Savannah Harbor Expansion Project

Sensitivity Analysis of Proposed Sill on Middle River

September 2009

Introduction

This report summarizes the results of **1)** impacts to Shortnose Sturgeon (SNS) habitat within the Savannah River estuary, **2)** freshwater marshes/wetlands adjacent to the estuary and **3)** water quality (dissolved oxygen, D.O.) due to the addition of a sill on Middle River to the mitigation plan. The sill on Middle River was proposed as a possible mitigation feature for protection of observed SNS habitat along a bend in lower Middle River. Evaluation of the new mitigation feature along with the feature's impacts to other resources is the focus of this report.

In addition to the impact analysis, the criteria for which SNS juvenile habitat is categorized as suitable or unsuitable has changed from previous reporting to better reflect observed SNS habitat in critical areas.

SNS Juvenile Habitat Research

Shortnose Sturgeon Research conducted in 1999-2000 by Collins et al [(a)] in the Lower Savannah River for the Georgia Ports Authority reported important findings, which are useful and pertinent to the SHEP. Based on discussions between the USACE and NOAA-Fisheries, the following findings from Collins et al research have become focal points for modeling analysis and defining SNS habitat.

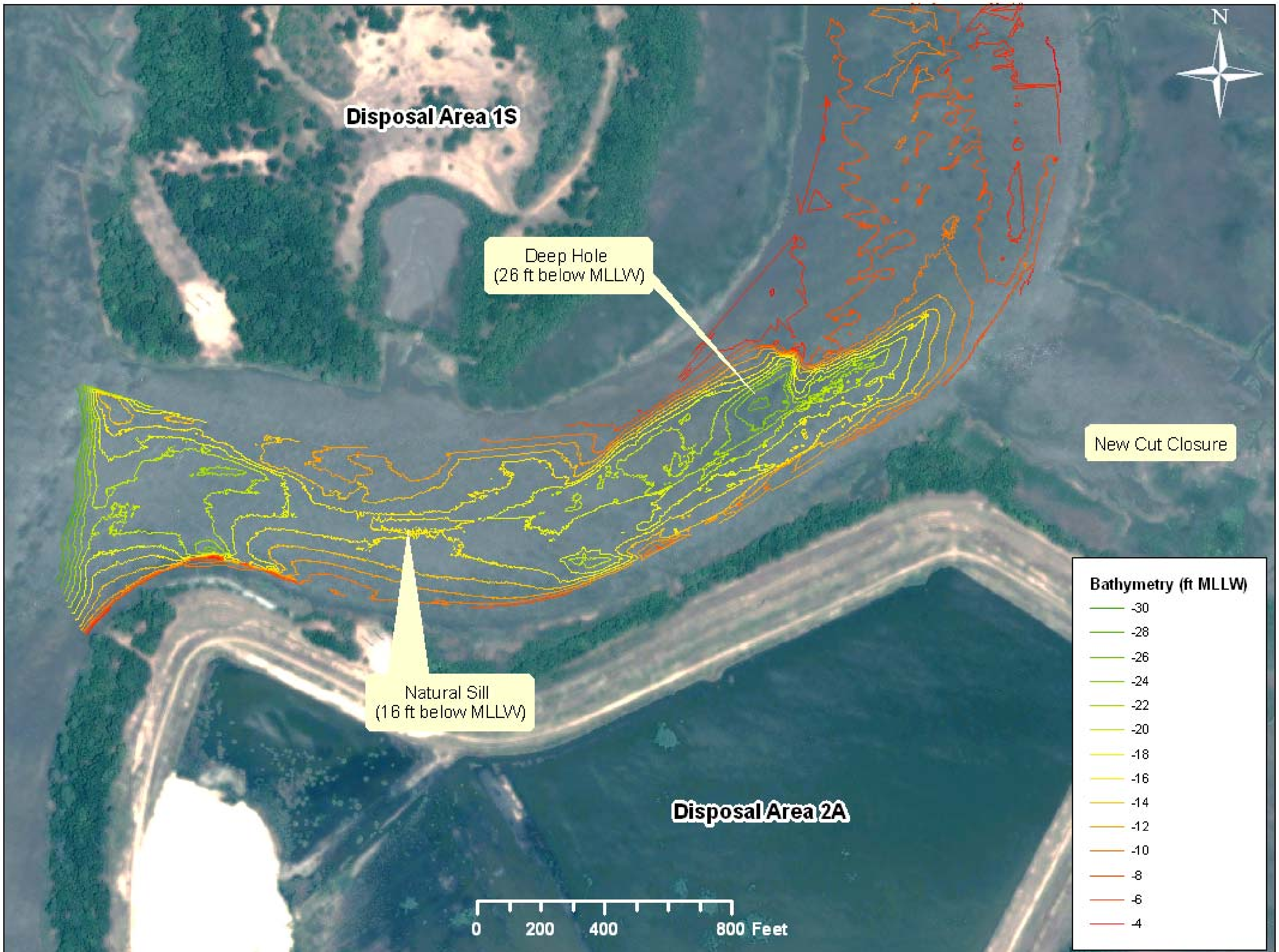
- SNS juveniles (defined as < 56 cm TL) occur in salinities up to 17.6 ppt
- During temperatures < 22^{o}C, juveniles prefer a location inside the Middle River (river km 31.3) in a 7.9 meter deep hole.
- At river km 31.3, 9 juvenile fish were captured with 4 measuring < 40 cm TL, Collins suggested this area is critical nursery habitat for young SNS
- Water quality data suggest that the natural sill between the 7.9 meter deep hole and the confluence with the Front River may minimize salinity fluctuations associated with the tidal cycle.
- Using Collins salinity data (43 data points) for juvenile SNS captured during temperatures < 22^{o}C adjacent to or within the deep hole, a max salinity tolerance of 14.9 ppt was identified.

Middle River Survey

To confirm the 7.9 m (approximately 26 ft) hole on Middle River and obtain more information about it's size and shape, a survey was completed in March 2009 of Middle River from the confluence with Front River to just upstream of the New Cut closure. See Figure 1. A large hole does exist within this area at a depth of approximately 26 ft below MLLW. There is also a sill 16 ft below MLLW between the deep hole and Front River that aids in protecting the area from high saline waters found on the bottom of Front River. There are some questions about how this hole and sill were formed, and if it is natural or man-made. There are some suggestions that the deep hole was man-made due to the steep side slope on the northeast edge of the hole. However, that is only speculation and has not been proven true or false.

(a) Collins, Mark R., William C. Post, Daniel C. Russ. *Distribution of Shortnose Sturgeon in the Lower Savannah River*. Report to Georgia Ports Authority.

Figure 1: Middle River Survey conducted March 2009



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Sill Design and Model Input Parameters

Improving the sill on Middle River at the Front River confluence was proposed as a mitigation feature to protect SNS habitat. The idea is that the sill would be low enough to allow fish movement to the Middle River bend, but would be high enough to inhibit high concentrations of bottom salinity moving from Front River into the bend. Table 1 outlines the design parameters of this sill. These are considered the maximum height and length parameters for the sill. Anything higher could be undesirable for the SNS, could impact navigation on the Middle River and/or could impact the current geometry of the deep hole in the bend on Middle River.

The sill was modeled by changing the bottom elevation in EFDC/WASP grid cells 16_82, 17_82 and 18_82 to elevation -2.88 m NGVD (-6.4 ft MLLW) which is an increase of approximately 4 meters over the three cells average bottom elevations. See Figure 2 for a map showing the cell locations. Due to the change in grid cell geometry both the hydrodynamic (EFDC) and water quality (WASP) models were re-run for the analysis.

Table 1: Design Parameters of the Middle River Sill

Current Conditions at Middle River/Front River Confluence	
Bottom elevation	~20 ft below MLLW
Channel Width	~600 ft
Proposed Sill Design Parameters	
Top of Sill	6.4 ft below MLLW
Sill Length	~1500 ft long
Sill would have sloped sides tapering to existing bottom elevations.	
Constructed with sandy materials possibly coming from nearby disposal areas 1S & 2A.	
Total channel area on Middle River impacted with design is approximately 19 acres.	

Figure 2: EFDC/WASP Grid

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Deep hole is located within EFDC grid cell 20 82 and 21 82.

SNS Habitat Impact Analysis

SNS Habitat Criteria

The SNS juvenile habitat evaluation criteria originally chosen for SHEP impact evaluation was decided upon by the Interagency Coordination Team. Details of this criteria are shown in Table 2. Figure 3 shows the results of the existing conditions model run with the original habitat suitability criteria.

A new set of SNS juvenile habitat criteria was suggested by NOAA-Fisheries in hopes that the existing conditions (basemaps) would better represent the observed SNS habitat patterns noted in research conducted by Collins et al in 1999-2000. See Table 3 for the new criteria. The change is shown in blue. The D.O. criteria does not change with the new evaluation, only the salinity criteria changes.

The area of interest in this analysis is the bend in Middle River just upstream of the confluence with Front River and on Front River below Houlihan Bridge to the Middle River confluence. SNS juveniles have been observed in this area during cool months of the year by Collins et al, however our initial impact basemaps used for SHEP impacts did not show this area to be suitable habitat for SNS Juveniles during January due to high salinity recordings. See Figure 3. Once the new criteria was established the existing conditions basemap better correlates the predicted SNS Juvenile habitat with the observed datasets. See Figure 4.

Table 2: SNS Criteria Developed by the Interagency Coordination Team

Species & Life Stage	Freshwater Flow Conditions	Simulation Period	Habitat Criteria
Shortnose Sturgeon (juvenile)	50%-ile of Long Term	January	Suitable habitat when DO >= 3.5 mg/l at 90% exceedance (10th %ile), >=3.0 at 95% (5th percentile), and >=2.0 at 99% (1 percentile) Suitable habitat when Max Salinity <= 4 ppt

Table 3: SNS Criteria Developed by National Marine Fisheries

Species & Life Stage	Freshwater Flow Conditions	Simulation Period	Habitat Criteria
Shortnose Sturgeon (juvenile)	50%-ile of Long Term	January	Suitable habitat when DO >= 3.5 mg/l at 90% exceedance (10th %ile), >=3.0 at 95% (5th percentile), and >=2.0 at 99% (1 percentile) AND Suitable habitat when **50%ile of Max Salinity <= 14.9 ppt**

Figure 3: SNS Habitat Basemaps (Previously Approved Criteria)

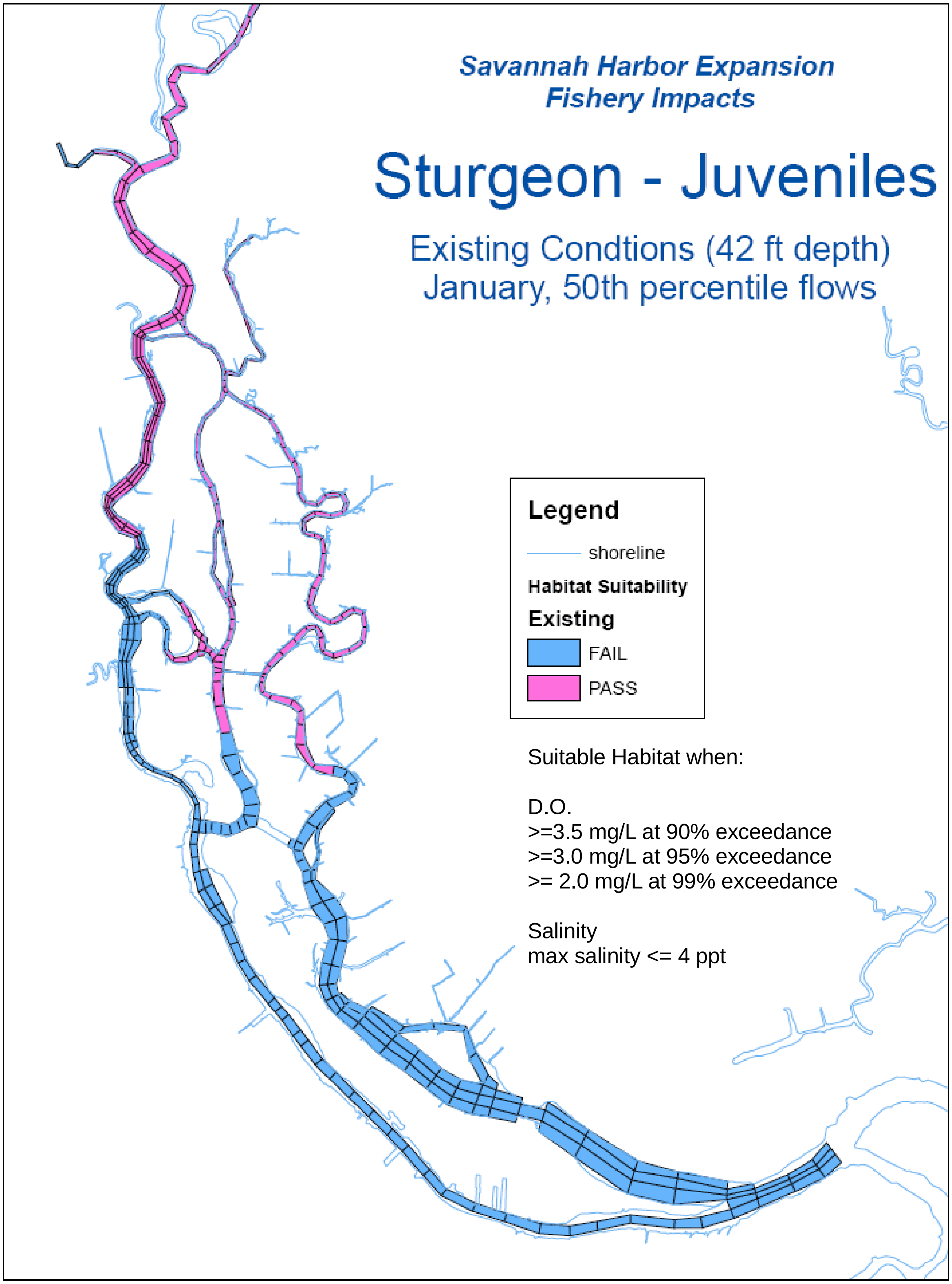
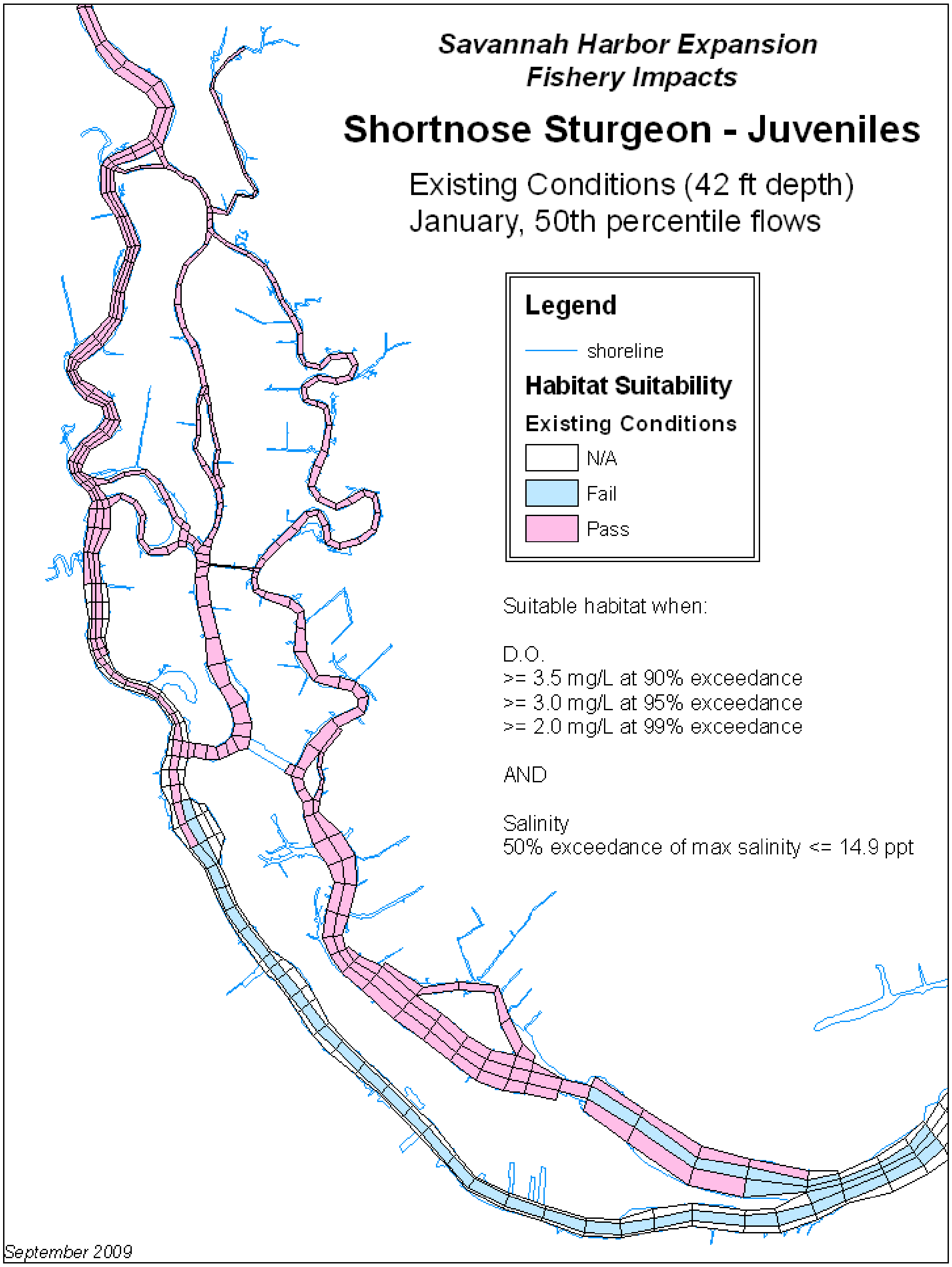


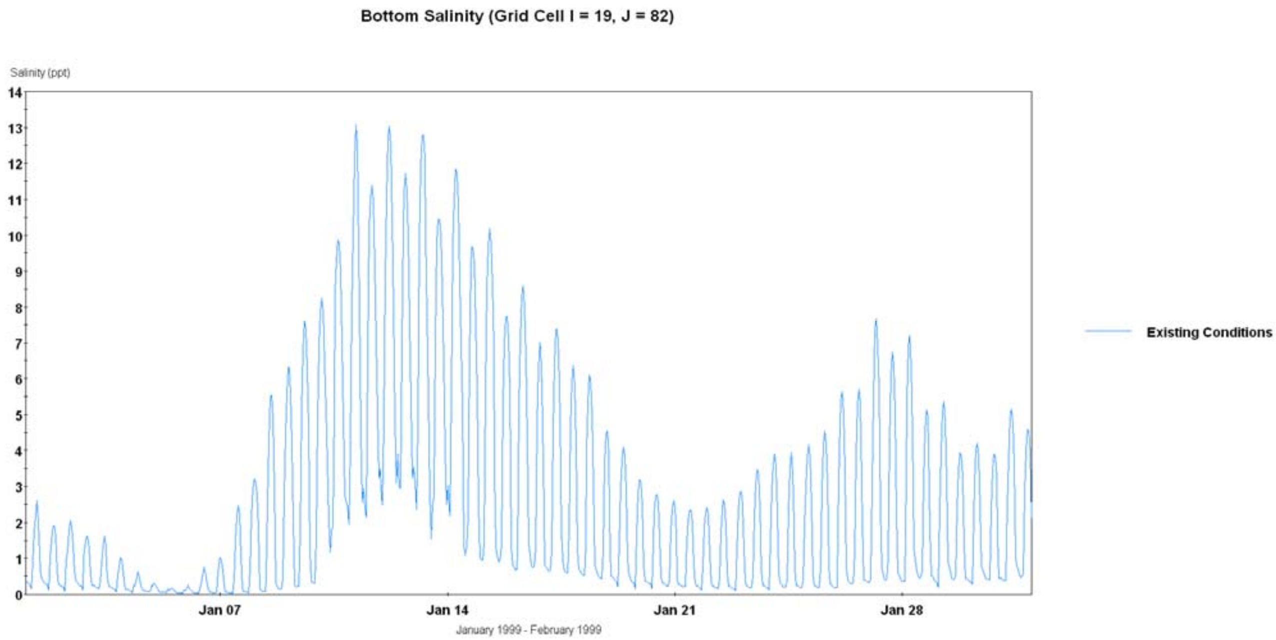
Figure is from the report titled *Evaluation of Fishery Habitat Impacts with Proposed Mitigation Plan* dated June 2008.

Figure 4: SNS Habitat Basemaps (New Approved Criteria)



In the area of interest maximum bottom salinities range from 9.6 to 14.9 ppt for the January run scenario with existing bathymetry conditions. This range of maximum bottom salinity satisfies both sets of the new habitat criteria, and failed the original criteria. At model grid cell 19_82 (on Middle River at site of deep hole) the maximum bottom salinity was 13.1 ppt which occurred during the spring high tide. The average bottom salinity throughout the run period within the bend was 2.6 ppt. Indicating the spring peak tides have a substantial impact on the salinity in Middle River. Outside of this tidal condition the salinity values are much lower. Figure 5 shows the salinity variation over the full month at model grid cell 19_82.

Figure 5: Modeled Bottom Salinity Output (Grid Cell 19_82 on Middle River at deep hole)

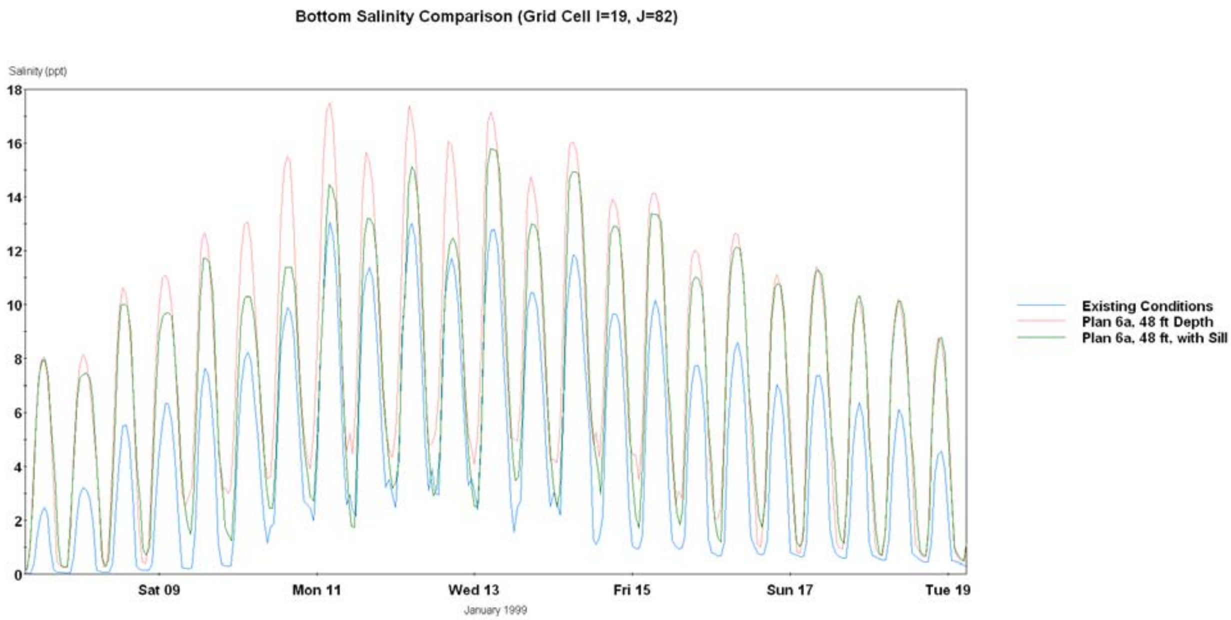


The new criteria appears to be more appropriate than the original for the Juveniles since they have been observed in the Middle River bend and the modeled salinity seems to be in line with Collins et al research.

SNS Habitat Feature Evaluation

To preserve the SNS Juvenile habitat on Middle River, especially within the deep hole at the bend, improvements to the sill on Middle River were suggested, modeled and incorporated into the mitigation plan. Figure 6 shows a comparison between the existing conditions, the 48 ft channel depth with mitigation plan 6a without the sill on Middle River and with the sill on Middle River. The comparison is zoomed to the week of the January spring tide event and shows bottom salinities within the Middle River bend. As shown in the figure, the sill in place on Middle River does reduce bottom salinities. However, it doesn't fully mitigate for the impact due to deepening the channel to 48 feet.

Figure 6: Bottom Salinity Comparison on Middle River Bend (Beyond Sill)



The following figures, 7 and 8, show the changes in habitat suitability due to the project. In Figure 7 the comparison is made between the existing conditions and the 48 ft channel depth with mitigation plan 6a. In Figure 8 the comparison is made between the existing conditions and the 48 ft channel depth with mitigation plan 6a and the sill at Middle River. Gains and losses in habitat are shown on the figures for the new approved habitat criteria. Since the run period is in January, the habitat suitability is based on the salinity criteria. The D.O. values predicted for this run period are high enough to meet the water quality criteria.

Both figures show a loss of habitat on Front River from Kings Island Turning Basin up to Steamboat River. Losses in this area are due to increases in salinity caused by the project, not water quality impacts to D.O. values. The habitat losses do not extend up Middle River through the area of interest in the bend. These figures do not definitively show the benefit of the sill for Juvenile SNS in the Middle River bend. However, comparing the bottom salinity over the full tidal run period as seen in Figure 6 does show a decrease in salinity due to the improvement of the sill.

In addition to salinity and D.O., the velocities were also evaluated within the Middle River bend (grid cell 19_82) to assess the potential for shoaling within the observed SNS habitat area due to improvements to the sill. The peak velocities were compared between the model runs with and without the sill in place. The sill showed a maximum difference in the daily peaks of 0.42 fps at mid-depth in the water column. The maximum differences on the bottom was 0.14 fps and the max difference on the surface was actually a slight increase with the sill. Averaging over the full water column a very minor difference was noted, and was not a significant change with the sill in place. However, looking at the velocity comparisons by depth show that there are decreases at mid-depth and at the bottom of the water column that could have an influence on shoaling in the area. Slower velocities would allow an opportunity for sediment to fall out of the water column behind the sill. The potential for increased shoaling in this area with the sill does exist, but can’t be defined as great and is not expected to be significant.

Figure 7: SNS Habitat Impacts Comparison Between Existing Conditions and 48 ft Channel Depth, Mitigation Plan 6a ONLY - no Sill on Middle River (New Approved Criteria)

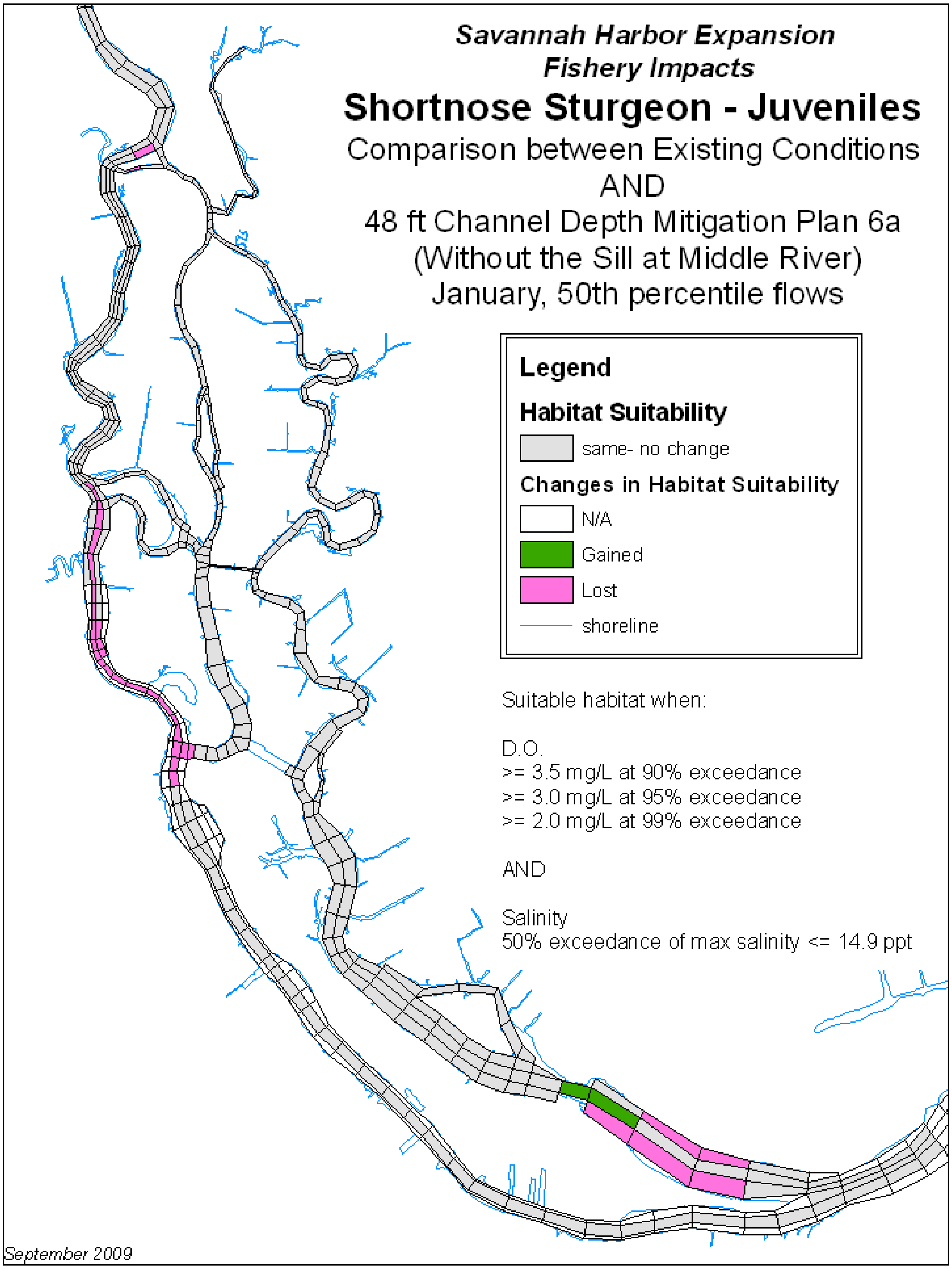
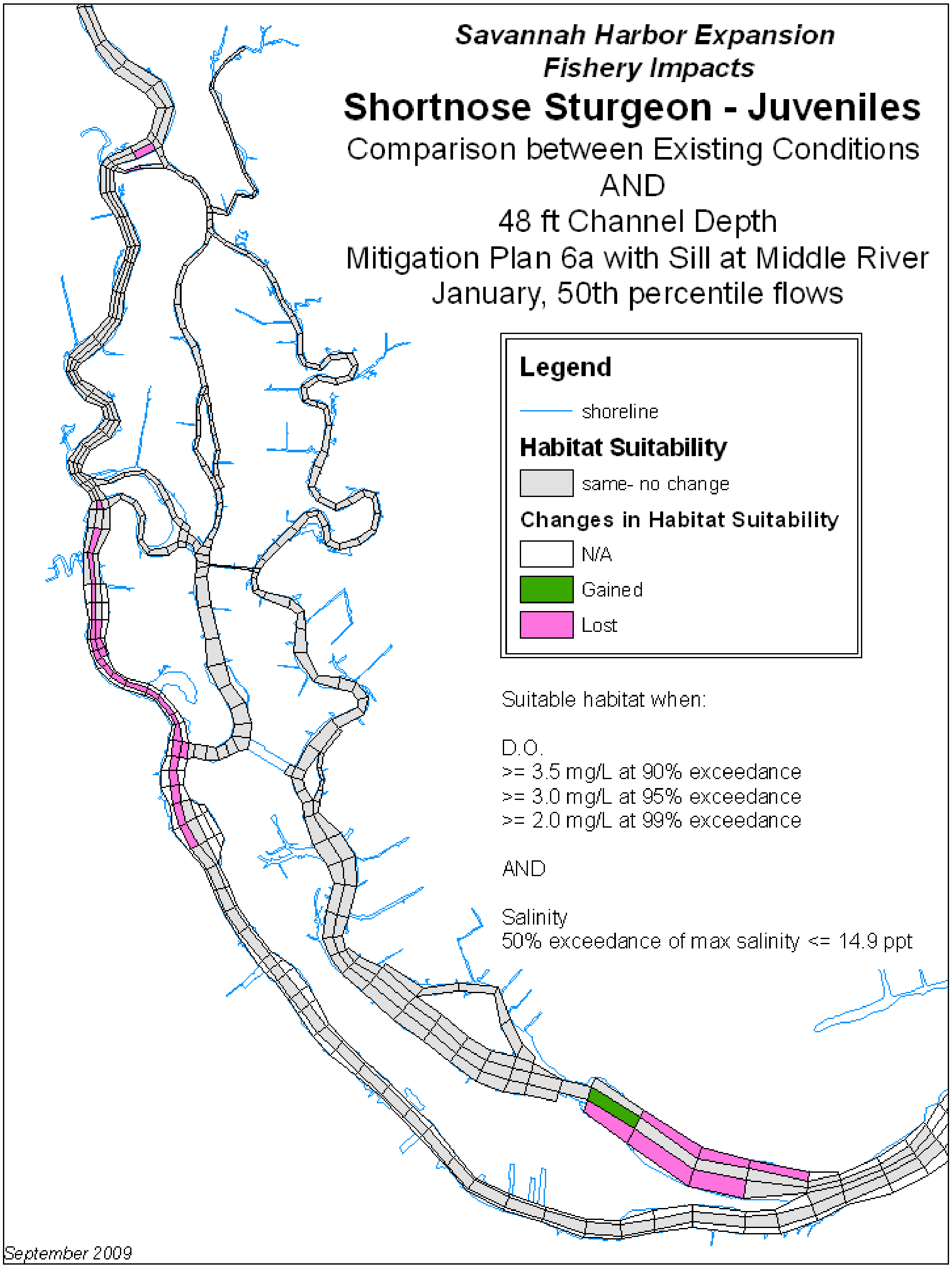


Figure 8: SNS Habitat Impacts Comparison Between Existing Conditions and 48 ft Channel Depth, Mitigation Plan 6a with the Sill on Middle River (New Approved Criteria)



Freshwater Marsh/Wetland Impact Analysis

Marsh/Wetland Impact Analysis

Impacts to Tidal Fluctuations

Impacts to tidal fluctuations within the estuary due to inclusion of a new mitigation feature (sill at the mouth of Middle River) were examined at several grid cell locations on Back and Middle Rivers. See Figure 4. Details of tidal variability are shown by water depth in Figures 5 through 11. None of these seven locations along Middle and Back River show an impact to tidal depth or timing as a result of inclusion of the new mitigation feature within the model geometry. Comparisons are made between the 48 ft depth alternative with Mitigation Plan 6a in place with and without the new mitigation feature modeled.

Figure 4: EFDC Grid Cell Locations Examined for Impacts to Tidal Fluctuations

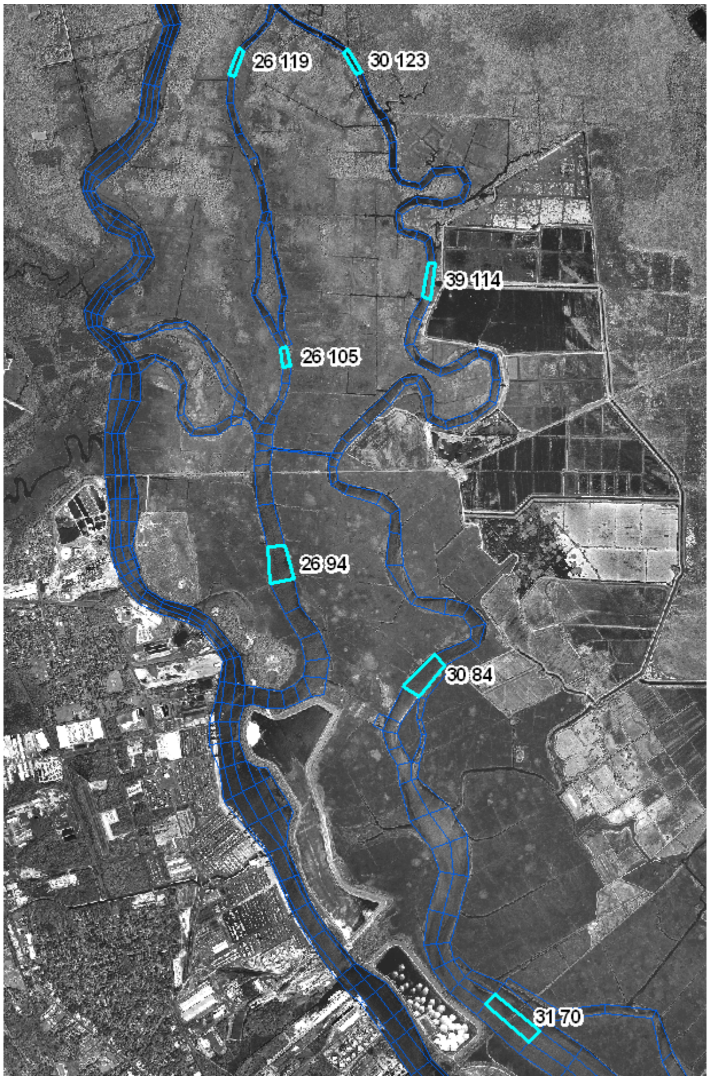


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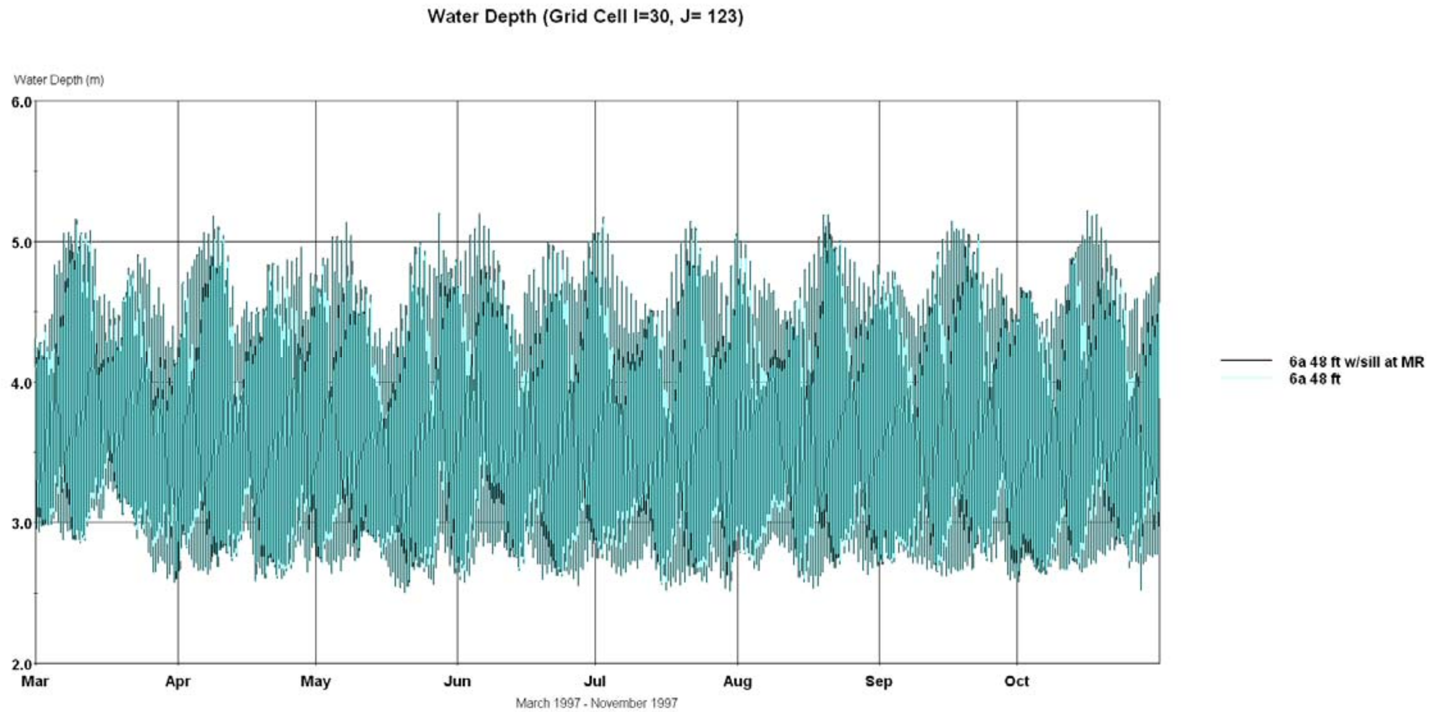
Figure 5: Water Depth Comparison at EFDC Grid Cell 30 123

A: full run period March through October 1997



B: zoomed run period August 1997

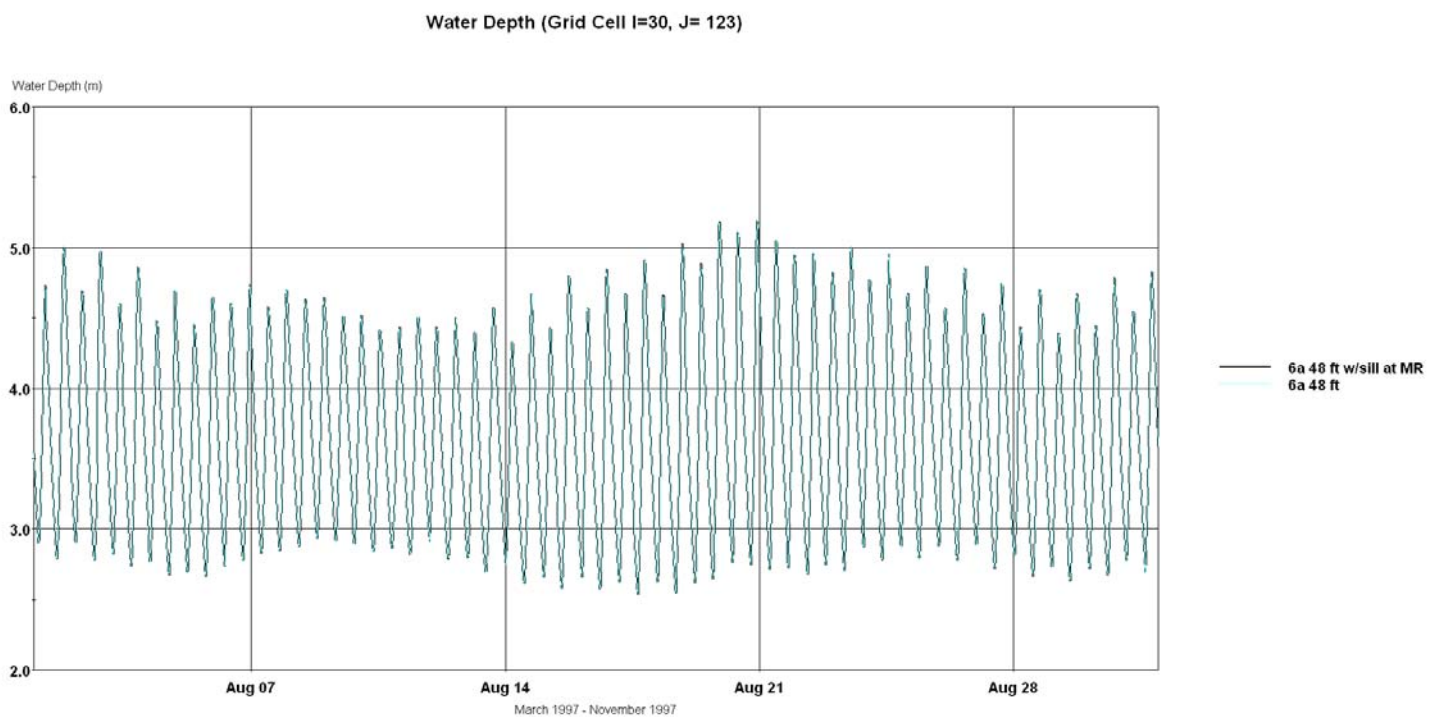
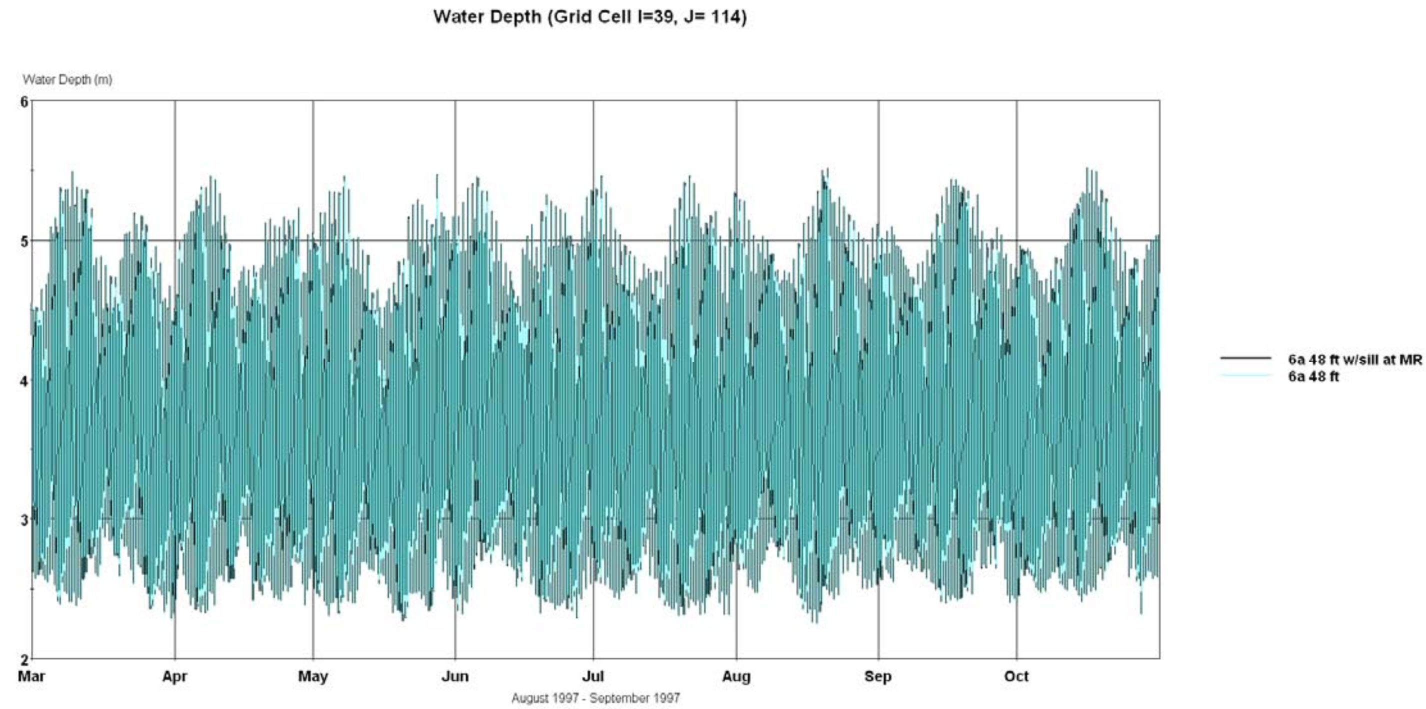


Figure 6: Water Depth Comparison at EFDC Grid Cell 39 114

A: full run period March through October 1997



B: zoomed run period August 1997

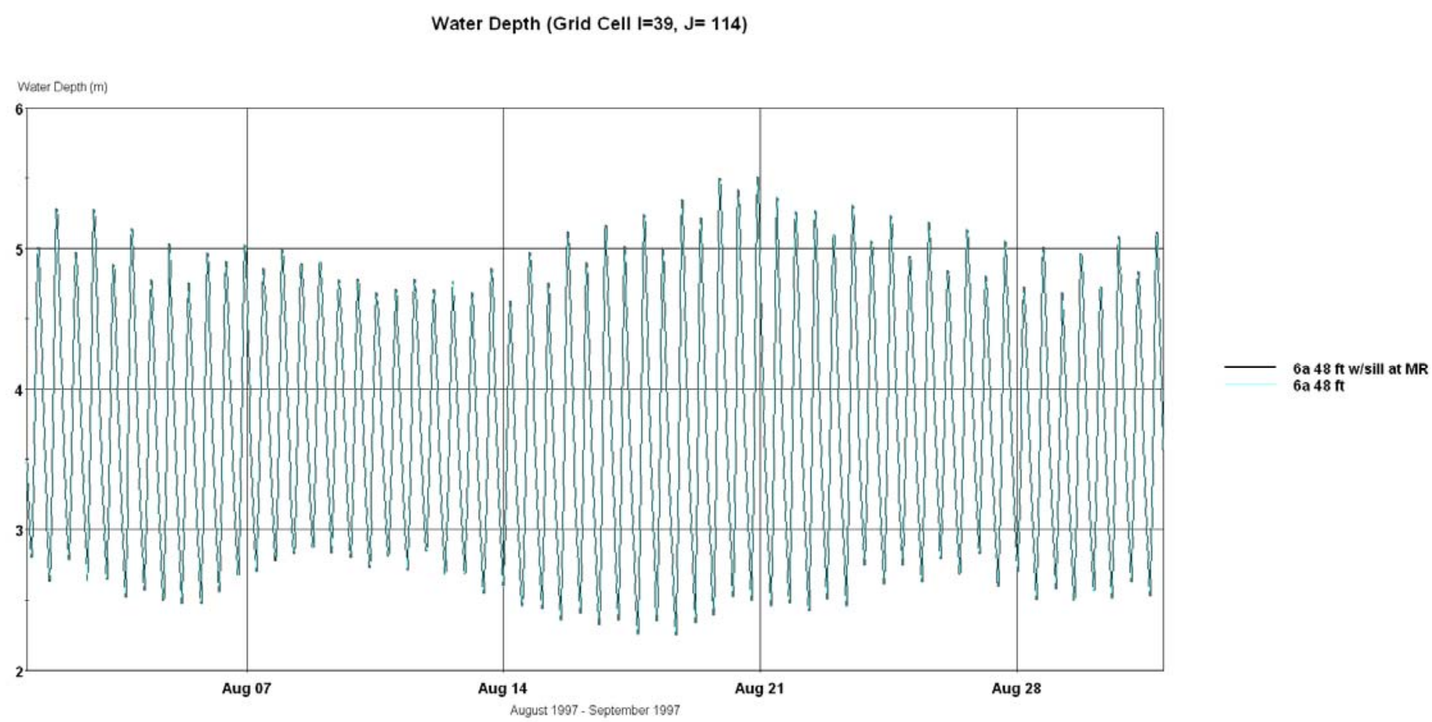
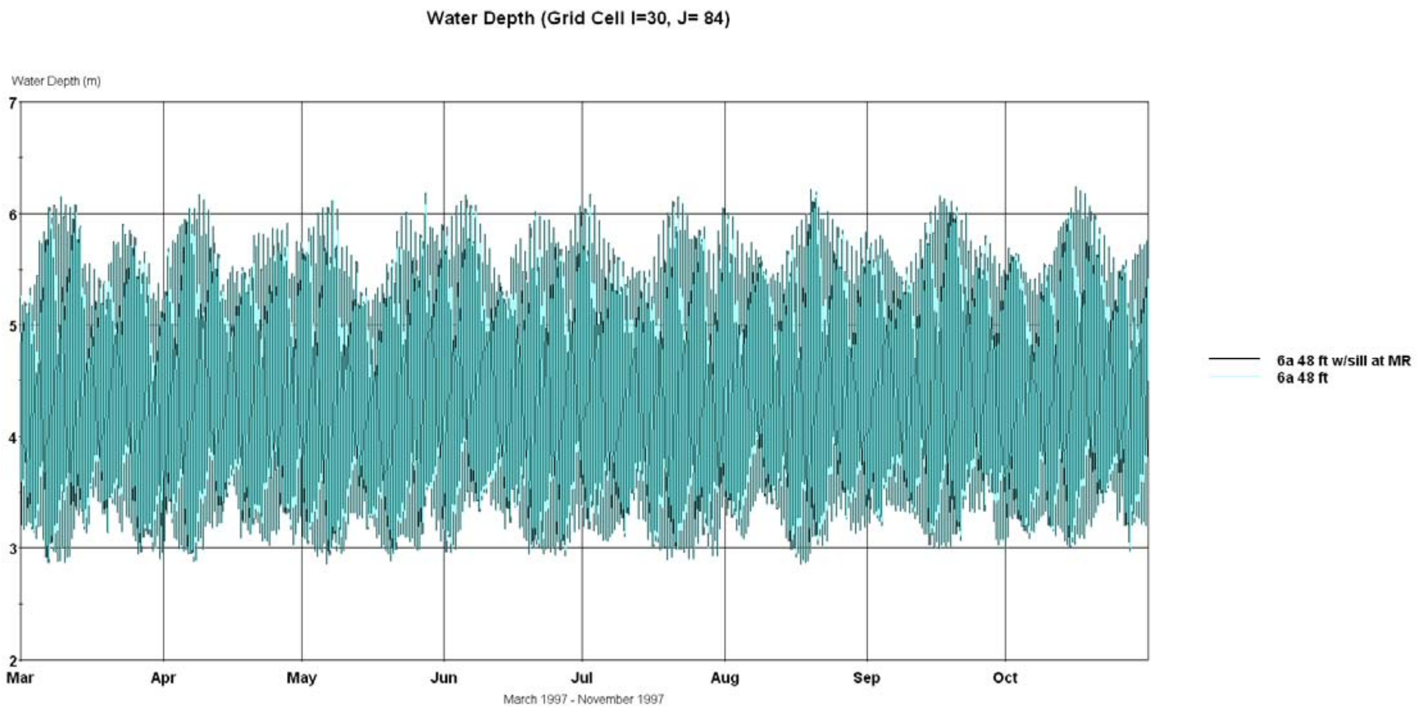


Figure 7: Water Depth Comparison at EFDC Grid Cell 30 84

A: full run period March through October 1997



B: zoomed run period August 1997

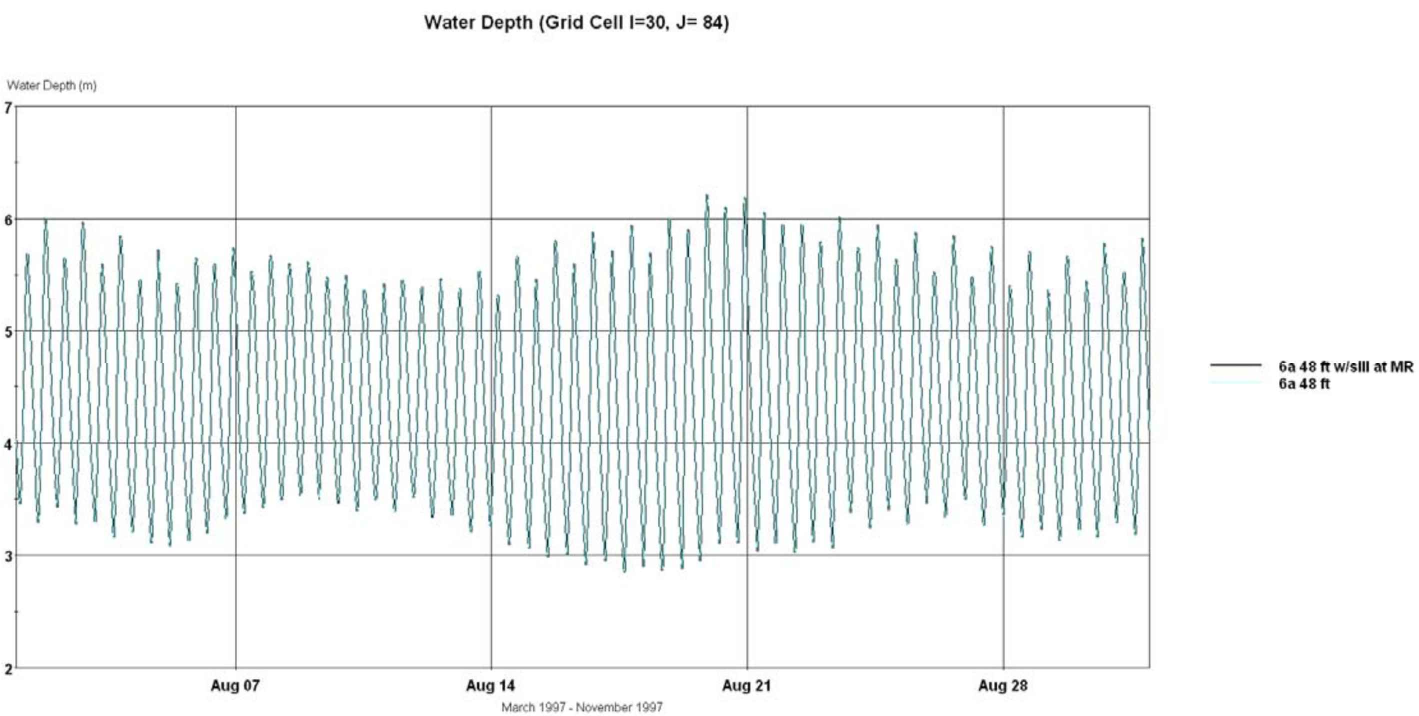
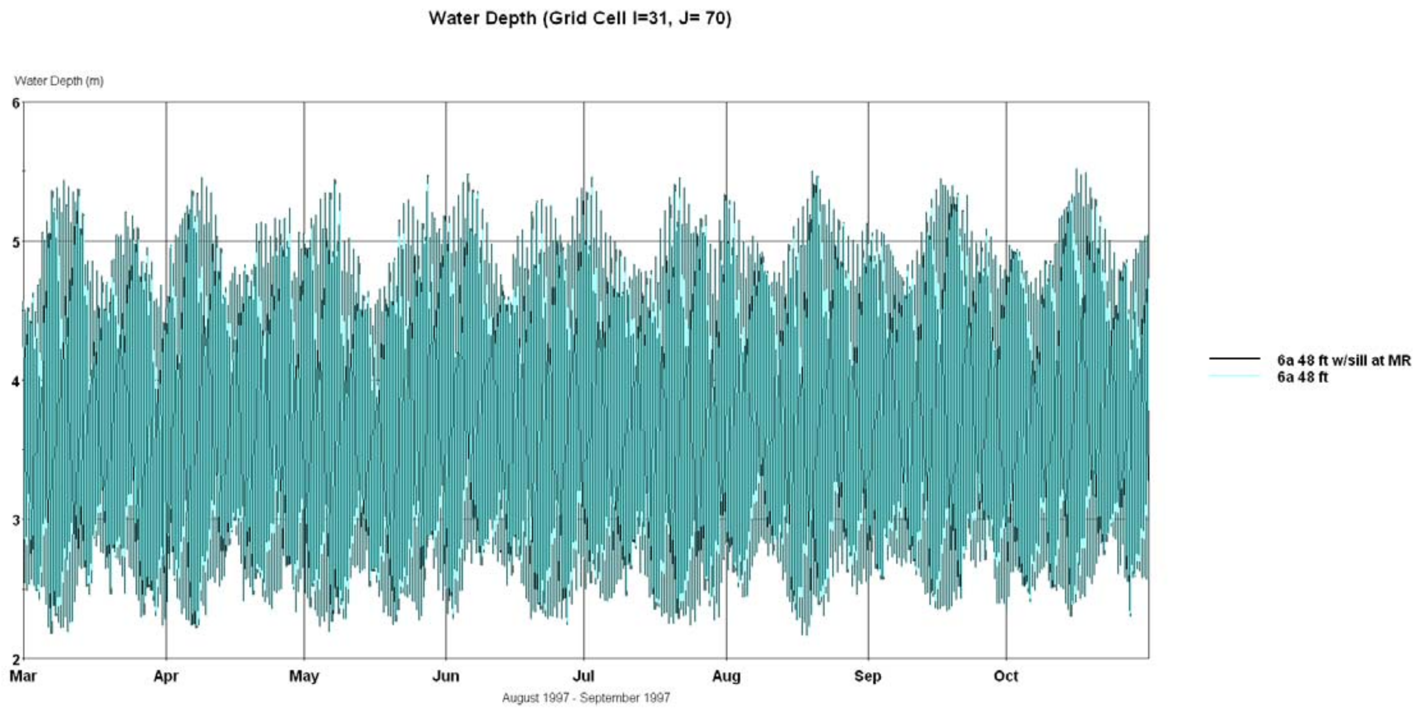


Figure 8: Water Depth Comparison at EFDC Grid Cell 31 70

A: full run period March through October 1997



B: zoomed run period August 1997

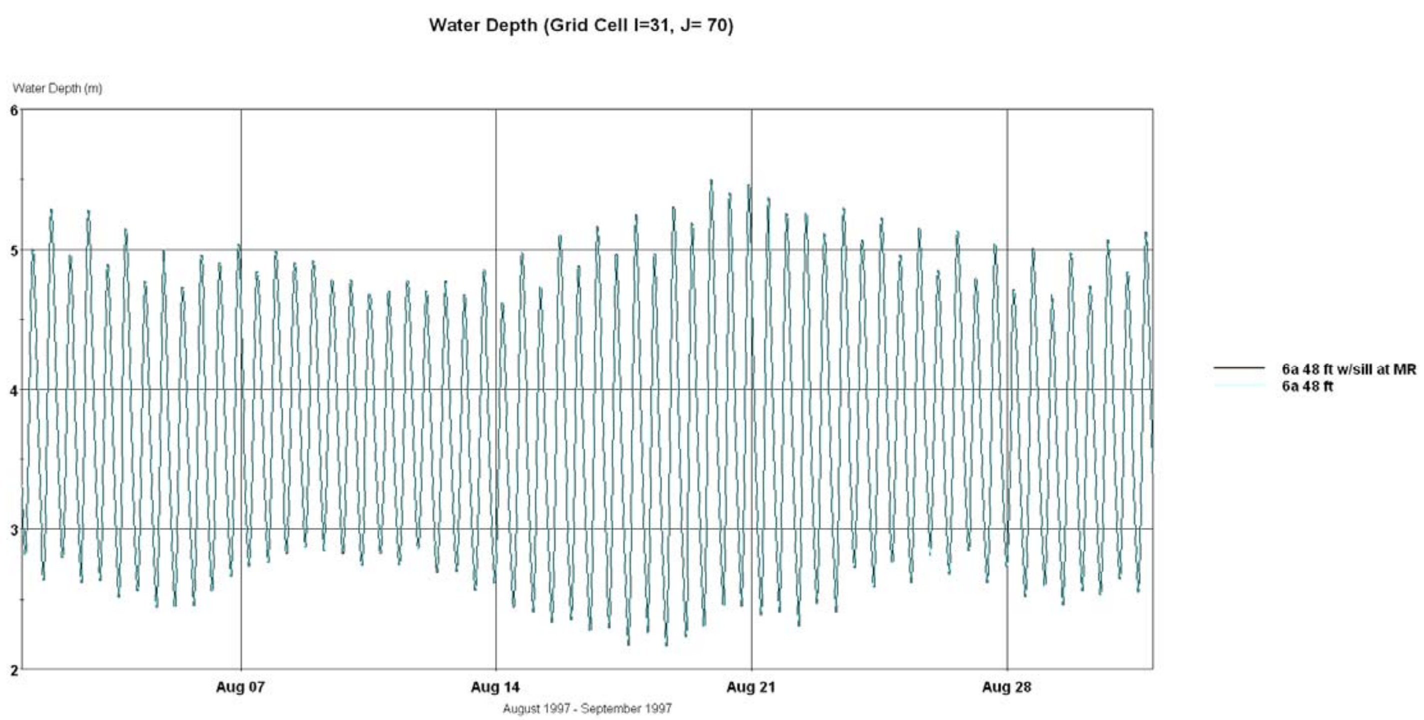
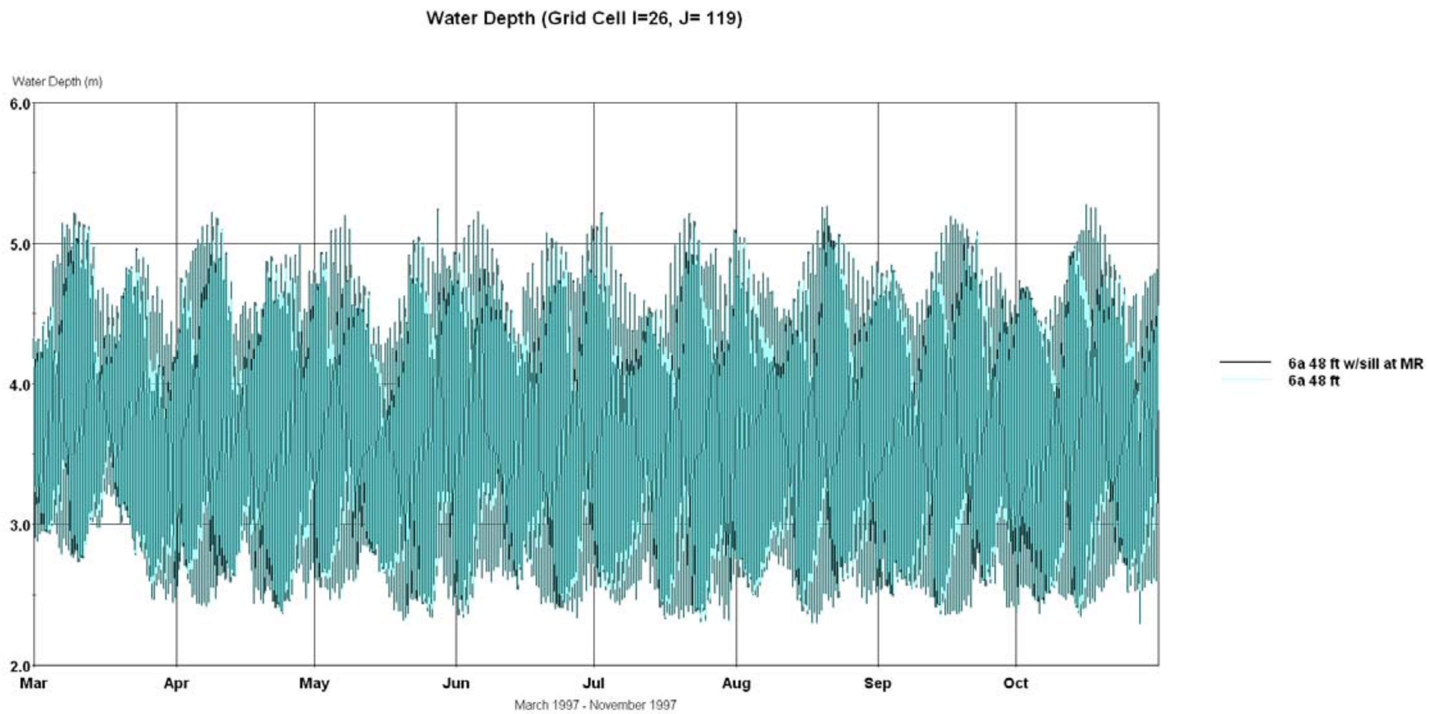


Figure 9: Water Depth Comparison at EFDC Grid Cell 26 119

A: full run period March through October 1997



B: zoomed run period August 1997

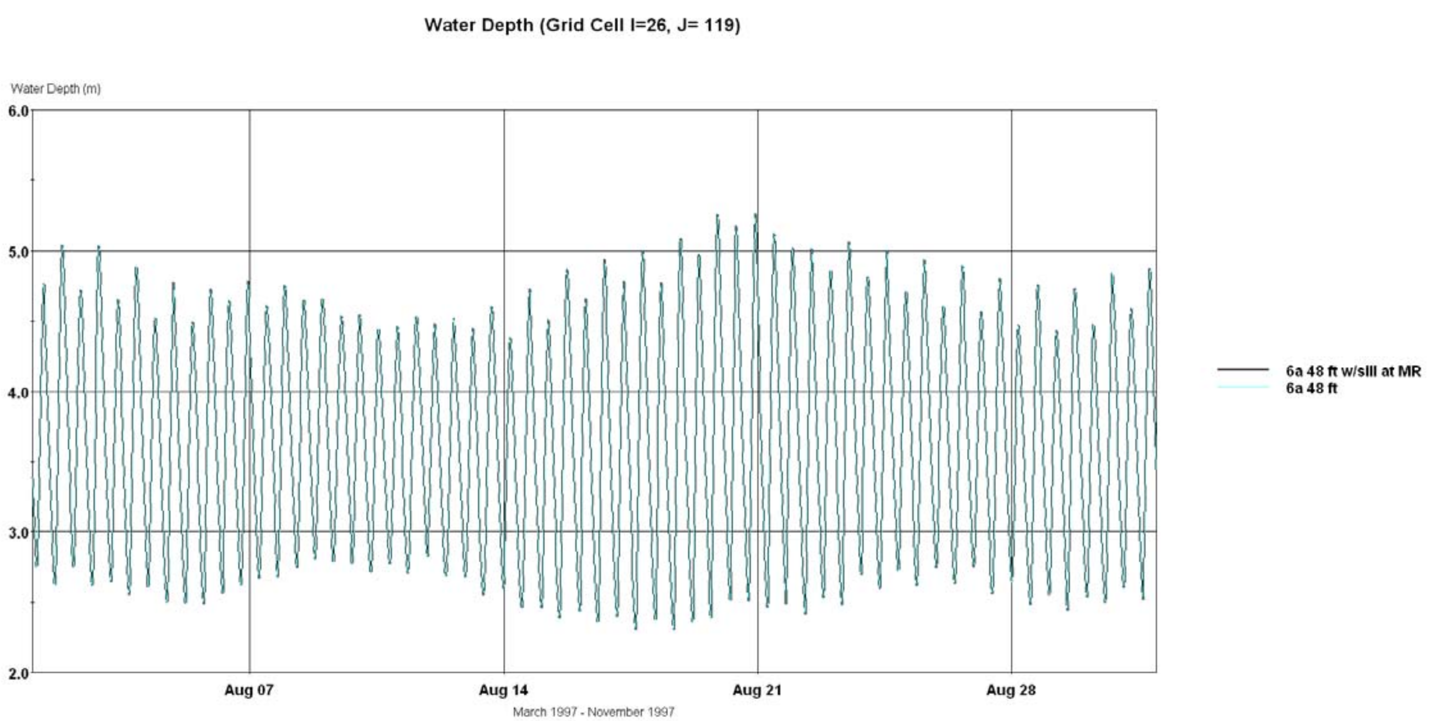
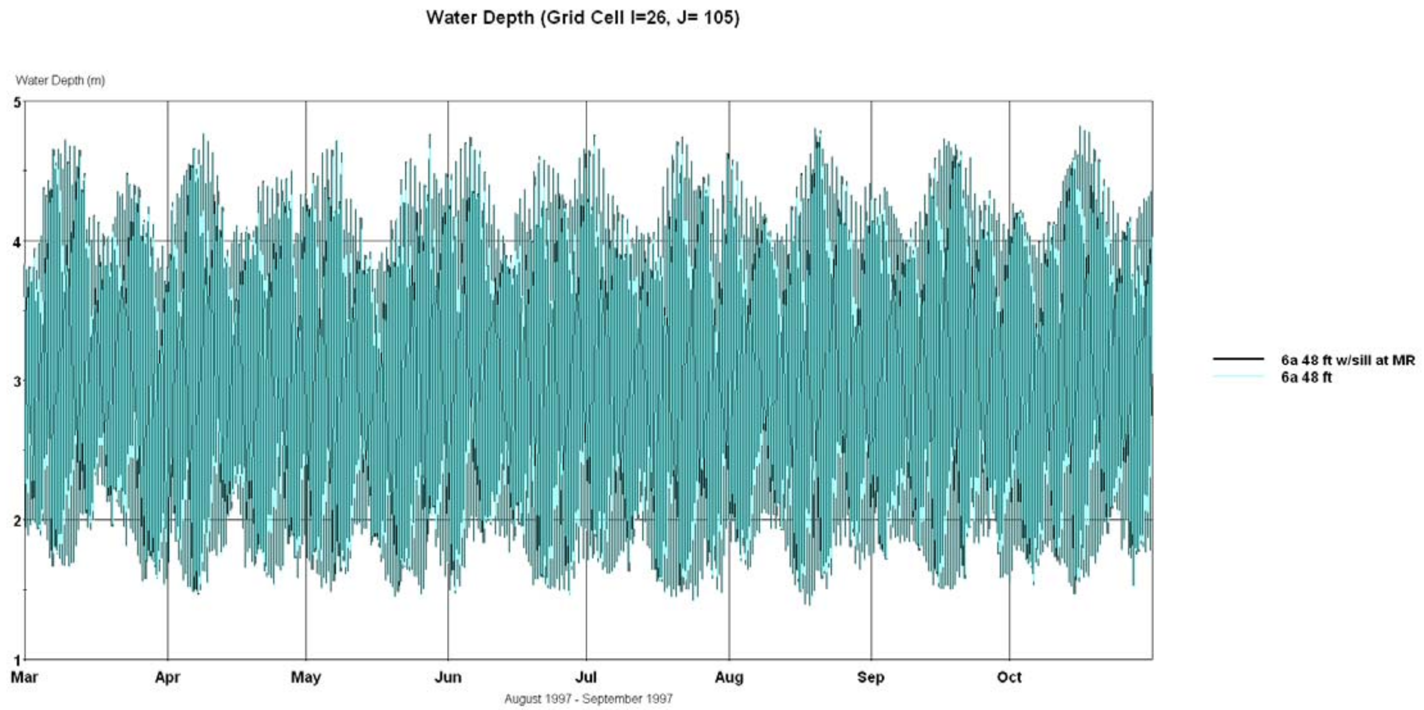


Figure 10: Water Depth Comparison at EFDC Grid Cell 26 105

A: full run period March through October 1997



B: zoomed run period August 1997

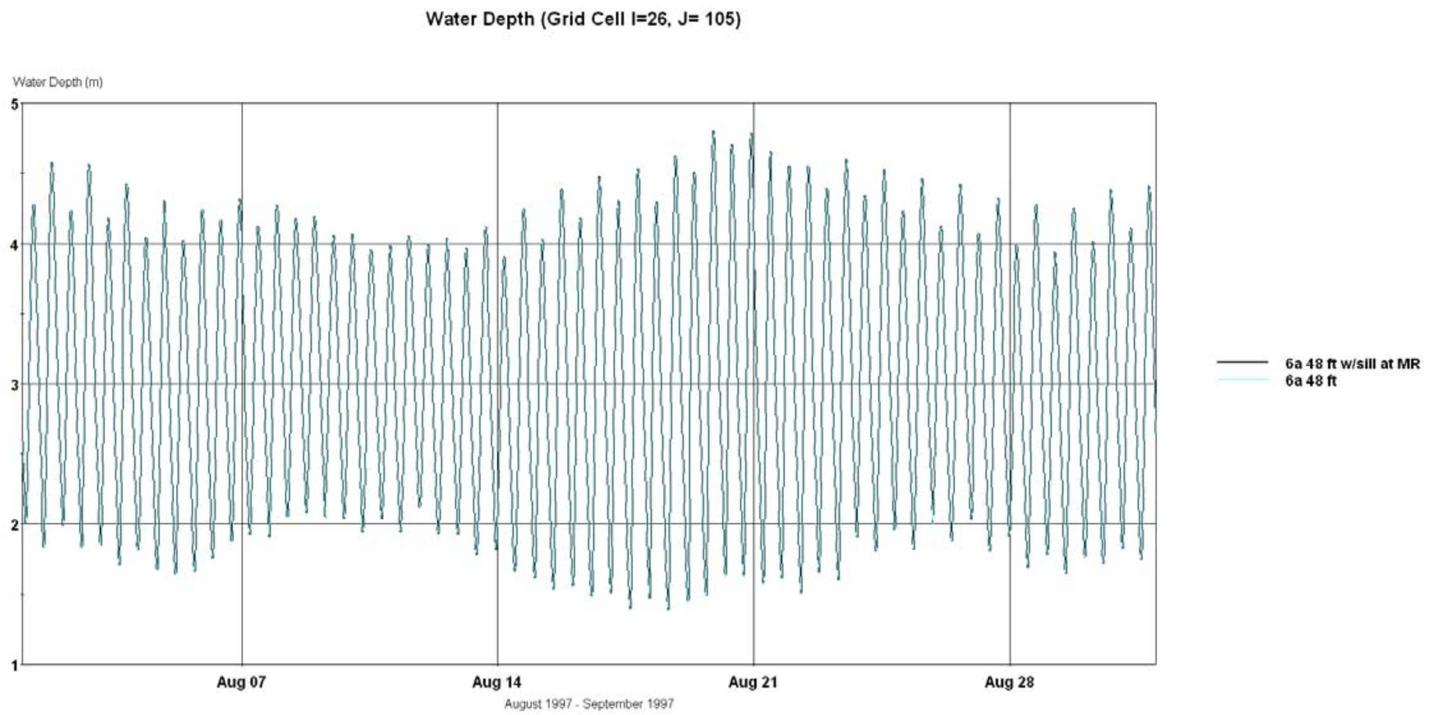
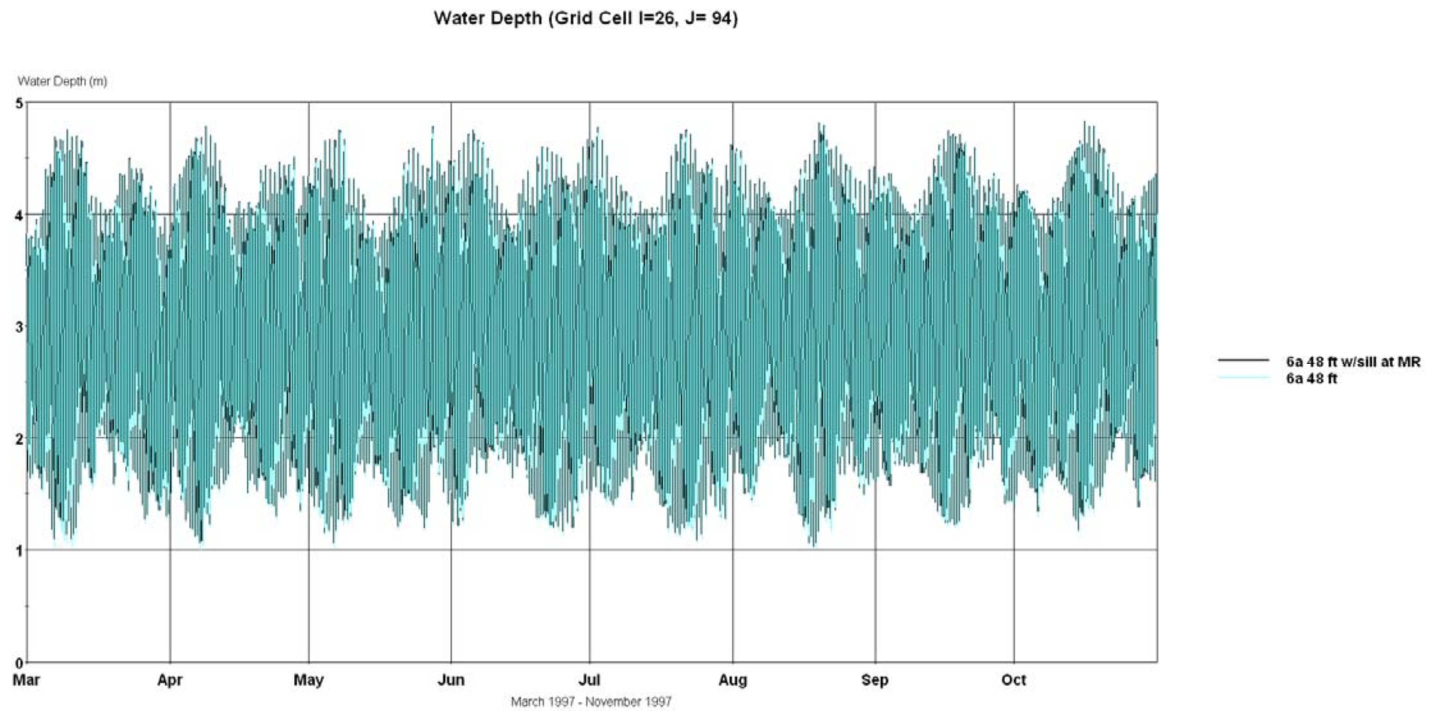
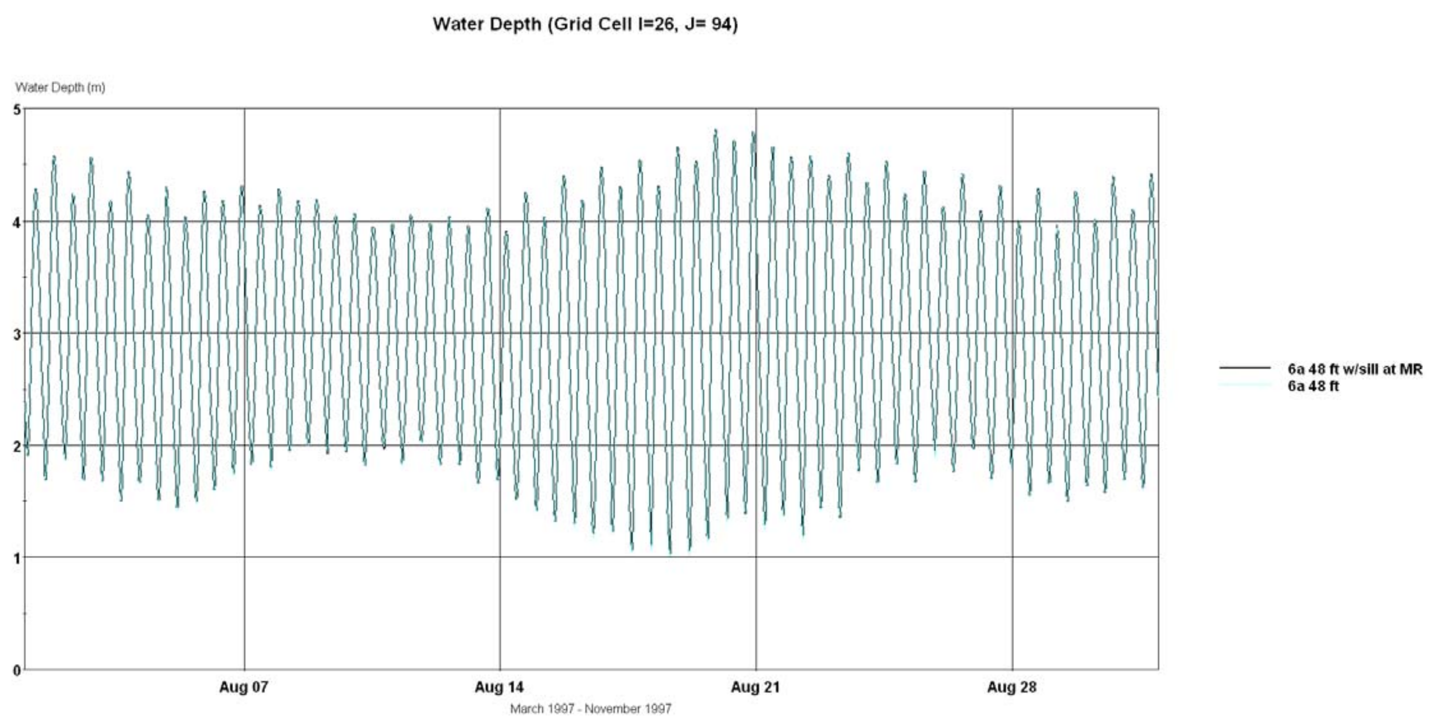


Figure 11: Water Depth Comparison at EFDC Grid Cell 26 94

A: full run period March through October 1997



B: zoomed run period August 1997



Impacts to Salinity Regime

Impacts to the salinity regime within the estuary due to inclusion of the new mitigation feature (sill at mouth of Middle River) in the model grid geometry were examined and results are shown in Figures 12 through 14. Comparisons are made between the 48 ft depth alternative with Mitigation Plan 6a in place with and without the mitigation feature modeled.

Figures 12 and 13 show the changes in salinity for both the model grids surface and bottom salinity predictions for the Basic Evaluation run period. The Basic Evaluation occurs from March through October in 1997 which is considered an average flow year. These would be conditions experienced within the estuary on an average basis.

Inclusion of the sill as a mitigation feature does cause a rise in predicted surface salinity values for the Basic Evaluation (average flow year). The maximum rise is 0.06 ppt. However, the predicted bottom salinity drops in the same location to values between 0.5 ppt and 0.99 ppt.

Figure 14 shows surface salinity changes under the Sensitivity Analysis #1 (low flow/drought conditions). Minor surface salinity increases are seen along Front River (less than 0.1 ppt). The peak increases are seen in the bend on Middle River. The maximum increase for surface salinity in this area is 0.28 ppt. Comparatively, Figure 15 shows the bottom salinity changes with the Sensitivity Analysis #1 low flow scenario. The decreases in bottom salinity prediction for this scenario on Middle River with the sill in place range from 0.1 ppt to 0.99 ppt.

For both run scenarios, average and low flow/drought conditions, the surface salinities increase slightly, while the bottom salinities are predicted to be lowered by a much larger amount.

Figure 12: Surface Salinity Difference Comparison – with and without meeting areas modeled

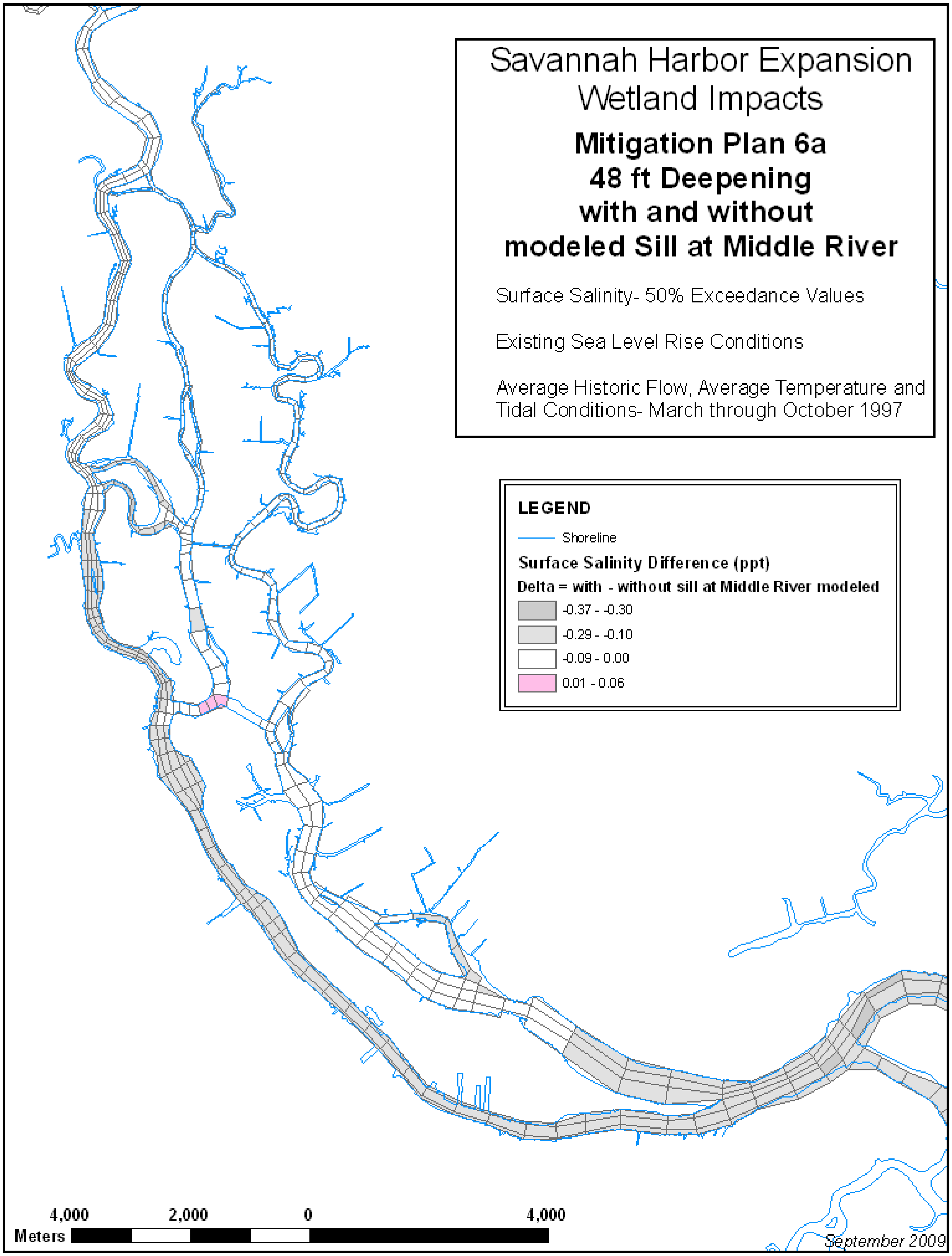


Figure 13: Bottom Salinity Difference Comparison – with and without meeting areas modeled

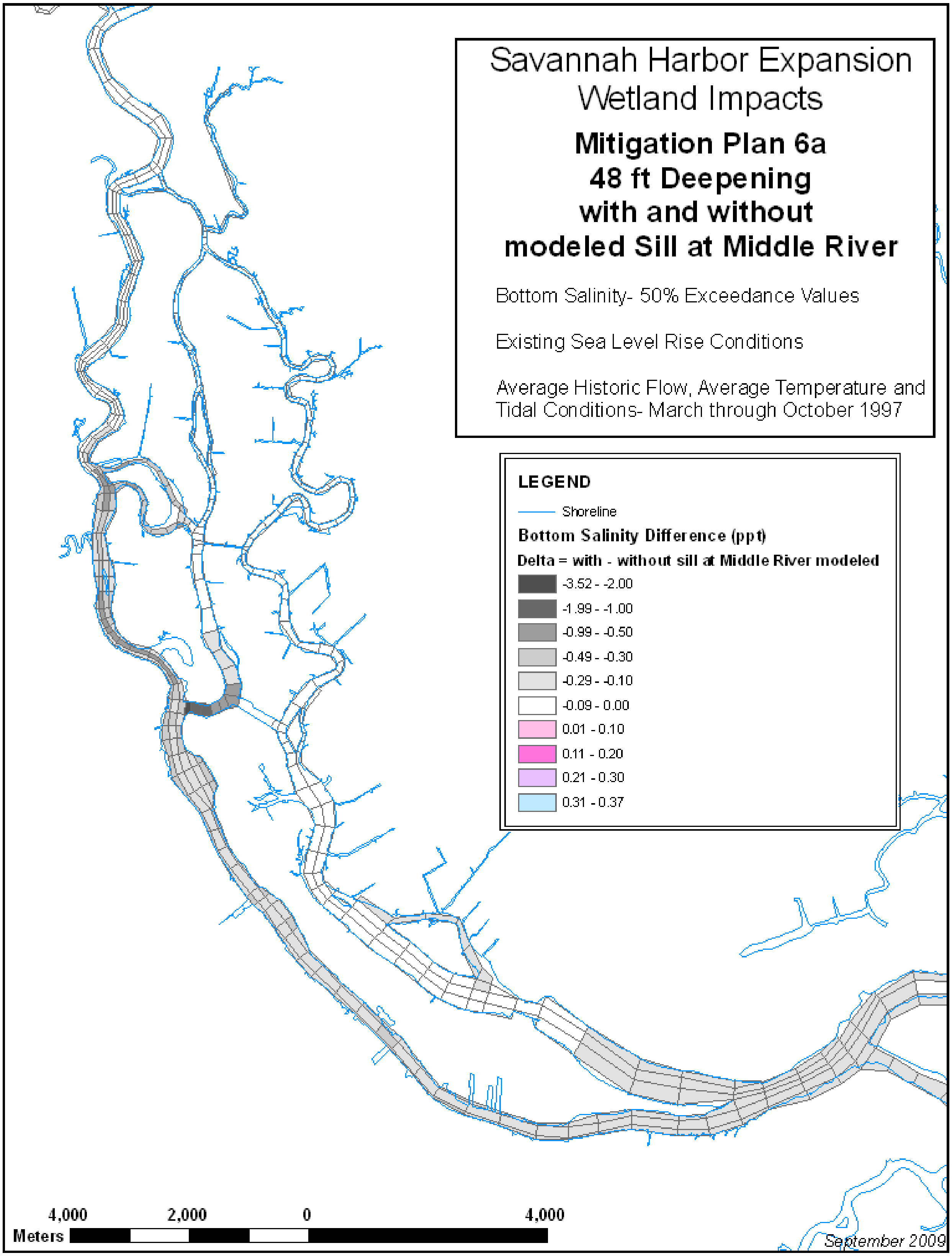


Figure 14: Surface Salinity Difference Comparison – with and without meeting areas modeled

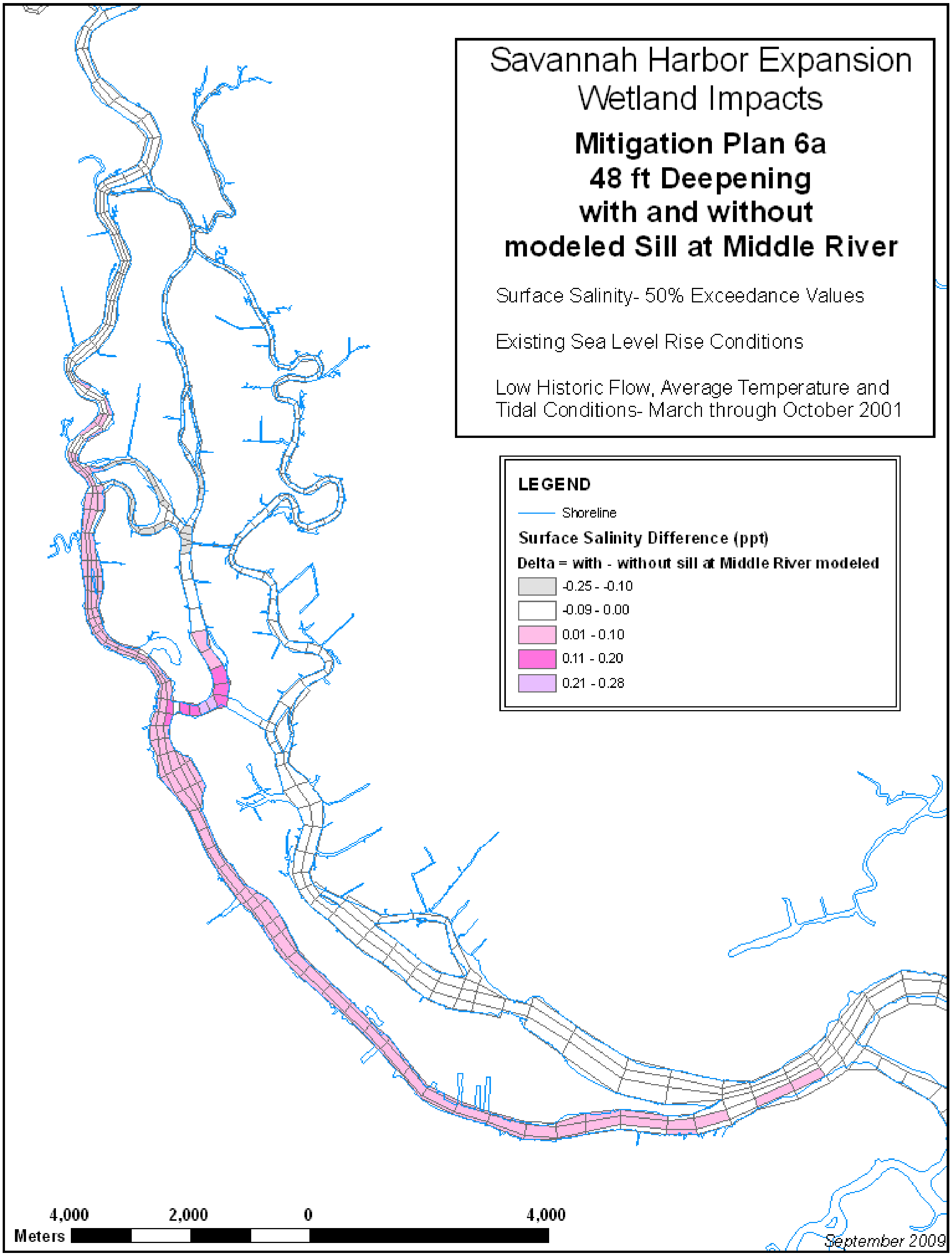
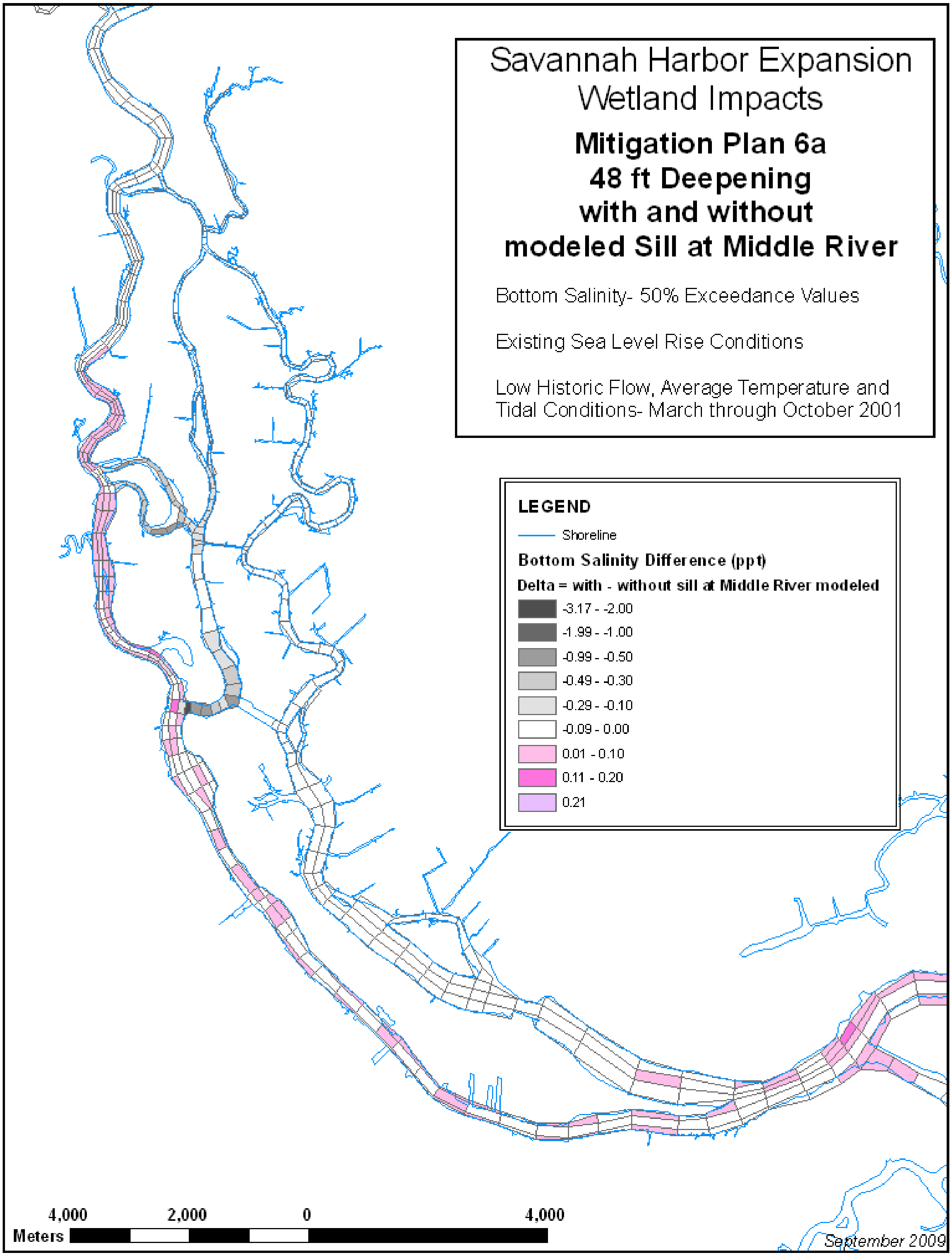


Figure 15: Bottom Salinity Difference Comparison – with and without meeting areas modeled



Water Quality (D.O.) Impact Analysis

Impacts to D.O. within the estuary due to inclusion of the Middle River sill in the model grid geometry are shown in Tables 4 and 5. Table 4 shows the change in D.O. percentiles for critical cells. A critical cell is the cell with the lowest D.O. concentrations during the simulation within each Zone. Table 5 shows the change in D.O. percentiles for each zone. A zone is an assemblage of cells that is limited by specified horizontal and vertical boundaries. The extents of each zone are shown in Figure 16.

The changes in D.O. in the critical cells (shown in Table 4) as a result of modification to the model are concentrated on Front River, zones FR7 and FR9. There are also some changes on Back River in zone BR3. The maximum decrease in D.O. is 1.06 mg/L which is a relative difference of 15.6% at the 25th percentile. Comparatively, there are some increases in D.O. as a result of the model grid modification as well, which mostly occur on Front River (FR9) with a maximum predicted increase in D.O. of 4.22 mg/L, which is a relative difference of 39.6%. The decreases in D.O. predicted values overall are minor with the exception of the maximums. The majority of the 50th percentile decreases are at or near zero.

The decreases in D.O. in the for the zones (shown in Table 5) as a result of modification to the model are minor. The maximum decrease is 0.13 mg/L which is a relative difference of only 2.3%. Comparatively, there are some increases in D.O. as a result of the model grid modification as well, which occurs on Middle River (MR1) with a maximum predicted increase in D.O. of 0.23 mg/L, which is a relative difference of 4.8%. Both of these maximum increases and decreases in D.O. occur at the 1st and 5th percentiles. It should be noted that the D.O. changes from the 50th percentile values are minor, many are zero. The maximum change is an increase in D.O. by only 1%.

Figure 16: Spatial Zones for D.O. Impact Evaluation

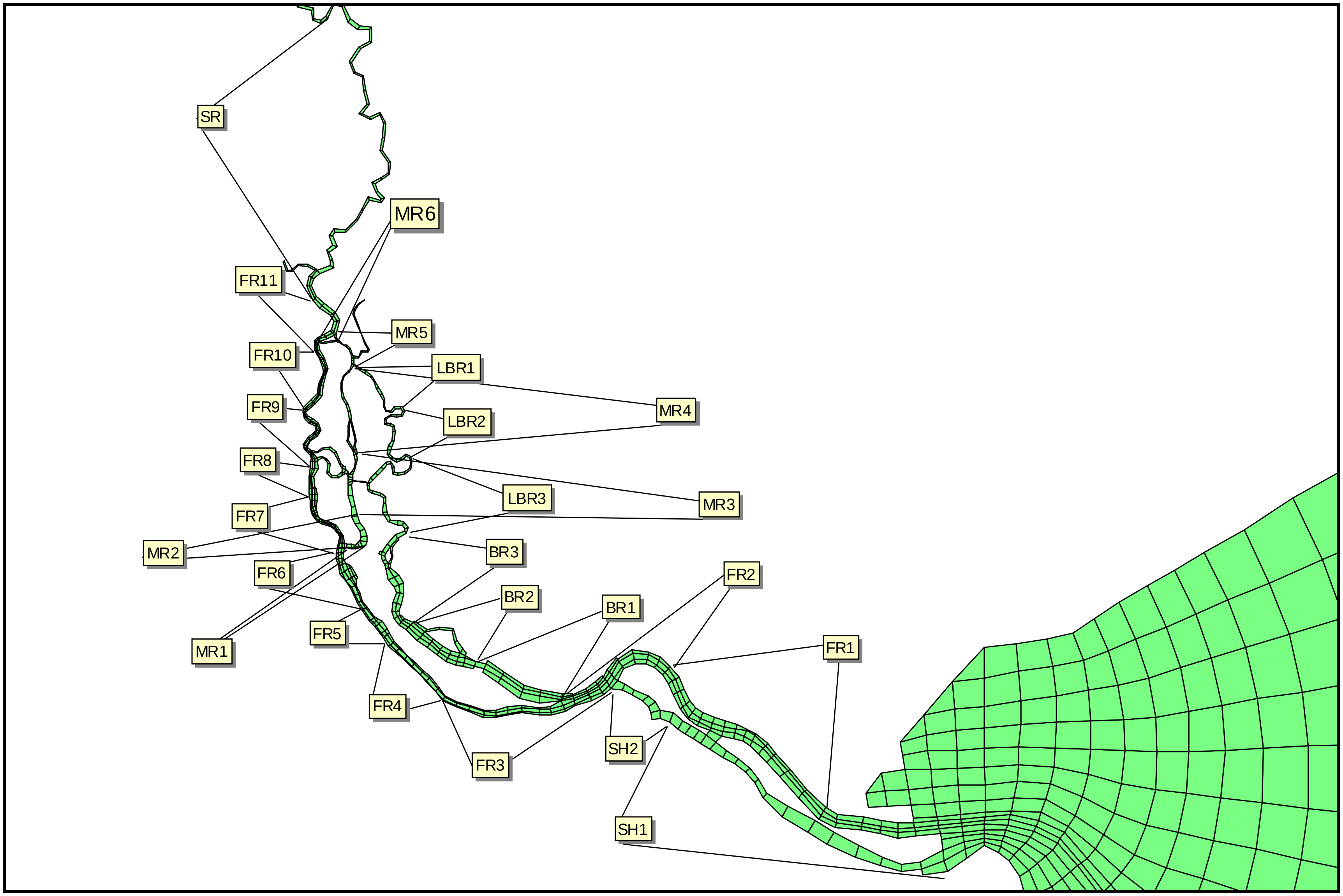


Table 4: Changes in D.O. Percentiles for Critical Cells With and Without the New Mitigation Feature Included in the Model Grid.

Delta D.O. Percentiles for Critical Cells

Baseline: Scenario: 6A6ft-withDOmitigation
Project: Scenario: DO_Plan6aPLUS-1997-6ftWASP

Zone	Delta D.O. Percentile																	
	1%		5%		10%		25%		50%		75%		90%		95%		99	
	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%
FR1	0	0.0	0.01	0.2	0	0.0	0.05	1.2	0.01	0.2	-0.01	-0.2	-0.01	-0.2	-0.02	-0.4	-0.09	-1.9
FR2	0	0.0	-0.02	-0.5	-0.01	-0.2	-0.01	-0.2	0	0.0	0.02	0.4	0	0.0	0	0.0	0	0.0
FR3	0.01	0.3	0	0.0	-0.01	-0.3	0	0.0	0	0.0	-0.01	-0.2	-0.01	-0.2	-0.05	-0.9	0.02	0.3
FR4	-0.02	-0.5	-0.01	-0.3	0	0.0	-0.01	-0.2	0	0.0	-0.02	-0.4	0	0.0	-0.01	-0.2	0.02	0.3
FR5	0	0.0	-0.02	-0.5	0	0.0	0.01	0.2	0	0.0	0	0.0	-0.01	-0.2	0.01	0.2	0.01	0.2
FR6	0	0.0	-0.02	-0.5	-0.02	-0.5	-0.02	-0.5	0.01	0.2	0.01	0.2	0	0.0	0	0.0	0	0.0
FR7	0.56	13.0	0.54	12.1	0.64	14.1	0.7	14.7	1.19	23.7	1.36	24.3	0.95	14.6	0.71	10.2	0.65	8.8
FR8	-0.02	-0.4	-0.03	-0.6	-0.04	-0.8	-0.03	-0.5	-0.04	-0.6	0.02	0.2	-0.06	-0.7	-0.02	-0.2	0.02	0.2
FR9	-0.57	-10.2	-1.02	-16.4	-1.02	-15.8	-1.06	-15.6	-0.11	-1.5	0.37	4.5	3.02	34.4	4.31	47.4	4.22	39.6
FR10	0	0.0	0	0.0	0	0.0	-0.01	-0.2	0	0.0	0	0.0	0.01	0.2	0.01	0.1	0.01	0.1
FR11	0	0.0	0	0.0	0.01	0.2	0	0.0	0.01	0.2	0.01	0.2	0	0.0	0	0.0	0.01	0.1
MR1	0.24	5.3	0.19	4.0	0.14	2.8	0.04	0.8	0.03	0.5	0.05	0.9	-0.06	-1.0	-0.02	-0.3	-0.07	-1.1
MR2	0.01	0.2	0.02	0.4	0.01	0.2	0.02	0.4	0.04	0.7	0.07	1.2	0.06	1.0	0.02	0.3	-0.02	-0.3
MR3	-0.04	-0.9	0.03	0.7	0.01	0.2	0	0.0	0.02	0.4	0.05	0.9	0.07	1.2	0.12	2.0	0.07	1.1
MR4	-0.02	-0.4	0.01	0.2	0	0.0	0.02	0.4	0.01	0.2	0.02	0.4	0.03	0.5	0	0.0	-0.01	-0.2
MR5	0.02	0.9	0.01	0.4	0.02	0.6	0.02	0.5	0	0.0	-0.01	-0.2	0.01	0.2	0	0.0	0	0.0
MR6	0.01	0.2	0	0.0	0	0.0	0.01	0.2	-0.01	-0.1	0	0.0	0	0.0	0	0.0	0	0.0
LBR1	-0.01	-0.2	-0.09	-1.9	-0.01	-0.2	0.02	0.4	0.02	0.3	0.01	0.2	0.01	0.2	0.02	0.3	0	0.0
LBR2	0.19	4.4	0.02	0.4	0.01	0.2	0.01	0.2	0.01	0.2	0.02	0.4	0.01	0.2	-0.01	-0.2	0	0.0
LBR3	0	0.0	0.01	0.4	0.02	0.7	0.01	0.3	0.02	0.6	0	0.0	0.02	0.5	-0.02	-0.5	-0.02	-0.5
BR1	-0.01	-0.3	0.03	0.8	0.02	0.5	-0.03	-0.7	0	0.0	0.02	0.4	0	0.0	-0.01	-0.2	0	0.0
BR2	0.03	1.3	0.02	0.8	0	0.0	0.02	0.6	0.02	0.5	-0.02	-0.4	0.01	0.2	-0.01	-0.2	-0.04	-0.8
BR3	0.02	0.9	-0.01	-0.4	-0.03	-1.2	0	0.0	0	0.0	-0.04	-1.4	-0.23	-7.1	-0.27	-7.8	-0.37	-9.9
SCH1	0.01	0.4	0	0.0	0.03	1.0	0.03	1.0	0.01	0.3	0	0.0	0.03	0.7	-0.01	-0.2	-0.04	-0.9
SCH2	-0.01	-0.3	-0.05	-1.2	0	0.0	-0.03	-0.7	0	0.0	0	0.0	0.02	0.4	-0.02	-0.4	0.04	0.8
SR	0	0.0	0.01	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
StbR	-0.39	-9.5	-0.42	-8.6	-0.31	-5.8	-0.25	-4.1	-0.09	-1.3	0.05	0.6	0.16	1.9	0.15	1.7	0.23	2.5

Table 5: Changes in D.O. Percentiles for Zones With and Without the New Mitigation Feature Included in the Model Grid.

Difference of D.O. %-tiles for zones of Savannah Estuary

Simulation Period: Year 1997 AUGUST 1 -AUGUST 31

Baseline ario: 6A6ft-withDOmitigation

Project DO_Plan6aPLUS-1997-6ftWASP

Zone Name	Project - Baseline Difference (mg/l)									Project - Baseline Relative Difference (%)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	-0.01	0.00	-0.01	0.00	-0.01	0.00	0.02	0.00	0.00	-0.2	0.1	-0.1	0.0	-0.3	0.0	0.5	0.0	0.1
FR2	-0.01	-0.01	-0.02	-0.01	-0.01	0.00	0.01	0.00	0.00	-0.2	-0.2	-0.4	-0.2	-0.3	0.0	0.3	0.1	0.1
FR3	-0.01	-0.01	-0.01	-0.02	0.00	0.00	0.01	0.01	0.01	-0.2	-0.1	-0.2	-0.4	0.0	-0.1	0.1	0.2	0.2
FR4	-0.01	-0.01	-0.01	-0.01	0.00	0.01	0.01	0.00	0.01	-0.3	-0.3	-0.1	-0.3	0.0	0.1	0.2	0.0	0.3
FR5	0.00	-0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.02	-0.1	-0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.3
FR6	0.00	0.01	0.00	-0.01	0.01	0.00	0.01	0.00	0.01	0.0	0.1	0.0	-0.2	0.2	0.0	0.3	0.0	0.1
FR7	0.01	0.01	0.01	0.00	0.03	0.04	0.03	0.06	0.06	0.2	0.2	0.3	0.1	0.4	0.6	0.4	0.7	0.8
FR8	-0.02	-0.03	-0.03	-0.06	-0.01	-0.01	-0.05	0.00	0.02	-0.5	-0.6	-0.6	-1.0	-0.1	-0.2	-0.6	0.0	0.2
FR9	0.04	0.04	-0.02	0.02	-0.02	-0.03	-0.02	-0.03	0.01	0.6	0.6	-0.3	0.2	-0.2	-0.3	-0.3	-0.3	0.1
FR10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.01	0.01	0.0	0.1	0.1	0.0	0.0	0.0	0.1	-0.2	0.1
FR11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MR1	0.23	0.13	0.04	0.04	0.05	0.04	0.04	-0.04	0.01	4.8	2.7	0.8	0.7	1.0	0.7	0.6	-0.7	0.1
MR2	0.01	0.05	0.01	0.03	0.04	0.04	-0.04	-0.02	0.02	0.3	1.0	0.2	0.6	0.8	0.6	-0.7	-0.4	0.3
MR3	-0.01	-0.01	0.00	0.02	0.03	0.04	0.10	0.07	0.11	-0.1	-0.3	0.1	0.3	0.5	0.7	1.7	1.2	1.8
MR4	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
MR5	0.00	0.02	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.1	0.7	0.3	0.4	0.0	0.0	0.0	0.0	0.1
MR6	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	0.6	-0.1	0.0	0.1	0.0	0.0	0.0	0.0
LBR1	0.00	-0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	-0.1	-0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.2
LBR2	0.00	0.00	0.01	0.00	0.00	0.01	0.03	0.04	-0.01	0.1	0.1	0.2	-0.1	0.0	0.3	0.6	0.6	-0.2
LBR3	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.2	0.2	0.3	0.3	0.1	0.2	0.2	0.2	0.3
BR1	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.02	0.1	0.0	0.0	0.2	0.1	0.1	0.0	0.3	0.4
BR2	0.05	0.00	0.02	-0.02	0.00	0.00	0.02	0.00	0.00	1.7	0.0	0.6	-0.5	0.0	0.0	0.4	0.1	0.0
BR3	0.00	-0.01	-0.01	0.00	0.02	-0.01	0.00	0.00	0.01	-0.1	-0.4	-0.4	0.1	0.6	-0.2	0.0	0.1	0.3
SCh1	0.03	-0.02	-0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.7	-0.6	-0.2	0.3	0.4	0.4	0.3	0.0	-0.1
SCh2	0.00	-0.02	0.00	-0.01	0.00	0.01	0.01	0.01	0.01	0.1	-0.5	-0.1	-0.3	0.0	0.3	0.2	0.3	0.2
SR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
StbR	-0.10	-0.13	-0.11	-0.06	0.01	0.04	0.04	0.09	0.08	-1.9	-2.3	-1.9	-0.9	0.1	0.5	0.6	1.1	1.0

Conclusions

The new SNS habitat criteria with the existing channel bathymetry does seem to be a better representation of the observed Juvenile SNS locations by including the Middle River bend within the suitable habitat boundary as compared to the original criteria.

Based on the habitat suitability maps, the Middle River sill does not show benefits to SNS habitat in the Middle River bend over the maps created without the bend. However, when a closer look is taken with the raw datasets a decrease in bottom salinity in the bend is noted. Despite the lack of benefits shown in the habitat suitability maps, the mitigation feature does in fact provide some benefits in lowering predicted bottom salinity values. The model output shows that the benefits are largely concentrated during the spring tidal event. Outside of the spring tidal event, the sill does not offer a large amount of salinity protection to the area. It may be helpful to have more information about the tidal conditions during the research period conducted by Collins et al to have a better comparison between the maximum salinities observed and modeled. Specifically, it may be helpful to know if the maximum salinities readings observed by Collins in the Middle River bend were collected during high tide of the spring tidal cycle.

The hydrodynamic model shows only minor changes in velocities behind the sill, which were used to indicated possible shoaling areas. Since the changes are small and only found in the bottom layers of the water column, shoaling is not expected to rapidly impact the habitat on Middle River. However, the model is a predictive tool and does not guarantee that shoaling in this area will not occur.

In addition to completing the impact analysis for SNS, a sensitivity analysis was also completed for impacts to freshwater marshes/wetlands and to water quality (D.O). Overall and generally speaking the impacts to these two resources appear to be minor.

Impacts to tidal fluctuations and the salinity regime are minor. Surface salinities are impacted with inclusion of the feature in the model grid, however the impact is not significant and is not expected to alter the previously determined acreage amounts. The greatest impacts or changes are seen locally with the project feature and are not far reaching.

The largest negative impacts to D.O. as a result of altering the model grid occur in the critical cell differences along Front River (FR9) and Back River (BR3). The impacts categorized by zone are very minor, close to zero, with the largest changes actually benefiting the D.O. concentrations by raising them 4.8%.

For completeness, this proposed mitigation feature could be incorporated into the project conditions model grid. However, as shown by this sensitivity analysis, the changes are likely to have little to no impact on the previous estimates to freshwater marsh/wetland or water quality impacts and therefore no bearing on the mitigation plan or project cost estimates.

Alternatively, due to the lack of benefits shown in the habitat suitability maps along with the uncertainty of shoaling that may or may not occur behind the sill, this feature may be more appropriate as an adaptive management feature.