Comparison of Marsh Elevations to Model Predictions of Dredging Effects on Tides in the Narrow River

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Introduction

During the 10 September 2018 meeting held at RI Coastal Resources Management Council (CRMC) offices to discuss the potential effects on the tidal regime in the Narrow River of dredging its lower reach it was decided to compare the duration of tidal inundation based on hydrodynamic model predictions for different dredge alternatives with respect to measured marsh control point elevations conducted by US Fish and Wildlife Service (USFWS). The model predictions are documented in Swanson et al (2016). The following analysis summarizes those results.

Marsh Control Point Elevations

The USFWS provided five measurements of elevations at control points in three marshes in the Narrow River as summarized in Table 1. Figure 1 shows the USFWS tidal time series for 1-19 April 2016 deployment at Sprague Bridge located at the upstream end of the lower reach of the Narrow River along with the marsh elevations, all relative to NAVD88. Of note are some non-tidal excursions seen on 3 April and 7 to 9 April.

The offset between NAVD88 and mean sea level (MSL), 0.188 m, was determined by averaging the 19-day period from the USFWS tide gauge. Control point elevations with respect to MSL are also shown in Table 1. Note that this offset is larger than the mean offset at Newport which is 0.093 m and reflects in part the limited duration of the observations as well as the superelevation effect present in the river.

Table 1. USFWS marsh elevation information.

Measurement Location	Description of Vegetation / Condition	Elevation wrt NAVD88 (m)	Elevation wrt MSL (m)
North Middlebridge (control, n=17)	Low/mixed marsh, undrained pool	0.323	0.135
North Middlebridge (runnel, n=18)	Low marsh, extensive area of revegetating pool/panne	0.299	0.111
South Middlebridge (TLD, n=26)	Mostly sand	0.475	0.287
Starr Drive (control, n=16)	Mixed marsh, extensive pool/panne area	0.402	0.214
Starr Drive (runnel, n=16)	Mixed/higher marsh, revegetating pool/panne	0.411	0.223

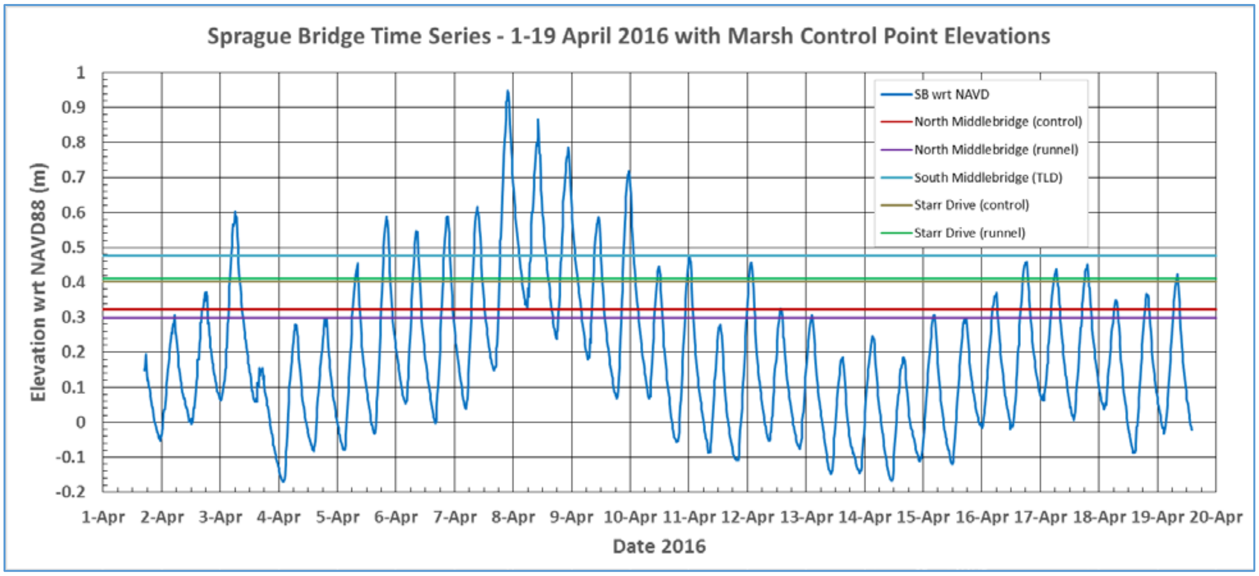

Figure 1. Time series of the USFWS water level observations as well as the five elevations of the marsh control points relative to NAVD88.

The hydrodynamic model was run using the actual observations from the NOAA Newport tidal station reduced to 92%, as determined by NOAA at Narragansett Pier, which was the closest location to the model open boundary. The resulting model time series is shown for Sprague Bridge along with the USFWS observations at Sprague Bridge adjusted to MSL in Figure 2 (Figure 5-1 in Swanson et al, 2016). The comparison between model predictions to observations was generally good showing the same slight tidal asymmetry and no phase difference. Observations and predictions were close during the 3 April non-tidal event but diverged more significantly during the 7-9 April 2016 non-tidal event.

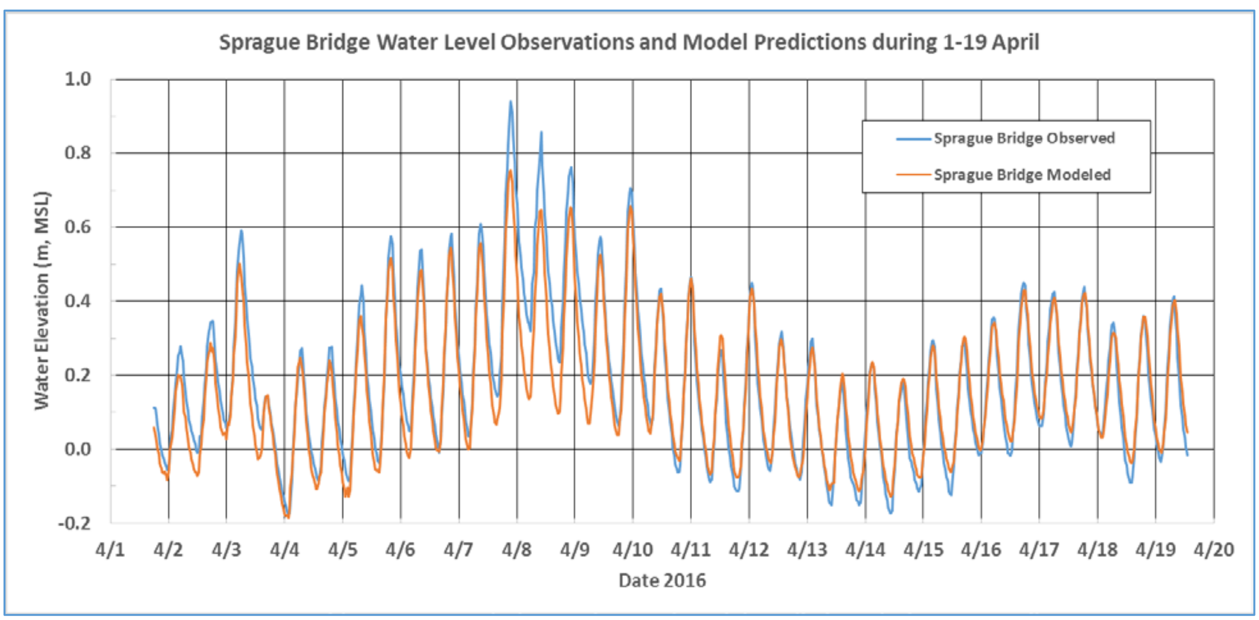

Figure 2. Time series comparison of the hydrodynamic model predictions and the USFWS observations for the 1-19 April 2016 period at Sprague Bridge with elevations relative to MSL.

The hydrodynamic modeling then examined a series of conceptual dredging alternatives which were defined as dredging shallow areas to the minimum specified depths. The depths chosen for this comparison included 1, 1.4, and 2 m below MSL. The resulting model predictions of water elevation time series at Sprague Bridge are shown in Figure 3 for the current bathymetry and the three dredged alternatives for the period 10 through 14 April 2016. This period was chosen since the model-data comparison was closest during this period, as seen in Figure 2. Note that the tidal ranges showed larger variations among the low tide elevations than the high tide elevations. This figure was modified from Figure 6-2 in the report by eliminating the -3 m alternative and adding in the five marsh control point elevations.

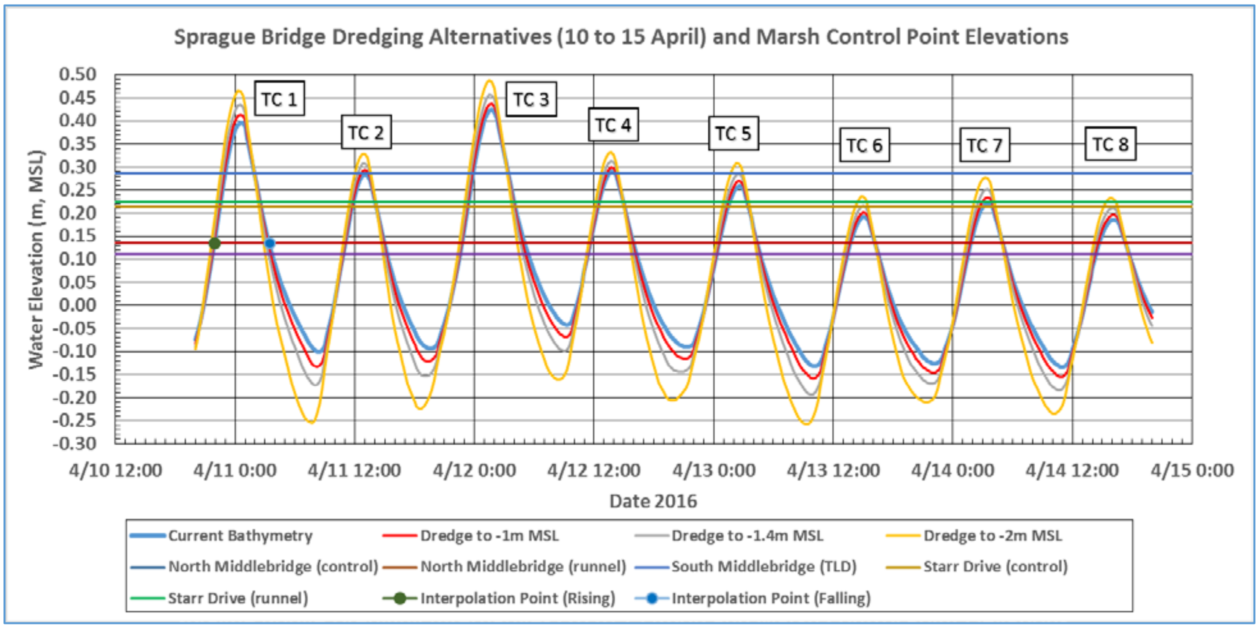

Figure 3. Tidal time series from model simulations of dredging alternatives compared to marsh elevations. The eight tidal cycles are labeled TC 1 through TC 8.

The high tide elevations, relative to MSL, for the four dredging alternatives and for the eight tidal cycles shown in Figure 3 are summarized in Table 2.

Table 2. High tide elevations relative to MSL for the four dredging alternatives for the eight tidal cycles along with the elevation differences from the current bathymetry.

Tidal Cycle	Current Bathymetry (m)	Dredged - 1m (m)	Dredged - 1.4 m (m)	Dredged -2m (m)	Diff Dredge 1m - Current	Diff Dredge 1.4 m- Current	Diff Dredge 2m - Current
1	0.396	0.414	0.435	0.466	0.0180	0.0390	0.0700
2	0.284	0.294	0.308	0.329	0.0100	0.0240	0.0450
3	0.424	0.438	0.457	0.487	0.0140	0.0330	0.0630
4	0.29	0.299	0.312	0.333	0.0090	0.0220	0.0430
5	0.259	0.27	0.285	0.308	0.0110	0.0260	0.0490
6	0.193	0.202	0.216	0.236	0.0090	0.0230	0.0430

Tidal Cycle	Current Bathymetry (m)	Dredged - 1m (m)	Dredged - 1.4 m (m)	Dredged -2m (m)	Diff Dredge 1m - Current	Diff Dredge 1.4 m- Current	Diff Dredge 2m - Current
7	0.222	0.234	0.252	0.278	0.0120	0.0300	0.0560
8	0.186	0.197	0.211	0.233	0.0110	0.0250	0.0470
Average	0.282	0.294	0.310	0.334	0.0118	0.0277	0.0520

As shown in Table 2 the high tide elevations consistently increased by a few centimeters with increased dredged depths.

Exceedance Durations

The next step in the analysis was to determine the duration of inundation for each marsh elevation over the eight high tides and for each dredge alternative. An example of the durations for the sixth high tide cycle (13 April between 13:00 and 17:00) is shown in Figure 4. The two circle markers indicate when inundation starts on the rising tide and when it stops on the falling tide, with the duration defined as the time between the two markers. This example shows that one marsh control point elevation, South Middlebridge (TLD), shown as the blue horizontal line, was not inundated by any dredge alternative.

The marsh control point elevation Starr Drive (runnel), the green horizontal line, showed inundation for 0.95 hr by the dredged -2m alternative. The marsh control point elevation Starr Drive (control), the brown horizontal line, was inundated by two dredge alternatives, dredged -2m (1.27 hr) and dredged -1.4m (0.42 hr).

The lower two control point elevations, North Middlebridge (control) (red) and (runnel) (purple), were exceeded by all four dredge alternatives with durations of 2.92, 2.73, 2.85 and 2.47 hr for dredged -2m, dredged -1.4m, dredged -1m and current bathymetry, respectively, for North Middlebridge (control) and durations of 3.33, 3.22, 3.12 and 3.07 hr for North Middlebridge (runnel).

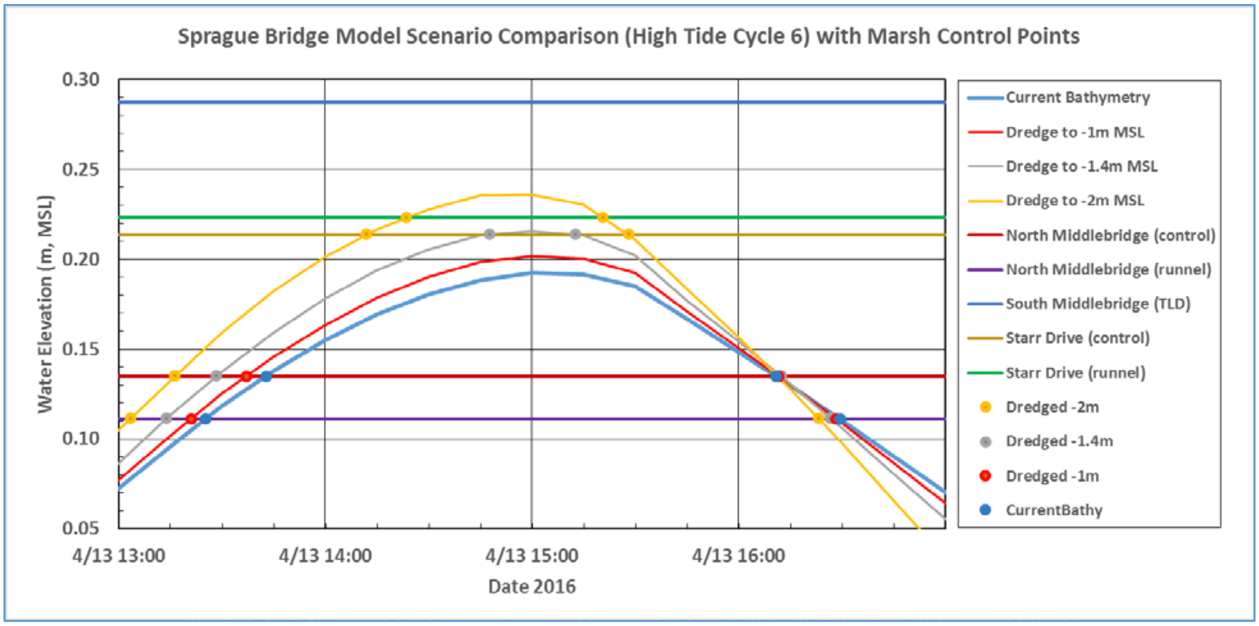

Figure 4. Sixth high tide showing the dredge alternatives relative to the marsh control point elevations with circle markers indicating start and stop times defining the duration.

To increase clarity in showing the intersection points among the dredging alternatives and the marsh control point elevations two figures are used, one for the first four high tides and the other for the last four high tides. Figure 5 presents the first four high tides (10-12 April). All alternatives exceeded all the marsh control point elevations for the first, third and fourth high tides. The second high tide showed that only the current bathymetry was not exceeding the South Middlebridge (TLD) control point elevation.

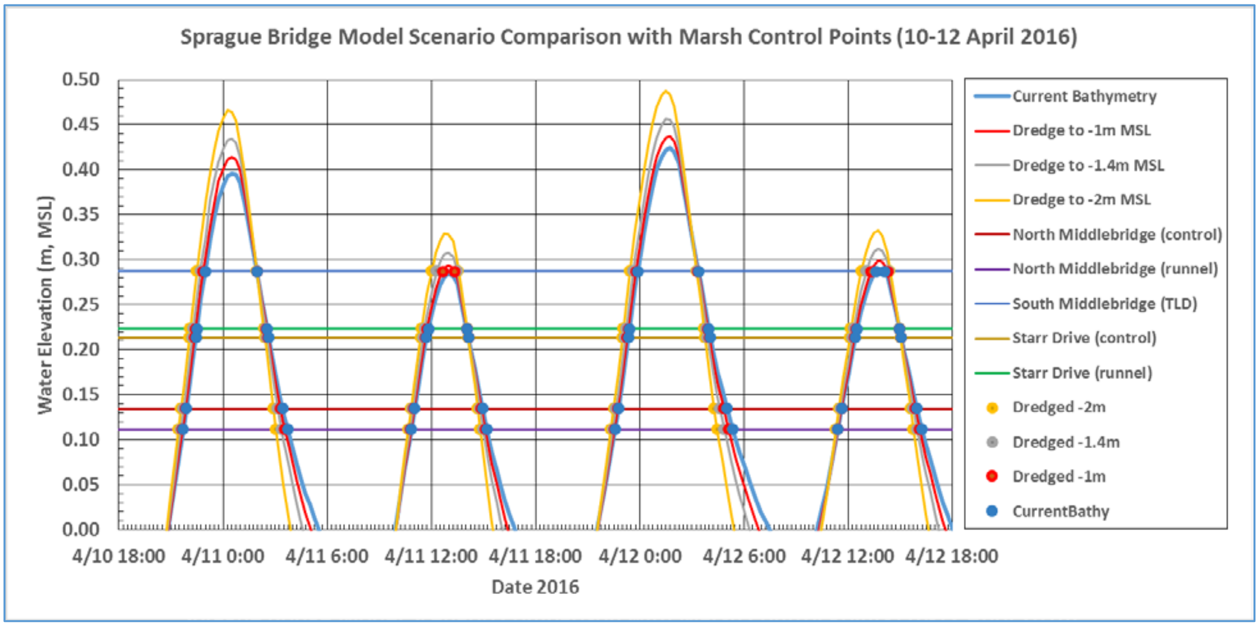

Figure 5. First four high tides (10-12 April) showing dredging alternatives and marsh control point elevations.

Figure 6 displays the fifth through eighth high tides (12-14 April) that are generally lower than the first four. The fifth high tide exceeded the five marsh control point elevations but only for the dredged -2m alternative with the rest of the dredged alternatives exceeding only the lower four marsh control point elevations. The sixth high tide was described above. The seventh high tide showed three exceedances (dredged -1m, dredged -1.4m and dredged -2m) of the lower four marsh control point elevations and all alternatives exceeded the lower three marsh control point elevations. The last high tide showed the dredged -2m exceeded the lower four marsh control point elevations and the rest of the dredge alternatives exceeded only the lowest two marsh control point elevations.

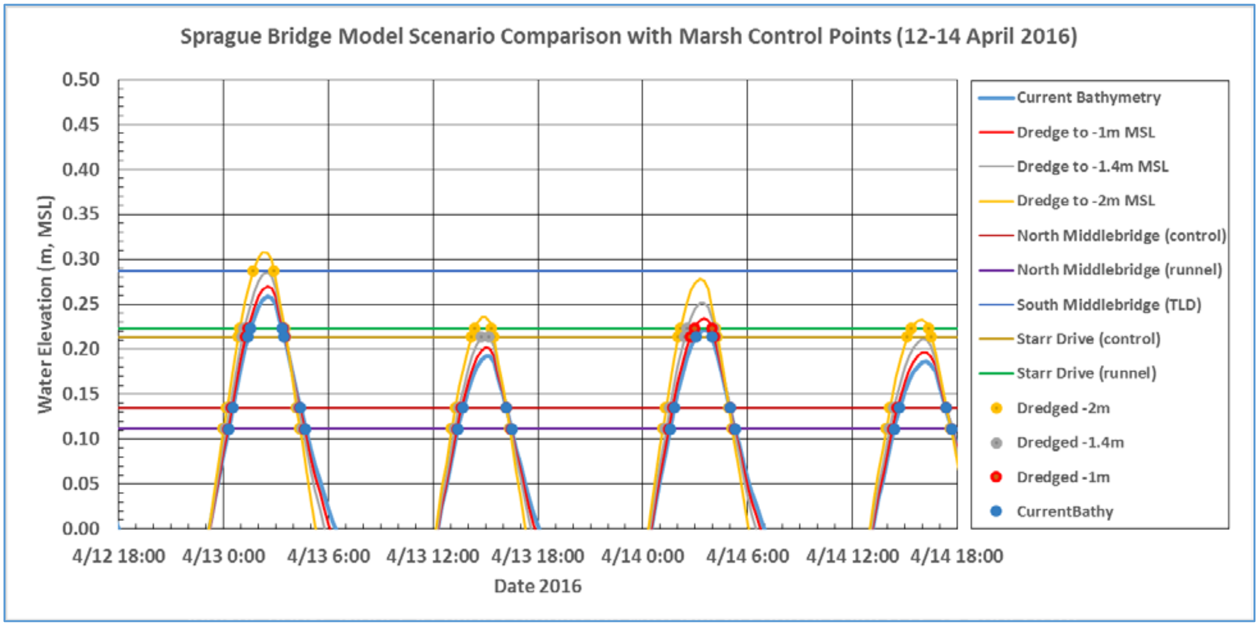

Figure 6. Last four high tides (12-14 April) showing dredging alternatives and marsh control point elevations.

The duration of each exceedance as defined by the intersections of tide time series of the dredge alternatives with each of the marsh control point elevations is summarized in Table A1 (in Appendix) by the eight high tides resulting in 36 unique durations.

The eight high tide durations were then summed to get the total durations for each of the four dredge alternatives and each of the five marsh control point elevations. The duration exceedances from the -1m, -1.4m and -2m dredging alternatives were then compared to the total duration of the eight tidal cycles (96 hr) to show the percentage of inundation duration. They were also compared to the current bathymetry scenario duration exceedance to show how the increase in tide range with increasing dredging affected the inundation duration. These results are presented in Table 3. Note the tidal cycle number (see Figure 3) is not included in Table 3 for a given alternative if the water level was not above the marsh elevation at a given control point.

Table 3. Durations of exceedances for each of the four dredge alternatives with each of the five marsh control point elevations for the eight high tidal cycles.

Dredge Alternative	Marsh Control Point Elevations	High Tide Number	Duration Exceed-ances (hr)	Duration (%) of Total Duration (96 hr)	Duration (%) > Current Bathymetry Duration
Current Bathymetry	S. Middlebridge (TLD)	1,3,4	6.97	7%	0%
Current Bathymetry	Starr Drive (runnel)	1,2,3,4,5	15.05	16%	0%
Current Bathymetry	Starr Drive (control)	1,2,3,4,5,7	16.97	18%	0%
Current Bathymetry	N. Middlebridge (control)	1,2,3,4,5,6,7,8	32.22	34%	0%
Current Bathymetry	N. Middlebridge (runnel)	1,2,3,4,5,6,7,8	36.55	38%	0%
Dredged to -1m	S. Middlebridge (TLD)	1,2,3,4	8.35	9%	20%
Dredged to -1m	Starr Drive (runnel)	1,2,3,4,5,7	16.53	17%	10%
Dredged to -1m	Starr Drive (control)	1,2,3,4,5,7	17.78	19%	5%
Dredged to -1m	N. Middlebridge (control)	1,2,3,4,5,6,7,8	32.28	34%	0%
Dredged to -1m	N. Middlebridge (runnel)	1,2,3,4,5,6,7,8	36.20	38%	-1%
Dredged to -1.4m	S. Middlebridge (TLD)	1,2,3,4	9.47	10%	36%
Dredged to -1.4m	Starr Drive (runnel)	1,2,3,4,5,7	17.68	18%	17%
Dredged to -1.4m	Starr Drive (control)	1,2,3,4,5,6,7	19.13	20%	13%
Dredged to -1.4m	N. Middlebridge (control)	1,2,3,4,5,6,7,8	32.58	34%	1%
Dredged to -1.4m	N. Middlebridge (runnel)	1,2,3,4,5,6,7,8	36.10	38%	-1%
Dredged to -2m	S. Middlebridge (TLD)	1,2,3,4,5	11.72	12%	68%
Dredged to -2m	Starr Drive (runnel)	1,2,3,4,5,6,7,8	20.80	22%	38%
Dredged to -2m	Starr Drive (control)	1,2,3,4,5,6,7,8	22.40	23%	32%
Dredged to -2m	N. Middlebridge (control)	1,2,3,4,5,6,7,8	32.80	34%	2%
Dredged to -2m	N. Middlebridge (runnel)	1,2,3,4,5,6,7,8	35.72	37%	-2%

Results

The duration exceedances were found to increase with higher marsh control point elevations for all dredge alternatives, as expected. As the dredging depth was increased the duration also increased although the increase was reduced as the marsh control point elevation was decreased. This is seen graphically in Figure 7 where the percentage of the duration relative to the eight tidal cycle simulation duration (96 hr) as a function of the five marsh control point elevation levels is shown.

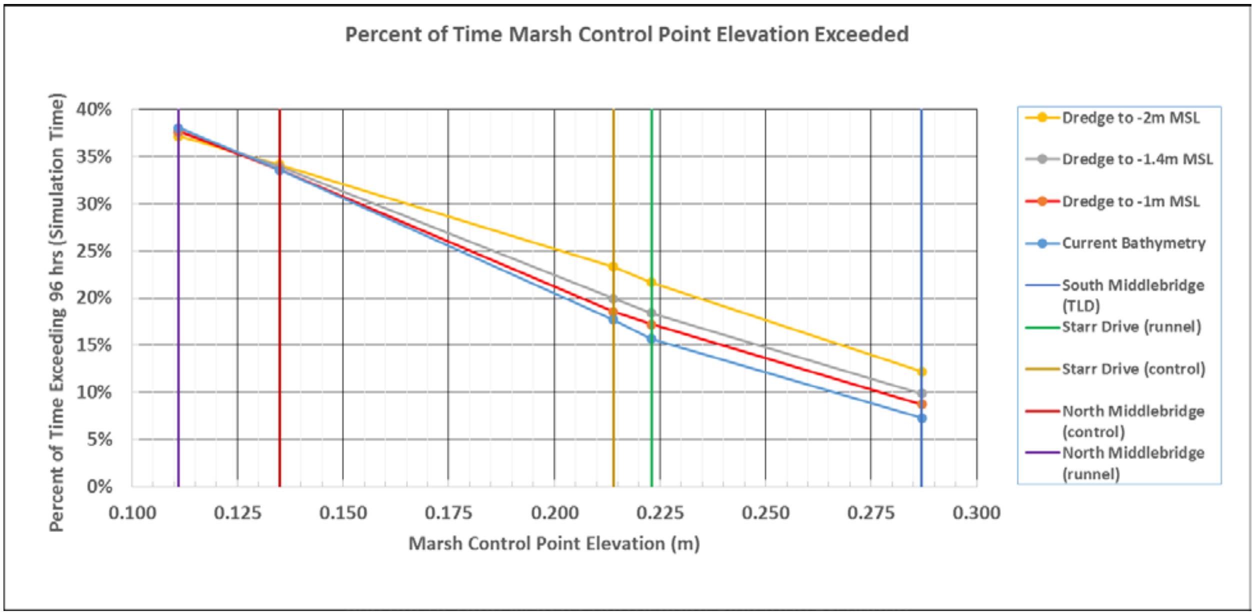

Figure 7. Relationship of the percentage of time that each dredging scenario exceeds the total simulation time (96 hr) for the five marsh control point elevations.

The relationship for each dredge alternative was found to be close to linear with a somewhat shallower negative slope as the dredge depth was increased. The difference among the dredge alternatives was minimal for the lower two marsh control point elevations but almost equally offset from each other for the three higher marsh elevations.

The percentage increase of each dredging scenario exceeding the current bathymetry scenario for the five marsh control point elevations is shown in Figure 8. The highest marsh control point elevation [0.287 m (MSL) for South Middlebridge (TLD)] showed the greatest increase, from 20%, 36% and 68% more than the current bathymetry for the -1m, -1.4m and -2m dredging alternatives, respectively. The lowest marsh control point elevations [0.111 m (MSL) for North Middlebridge (runnel) and 0.135 m (MSL) for North Middlebridge (control)] showed essentially no change (<±2%) for any of the dredging alternatives.

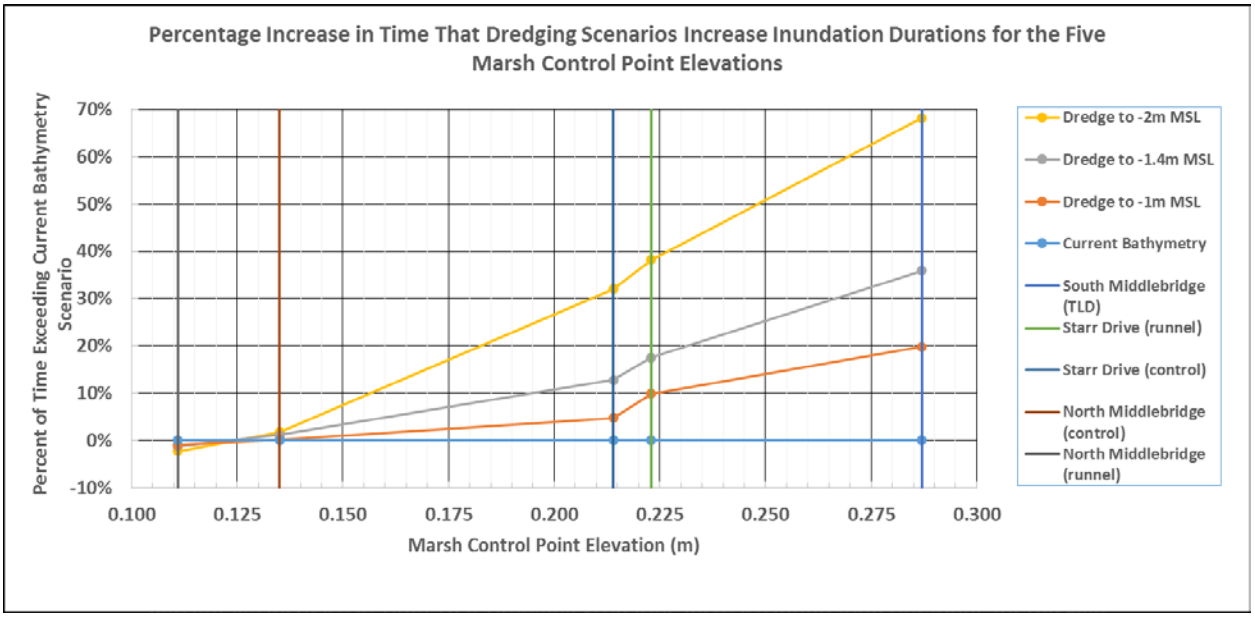

Figure 8. Relationship of the percentage increase in time that each dredging scenario increases inundation durations compared to the current bathymetry for the five marsh control point elevations.

Conclusions

The results at the two lower marsh control point elevations [North Middlebridge (runnel) and (control)] were insensitive to the amount of dredging while the higher three marsh elevations [Starr Drive (control) and (runnel) and South Middlebridge (TLD)] indicated an increasing sensitivity to increased dredging depths.

Reference

Swanson, C., M. Spaulding and A. Shaw, 2016. *Impact of Dredging the Lower Narrow River on Circulation and Flushing in the Narrow River*. Prepared for Rhode Island Coastal Resources Management Council. Prepared by Ocean Engineering, University of Rhode Island, 25 August 2016.

Appendix

Table A1. Durations of exceedances (hr) for each of the four dredge alternatives for the eight high tides with each of the five marsh control point elevations where SMB Is South Middlebridge (TLD), SDr is Starr Drive (runnel), SDc is Starr Drive (control), NMBc is North Middlebridge (control), and NMBr is North Middlebridge (runnel). The marsh control point elevations, shown in brackets, have been ordered from largest to smallest which generally results in durations from shortest to longest.

Dredge Alternative	High Tide Number	SMB (hr) [0.287m]	SDr (hr) [0.223m]	SDc (hr) [0.214m]	NMBc (hr) [0.135m]	NMBr (hr) [0.111m]
Current Bathymetry	1	2.98	4.02	4.18	5.55	6.02
Current Bathymetry	2	-	2.22	2.42	3.92	4.37
Current Bathymetry	3	3.50	4.57	4.73	6.25	6.78
Current Bathymetry	4	0.48	2.45	2.65	4.32	4.85
Current Bathymetry	5	-	1.80	2.05	3.90	4.42
Current Bathymetry	6	-	-	-	2.47	3.07
Current Bathymetry	7	-	-	0.93	3.18	3.73
Current Bathymetry	8	-	-	-	2.63	3.32
Current Bathymetry	All 8	6.97	15.05	16.97	32.22	36.55
Dredged to -1m	1	3.12	4.10	4.23	5.48	5.90
Dredged to -1m	2	0.68	2.32	2.48	3.88	4.30
Dredged to -1m	3	3.58	4.58	4.72	6.10	6.58
Dredged to -1m	4	0.95	2.52	2.72	4.23	4.72
Dredged to -1m	5	-	2.00	2.23	3.90	4.38
Dredged to -1m	6	-	-	-	2.58	3.12
Dredged to -1m	7	-	1.03	1.38	3.28	3.80
Dredged to -1m	8	-	-	-	2.80	3.42
Dredged to -1m	All 8	8.35	16.53	17.78	32.28	36.20

Dredge Alternative	High Tide Number	SMB (hr) [0.287m]	SDr (hr) [0.223m]	SDc (hr) [0.214m]	NMBc (hr) [0.135m]	NMBr (hr) [0.111m]
Dredged to -1.4m	1	3.28	4.17	4.30	5.43	5.80
Dredged to -1.4m	2	1.18	2.45	2.62	3.87	4.25
Dredged to -1.4m	3	3.70	4.60	4.75	5.98	6.42
Dredged to -1.4m	4	1.30	2.65	2.82	4.18	4.62
Dredged to -1.4m	5	-	2.25	2.45	3.95	4.38
Dredged to -1.4m	6	-	-	0.42	2.73	3.22
Dredged to -1.4m	7	-	1.55	1.78	3.43	3.88
Dredged to -1.4m	8	-	-	-	3.00	3.53
Dredged to -1.4m	All 8	9.47	17.68	19.13	32.58	36.10
Dredged to -2m	1	3.45	4.23	4.35	5.30	5.60
Dredged to -2m	2	1.58	2.62	2.77	3.83	4.15
Dredged to -2m	3	3.83	4.63	4.75	5.78	6.12
Dredged to -2m	4	1.67	2.78	2.93	4.12	4.47
Dredged to -2m	5	1.18	2.55	2.72	4.00	4.37
Dredged to -2m	6	-	0.95	1.27	2.92	3.33
Dredged to -2m	7	-	2.03	2.23	3.60	3.98
Dredged to -2m	8	-	0.98	1.38	3.23	3.70
Dredged to -2m	All 8	11.72	20.80	22.40	32.80	35.72