Impact of Dredging the Lower Narrow River on Circulation and Flushing

Craig Swanson Ph.D.
Swanson Environmental
Alex Shaw
Ocean Engineering, URI
Prof. Malcolm L. Spaulding
Ocean Engineering, URI

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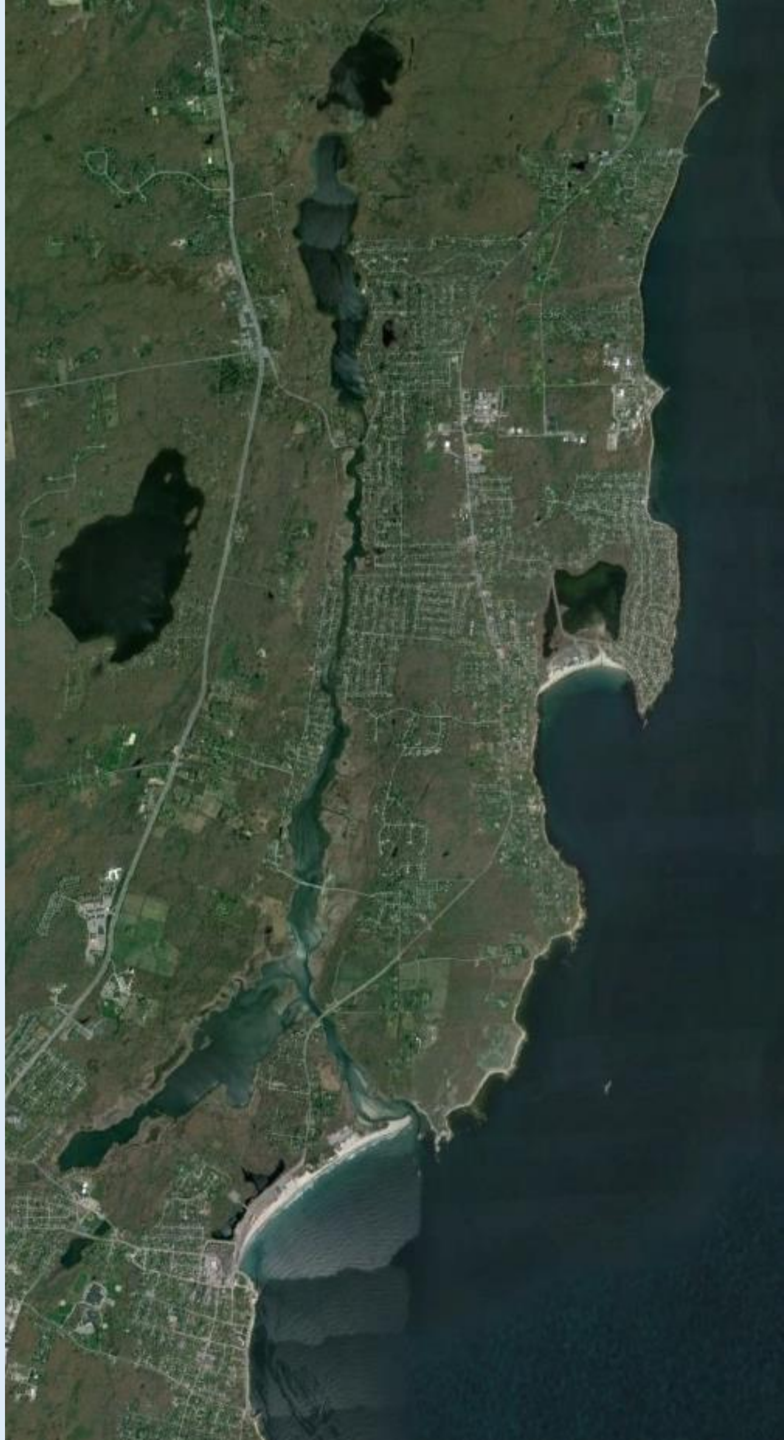
Narrow River Preservation Association



Study Background

- USFWS and TNC, with USACE and RICRMC, undertook a study of the impact of dredging and applying the dredged material to raise the level of the marsh system in the southwest portion of the Narrow River (Pettaquamscutt Cove) to restore and enhance its long term viability and ecological health in the presence of sea level rise. Dredging of sections of the River and application of the material to the marsh system is scheduled for completion in early 2017.
- In addition, local and state representatives from the Town of Narragansett expressed interest that dredging the lower Narrow River (The Narrows) be considered to increase the tidal flushing of the Cove and hence reduce high concentrations of nutrients (improve water quality) that may lead to degradation of the salt marsh and its benthic habitats.
- The sand dredged from the Narrows could be used to nourish Narragansett Beach, just west of the Narrow River mouth. It could also be used in the future as material for raising the level of marshes in the Cove.
- In order to determine what the impact of dredging, and hence increasing the cross sectional area, might be on the circulation, flushing, and water quality in the river the USFWS, USACE, and RICRMC recommended that a numerical circulation modeling study be undertaken to address this question.

Project Objective

- Determine the impact of dredging in the lower reach (The Narrows) on circulation and tidal flushing in the river.
- Improve water quality in the River by increasing the tide range via increased tidal flushing.
- Provide a potential source of sediment for future raising of marsh levels.

Project Technical Approach

- Review past river studies to determine variation in tidal range attenuation from mouth to head of the estuary.
- Apply, calibrate and validate ADCIRC, the Advanced CIRCulation model, a vertically averaged, finite element hydrodynamic model to the river.
- Use the model to predict the change in tidal range (attenuation) and flushing for different hydrodynamic conditions and different scenarios of dredging in The Narrows.

Study Area: The Narrow River

- Located west of Narragansett Bay.
- Generally aligned on north-south axis.
- 10 km (6.2 mi) long, 30 to 700 m (100 to 2,300 ft) wide, generally less than 2 m (6.5 ft) deep for most of length (kettle hole ponds 12 and 20 m (39 and 66 ft) deep at its north end).
- Connected to Rhode Island Sound.
- Small watershed (~36 km^2 [~14 mi^2]).
- From historical studies the tide range in River relative to tide range at mouth decreased exponentially upriver: ~57% at Sprague Bridge and ~18% at Upper Pond.

Study Subarea: The Narrows

- Lower reach of the Narrow River from Sprague Bridge to Rhode Island Sound.
- Lower half contains flood and ebb channels, flood tidal delta system.
- Deeper areas (>-2 m [-6.5 ft] MSL) located near Bass Rock at mouth and areas around Sprague Bridge.

Past Water Level Measurements (1970 – 2015)

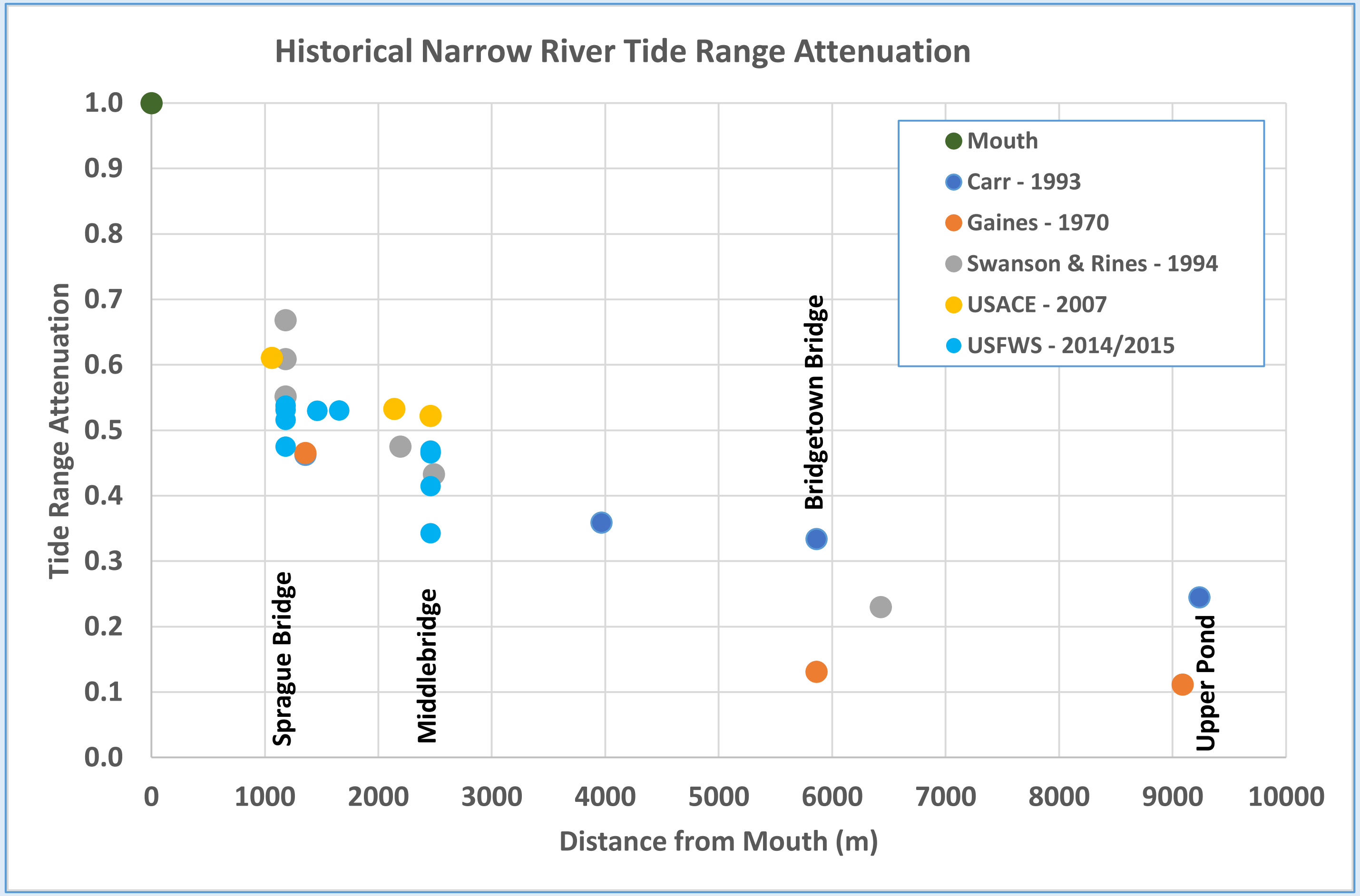
Reference	Start Date	End Date	No. of Surveys	Survey Durations (days)	No. of Stations
Gaines (1975)	4 Jun 1970	24 Jun 1970	1	20	3
Carr (1995)	6 Aug 1993	1 Nov 1993	4	3, 15, 27, 63	4*
Swanson and Rines (1995)	25 Sep 1994	30 Nov 1994	6	7, 11, 13, 17, 54, 65	4*
USACE (2009)	12 Jun 2007	12 Jun 2007	1	0.4	3**
USFWS (Spreadsheet)	3 Jun 2014	18 Jun 2015	5	34, 49, 73, 77	1 to 4**

* One station per overlapping survey.

**Stations within Pettaquamscutt Cove not included.

Historical Tide Range Attenuation

- Attenuation is the ratio of local tide range to tide range at mouth (~0.97 m [3.2 ft]).
- Largest attenuation occurs in The Narrows between the mouth and Sprague Bridge.
- Tide range attenuation appears to be primarily based on constriction in the lower portion of The Narrows .
- Significant variation of attenuation found:
  - 0.47 to 0.67 at Sprague Bridge
  - 0.34 to 0.52 at Middlebridge
  - 0.13 to 0.33 at Bridgetown Bridge
  - 0.11 to 0.25 in Upper Pond
- Attenuation variation likely due to constriction continually changing over time with sediment transport from Narragansett Beach into river mouth.
- Variation also likely due to varying durations of tidal measurement surveys from 1 day, spring/neap cycle variation (15 days), and 77 day deployments.

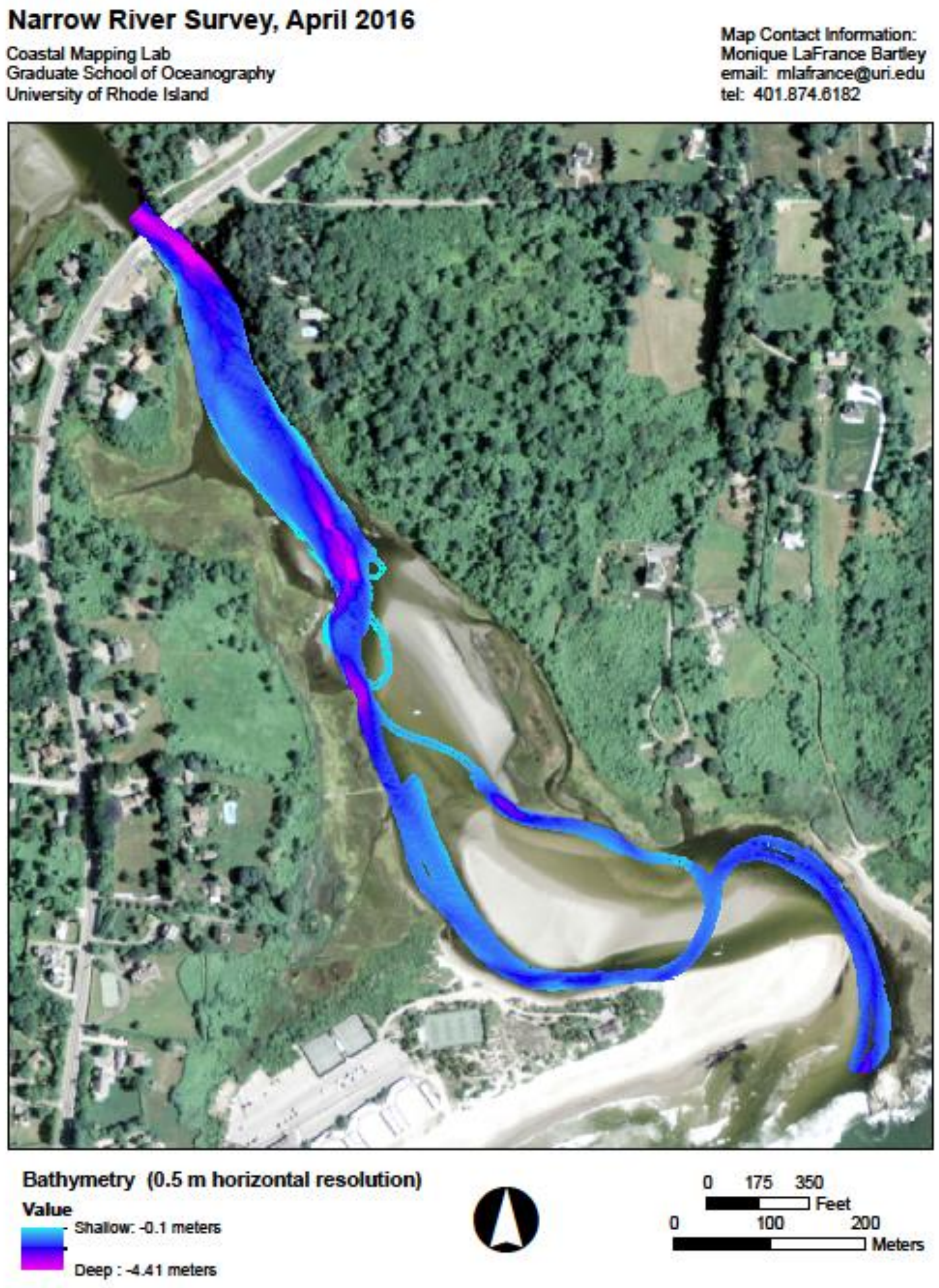


Synoptic Observations Required

- USACE (2009) reported difficulty in calibrating their model of the Narrow River with previous bathymetric and tidal information so they conducted a water level survey in 2007 with URI performing a bathymetric survey. USACE successfully calibrated its model with these data.
- The project team made a decision in 2016 to follow USACE's approach and commissioned a bathymetric survey by URI/GSO in The Narrows along with water elevation measurements by USFWS at Sprague Bridge to provide a synoptic view of the effects of bathymetric constrictions on tide range along the river.

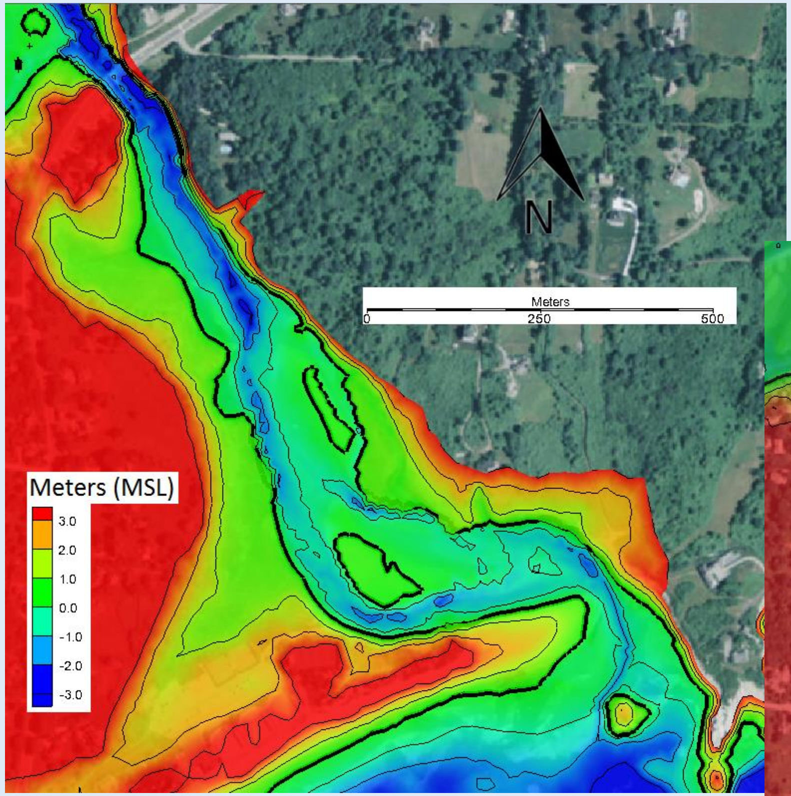
URI/GSO Bathymetry Survey

- Bathymetric data collected by URI/GSO on 15 April 2016 in The Narrows.
- Shallow draft (0.3 m [1 ft]), 8.5 m (28 ft) pontoon boat used to reach shallow areas.
- Not possible to follow planned survey lines due to strong currents, sand bars, and boulders.
- Data collected with an echo sounder system; corrected for tide, sound velocity and vessel motion.
- Data filtered to remove outlier soundings and converted to a 0.5-m (1.6–ft) horizontal grid resolution in the surveyed area.
- Vertical resolution was typically within 5-10 cm (0.16-0.32 ft).

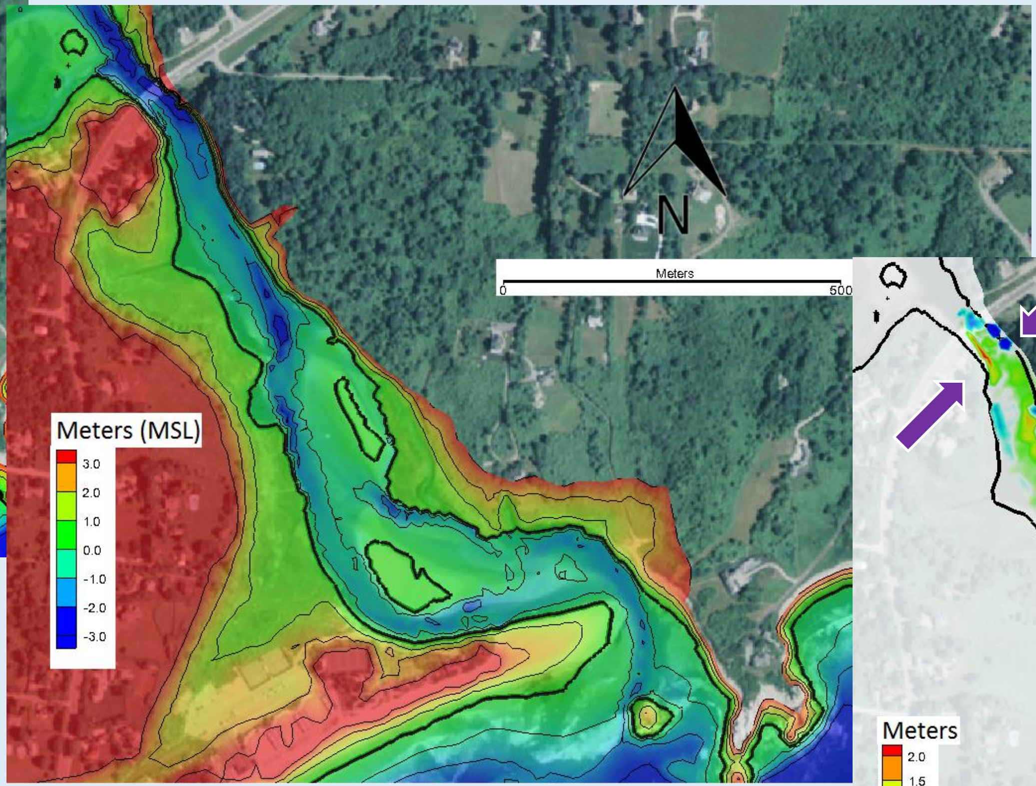


Bathymetric Results

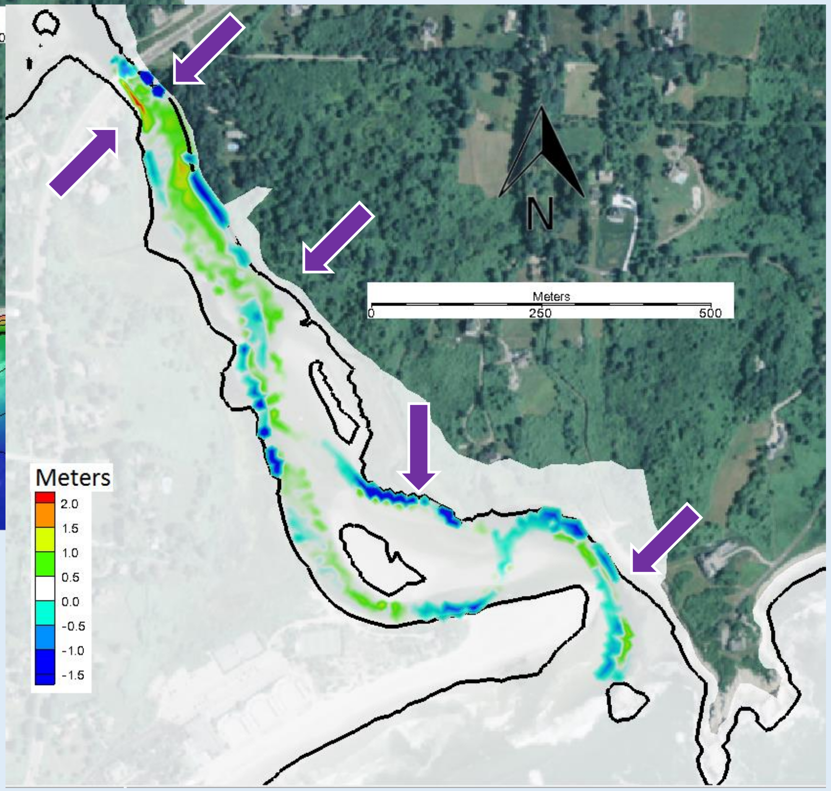
Original RIGIS Bathymetry



Bathymetry Updated with URI/GSO Data



Bathymetric Differences



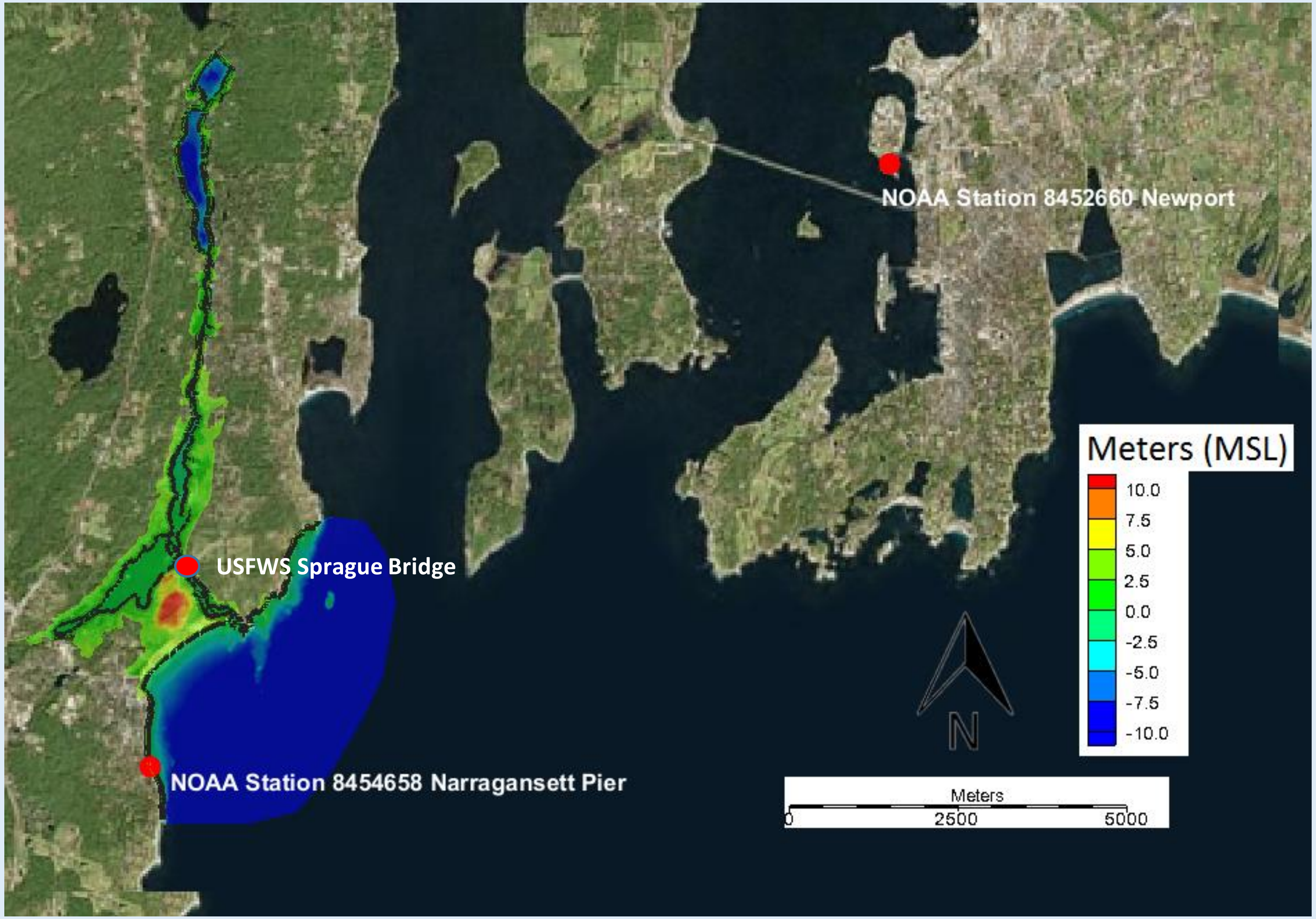
Bathymetry Differences (updated minus original) showed:

- Portion of flood channel now deeper north of flood delta shoal by 2 m (6.6 ft).
- Western portion of channel at Sprague Bridge shallower (1 m [3.3 ft]) while eastern deeper (2 m [6.6 ft]).
- Areas south of Sprague Bridge and south of flood delta shoal shallower (0.5 to 1.5 m [1.6 to 4.9 ft]).

- Net differences equivalent to 6,990 m^3 (9,140 yd^3) more sediment (16,180 m^3 [21,160 yd^3] added and 9,190 m^3 [12,220 yd^3] removed).

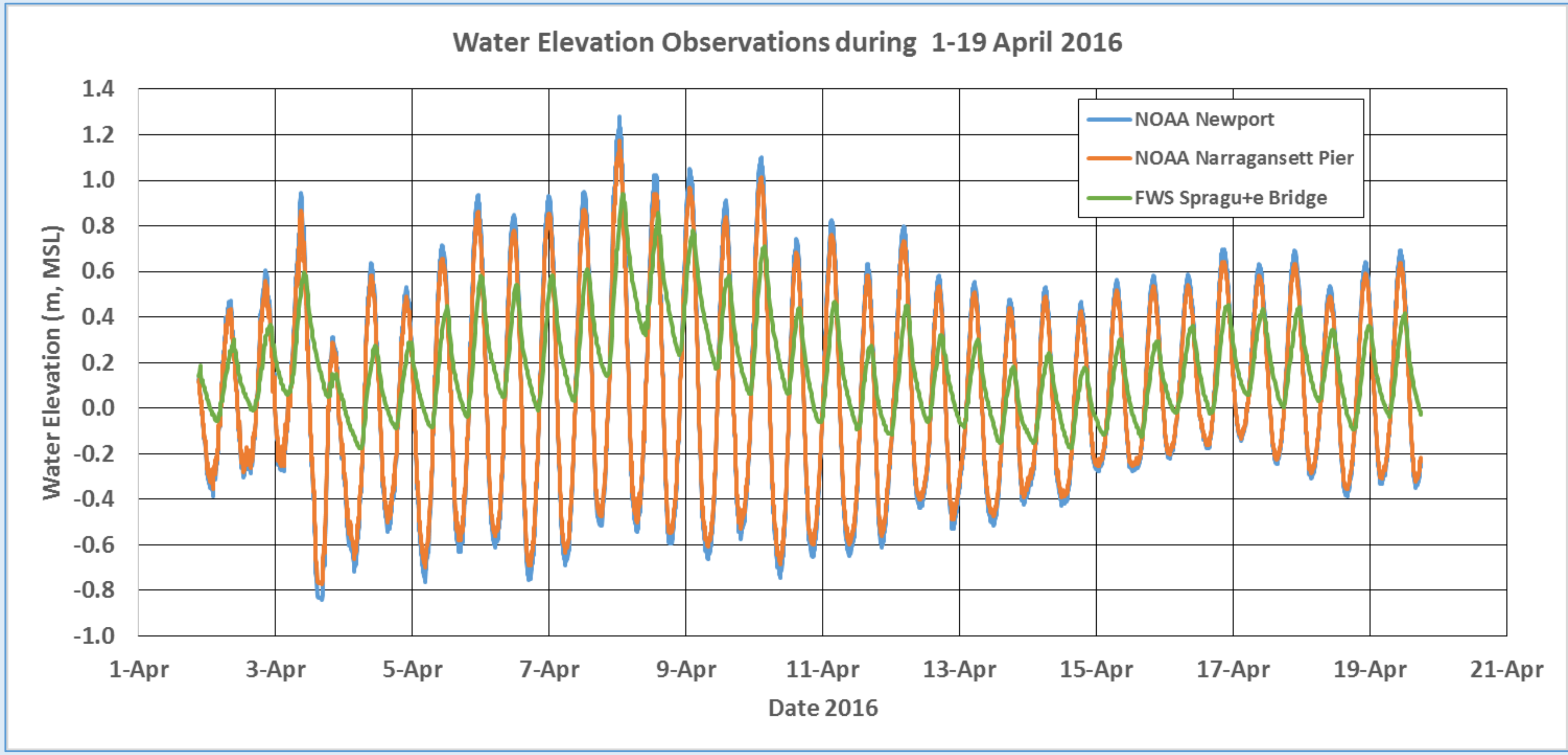
Water Elevation Data – April 2016

- USFWS installed tide gauge during 1 to 19 April 2016 just below Sprague Bridge.
- Used satellite-based system to establish average gauge elevation.
- Downloaded verified observations from NOAA Newport Station for April 2016 period from website.
- Applied NOAA Narragansett Pier Station offsets to Newport for use in model forcing.



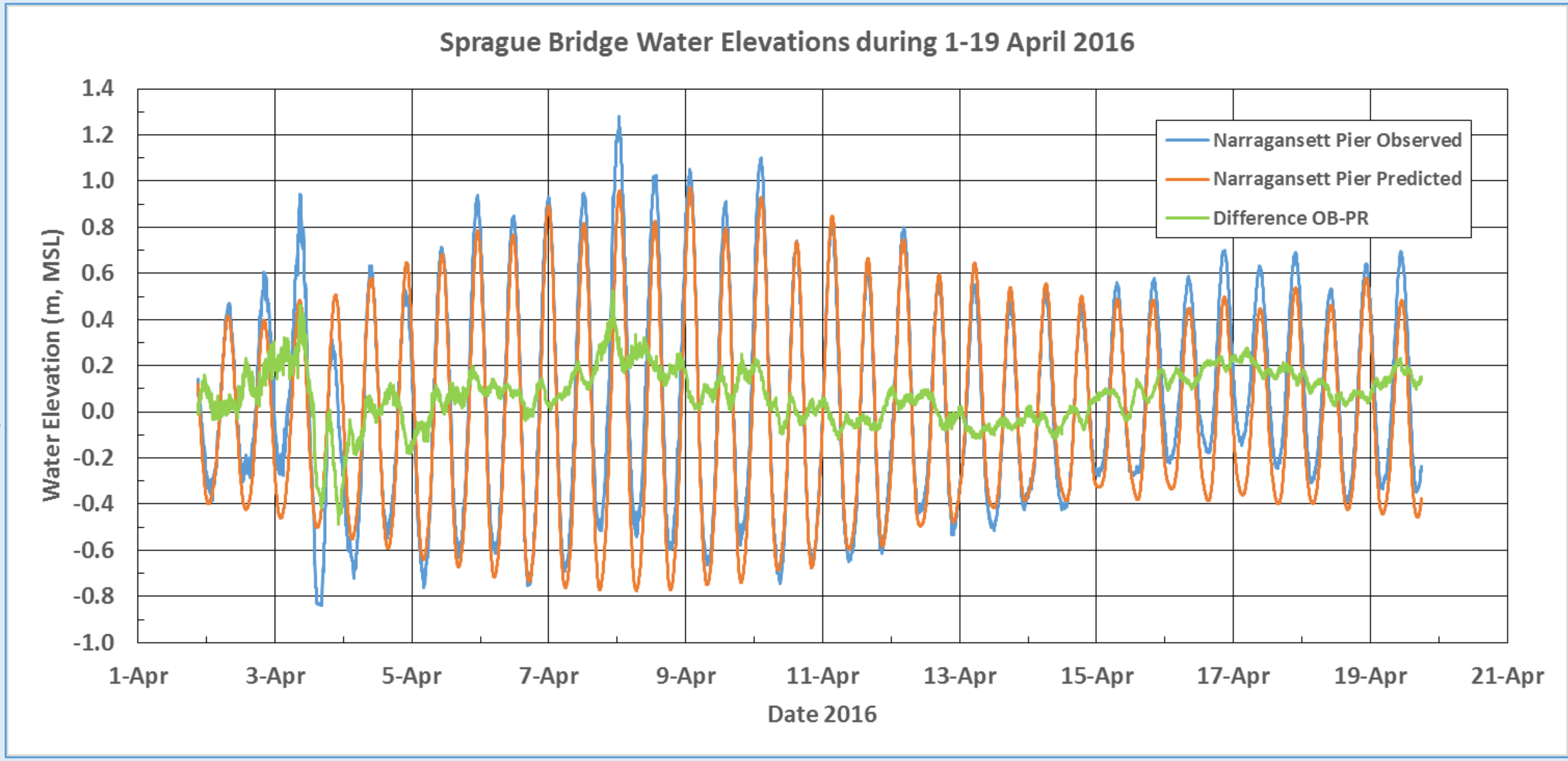
Water Level Time Series - April 2016

- NOAA Newport data downloaded from website for 1 to 19 April 2016 period.
- NOAA Narragansett Pier Station data calculated as 92% of NOAA Newport Station amplitude with no time shift.
- USFWS tide gauge at Sprague Bridge showed asymmetry in tidal cycle (shorter steeper rise during flood, longer shallower fall during ebb).
- Mean of Sprague Bridge elevations higher (~0.2 m [0.66 ft]) than Narragansett Pier elevations indicating superelevation during spring tides in Narrow River.
- Events and non-tidal variations seen in records (3, 7, 9 April).



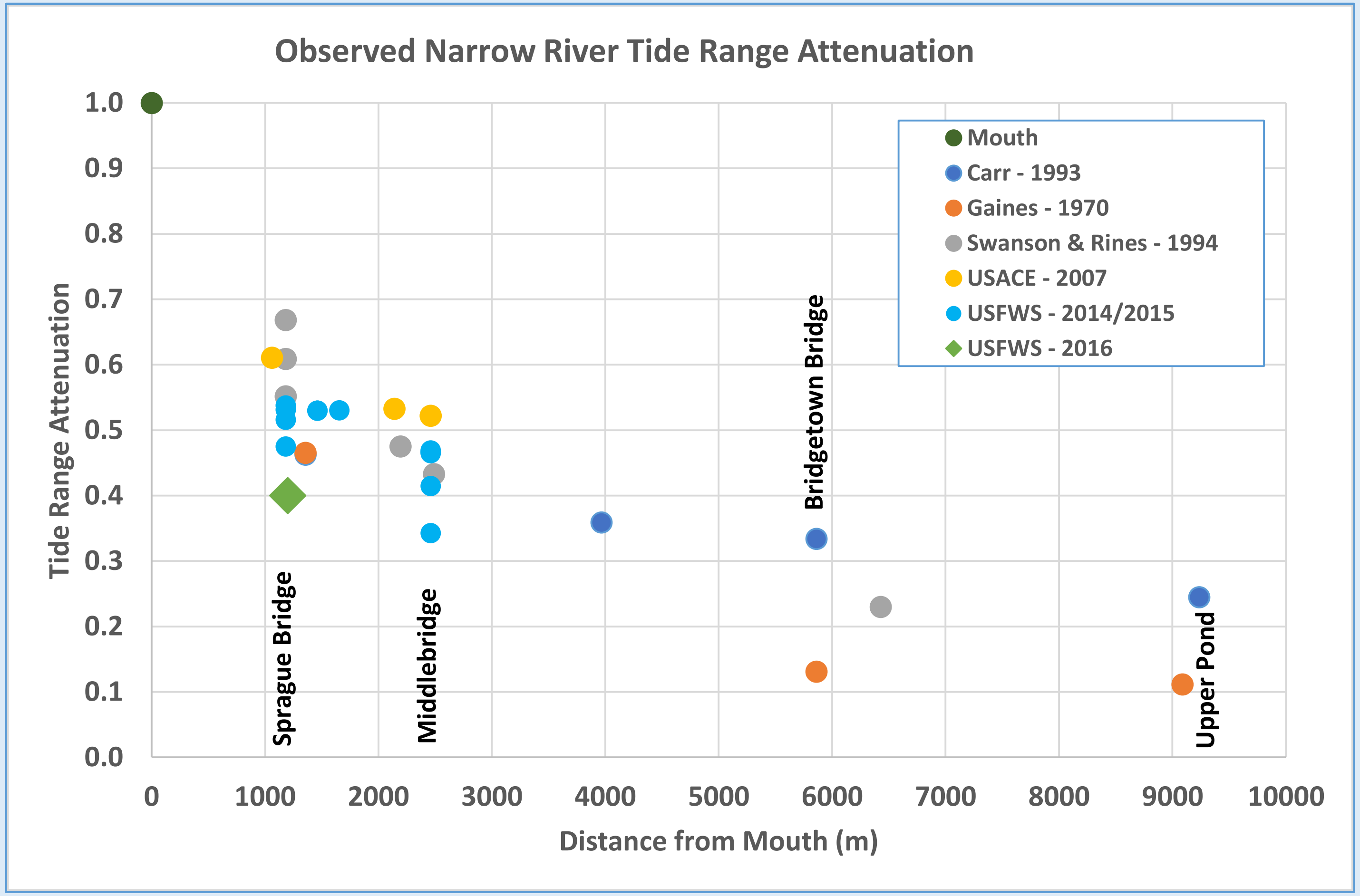
NOAA Newport Observations and Predictions- April 2016

- Observed and Predicted track relatively well with both showing significant spring / neap variation
- Observed and Predicted diverge during non-tidal events on 3 April and on 7-9 April.
- High frequency oscillations seen in Observations were removed using time-averaging filter before use in modeling.
- Non-tidal (wind?) variations evident in Difference calculation during non-tidal events as well as during 15-18 April period.



Present and Historical Tide Range Attenuation

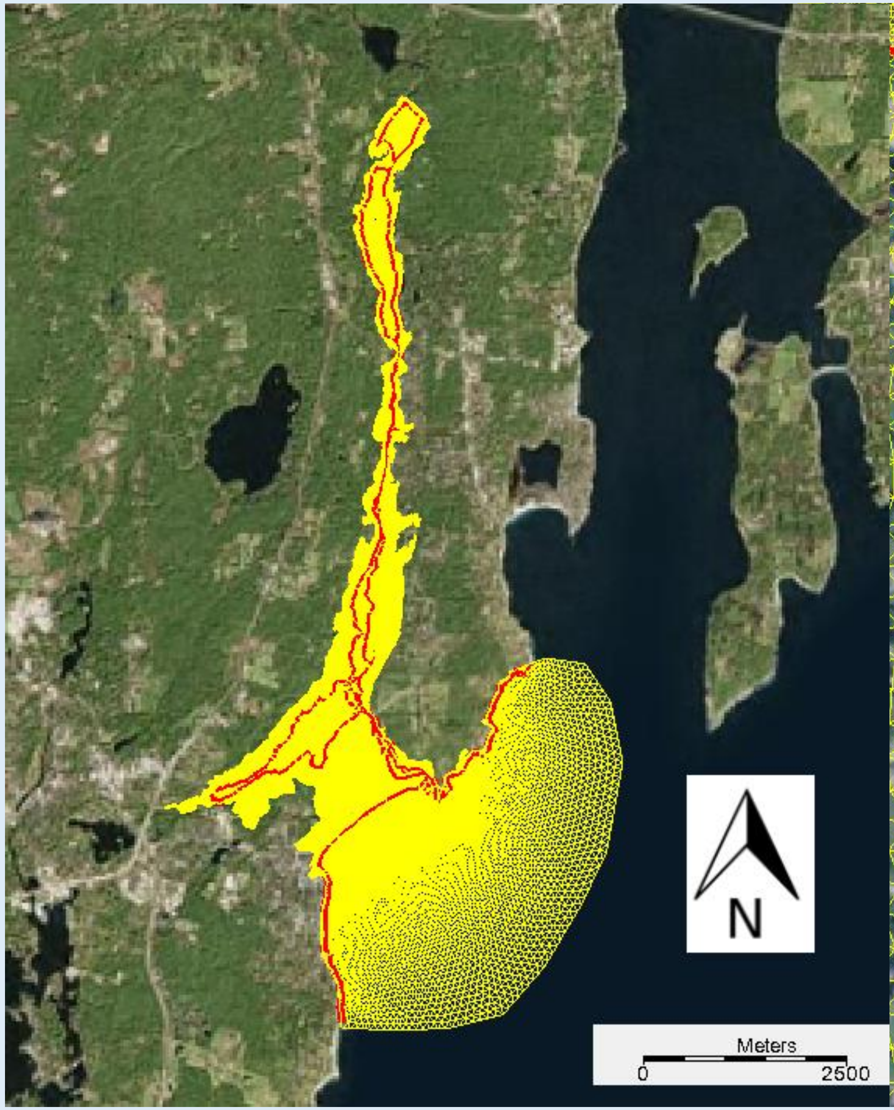
- Largest attenuation change occurs in The Narrows with most recent study with the tide range attenuation at 0.40 indicating the constriction in the Narrows is likely most severe at the present time.
- Attenuation variation likely due to constriction continually changing over time with sediment transport from Narragansett Beach into river mouth.
- Historical variation also likely due to varying durations of tidal measurement surveys from 1 day (USACE -2007) to 77 days (USFWS – 2014/15).



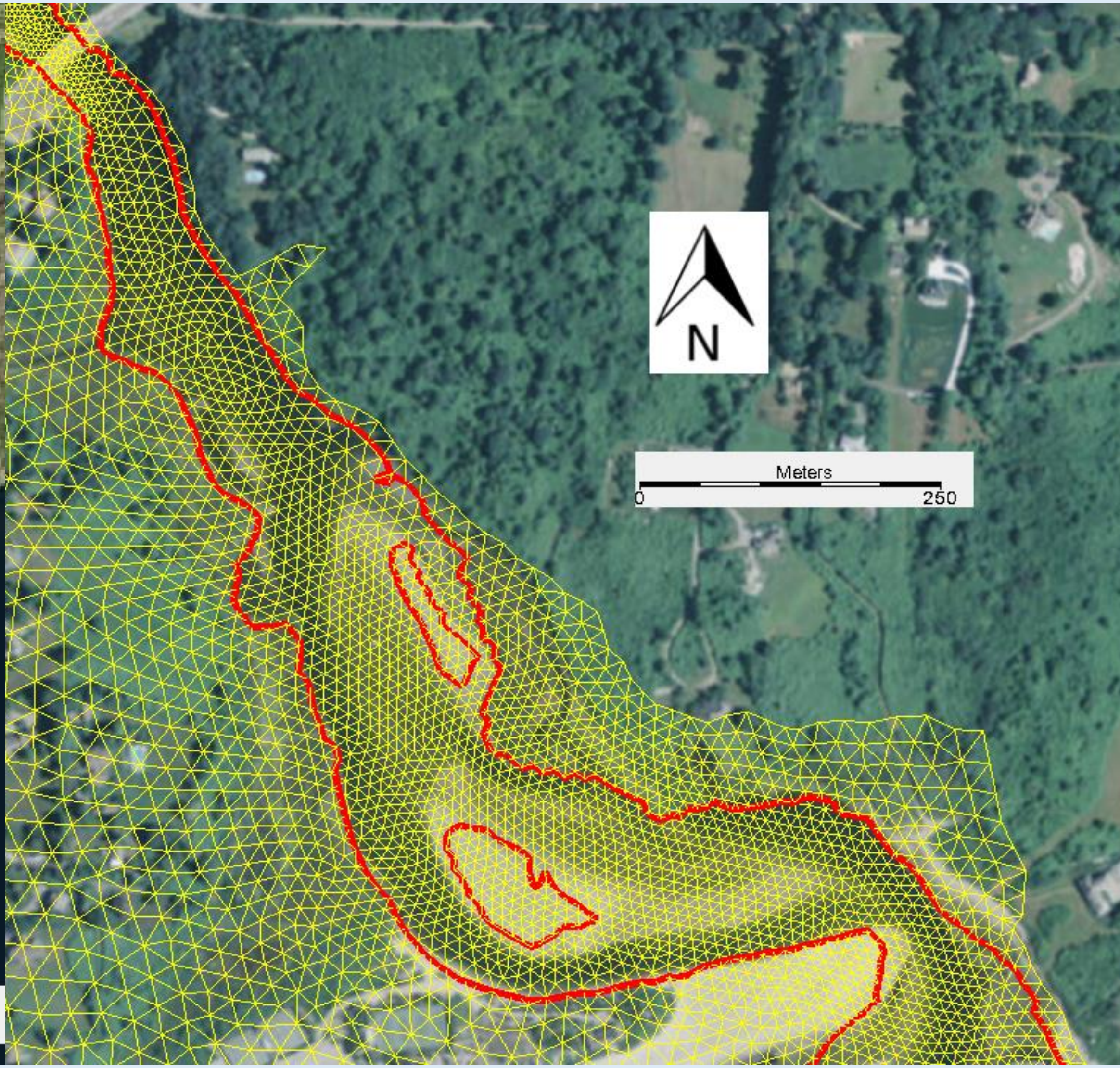
ADCIRC Model Application

- Domain extends to 3 m (10 ft) above MSL
- 38,765 nodes and 75,792 elements
- Element size in river varies from 5 to 30 m (16 to 100 ft) with RI Sound boundary up to 200 m (660 ft)

Entire model grid

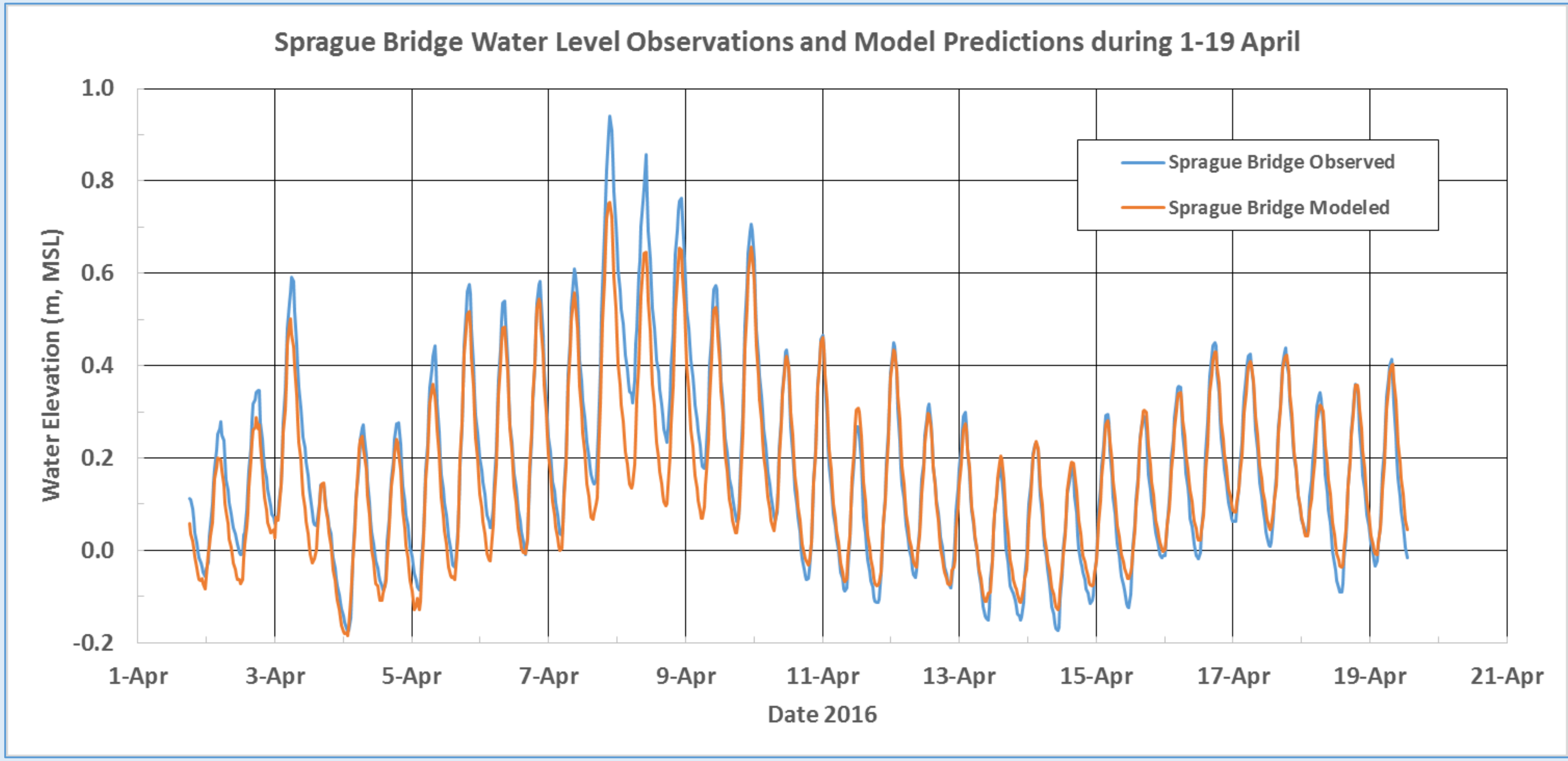


Model grid zoomed to The Narrows



Model – Data Comparison of Water Level at Sprague Bridge for 1-19 April Period

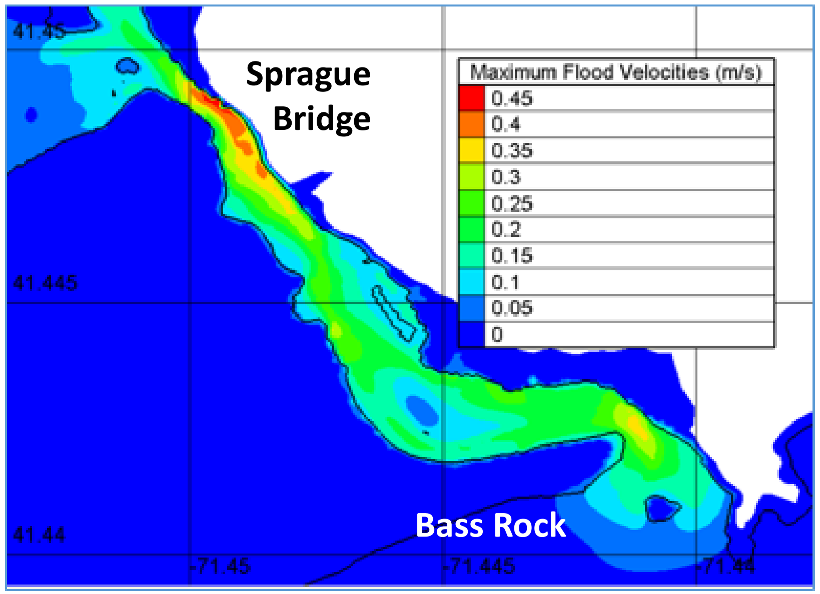
- RMSE was 0.065 m, generally very good comparison.
- Model predictions and observations were close in 3 April event but diverged during 7-9 April event seen in Newport data.
- Model correctly simulated super-elevation (mean above MSL).



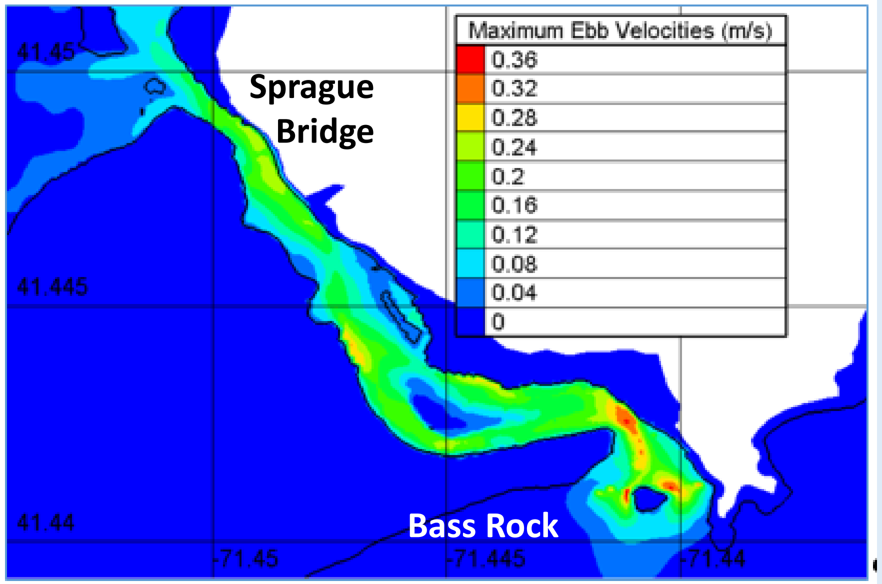
Velocity Predictions in The Narrows

- Highest maximum flood currents occur at Sprague Bridge reaching 0.45 m/s (1.5 ft/s) and north of Bass Rock reaching 0.34 m/s (1.12 ft/s).
- Highest maximum ebb currents occur north of Bass Rock reaching 0.31 m/s (1.02 ft/s).
- Most areas see maximum flood and ebb currents of 0.15 to 0.25 m/s (0.49 to 0.82 ft/s).
- Sediment resuspension threshold is ~ 0.20 m/s (~0.66 ft/s) so sediment transport during tidal cycle is likely, particularly near mouth.

Maximum Flood Velocity
(defined north of Bass Rock)

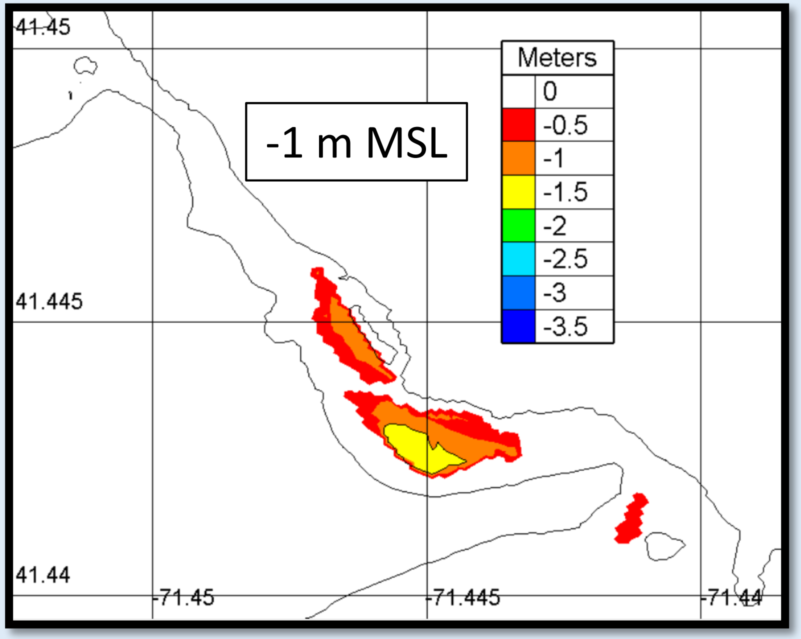


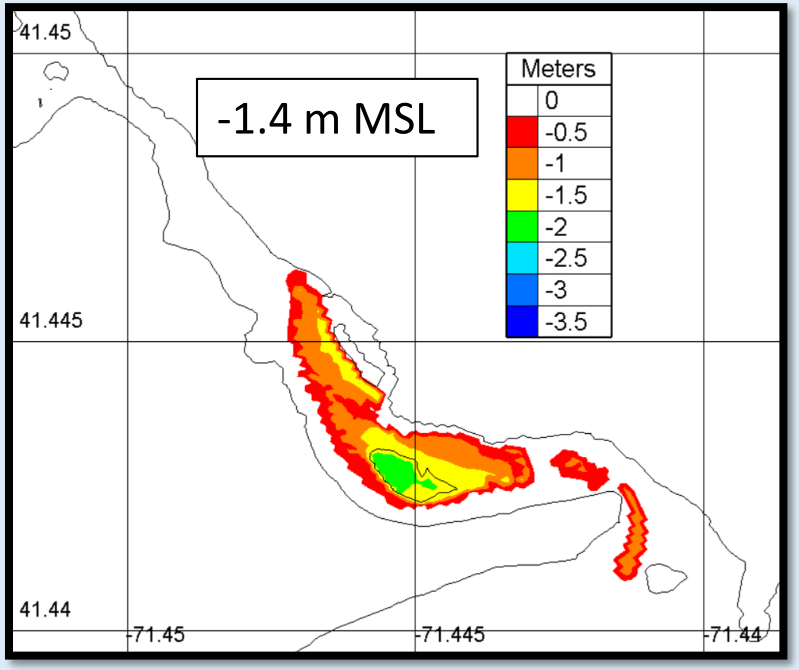
Maximum Ebb Velocity
(defined north of Bass Rock)

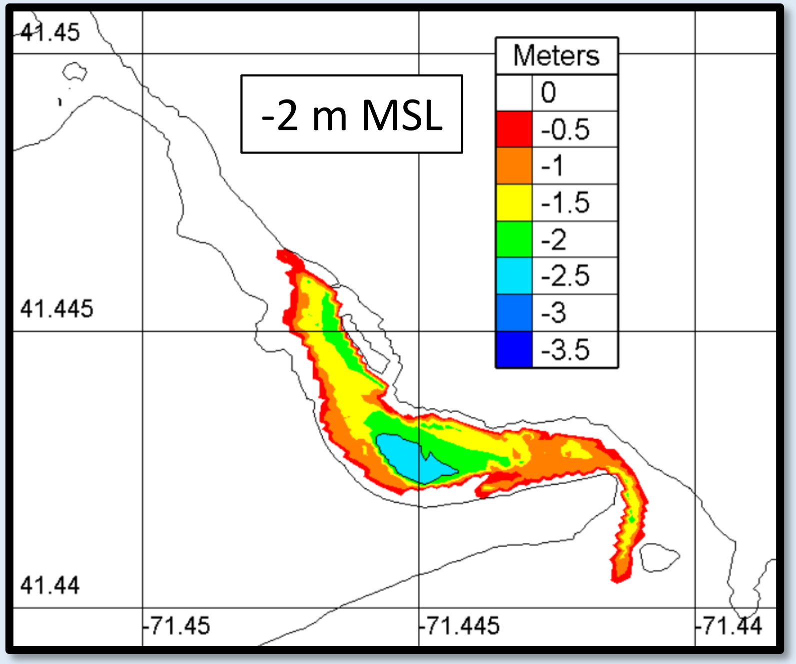


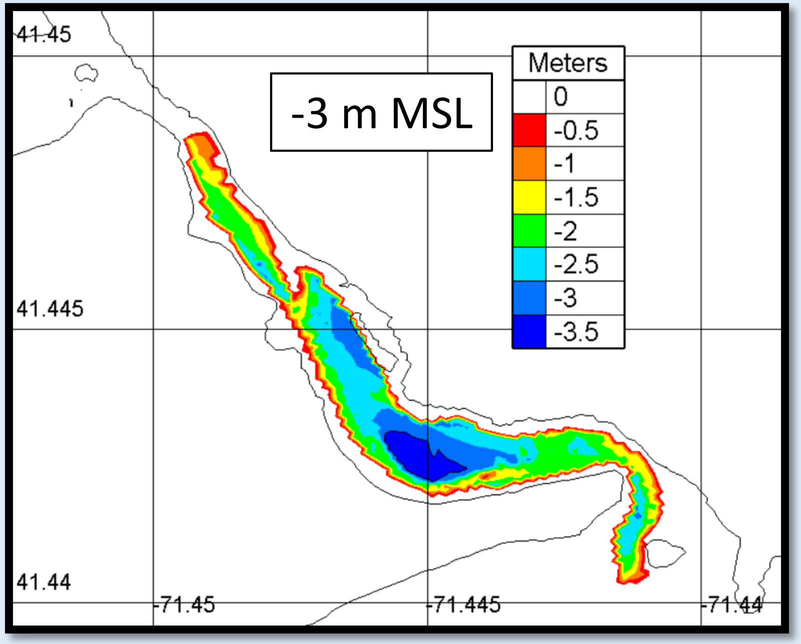
The Narrows Dredging Scenarios

- A set of dredging scenarios were selected for evaluation:
  - Dredging to -1 m MSL (-2.9 ft NGVD). Volume removed: 21,500 m^3 (28,100 yds^3)
  - Dredging to -1.4 m MSL (-4 ft NGVD) [USACE]. Volume removed: 43,000 m^3 (56,200 yds^3)
  - Dredging to -2 m MSL (-5.7 ft NGVD). Volume removed: 80,500 m^3 (105,000 yds^3)
  - Dredging to -3 m MSL (-8.6 ft NGVD). Volume removed: 184,000 m^3 (241,000 yds^3)
- Graphic shows thickness of material removed for each scenario.



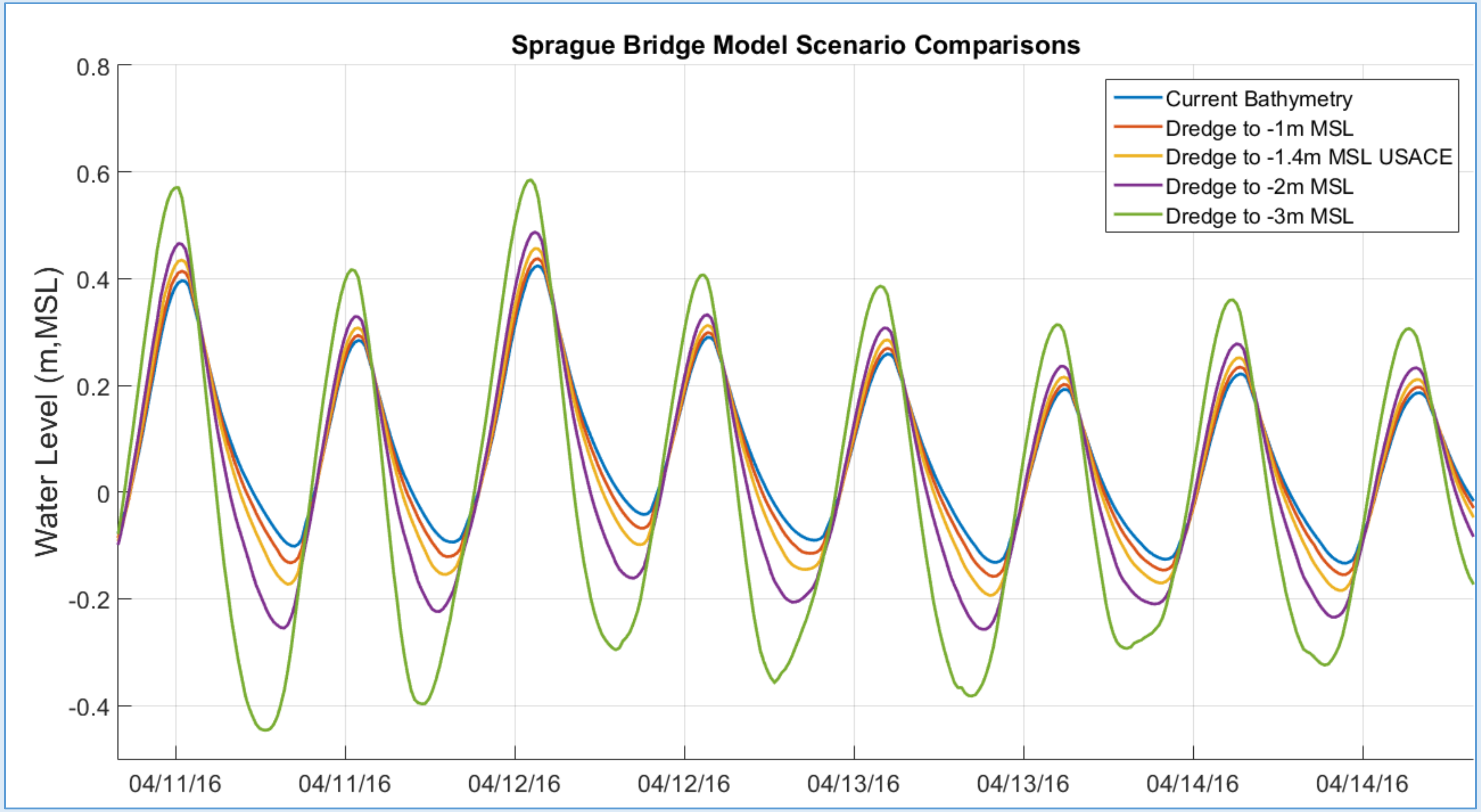






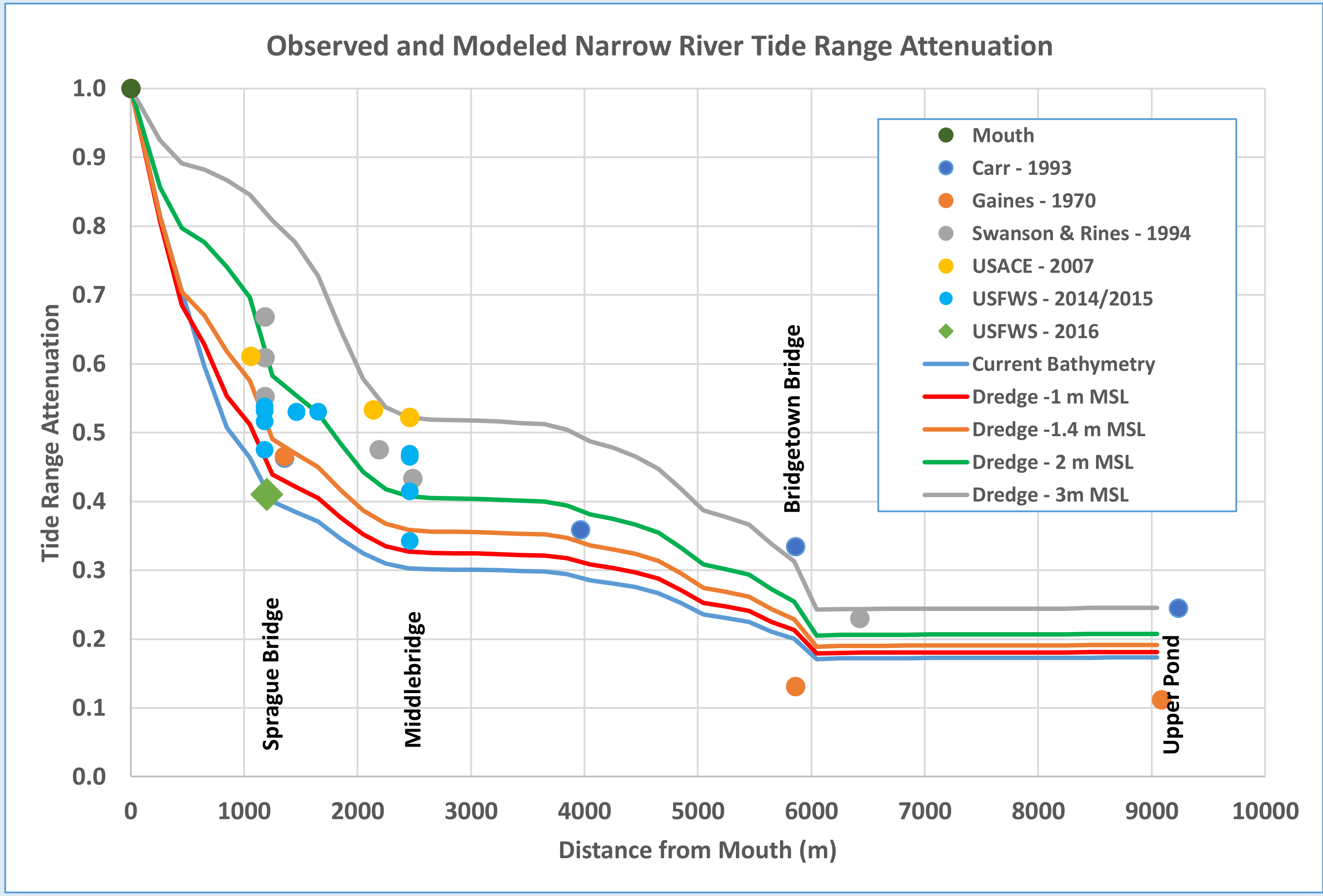
Water Elevation Changes due to Dredging

- Model results show superelevation decreases (mean approaches MSL) as dredged depth increases.
- Tidal cycle shape becomes more symmetrical as dredged depth increases with reduction in low tide phase lag.



Model – Data Comparison of Tide Range Attenuation

- All model runs show drop in tide range attenuation for first 1 to 2.5 km (0.6 to 1.5 mi) of river, continues with lower rate of attenuation loss until 6 km (3.7 mi) and then no change in attenuation thereafter.
- Modeled Current Bathymetry scenario tide range attenuation compares well with USFWS - 2016 observed attenuation (0.40) at Sprague Bridge.
- As dredging depth increases the tide range attenuation value increases from 0.44 (Dredge -1 m scenario) to 0.81 (Dredge -4 m scenario) at Sprague Bridge.
- Dredge -1 m scenario matches attenuation (0.61) with Swanson & Rines – 1994 at Sprague Bridge suggesting less historical constriction in the Narrows.
- As dredging depth increases the tide range attenuation value only slightly increases from 0.18 (Dredge -1 m scenario) to 0.25 (Dredge -4 m scenario) in Upper Pond.
- Flat response above Bridgetown Bridge due to depth of Lower (20 m) and Upper (12 m) Ponds exerting no frictional losses so Ponds act as storage volumes.



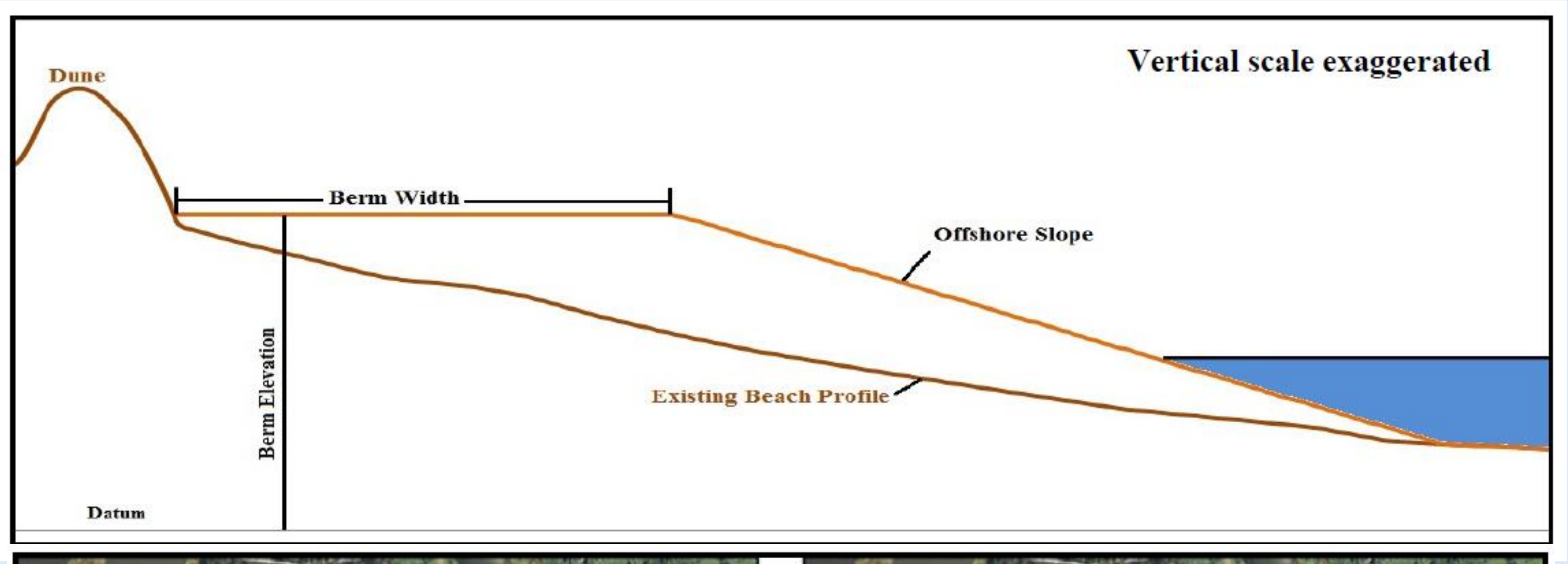
Results from Selected Dredging Scenarios

Scenario	**Dredging Volume (m^3)** ***(yds^3)***	**Sprague Bridge Tide Range (m)** ***(ft)***	**Sprague Bridge Attenuation**	**Upper Pond Tide Range (m)** ***(ft)***	**Upper Pond Attenuation**	**Tidal Prism (m^3)** ***(ac-ft)***	**High Tide Volume (m^3)** ***(ac-ft)***	**Tidal Flushing (days)**
Present	n/a	0.38 *1.24*	0.41	0.17 *0.57*	0.17	675,100 *550*	4,928,000 *4,000*	3.8
Dredging to -1 m MSL	21,500 *28,100*	0.41 *1.35*	0.42	0.18 *0.59*	0.18	731,670 *590*	4,971,800 *4,030*	3.5
Dredging to -1.4 m MSL (USACE)	43,000 *56,200*	0.44 *1.44*	0.48	0.19 *0.61*	0.19	771,630 *630*	5,010,800 *4,060*	3.4
Dredging to -2 m MSL	80,500 *105,000*	0.54 *1.78*	0.60	0.21 *0.68*	0.21	912,580 *740*	5,098,600 *4,130*	2.9
Dredging to -3 m MSL	184,000 *241,000*	0.77 *2.51*	0.84	0.24 *0.80*	0.25	1,185,400 *960*	5,357,000 *4,340*	2.3

Tidal flushing was calculated as (high tide volume)/(tidal prism)*(12.42 hr)/(24 hr/day).

Narragansett Town Beach Nourishment (WHG, 2011)

- WHG developed a series of 5 beach nourishment alternatives or "templates" defined by beach profiles.
- Two scenarios analyzed using templates based on project lengths evaluated:
  - 2,465 ft (863 m) for Narragansett Town Beach
  - 5,205 ft (1,822 m) for town beach plus privately-owned beaches.



Narragansett Beach Nourishment Requirements (WHG, 2011)

Scenario	Case 2 Berm Width 100 ft Berm Elevation 6 to 12 ft Offshore Slope (12H:1V) Volume (yd^3) *(m^3)*	Case 3 Berm Width 100 ft Berm Elevation 8 to 12 ft Offshore Slope (12H:1V) Volume (yd^3) *(m^3)*	Case 5 Berm Width 50 ft Berm Elevation 6 to 12 ft Offshore Slope (12H:1V) Volume (yd^3) *(m^3)*	Case 7 Berm Width 75 to 100 ft Berm Elevation 8 to 10 ft Offshore Slope (15H:1V) Volume (yd^3) *(m^3)*	Case 9 Berm Width 30 to 50 ft Berm Elevation 8 to 9 ft Offshore Slope (15H:1V) Volume (yd^3) *(m^3)*
1 –Narragansett Town Beach (2,465 ft)	102,240 *78,170*	148,450 *113,500*	60,170 *46,000*	119,800 *91,590*	50,000 *38,230*
2 - Narragansett Town Beach and private sections of Narragansett barrier spit (5,205 ft)	171,040 *130,770*	327,200 *250,160*	150,670 *115,200*	245,470 *187,680*	92,300 *70,570*

- Dredging to -1.4 m MSL (56,200 yd^3) can supply enough volume for Case 9 Scenario 1 (50,000 yd^3) and almost enough for Case 5 Scenario 1 (60,000).
- Dredging to -2 m MSL (105,000 yd^3) can supply enough volume for Case 2 Scenario 1 (102,240 yd^3) and Case 9 Scenario 2 (92,300 yd^3).

Conclusions

- Previous studies have shown a significant variation in tide range over the last 45 years likely due to sediment dynamics (shoaling and channeling) in The Narrows reach located downstream of the Sprague Bridge.
- Based on 2016 measurements the tide range (attenuation) is smaller than that measured during previous studies between 1970 and 2007 indicating that tidal flushing time has increased.
- Model results indicate that dredging would increase the average tide range at Sprague Bridge by 8% (Dredging -1 m MSL), 16% (Dredging -1.4 m MSL), 42% (Dredging -2 m MSL) and 103% (Dredging -3 m MSL).
- Model results indicate that dredging would increase the average tide range at the Upper Pond by 6% (Dredging -1 m MSL), 12% (Dredging -1.4 m MSL), 24% (Dredging -2 m MSL) and 41% (Dredging -3 m MSL).
- Model results indicate that dredging would decrease tidal flushing time by 8% (Dredging -1 m MSL), 11% (Dredging -1.4 m MSL), 24% (Dredging -2 m MSL) and 39% (Dredging -3 m MSL).
- Dredging to more than -1.4 m MSL will significantly change the average tide range and potentially impact the Cove marsh system but some of the dredged material for larger dredging programs could be used both to raise the level of the marsh system to offset tidal flooding and to supply renourishment for Narragansett Town Beach.

Recommendations

- Further assessment of the impact of dredging the mouth of the Narrow River and resulting increased MHW elevations on saltmarsh habitat is warranted to determine if such dredging could be used both to raise the marsh elevation in future and also supply material for renourishment of the town beach.
- To quantify the effects of increased flushing in the Narrow River an additional model is required which accounts for pollutant movement by the predicted current velocities, physical diffusion and the kinetics of the pollutant.
- This pollutant transport model should be calibrated to properly assess these effects so a field study using a non-toxic dye is recommended.
- The pollutant transport model can be used to assess accumulation and flushing for a variety of pollutants of concern and ultimately to provide information for a more quantitative benefit/cost analysis of dredging the Narrows.