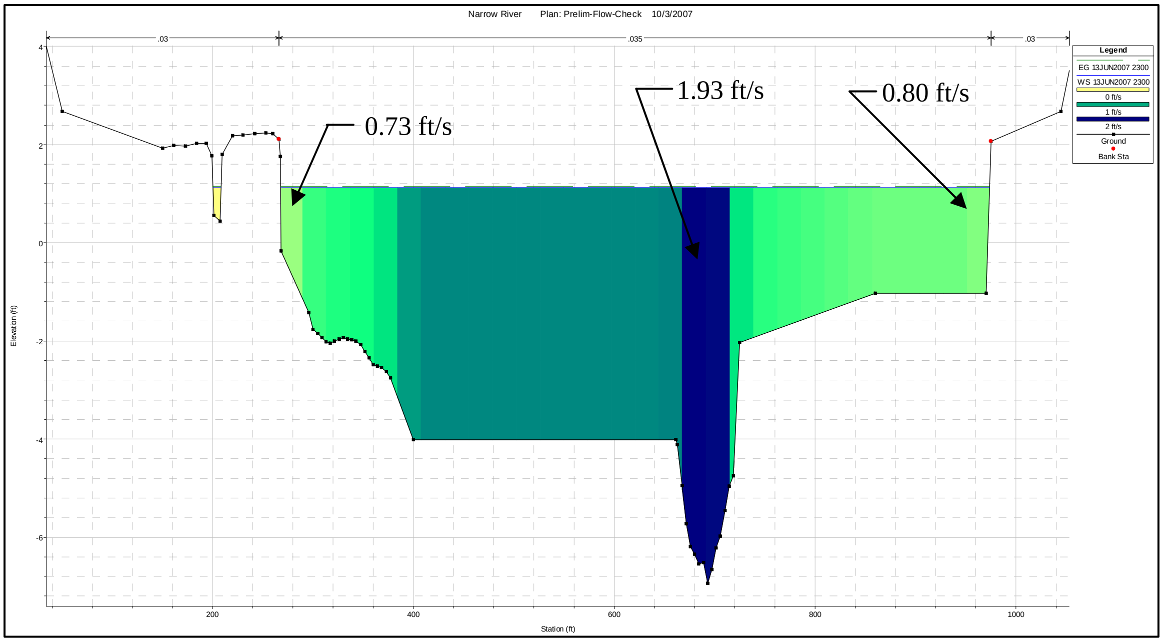


Figure 31c. Full alternative condition station 2.7 (inlet/Narrows) peak spring current speeds (ebb tide).

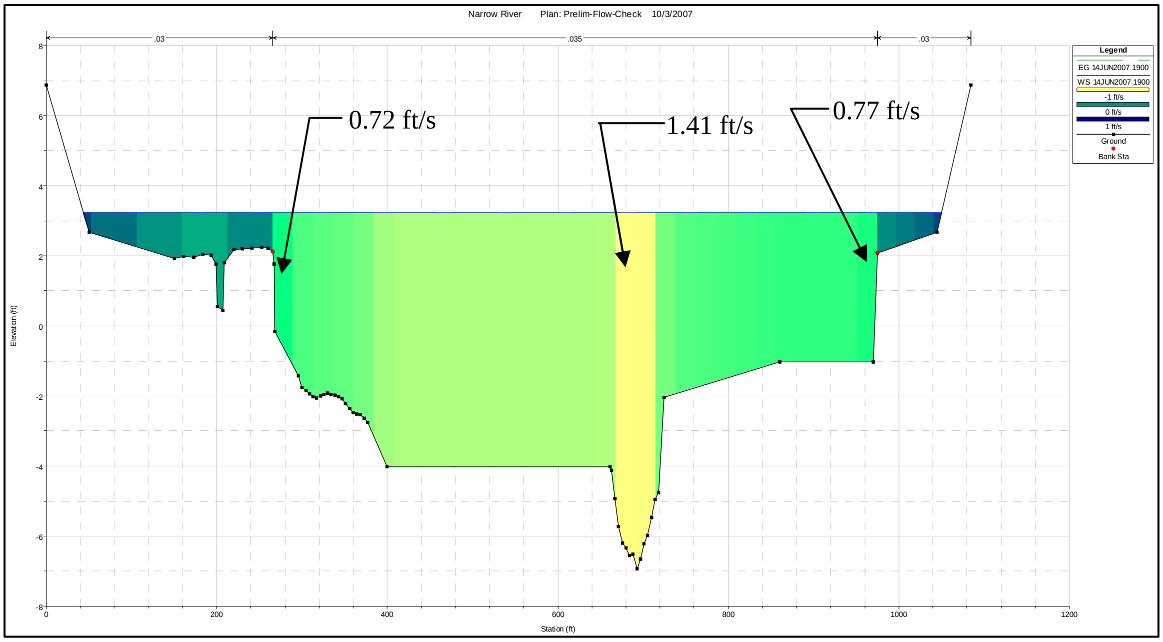


Figure 31d. Full alternative condition station 2.7 (inlet/Narrows) peak spring current speeds (flood tide).

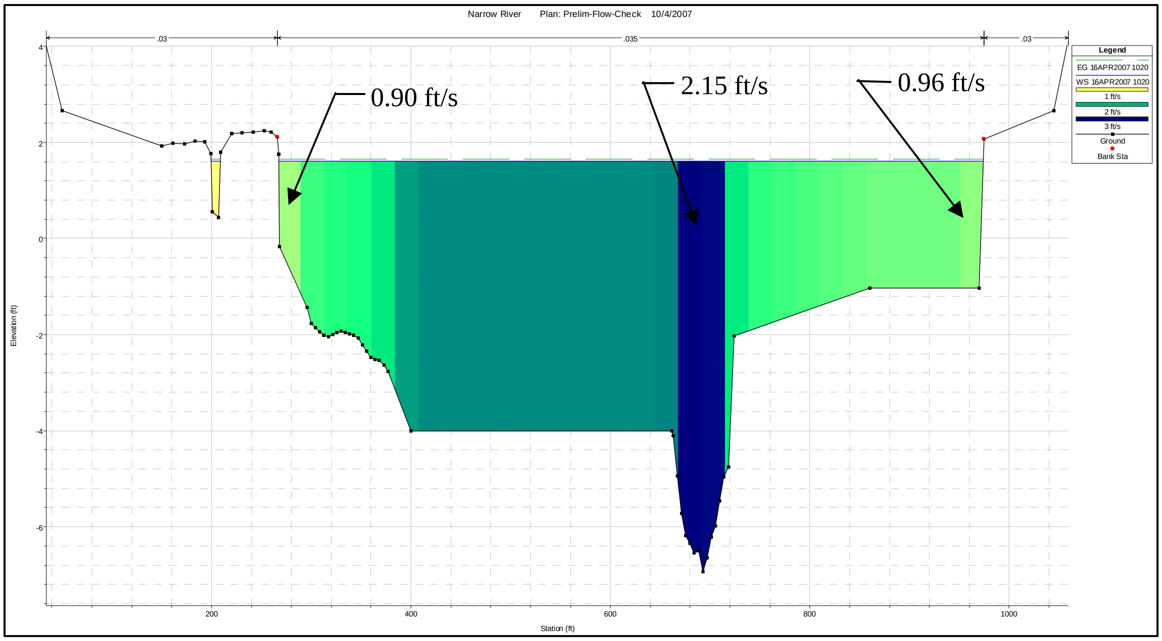


Figure 31e. Full alternative condition with Patriots Day Storm @ station 2.7 (inlet/Narrows) peak current speeds (ebb tide).

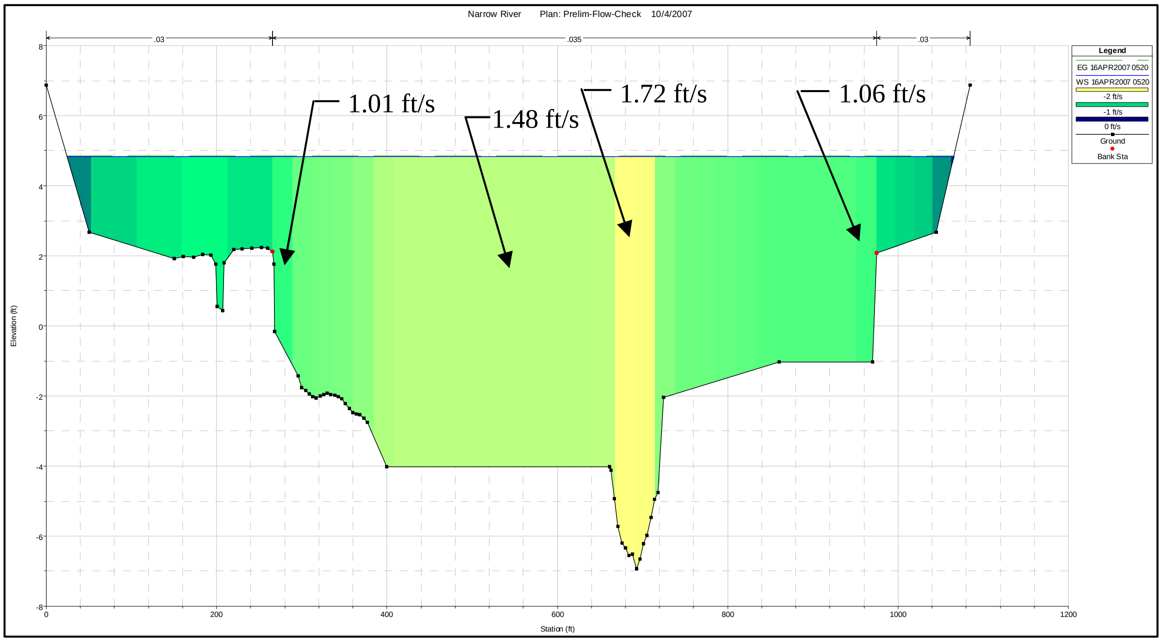


Figure 31f. Full alternative condition with Patriots Day Storm @ station 2.7 (inlet/Narrows) peak current speeds (flood tide).

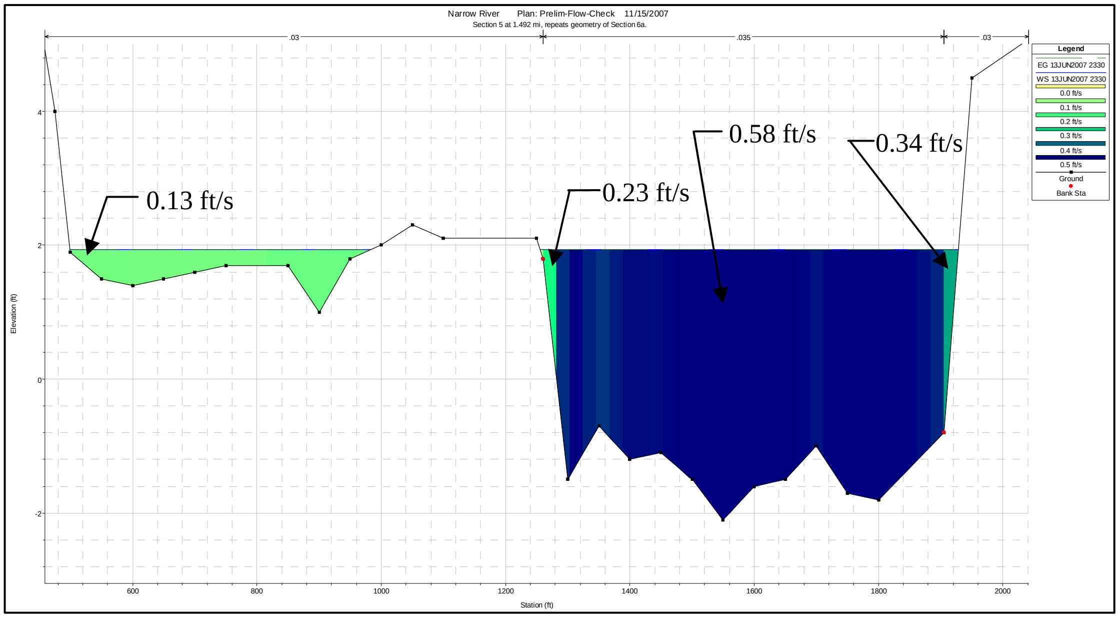


Figure 32a. Existing conditions station 5 (Narrow River) peak spring current speeds (ebb tide).

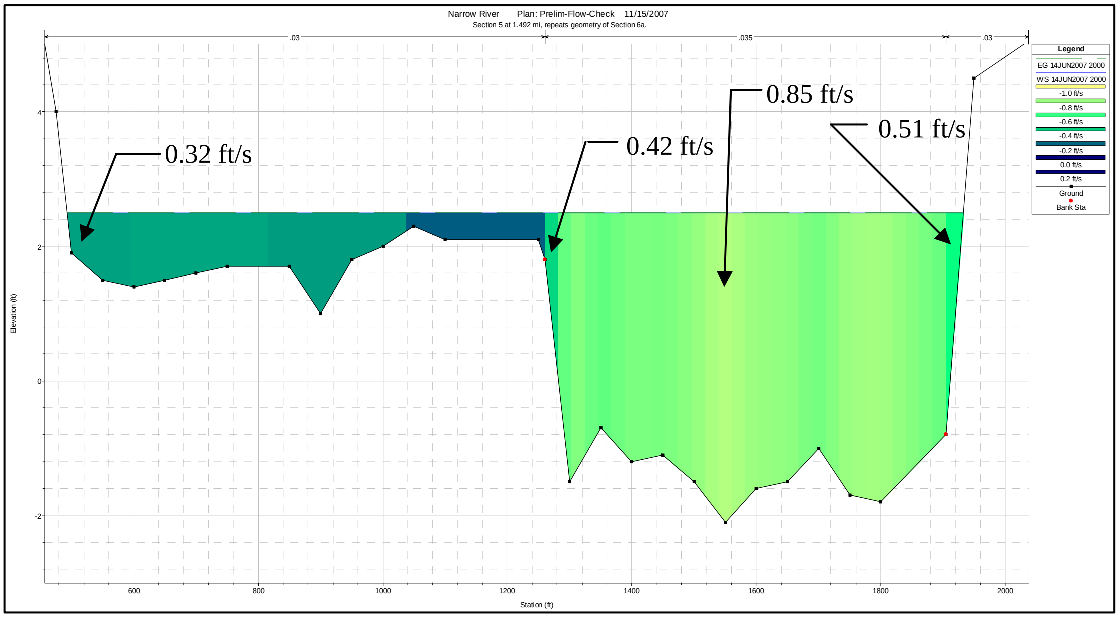


Figure 32b. Existing conditions station 5 (Narrow River) peak spring current speeds (flood tide).

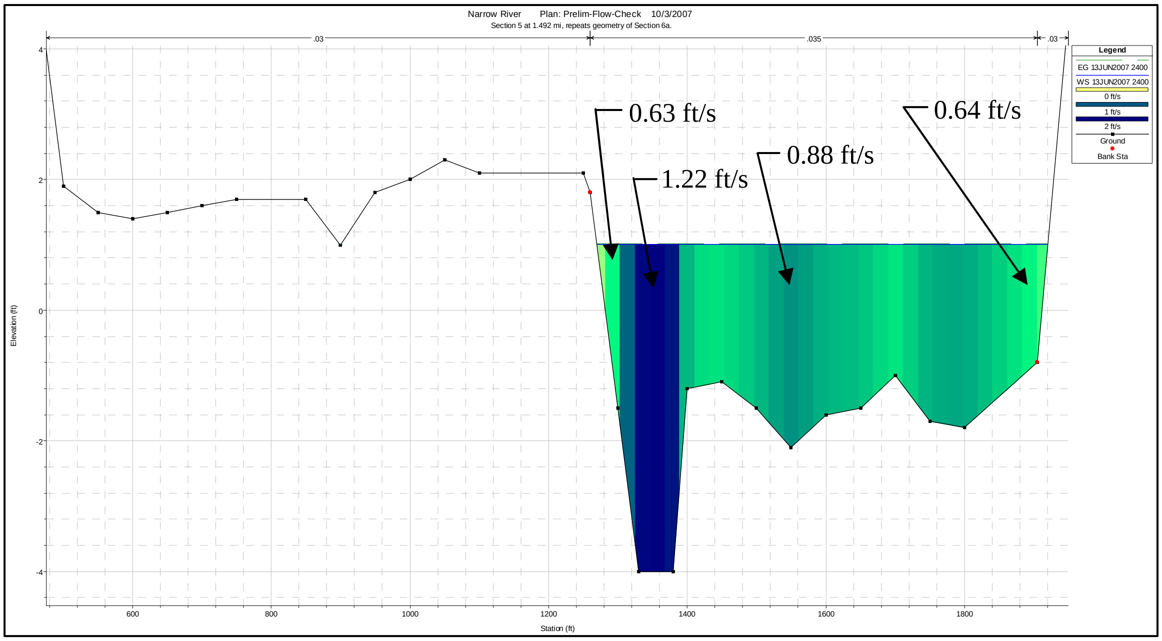


Figure 32c. Full alternative condition station 5 (Narrow River) peak spring current speeds (ebb tide).

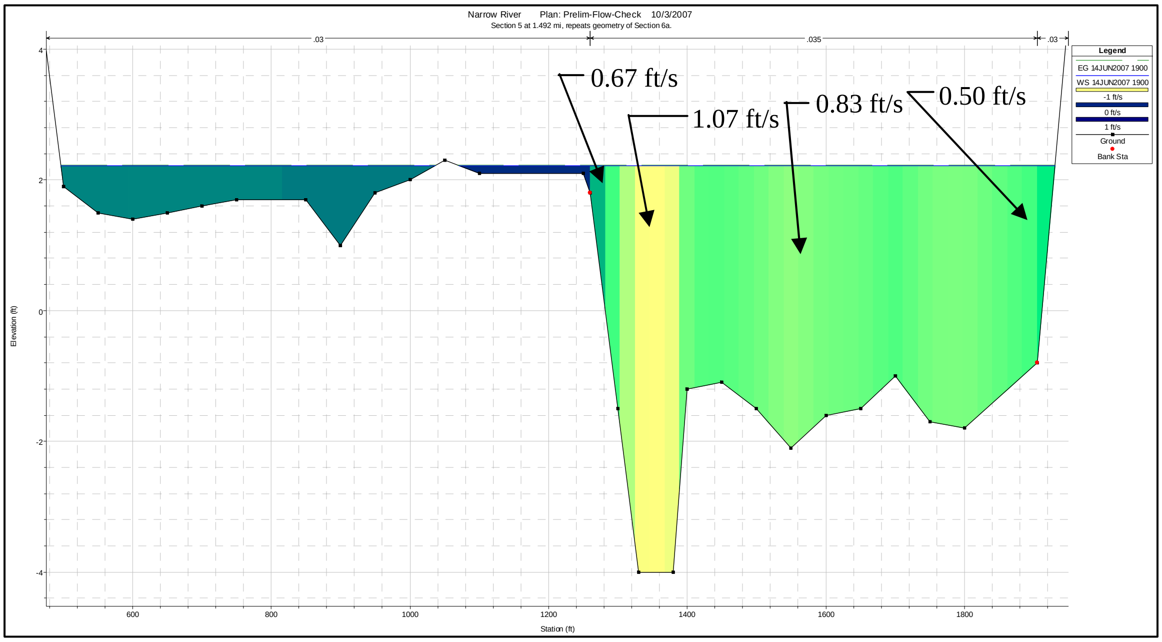


Figure 32d. Full alternative condition station 5 (Narrow River) peak spring current speeds (flood tide).

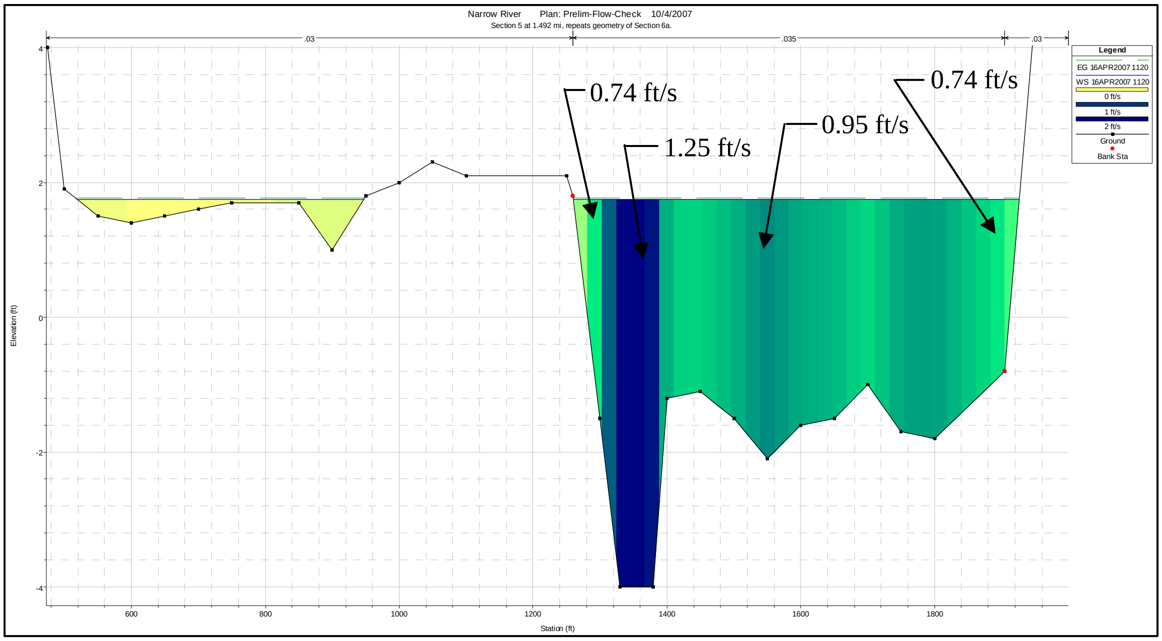


Figure 32e. Full alternative condition with Patriots Day Storm @ station 5 (Narrow River) peak current speeds (ebb tide).

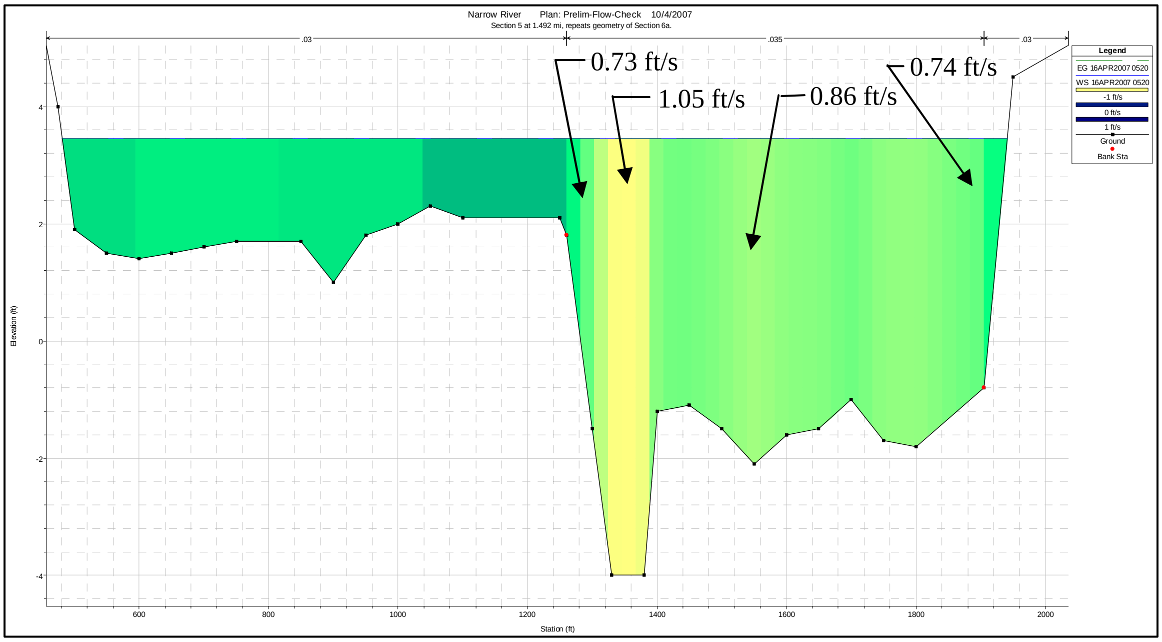


Figure 32f. Full alternative condition with Patriots Day Storm @ station 5 (Narrow River) peak current speeds (flood tide).

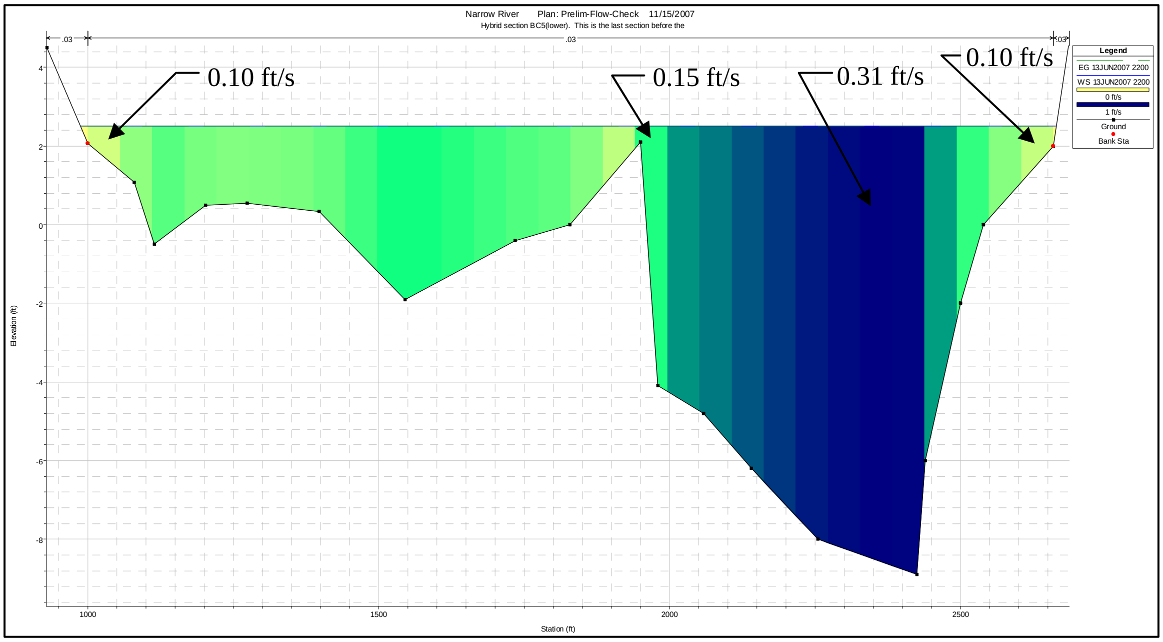


Figure 33a. Existing conditions station 4.7 (Petta Cove Entrance) peak spring current speeds (ebb tide).

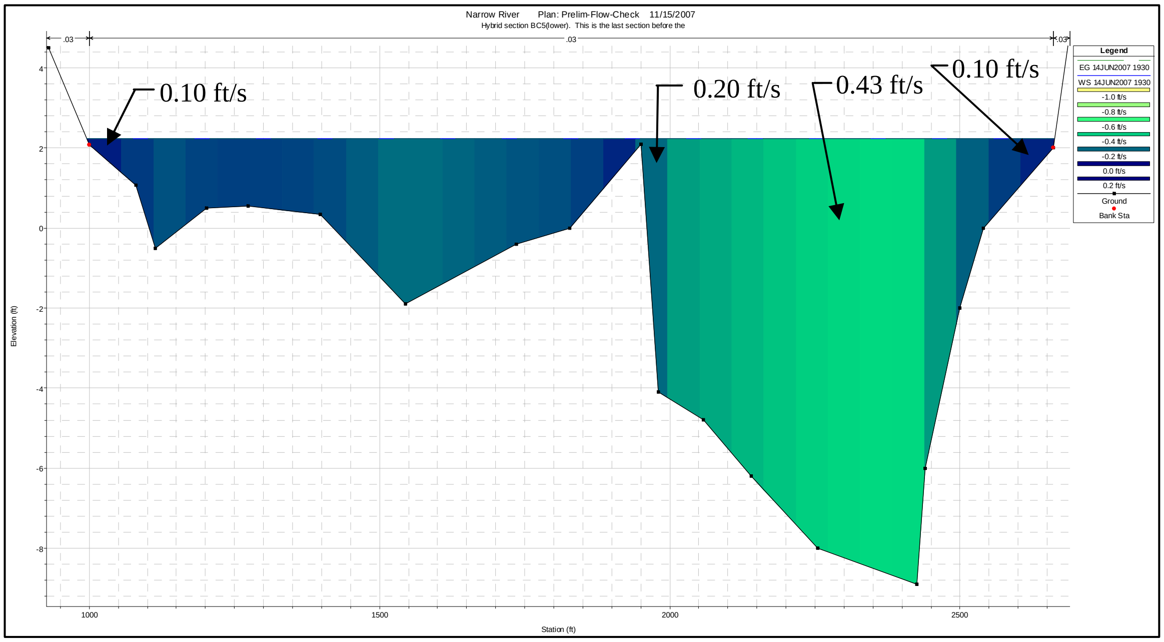


Figure 33b. Existing conditions station 4.7 (Petta Cove Entrance) peak spring current speeds (flood tide).

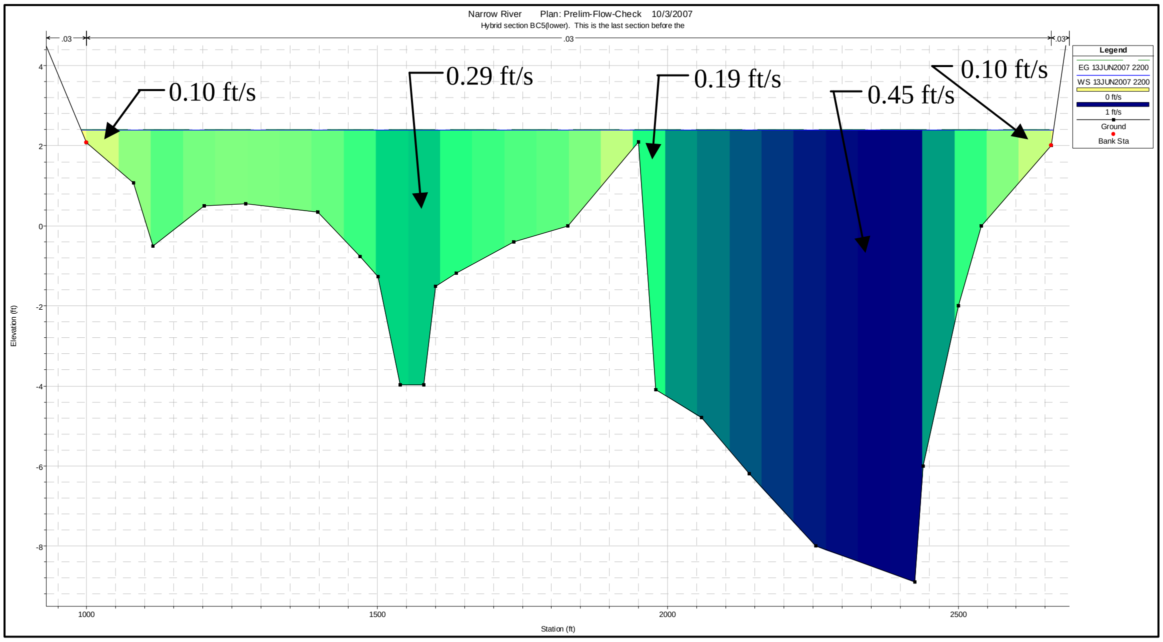


Figure 33c. Full alternative condition station 4.7 (Petta Cove Entrance) peak spring current speeds (ebb tide).

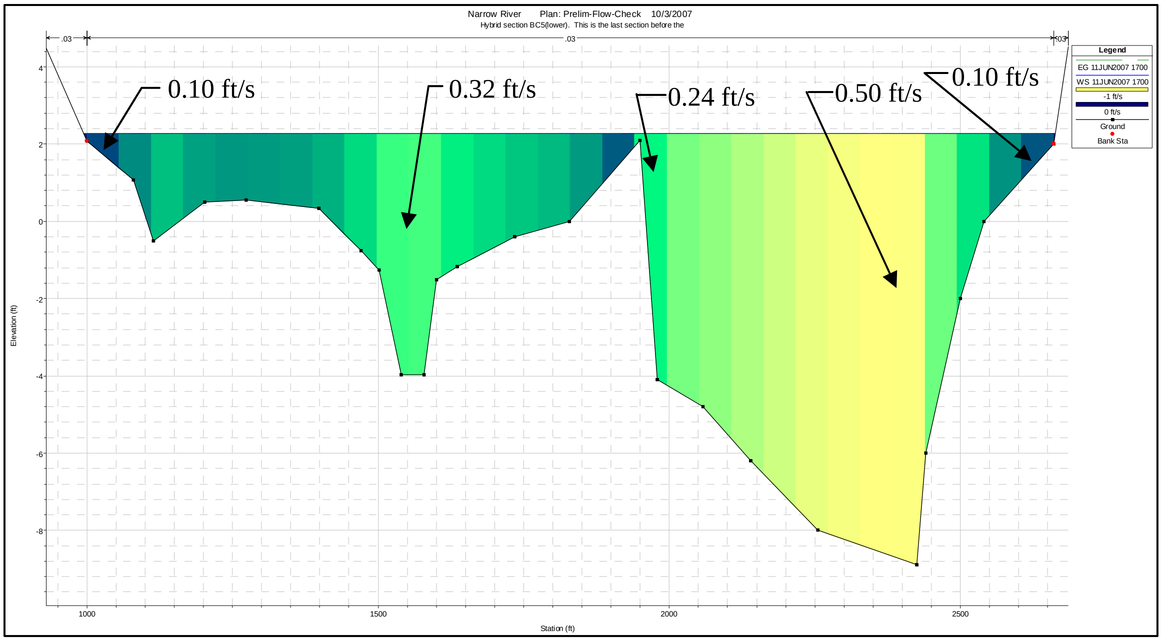


Figure 33d. Full alternative condition station 4.7 (Petta Cove Entrance) peak spring current speeds (flood tide).

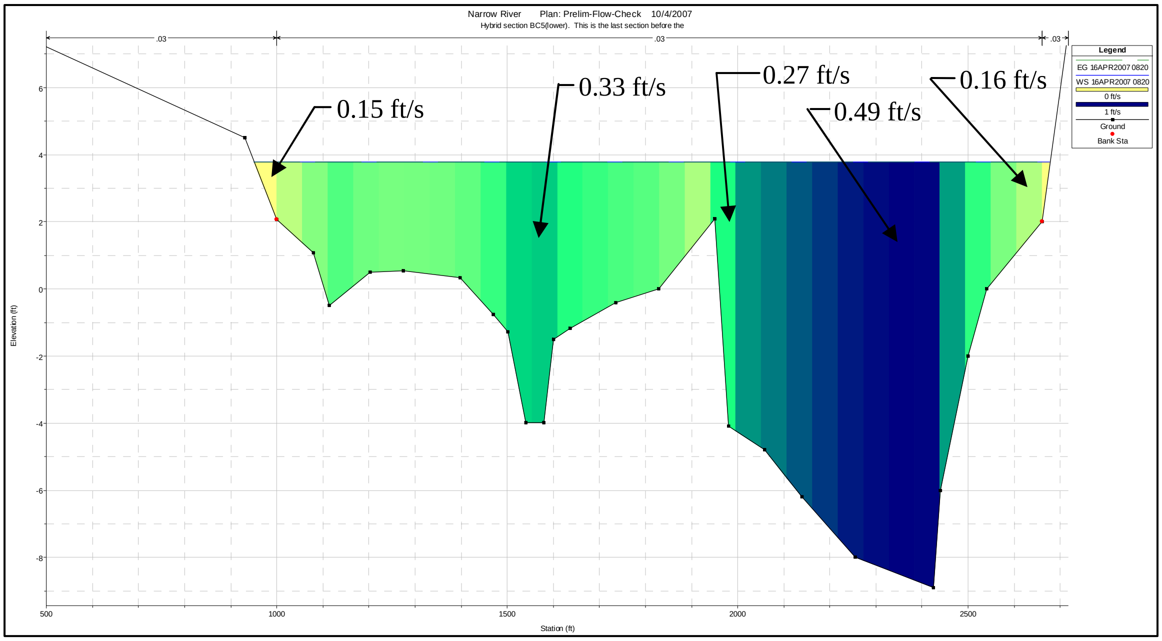


Figure 33e. Full alternative condition with Patriots Day Storm @ station 4.7 (Petta Cove Entrance) peak current speeds (ebb tide).

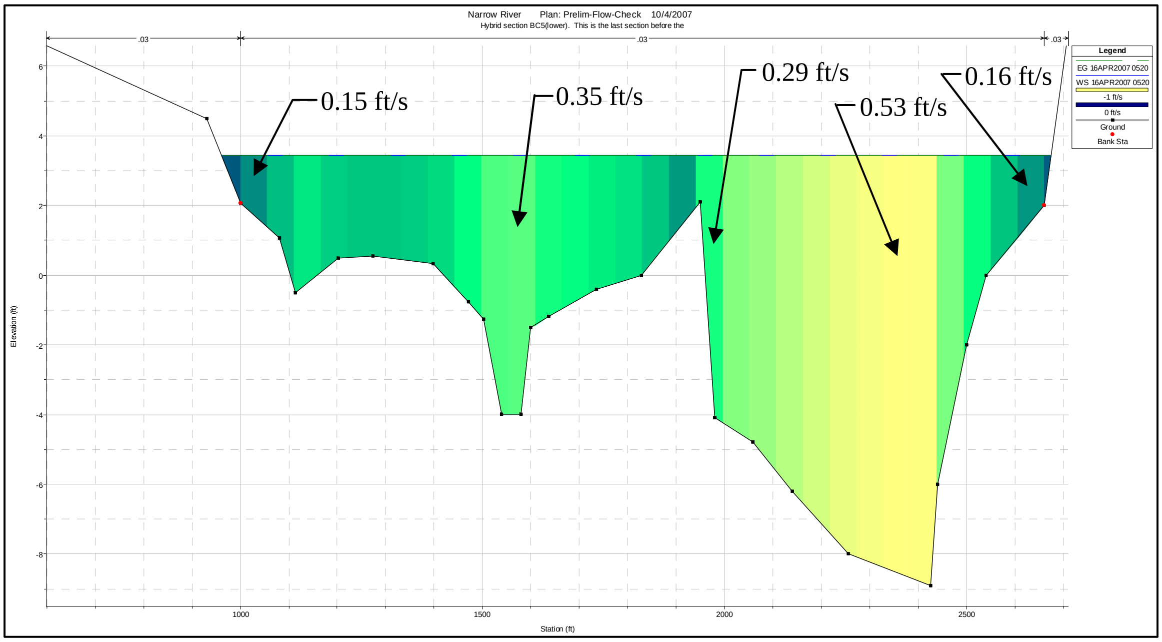


Figure 33f. Full alternative condition with Patriots Day Storm @ station 4.7 (Petta Cove Entrance) peak current speeds (flood tide).

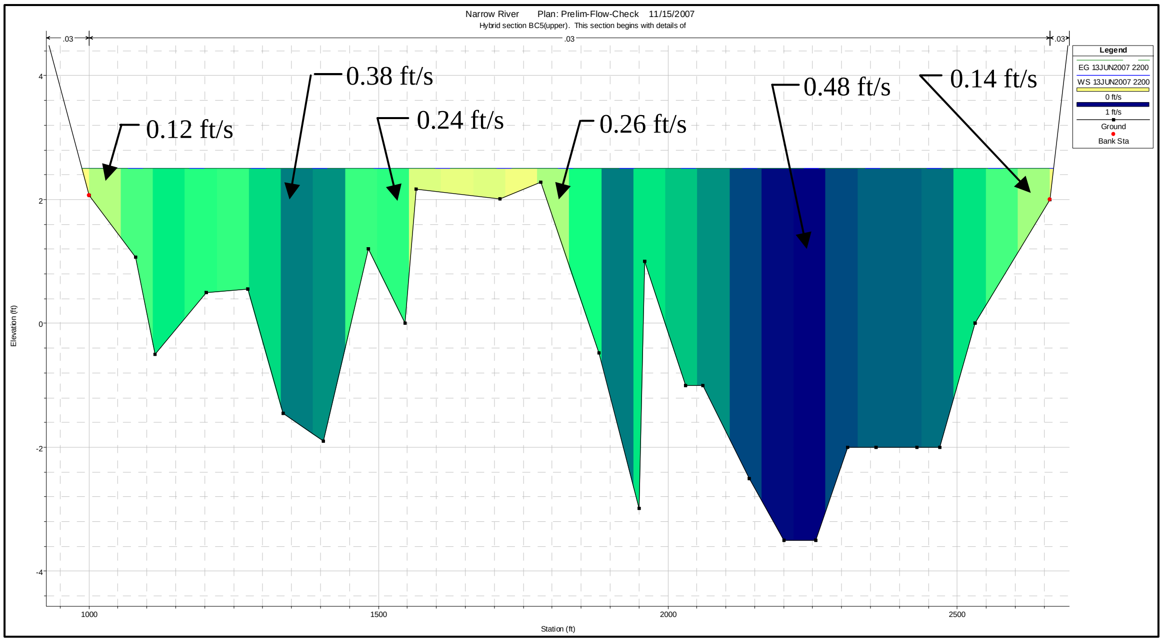


Figure 34a. Existing conditions station 4.9 (Petta Cove Entrance) peak spring current speeds (ebb tide).

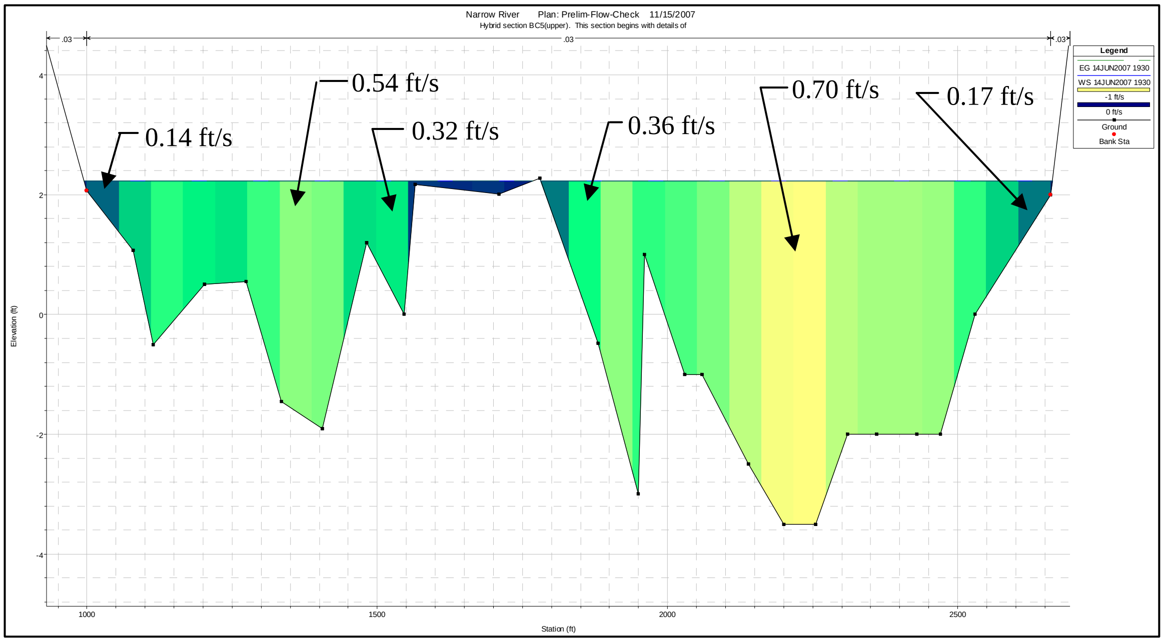


Figure 34b. Existing conditions station 4.9 (Petta Cove Entrance) peak spring current speeds (flood tide).

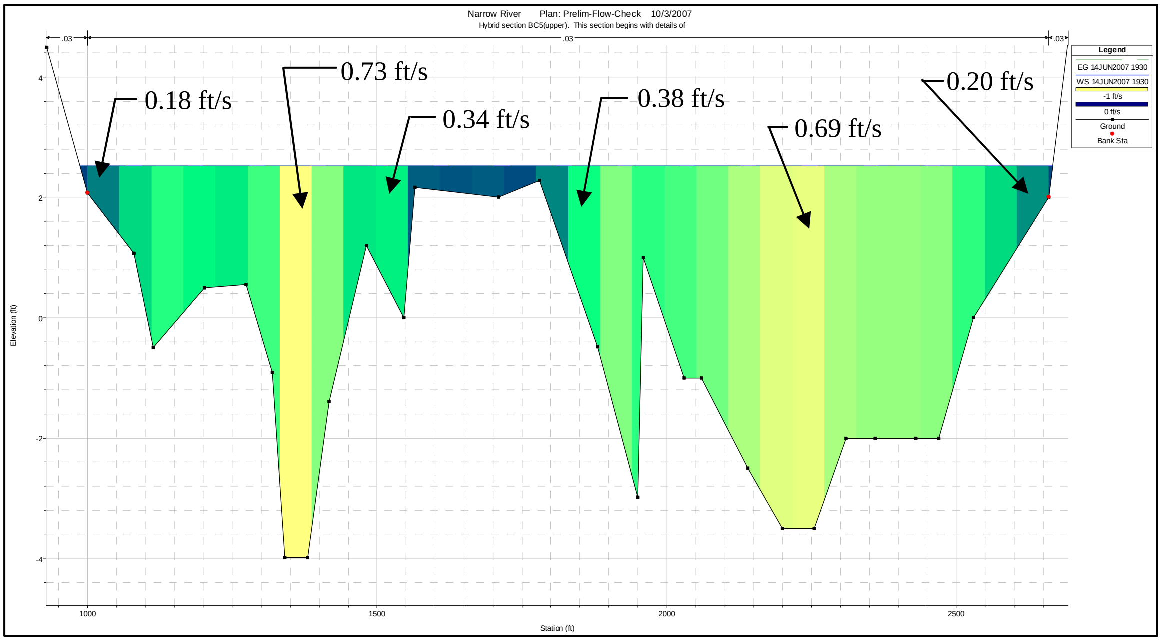


Figure 34c. Full alternative condition station 4.9 (Petta Cove Entrance) peak spring current speeds (ebb tide).

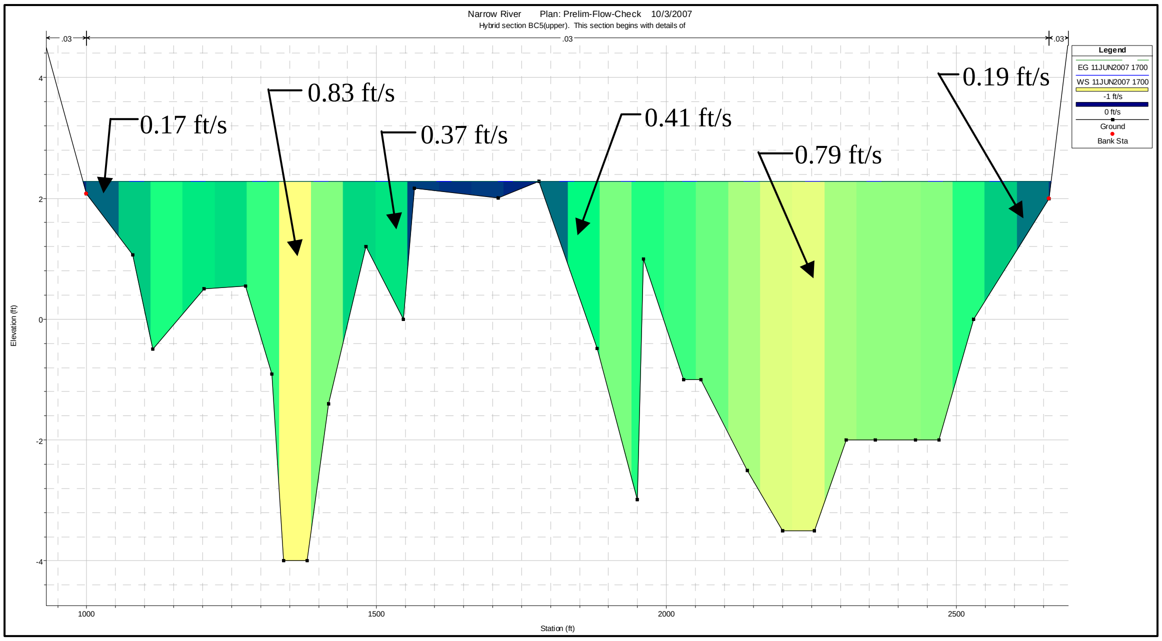


Figure 34d. Full alternative condition station 4.9 (Petta Cove Entrance) peak spring current speeds (flood tide).

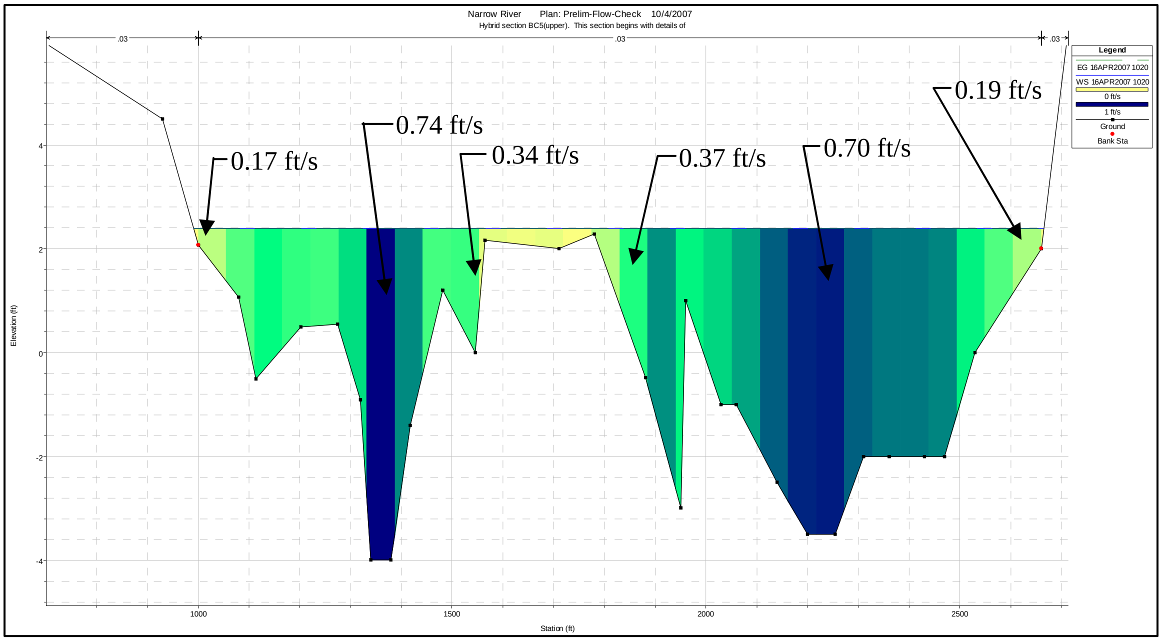


Figure 34e. Full alternative condition with Patriots Day Storm @ station 4.9 (Petta Cove Entrance) peak current speeds (ebb tide).

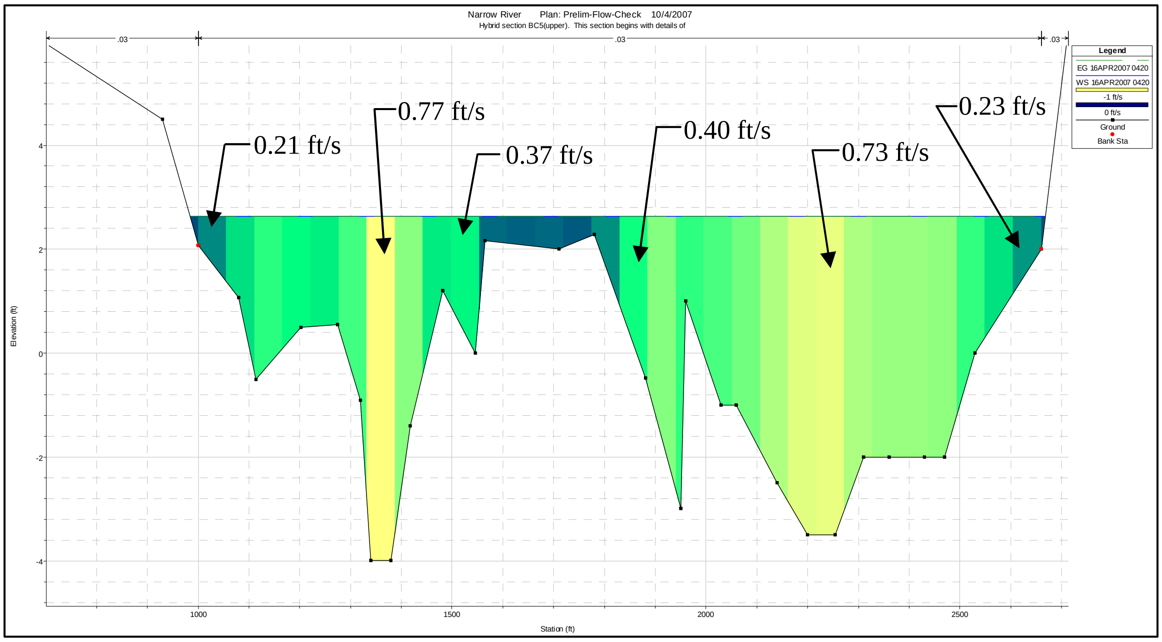


Figure 34f. Full alternative condition with Patriots Day Storm @ station 4.9 (Petta Cove Entrance) peak current speeds (flood tide).

6.4 Storm Surges

With the idea of improving the flushing of the bay through increased tidal prism, it was necessary to investigate the impacts of the alternatives on storm surge flooding potential. The fear would be by “opening” up the system and improving the flow into and out of the tidal river, more storm surge would propagate up the system increasing both flood elevations and durations. In order to investigate this possibility the fairly significant storm event that has been dubbed the Patriot’s Day storm that occurred in mid April of 2007 was modeled with the existing conditions and with the inlet opened and interior channels dredged to -4’ NGVD29. It is anticipated that this would provide the worst case flooding potential since this alternative was shown to increase the tide elevation the most during the alternative analysis. It was shown that this alternative increased tide elevations by a maximum of 0.24’ at station 3 (below the Sprague Bridge) and by a maximum of 0.23’ at Station 20 (southern end of Petta Cove). The average increase across the recorded model stations was 0.20’ or 2.4 inches. Shown in Figure 35 is the maximum water level reached at each of the previously looked at model stations.

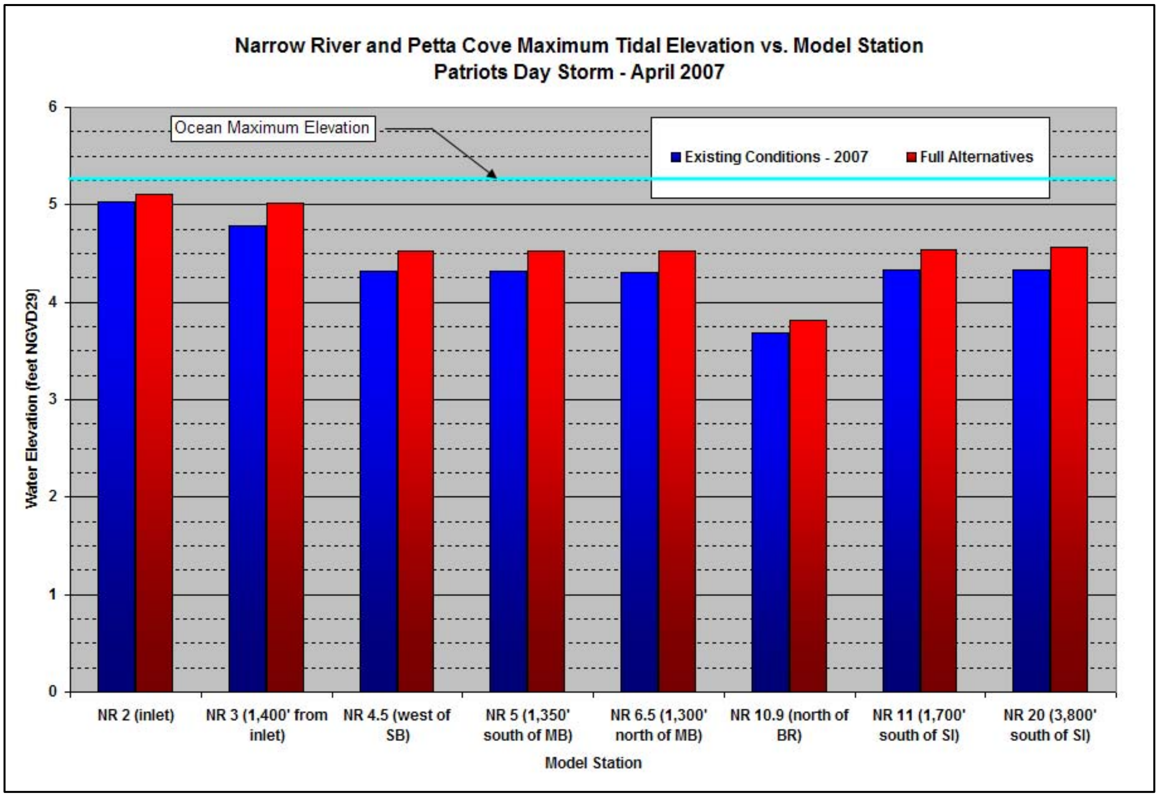


Figure 35. Maximum elevation during Patriots Day Storm (April 2007).

While larger storms were not modeled the differences in flood elevations for the with-project and without project conditions is expected to decrease with larger storms. The reason being, that with larger storms, the higher storm surge would flow over the existing bathymetry and topography even easier resulting in larger flow cross sections.

7.0 Sedimentation and Sediment Basin Discussion

While it was shown in Sections 6.1 and 6.2 that dredging the inlet has the largest beneficial impact on tidal prism and flushing for the Narrow River, this alternative has also been proposed to create a sediment basin to keep Narragansett Beach sand from being transported into the system and depositing at the mouth of Petta Cove.

In the following discussion four main points will be covered regarding the sediment basin or sediment trap. These are the need for the basin, the potential function of the basin, potential problems with the basin, and an outline of the recommended level of study necessary if this alternative is selected to move forward.

Sediment Basin Need

The need for the basin, or theory behind dredging The Narrows and creating a basin is that as the sediment (sand and gravel) laden current enters through the inlet it will hit the wider and deeper basin and slow, causing a portion of its suspended and bed load to deposit. This will help keep sand from flowing further north and depositing on the systems second flood shoal delta just upstream from Sprauge Bridge at the mouth of Petta Cove. While this seems practical and beneficial, it is unclear if this is really needed after further consideration. The first main issue is a lack of study for the flood at the Mouth of Petta Cove and of the sediment load entering the system. At the time of this report a reasonable sediment budget or determination of historical growth rates for these shoal features was not done, nor was it a part of this study. Based on aerial photos it appears that this large deposit of sand was caused by the 1938 Hurricane and not processes experienced under normal tidal conditions or during higher frequency storm processes.

Potential Function

The functionality of the basin was looked at during this study at a cursory level. The first process looked at was the reduction in current speed between the existing conditions, the full alternative bathymetry, and with the Patriot's Day storm. Using the same plots from Section 6.2 peak current speeds were compared at model station 2.7 for both flood and ebb tides. The only condition not looked at in Section 6.2 was the existing conditions peak currents for the Patriot's Day Storm. That figure has been provided below as Figure 36. It can be seen by comparing Figure 31b and Figure 31d that dredging the channel does reduce the current speed by 0.71 ft/s under normal spring tide conditions, which implies that sediment should drop out and deposit, or at least should not be transported as far north. However, as discussed earlier, it is hypothesized that the most significant sediment transport occurs during storm conditions. Comparing the with project condition to the existing condition for the Patriot's Day storm showed that current speeds during the flood tide would drop from 2.44 ft/s in the thalweg to 1.72 ft/s which is a reduction of 0.72 ft/s or a 30% reduction. Outside of the thalweg the current speed dropped from 1.88 ft/s to 1.48 ft/s which is a reduction of 0.40 ft/s or a 21.3% reduction. This indicates that there is potential for the basin to work.

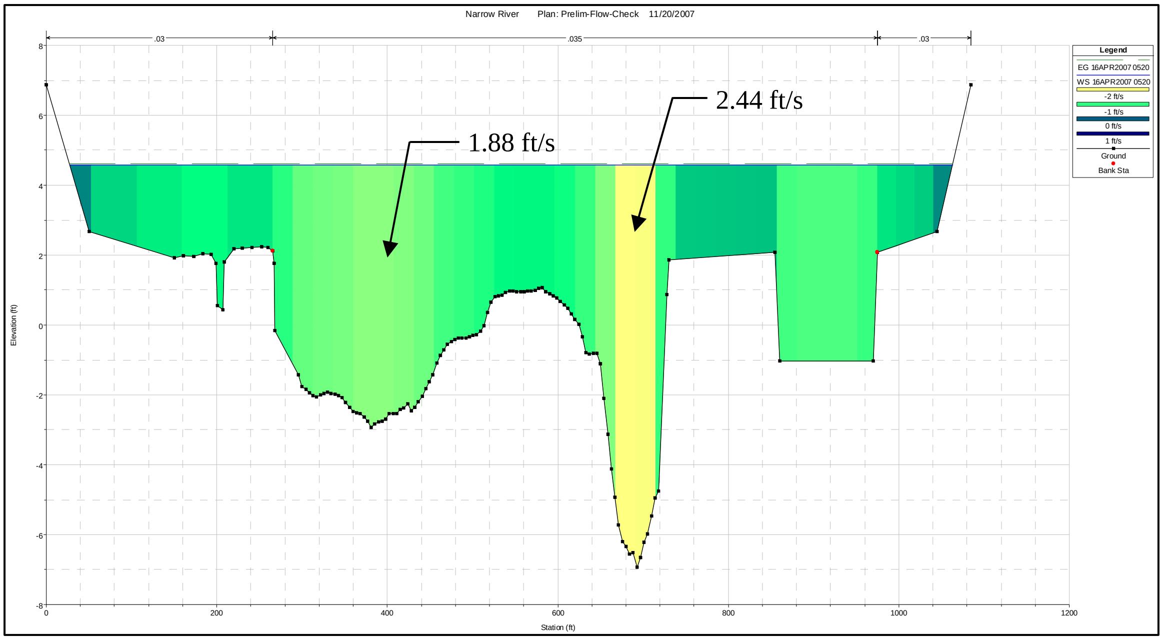


Figure 36. Existing conditions with Patriots Day Storm @ station 2.7 (inlet/Narrows) peak current speeds (flood tide).

<u>Sediment Basin - Potential Problems</u>

Based on the above information the potential for the dredged The Narrows area to act as a sediment basin was shown, but there are several issues. The first is that due to the proximity of this area to the inlet the basin will not likely be a basin but really just a wider and deeper channel down to and through the inlet. This will reduce the efficiency of the sediment trap since the current speeds will not be dropping, but will just be flowing slower through the inlet and through The Narrows. An ideal sediment basin is just that - a basin or hole of sufficient depth and length that causes current speeds to drop and subsequently some of the sediment load to drop.

The second issue is the longevity of such a feature. Being so close to a natural, sandy, exposed inlet, the potential for this area to fill back in quickly is significant and expected. As witnessed during the Patriots Day Storm, the inlet experienced very dramatic changes with the barrier spit being severely over washed and rolled backwards towards The Narrows. Regular maintenance would likely be needed for this feature to have any prolonged beneficial impact.

The third issue is that if this option is chosen then much further study is recommended. Unfortunately there is no simple analytical formula or calculations that can be used to determine how this sediment basin will perform. Most literature is for fresh water streams with unidirectional flow, for navigation channels in which flow is perpendicular or across the channel, or for situations like this where a site-specific study is needed.

Recommendations for Further Study

As discussed above, if the inlet/Narrows area is to be dredged significantly then a more robust study for this alternative must be conducted. A sediment budget would need to be developed along with sediment transport modeling in order to better understand how this alternative would function as a sediment basin, determine impacts to the inlet configuration, and future maintenance needs. In order to develop a sediment budget the amount of sand being transported to the inlet from the beach would need to be determined. This would likely require wave modeling and the use of a long shore transport model. Additionally, a 2-D hydraulic model with sediment transport capabilities would be recommended for this effort as well. To conduct this effort would require a significant investment with the cost likely ranging from $100,000 to $200,000.

8.0 Summary and Conclusions

As part of the Narrow River Study, the Water Management Section of the New England District USACE performed a hydraulic modeling study using the HEC-RAS Unsteady model. The use of this model facilitated the hydraulic evaluation of several alternatives proposed for this study. Both changes in current speed and tidal regime in the system were determined. To support the modeling effort several bathymetric surveys were conducted along with a one-day tide elevation survey.

Through the tidal elevation survey and the numerical model it was found that the only significant tide range reduction in the lower river system (below Bridgetown Road) is caused by the inlet. For the system below Bridgetown Road the tide range is within several tenths of foot and lags/leads by 0.5 to 0.75 hours. It was shown that the flood shoal at the mouth of Petta Cove and the Middle Bridge do not cause any notable impact on tide range or timing. As such it was shown that out of all the alternatives, the only one that impacted tidal prism and flushing in any considerable fashion was dredging the inlet/Narrows channel down to -4.0’ NGVD29.

The model was also used to determine current speeds at key points across profiles that were at or near proposed alternatives to determine the need for erosion protection along various marsh faces. It was found that current speeds were not that significant near marsh faces, and erosion protection from currents would likely not be needed unless one of the alternatives locates a channel directly against a marsh front.

In the field during the tide elevations survey it was noted that boat wakes are a likely cause of marsh front erosion, and the removal of sediment during intermediate tide levels from the marsh faces was noted. This was especially true south of Sprauge Bridge.

8.0 References

RI DEM 2001. Fecal Coliform TMDL for the Pettaquamscutt (Narrow) River Watershed, Rhode Island. Rhode Island Department of Environmental Management.

Appendix
Collected Tide Data

Table A1. Recorded Tide Data (ft-NAVD88) June 12, 2007

	Inlet-Narrows	**Middle Bridge - South**	**Middle Bridge - North**	**Petta Cove**	**Narragansett Pier (Predicted)**	**Narragansett Pier (Measured)**	
	Tide Board #1	**Tide Board #2**	**North Tide Board #3**	**Tide Board #4**	**Predicted**	Taken from Newport, RI	
Time	ft-NAVD88	ft-NAVD88	ft-NAVD88	ft-NAVD88	ft-NAVD88	Time	ft-NAVD88
10:15					-1.80	10:12	-1.52
10:30					-2.00	10:18	-1.53
10:45	-0.30				-2.00	10:24	-1.61
11:00	-0.35	0.00	-0.10	-0.10	-2.10	10:30	-1.64
11:15	-0.40	-0.10	-0.15	-0.20	-2.10	10:36	-1.66
11:30	-0.45	-0.15	-0.20	-0.20	-2.10	10:42	-1.64
11:45	-0.50	-0.20	-0.23	-0.30	-2.10	10:48	-1.61
12:00	-0.55	-0.25	-0.25	-0.35	-2.00	10:54	-1.67
12:15	-0.60	-0.30	-0.30	-0.40	-2.00	11:00	-1.70
12:30	-0.65	-0.35	-0.35	-0.40	-1.90	11:06	-1.73
12:45	-0.70	-0.40	-0.40	-0.50	-1.80	11:12	-1.64
13:00	-0.70	-0.45	-0.45	-0.50	-1.60	11:18	-1.65
13:15	-0.70	-0.50	-0.45	-0.50	-1.50	11:24	-1.61
13:30	-0.75	-0.50	-0.45	-0.55	-1.30	11:30	-1.65
13:45	-0.70	-0.53	-0.50	-0.50	-1.10	11:36	-1.69
14:00	-0.65	-0.55	-0.50	-0.55	-0.90	11:42	-1.68
14:15	-0.55	-0.53	-0.48	-0.50	-0.70	11:48	-1.69
14:30	-0.40	-0.50	-0.45	-0.50	-0.50	11:54	-1.67
14:45	-0.20	-0.40	-0.35	-0.40	-0.30	12:00	-1.62
15:00	-0.15	-0.30	-0.25	-0.30	0.00	12:06	-1.56
15:15	0.10	-0.20	-0.15	-0.20	0.20	12:12	-1.52
15:30	0.20	-0.10	0.00	-0.10	0.50	12:18	-1.50
15:45	0.35	0.00	0.10	0.00	0.80	12:24	-1.49
16:00	0.55	0.20	0.20	0.20	1.00	12:30	-1.49
16:15	0.65	0.30	0.30	0.40	1.30	12:36	-1.47
16:30	0.90	0.50	0.50	0.50	1.50	12:42	-1.40
16:45	1.13	0.65	0.65	0.80	1.80	12:48	-1.30
17:00	1.28	0.80	0.80	0.90	1.90	12:54	-1.25
17:15	1.40	0.95	0.95	1.10	2.10	13:00	-1.23
17:30	1.60	1.10	1.10	1.30	2.20	13:06	-1.25
17:45	1.75	1.30	1.25	1.40	2.30	13:12	-1.08
18:00	1.85	1.45	1.40	1.50	2.40	13:18	-1.12
18:15	1.90	1.55	1.50	1.60	2.40	13:24	-1.04
18:30	1.95	1.60	1.60	1.70	2.30	13:30	-1.03
18:45	1.98	1.70	1.70	1.90	2.20	13:36	-1.05
19:00	2.00	1.80	1.80	2.00	2.10	13:42	-0.82
19:15	2.00	1.85	1.85	2.00	2.00	13:48	-0.87
19:30	1.95	1.85	1.85	2.10	1.80	13:54	-0.77
19:45	1.93	1.85	1.85	2.10	1.60	14:00	-0.72
20:00	1.85	1.80	1.80	2.00	1.40	14:06	-0.64
20:15		1.75	1.75	1.90	1.20	14:12	-0.48