Town of Sunset Beach

2016 Pre-Dredge Analysis

Jinks Creek Hydrodynamic Modeling Report

moffatt & nichol

EXECUTIVE SUMMARY

The Jinks Creek numerical modeling analysis evaluates the anticipated changes in tidal velocities and flow rates expected from dredging the respective waterway. The North Carolina Division of Coastal Management (DCM) and the US Army Corps of Engineers (USACE) requested the modeling analysis to evaluate three (3) potential concerns as follows:

1. Increased shoaling in the AIWW confluence with Jinks Creek;
2. Increased scour or shoreline erosion within the 'S' curve alignment of Jinks Creek; and,
3. Increased shoaling or migration patterns for Tubbs Inlet.

The modeling analysis evaluates the potential change in tidal velocities and flow rates created by multiple design alignments. The alignments include a conceptual, maximum, and preferred dredge alternative as described below. Appendix D contains the discussion regarding the conceptual and maximum design alignments, while the main report concentrates on the preferred alignment evaluation.

- Conceptual - 100' Wide @ -7 MLW (entire channel)
- Maximum - 100' Wide @ -7 MLW (entire channel & Tubbs Inlet)
- Preferred - 40' ~ 50' Wide @ -5 MLW (northern Jinks Creek)
  80'~100' Wide @ -7 MLW (southern Jinks Creek).

The current analysis builds upon a 2005 study and utilizes the same boundary conditions and field data collected for that analysis. This includes flow rate and velocity measurements collected within the interior waterways of Jinks Creek, the AIWW, and surrounding systems. The field data collection occurred in November 2004 during a spring tide event. Water level elevations collected from the Sunset Beach Pier (NOAA Tide Station #8659897) serve as the open boundary conditions used to drive the modeling scenarios. The tidal elevations, or boundary conditions, include an applicable lag time consideration for Tubbs Inlet, Shallotte Inlet, and Little River Inlet.

The Jinks Creek analysis also simulates extreme storm conditions and compares the performance of the preferred alignment with 2016 existing conditions. Storm surge data representing Hurricane Hugo (September 1989) provide the catalyst for the extreme storm conditions. The USACE developed the storm surge data through an ADCIRC-2DDI (Advanced CIRCulation 2-Dimensional, Depth-Integrated) model analysis.

Calculations conducted along 10 fixed transects afford the data used to compare the potential changes in tidal velocities and flow rates. The analysis evaluates the measured changes to determine how they may impact the existing shoaling or scour potential referenced by DCM and the USACE. The analysis calculates depth averaged velocities and average flow rates based on the bathymetry and tidal input representing each design scenario. The results are interpreted as a guide to assist the project stakeholders in making informed decisions regarding the project's path forward. Figure 1 shows the transect locations and study areas based on the concerns expressed by DCM and the USACE.

The results indicate the preferred alignment should not create a significant change in the tidal patterns for Jinks Creek and the surrounding waters. The change in tidal velocities should range below three (3%) percent for normal or spring tide conditions and extreme storm scenarios. Based on the data transects sampled, the modeling indicates the largest increase in maximum velocities would equal approximately 2.6% (0.07 ft/sec) and would occur approximate to the AIWW confluence with Jinks Creek. The modeling suggested the maximum velocity change would occur during normal or spring tide conditions as opposed

to extreme storm conditions. The spring tide modeling also suggested the maximum velocities traveling towards Ocean Isle Beach from Tubbs Inlet would experience a slight decrease in magnitude.

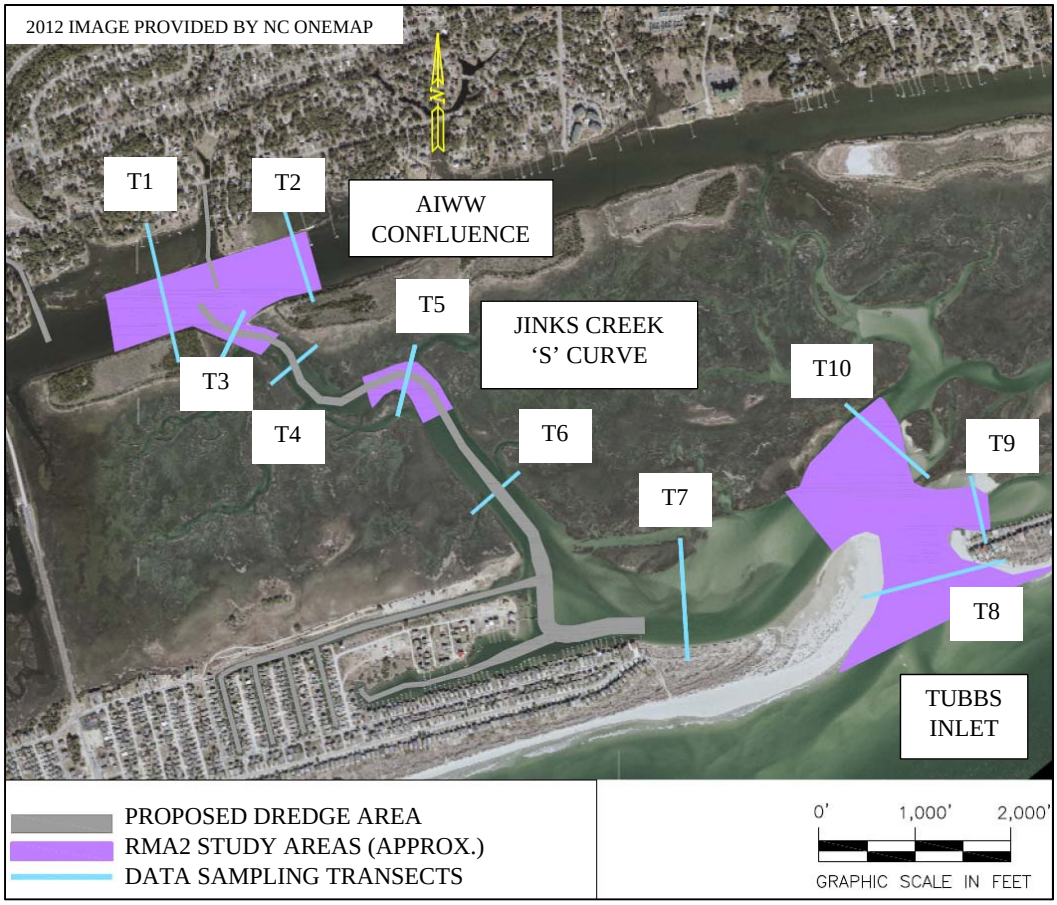

Figure 1. Data Collection Transect Locations

The largest increase in the maximum velocities estimated under the extreme storm conditions also occurs at the Jinks Creek and AIWW confluence. The modeling estimated the increase to reach approximately 0.05 ft/sec at Transect T3 for the extreme storm condition scenario. Although the greatest increase in velocity occurs during the spring tide conditions, the storm condition velocities reach higher magnitudes due to the abrupt tidal forcing. Storm surge created from a major hurricane will encapsulate interior coastal waterways considerably quicker than a normal astronomical tide. This creates a steeper velocity gradient and overall greater velocity magnitude compared to a normal astronomical tide. However, the analysis estimates the greatest change or increase in maximum velocities generated through the preferred alignment would occur during spring tide conditions. Table 1 shows the estimated changes in the maximum velocities for both the spring tide and extreme storm conditions. Figures 2 and 3 show the percent change in maximum velocities in planview for the preferred alignment under the modeled spring tide and extreme storm conditions, respectively.

Table 1. Maximum Velocities for the Preferred Alignment

Transect		Spring Tide Conditions			Extreme Storm Conditions		
		2016 Existing Conditions	Preferred Alignment	Percent Change (%)	2016 Existing Conditions	Preferred Alignment	Percent Change (%)
AIWW Confluence	T1	1.53 ft/sec	1.56 ft/sec	1.6%	-	-	-
	T2	1.05 ft/sec	1.06 ft/sec	0.8 %	-	-	-
	T3	2.75 ft/sec	2.82 ft/sec	2.6%	2.02	2.07	2.4%
'S' Curve Alignment	T4	3.45 ft/sec	3.46 ft/sec	0.3%	-	-	-
	T5	2.86 ft/sec	2.88 ft/sec	0.7%	3.07	3.11	1.3%
	T6	3.01 ft/sec	3.02 ft/sec	0.3%	-	-	-
Tubbs Inlet	T7	2.28 ft/sec	2.30 ft/sec	0.9%	3.41	3.45	1.2%
	T8	4.72 ft/sec	4.74 ft/sec	0.4%	-	-	-
	T9	3.69 ft/sec	3.68 ft/sec	-0.3%	-	-	-
	T10	2.45 ft/sec	2.44 ft/sec	-0.4%	-	-	-

1. Spring tide conditions simulated from Nov. 13, 2004 (13:15) to Nov. 20, 2004 (13:15).
2. Extreme storm conditions simulated from Sept. 20, 1989 (10:30) to Sept. 22, 1989 (18:29).
3. (-) indicates transect was not included in the analysis.
4. Values are depth averaged.

Figure 2. Preferred Alignment % Change in Maximum Velocities (Spring Tide Condition)

Figure 3. Preferred Alignment % Change in Maximum Velocities (Extreme Storm Condition)

The flow rate measurements determined from the modeling also suggest the preferred alignment will not significantly change the shoaling or scouring patterns within the study area. Table 2 provides the percent increase in flow rate measured at each transect in the modeling analysis. The largest increase in the flow rate occurs during the spring tide analysis adjacent to the Jinks Creek 'S' curve alignment (T4) and equals approximately 3.2% for the flood tide cycle. Although generally the ebb tide flow rates experience a higher percent change at all transects, the flood tide flow rates remain significantly higher in magnitude. Therefore, the analysis considers the changes experienced during the flood tide cycle as the controlling values. The calculations for the extreme storm conditions provide similar results compared to the spring tide analysis. The largest percent increase for the flood tide cycle occurs adjacent to the AIWW confluence (T3) and equals approximately 1.9%.

Results shown in Appendix D for the conceptual and maximum design analyses also support the preferred alignment. The results indicate an approximate 20% to 40% increase in flow rates could be expected in the AIWW confluence with the conceptual or maximum design alternatives, respectively. The estimated change in flow rates increase traveling through Jinks Creek from Tubbs Inlet. Within southern Jinks Creek the flow rates show less than a 10% increase for both alternatives. However, in northern Jinks Creek the estimated changes grow substantially to the referenced 20% to 40%. These results suggest the material shoaling in northern Jinks Creek obstructs the channel flow way and helps control the governing flow rate. Therefore, increasing the proposed channel dimensions substantially beyond the preferred alignment may create significant changes to the average flow rates and velocities in northern Jinks Creek.

Table 2. Average Flow Rates for the Preferred Alignment (Flood Tide Cycle)

Transect		Spring Tide Conditions			Extreme Storm Conditions		
		2016 Existing Conditions	Preferred Alignment	Percent Change (%)	2016 Existing Conditions	Preferred Alignment	Percent Change (%)
AIWW Confluence	T1	3,140 cfs	3,190 cfs	1.6%	-	-	-
	T2	1,450 cfs	1,440 cfs	-0.7%	-	-	-
	T3	2,450 cfs	2,520 cfs	2.9%	3,720 cfs	3,790	1.9%
'S' Curve Alignment	T4	2,790 cfs	2,880 cfs	3.2%	-	-	-
	T5	3,230 cfs	3,300 cfs	2.2%	5,680 cfs	5,770 cfs	1.5%
	T6	4,220 cfs	4,290 cfs	1.7%	-	-	-
Tubbs Inlet	T7[1]	5,740 cfs	5,840 cfs	1.7%	13,090 cfs	13,270 cfs	1.4%
	T8	12,110 cfs	12,200 cfs	1.0%	-	-	-
	T9	1,230 cfs	1,230 cfs	0.0%	-	-	-
	T10	2,180 cfs	2,170 cfs	-0.5%	-	-	-

1. Flood tide flow rates are considered the governing values and therefore, the ebb flow values have been removed for clarity, except for Transect T7. Along this transect the ebb tide flow rates provide the governing conditions.
2. Spring tide conditions simulated from Nov. 13, 2004 (13:15) to Nov. 20, 2004 (13:15).
3. Extreme storm conditions simulated from Sept. 20, 1989 (10:30) to Sept. 22, 1989 (18:29).
4. (-) indicates transect was not included in the analysis.

The analysis also reviewed the anticipated change in the maximum water surface elevations expected under extreme storm condition between the 2016 existing conditions and the preferred alignment. The modeling showed a negligible increase in water surface elevations could be expected as a result of constructing the preferred alternative. The modeling estimated the maximum increase to occur in southern Jinks Creek and may equal on the order of 1/64th of an inch. The increase estimated for the remaining project area ranged between 0 and 1/100th of an inch. Figure 4 shows the estimated change in maximum water surface elevations for the extreme storm condition.

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Appendix B – 2004/05 Velocity Vector Plots
Appendix C – Comparison of Measured & Modeled Flow Rates & Velocities
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1.0 INTRODUCTION

The Town of Sunset Beach (Town) initiated an analysis to determine the potential effects of conducting a navigational dredging project along the Town's eastern waterways. The proposed project includes the necessary waterbodies to connect the residential docks on the Town's eastern border with the Atlantic Intracoastal Waterway (AIWW). Figure 1 shows the waterbodies included in the analysis, which comprise the following:

- Mary's Creek;
- Turtle Creek;
- Jinks Creek;
- Feeder Canal & Finger Canals;
- Bay Area.

These water bodies provide navigation access to the residents and guests along the east end of Sunset Beach, with Jinks Creek serving as the main connector. Jinks Creek provides a tidal connection between the Atlantic Intracoastal Waterway (AIWW) and Tubbs Inlet with additional links to the Feeder Canal and the Bay Area. Previous dredging activities have been conducted within the southern portion of Jinks Creek[1]; however, the northern portion of the creek functions as a natural flow way. The previous dredging activities within the southern portion of Jinks Creek occurred during the early 1970's, presumably for land reclamation. The changes created by the 1970's dredging have been linked to the migration reversal displayed by Tubbs Inlet during the same 1970 time period[1].

The project includes Jinks Creek to provide a safe and fixed passageway to navigable waters through the AIWW without creating the need to traverse Tubbs Inlet. Safe navigation through Tubbs Inlet is currently questionable as the inlet channel may shoal and migrate unexpectedly. The Town considers a navigable passageway through Jinks Creek to the AIWW as a preferred alternative compared to attempting to manage and maintain navigable access through Tubbs Inlet.

As part of the project review the North Carolina Division of Coastal Management (DCM) required the Town to specifically investigate the potential impacts of dredging Jinks Creek through a modeling analysis. DCM made this requirement in an effort to avoid potentially re-creating a similar situation as the 1970's dredging may have stimulated for Jinks Creek. The US Army Corps of Engineers (USACE) shared DCM's concerns regarding the project and supported the investigation. The concerns stem at least in part as a precaution to understand the anticipated response of Jinks Creek. The results should help to avoid unintended changes in the migration trends of Tubbs Inlet and additionally in the AIWW. The modeling analysis covers three main objectives as requested by DCM and the USACE as shown below: (Figure 1 shows the location where each listed modeling objective applies.)

1. Evaluate the potential change in material shoaling patterns within the confluence of the AIWW and Jinks Creek.
2. Evaluate the potential change in the channel alignment at the 'S' curve within Jinks Creek.
3. Evaluate the potential change in material shoaling or inlet migration patterns within Tubbs Inlet.

[1] Cleary, W.J. & Marden, T.P. (1999). Shifting sands: a pictorial atlas of North Carolina inlets. North Carolina Sea Grant. Raleigh: NC State University.

Figure 1. RMA2 Study Areas

2.0 MODEL CALIBRATION

The current analysis, referenced as the 2016 Pre-Dredge Analysis, utilizes the RMA2 (Version 4.58) hydrodynamic 2-D model to evaluate the potential change in tidal velocities and flow patterns within Jinks Creek and the surrounding waters. The USACE developed the RMA2 software model as a depth averaged finite element numeric model[2]. The model solves the Reynolds form of the Navier-Stokes equation for turbulent flow. Friction is calculated through Manning's equation and eddy viscosity coefficients define turbulent losses. Recommended applications for the RMA2 model include analyzing water levels and flow distributions near islands and around bridge abutments. Additional applications recommended by the USACE include evaluating flow distributions through structures with more than one (1) outfall, channel design and infilling, and general circulation and sediment transport near marsh or wetlands including rivers, reservoirs, and estuaries[3]

The current analysis builds from a 2004/05 study that evaluated scour velocities surrounding the Sunset Beach Bridge replacement. The current analysis verified the 2004/05 model calibration and then updated the project bathymetry and model domain. The calibration for the 2004/05 model application compared tidal flow rates (cfs) measured at approximately 32 locations encompassing Little River Inlet, Tubbs Inlet, and Shallotte Inlet. The 2004/05 analysis also compared measured velocities at nine (9) of the referenced locations or transects. The current analysis utilizes these same field measurements and data sets to estimate the model performance and calibration standards. Appendix A provides an aerial view of the transects utilized for the 2004/05 field measurements.

2.1 2004/05 Flow Rate and Velocity Field Measurements

The 2004/05 calibration measurements were collected during an extreme spring tide period extending through November 16 & 17, 2004. Two (2) boat mounted Acoustic Doppler Current Profilers (ADCPs) collected the measurements over a split 19.5 hour period extending through both days of the sampling event. An additional bottom mounted ADCP operated for approximately 31 hours during the 2 day period to also collect velocity data.

2.1.1 Boat Mounted ADCP Data Description

The boat mounted ADCPs collected data in approximate 25cm bins extending from 30cm below the water surface. The ADCP software averaged the velocities measured within a respective bin over a 2 second period to produce a single record. These 2 second depth averaged records for each bin then combined to form an ensemble. Further data processing techniques averaged the results of each ensemble to simplify the velocity and flow rate determination. This included horizontal averaging of the ensembles based on the length of each sampling transect as follows:

Transects < 150 m – Average of every 2 ensembles provided

Transects > 150 m – Average of every 4 ensembles provided.

The results of this process provided a horizontal array of velocity vectors extending across a respective transect that could be plotted for any respective time period. Appendix B shows the vector plot of the original velocity data collected for the 2004/05 model application[4].

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[2] Aquaveo. (2016). RMA2 2D flow modeling with SMS. URL. www.aquaveo.com/software/sms-rma2 (visited 2017, Jan. 25.)
[3] Donnell, B.P. (2011) RMA2 WES Version 4.5. USACE-ERDC Valhalla, NY: WexTech Systems, Inc.
[4] Moffatt & Nichol. (2004/05). Hydraulic modeling Sunset Beach bridge replacement. Raleigh: NCDOT

The 2004/05 calibration also provides a flow rate and direction for each transect during a respective monitoring time frame. The flow rate determination accounts for the cross-sectional area and depth averaged velocities measured during the data collection process. Considerations were also provided for the velocities near the sampling area or transect boundaries. This includes near the water surface and flow way bottom where the ADCP equipment could not accurately measure the tidal velocities. This also includes the landward extents of each transect where the water depths prohibited any bin measurements[4].

2.1.2 Bottom Mounted ADCP Data Description

The bottom mounted ADCP or current meter comprised of a Nortek Vector installed on the western side of the Sunset Beach Bridge. The bottom mounted ADCP unit collected velocity measurements in bursts occurring every 10 minutes. Each burst consisted of approximately 120 measurements collected approximately 5 ft (1.5 m) above the bottom of the AIWW at a frequency of 2 Hertz.

The bottom mounted unit operated at 2 locations during the referenced 31 hour sampling period. The first deployment (Location A) extended approximately 24 hours in the confluence of the AIWW and Big Narrows Channel. The unit was eventually repositioned further to the west in the AIWW (Location B), outside the direct influence of Big Narrows Channel. The tidal currents traversing Big Narrows Channel created discrepancies in the velocity calculations regarding the appropriate direction of flow in the AIWW. Data collection continued for approximately 7 hours at the repositioned Location B. For reference, Figure 2 shows both the A & B approximate locations for the bottom mounted Nortek Vector.

Figure 2. Bottom Mounted ADCP Locations A & B

Data processing for the bottom mounted ADCP unit consisted of producing 1 average velocity measurement for each burst recorded. The process then combined the single results from all of the burst into 3 separate recordings. The recordings covered the following respective timeframes[4]:

1. SSB0101 (Location A) – November 16, 2004, 8:20 - November 16, 2004, 16:10.
2. SSB0301-A (Location A) – November 16, 2004, 17:00 – November 17, 2004, 9:20.
3. SSB0301-B (Location B) – November 17, 2004, 9:40 – November 17, 2004, 16:50.

The average current velocity and direction of each burst could then be plotted in series to form a record of the observed velocity and flow rate trends.

2.2 Tidal Input

The current analysis also utilizes the same tidal input as the 2004/05 study. This entails observed water surface elevations from NOAA tide station #8659897 referenced as Sunset Beach Pier. The collected tidal data covers approximately 1 month or a full lunar cycle, extending through November 2004. Encompassing a full lunar cycle helps to ensure the data represents a neap and spring tide measurement. Neap tides occur when the moon appears in halves and result in generally lower variations in the water level during tidal exchanges. Conversely, spring tides occur during full or new moons and generate the maximum variations in tidal levels for a given area[5].

Similar to the 2004/05 study, the current analysis concentrates on the spring tide events to provide the extremes expected within the dredge areas. Figure 3 shows the water level measurements collected at the Sunset Beach Pier tide station for November 2004. Both the 2004/05 and the 2016 study utilize the tidal data extending from November 13th through November 19th, as shown in red in the figure below. The extracted data encompasses the spring tidal event, which occurred on November 16 - 17. The analysis utilizes the data extending from November 13th to allow sufficient ramp-up time for the model prior to the spring tide event referenced above.

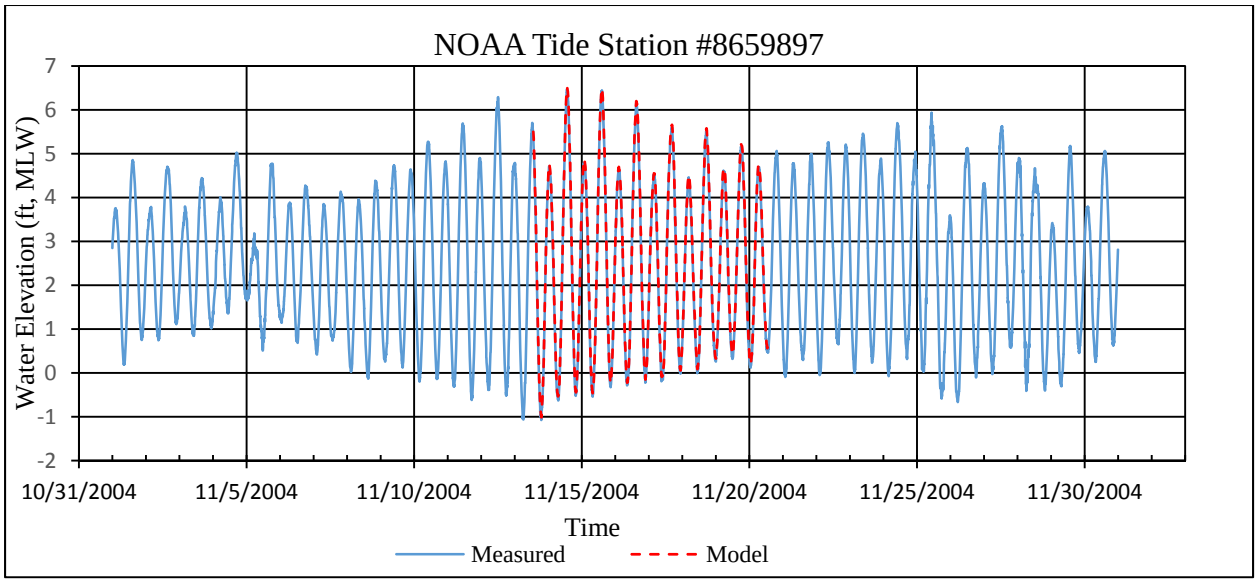


Figure 3. Observed Water Level Elevations at Sunset Beach Pier (November 2004)

During the modeling simulations, the analysis uses the water surface elevations measured at Sunset Beach Pier to force the tidal conditions at Tubbs Inlet. The analysis also establishes tidal conditions at Little River

[5] National Ocean Service (2017). What are spring and neap tides? NOAA URL http://oceanservice.noaa.gov/facts/springtide.html (visited 2017, February 07)

Inlet and Shallotte Inlet by translating the Sunset Beach Pier data in accordance with lag times derived from designated tidal stations near each inlet as shown below[6]:

Little River Inlet (+12 min Lag) – NOAA Tide Station 8660098 (Little River Neck)

Shallotte Inlet (+30 min Lag) – NOAA Tide Station 8659665 (Bowen Point).

Figure 4 shows a graphical representation of the tidal water levels applied as boundary conditions at each inlet location. The figure represents the tidal conditions measured for November 17, 2004 at Sunset Beach Pier and utilized directly for Tubbs Inlet. The figure shows the same data translated by the above referenced lag times for application at Little River Inlet and Shallotte Inlet. Since the current study area resides so close to Tubbs Inlet the present analysis most likely could have neglected the additional boundary conditions at Little River Inlet and Shallotte Inlet. The tidal conditions stemming from Tubbs Inlet most likely provide the main source for the water velocities traversing through Jinks Creek up to the AIWW. However, with the model set-up already established for the additional input, this analysis maintained the additional boundary inputs as a precautionary measure.

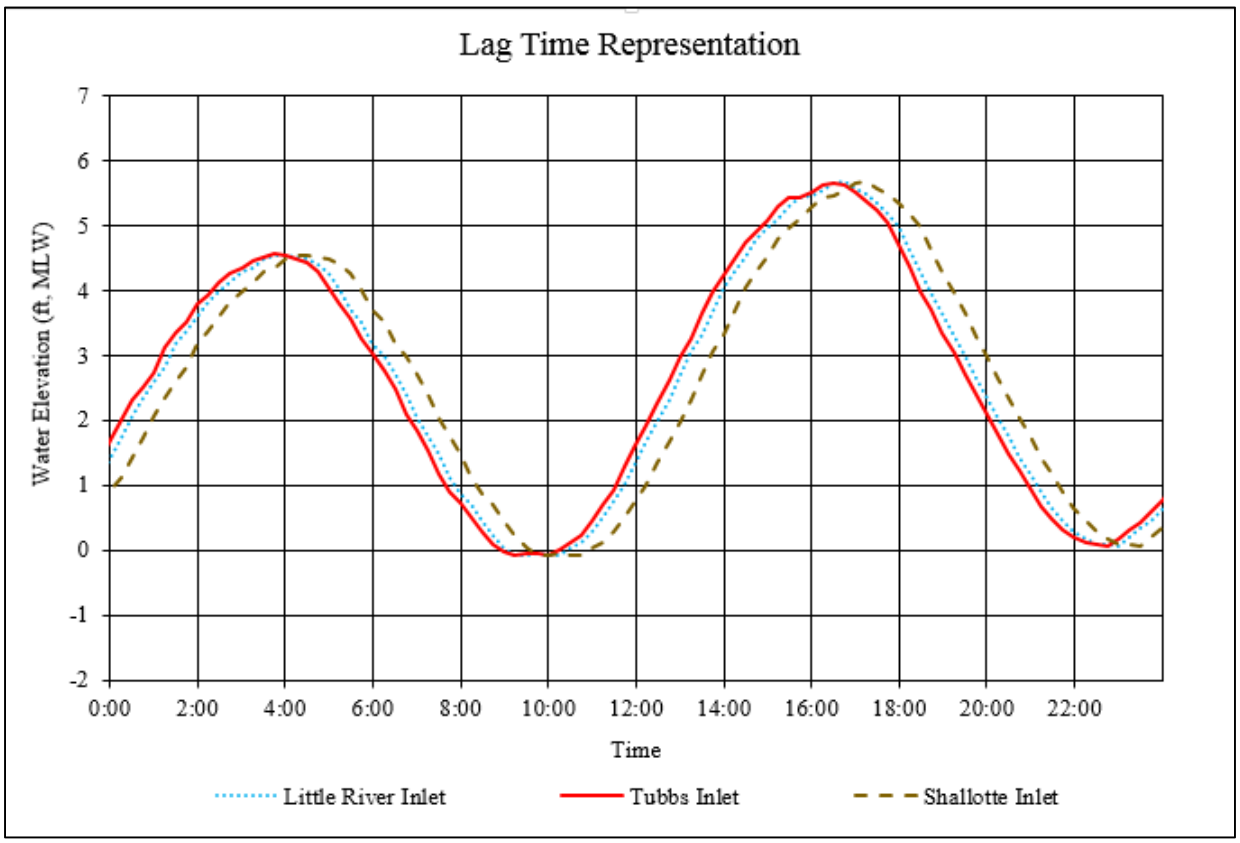


Figure 4. Lag Time Representation for the Open Boundary Tidal Conditions (Tubbs, Little River & Shallotte Inlets)

2.3 Interior Boundary Conditions

The translated tidal data helps to produce an open boundary conditions at each inlet location. The boundary conditions will force the tidal currents through the model domain using the water surface parameters as the

[6] Tides & Currents (2017). NOAA tide predictions. URL. https://tidesandcurrents.noaa.gov/tide_predictions.html (visited 2017, February 08).

catalyst. However, the model also requires boundary conditions along the interior domain. The interior boundaries exist along the major creeks and water bodies feeding into the model domain. Both the 2004/05 and the 2016 analysis utilize reflection/absorption boundary elements located at the edge of the model domain within the interior water systems. Figure 5 shows the reflection/absorption elements generally located on each end of the AIWW, the inland extent of Shallotte River, the terminus of Dunn Sound, and Calabash River. The reflection/absorption elements allow the RMA2 software to produce a dynamic response to the water surface elevations and tidal velocities flowing across the boundary point from the model domain. The elements generate the response through the linear wave theory and help simplify the modeling process by simulating the harmonic solution of a tide cycle. This reduces the need to expand the modeling domain to a known tidal source or input station further upstream.

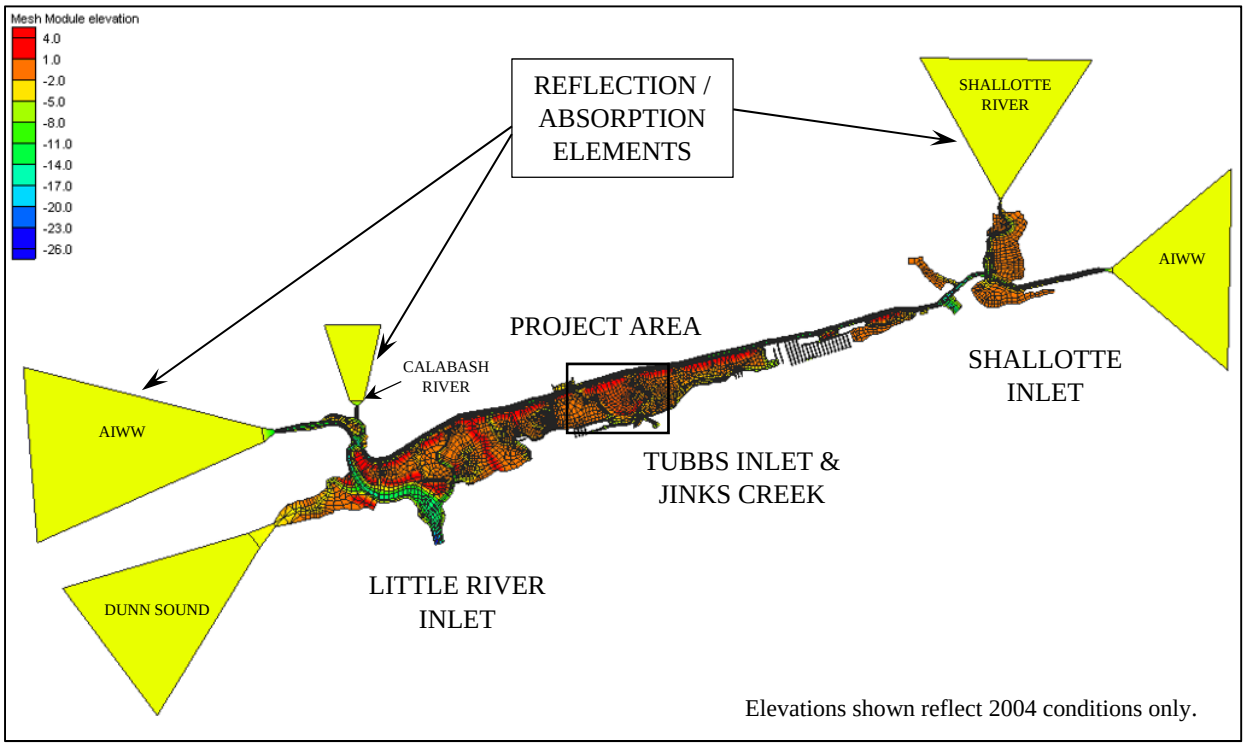


Figure 5. Model Domain (2004/05 & 2016)[4]

2.4 2004/05 Modeled vs. Measured Results

The 2004/05 analysis compared the measured field data with modeled results of the tidal conditions to gauge how well the RMA2 software package replicated the real world conditions. During the comparison, the analysis adjusted the model parameters such as the Manning's 'n' coefficient and the marsh porosity values, to provide the best comparison of modeled and measured results. Appendix C shows the 2004/05 plots of the data comparison. The 2004/05 analysis notes a discrepancy in the measurements at transect R12, located west of Sunset Beach Bridge. The discrepancy is credited to the averaging procedures utilized by the model and field data collection devices. Otherwise the 2004/05 analysis concluded the data sets matched reasonably well[4].

2.5 2016 Updates & Input for the RMA2 Modeling Analysis

The calibration process for the current 2016 pre-dredge analysis consisted of updating the modeling software as well as updating the existing conditions of the model domain. The current analysis updates the RMA2 software from version 4.5 used in the 2004/05 analysis, to version 4.58. Version 4.58 reflects the

current edition of the software package as developed in conjunction with the USACE and maintained privately[7].

2.5.1 Mesh & Domain Refinement

The modeling updates included revising the mesh or calculation points for the model grid. The mesh is comprised of 2-dimensionsal polygons or elements extending across the study area. Refining the mesh allowed a more concentrated focus on Jinks Creek and the surrounding waters as opposed to the Sunset Beach Bridge vicinity. The modeling software provides results based on the location of the nodes which join the mesh elements together. The 2016 analysis added additional elements to the mesh system to obtain a higher concentration of results. The analysis also aligns the new elements with respect to the proposed channel for Jinks Creek to provide a better representation of the potential influence. Larger mesh systems could extend outside of the dredge limits and not capture the proposed depths at the current nodal points. The refinement will aid in providing better results for the flow exchange and velocity measurements[8]. Figure 6 shows the revised mesh and nodal points utilized in the 2016 modeling analysis.

The current analysis utilized the same model domain as the 2004 analysis. This includes the AIWW and interior waters extending from Little River Inlet, located to the west of Sunset Beach, to Shallotte Inlet, located to the east of Sunset Beach. The domain also extends through Tubbs Inlet to capture the velocity and flow rates estimated to traverse this location. Figure 5 shows the domain included in both the 2004/05 and current 2016 modeling analysis.

The inclusion of Little River Inlet and Shallotte Inlet provides confidence the analysis captures the appropriate tidal influence along the AIWW and Jinks Creek. The 2004/05 analysis suggested a nodal point in the tidal influence exists near Sunset Beach Bridge. The nodal point represents the diversion point where the majority of tidal flows will travel towards Little River Inlet or back towards Tubbs and Shallotte inlets[4].

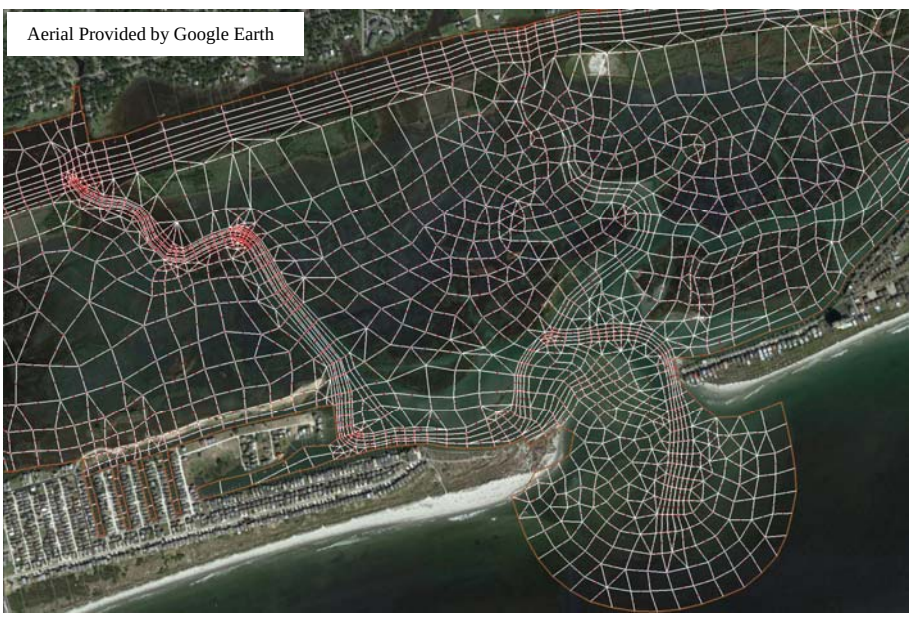


Figure 6. Jinks Creek 2016 RMA2 Mesh (Planview)

[7] Aquaveo. (2017) SMS:TABS. URL http://www.xmswiki.com/wiki/SMS:TABS (visited 2017, January 31).
[8] USACE. (2009). RMA2 WES version 4.5. US Army Research and Development Center, Waterways Experiment Station, Coastal and Hydraulics Laboratory.

2.5.2 Bathymetry Updates

Figure 5 also shows an overview of the bathymetry utilized for the 2004/05 analysis extending across the model domain; however, the current analysis updates the bathymetry within the immediate study area. The updated bathymetry allows for a better comparison of the current conditions of 2016 as opposed to the conditions represented in the 2004/05 study. Some material shoaling has occurred in the vicinity of Tubbs Inlet and the updated bathymetry helps to capture these changes. In addition, the 2004/05 analysis did not include a concentrated effort to collect bathymetric data for Jinks Creek and the surrounding waters. The bathymetry used for the 2004/05 analysis generally stemmed from existing data sets for areas located away from the Sunset Beach Bridge. The 2004/05 analysis did collect bathymetric surveys along the transects used for the field data collection. However, the data density does not provide adequate coverage to detail the existing and proposed conditions of the 2016 study area. Therefore, the current analysis collected additional bathymetric data to help describe the project conditions. Data collection occurred in February and August 2016 and covers each component of the pre-dredge analysis, including Jinks Creek, Mary's Creek, Turtle Creek, the Bay Area, and the Feeder Canal, along with the AIWW and Tubbs Inlet. Figure 7 shows the combined data coverage from the February and August survey events. Outside of the coverage area shown in Figure 7, the current analysis utilized the same bathymetry as the 2004/05 study. The current analysis assumes that although the bathymetric changes occurring between the 2004/05 and 2016 may be significant, the relative difference the changes imply into the analysis remain insignificant. Changing the bathymetry outside of the immediate study area may produce different results during the modeling exercise. However, when comparing the effects of the proposed dredging project, the relative changes created by using the 2004/05 bathymetry versus potentially updated bathymetry should remain minimal.

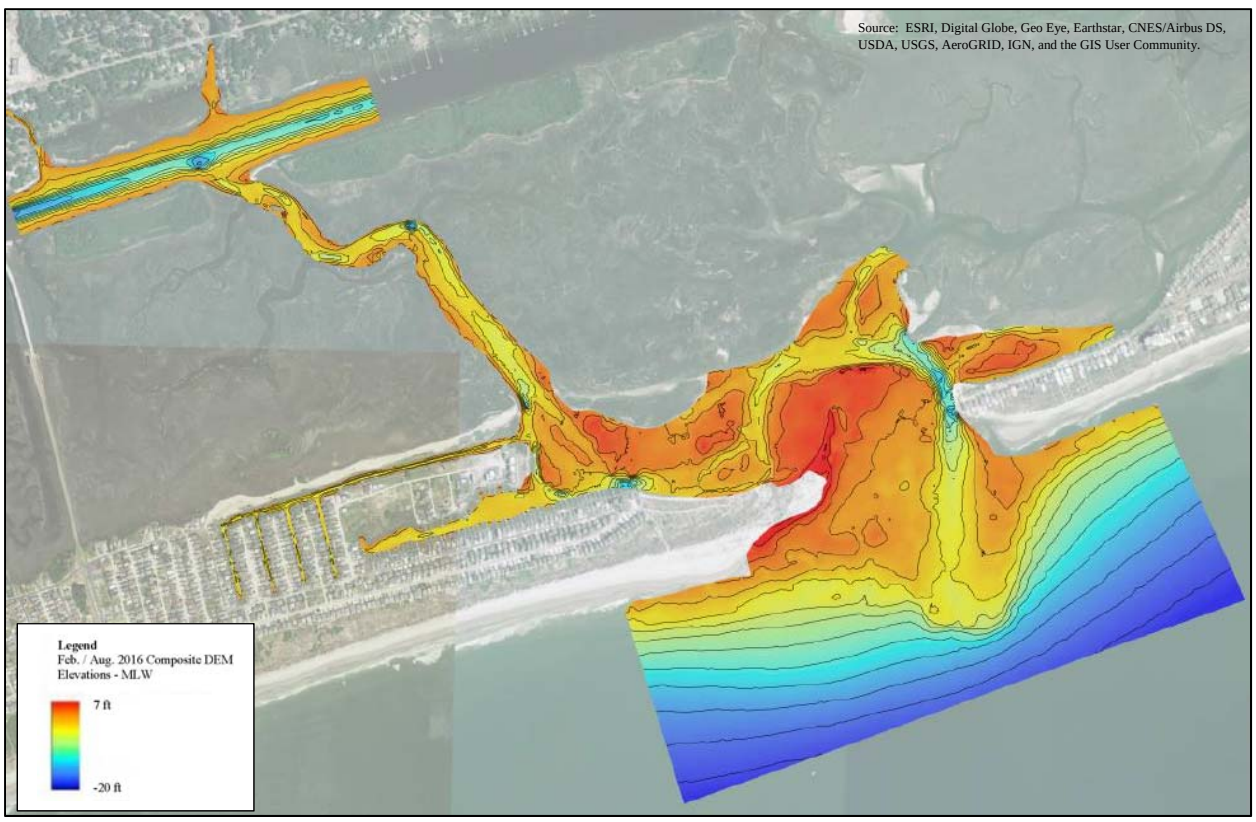


Figure 7. Updated Bathymetry for 2016 Pre-Dredge Analysis

2.5.3 2016 Calibration Results

The final calibration step entails verifying the measurements produced by the 2016 model agree with the results provided by the 2004/05 analysis. This includes the velocity and flow rate field measurements in addition to the model results of the 2004/05 study. To complete the calibration process, five (5) transects were chosen to compare the results including R18, R19, R20a, R20, and R22. Figure 8 shows the referenced transects enclose the study area in Jinks Creek and the AIWW. Flow rate measurements were compared at all five (5) transects and velocity measurements were compared at Transect R20a. (The 2004/05 analysis did not collect velocity measurements at any other transect in the current study area.)

As shown in Figures 9 through 13 the calculated flow rates for the updated model configuration match well with the original 2004/05 analysis. The results show minimal variations between the calculated flow rates experienced with the updated bathymetry in the 2016 model set-up and the original 2004/05 analysis. This adds confidence to the results of both analyses to suggest the model scenarios depict a similar tidal prism for each application.

Figure 8. 2016 vs. 2004/05 Flow Rate Comparison Transects (Planview)

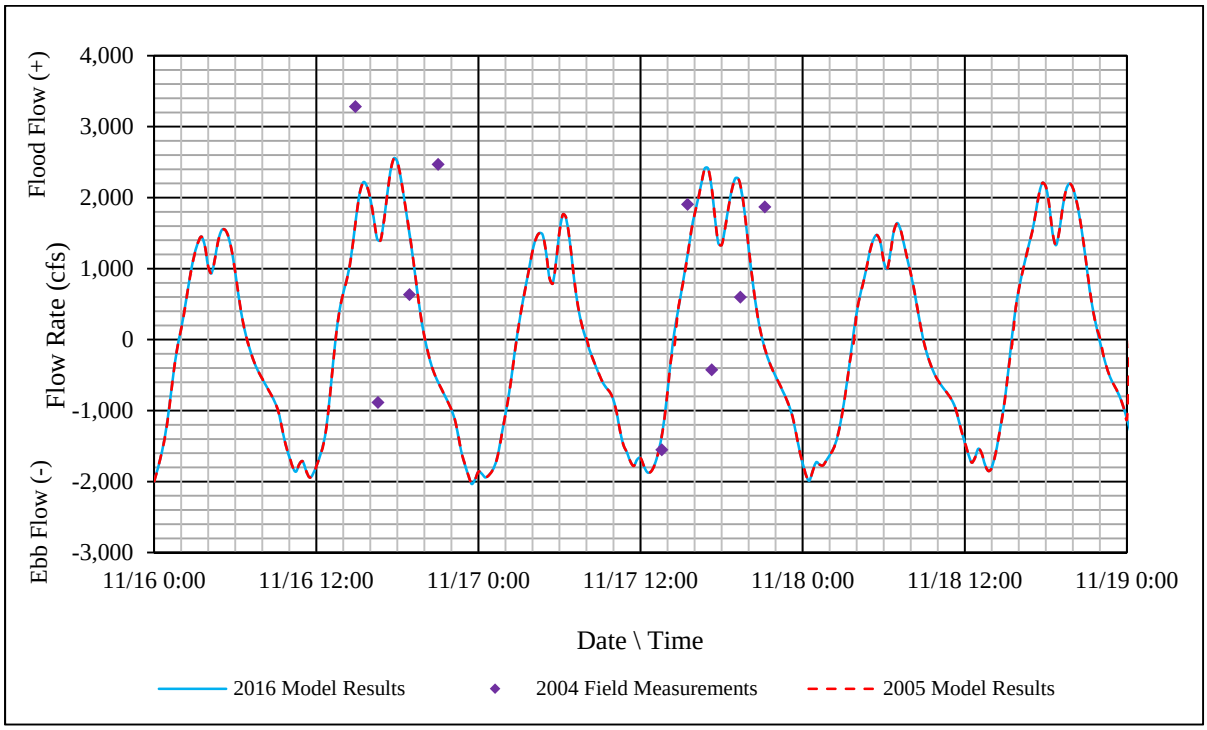


Figure 9. 2016 vs. 2004/05 Flow Rate Comparison (Transect R18)

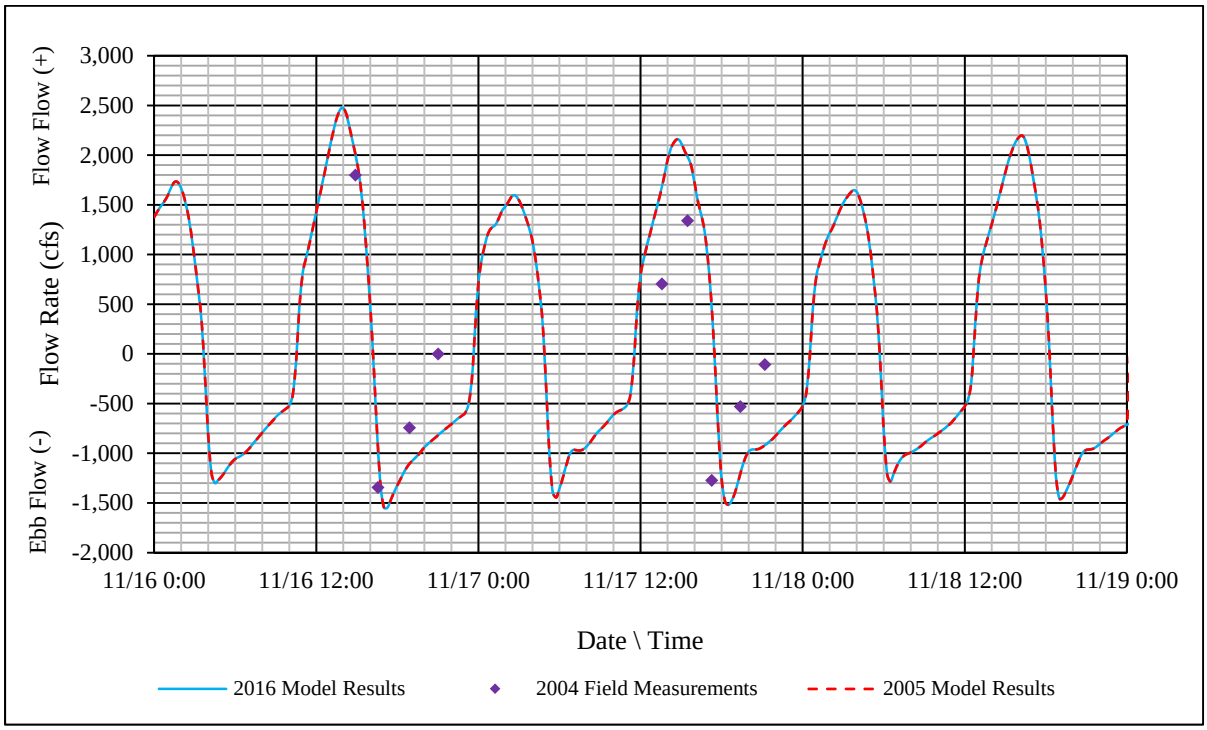


Figure 10. 2016 vs. 2004/2005 Flow Rate Comparison (Transect R19)

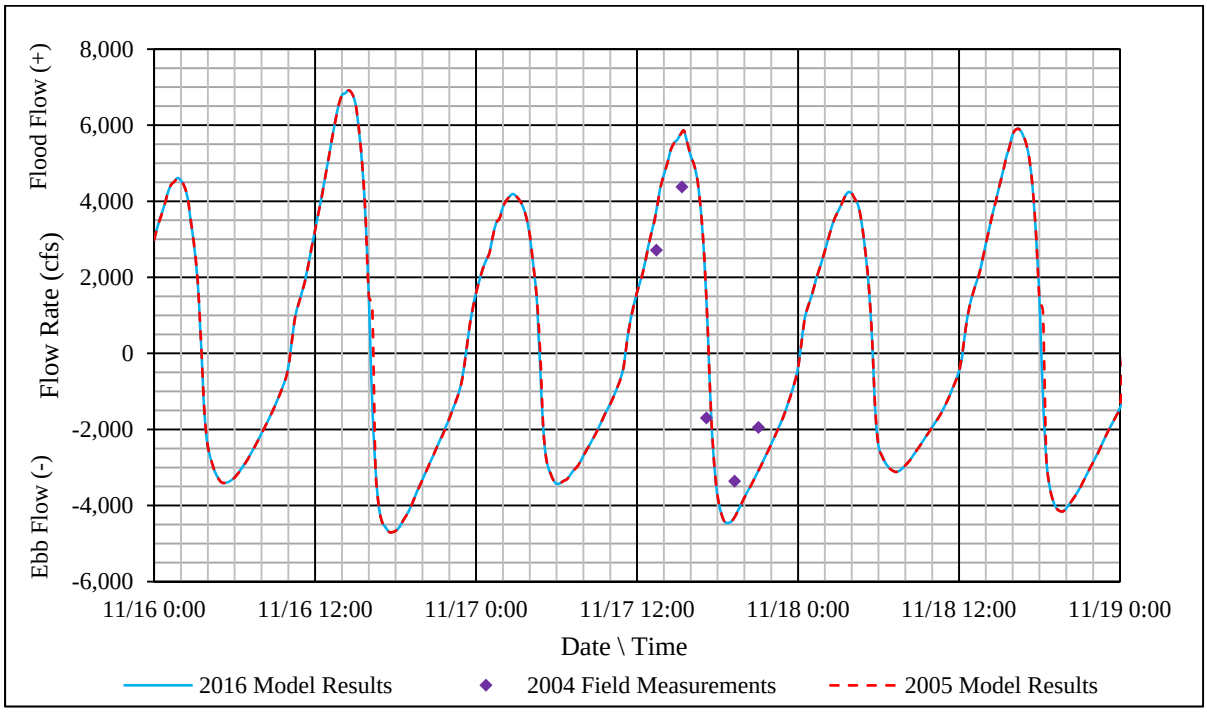


Figure 11. 2016 vs. 2004/05 Flow Rate Comparison (Transect T20a)

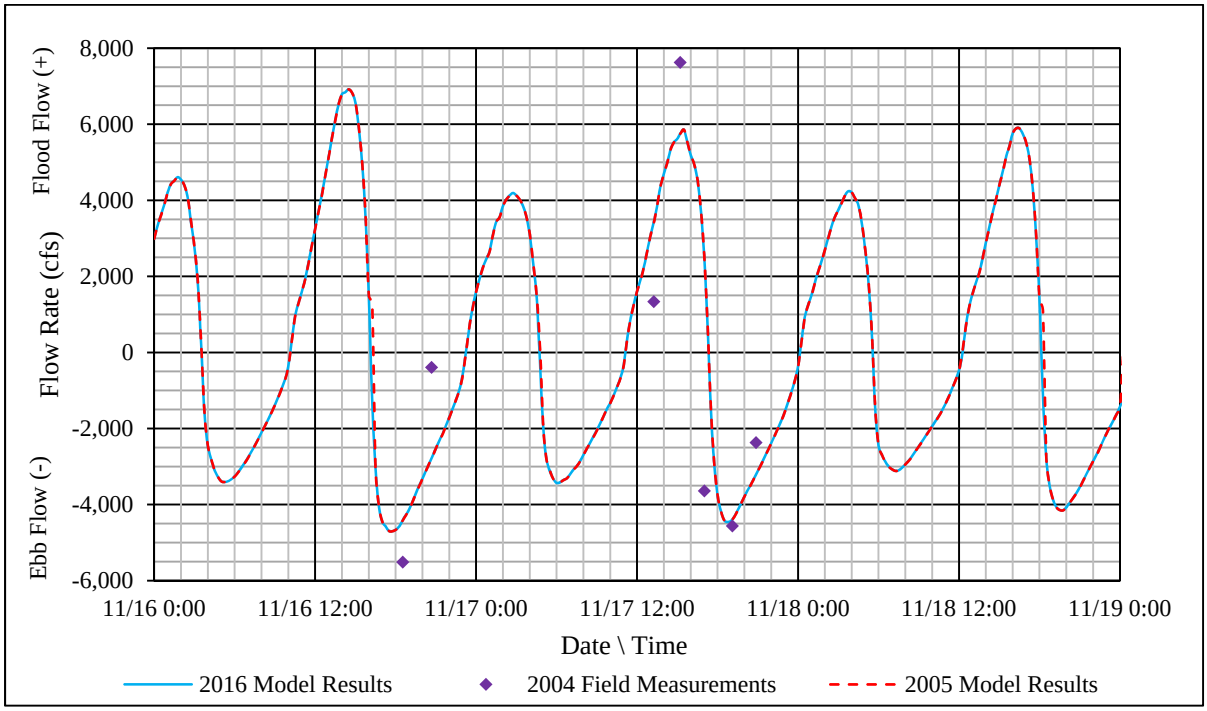


Figure 12. 2016 vs. 2004/05 Flow Rate Comparison (Transect 20)

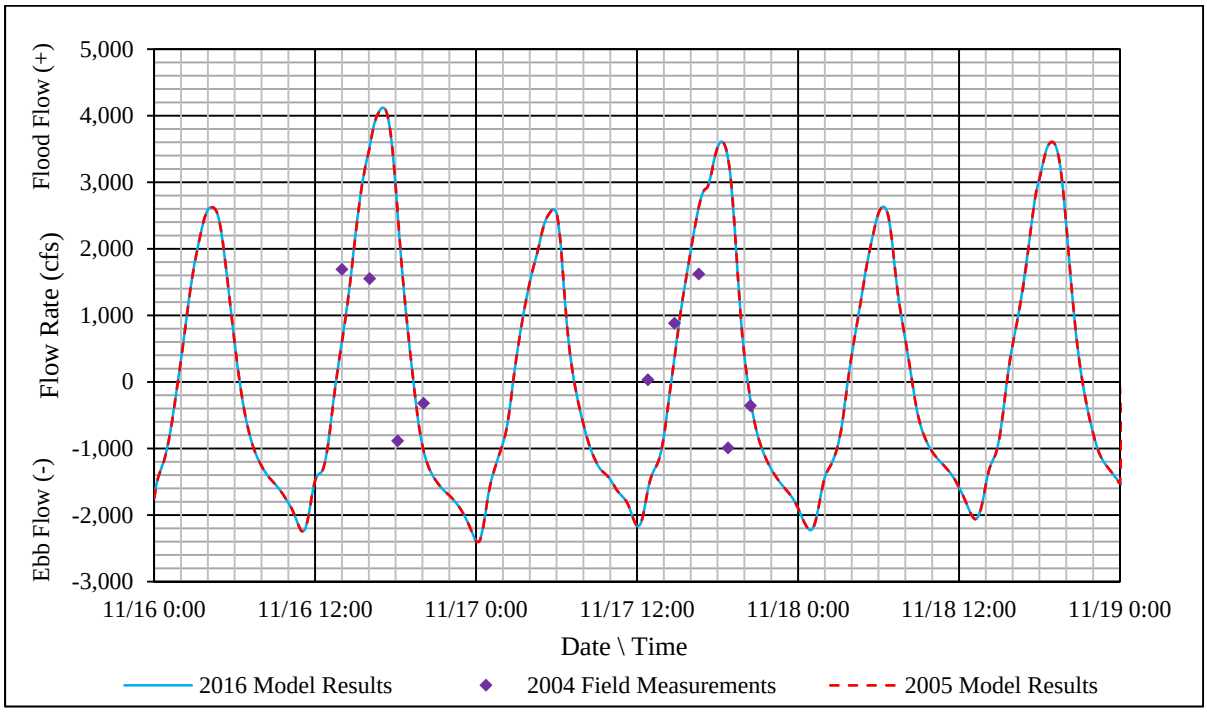


Figure 13. 2016 vs. 2004/05 Flow Rate Comparison (Transect R22)

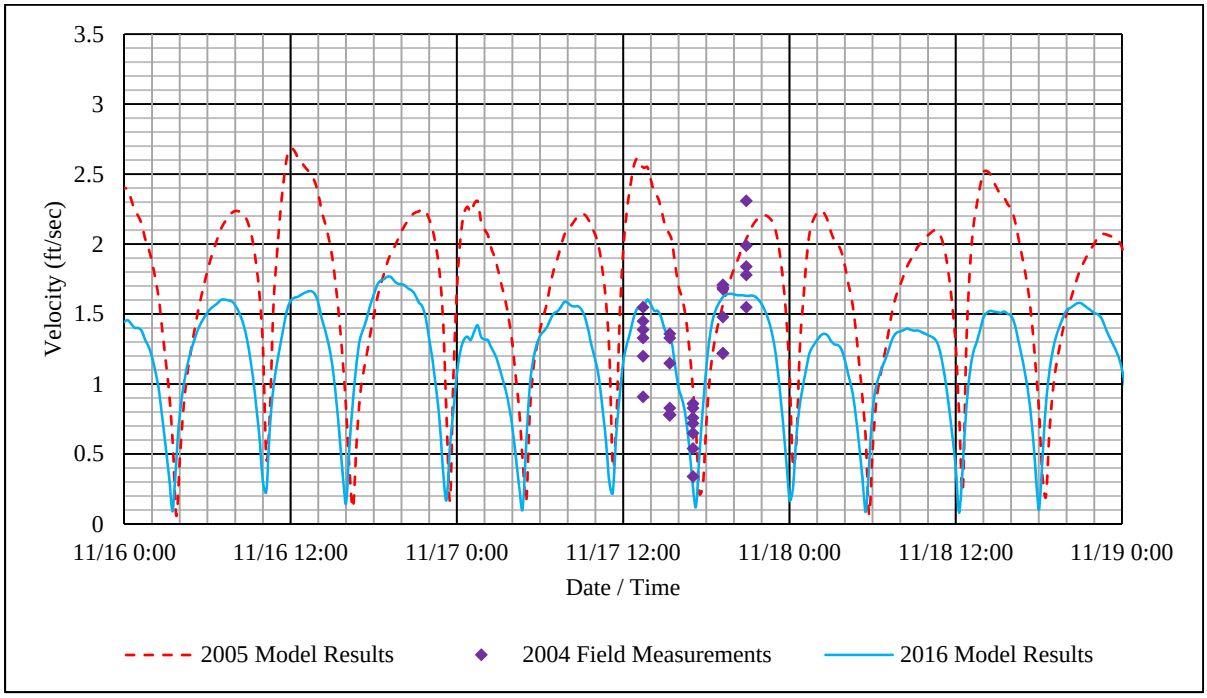


Figure 14. 2016 vs. 2004/05 Velocity Comparison (Transect R20a)

The velocity data shown in Figure 14 also shows a reasonable comparison with the 2004/05 measured results. As shown in the figure, the 2016 modeled velocity measurements consistently range below the maximum velocities estimated from the 2004/05 modeling analysis. The reduction in magnitude results from the changed bathymetry between the 2004/05 and 2016 model domains.

Beyond the change in bathymetry some discrepancies may be observed in the flow rate comparisons shown in Figures 9 through 13. For instance, the peak flow results modeled for Transects R18 and R19, closer to the Sunset Beach Bridge in the AIWW, show an approximate 20% exceedance compared to the measured values. The peak ebb (-) flow rate measured for R18 on November 17 (12:00) equals approximately -1,550 cfs while the modeled rate totals approximately -1,850 cfs. Likewise, the measured peak flood (+) flow on the same date equals approximately +1,910 cfs and the modeled rate reached a maximum of +2,410 cfs. In both scenario's the modeled extremes exceed the measured data points by approximately 20% or greater. Figure 10 shows similar results occurred for Transect R19, located in northern Jinks Creek. The discrepancy could be related to the averaging methods utilized to provide the measured and modeled data points. However, the final results must consider the potential variation in the modeling analysis compared to the observed tidal constituents.

The flow rate comparison for Transect R20a shows a larger discrepancy, with the modeling results exceeding the measured data points by approximately 30%. Figure 11 shows the peak ebb (-) flow on November 17th measured approximately -3,350 cfs and the peak modeled rate totaled approximately -4,460 cfs. Data points showing the flood flow rate comparison provide a similar scenario. The peak observed flood (+) flow measured approximately +4,380 cfs and the modeled rate reached a peak of approximately +5,850 cfs. The larger discrepancy most likely results from the influence of Tubbs Inlet located adjacent to Transect R20a. The influence of Tubbs Inlet most likely exaggerates the modeling discrepancies as the flows adjacent to the inlet experience the maximum variation in ebb (-) and flood (+) values. The analysis results must also consider these variations in magnitudes near Tubbs Inlet.

3.0 2016 MODEL RESULTS

The modeling analysis conducted for Jinks Creek concentrates on evaluating the potential change in tidal velocities and flow rates the project may create. The analysis focuses on the preferred alignment, but also includes a conceptual and maximum alignment to show how the results may differ. The analysis evaluates the performance of all three alternatives under the assumption of the November 2004 spring tide event. In each scenario, the study compares the modeling results against the expected performance of the current system. The modeling uses the 2016 bathymetry referenced previously to define the current conditions of the interior system. The results below discuss the performance of the preferred alternative while Appendix D provides the analysis of the conceptual and maximum alternatives. For reference, the following list details the modeling alignments reviewed for the 2016 Pre-Dredge Analysis:

- Conceptual - 100' Wide @ -7 MLW (entire channel)
- Maximum - 100' Wide @ -7 MLW (entire channel & Tubbs Inlet)
- Preferred - 40' ~ 50' Wide @ -5 MLW (northern Jinks Creek)
  80'~100' Wide @ -7 MLW (southern Jinks Creek)

The preferred alignment extends approximately 6,800 feet in Jinks Creek from the AIWW and terminates approximately 3,600 feet from Tubbs Inlet. Figure 15 shows a general planview of the preferred alignment for Jinks Creek along with the dredging areas proposed for the complete project. For additional detail, Appendix E shows the plan and profile view of the preferred alignment through Jinks Creek.

The preferred alignment provides varying depths and widths in response to environmental concerns voiced for northern Jinks Creek as well as sediment quality issues. Several Sunset Beach residents voiced concerns of dredging northern Jinks Creek based on the potential of this area providing shellfish or oyster habitat. Therefore, in an attempt to avoid any potential impacts the preferred alternative minimizes the channel alignment and strives to follow the deep water thalweg through northern Jinks Creek. This action also helps provide a buffer between the proposed channel and the adjacent Primary Nursery Area (PNA). The North

Carolina Division of Marine Fisheries (DMF) has designated the marsh and wetlands adjacent to northern Jinks Creek as critical habitat for young and juvenile fishery species or PNA[9]. DMF manages the state's aquatic resources and holds the responsibility to protect the estuarine resources. Erosional losses occurring along the channel banks or transition areas between Jinks Creek and the adjacent marsh may be viewed as a negative impact after project construction. The impacts could be created by dredging too close to the marsh and having material slough into the work area or by increased wake and scour velocities creating erosion along the boundary areas. Therefore, minimizing the channel dimensions also helps reduce the potential for impacts to the PNA.

Figure 15. Proposed Dredge Area in Jinks Creek & Surrounding Waters

Within southern Jinks Creek the shoaling potential elevates and reducing the channel dimensions could increase the maintenance frequency necessary to maintain the channel. Southern Jinks Creek currently maintains more visible shoaling as emergent sand covers most of the area at low tide. Although a shoaling study has not been conducted as part of this pre-dredge analysis, reducing the dredging footprint within southern Jinks Creek may not provide the same benefits as envisioned for northern Jinks Creek. Figure 16 shows representative photos of northern and southern Jinks Creek for reference.

[9] North Carolina Department of Environmental Quality (NCDEQ), (2017). North Carolina's fishery nursery areas. URL. http://nc.maps.arcgis.com/home/item.html?id=3de2e2ee7def4e5eae1d52b836ade23a (visited 2017, February 10).

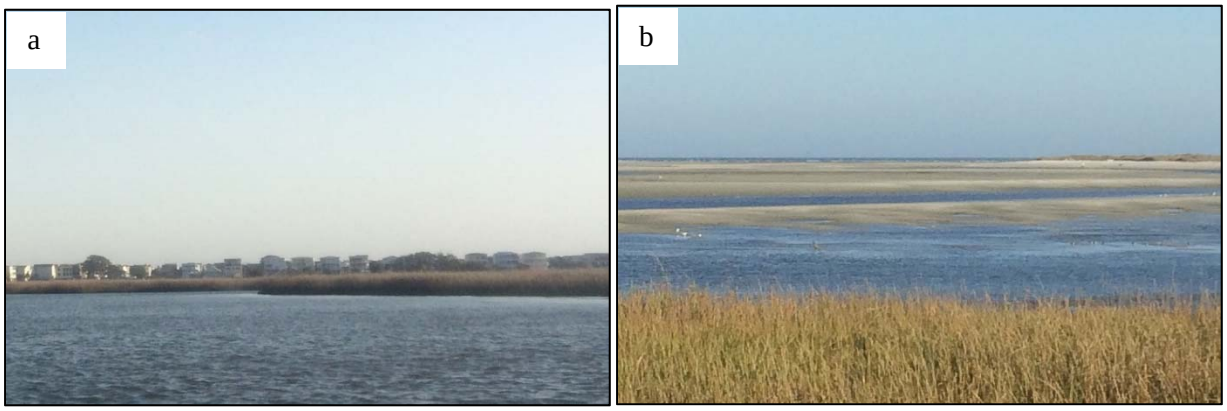


Figure 16. Representative Photos of (a) Northern & (b) Southern Jinks Creek

The modeling analysis provides the estimated change in tidal velocities and flow rates observed along multiple locations within Jinks Creek and the AIWW. The analysis compares the estimated changes with the modeled results of the existing bathymetry under the same tidal conditions. Fixed transects provide consistent reference points for extracting the results information. The transect locations concentrate on providing information to address the following concerns:

1. Will the dredging project create additional shoaling within the AIWW confluence with Jinks Creek?
2. Will the dredging create increased scouring velocities within the 'S' curve alignment of Jinks Creek?
3. Will the dredging impact the shoaling or migration patterns of Tubbs Inlet?
4. How will the new channel respond during extreme storm conditions?

DCM and the USACE identified the first 3 of the listed concerns through the coordination process. The analysis includes the 4th concern regarding the extreme storm condition in response to citizen comments regarding the expected performance of the new channel. The analysis utilizes tidal characteristics similar to those measured during Hurricane Hugo to compare how the dredging may influence water flow velocities, elevations, and magnitudes during extreme conditions.

Figure 17 shows the plan view locations of the fixed transects used to extract the flow rate and velocity measurements for each of the referenced concerns. As shown in the list below, the analysis identifies a minimum of three (3) transects to evaluate the performance of each study area. The analysis utilizes data from multiple transects or sampling locations to provide a comprehensive review of the relative changes in the velocity magnitudes and flow rates that may result from each alternative.

- AIWW confluence with Jinks Creek: T1, T2, & T3
- The 'S' curve alignment in Jinks Creek: T4, T5, & T6
- Migration of Tubbs Inlet: T7, T8, T9, & T10
- Extreme storm condition performance: T3, T5, & T7

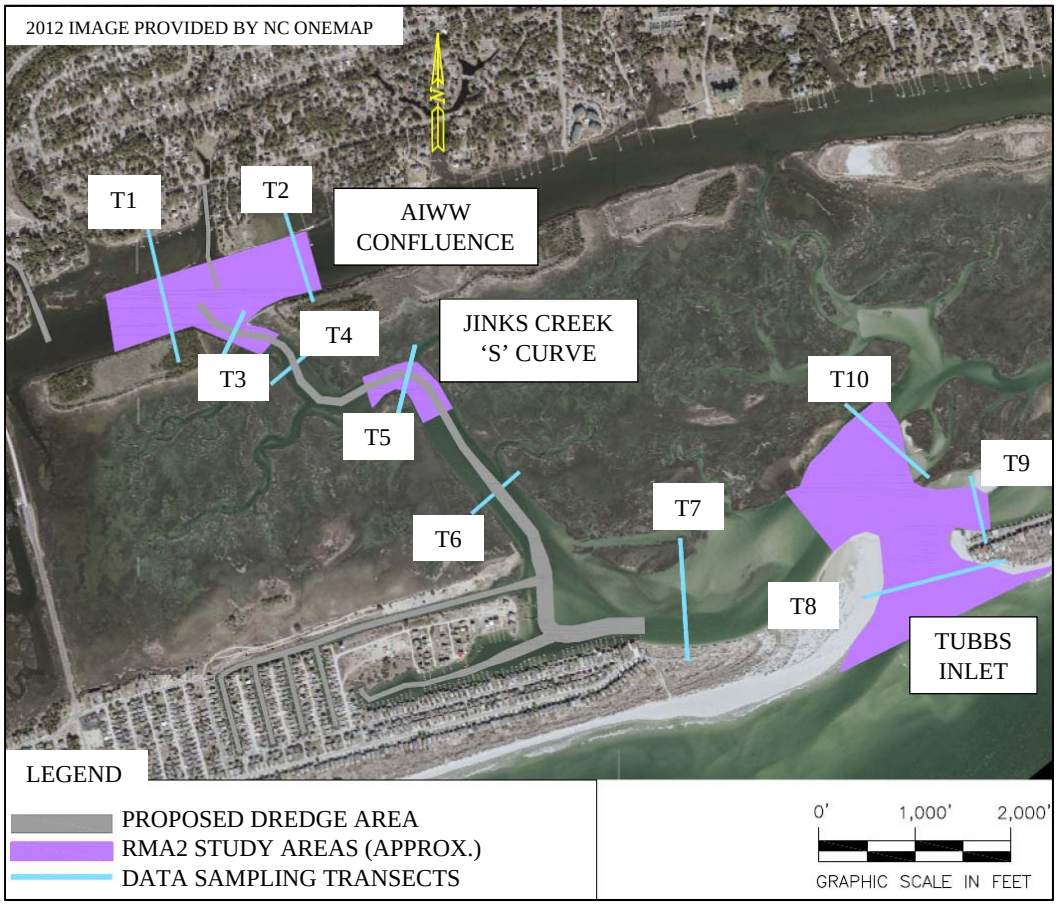


Figure 17. Transect Locations Used for the 2016 Pre-Dredge Analysis

Similar to the calibration process, the modeling analysis utilizes the tidal conditions recorded during the November 2004 spring tide event. The results represent the tidal velocities and flow rates encapsulating the November 16-17, 2004 spring tide event and extend from November 13 through November 19, 2004. The decision to use the 2004 data helped alleviate the need for additional field work and helped expedite the modeling schedule.

3.1 Concern 1 - Additional Shoaling in the AIWW Confluence with Jinks Creek

The modeling results indicate a minimal change in tidal velocities will occur as a result of the dredge project. Hence, the change should not significantly increase the shoaling potential in the AIWW confluence. Figures 18 through 20 show the comparison of the maximum velocities recorded under the 2016 existing conditions and the preferred alignment for Transects T1 through T3, respectively. The maximum change resulting from the analysis equates to an approximate 2.6% increase across Transect T3. The modeling analysis estimates the maximum velocity will increase from 2.75 ft/s under the existing conditions, to approximately 2.82 ft/s with the dredging project. As a note, the modeling software calculates depth averaged velocities and not absolute values. However, understanding the relative change indicated by the model provides a reasonable assurance to conclude the velocities will not incur a significant increase.

The calculations along T1 and T2 indicate the additional velocities will diverge on a 2:1 pattern between the southwest and northeast channels of the AIWW, respectively. The modeling indicates the maximum velocity change along T1 should result in an approximate 1.6% increase, and along T2 an approximate 0.8% increase. Table 1 provides a summary of the maximum velocity percent change estimated for each transect within the AIWW confluence with Jinks Creek.

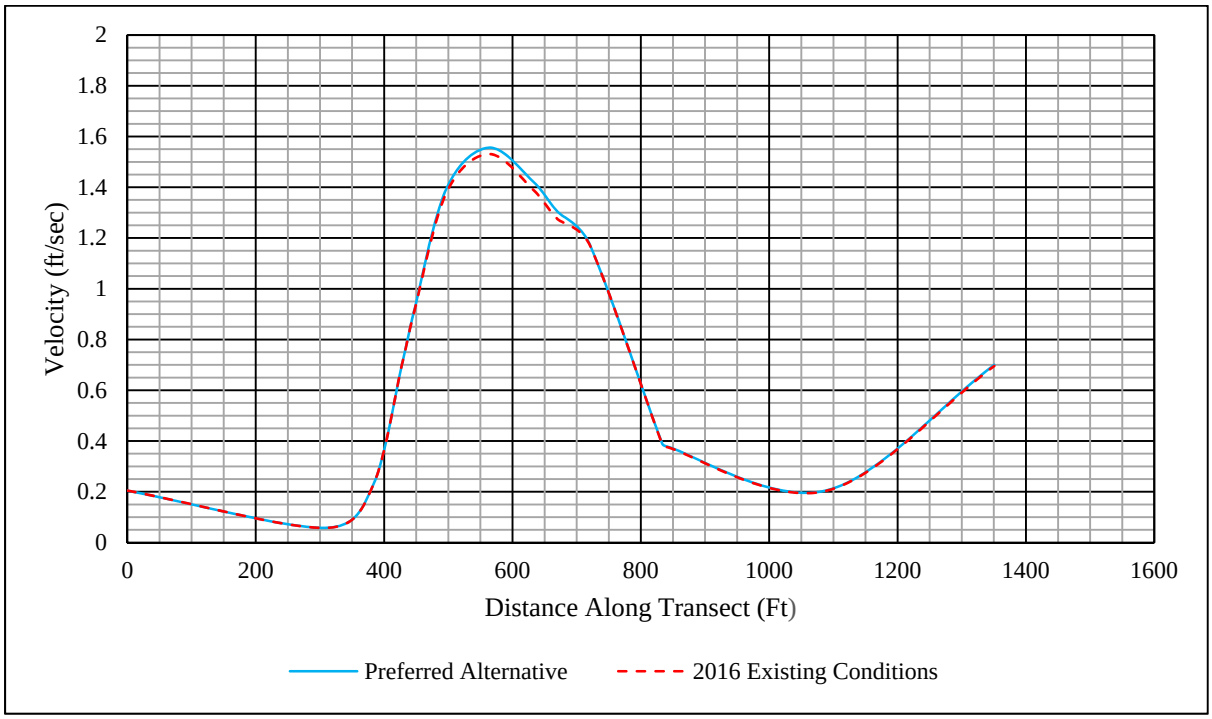


Figure 18. Transect T1 - Maximum Velocity Measurements (Spring Tide Condition)

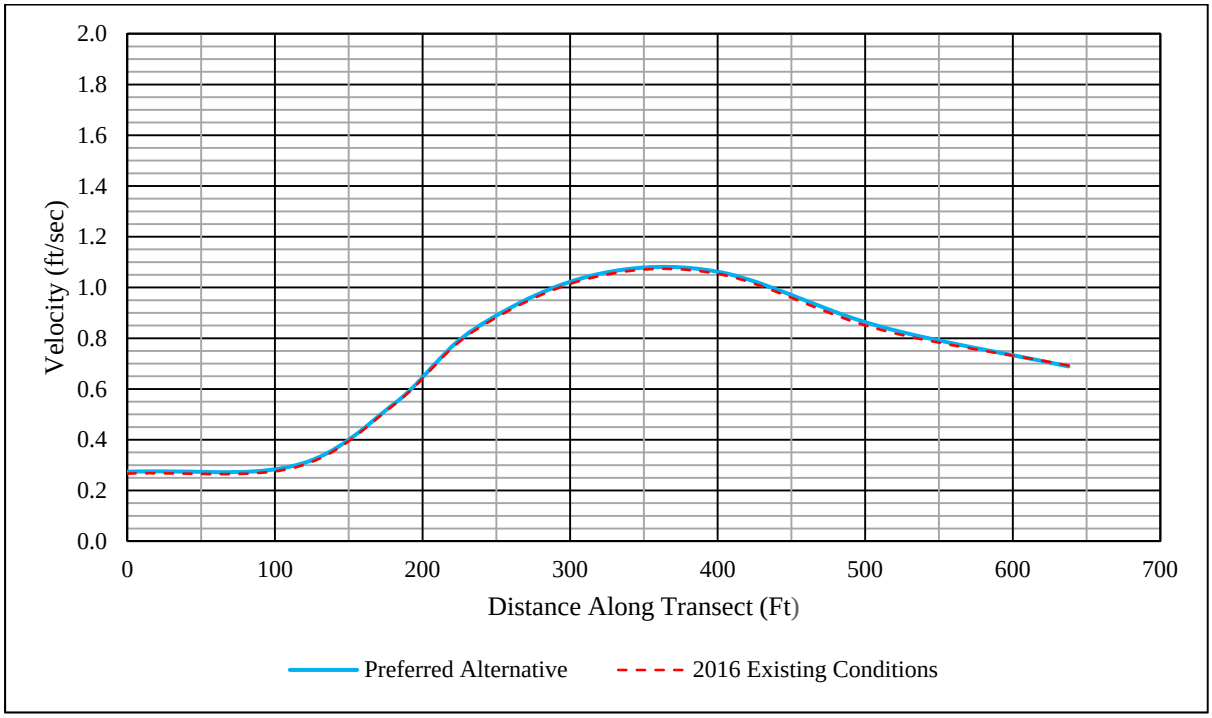


Figure 19. Transect T2 - Maximum Velocity Measurements (Spring Tide Condition)

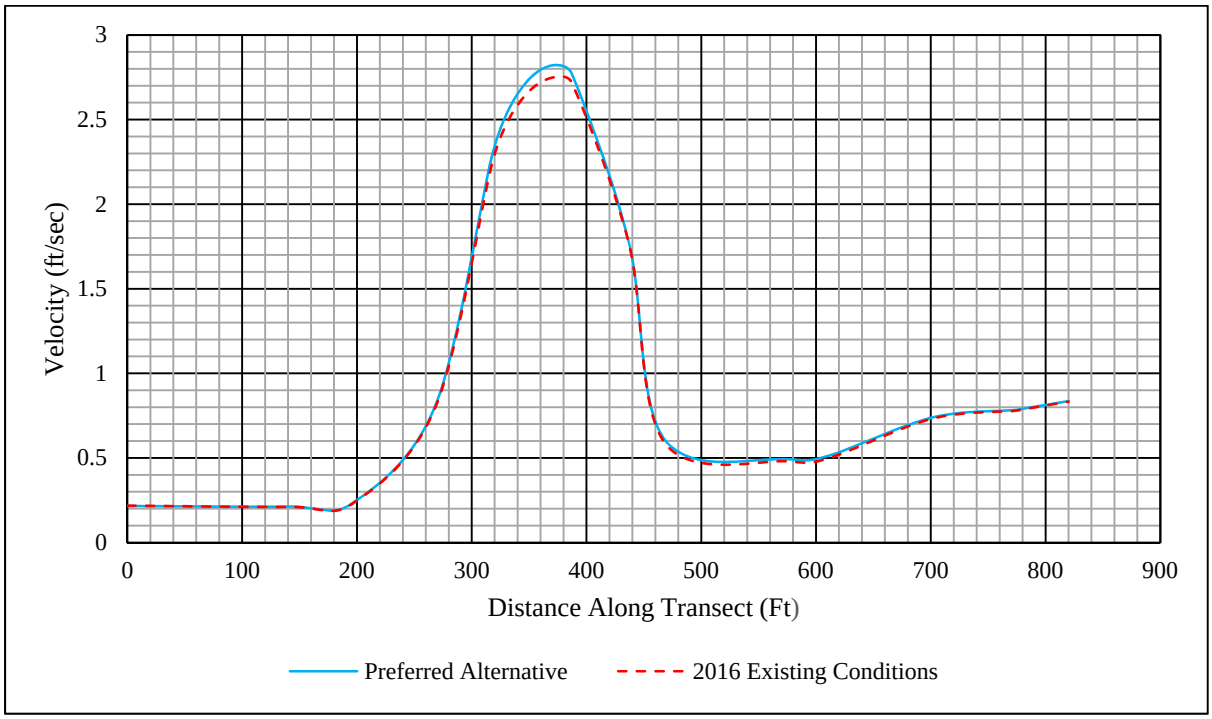


Figure 20. Transect T3 - Maximum Velocity Measurements (Spring Tide Condition)

Table 1. AIWW & Jinks Creek Confluence - Maximum Velocity Changes (Spring Tide Condition)

Transect	2016 Existing Conditions	Preferred Alternative	Percent (%) Change
T1	1.53 ft/sec	1.56 ft/sec	1.6%
T2	1.05 ft/sec	1.06 ft/sec	0.8 %
T3	2.75 ft/sec	2.82 ft/sec	2.6%

1. Values are depth averaged velocities simulated from Nov. 13, 2004 (13:15) to Nov. 20, 2004 (13:15) tidal conditions.

The modeling analysis also determined flow rate measurements across each transect within the AIWW confluence area. The flow rate measurements provide indications of how the current velocities will change throughout the tidal cycle, as opposed to only the change in the maximum velocities. The flow rate calculations represent the depth averaged velocities multiplied against the cross-sectional area of the channel flow way. This provides another indication of any potential changes to the flow patterns that may be expected with the proposed project. Figures 21 through 23 provide a comparison of the modeled flow rates calculated along transects T1 through T3, respectively, for the 2016 existing conditions and the preferred alternative. The figures provide a representative sample of the modeled data encapsulating the November 16-17, 2004 spring tide event.

The modeled flow rates add confidence to the conclusion that significant shoaling impacts should not occur within the AIWW confluence with Jinks Creek as a result of the proposed dredging. Table 2 shows the average flow rates exiting Jinks Creek may be expected to change approximately 3%. This determination matches well with the calculated maximum velocity change and indicates the velocity increase should be uniform across the ebb tidal cycle.

Table 2 also shows the flow rate across Transect T3 during ebb (outgoing) condition experiences over a 4% increase. However, the modeled flow rate for the preferred alternative remains significantly lower than the rate anticipated during the 2016 existing flood (incoming) stages. The average flow rate modeled for the preferred alignment at Transect T3 equals approximately 1,580 cfs during the ebb event, while the flood

flow rate estimated under the 2016 existing conditions totals approximately 2,450 cfs. Thus, the modeling suggest approximately 60% more water flows across the sampling area during the flood stage of the current conditions than would be expected during the ebb stage of the preferred alternative. Therefore, the increase in flow during the ebb tidal stage of the preferred alignment would not be expected to create additional scour above the 2016 existing flood tidal cycle.

Table 2. AIWW & Jinks Creek Confluence - Average Flow Rates (Spring Tide Condition)

Transect	Average Ebb Flow (Outgoing) cfs		Percent (%) Change	Average Flood Flow (Incoming) cfs		Percent (%) Change
	2016 Conditions	Preferred Alternative		2016 Conditions	Preferred Alternative	
T1	1,250	1,270	1.8%	3,140	3,190	1.6%
T2	1,530	1,560	2.0%	1,450	1,440	-0.7%
T3	1,510	1,580	4.6%	2,450	2,520	2.9%

1. Values represent averaged measurements simulated from Nov. 13, 2004 (13:15) to Nov. 20, 2004 (13:15) tidal conditions.

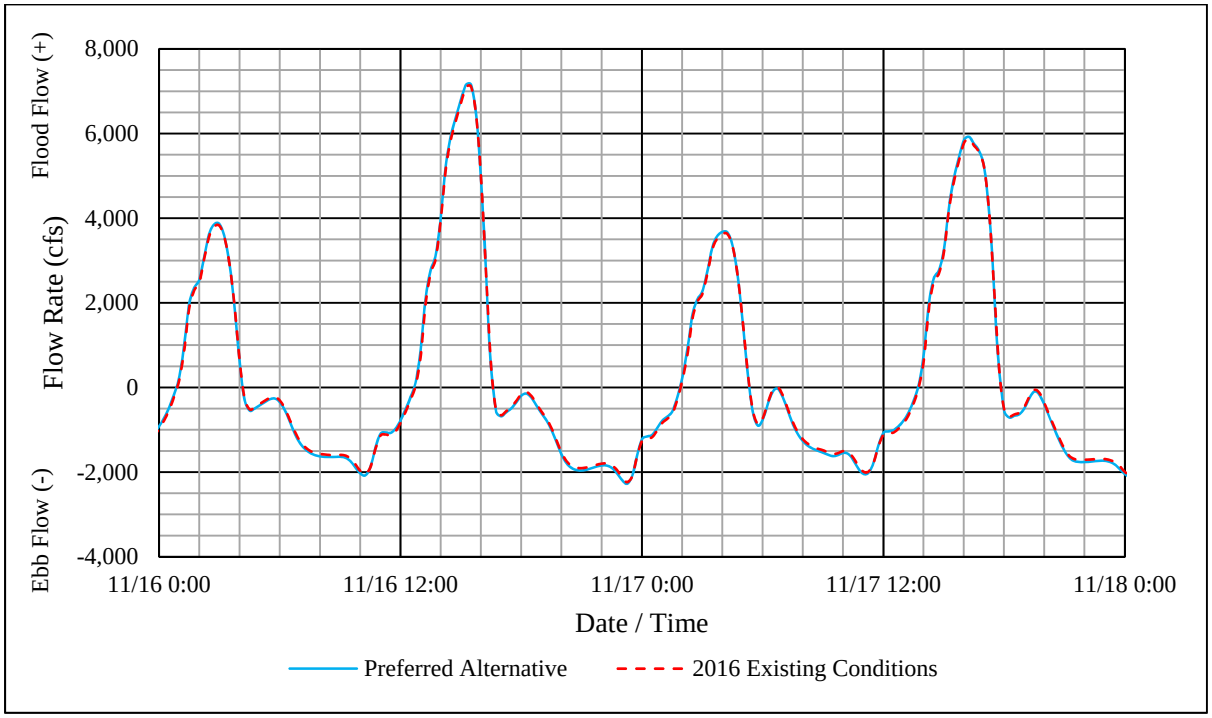


Figure 21. Transect T1 - Average Flow Rates (Spring Tide Condition)

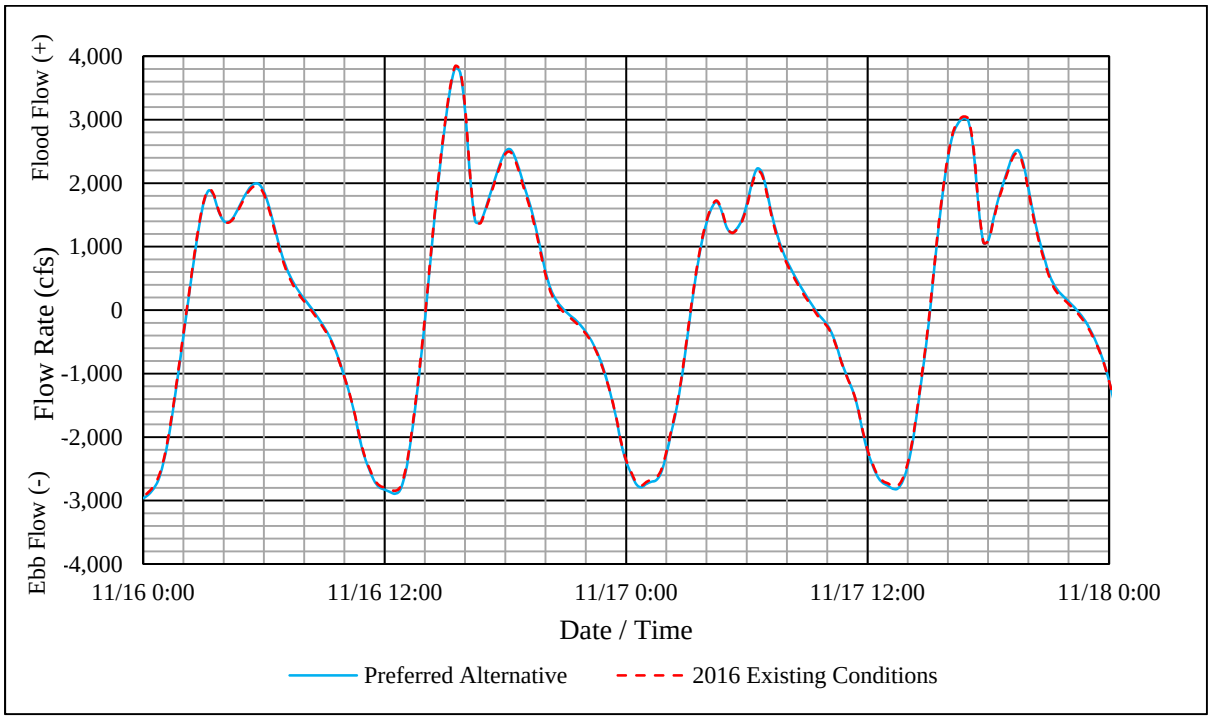


Figure 22. Transect T2 - Average Flow Rates (Spring Tide Condition)

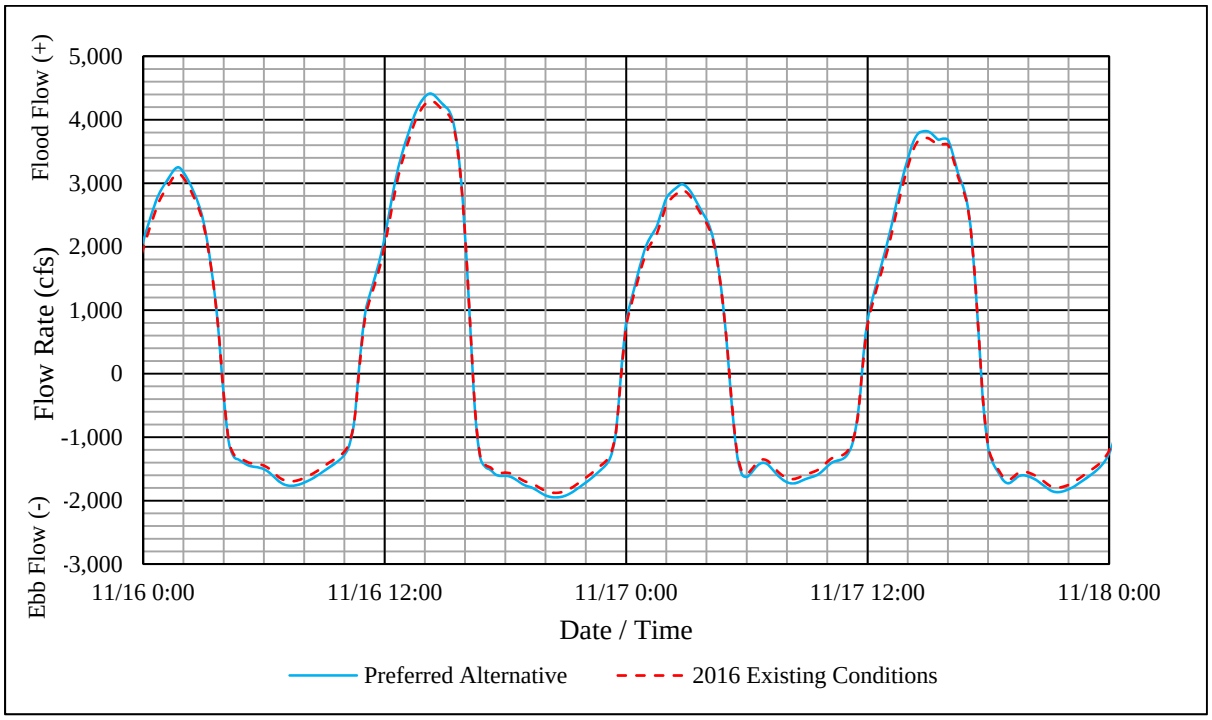


Figure 23. Transect T3 - Average Flow Rates (Spring Tide Condition)

3.2 Concern 2 – Increased Scour Potential along Jinks Creek 'S' Curve

The analysis references measurements at three (3) additional transects to evaluate the anticipated new flow regime that may be expected within the 'S' curve of Jinks Creek. Figure 17 shows the respective transects as T4, T5, and T6. The referenced transects enclose the 'S' curve alignment with T5 located in the center

of the sharpest bend. The analysis established the respective transect locations to gauge how the tidal velocities may change while traveling through the 'S' curve alignment.

The modeling results indicate the tidal velocities traversing the 'S' curve should not experience a significant increase under the proposed work. Table 3 shows the maximum velocities calculated for the 2016 existing conditions and the preferred alternative. The velocities under the preferred alternative measured less than a 1% change in magnitude when considering a spring tide event. The analysis suggests the velocities within the 'S' curve at Transect T5 will experience an increase on the order of double the increase expected along Transects T4 and T6. However, the modeling also estimates the velocity magnitudes along Transect T5 will still measure below the magnitudes expected along Transects T4 & T6. Figures 24 through 26 provide the maximum velocity plots for Transects T4 through T6, respectively.

Table 3. 'S' Curve Alignment - Maximum Velocity Changes (Spring Tide Condition)

Transect	2016 Existing Conditions	Preferred Alternative	Percent (%) Change
T4	3.45 ft/sec	3.46 ft/sec	0.3%
T5	2.86 ft/sec	2.88 ft/sec	0.7%
T6	3.01 ft/sec	3.02 ft/sec	0.3%

1. Values are depth averaged velocities simulated from Nov. 13, 2004 (13:15) to Nov. 20, 2004 (13:15) tidal conditions.

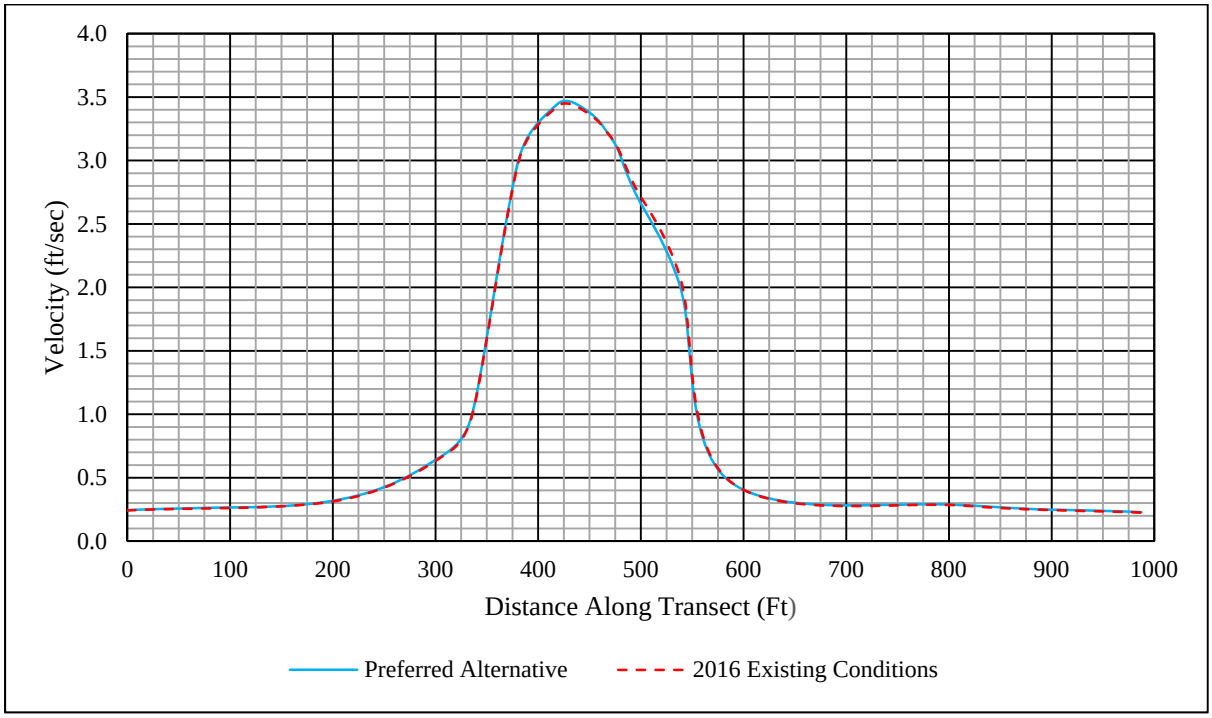


Figure 24. Transect T4 - Maximum Velocity Measurements (Spring Tide Condition)

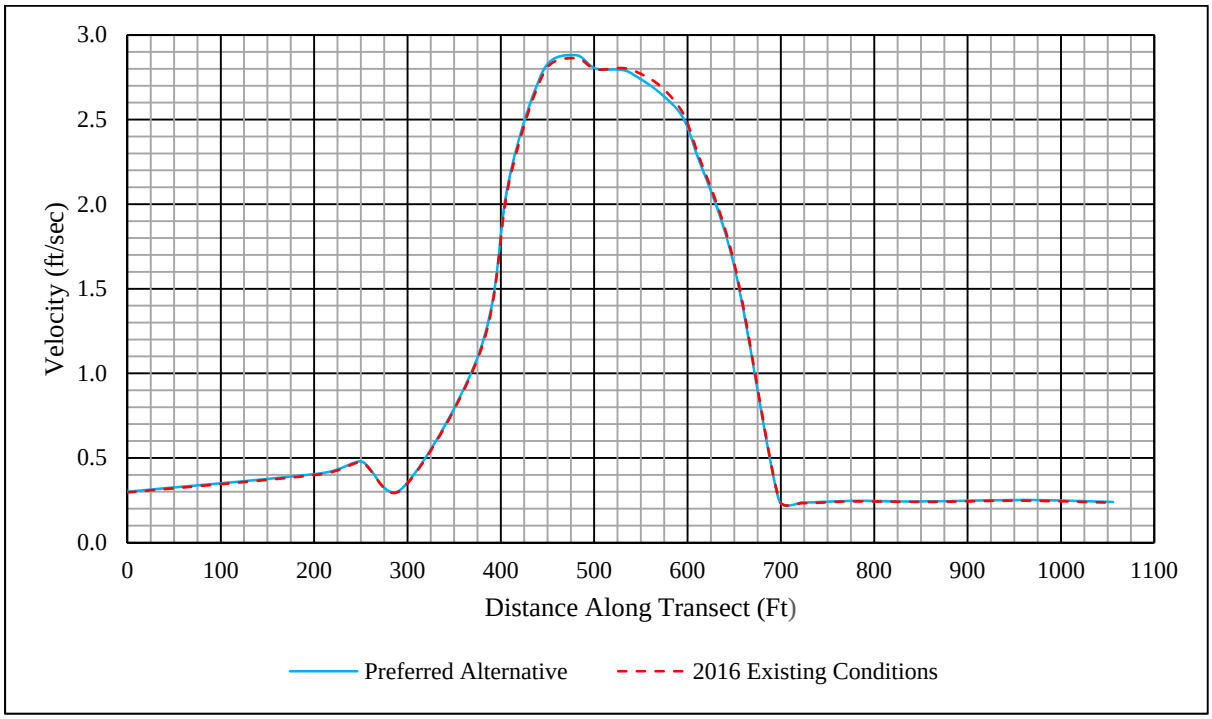


Figure 25. Transect T5 - Maximum Velocity Measurements (Spring Tide Condition)

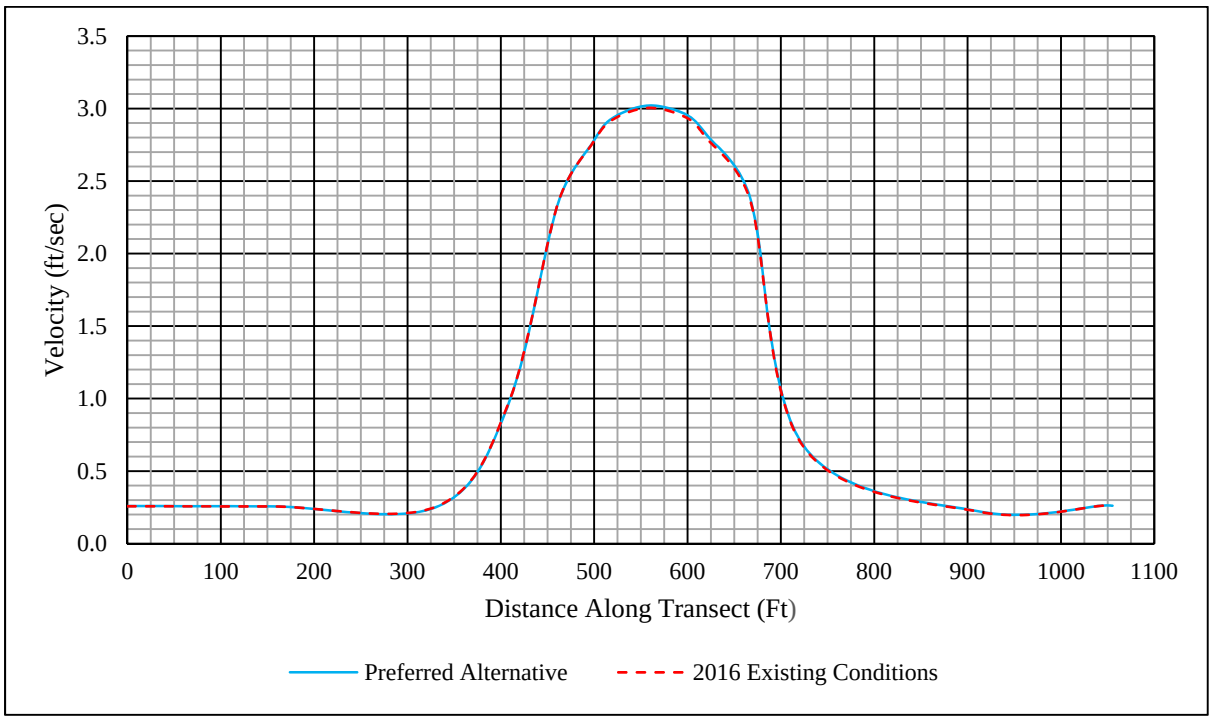


Figure 26. Transect T6 - Maximum Velocity Measurements (Spring Tide Condition)

The velocity measurements agree with field observations indicating the existing velocities already reach the scouring threshold within the 'S' curve alignment. The limiting velocity for scour equates to

approximately 3.28 ft/sec[10] and the modeling indicates the velocities throughout Jinks Creek trend towards this limit. Field observations also suggest the velocities within the 'S' curve already meet or exceed this limiting scour threshold. Depths observed within the 'S' curve alignment, approximate to Transect T5, extend the deepest of any portion of Jinks Creek. Figure 27 shows the existing grade approximate to Transect T5 along Station 27+00 in the 'S' curve alignment. The 27+00 designation refers to the approximate distance from the AIWW confluence as measured along the centerline of the preferred alternative.

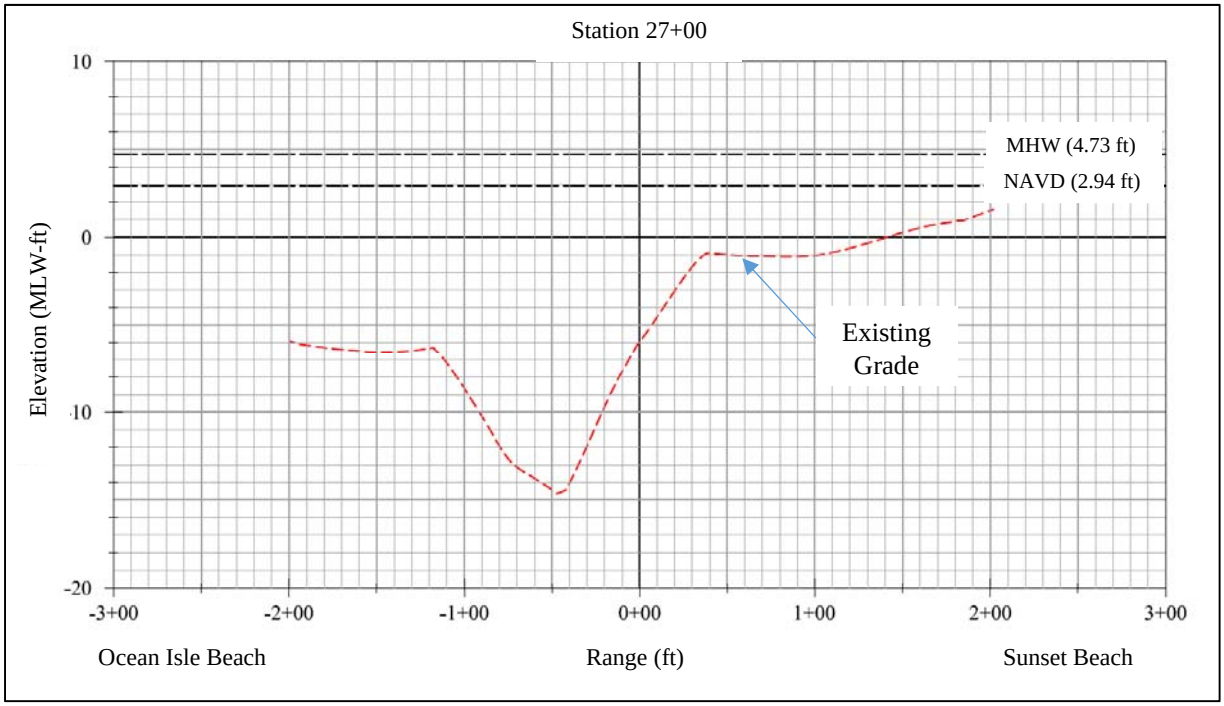


Figure 27. Station 27+00 - Existing Grade in 'S' Curve Alignment (Transect T5)

As shown in Figure 27, the maximum depth approaches -15 MLW within the 'S' curve. This extreme depth within the curve most likely results from the tidal velocities scouring the existing thalweg as sediment shoals along the channel banks. As shown in Figure 28, a tributary empties into Jinks Creek in the heart of the 'S' curve, approximate to Station 27+00 (Transect T5).

The analysis also compares the anticipated flow rate expected for the 'S' curve alignment under the preferred alternative and the 2016 existing conditions. Figures 29 through 31 show the calculated flow rates based on the November 2004 spring tide measurements. The flow rate comparison shows insight on the influence of the tributaries connecting to Jinks Creek. The volume of flow decreases traveling north in Jinks Creek towards the AIWW. Comparing the largest flow rate measurements shown for T4 through T6 shows approximately 8,500 cfs should be expected along Transect T6 during the incoming (flood) spring tide. Transect T6 borders the 'S' curve alignment to the southeast in Jinks Creek and would capture most of the flood tide prism prior to the flow diverging into adjacent tributaries. However, the estimated flow rate reduces to approximately 5,200 cfs prior to Transect T4, located on the northwest side of the 'S' curve alignment and closer to the AIWW. A similar observation exists for the ebb (outgoing) tide cycle. The

[10] Dean, R.G. & Dalyrmple, R.A., (2002) Coastal processes with engineering applications. Cambridge: Cambridge University Press.

largest estimated flow at Transect T4 measures approximately 3,500 cfs and increases to approximately 6,000 cfs at Transect T6. For the ebb cycle, flow from the adjacent tributaries converging with Jinks Creek would increase the overall volume as the alignment advances towards Tubbs Inlet.

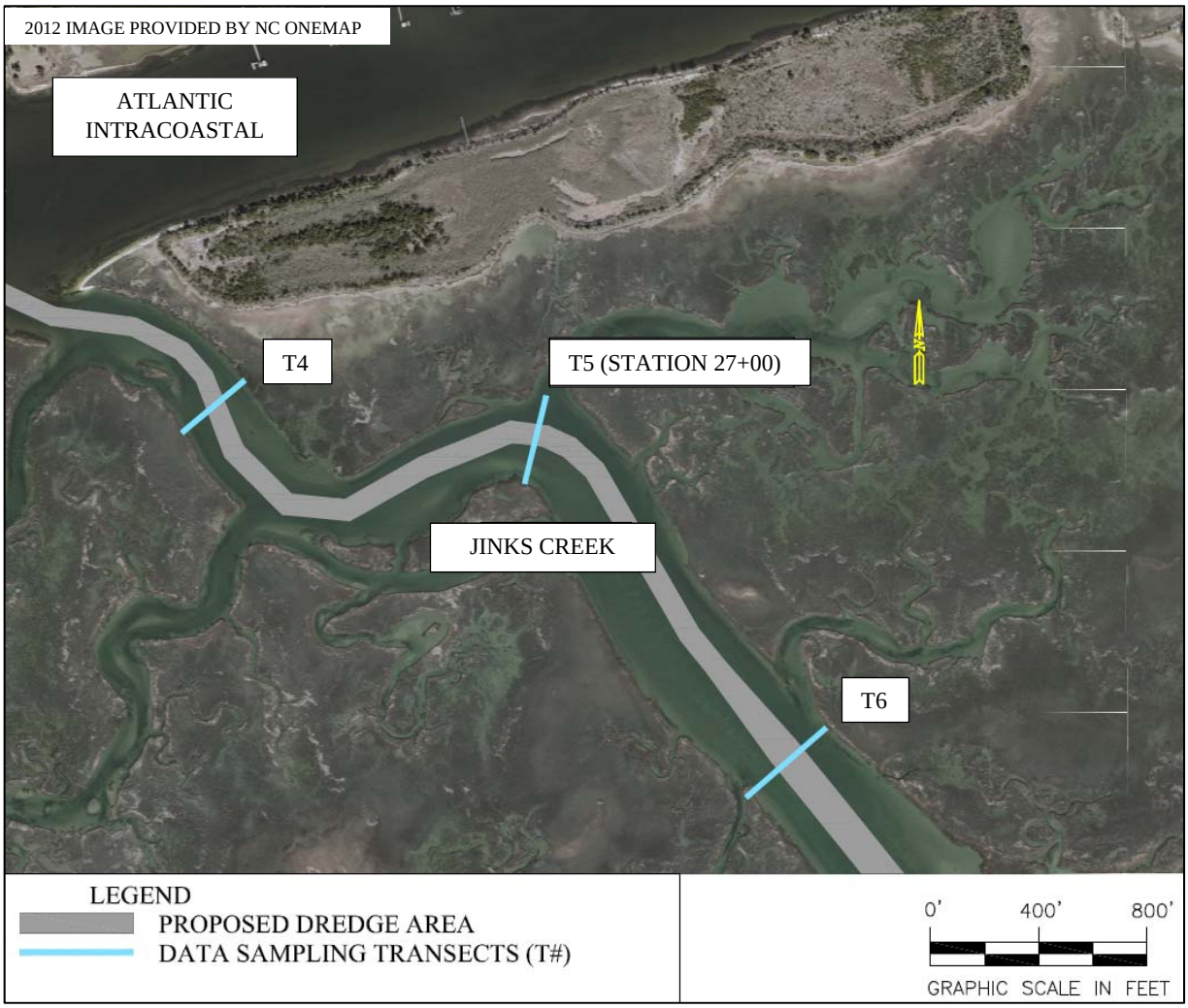


Figure 28. Transect Locations in Jinks Creek 'S' Curve

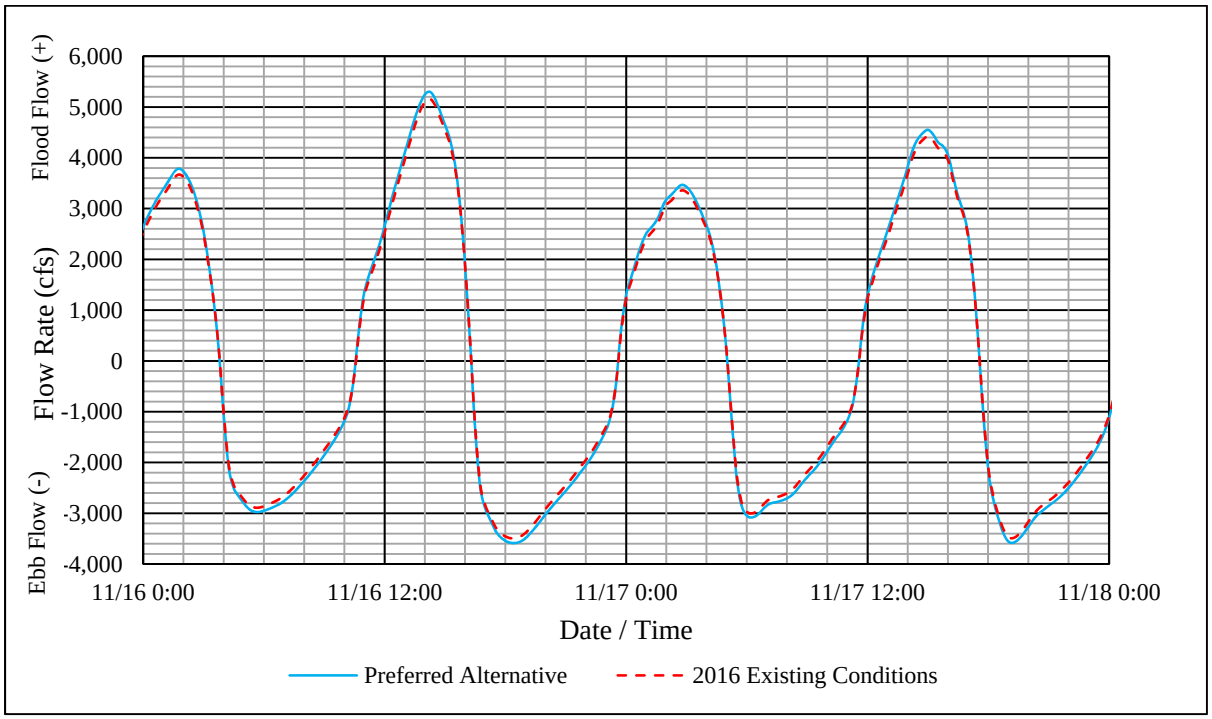


Figure 29. Transect T4 - Average Flow Rates (Spring Tide Condition)

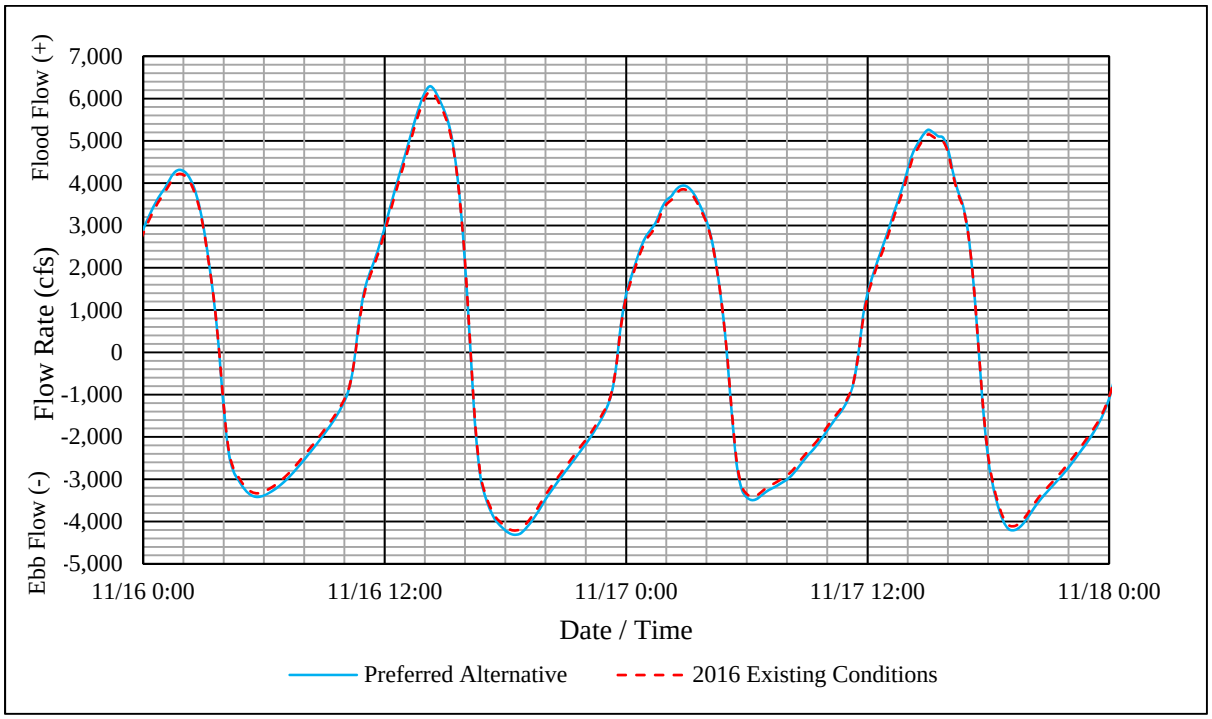


Figure 30. Transect T5 - Average Flow Rates (Spring Tide Condition)

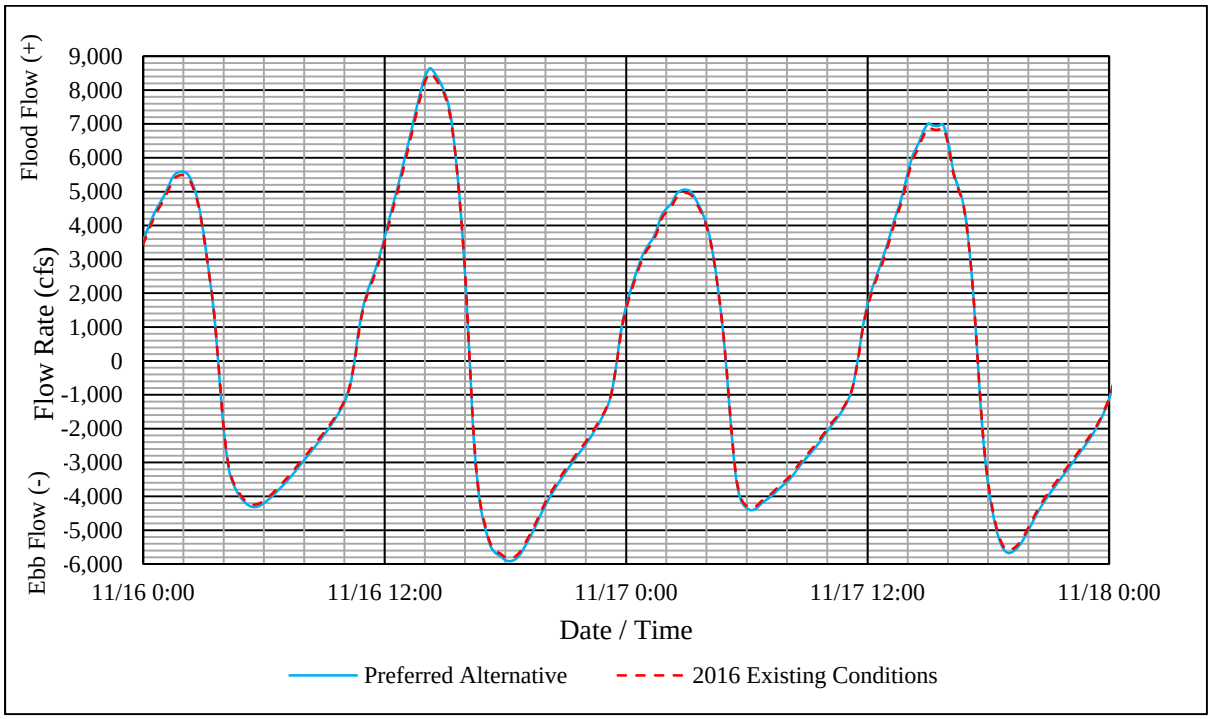


Figure 31. Transect T6 - Average Flow Rates (Spring Tide Condition)

Analysis of the flow rates does show a change in the flow rates should be expected with the project. However, the estimated change remains below a 5% increase for each tidal cycle, which should result in an insignificant change for the system. Table 4 shows the average flow rates anticipated under the 2016 existing conditions and the preferred alternative for Transects T4 through T6. Comparing the respective flow rate measurements shows the maximum change should occur along Transect T4 for both flood (incoming) and ebb (outgoing) tide cycles. The change magnitude estimated along Transect T5 & T6 matches reasonably well with the increase magnitude estimated along T4. This suggests the additional tidal flows should continue through Jinks Creek as opposed to diverging into a connecting tributary. Table 4 also shows the relative differences measured along Transect T4 remains slightly higher than that measured for Transects T5 or T6. This results from the current divergence of flow rates traveling through Jinks Creek. Although the modeling estimates roughly the same change magnitude at Transects T4 through T6, the change will be more noticeable along T4 in northern Jinks Creek due to the respective lower initial flow.

Table 4. 'S' Curve Alignment - Average Flow Rates (Spring Tide Condition)

Transect	Average Ebb Flow (Outgoing) cfs		Percent (%) Change	Average Flood Flow (Incoming) cfs		Percent (%) Change
	2016 Conditions	Preferred Alternative		2016 Conditions	Preferred Alternative	
T4	-2,320	-2,400	3.4%	2,790	2,880	3.2%
T5	-2,600	-2,680	3.1%	3,230	3,300	2.2%
T6	-3,250	-3,340	2.8%	4,220	4,290	1.7%

2. Values represent averaged measurements simulated from Nov. 13, 2004 (13:15) to Nov. 20, 2004 (13:15) tidal conditions.

3.3 Concern 3 – Tubbs Inlet Shoaling & Migration Patterns

The analysis of Tubbs Inlet concentrates on evaluating the potential for increased shoaling or migration trends to occur as a result of the proposed dredging. The analysis utilizes four (4) transects to compare the changes in the estimated tidal velocities and flow rates expected under the 2016 current conditions and the

preferred alignment. Figure 32 shows the location of Transects T7, T8, T9, and T10 surrounding the Tubbs Inlet complex. Similar to the analysis of the AIWW confluence and the Jinks Creek 'S' curve alignment, the analysis strives to estimate the changes expected within the dredge area as well as those implied on adjacent waters. Also similar to the AIWW and the 'S' curve analysis, the Tubbs Inlet study applies the measured tidal conditions from the November 2004 spring tide event to evaluate the potential change in tidal velocities and flow rates.

The results show the velocities traversing Tubbs Inlet should experience a similar change as that indicated for the remainder of the project area. The modeling indicates the velocities will experience the largest relative change further away from the Inlet, as opposed to directly in the inlet passage. The maximum velocities measured along Transect T7 should experience an approximate 1% increase while at Transect T8 an increase of less than 0.5% may be expected. These results suggest the change in tidal velocities should remain insignificant towards influencing the future shoaling and migration patterns of Tubbs Inlet.

The measurements within the shoal complex also provide support towards an important project goal. The results suggest the velocities within southern Jinks Creek may experience an increase approximately two (2) times greater than the velocities within Tubbs Inlet. This observation supports the project intent to remain sufficiently away from the inlet in order to reduce the potential for influencing the shoaling and migration patterns of the passageway. The proposed work terminates approximately 3,600 ft prior to Tubbs Inlet. Based on the velocity results, the existing condition of Tubbs Inlet should provide a sufficient blockage or impediment to counteract the influence of improving the Jinks Creek flow way.

Traveling east from Tubbs Inlet, or away from the work area, the modeling shows the tidal velocities should experience a decrease or remain relatively constant. The calculated change in the maximum velocity equals approximately -0.3% (decrease) along Transect T9 and approximately -0.4% at Transect T10. Figures 33 through 36 show the measured velocities along the Transects T7 through T10 in Tubbs Inlet. Also, Table 5 shows the changes estimated in the maximum velocities for the respective transects.

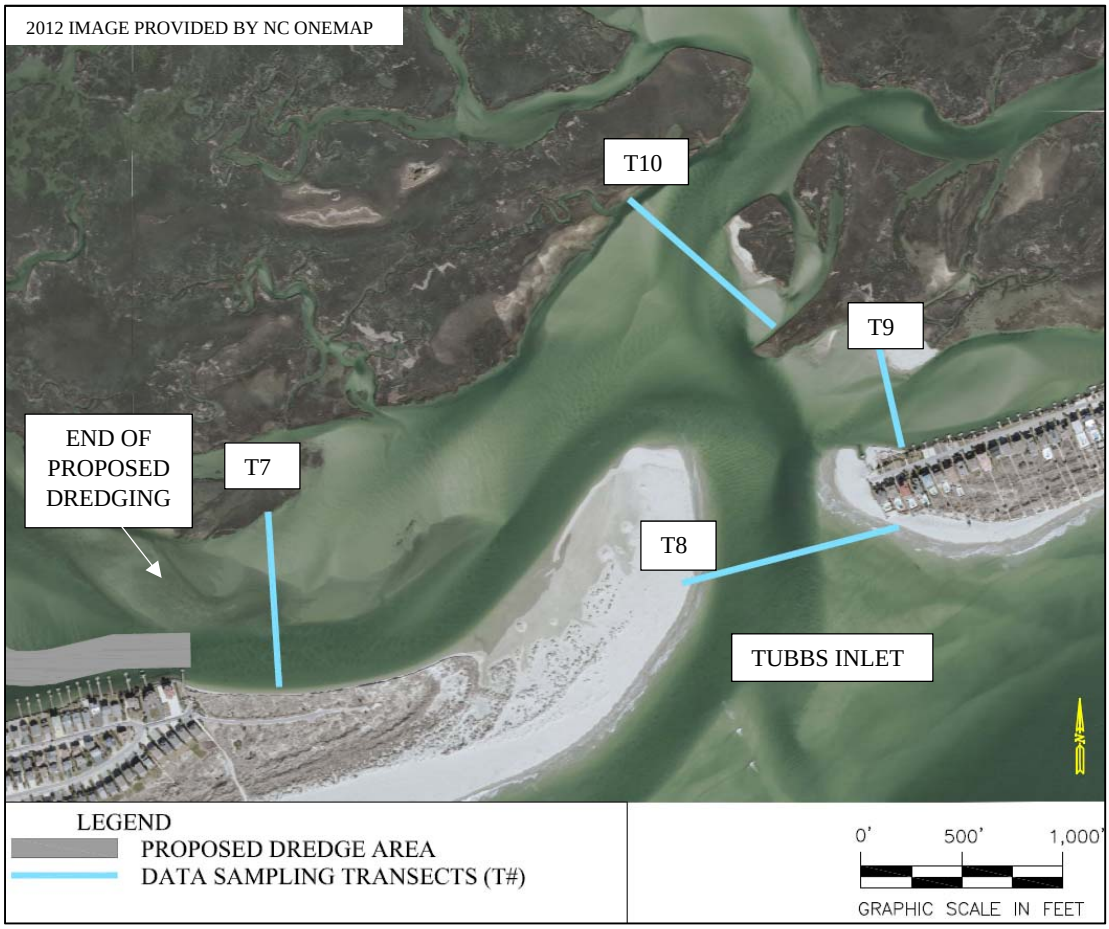


Figure 32. Tubbs Inlet Transect Locations

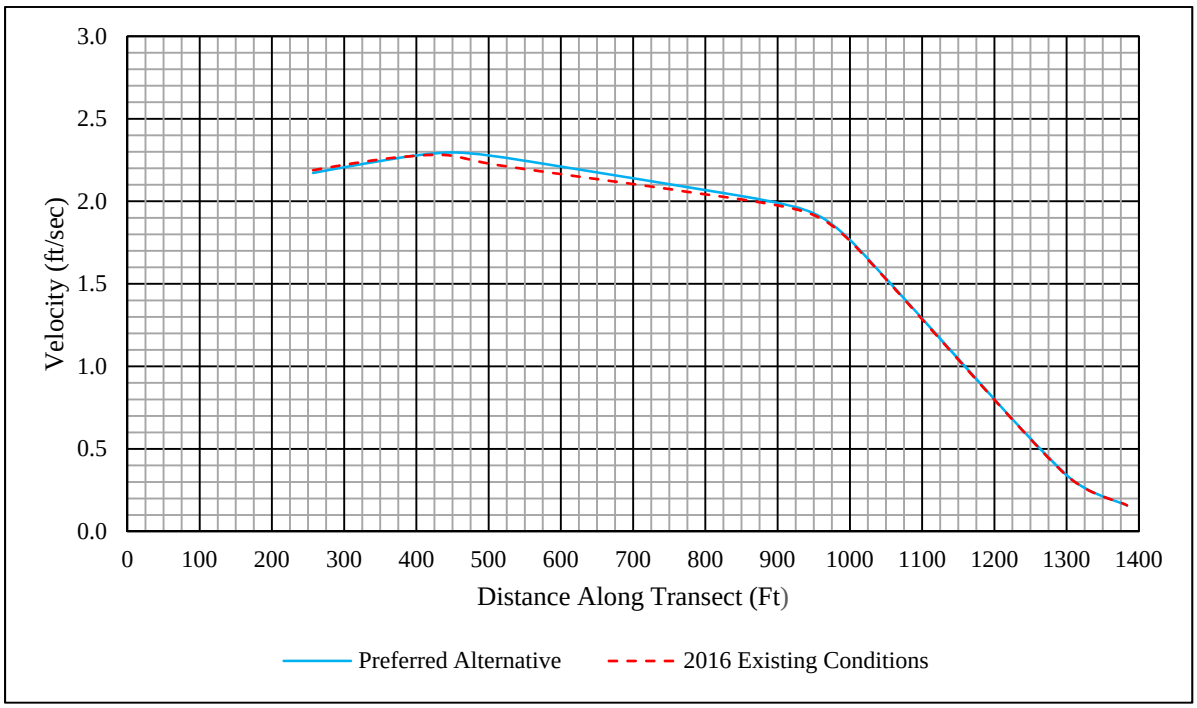


Figure 33. Transect T7 - Maximum Velocity Measurements (Spring Tide Condition)

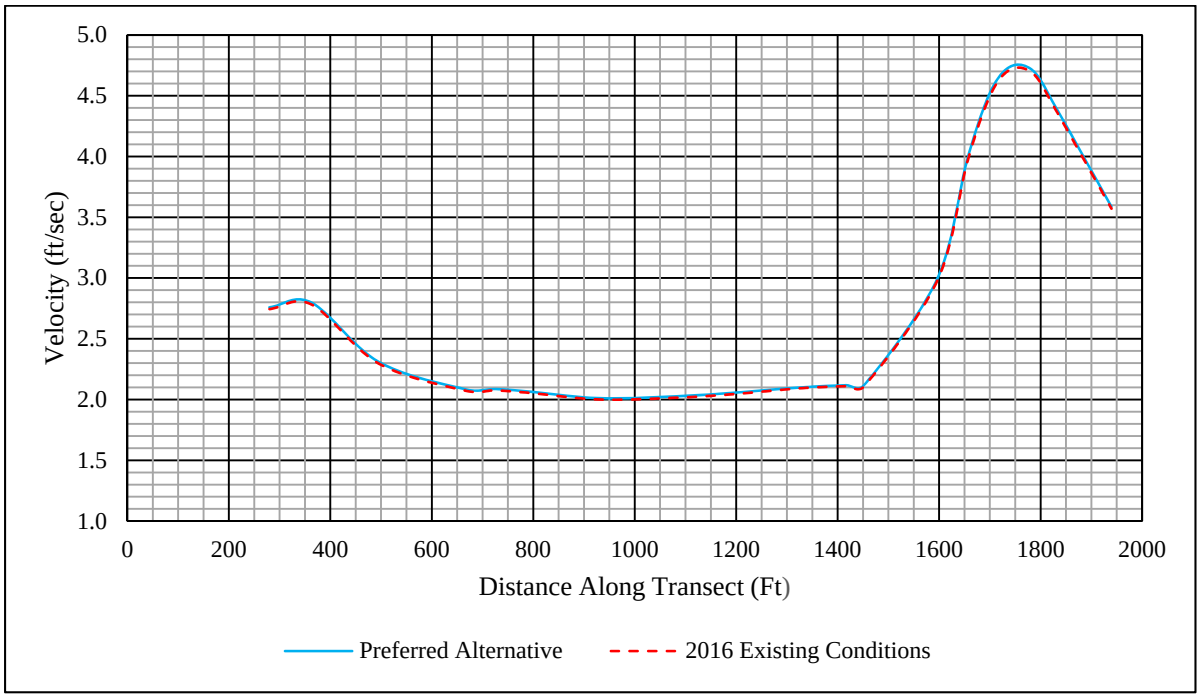


Figure 34. Transect T8 - Maximum Velocity Measurements (Spring Tide Condition)

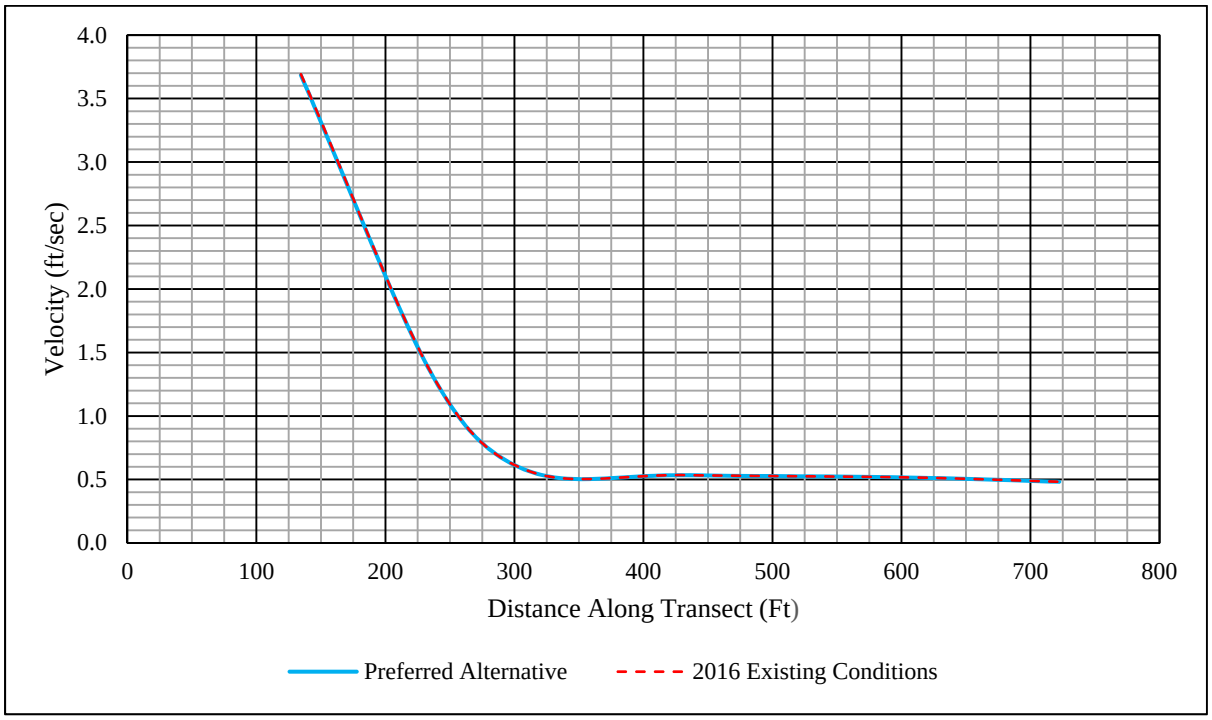


Figure 35. Transect T9 - Maximum Velocity Measurements (Spring Tide Condition)

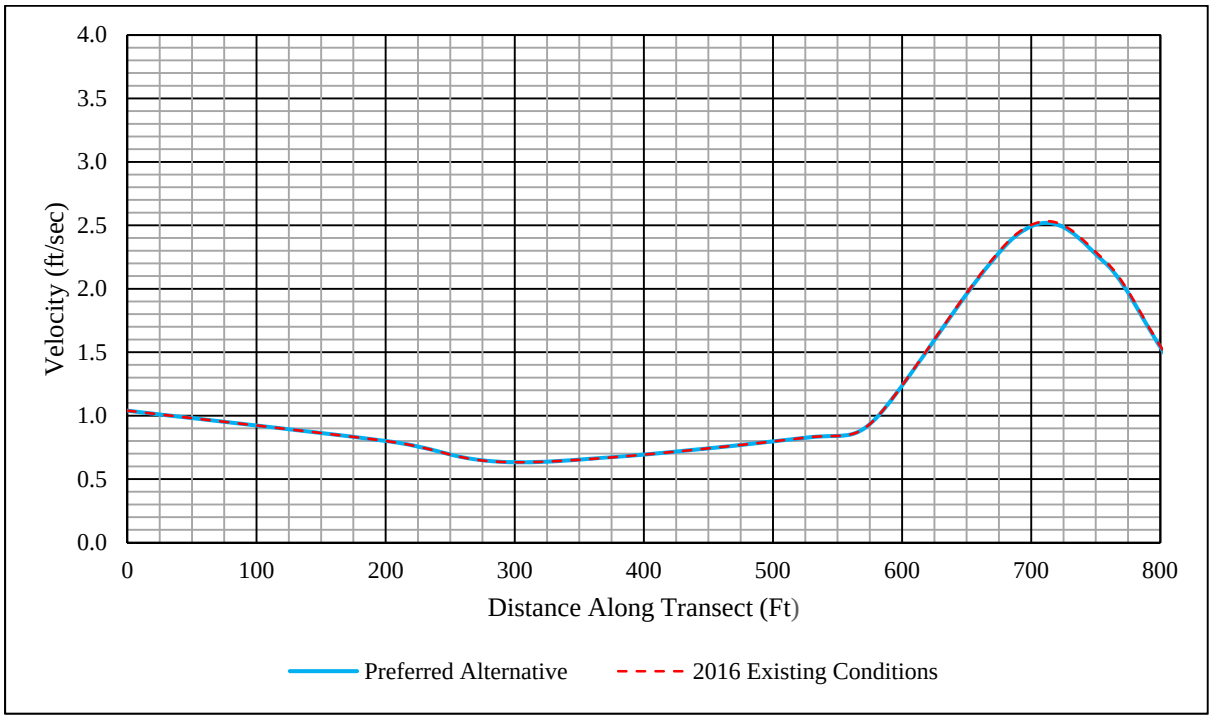


Figure 36. Transect T10 - Maximum Velocity Measurements (Spring Tide Condition)

Table 5. Tubbs Inlet - Maximum Velocity Changes (Spring Tide Condition)

Transect	2016 Existing Conditions	Preferred Alternative	Percent (%) Change
T7	2.28 ft/sec	2.30 ft/sec	0.9%
T8	4.72 ft/sec	4.74 ft/sec	0.4%
T9	3.69 ft/sec	3.68 ft/sec	-0.3%
T10	2.45 ft/sec	2.44 ft/sec	-0.4%

1. Values are depth averaged velocities simulated from Nov. 13, 2004 (13:15) to Nov. 20, 2004 (13:15) tidal conditions.

Similar to the velocity analysis, the flow rate analysis estimates the average flow rate between Jinks Creek and Tubbs Inlet should experience the largest change with the proposed work. The analysis estimates the change in magnitude for the average flow rate across Transect T7 may increase approximately 2% for both the ebb (outgoing) and flood (incoming) tidal events. Table 6 shows the relative increase anticipated in the flow rate at each transect within the Tubbs Inlet complex. The modeling estimates the remaining transects (T8, T9, & T10) will experience a 1% increase or less for both the ebb and flood tide cycles. Figures 37 through 40 show the flow rate comparison for Tubbs Inlet during the simulated November 16-17 2004 spring tide event.

Table 6. Tubbs Inlet - Average Flow Rates (Spring Tide Condition)

Transect	Average Ebb Flow (Outgoing) cfs		Percent (%) Change	Average Flood Flow (Incoming) cfs		Percent (%) Change
	2016 Conditions	Preferred Alternative		2016 Conditions	Preferred Alternative	
T7	4,400	4,500	2.3%	5,740	5,840	1.7%
T8	10,620	10,670	0.5%	12,110	12,230	1.0%
T9	1,530	1,520	-0.7%	1,230	1,230	0.0%
T10	2,350	2,350	0.0%	2,180	2,170	-0.5%

1. Values represent averaged measurements simulated from Nov. 13, 2004 (13:15) to Nov. 20, 2004 (13:15) tidal conditions.

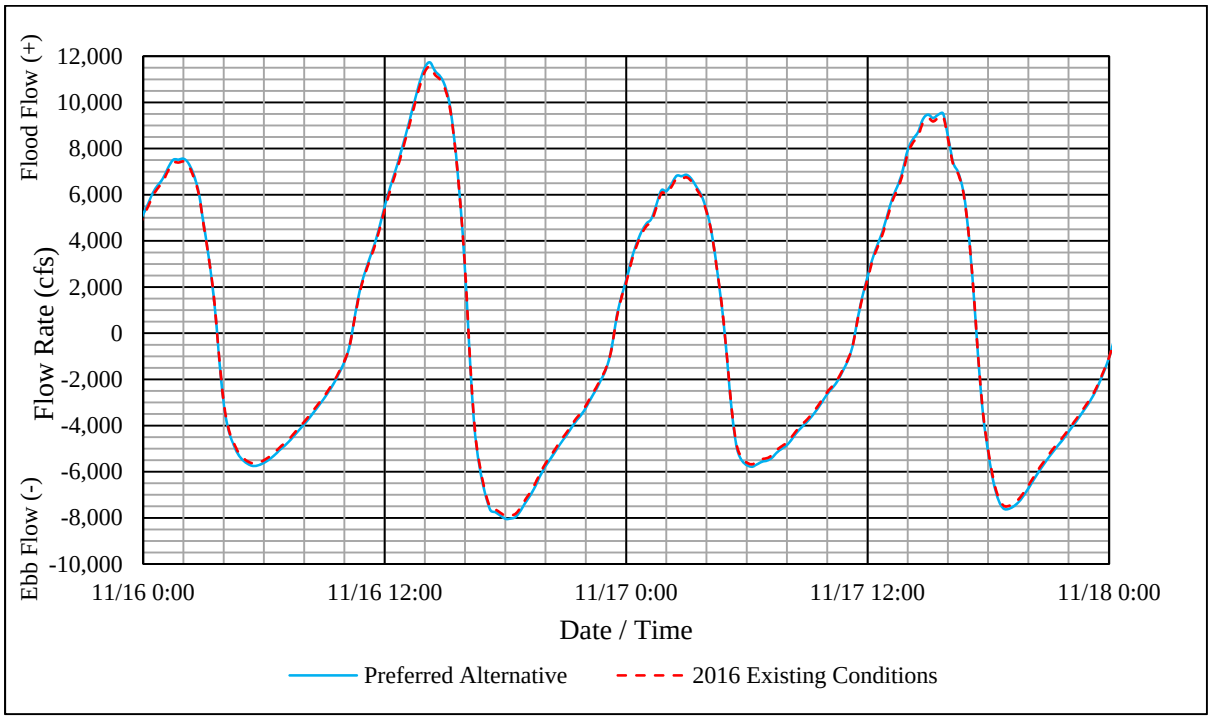


Figure 37. Transect T7 - Average Flow Rates (Spring Tide Condition)

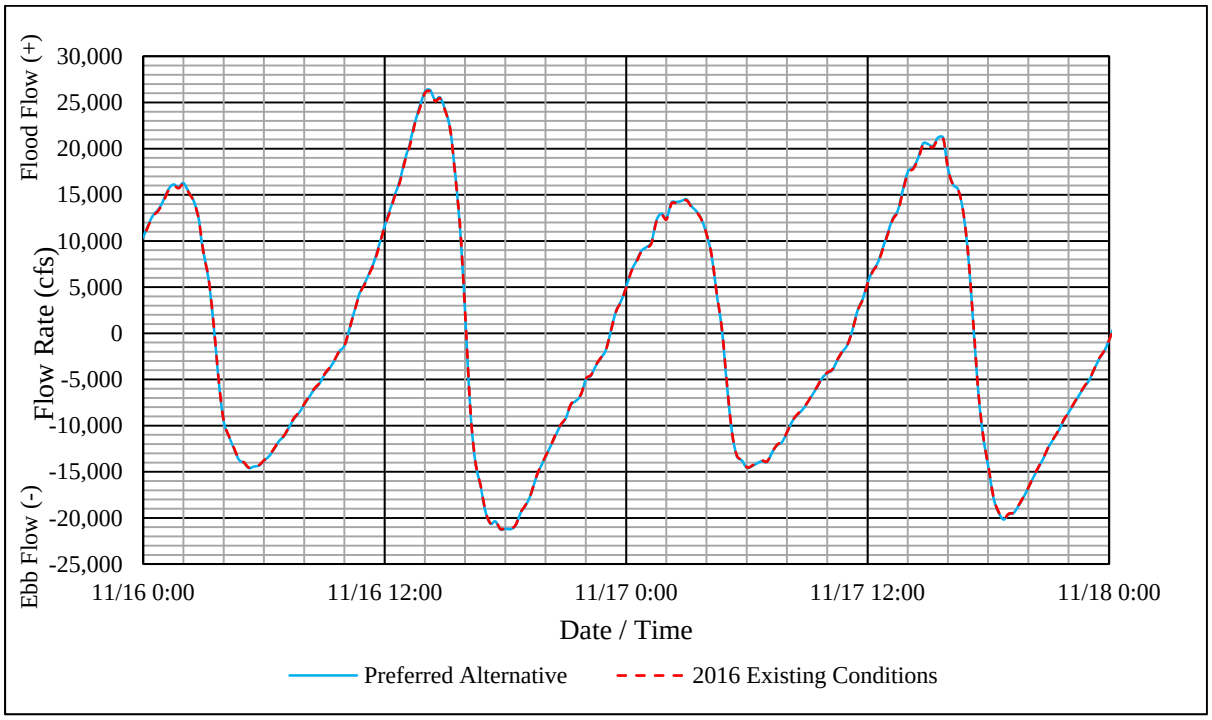


Figure 38. Transect T8 - Average Flow Rates (Spring Tide Condition)

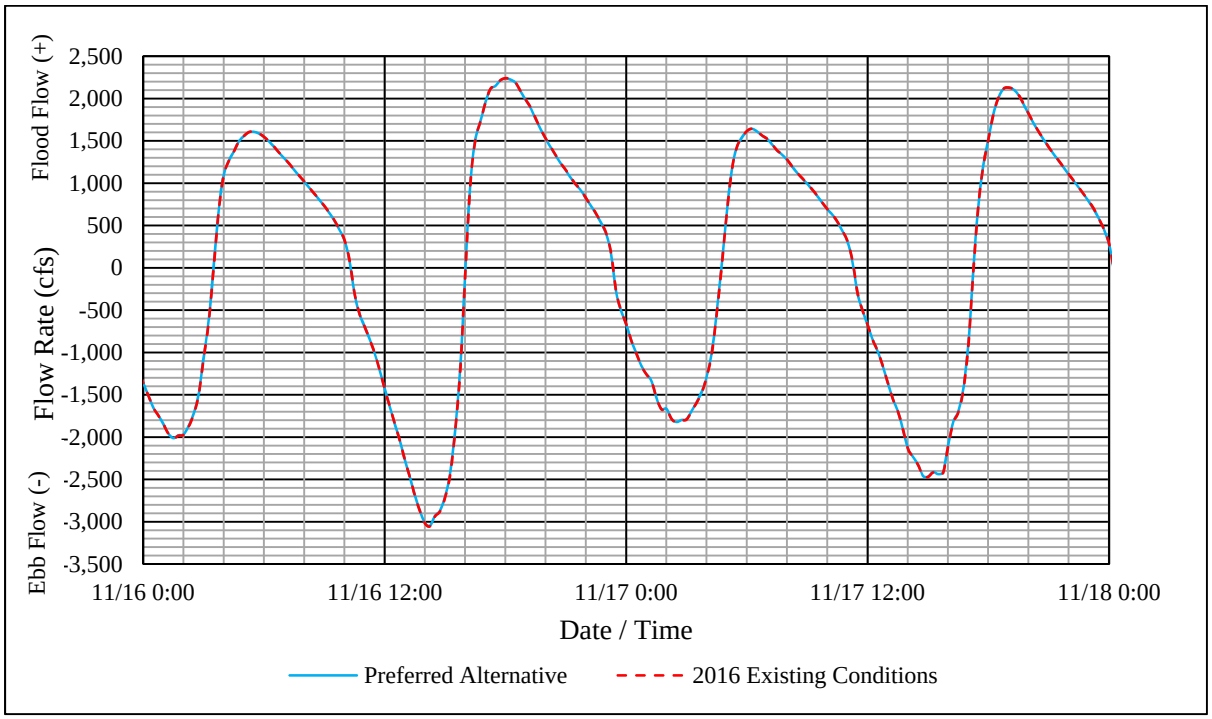


Figure 39. Transect T9 - Average Flow Rates (Spring Tide Condition)

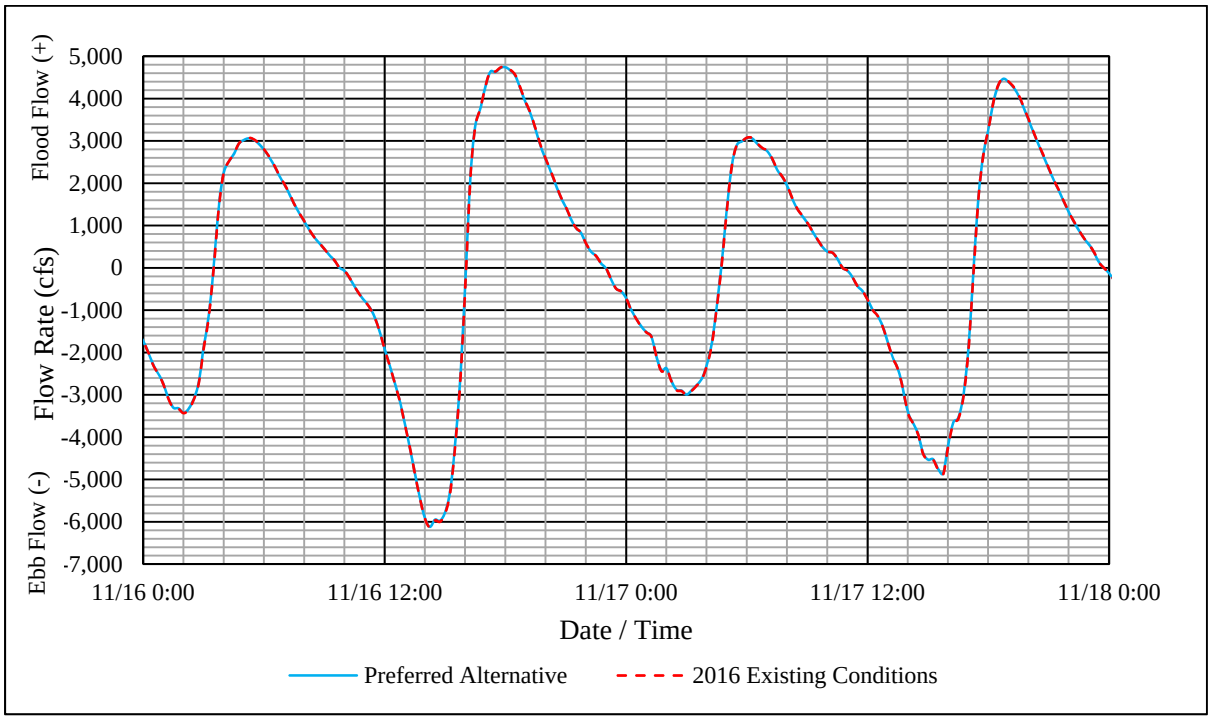


Figure 40. Transect T10 - Average Flow Rates (Spring Tide Condition)

3.4 Concern 4 – The Preferred Alignments Response during Extreme Storm Conditions

During the design process citizen concerns inquired on how the proposed work may influence the response of Jinks Creek during extreme tidal conditions, or major hurricanes. To address this concern the modeling analysis replicated the tidal conditions derived from Hurricane Hugo in 1989. The analysis used the

simulated conditions of Hurricane Hugo to compare the response estimated from the 2016 existing conditions with those of the preferred alignment.

As part of the 2004/05 modeling analysis for the Sunset Beach bridge replacement, the USACE[11] provided storm surge information developed utilizing the ADCIRC-2DDI (Advanced CIRCulation 2-Dimensional, Depth-Integrated) model. The current analysis uses this data to compare the anticiapted change in the maximum velocites, flow rates, and water levels generated within the Preferred Alignment during major storm events. The analysis compares the estimated change in tidal velocities and flow rates along three (3) transects within Jinks Creek. In addition, the analysis reviews the planview results of water surface elevation change calcuated for the complete proejct area. Figure 41 shows the three respective transects chosen for the tidal velocity and flow rate change analysis for the exterme storm conditions.

Figure 41. Transect Locations for the Extreme Storm Condition Analysis (Hurricane Hugo)

Hurricane Hugo delivered a storm surge equivalent to a 50-year return period event when considered with the normal tidal conditions[12]. The maximum still water level produced by Hurricane Hugo rose to approximately 12.3 ft (MLW) during the peak surge event. Table 7 shows the preliminary flood stage

[11] Scheffner, N.W., et al., (1994) ADCIRC: an advanced three-dimensional circulation model for shelves, coasts, and estuaries; Report 5, a tropical storm database for the east coast and Gulf of Mexico coasts of the United States. Technical Report DRP-92-6, US Army Engineers Waterways Experiment Station, Vicksburg, MS.
[12] FEMA (2017) North Carolina floodplain mapping program. URL http://www.ncfloodmaps.com/ (visited 2 March, 2017). Preliminary Flood Information Studies

elevations for Sunset Beach and indicates the water level produced by Hugo equates to an approximate 50 year return period event. For reference, Figure 42 shows the still water levels produced by Hurricane Hugo in September 1989.

Table 7. Still Water Levels for Return Period Storms (Sunset Beach)

Return Period (Years)	Still Water Level Elevation (ft, MLW)
10	7.9
25	9.2
50	12.2
100	16.4

1. Elevations reference MLW based on Little River Neck Benchmark (NOAA Station 8660098)

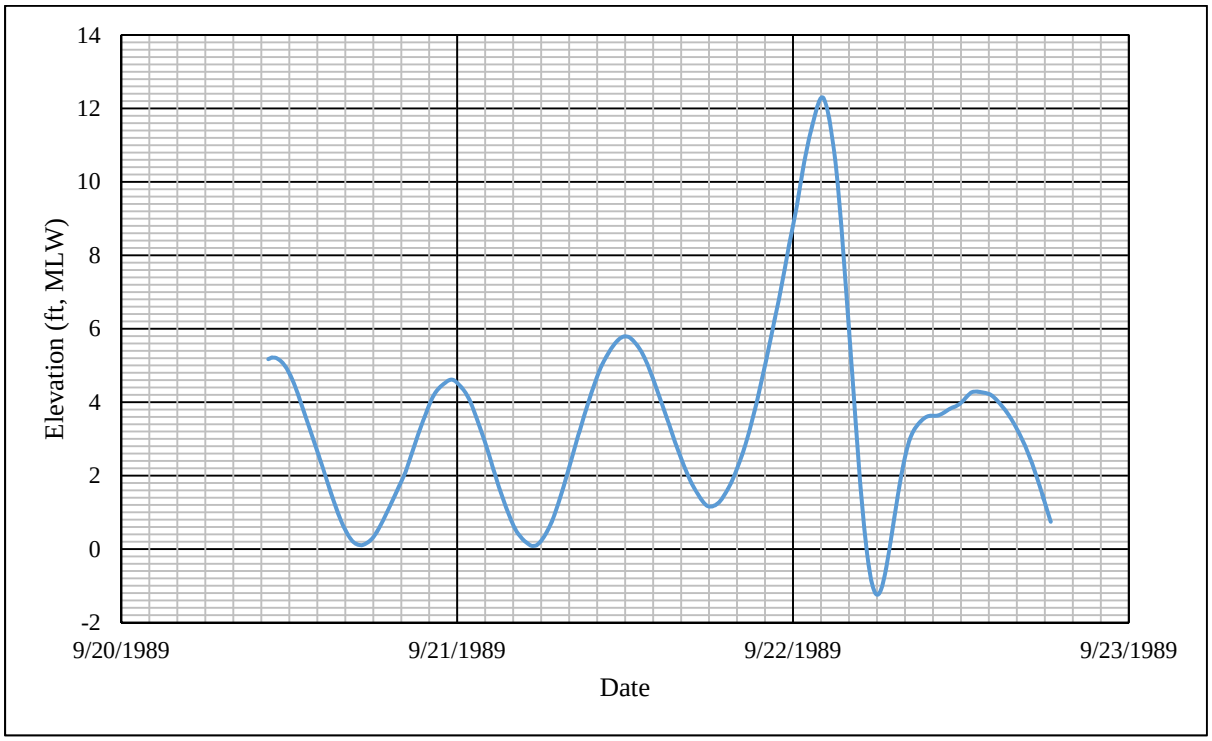


Figure 42. Still Water Levels Produced by Hurricane Hugo (September 1989)

Figures 43 and 44 provide an overview of the velocity contours modeled for the 2016 existing conditions and the preferred alternative, respectively. Evaluating the change in the maximum velocities expected during an extreme storm event suggests similar results as observed for the spring tide event. Table 8 provides the analysis results and shows the results in southern Jinks Creek may be expected to experience an approximate 1% increase in magnitude. The estimate grows to more than a 2% increase for northern Jinks Creek. Although the analysis estimates the largest percent increase to occur in northern Jinks Creek, the analysis also suggests the tidal velocities in northern Jinks Creek should remain below the scouring threshold of approximately 3.28 ft/sec. The maximum velocity magnitude estimated in northern Jinks Creek (Transect T3) under the preferred alignment equals approximately 2.07 ft/sec. Within southern Jinks Creek (T5 & T7) the velocities may be expected to raise above 3 ft/sec under the 2016 existing conditions and the preferred alternative.

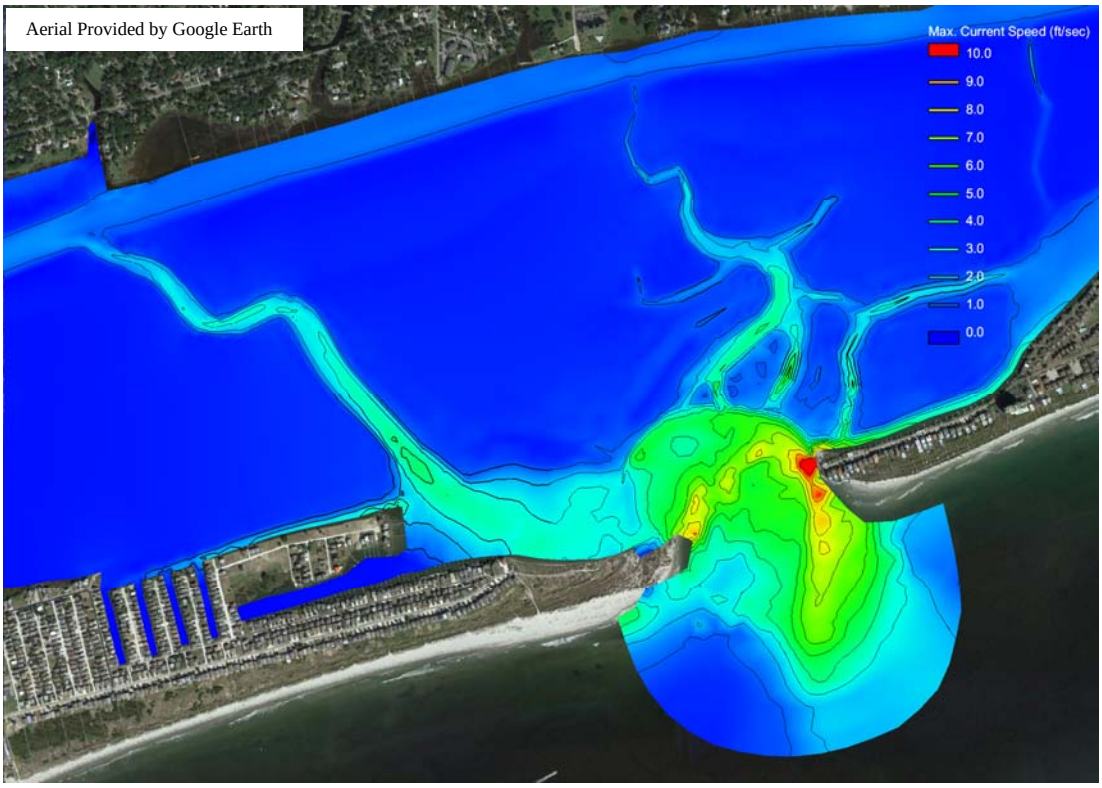


Figure 43. 2016 Existing Conditions - Maximum Velocity Contours (Extreme Storm Condition)

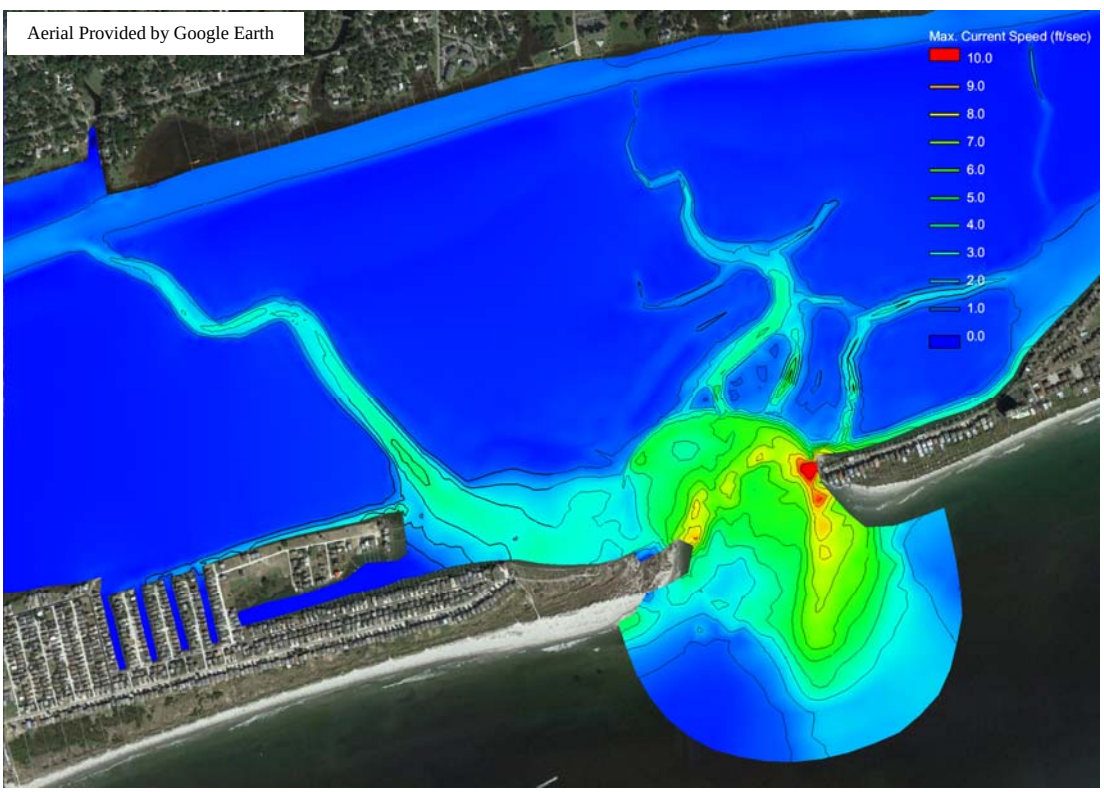


Figure 44. Preferred Alignment - Maximum Velocity Contours (Extreme Storm Condition)

Table 8. Jinks Creek Maximum Velocity Changes - Extreme Storm Condition (Hurricane Hugo)

Transect	2016 Existing Conditions	Preferred Alternative	Percent (%) Change
T3	2.02 ft/sec	2.07 ft/sec	2.4%
T5	3.07 ft/sec	3.11 ft/sec	1.3%
T7	3.41 ft/sec	3.45 ft/sec	1.2%

1. Values are depth averaged velocities simulated from Sept. 20, 1989 (10:30) to Sept. 22, 1989 (18:29) tidal conditions.

The modeling suggest an additional significant finding by showing the tidal velocities should decrease between southern and northern Jinks Creek in an extreme storm condition. The velocity decrease most likely occurs due to the influence of the AIWW and the reduced lag time experienced thorough the extreme surge event. The AIWW provides a major flow way and tidal connection for multiple inlets along the Brunswick County coast. Both Little River Inlet to the west, and Shallotte Inlet to the east of Tubbs Inlet (Jinks Creek) provide a significantly larger and more efficient hydraulic passage for tidal velocities. Tidal velocities entering through these adjacent inlets most likely inundate the AIWW and limit the influence of Jinks Creek. Figures 45 and 46 demonstrate this theory through a comparison of flood velocity contours in the AIWW confluence with Jinks Creek. The figures show the velocity contours estimated during the November 2004 spring tide and during Hurricane Hugo for the preferred alternative, respectively. The tidal velocities intersect the AIWW from Jinks Creek and disperse uniformly under the November 2004 spring tide conditions. However, under the extreme storm conditions (Hurricane Hugo), velocities exiting Jinks Creek do not reach the same magnitudes as the spring tide condition. Under the extreme storm condition the tidal velocities also coalesce in a westward direction once they enter the AIWW. This suggests the tidal waters in the AIWW buffer the impact of the Jinks Creek, perhaps as the surge from Little River, Tubbs, and Shallotte Inlets converge near the AIWW confluence with Jinks Creek. As the surge from Little River and Shallotte inlets fill the AIWW, the velocity gradient from Jinks Creek would become less influential.

Figure 45. Flood Velocity Contours for Spring Tide Condition (Preferred Alignment)

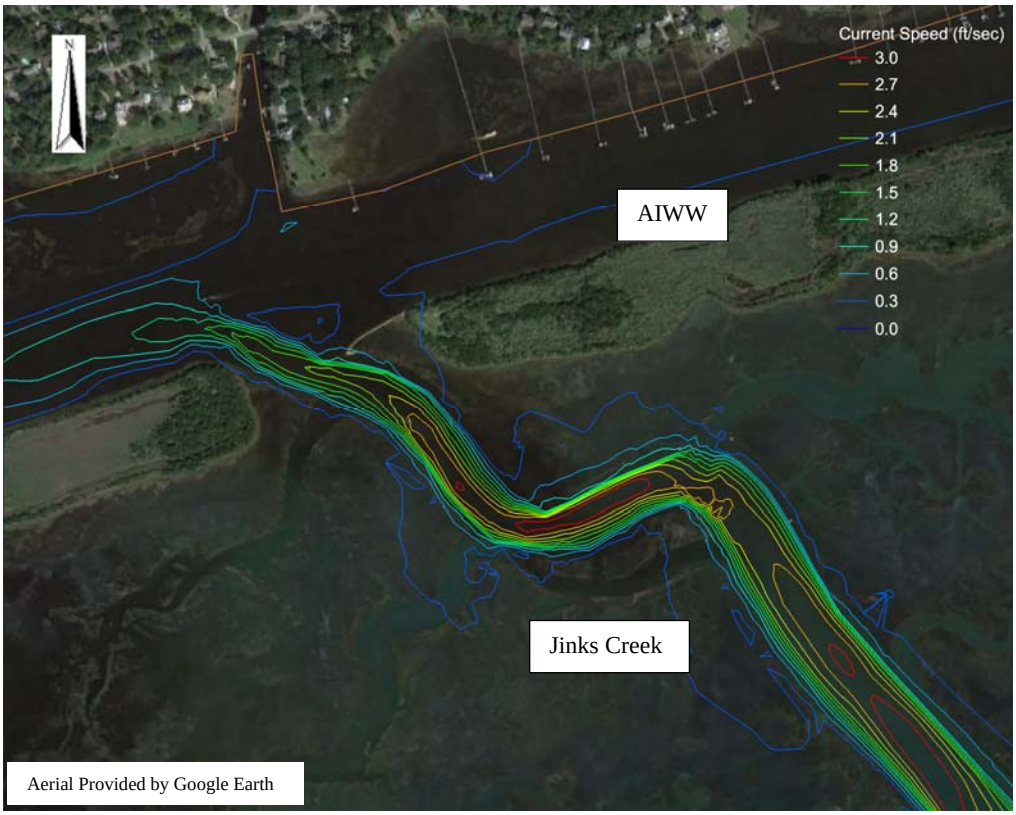


Figure 46. Flood Velocity Contours for Extreme Storm Condition (Preferred Alignment)

A similar scenario for the tidal velocities could be expected as the storm surge recedes. The flow way through Little River Inlet and Shallotte Inlet would be less restricted compared to the passage through Jinks Creek and Tubbs Inlet. Therefore, the tidal waters could be expected to be drawn away from Jinks Creek and towards the less restrictive inlets. For reference, Figures 47 through 49 show the maximum tidal velocities comparison for Transects T3, T5, and T7, respectively, for the extreme storm condition.

In order for the tidal velocities within northern Jinks Creek to encounter the type of situation described above, the nodal point for the converging tidal flows from Tubbs, Shallotte, and Little River Inlet would need to shift towards Jinks Creek in the AIWW. The 2004/05 modeling analysis determined the nodal point to exist on the western side of the Sunset Beach Bridge during typical tidal events. The nodal point most likely shifts as a result of the reduced lag times between Little River Inlet and Shallotte Inlet during an extreme storm or hurricane. The 2004/05 analysis for the Sunset Beach Bridge replacement makes note of a reduced lag measured between the storm surge samples. Storm surge would be generated through a faster process than a normal lunar tide cycle. As the storm system pushes the surge onshore the effects may be observed simultaneously along a relatively small shoreline reach. Thus, as the waters enter through the inlet systems and converge in the AIWW, the nodal point would shift based on the velocities from each direction.

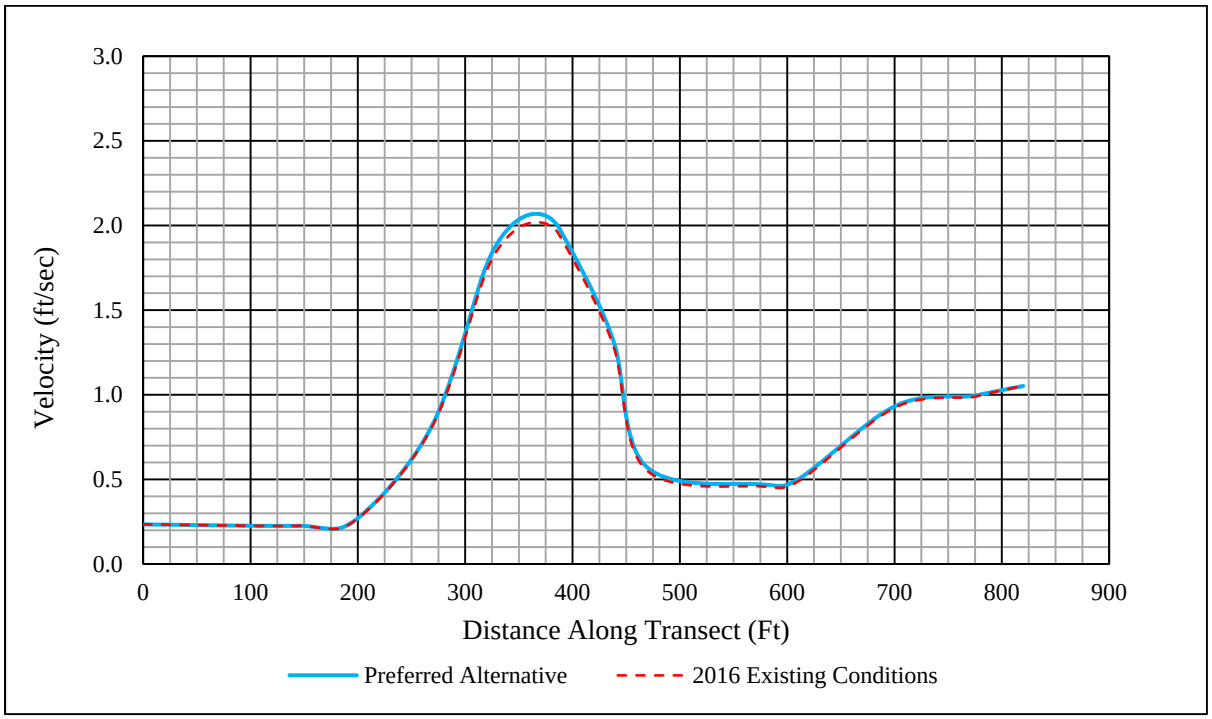


Figure 47. Transect T3 - Maximum Velocities for Extreme Storm Condition (Hurricane Hugo)

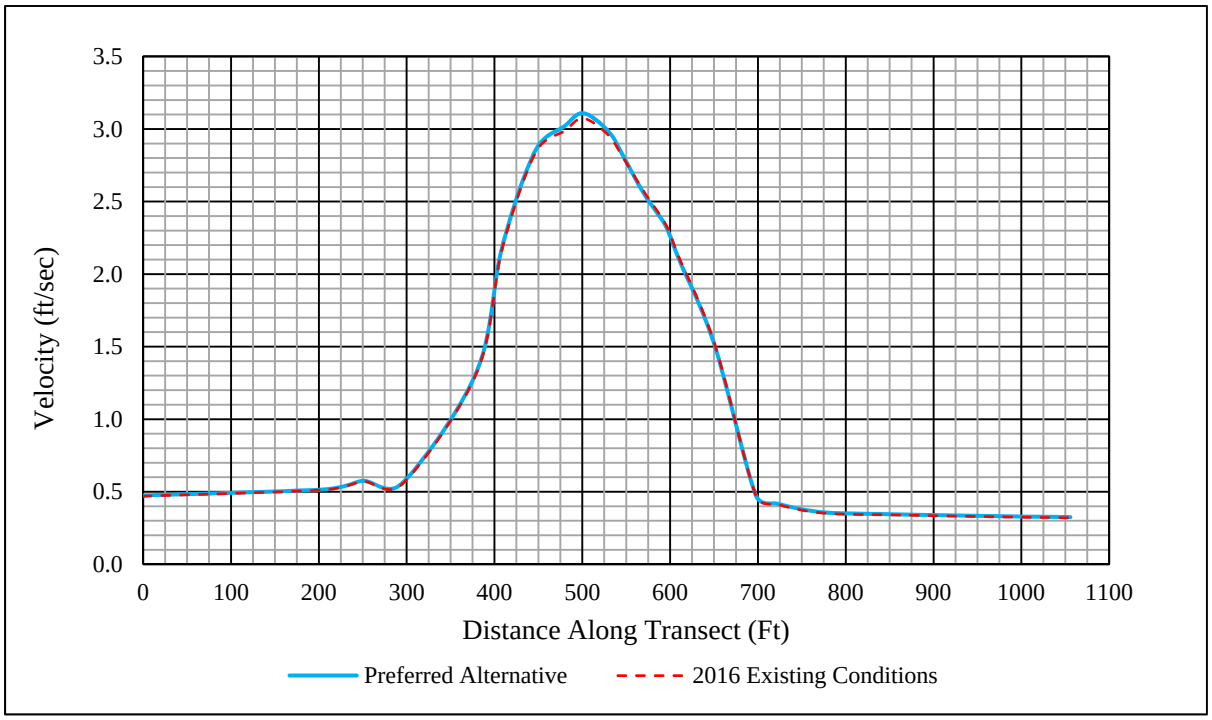


Figure 48. Transect T5 - Maximum Velocities for Extreme Storm Condition (Hurricane Hugo)

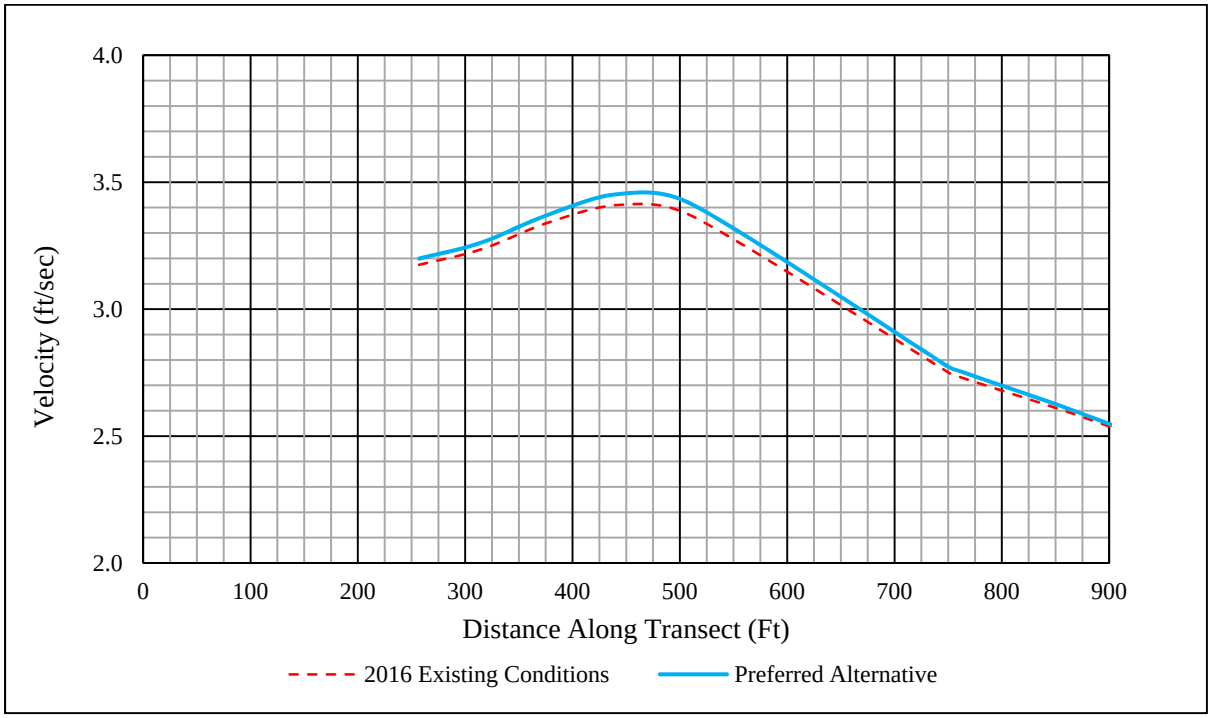


Figure 49. Transect T7 - Maximum Velocities for Extreme Storm Condition (Hurricane Hugo)

The analysis also compares the estimated change in the flow rates expected through Jinks Creek as a result of the project. Table 9 shows the flow rates will not incur a significant increase as a result of the project. The analysis estimates the increases will total approximately 2% for the project on average. Similar to the velocity measurements, the flow rate estimates suggest the larger variations will occur closer to the AIWW confluence with Jinks Creek. This results from the lower velocity and flow rate magnitudes estimated for the interior waterways where a similar magnitude in change provides a higher percent change. Figures 50 through 52 show the flow rate comparison for Transects T3, T5, and T7 under the extreme storm condition.

Table 9. Jinks Creek Average Flow Rates - Extreme Storm Condition (Hurricane Hugo)

Transect	Average Ebb Flow (Outgoing) cfs		Percent (%) Change	Average Flood Flow (Incoming) cfs		Percent (%) Change
	2016 Conditions	Preferred Alternative		2016 Conditions	Preferred Alternative	
T3	2,740	2,810	2.6%	3,720	3,790	1.9%
T5	5,160	5,270	2.1%	5,680	5,770	1.6%
T7	13,090	13,270	1.4%	12,130	12,280	1.2%

1. Values represent averaged measurements occurring from September 20, 1989 (10:30) to September 22, 1989 (18:29).

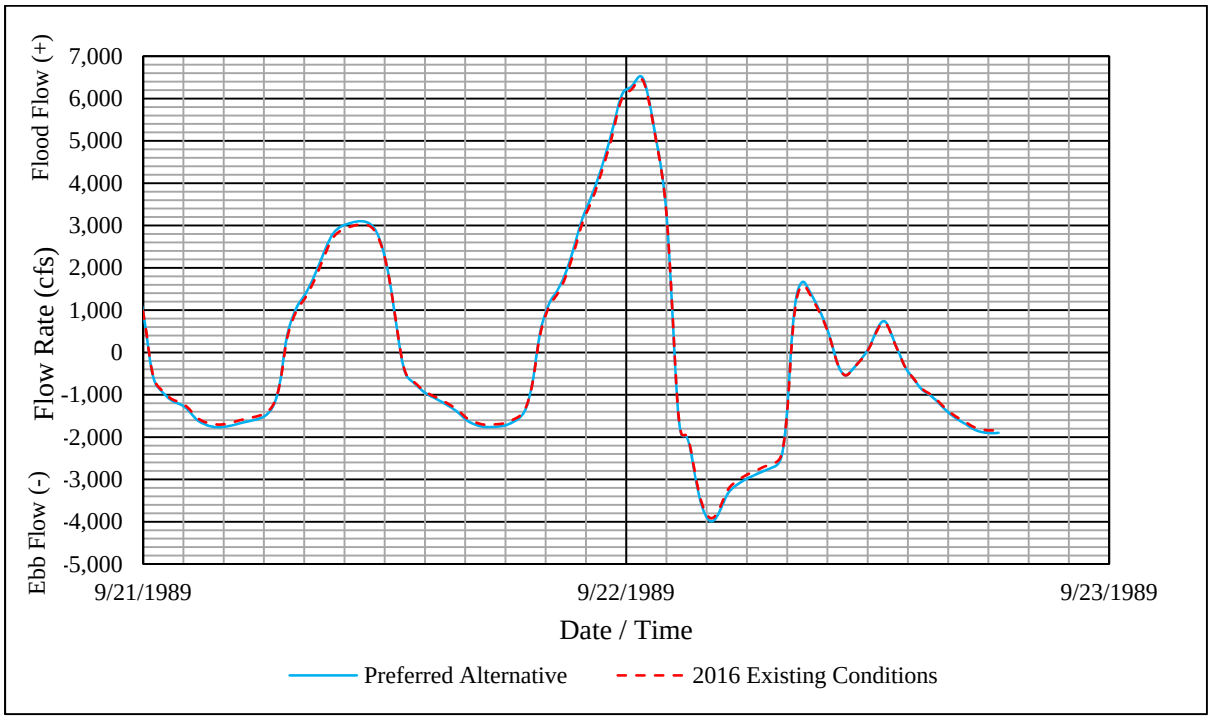


Figure 50. Transect T3 - Average Flow Rates (Extreme Storm Condition)

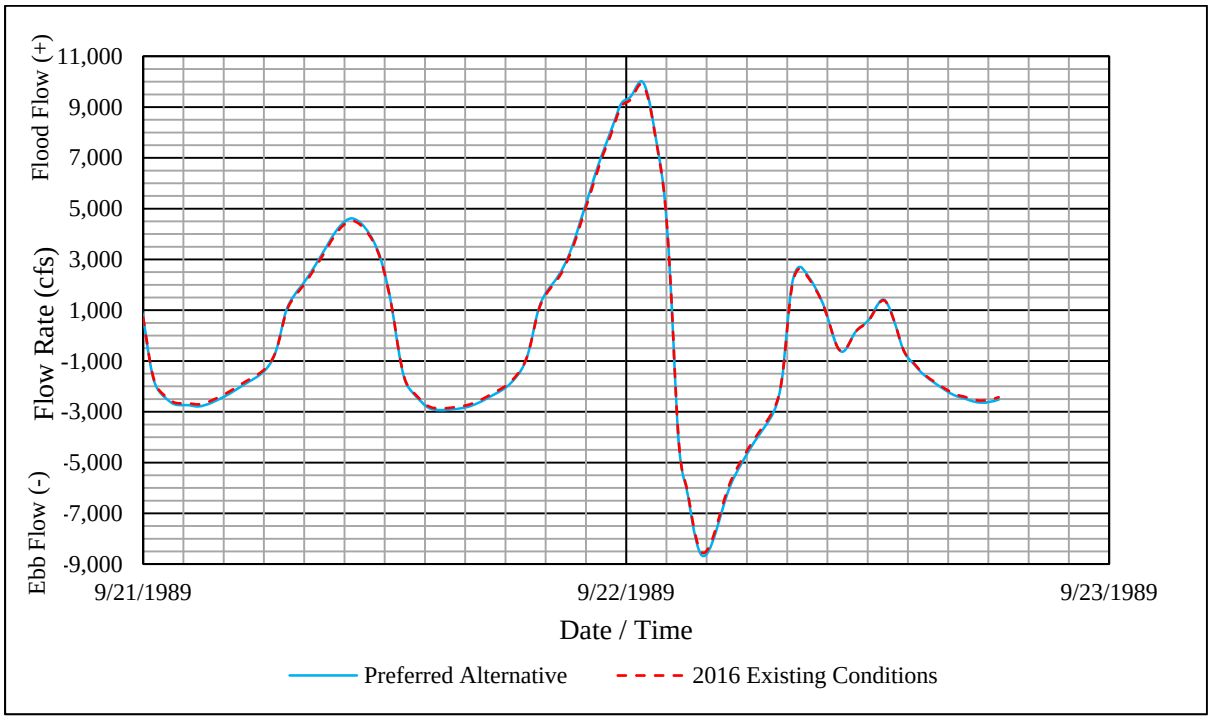


Figure 51. Transect T5 - Average Flow Rates (Extreme Storm Condition)

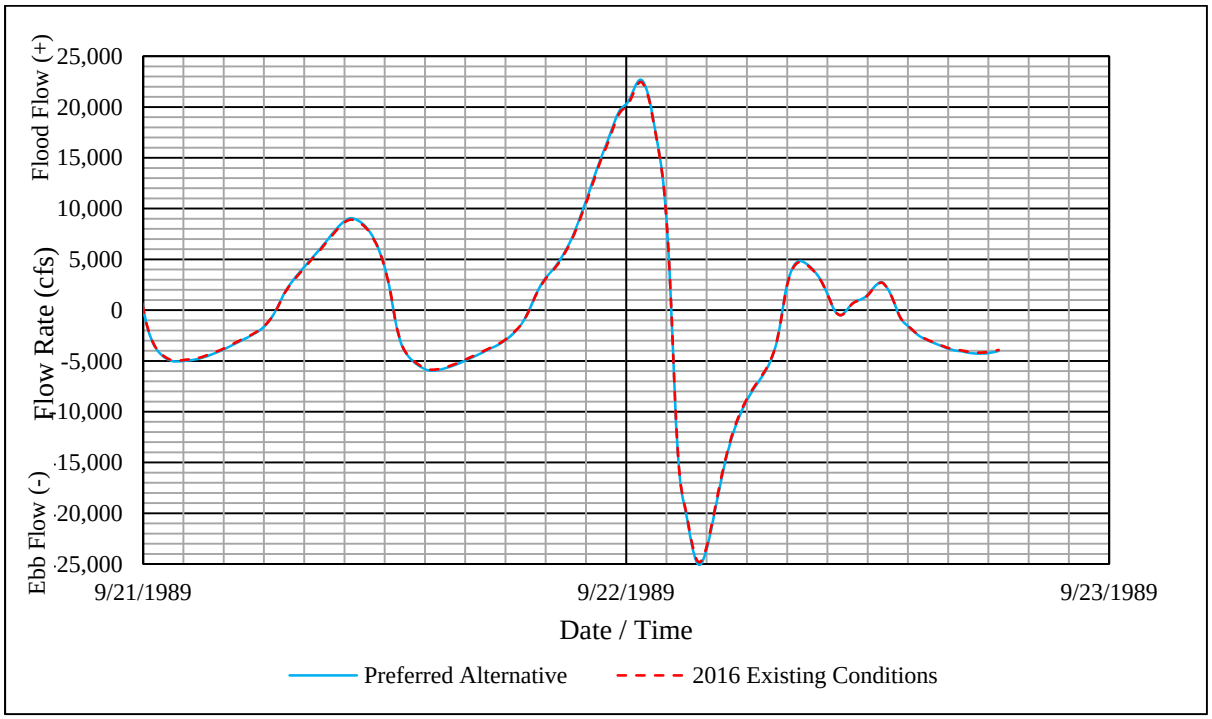


Figure 52. Transect T7 - Average Flow Rates (Extreme Storm Condition)

Evaluation of the potential change in water surface elevations or flooding potential also indicates the preferred alternative should create minimal changes to the tidal patterns of Jinks Creek. Figure 53 shows the estimated change in the maximum water surface elevation expected during an extreme storm event between the 2016 existing conditions and the preferred alternative. The figure shows the preferred alignment should not create a significant change in the surge levels expected during a major storm event. The modeling indicates the majority of the project area should experience less than a .0002 ft increase in water levels during an extreme storm event as a result of constructing the dredging project. The analysis estimates the largest increase in water surface elevations to occur in southern Jinks Creek adjacent to the feeder canal and totals approximately 1.2 x 10^{-3} ft, or approximately 1/64th of an inch.

This result suggests the project area should deliver a similar response to major storm events under the 2016 current condition or the preferred alternative condition. The surge levels generated by a respective storm event should not be influenced by the bathymetry change created by the dredging project. This most likely results because the dredging project would not improve the hydraulic efficiency of Jinks Creek beyond that of Shallotte Inlet or Little River Inlet. Thus, Jinks Creek would not receive a significant increase in tidal flows or velocities as a result of the dredging project and therefore, would not be expected to experience a significant increase in surge.

Figure 53. Water Surface Elevation Change between the 2016 Existing Conditions & the Preferred Alternative (Extreme Storm Condition)

4.0 SUMMARY OF RESULTS

The Town of Sunset Beach (Town) authorized a modeling analysis to evaluate the potential impacts of dredging Jinks Creek as part of an evaluation of the project's proposed alternatives. The North Carolina Division of Coastal Management (DCM) and the US Army Corps of Engineers (USACE) required the hydrodynamic analysis as part of a project review to investigate how the proposed dredging may change the existing environment of Jinks Creek. Both the DCM and the USACE expressed the following concerns related to the dredging project:

1. Will the project influence material shoaling within the AIWW & Jinks Creek confluence?
2. Will the project scour or erode the 'S' curve alignment in Jinks Creek?
3. Will the project influence material shoaling or migration patterns of Tubbs Inlet?

The DCM and USACE voiced these concerns in part due to the migration and shoaling patterns exhibited by Tubbs Inlet in apparent response to the 1970's dredging of southern Jinks Creek. Tubbs Inlet began a reversal in migration patterns near the same time as the 1970's dredging occurred, which now threatens existing homes on Ocean Isle. The analysis will also help evaluate if the proposed project will impact the federal maintenance of the Atlantic Intracoastal Waterway or the natural alignment of Jinks Creek. The USACE maintains responsibility for conducting all maintenance activities for the AIWW and must evaluate how potential projects may influence or change the waterways performance. In addition, Primary Nursery Area (PNA) extends adjacent to the banks of Jinks Creek and any change to the respective alignment could impact these environmentally sensitive lands.

The modeling analysis evaluates the performance of a preferred alignment against the performance of the 2016 existing conditions of Jinks Creek to estimate the potential for any adverse impacts. The preferred alignment presents a perceived least impactive alternative to provide a fixed and navigable connection to the AIWW. The Jinks Creek connection would serve residential docks located on the eastern end of the island of Sunset Beach along with tourists and guests visiting the area. The Town elected to potentially include Jinks Creek in the dredging project to avoid establishing and maintaining a navigable channel through Tubbs Inlet. Tubbs Inlet and Jinks Creek provide the only options in the project area for the Town to establish a long term navigable passage to open waters. Figure 54 shows the project area, including the AIWW, Tubbs Inlet, and the residential docks connected to Jinks Creek.

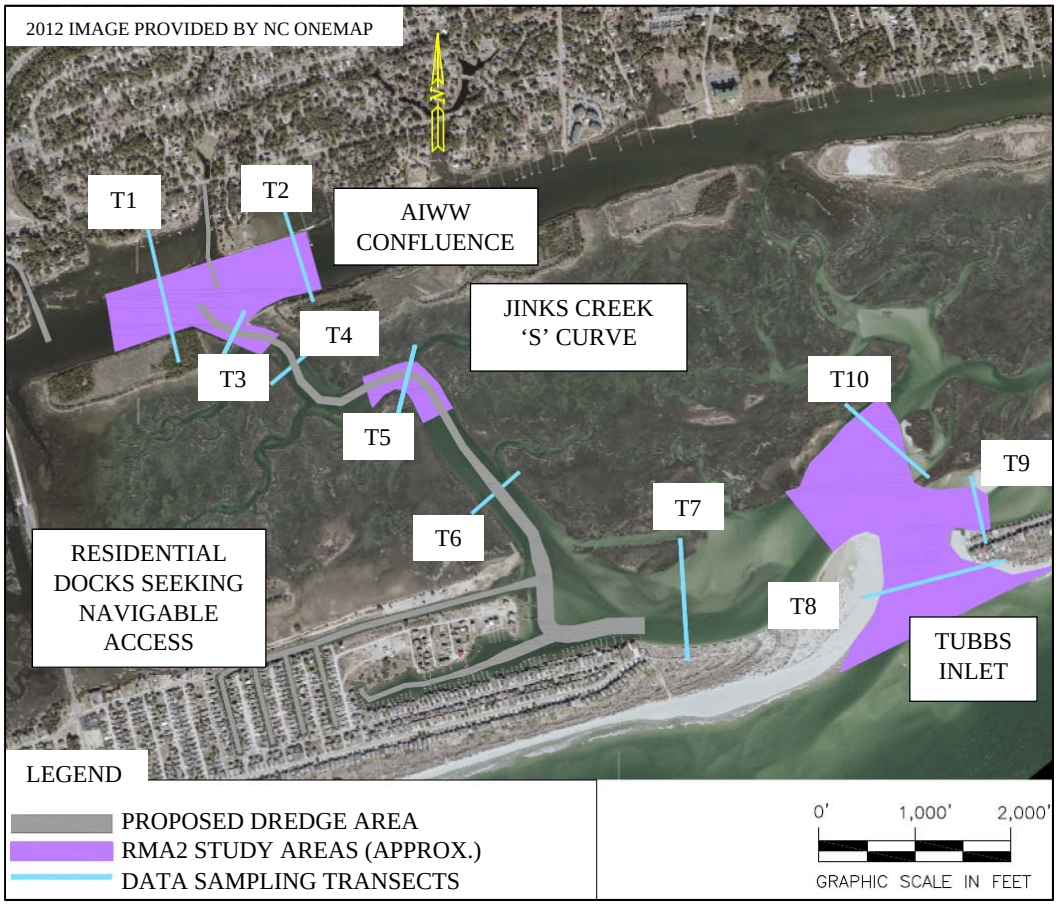


Figure 54. Jinks Creek & Tubbs Inlet Location Map

The analysis uses the RMA2 hydrodynamic 2-D modeling software to evaluate the tidal velocities and flow rates estimated for the project alternatives. The analysis builds from a 2004/05 study used to assess the scour velocities of the Sunset Beach Bridge replacement. The current analysis updates the modeling software from the 2004/05 study along with the bathymetry within Jinks Creek, Tubbs Inlet, and the AIWW confluence. However, the current analysis maintains the 2004/05 bathymetry outside of the immediate area of influence for the project.

The current analysis also utilizes the 2004/05 field measurements providing flow rate and velocity data across the project area. This option helped to control costs and expedite the project schedule by eliminating the need for additional field work and data processing. As part of the 2004/05 study, tidal flows were measured along 32 fixed transects over a 19.5 hour period inclusive of November 16 & 17, 2004. Two (2) boat mounted Acoustic Doppler Current Profilers (ADCPs) were used to collect the data along with a single

bottom mounted ADCP positioned near the Sunset Beach Bridge. The ADCPs also recorded tidal velocities along 9 of the 32 fixed transects. The collected data encapsulated a spring tide event where the tidal velocities and flow rates should have reached their largest magnitudes.

The current analysis also utilizes tidal or water level data recorded at NOAA station #8659897 (Sunset Beach Pier) to establish the open boundary conditions. The tidal data spans the month of November 2004 and serves as model input for generating the tidal velocities and flow rates measured during the field investigations. The analysis applies the single batch of tidal data to drive the water surface elevations at Tubbs Inlet as well as Shallotte and Little River Inlets. Tubbs Inlet receives the data without any time delays, whereas lag factors help maintain the chronological tides for Shallotte Inlet and Little River Inlet. Shallotte Inlet experiences a 30 minute lag time and Little River has a 12 minute lag compared to Tubbs Inlet. The present analysis verifies the calibration measurements along five (5) of the original 32 transects established for the 2004/05 analysis that enclose the study area.

The modeling results focus on the evaluation of the preferred alignment, although Appendix D includes additional results for the conceptual and maximum design alignments. The preferred alignment varies in width and depth throughout Jinks Creek. The preferred alignment begins with a 40-ft width at a bottom elevation of -5 MLW in northern Jinks Creek. The alignment expands as it traverses to southern Jinks Creek and terminates with a width of 100-ft at a bottom elevation of -7 MLW. The change in dimensions helps minimize the potential impacts that may be created through the dredging project and also helps address the concerns expressed by DCM and the USACE.

The analysis focuses on each of the three (3) concerns expressed by DCM and the USACE referenced above in addition to a citizens concern regarding the project performance during an extreme weather event. The analysis compares the tidal velocities and flow rates estimated through the modeling application at a minimum of three (3) transects for each concern. The analysis reviews the concerns expressed by DCM and the USACE by applying the tidal conditions of the November 2004 spring tide event and uses measurements recorded during Hurricane Hugo for the extreme storm analysis. The transect locations were established to provide results across the areas of concern. Figures 55 & 56 show the magnitude and percent change in maximum velocities, respectively, between the 2016 existing conditions and the preferred alignment.

4.1 Velocity Results (DCM & USACE Concerns)

The results indicate the preferred alignment should not create a significant change in the tidal velocities. The maximum percent change occurs in northern Jinks Creek in the confluence with the AIWW. Table 10 shows the velocities at Transect T3 should experience an approximate 2.6% or 0.07 ft/sec increase with the preferred alignment. The table shows the velocities should remain below the approximate 3.28 ft/sec threshold for scour, however the velocities do approach this limit. The 2.6% increase should not be expected to significantly alter the shoaling patterns of the Jinks Creek confluence with the AIWW.

Figure 55. Preferred Alignment - Change in Maximum Velocities (Spring Tide Condition)

Figure 56. Preferred Alignment - % Change in Maximum Velocities (Spring Tide Condition)

The 'S' curve alignment should also not experience a significant increase in tidal velocities under the preferred alignment. Table 10 shows the tidal velocities traversing the 'S' curve alignment already approach or exceed the approximate 3.28 ft/sec threshold for scour and should not experience a velocity increase greater than 1% during typical tidal events. Survey measurements collected during February 2016 suggest the 'S' curve alignment currently experiences scour velocities along the thalweg combined with material shoaling along the channel banks. The largest percent increase recorded along the 'S' curve alignment equaled approximately 0.7% along Transect T5, located in the center of the primary curve. Although Transect T5 recorded the largest percent change, the resulting velocities at Transect T5 should still remain below the original velocities measures along Transects T4 and T6 under the 2016 existing conditions. Therefore, significant impacts should not be expected along the 'S' curve as a result of the preferred alignment.

Table 10 shows the estimated maximum increase in tidal velocities along transects in the Tubbs Inlet complex equals approximately 1.0% along Transect T7. The increase estimated for Transect T7 totals more than double the percent increase indicated for Transect T8 in the mouth of Tubbs Inlet. This indicates a positive finding and supports the project intent to avoid Tubbs Inlet to reduce the potential for increased shoaling and migration patterns. Figure 54 shows the proposed dredging stops approximately 3,600 ft prior to Tubbs Inlet. The velocity change results indicate the shoal material between Tubbs Inlet and the proposed dredging provides a sufficient blockage to limit the relative increase in tidal flows in Tubbs Inlet.

Table 10. Maximum Velocities for the Preferred Alignment (Spring Tide Condition)

Transect		2016 Existing Conditions	Preferred Alternative	Percent (%) Change
AIWW Confluence	T1	1.53 ft/sec	1.56 ft/sec	1.6%
	T2	1.05 ft/sec	1.06 ft/sec	0.8 %
	T3	2.75 ft/sec	2.82 ft/sec	2.6%
'S' Curve Alignment	T4	3.45 ft/sec	3.46 ft/sec	0.3%
	T5	2.86 ft/sec	2.88 ft/sec	0.7%
	T6	3.01 ft/sec	3.02 ft/sec	0.3%
Tubbs Inlet	T7	2.28 ft/sec	2.30 ft/sec	0.9%
	T8	4.72 ft/sec	4.74 ft/sec	0.4%
	T9	3.69 ft/sec	3.68 ft/sec	-0.3%
	T10	2.45 ft/sec	2.44 ft/sec	-0.4%

5. Values are depth averaged velocities simulated from Nov. 13, 2004 (13:15) to Nov. 20, 2004 (13:15) tidal conditions.

4.2 Flow Rate Measurement (DCM & USACE Concerns)

The change in flow rate measurements support the velocity changes indicated above and provide confidence that significant impacts should not occur as a result of the preferred alignment. Within the AIWW confluence area the estimated flow rates should experience a maximum percent change of approximately 5% along Transect T3. However, this maximum change occurs during a lower flow rate event. Table 11 shows Transect T3 should experience an estimated 4.6% increase in flow rate during an ebb (outgoing) tidal cycle. However, the estimated flow rate during the ebb cycle remains significantly below the flow rates estimated for the flood (incoming) cycle. Therefore, the ebb tide scour potential for the preferred alignment will still remain significantly below the existing flood tide scour potential for the 2016 conditions. Consequently, the 2.9% change estimated for the flood tide cycle matches well with the percent change estimated for the maximum velocity change for Transect T3 shown in Table 10. Thus, the increase in average flow rates shown in the modeling analysis should not enhance the shoaling patterns significantly within the AIWW confluence area.

Table 11. Average Flow Rates for the Preferred Alignment (Spring Tide Condition)

Transect		2016 Existing Conditions		Preferred Alignment		Percent (%) Change	
		Ebb	Flood	Ebb	Flood	Ebb	Flood
AIWW Confluence	T1	1,250	3,140	1,270	3,190	1.6%	1.6%
	T2	1,530	1,450	1,560	1,440	2.0%	-0.7%
	T3	1,510	2,450	1,580	2,520	4.6%	2.9%
'S' Curve Alignment	T4	2,320	2,790	2,400	2,880	3.4%	3.2%
	T5	2,600	3,230	2,680	3,300	3.1%	2.2%
	T6	3,250	4,220	3,340	4,290	2.8%	1.7%
Tubbs Inlet	T7	4,400	5,740	4,500	5,840	2.3%	1.7%
	T8	10,620	12,110	10,670	12,230	0.5%	1.0%
	T9	1,530	1,230	1,520	1,230	-0.7%	0.0%
	T10	2,350	2,180	2,350	2,170	0.0%	-0.5%

1. Values represent averaged measurements simulated from Nov. 13, 2004 (13:15) to Nov. 20, 2004 (13:15) tidal conditions.

Flow rate measurements within the 'S' curve alignment support the results of the confluence area analysis and the conclusion that significant impacts should not occur as a result of the preferred alignment. The analysis suggest the flood flow rates along Transect T4 in northern Jinks Creek should experience an increase of approximately 3.2%. Similar to the measurements at Transect T3, the ebb tide measurements show a larger percent increase. However, the average flows estimated for an ebb tide cycle remain approximately 15% lower than the flood flows. Therefore, the maximum velocities should be expected to occur during the flood tide cycle and should experience a maximum increase around 3%.

The flow rate measurements within the Tubbs Inlet complex also indicate the preferred alignment will not create a significant impact. Table 11 shows the flow rates traversing through Tubbs Inlet (Transect T8) should experience an approximate 1% increase or less in magnitude. Transect T7, located at the terminus of the proposed dredging, shows an estimated increase of approximately 1.7% in average flood flow rates. This result matches well with the measurements for Transect T6 near the 'S' Curve alignment.

The consistency in the results between the multiple transects suggest the increased tidal flows should remain within the confines of Jinks Creek. The increased magnitudes in the average flow rates measured throughout Jinks Creek (T3 – T7) equals between 70 and 100 cfs. Therefore, the large majority of any additional flow resulting from the dredging project would be expected to travel within Jinks Creek between Tubbs Inlet and the AIWW.

4.3 Velocity & Average Flow Rate Measurements (Extreme Storm Conditions)

The velocity measurements recorded for the extreme storm event suggest less than a 3% change in maximum velocities may occur for northern Jinks Creek and just over a 1% change in southern Jinks Creek. Table 12 shows the calculation results for the measurements conducted along Transects T3, T5, & T7 to support this conclusion.

Table 12. Change in Maximum Velocity for Preferred Alignment (Extreme Storm Condition)

Transect	Magnitude Change	Percent (%) Change	Location (Jinks Creek)
T3	.05 ft/sec	2.4%	Northern
T5	.04 ft/sec	1.3%	Northern / Southern
T7	.04 ft/sec	1.2%	Southern

1. Determined from depth averaged velocities simulated from Sept. 20, 1989 (10:30) to Sept. 22, 1989 (18:29) tidal conditions.

Figures 57 and 58 show the measured increase in tidal velocities for all of Jinks Creek as an absolute magnitude and as a percent increase, respectively. The figures indicate the maximum increase in relation to the respective study areas, occurs in northern Jinks Creek and equals approximately 0.05 ft/sec (±2%).

Figure 57. Preferred Alignment - Change in Maximum Velocities (Extreme Storm Condition)

Figure 58. Preferred Alignment - % Change in Maximum Velocities (Extreme Storm Condition)

The measured increase in average flow rates provides very similar results as the velocity measurements for the extreme storm condition analysis. Table 13 shows the percent change in the average flow rates reflect an approximately 1% ~ 3% increase for the preferred alignment. This data along with the previous results discussed, provides confidence the preferred alignment will not create significant shoaling or scouring impacts compared to the 2016 existing conditions of Jinks Creek.

Table 13. Change in Average Flow Rate for Preferred Alignment (Extreme Storm Condition)

Transect	Average Ebb Flow (Outgoing)		Average Flood Flow (Incoming) cfs	
	Magnitude Change	Percent (%) Change	Magnitude Change	Percent (%) Change
T3	+80 cfs	2.6%	+70 cfs	1.9%
T5	+110 cfs	2.1%	+90 cfs	1.6%
T7	+180 cfs	1.4%	+150 cfs	1.2%

1. Values calculated from averaged measurements simulated from tidal conditions occurring from September 20, 1989 (10:30) to September 22, 1989 (18:29).

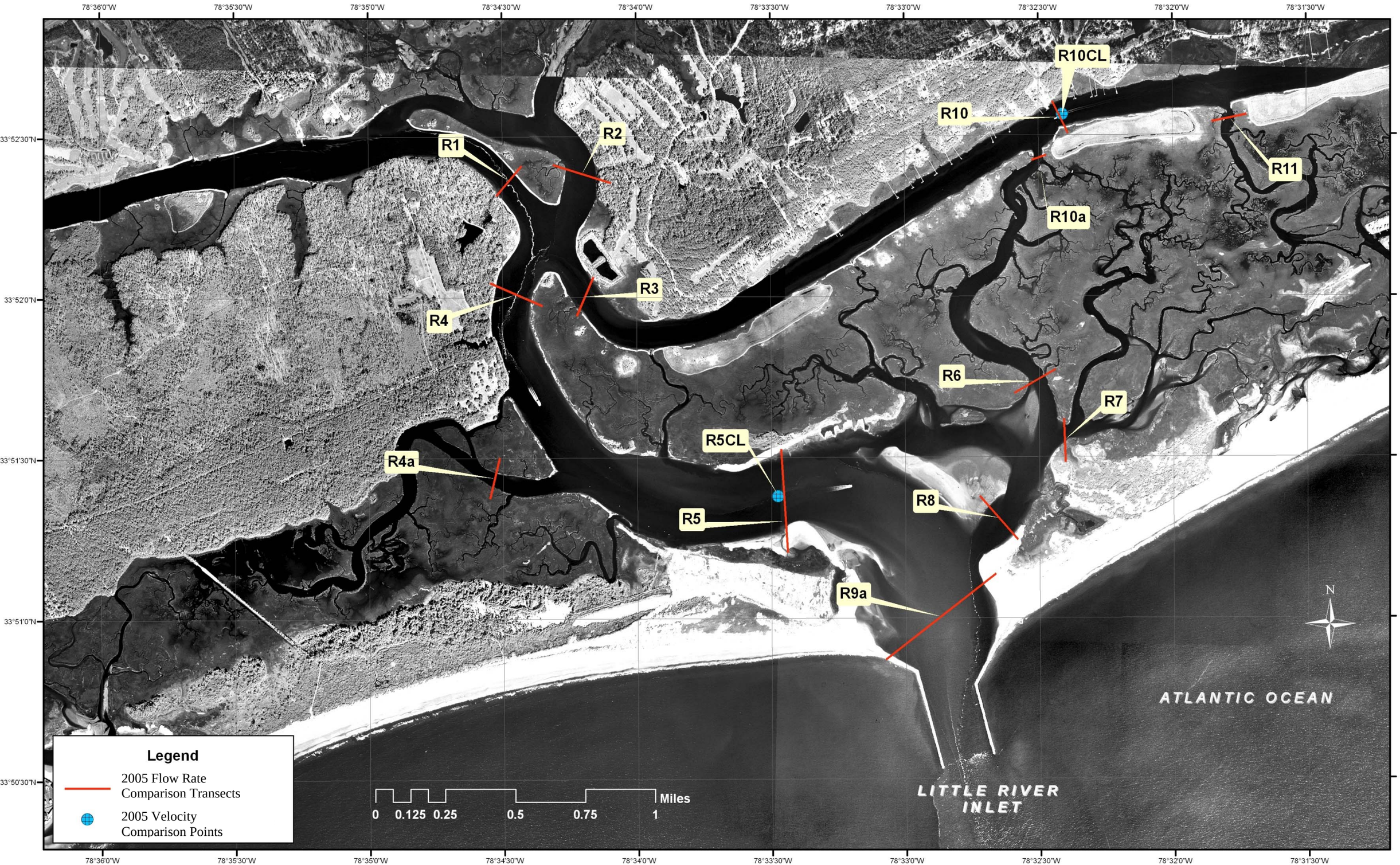
4.4 Change in Water Surface Elevations (Extreme Storm Conditions)

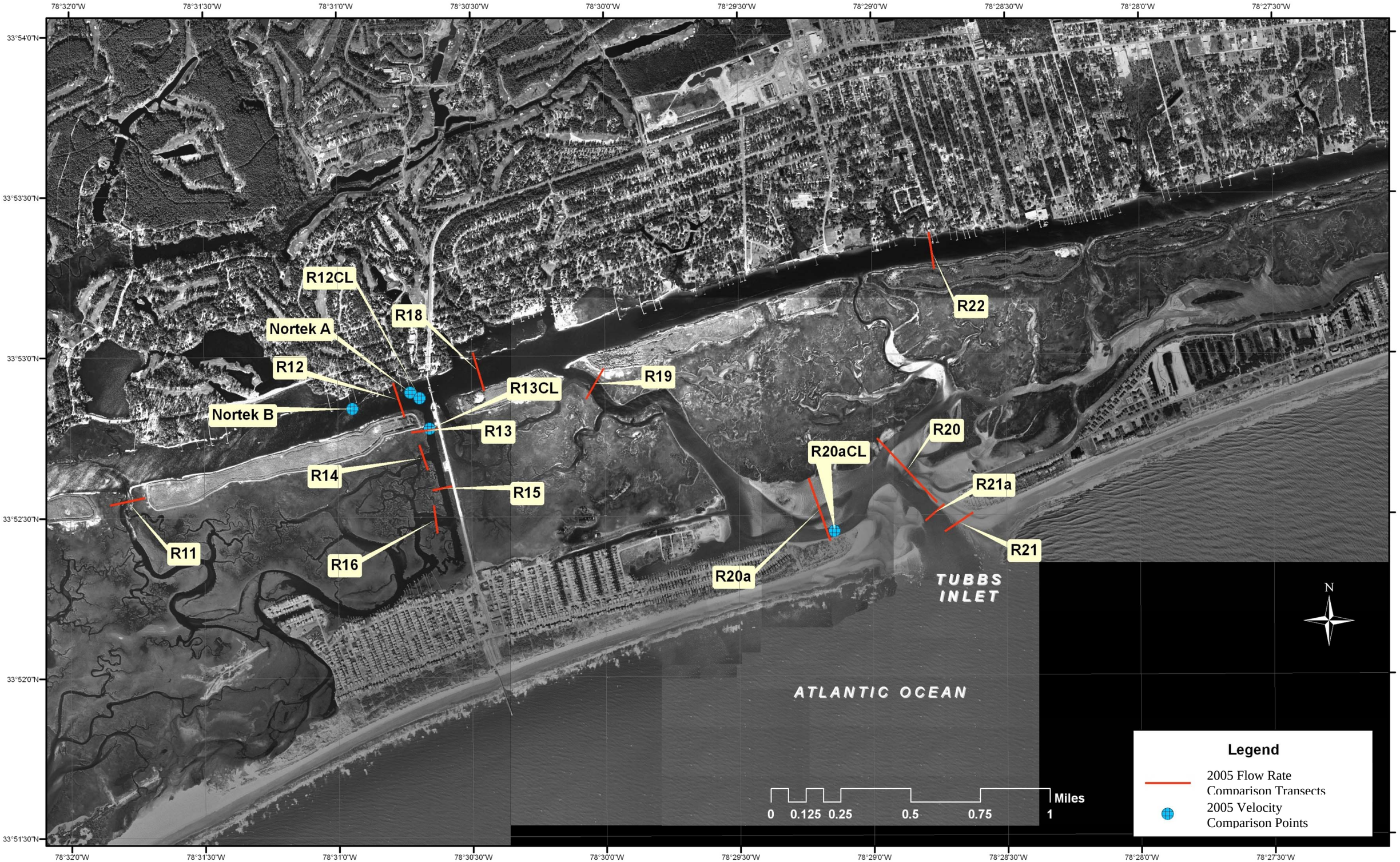
The modeling estimates a negligible change in the maximum water surface elevations during extreme storm events should occur as a result of constructing the preferred alternative. The modeling estimated the maximum water surface elevations would increase approximately 1/64th of an inch in southern Jinks Creek during extreme storm events. The analysis estimated the remaining portions of Jinks Creek, the AIWW, and Tubbs Inlet should experience considerably less of an increase than southern Jinks Creek. The estimated increase for these remaining project areas ranged between 0 and approximately 1/100th of an inch (0.0008 ft).

Appendix A

2004/05 Field Data Collection Transects

[Moffatt & Nichol. (2005). Hydraulic modeling Sunset Beach bridge replacement. Raleigh: NCDOT]


78°36'0"W
78°35'30"W
78°35'0"W
78°34'30"W
78°34'0"W
78°33'30"W
78°33'0"W
78°32'30"W
78°32'0"W
78°31'30"W
33°52'30"N
33°52'0"N
33°51'30"N
33°51'0"N
33°50'30"N
R1
R2
R3
R4
R4a
R5
R5CL
R6
R7
R8
R9a
R10
R10CL
R10a
R11
N
ATLANTIC OCEAN
LITTLE RIVER INLET
Legend
2005 Flow Rate Comparison Transects
2005 Velocity Comparison Points
0
0.125
0.25
0.5
0.75
1
Miles


78°32'0"W
78°31'30"W
78°31'0"W
78°30'30"W
78°30'0"W
78°29'30"W
78°29'0"W
78°28'30"W
78°28'0"W
78°27'30"W
33°54'0"N
33°53'30"N
33°53'0"N
33°52'30"N
33°52'0"N
33°51'30"N
R12CL
R18
Nortek A
R12
Nortek B
R13CL
R13
R19
R22
R14
R15
R11
R16
R20aCL
R20
R21a
R21
R20a
TUBBS INLET
ATLANTIC OCEAN
N
0 0.125 0.25 0.5 0.75 1 Miles
Legend
2005 Flow Rate Comparison Transects
2005 Velocity Comparison Points

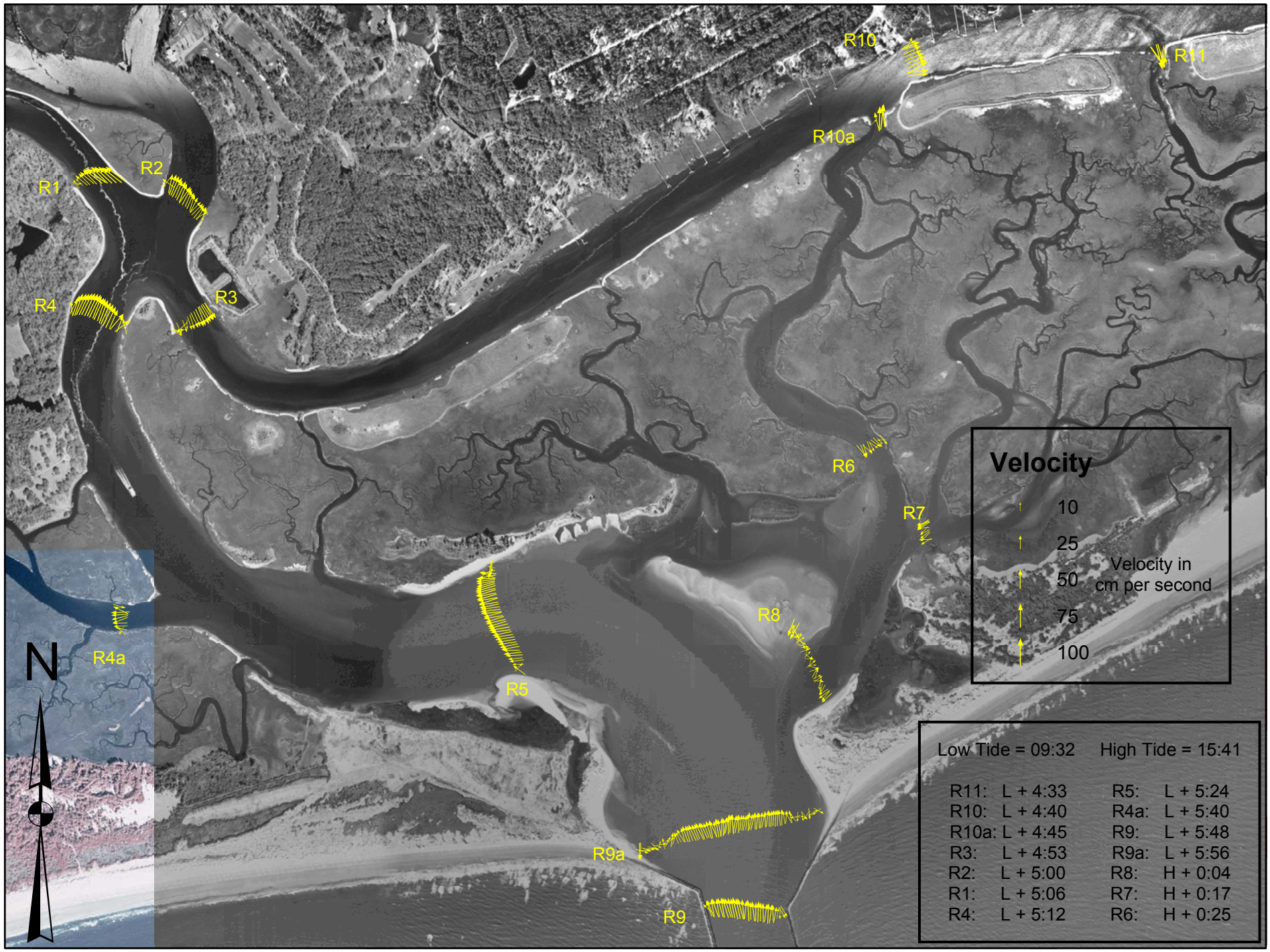
78°26'30"W
78°26'0"W
78°25'30"W
78°25'0"W
78°24'30"W
78°24'0"W
78°23'30"W
78°23'0"W
78°22'30"W
78°22'0"W
33°55'0"N
33°54'30"N
33°54'0"N
33°53'30"N
33°53'0"N
R24CL
R25
R26
R24
R23CL
R23a
R23
R27
SHALLOTTE INLET
ATLANTIC OCEAN
N
0 0.125 0.25 0.5 0.75 1 Miles
Legend
2005 Flow Rate Comparison Transects
2005 Velocity Comparison Points

Appendix B

2004/05 Velocity Vector Plots

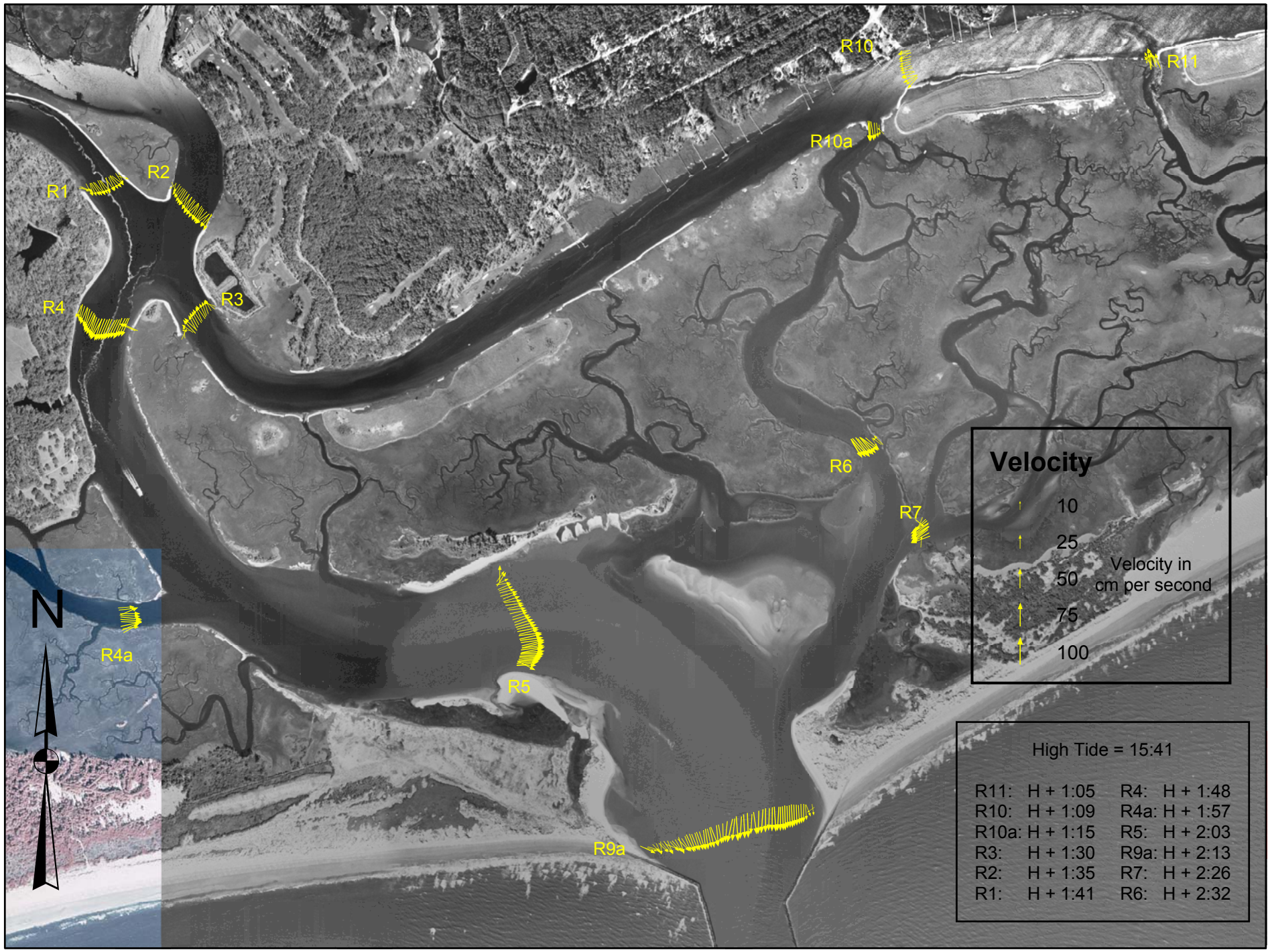
[Moffatt & Nichol. (2005). Hydraulic modeling Sunset Beach bridge replacement. Raleigh: NCDOT]

Little River Inlet 11/16/04 Flood Tide



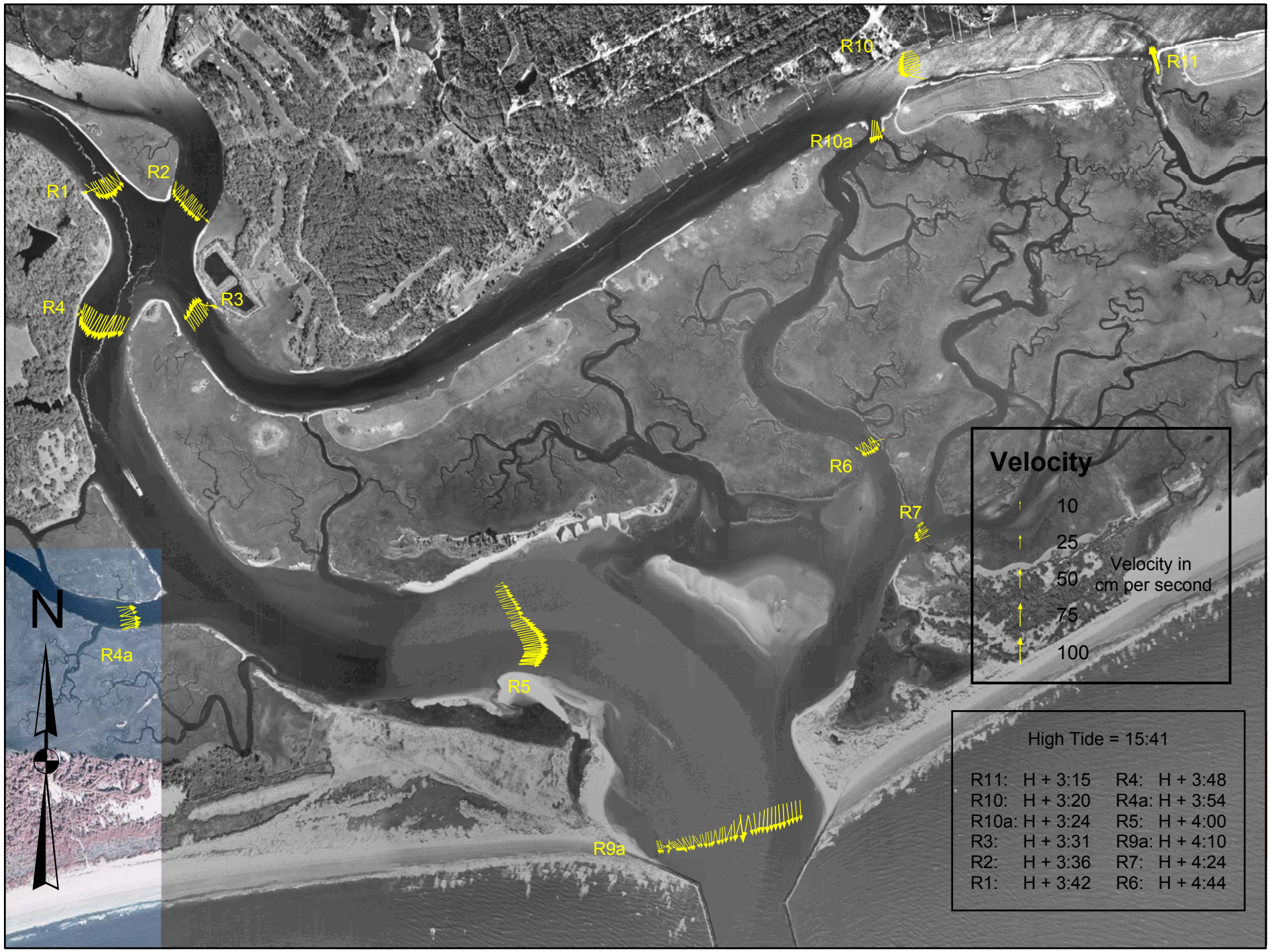
1,600 800 0 1,600 3,200 4,800 6,400 Feet

Little River Inlet 11/16/04 Ebb Tide



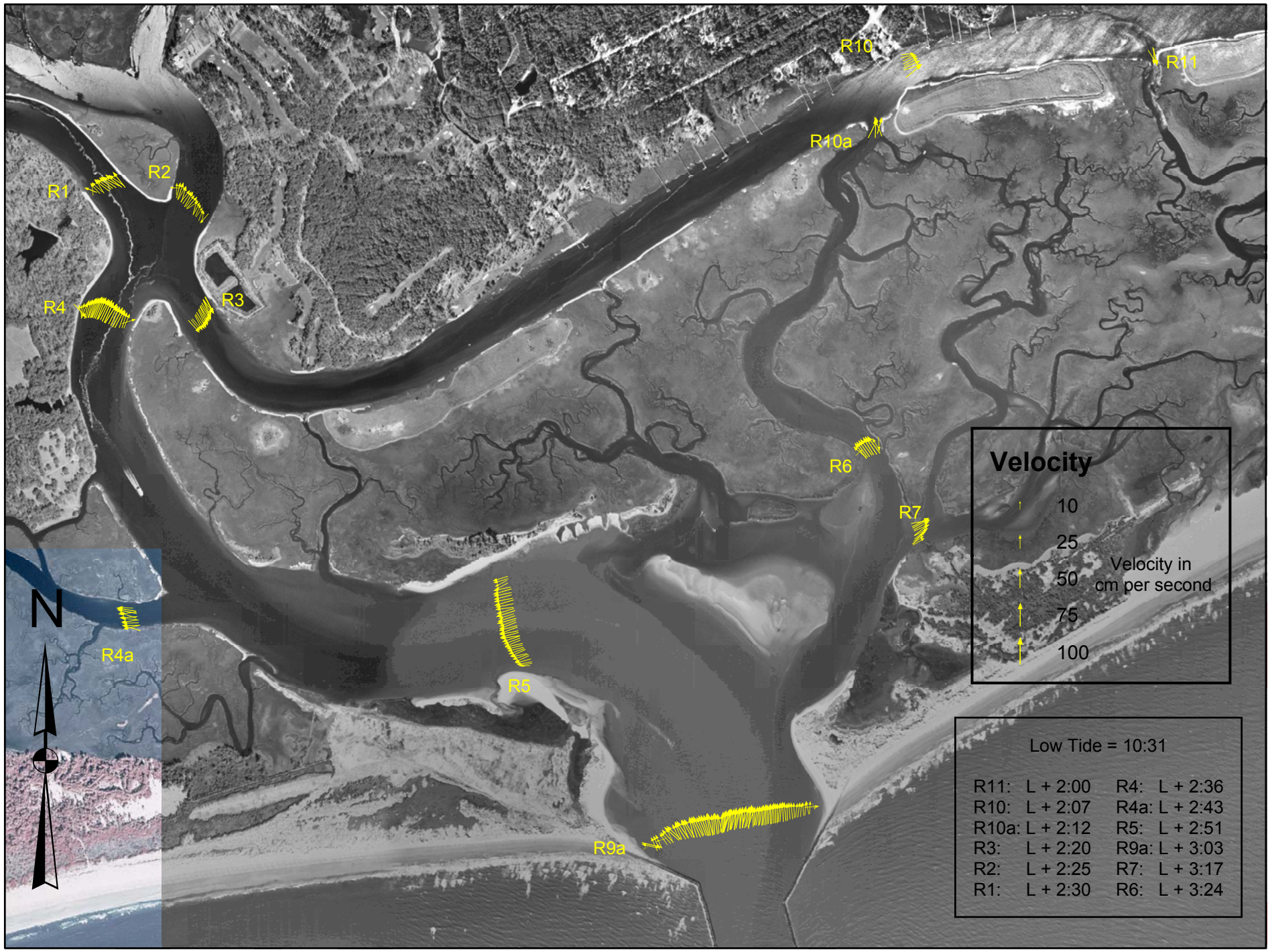
1,600 800 0 1,600 3,200 4,800 6,400 Feet

Little River Inlet 11/16/04 Ebb Tide



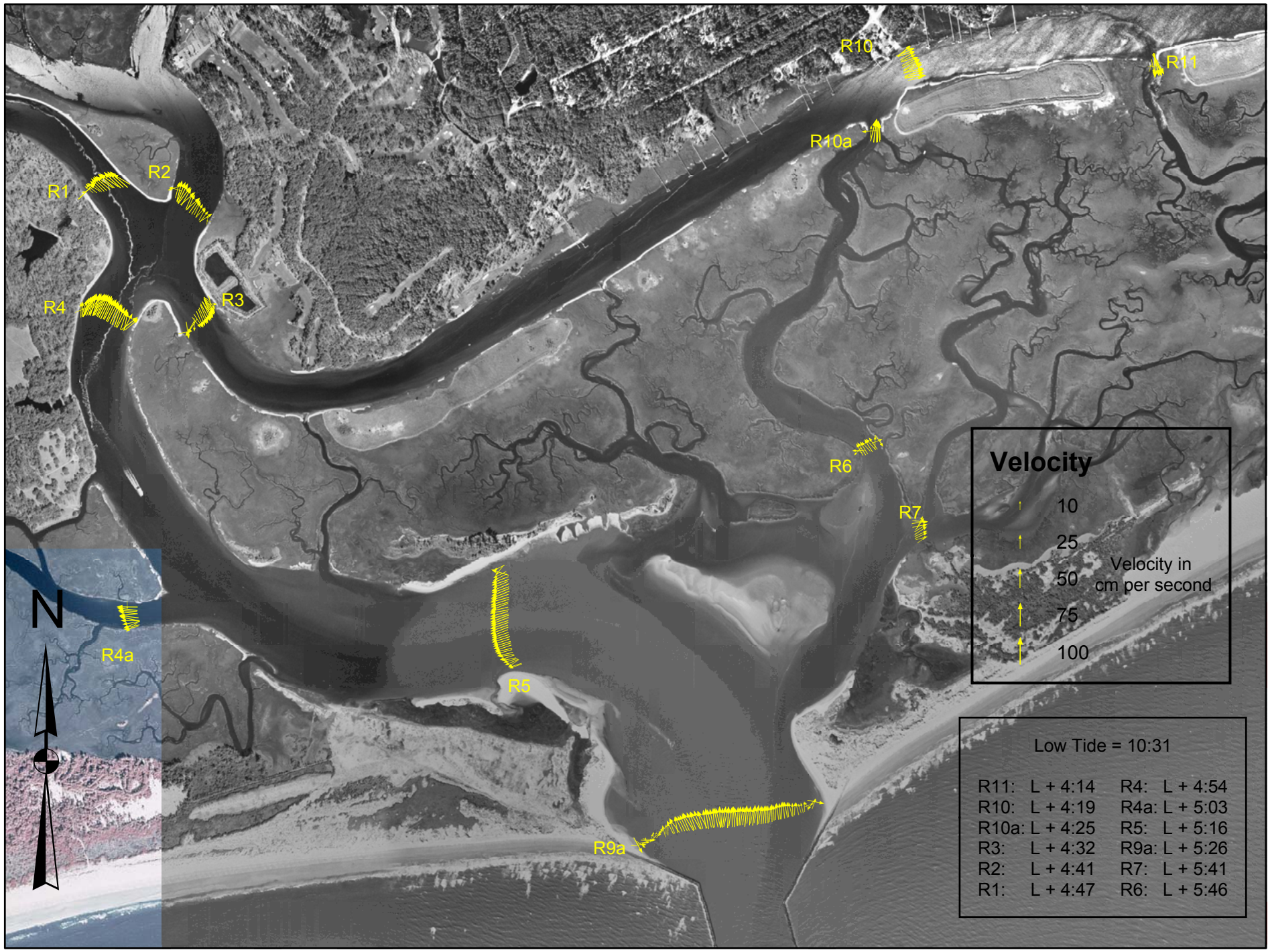
1,600 800 0 1,600 3,200 4,800 6,400 Feet

Little River Inlet 11/17/04 Flood Tide



1,600 800 0 1,600 3,200 4,800 6,400 Feet

Little River Inlet 11/17/04 Flood Tide

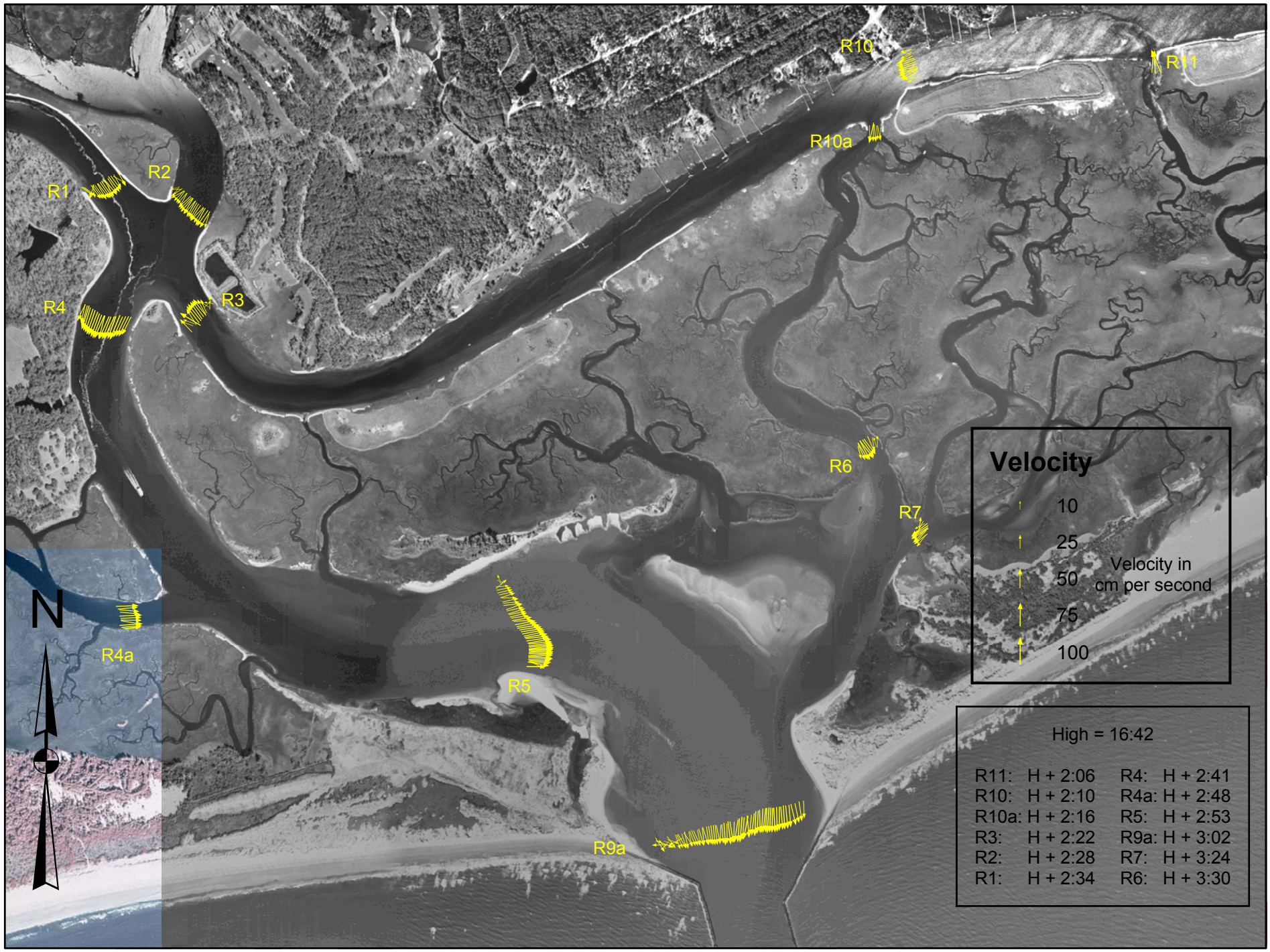


1,600 800 0 1,600 3,200 4,800 6,400 Feet

Little River Inlet 11/17/04 Ebb Tide

1,600 800 0 1,600 3,200 4,800 6,400 Feet

Little River Inlet 11/17/04 Ebb Tide



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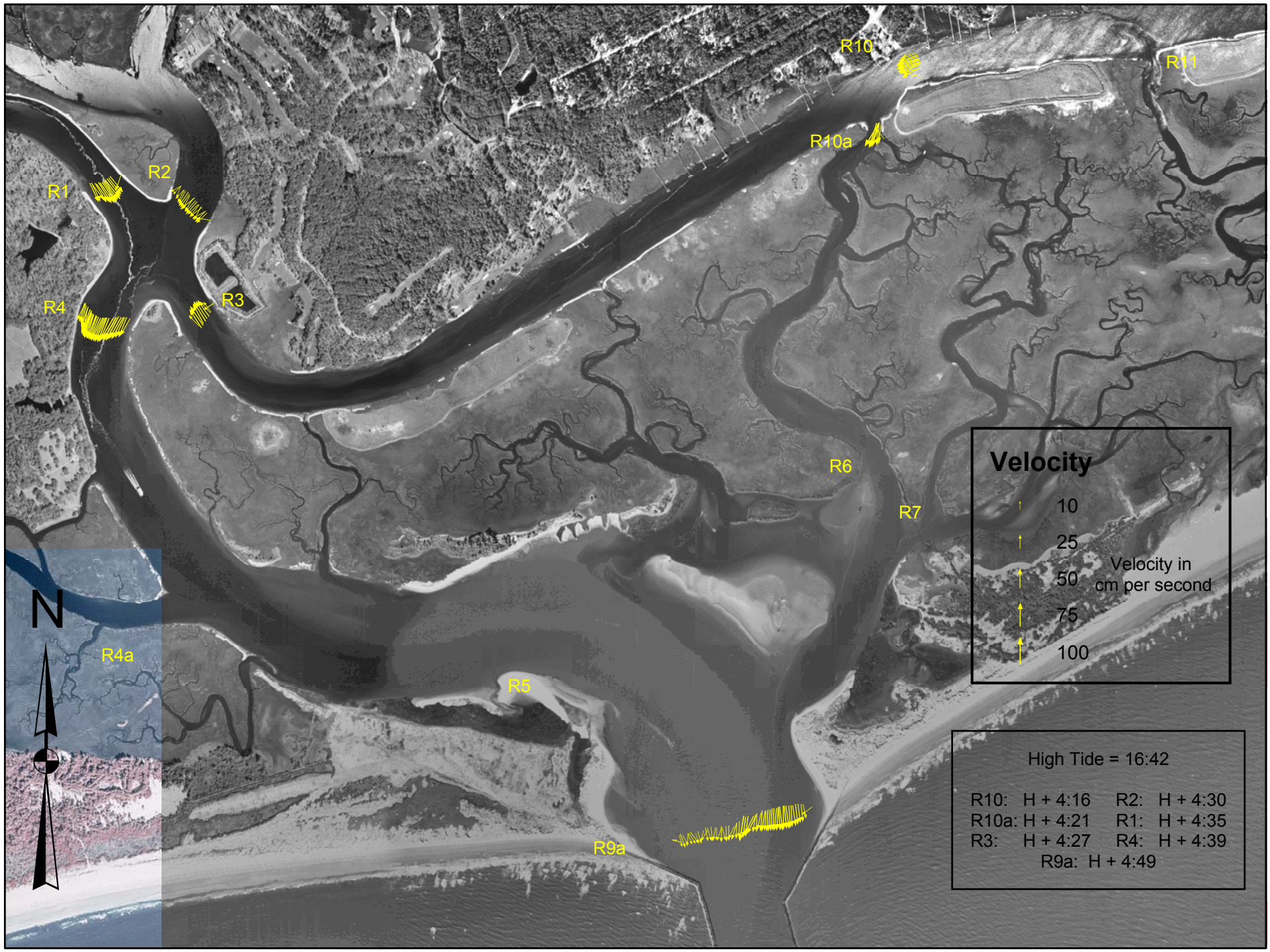
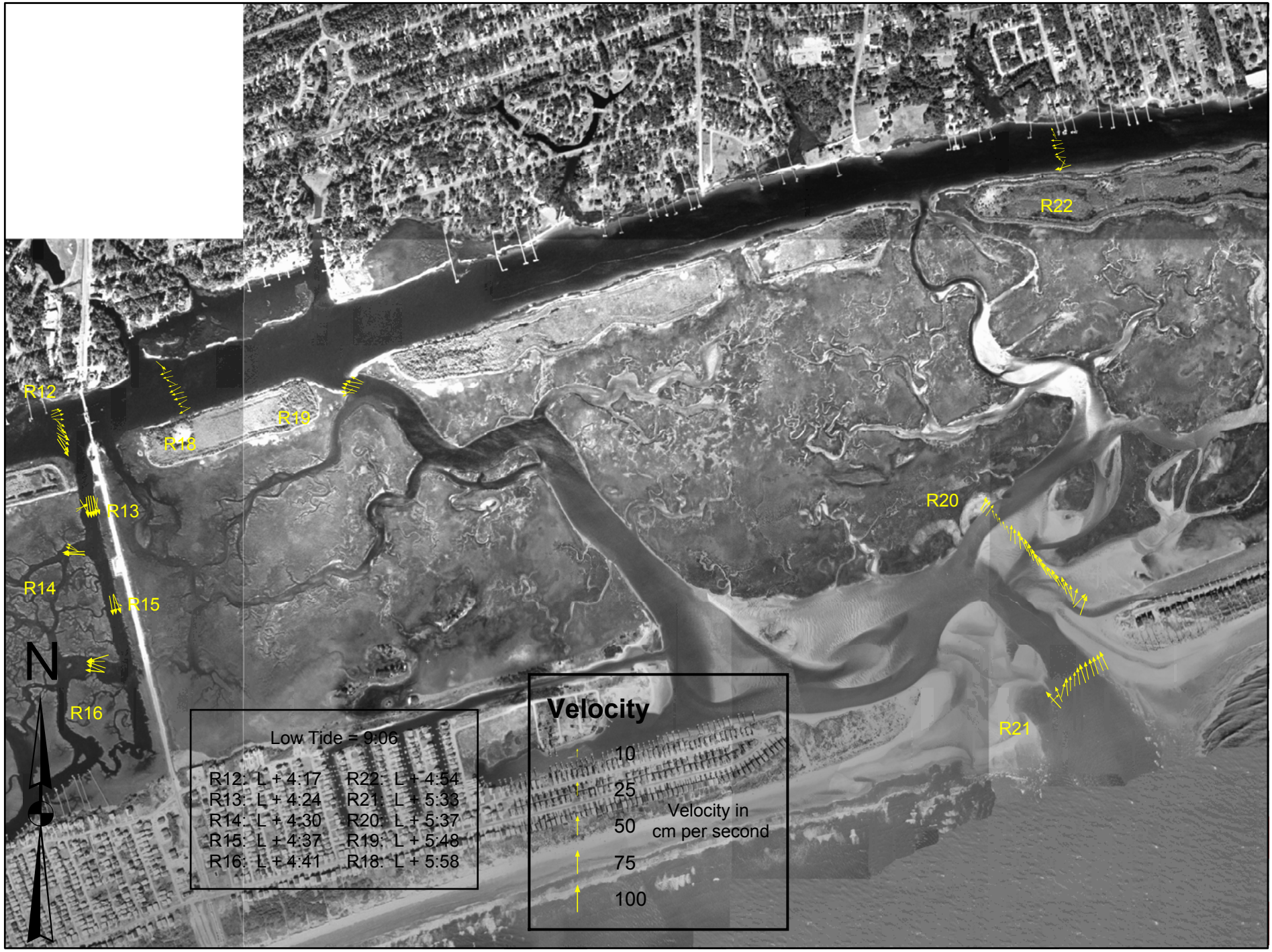
Little River Inlet 11/17/04 Ebb Tide



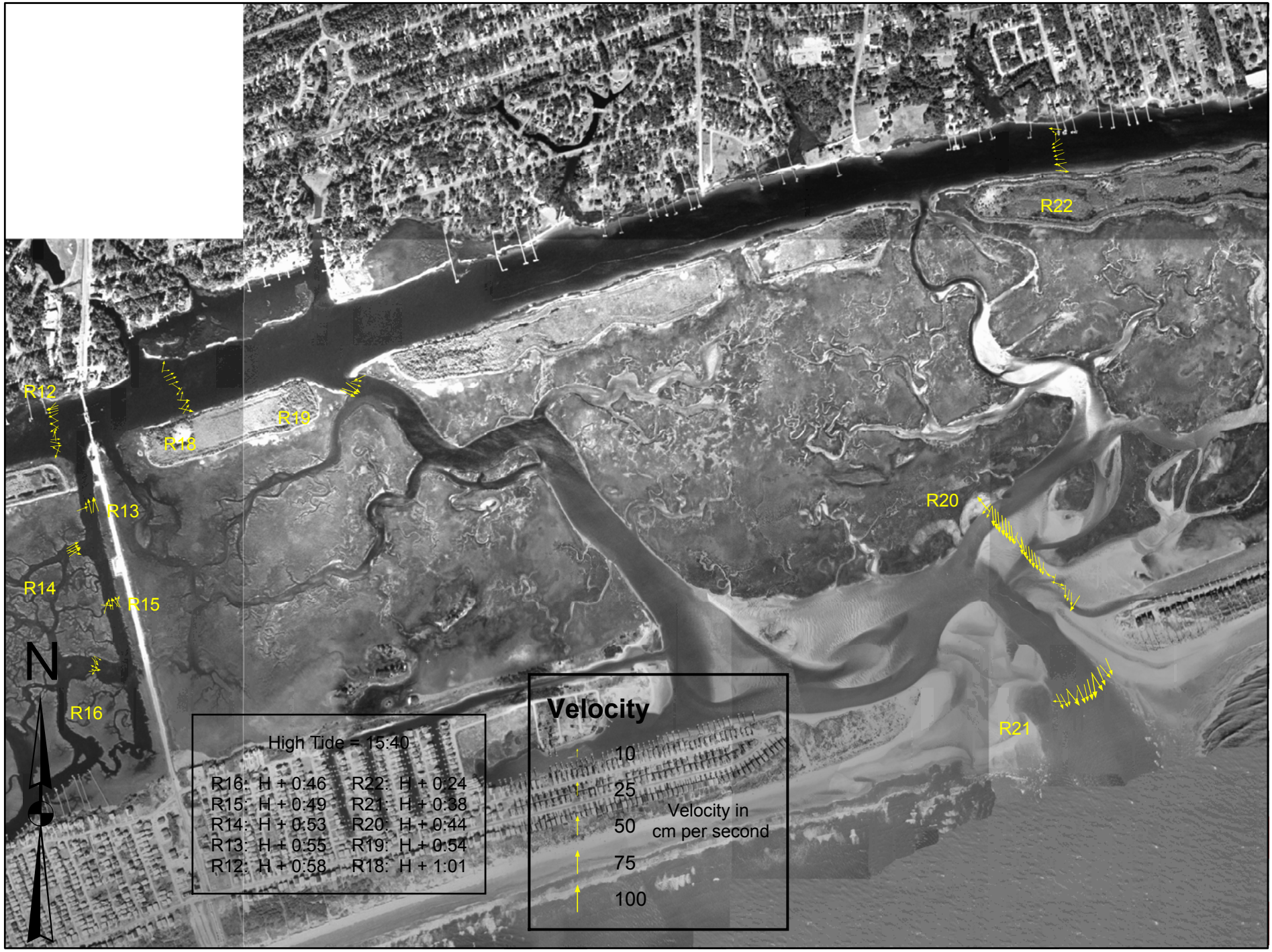
1,600 800 0 1,600 3,200 4,800 6,400 Feet

Sunset Beach Bridge & Tubbs Inlet 11/16/04 Flood Tide



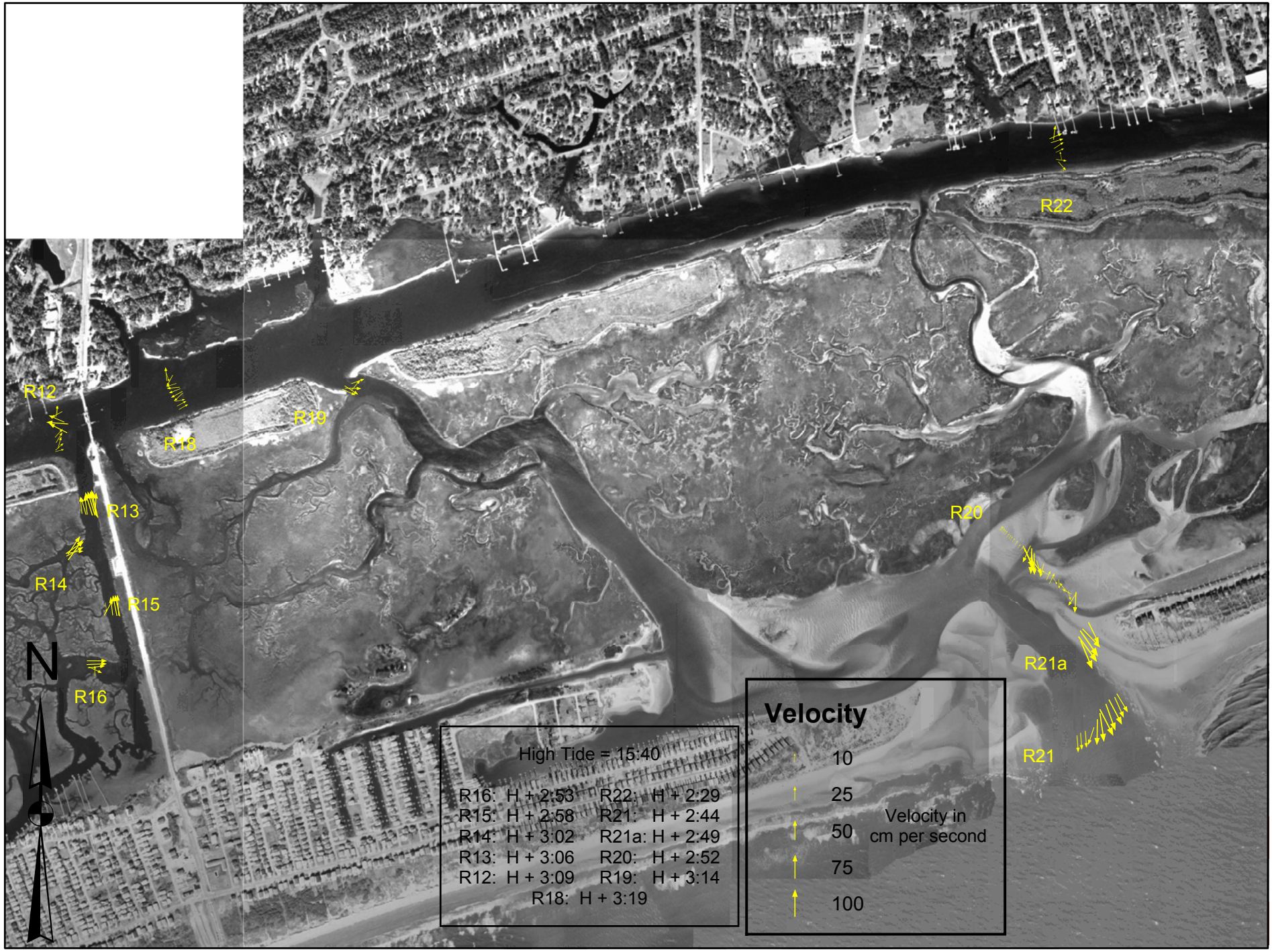
1,500 750 0 1,500 3,000 4,500 6,000 Feet

Sunset Beach Bridge & Tubbs Inlet 11/16/04 Ebb Tide



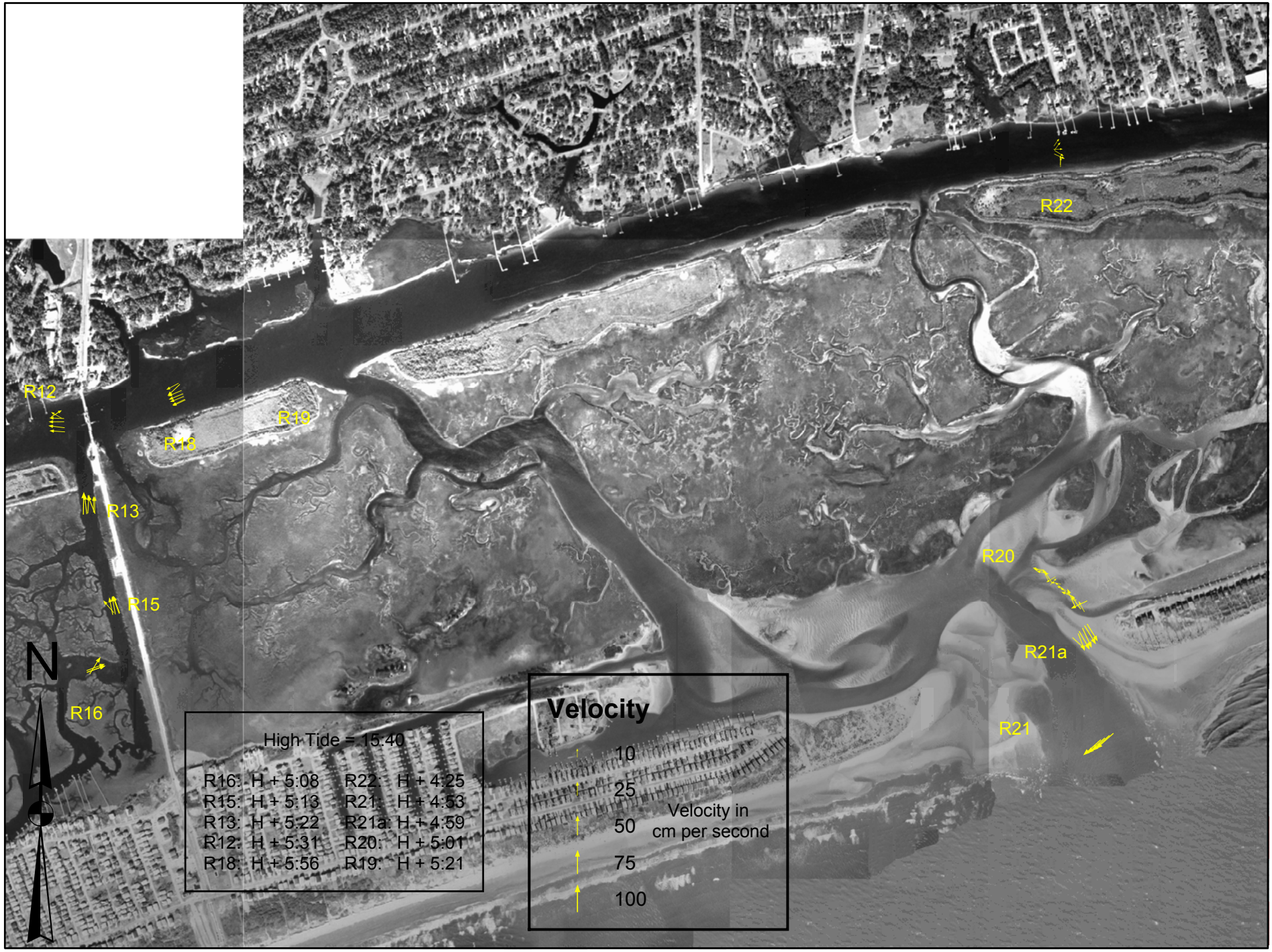
1,500 750 0 1,500 3,000 4,500 6,000 Feet

Sunset Beach Bridge & Tubbs Inlet 11/16/04 Ebb Tide



1,500 750 0 1,500 3,000 4,500 6,000 Feet

Sunset Beach Bridge & Tubbs Inlet 11/16/04 Ebb Tide



1,500 750 0 1,500 3,000 4,500 6,000 Feet

Sunset Beach Bridge & Tubbs Inlet 11/17/04 Flood Tide

1,500 750 0 1,500 3,000 4,500 6,000 Feet

Sunset Beach Bridge & Tubbs Inlet 11/17/04 Flood Tide

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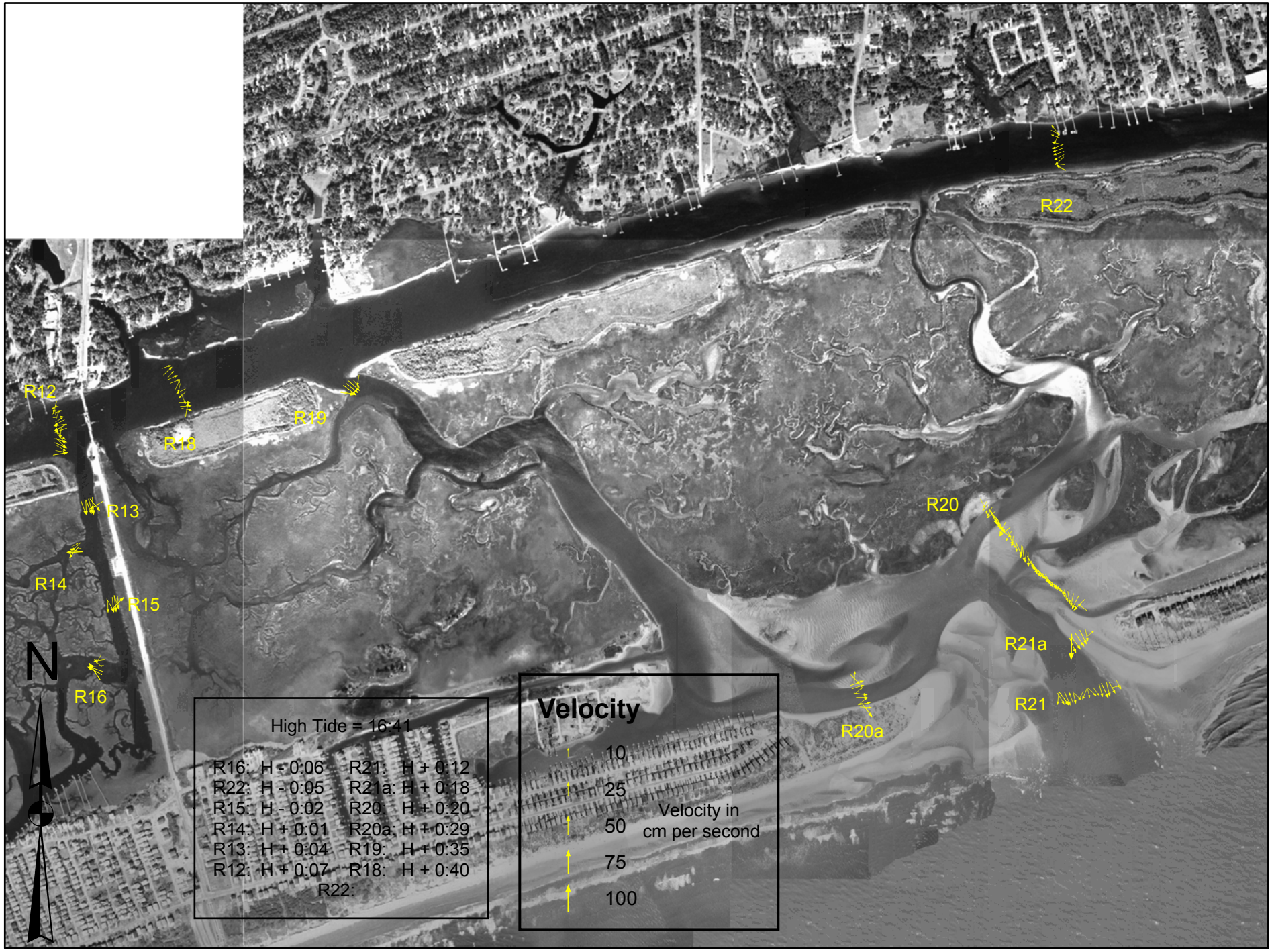
Sunset Beach Bridge & Tubbs Inlet 11/17/04 Ebb Tide



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Sunset Beach Bridge & Tubbs Inlet 11/17/04 Ebb Tide

1,500 750 0 1,500 3,000 4,500 6,000 Feet

Sunset Beach Bridge & Tubbs Inlet 11/17/04 Ebb Tide

1,500 750 0 1,500 3,000 4,500 6,000

Feet

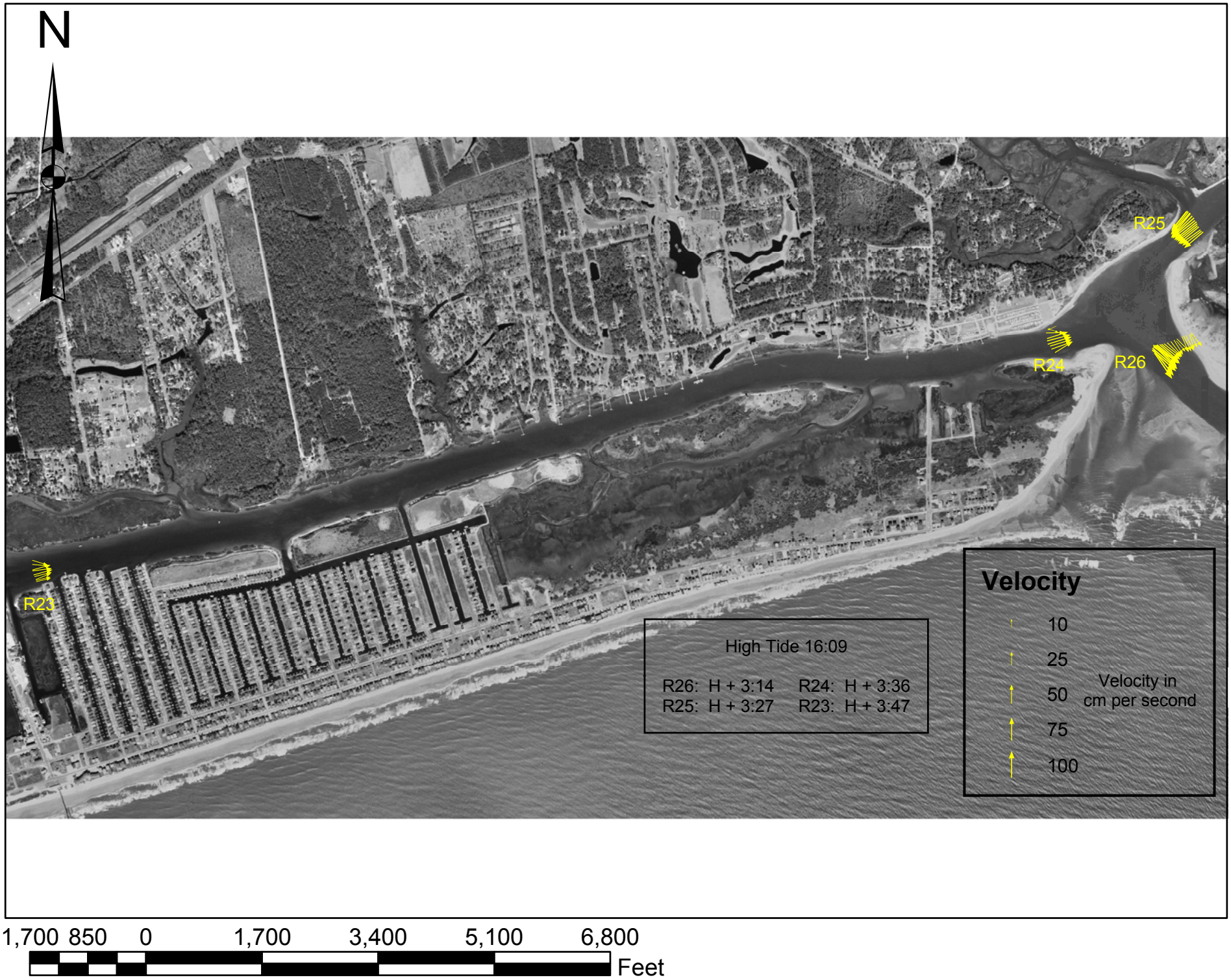
Shalotte Inlet 11/16/04 Flood Tide

1,700 850 0 1,700 3,400 5,100 6,800 Feet

Shalotte Inlet 11/16/04 Flood Tide

Shalotte Inlet 11/16/04 Ebb Tide

Shalotte Inlet 11/16/04 Ebb Tide



Shalotte Inlet 11/16/04 Ebb Tide

Shalotte Inlet 11/17/04 Flood Tide

1,700 850 0 1,700 3,400 5,100 6,800 Feet

Shalotte Inlet 11/17/04 Flood Tide

1,700 850 0 1,700 3,400 5,100 6,800 Feet

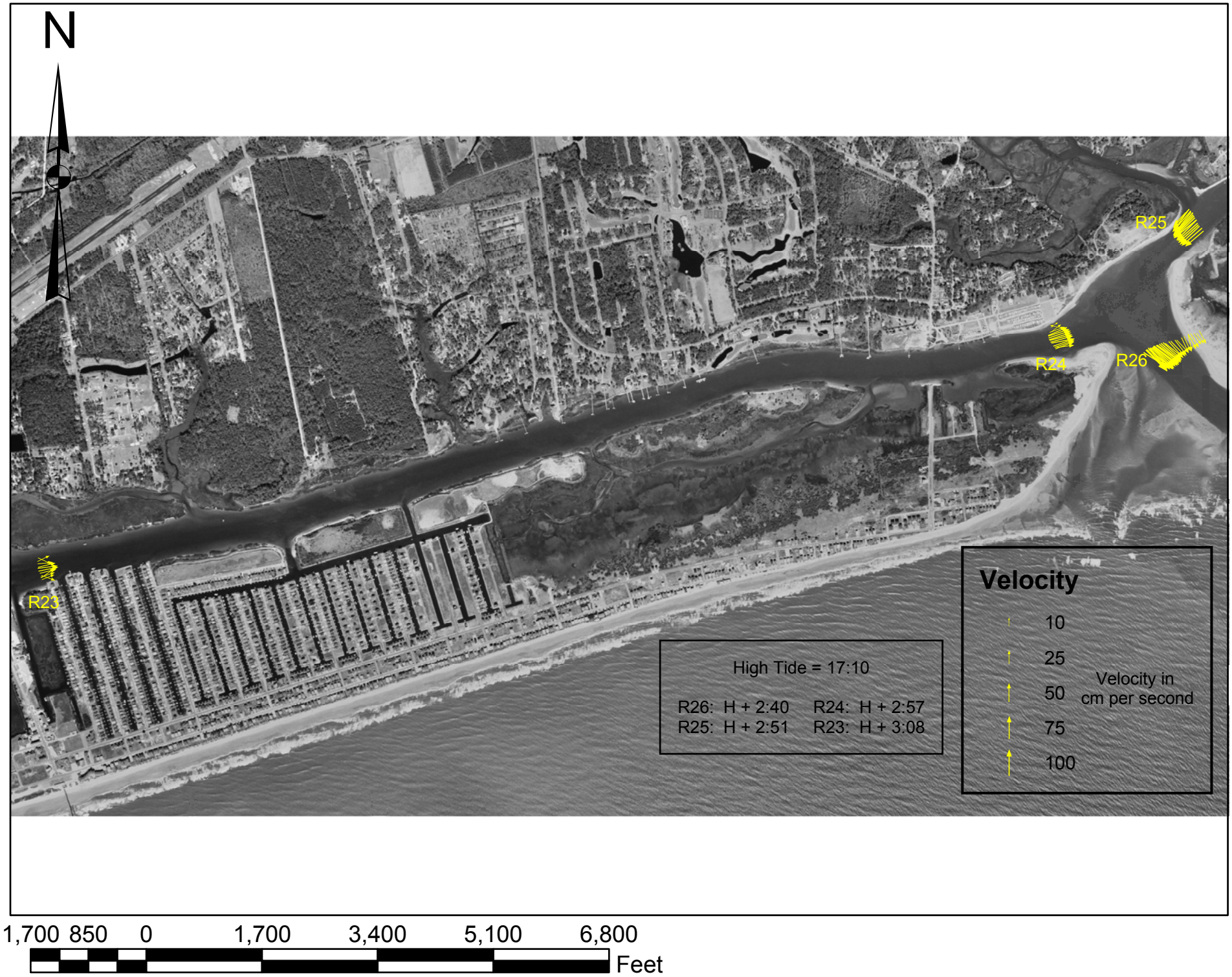
Shalotte Inlet 11/17/04 Flood Tide

1,700 850 0 1,700 3,400 5,100 6,800 Feet

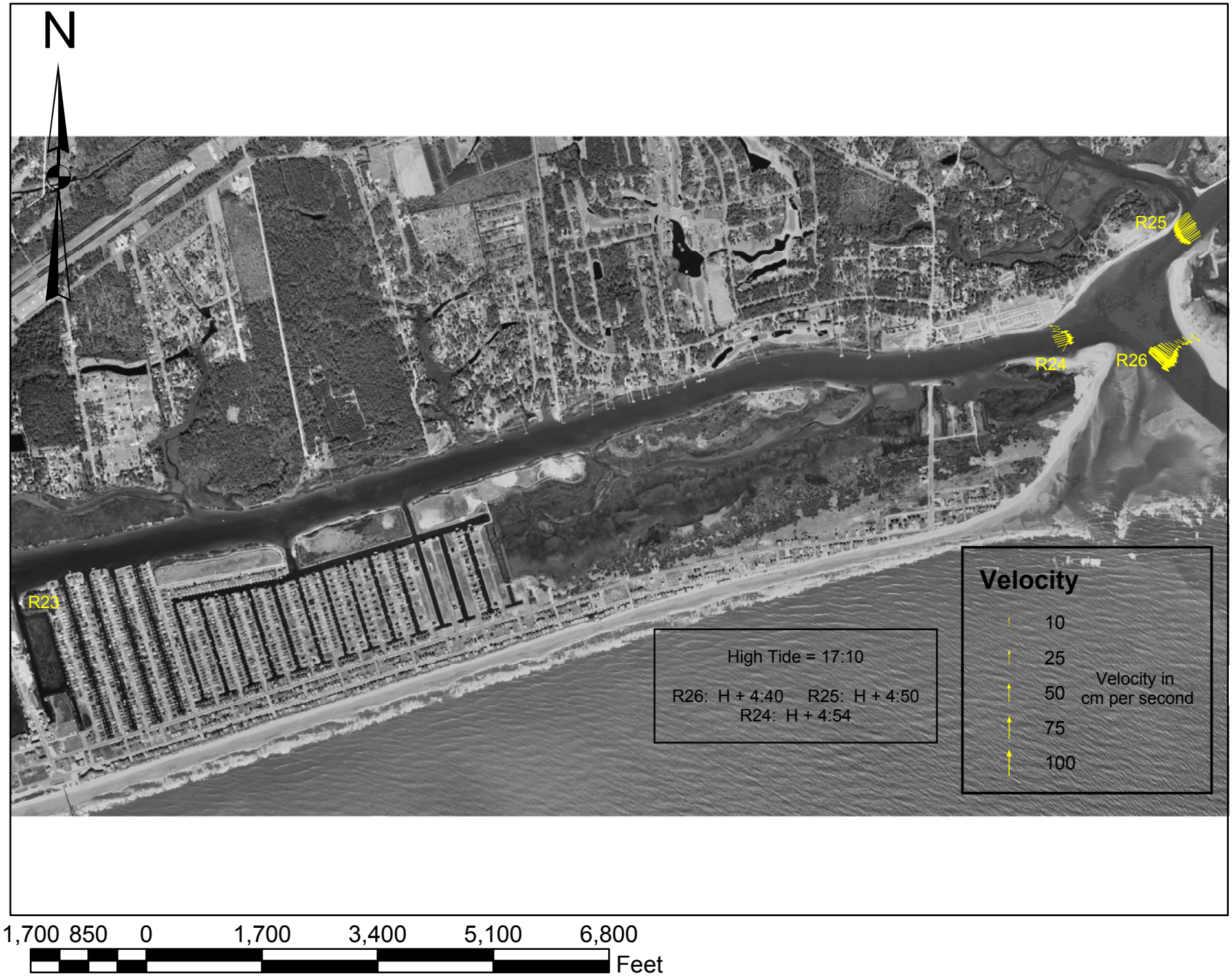
Shalotte Inlet 11/17/04 Ebb Tide

1,700 850 0 1,700 3,400 5,100 6,800 Feet

Shalotte Inlet 11/17/04 Ebb Tide



Shalotte Inlet 11/17/04 Ebb Tide

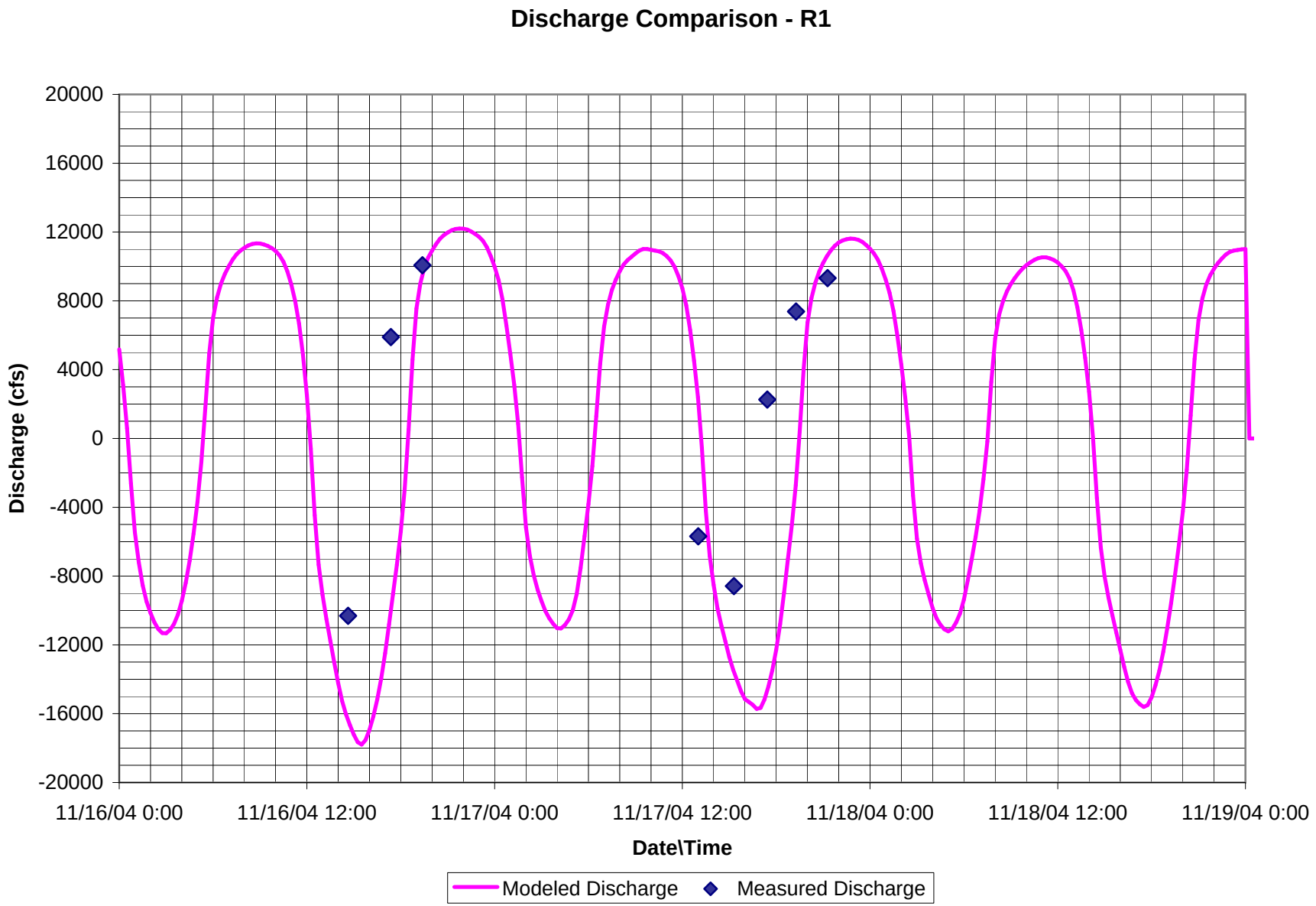


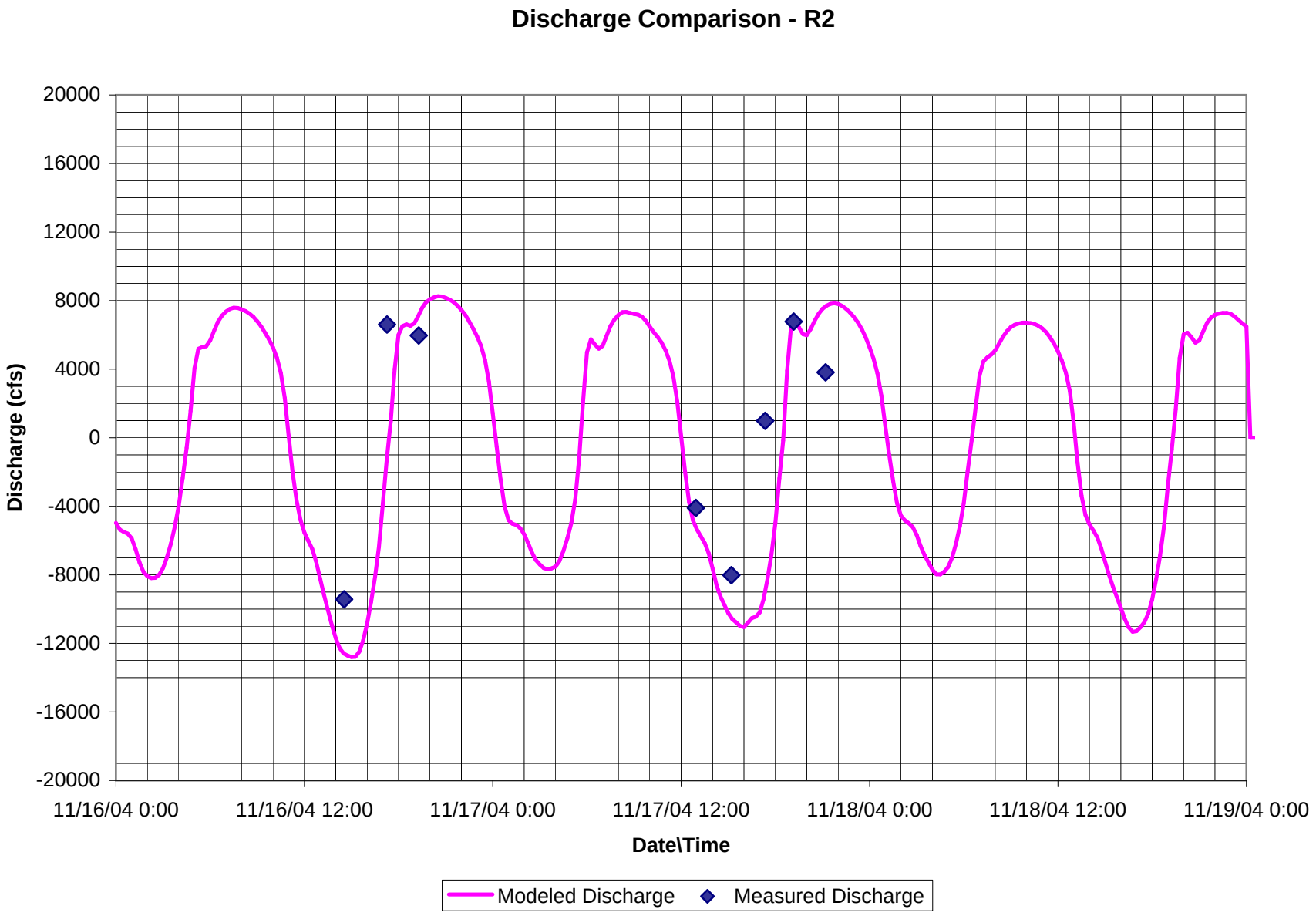
Appendix C – Comparison of Measured & Modeled Flow Rates & Velocities

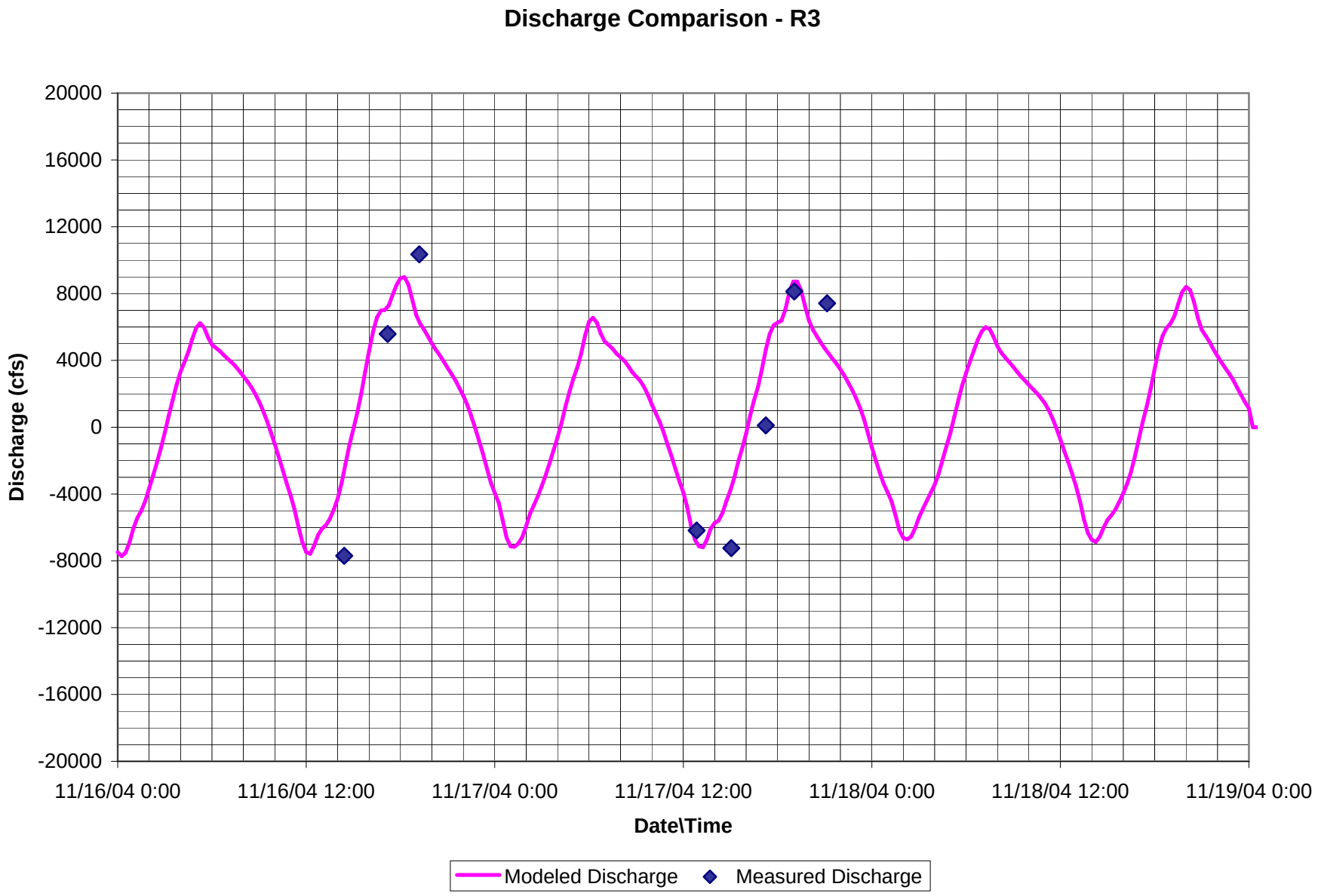
Appendix C

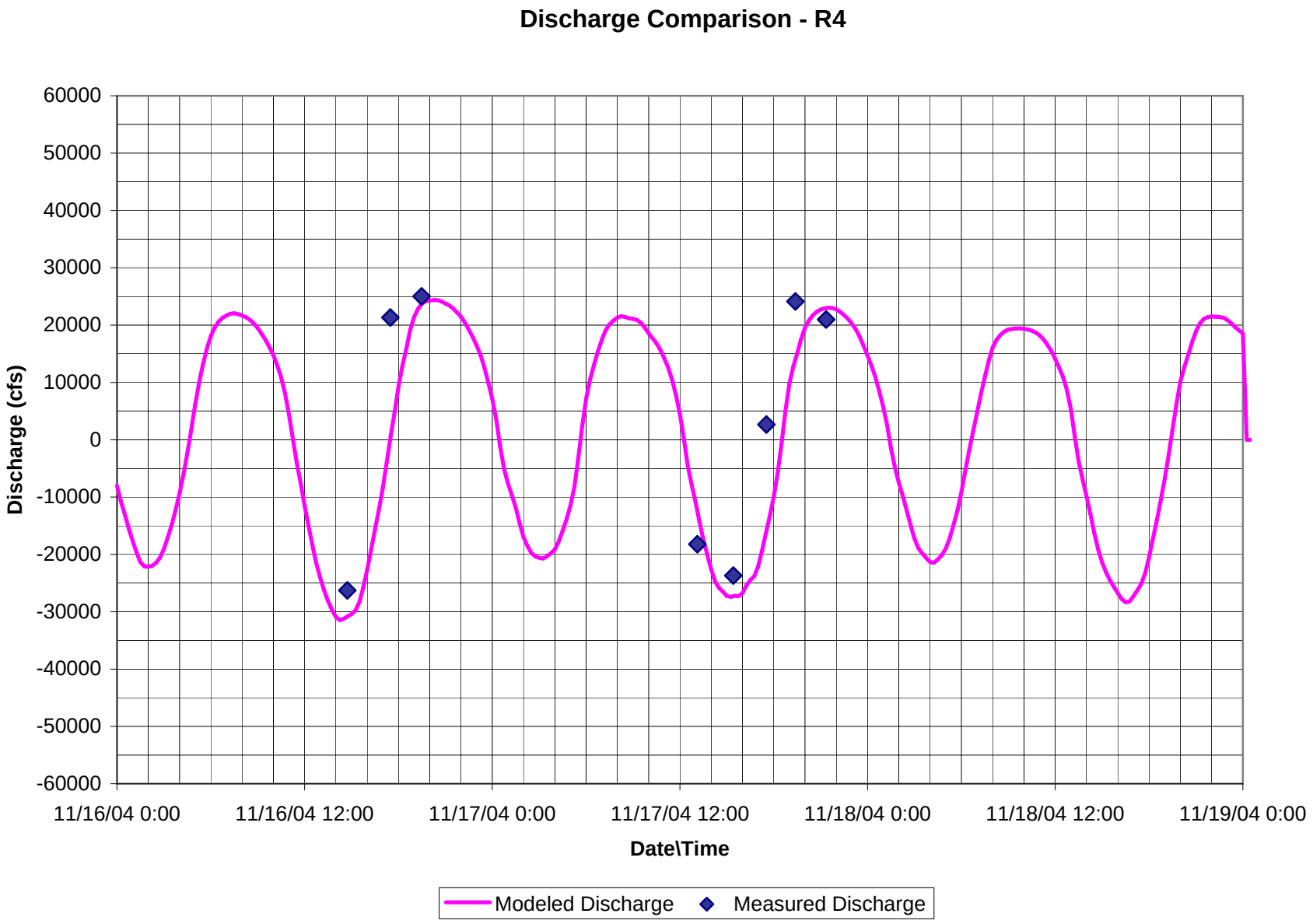
Comparison of Measured & Modeled Flow Rates & Velocities

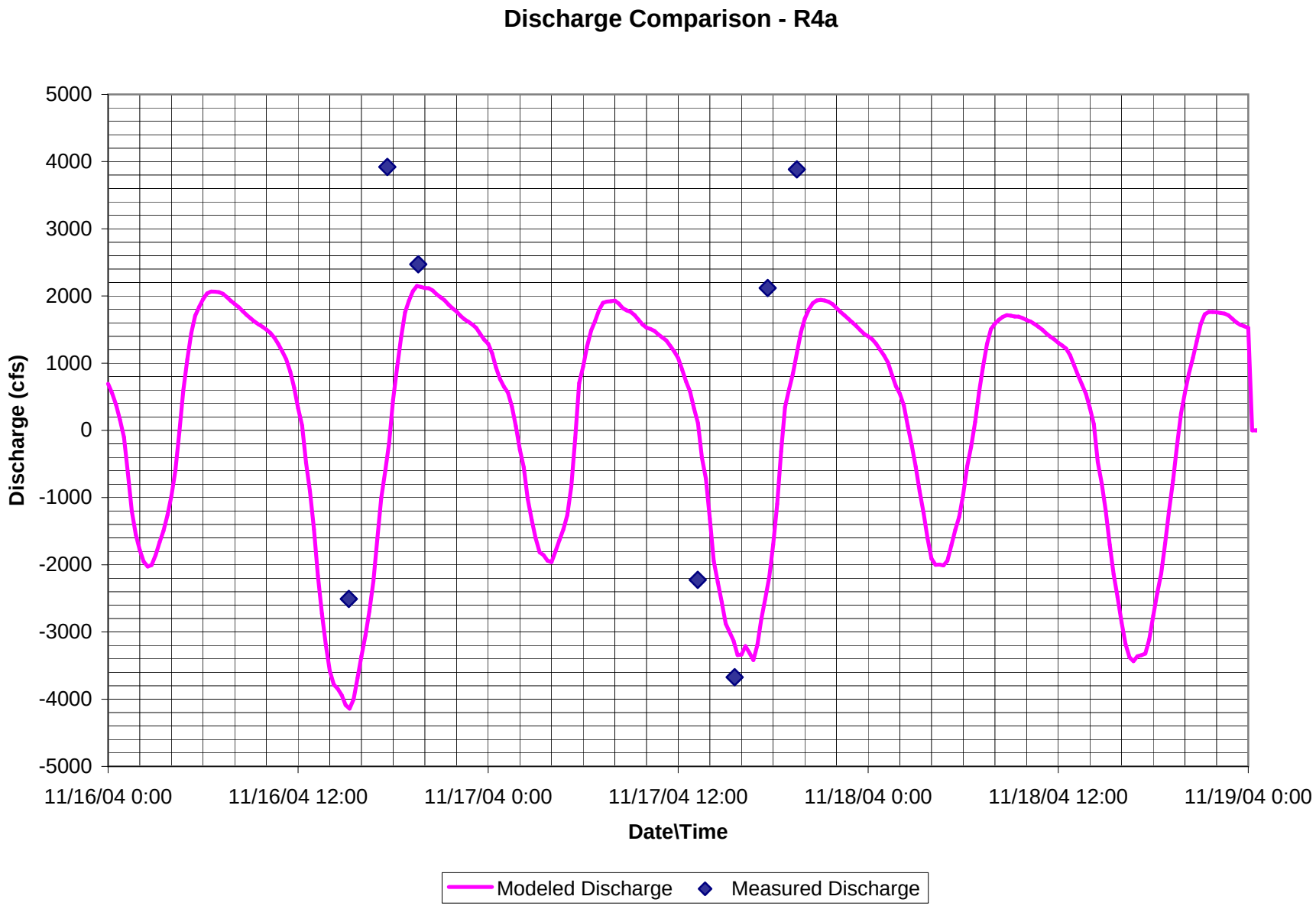
[Moffatt & Nichol. (2005). Hydraulic modeling Sunset Beach bridge replacement. Raleigh: NCDOT]

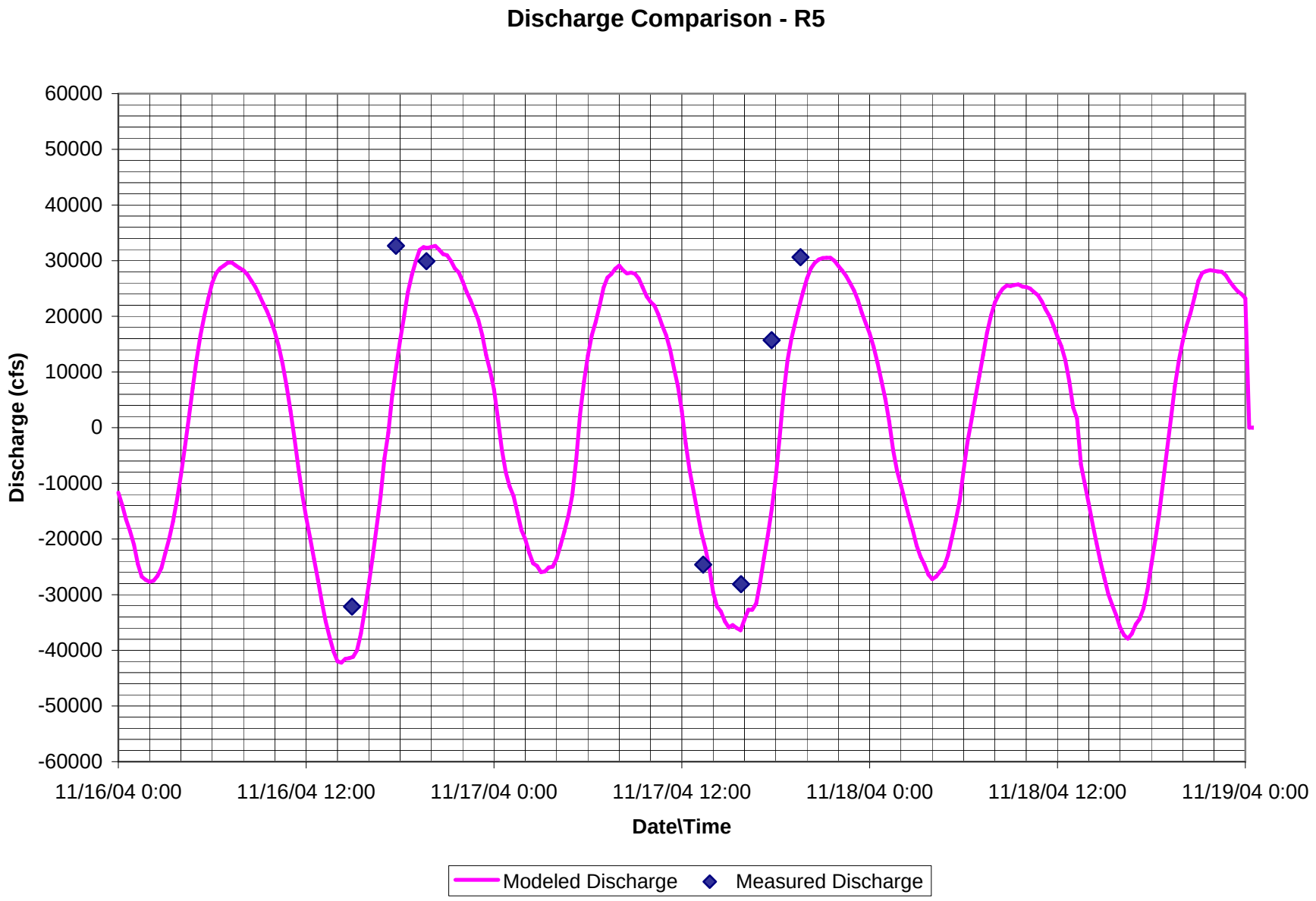

Discharge Comparison - R1
20000
16000
12000
8000
4000
0
-4000
-8000
-12000
-16000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

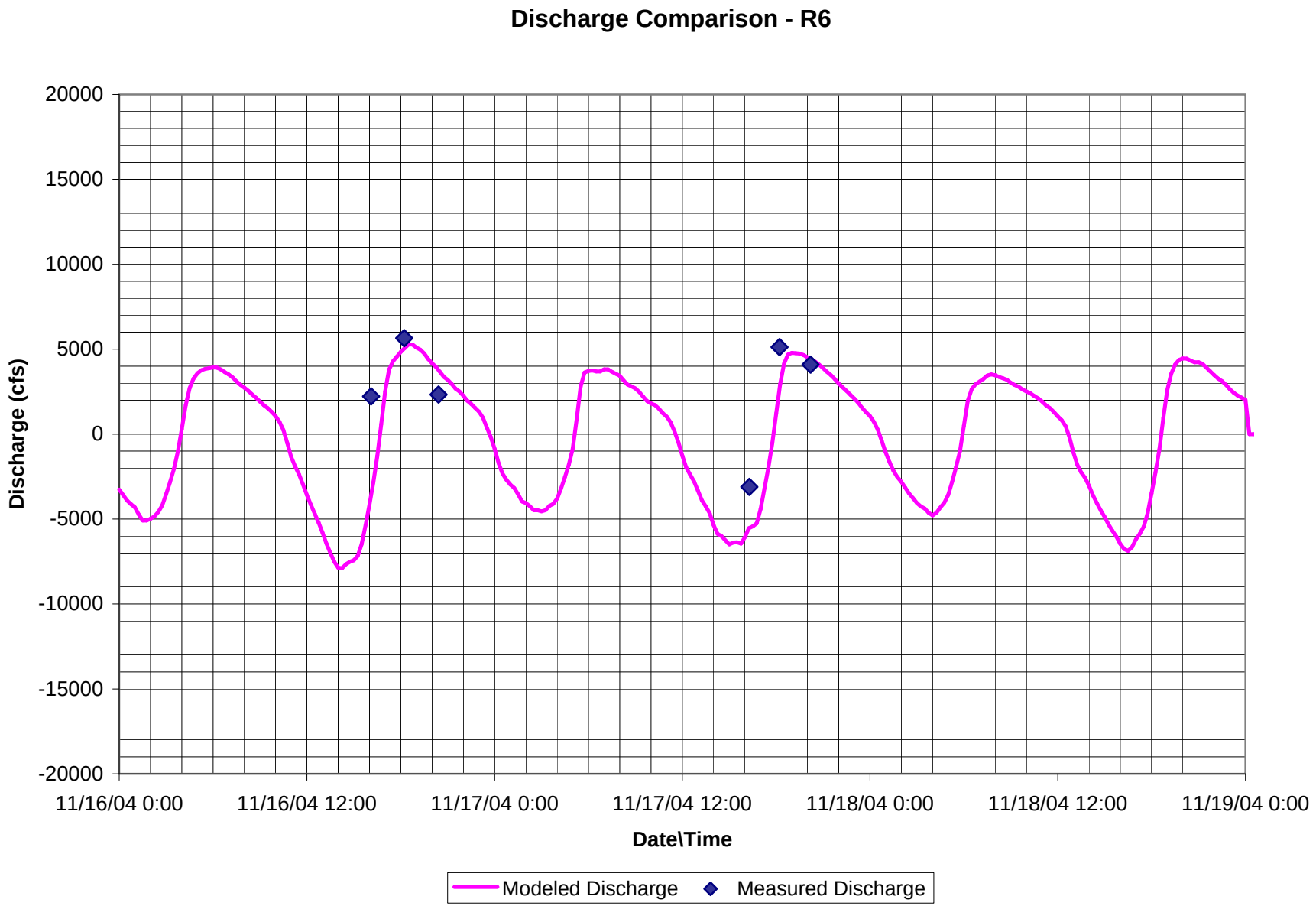

Discharge Comparison - R2
20000
16000
12000
8000
4000
0
-4000
-8000
-12000
-16000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

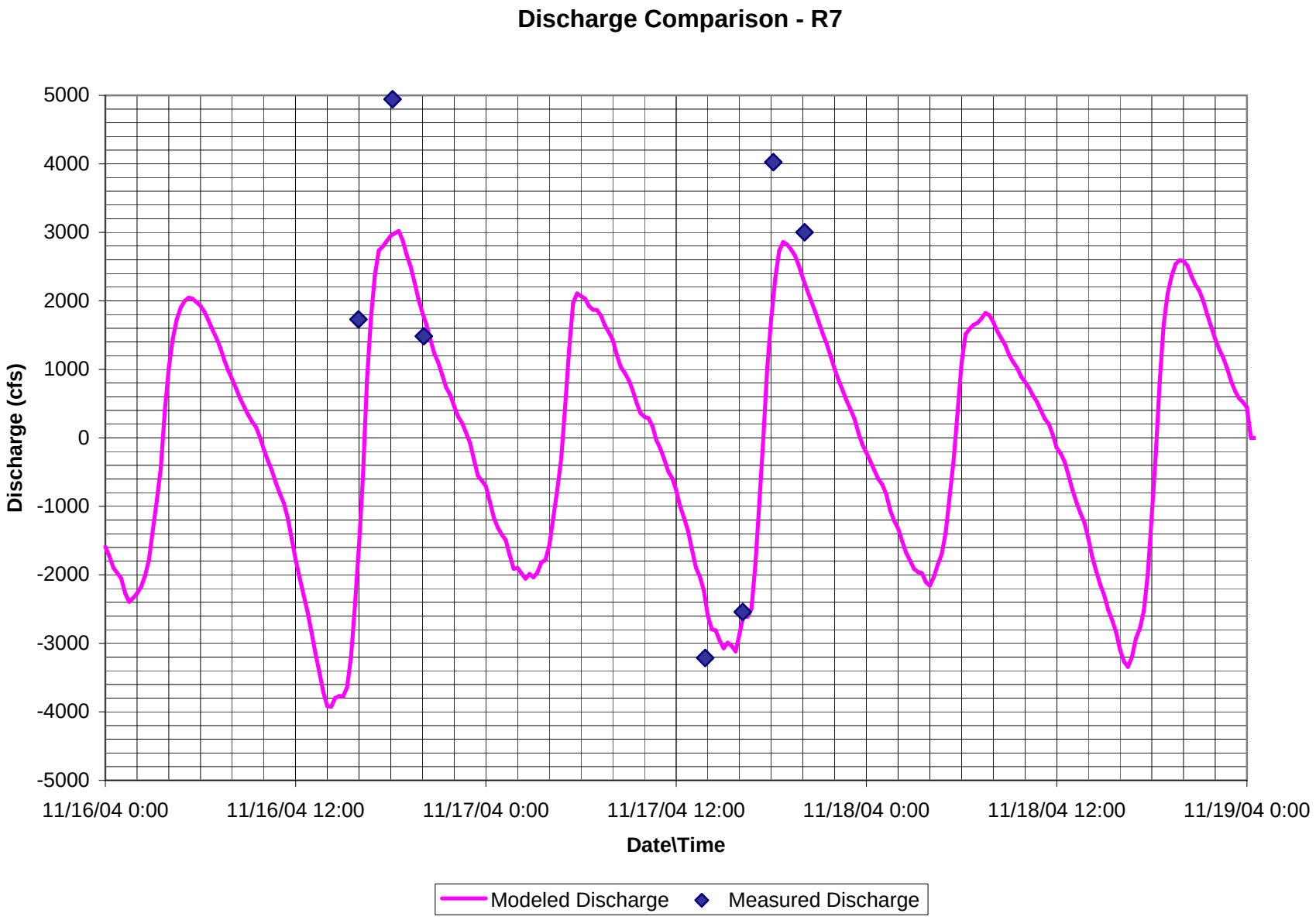

Discharge Comparison - R3
20000
16000
12000
8000
4000
0
-4000
-8000
-12000
-16000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

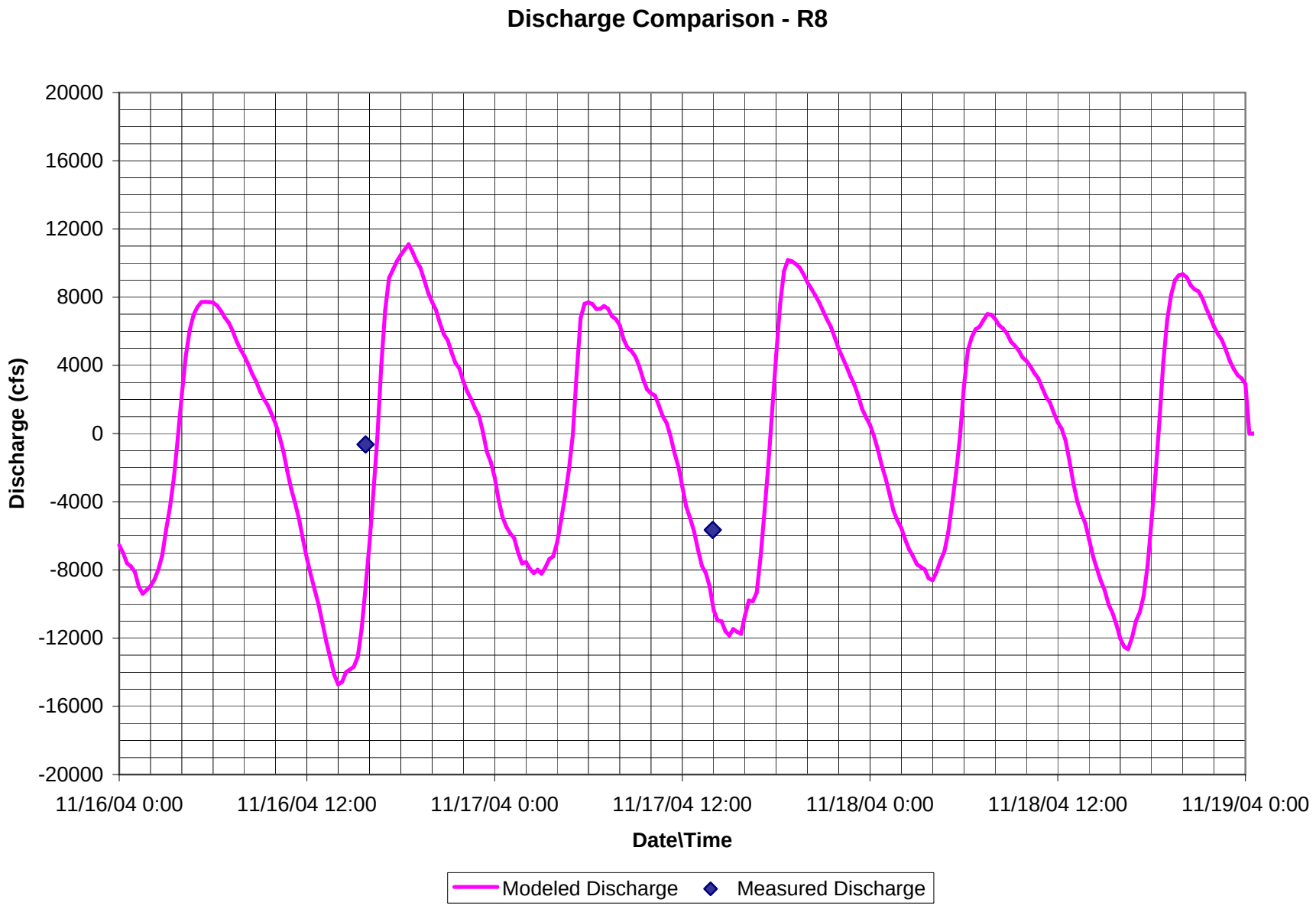

Discharge Comparison - R4
60000
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

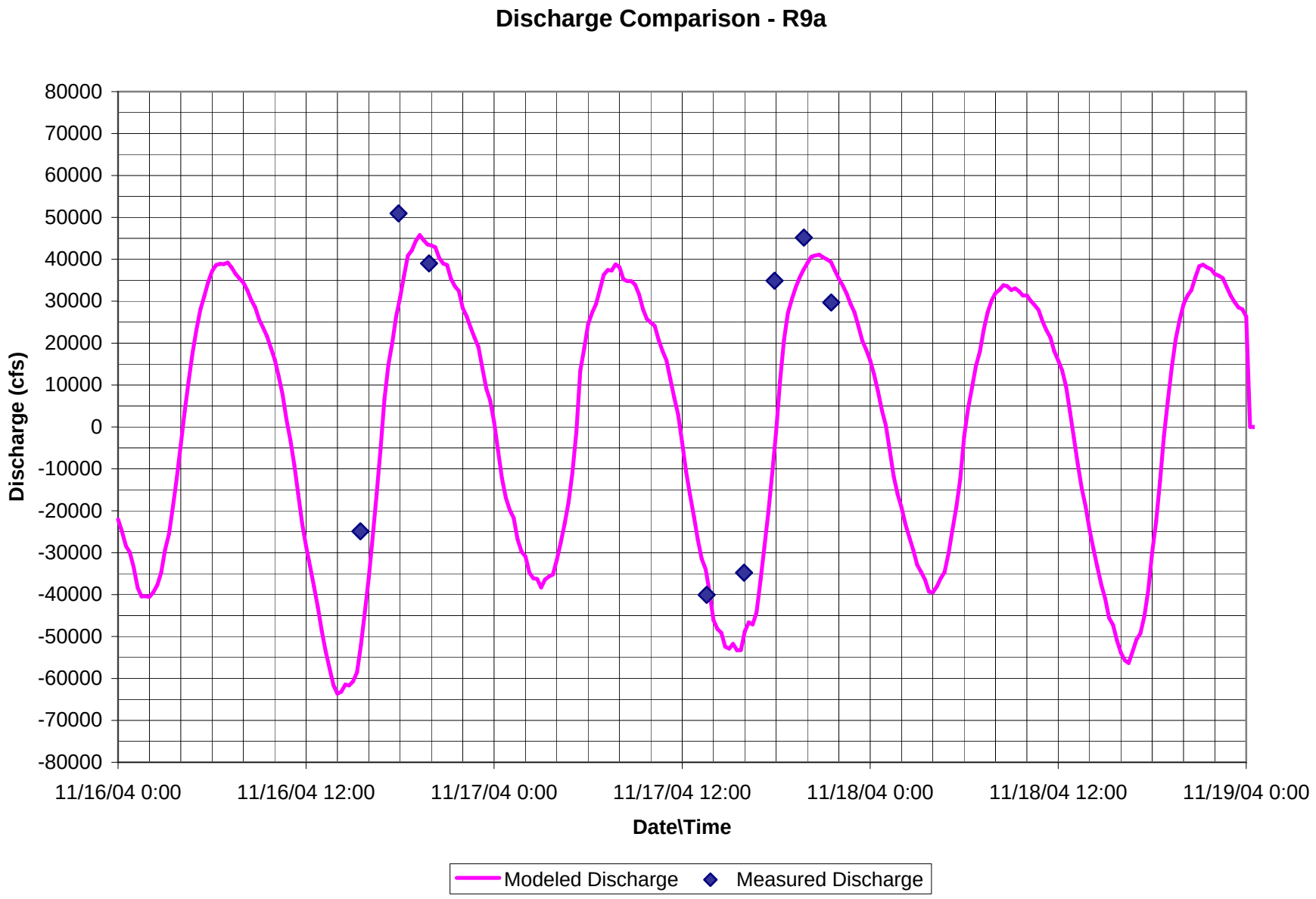

Discharge Comparison - R4a
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

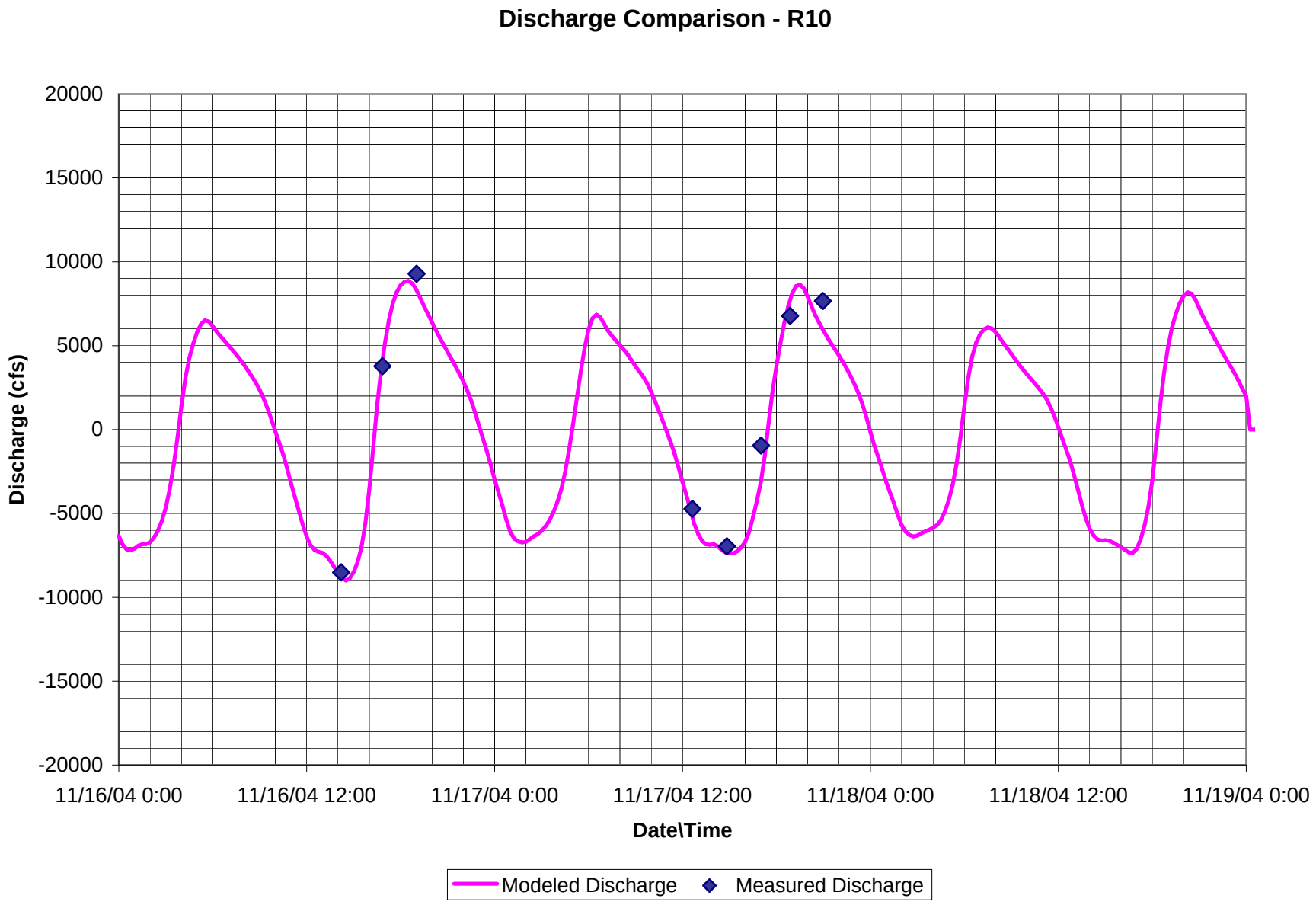

Discharge Comparison - R5
60000
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

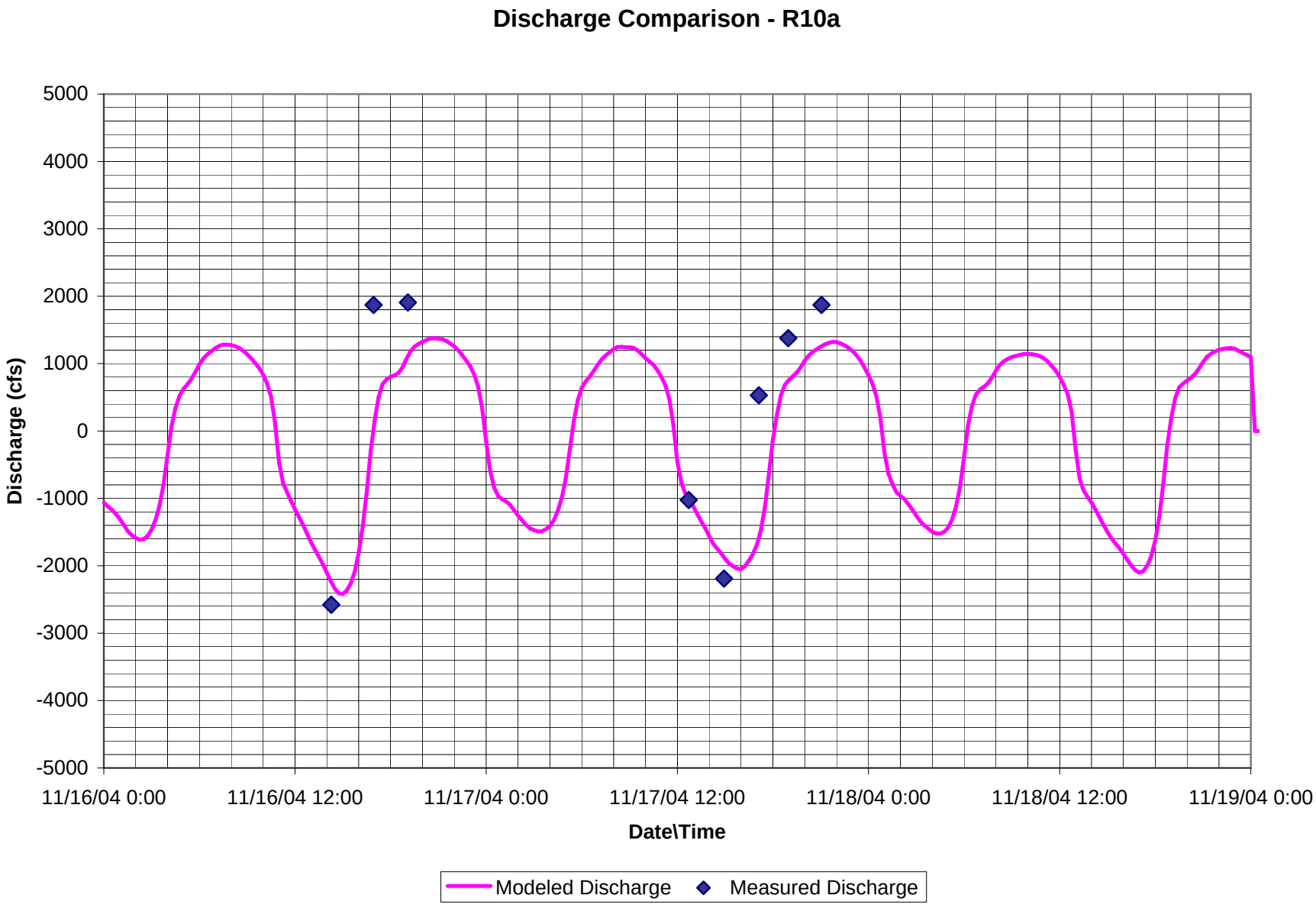

Discharge Comparison - R6
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

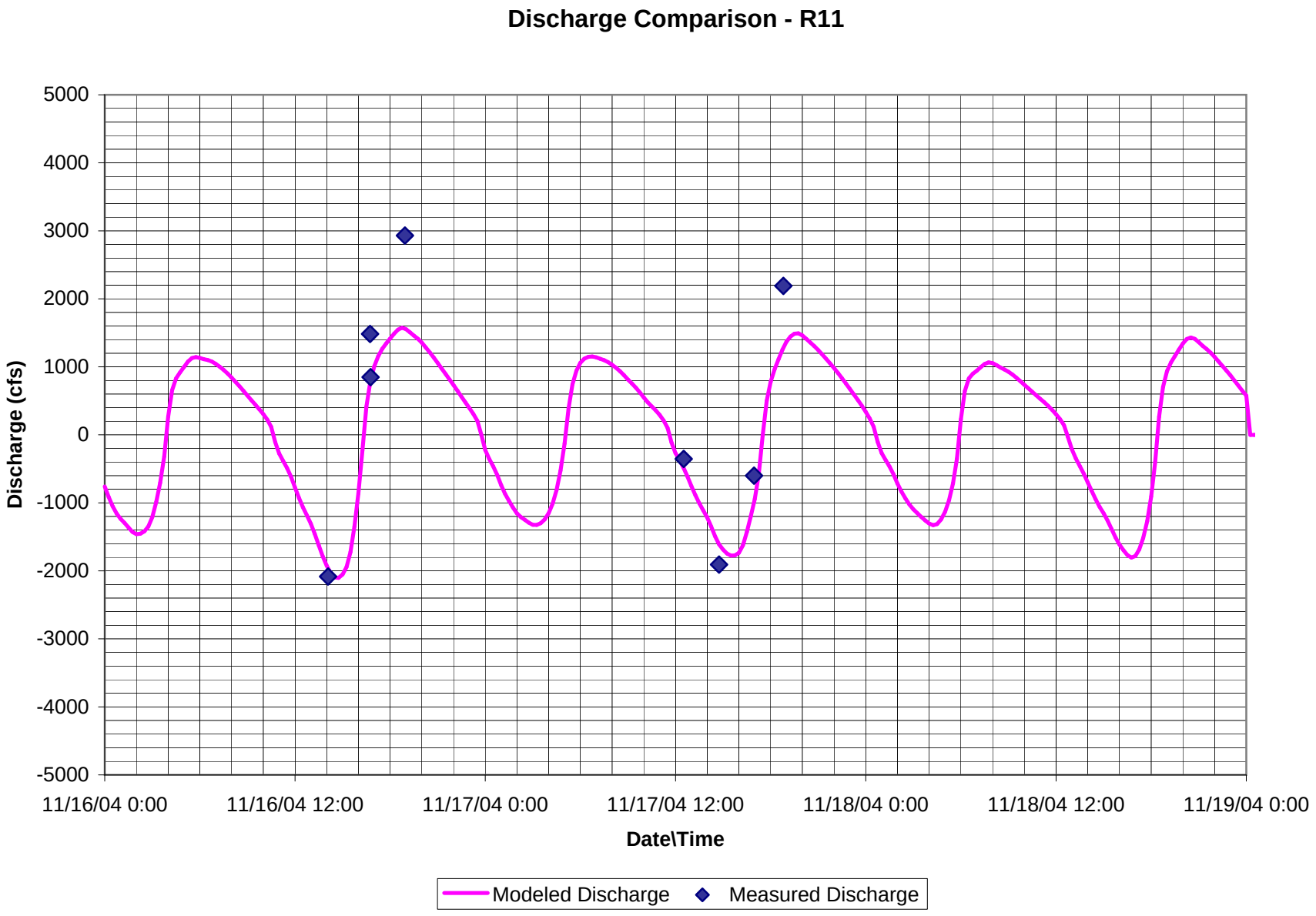

Discharge Comparison - R7
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

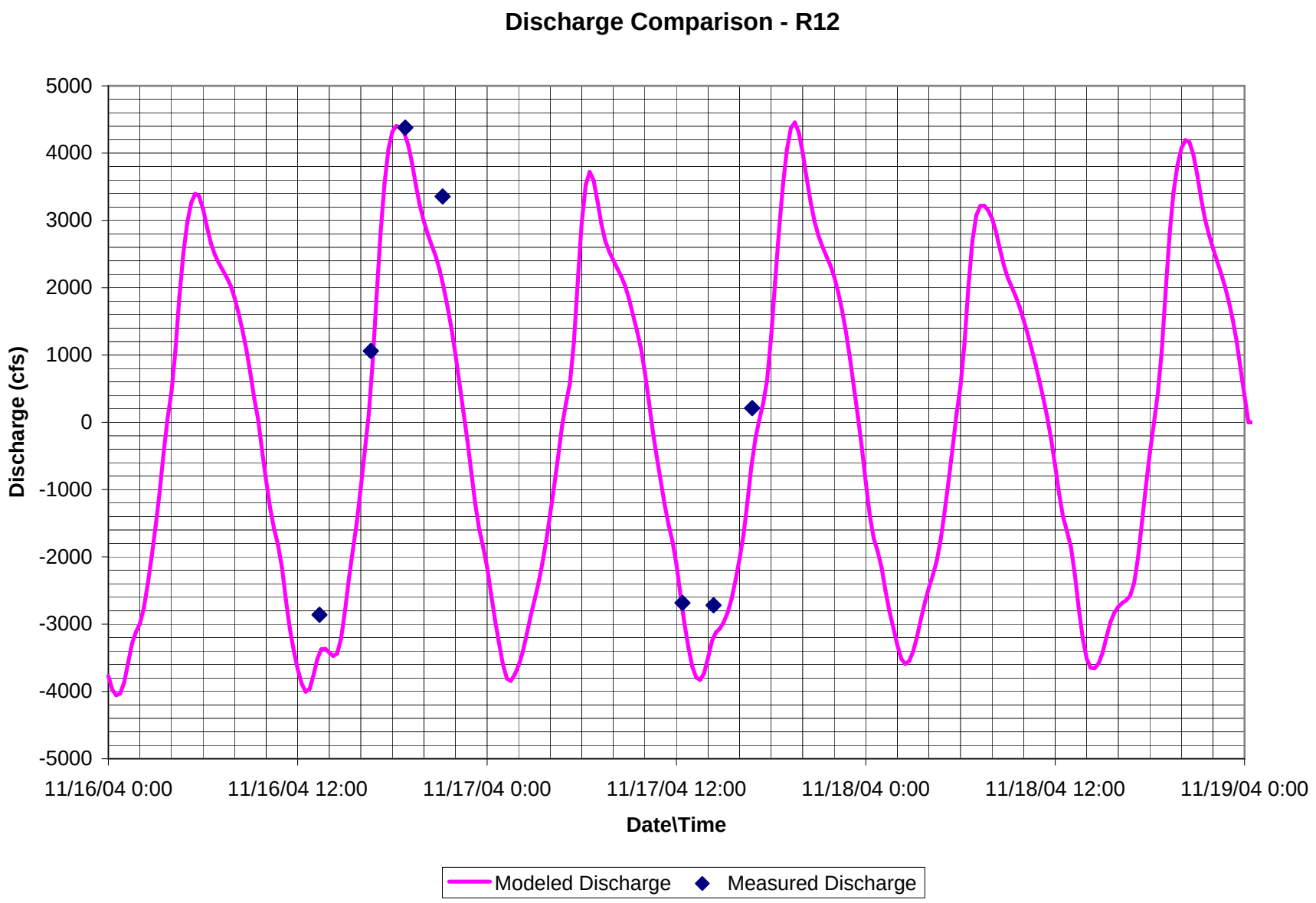

Discharge Comparison - R8
20000
16000
12000
8000
4000
0
-4000
-8000
-12000
-16000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

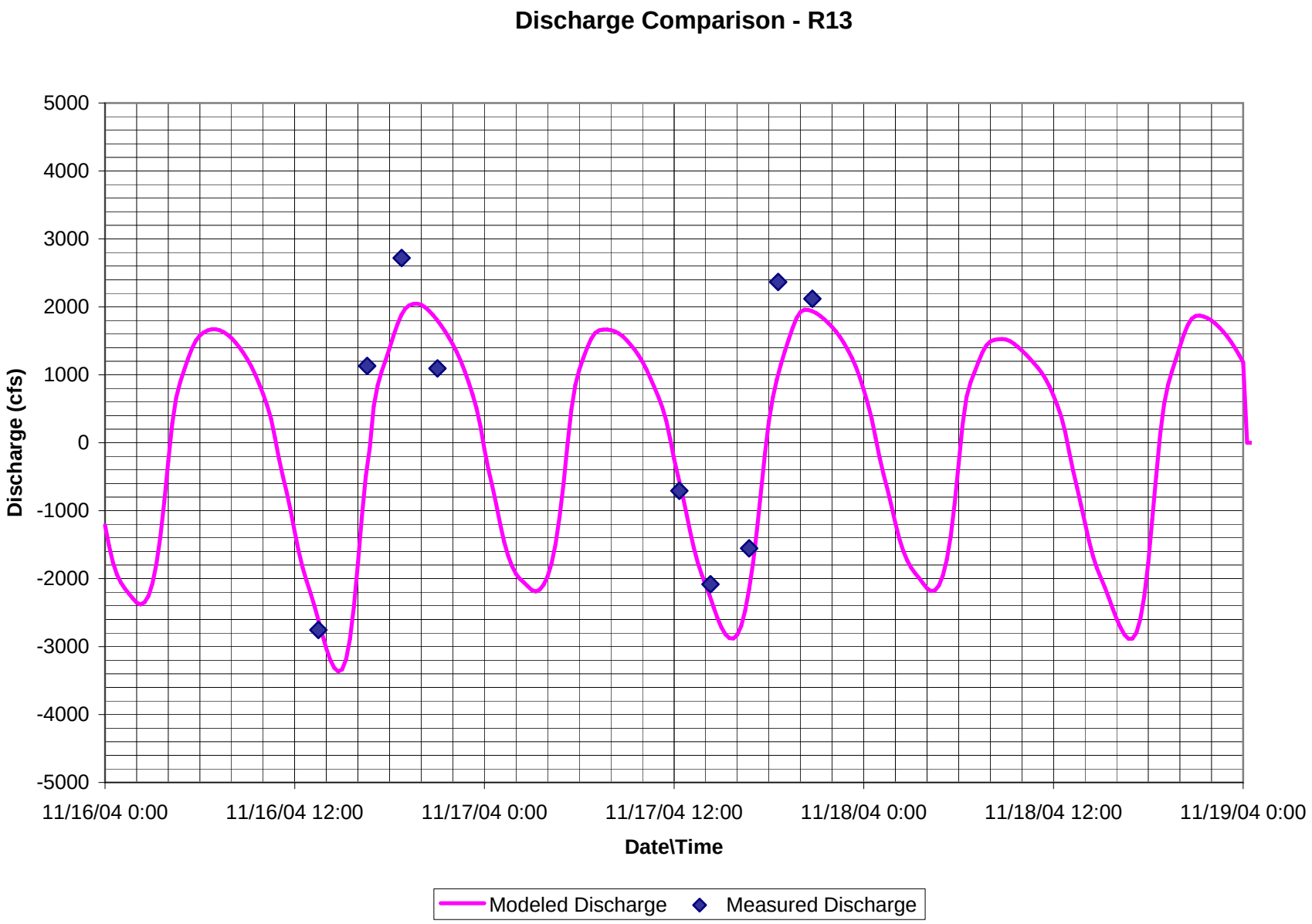

Discharge Comparison - R9a
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

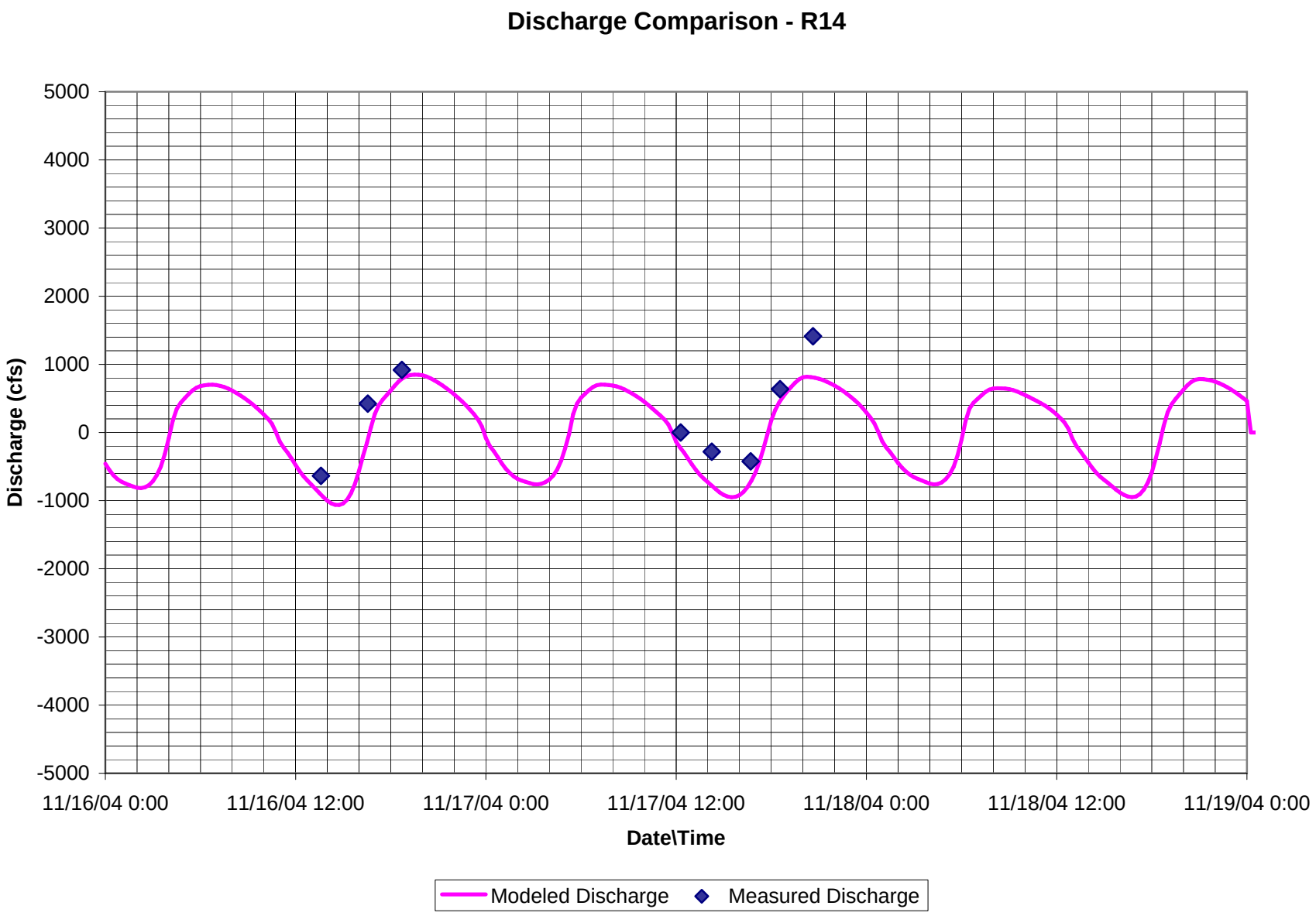

Discharge Comparison - R10
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

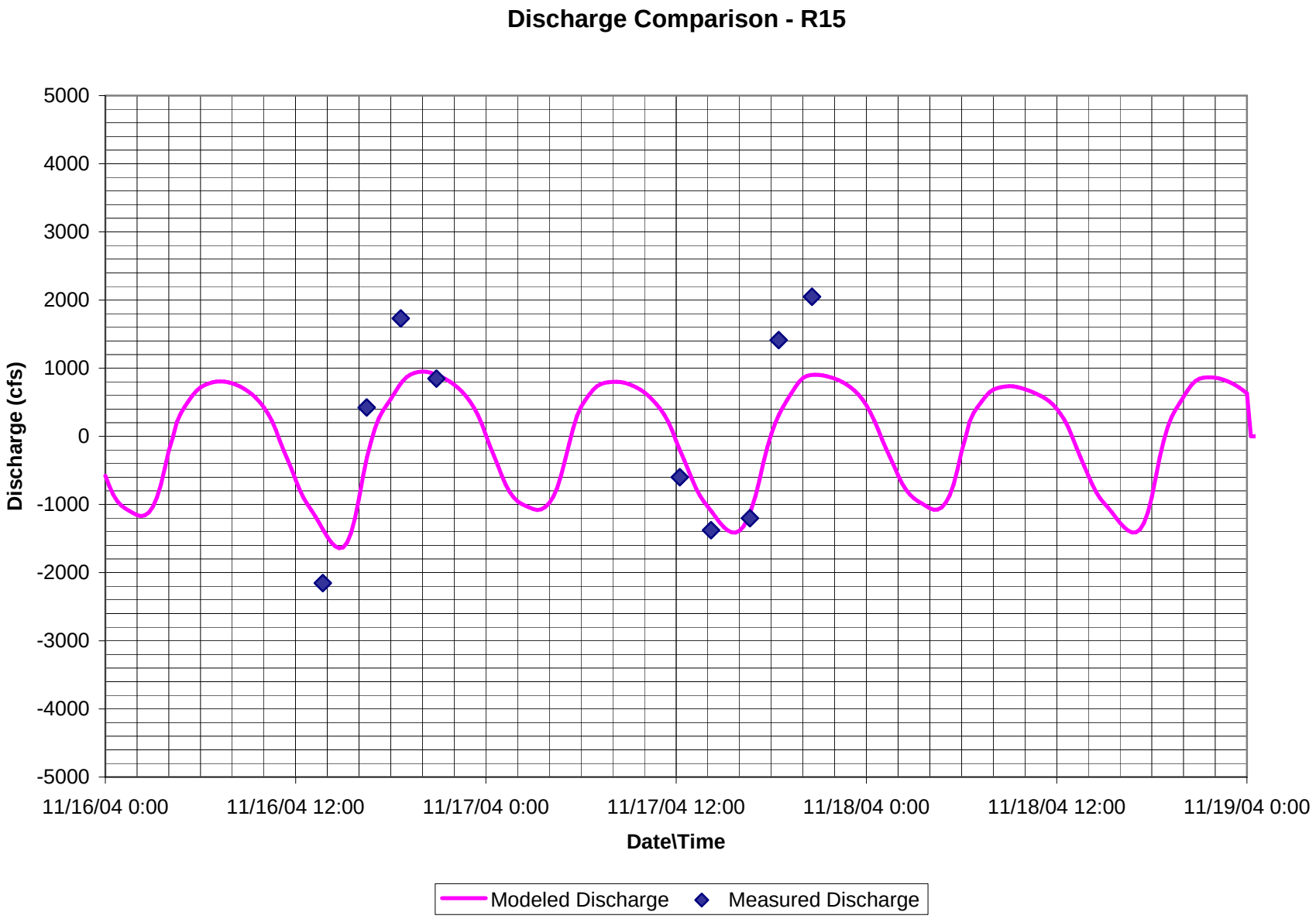

Discharge Comparison - R10a
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

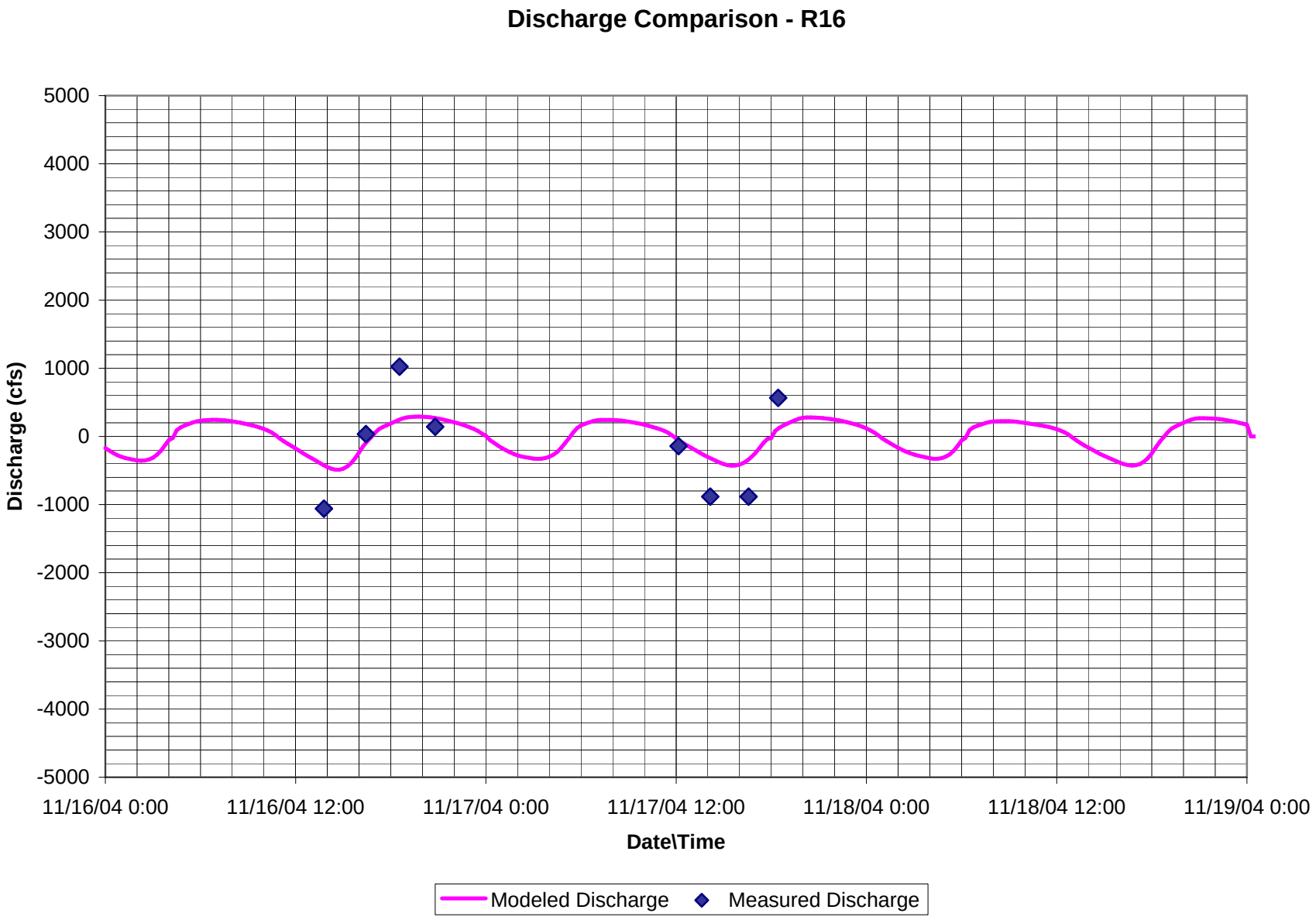

Discharge Comparison - R11
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

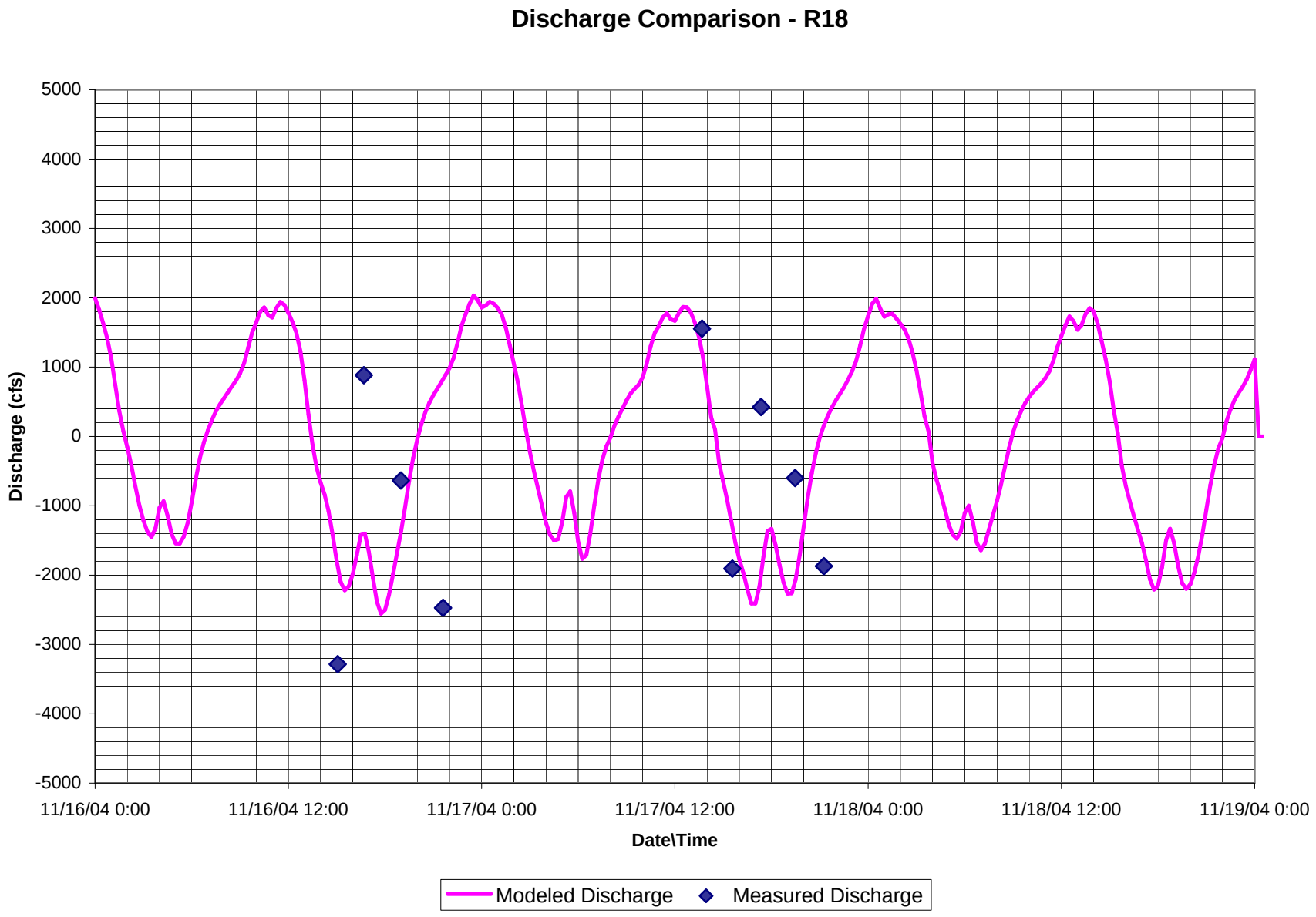

Discharge Comparison - R12
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

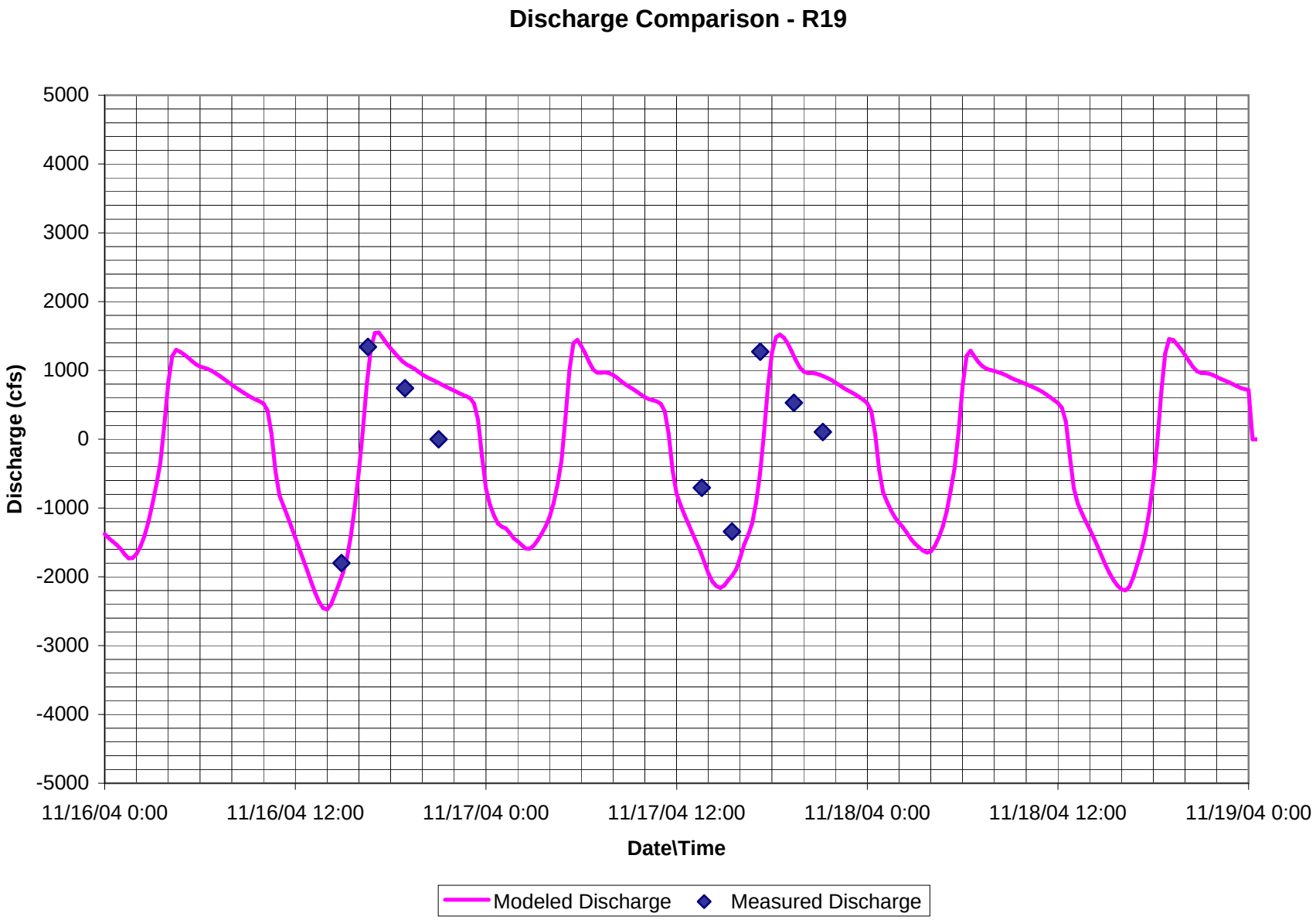

Discharge Comparison - R13
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

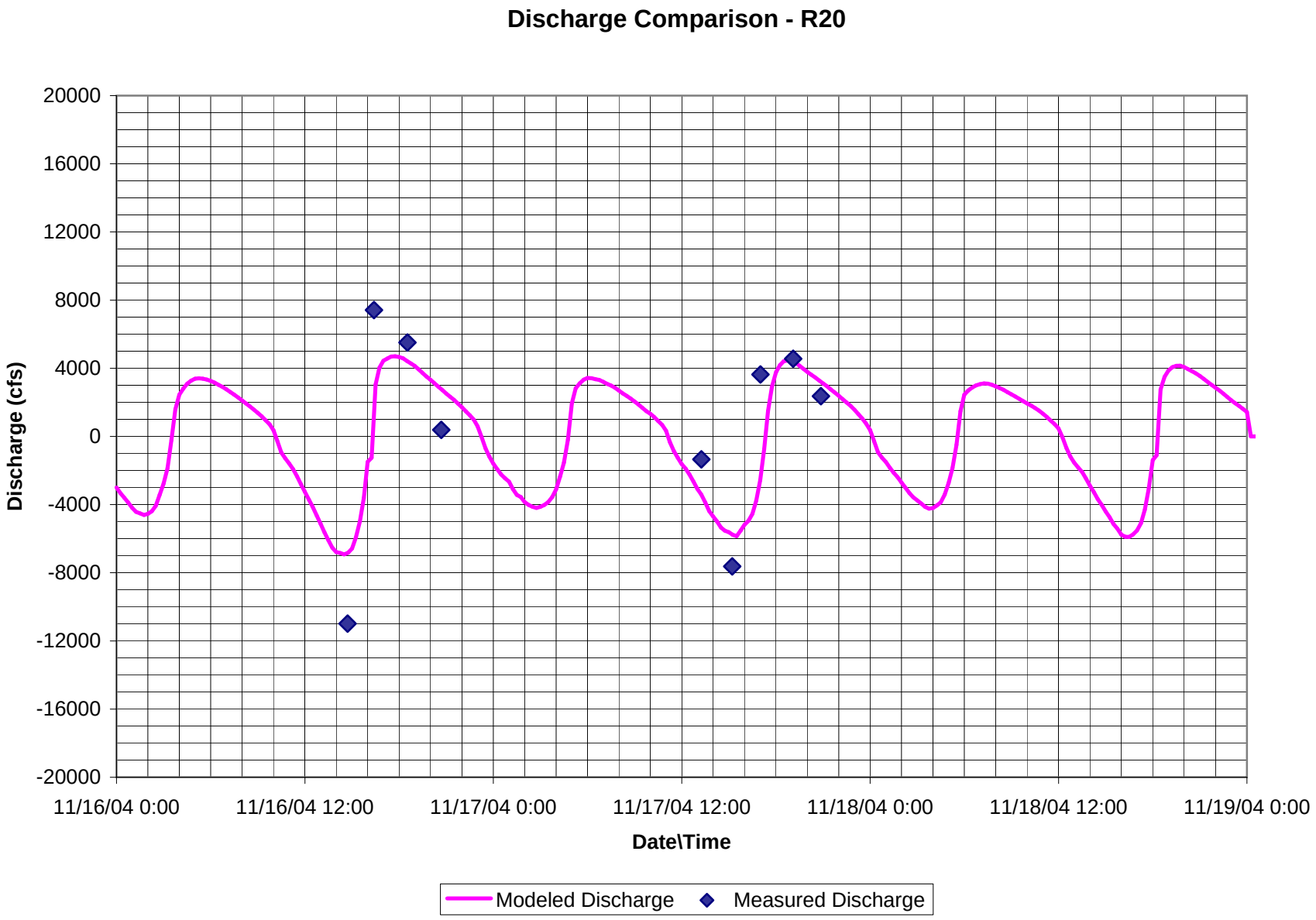

Discharge Comparison - R14
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

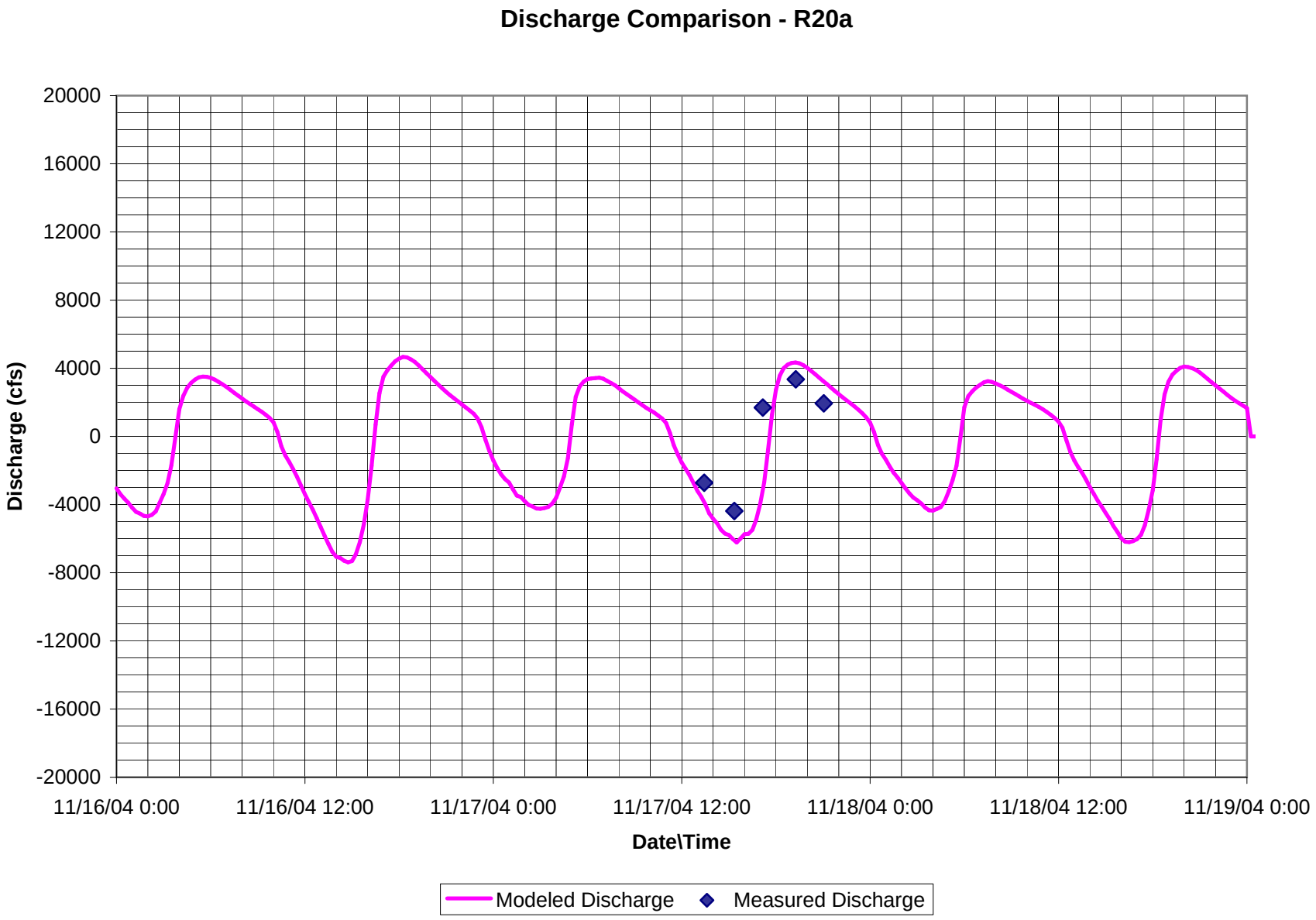

Discharge Comparison - R15
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

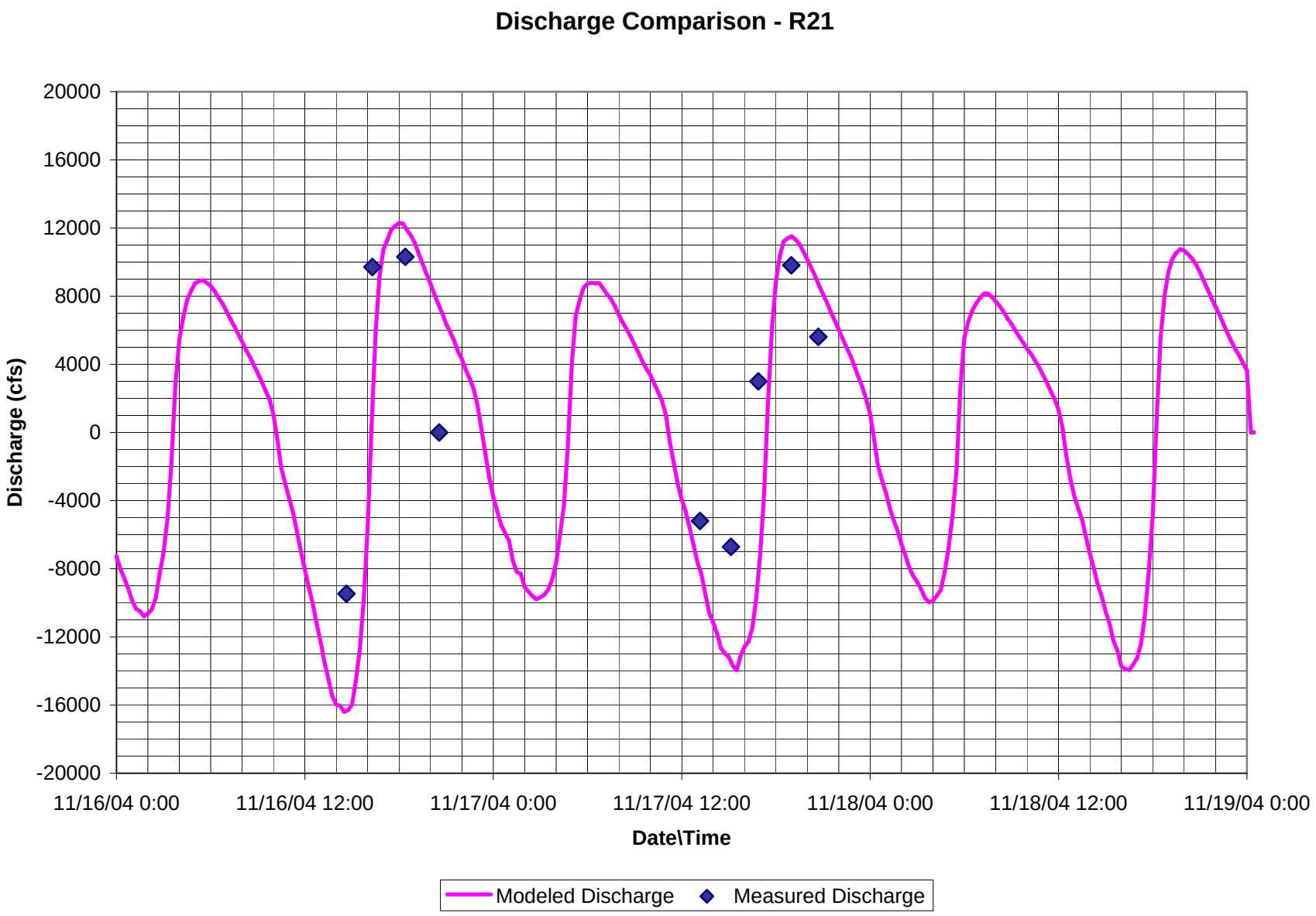

Discharge Comparison - R16
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

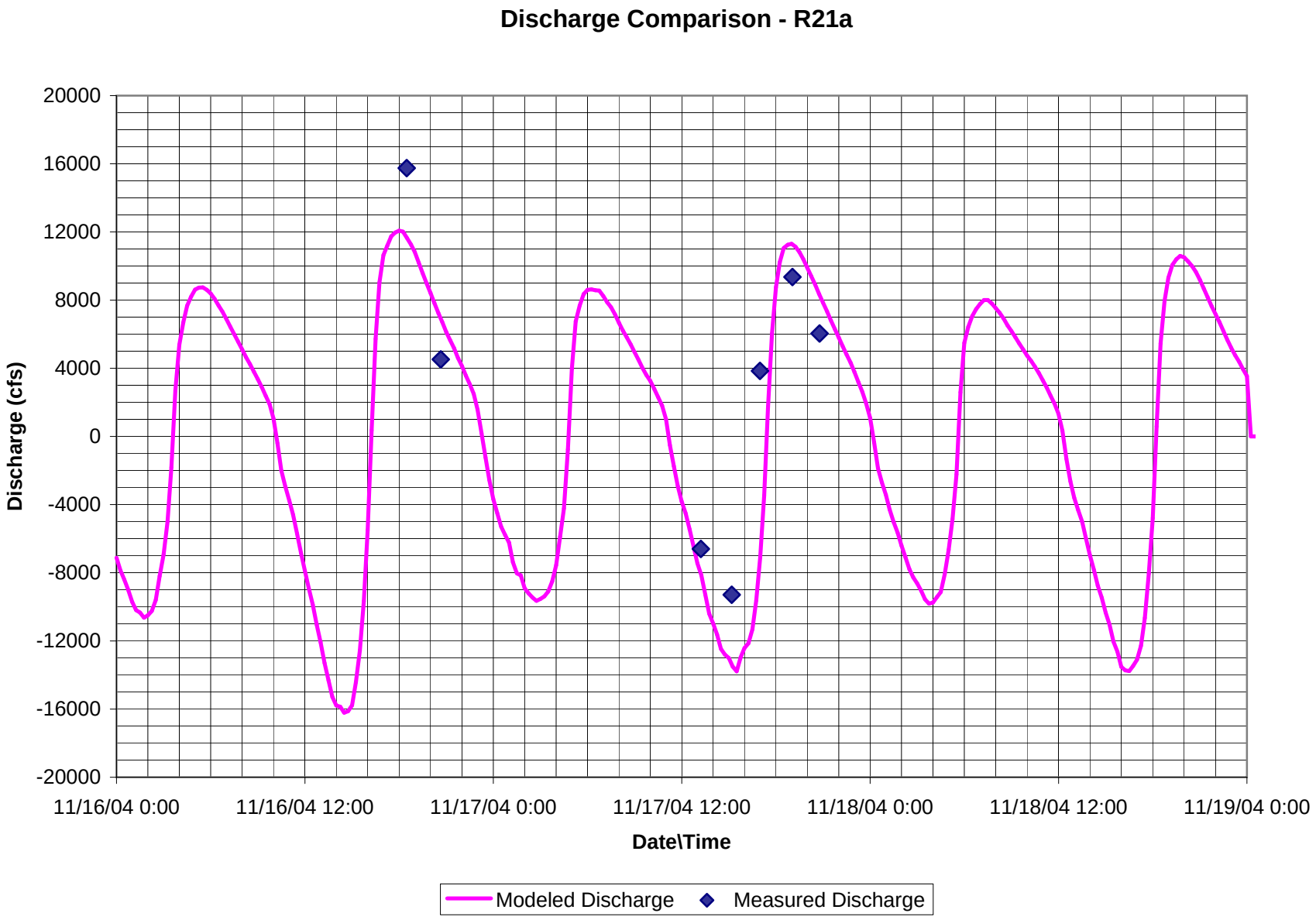

Discharge Comparison - R18
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

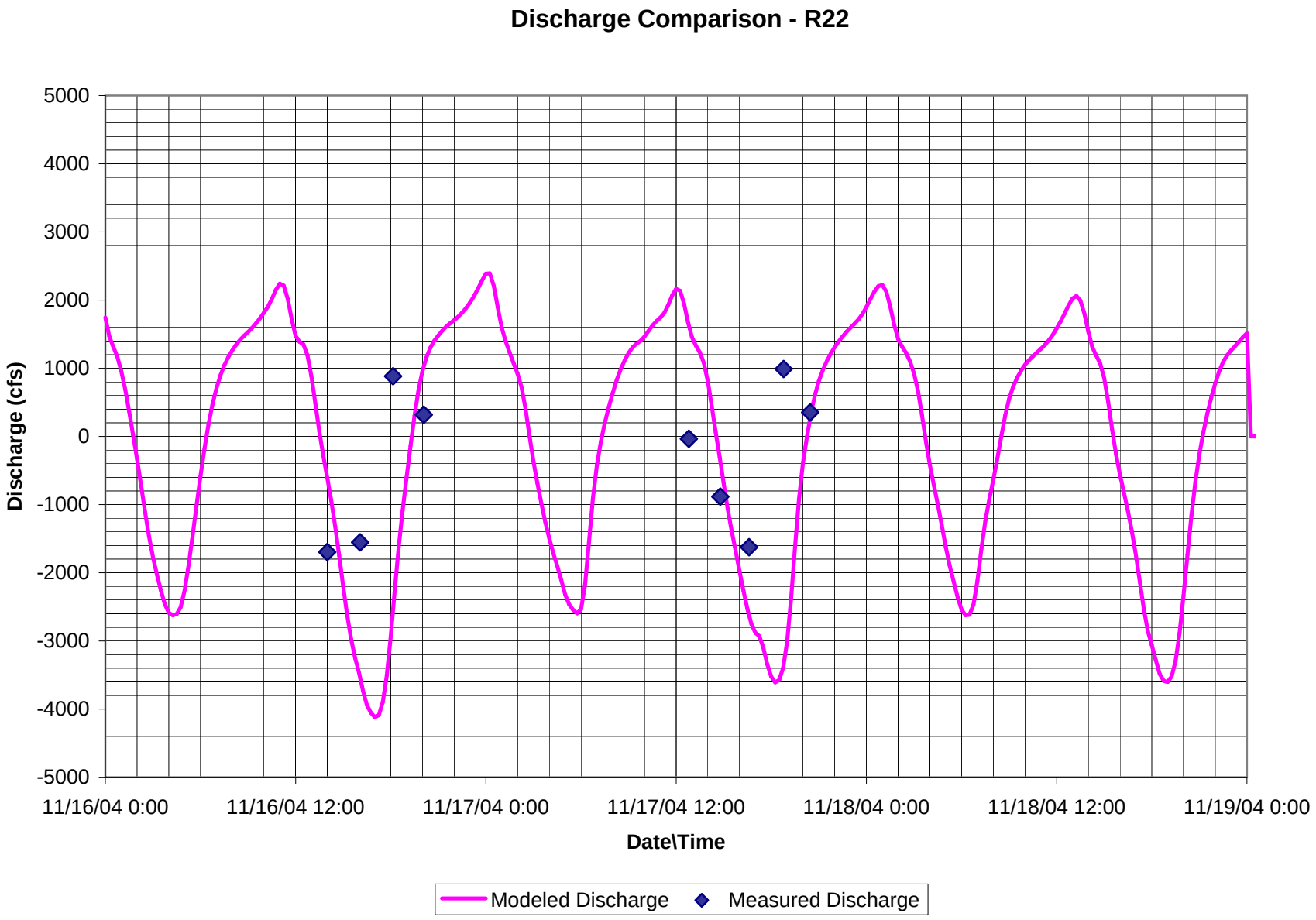

Discharge Comparison - R19
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

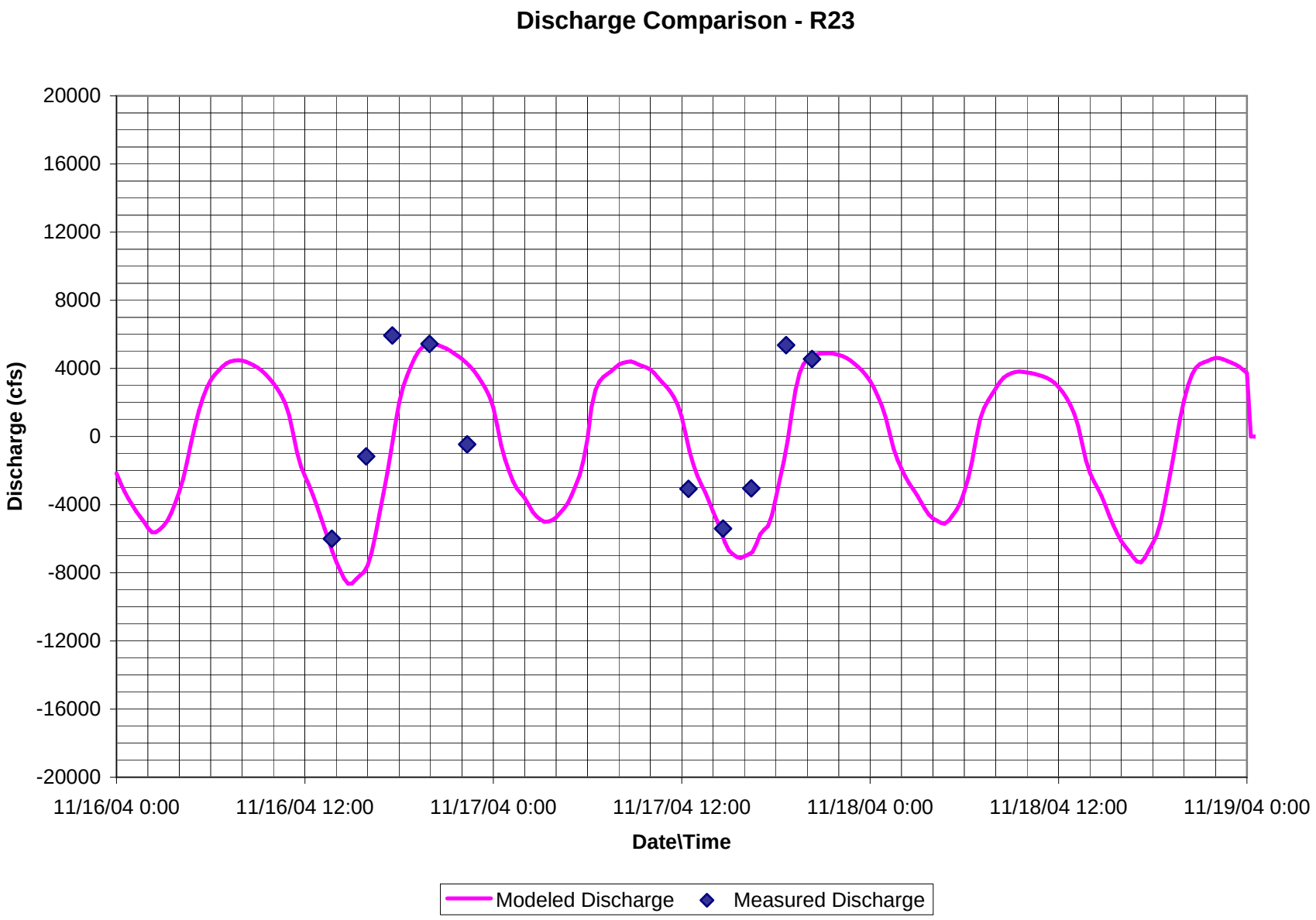

Discharge Comparison - R20
20000
16000
12000
8000
4000
0
-4000
-8000
-12000
-16000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

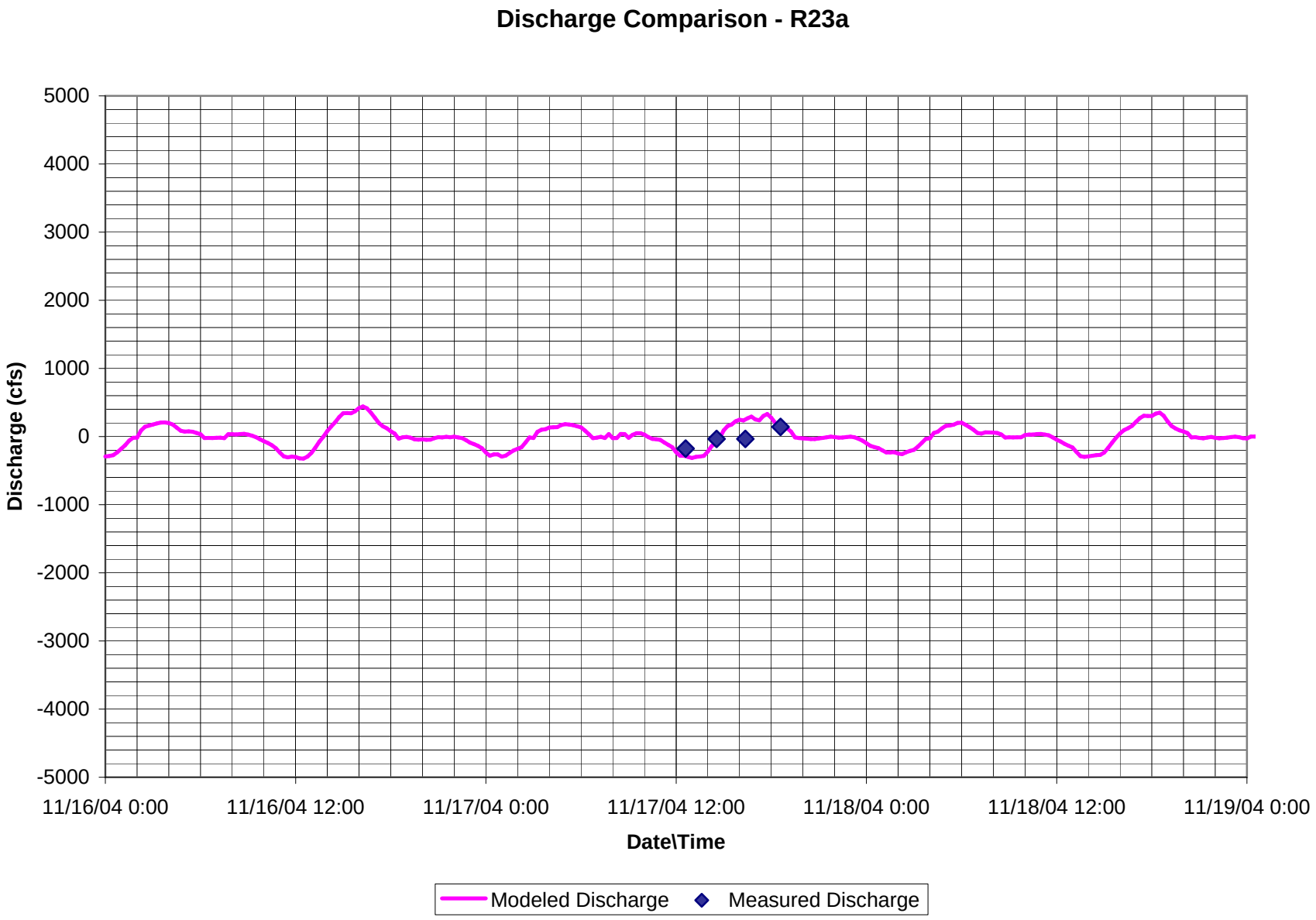

Discharge Comparison - R20a
20000
16000
12000
8000
4000
0
-4000
-8000
-12000
-16000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

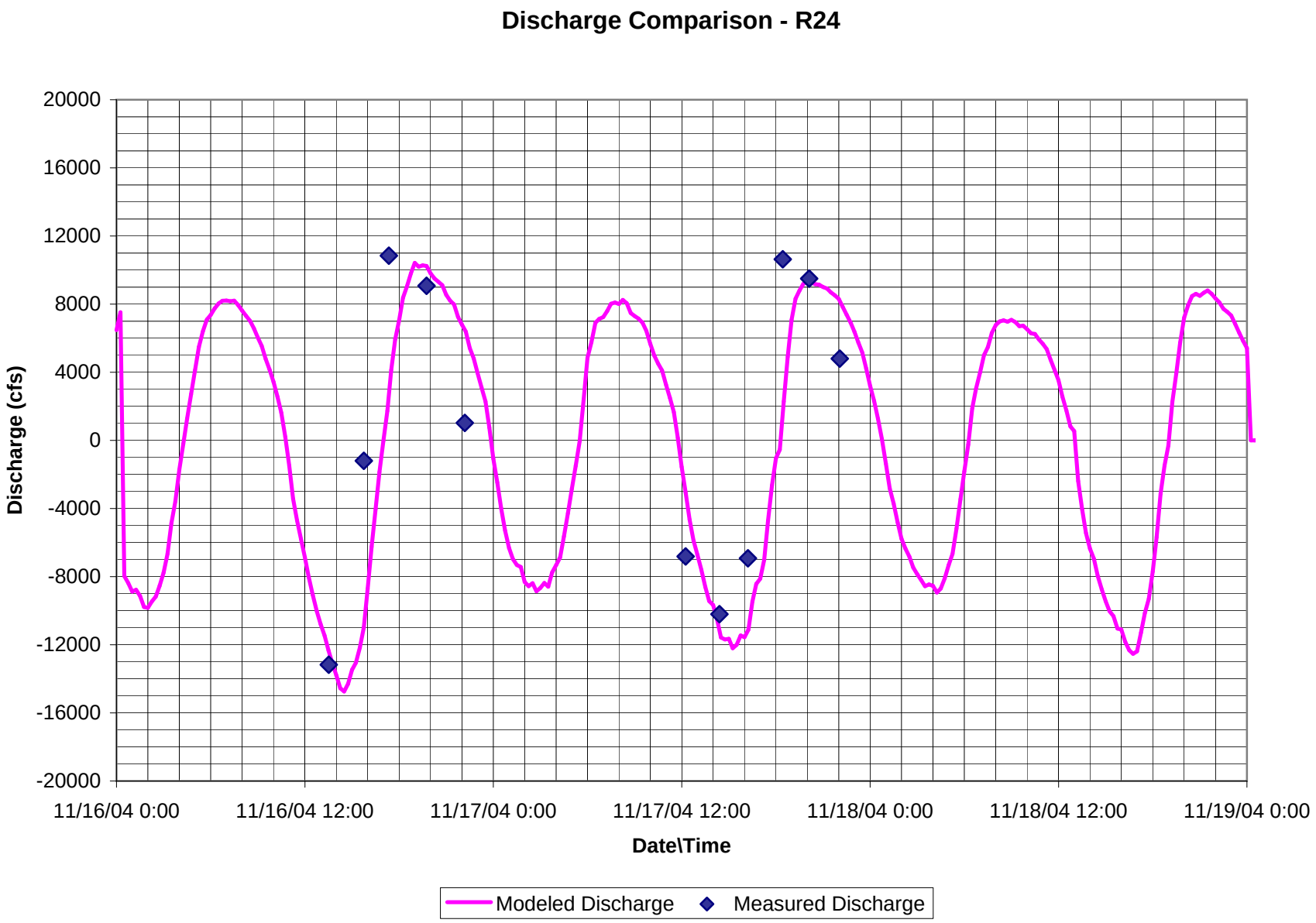

Discharge Comparison - R21
20000
16000
12000
8000
4000
0
-4000
-8000
-12000
-16000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

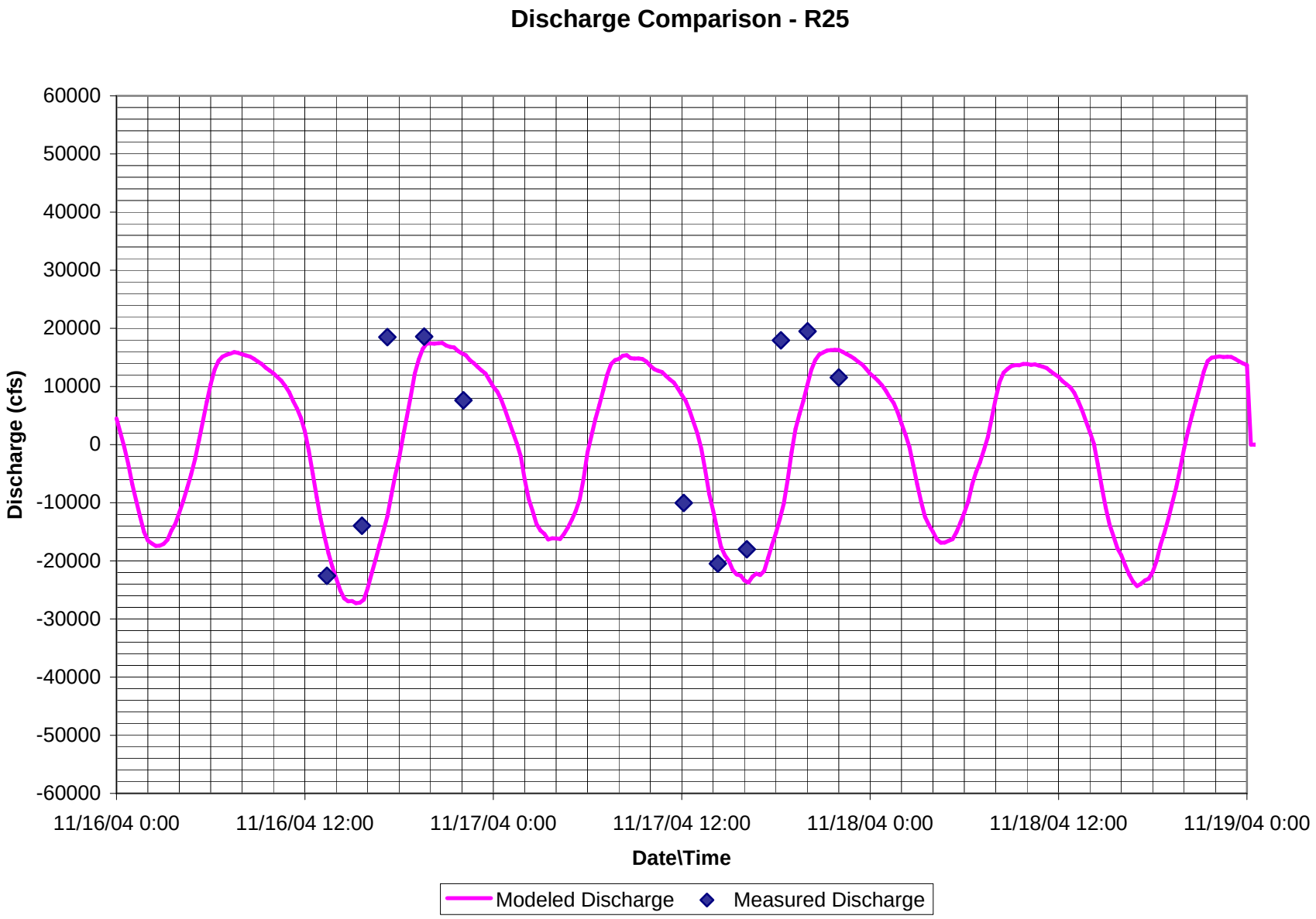

Discharge Comparison - R21a
20000
16000
12000
8000
4000
0
-4000
-8000
-12000
-16000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

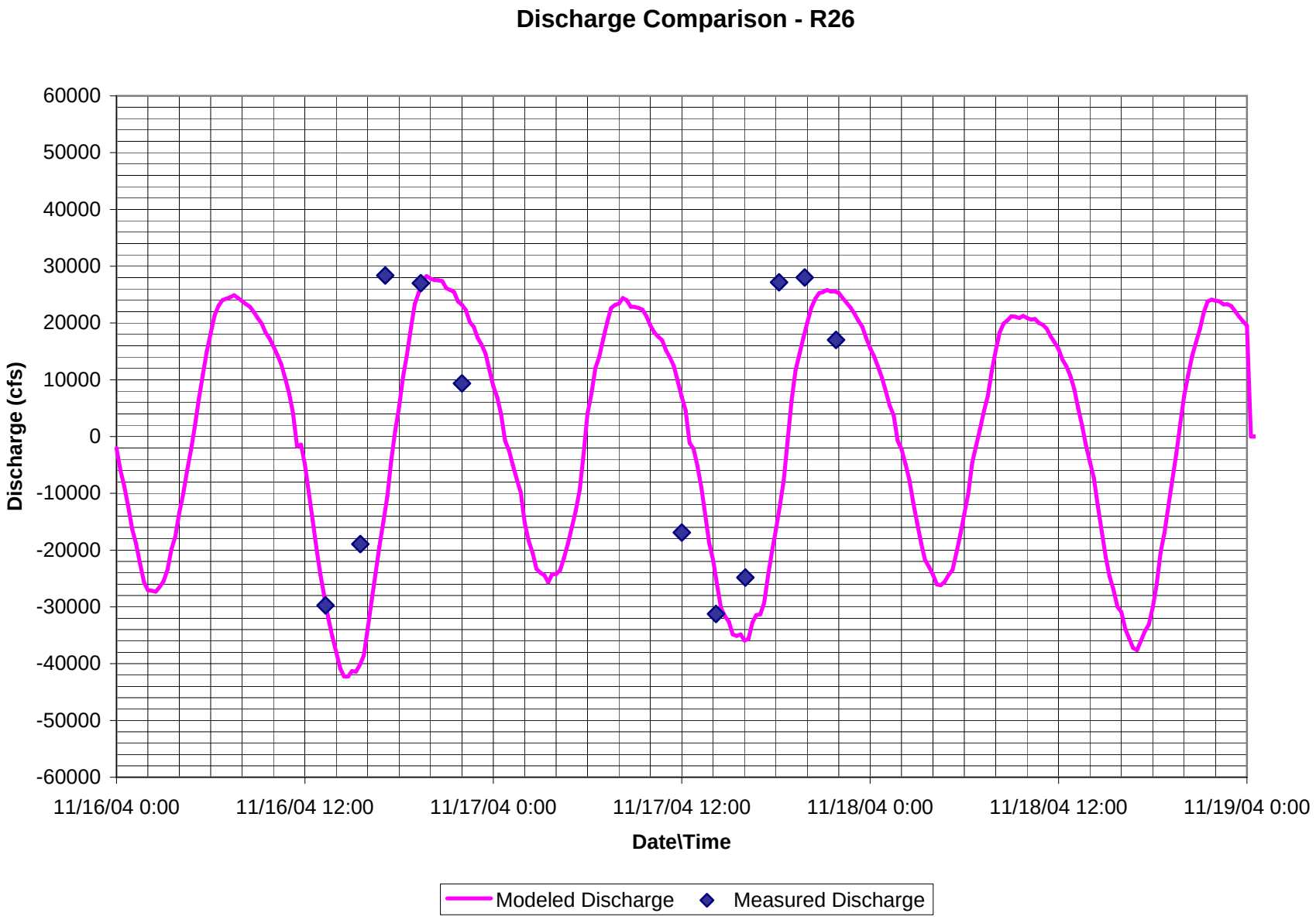

Discharge Comparison - R22
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

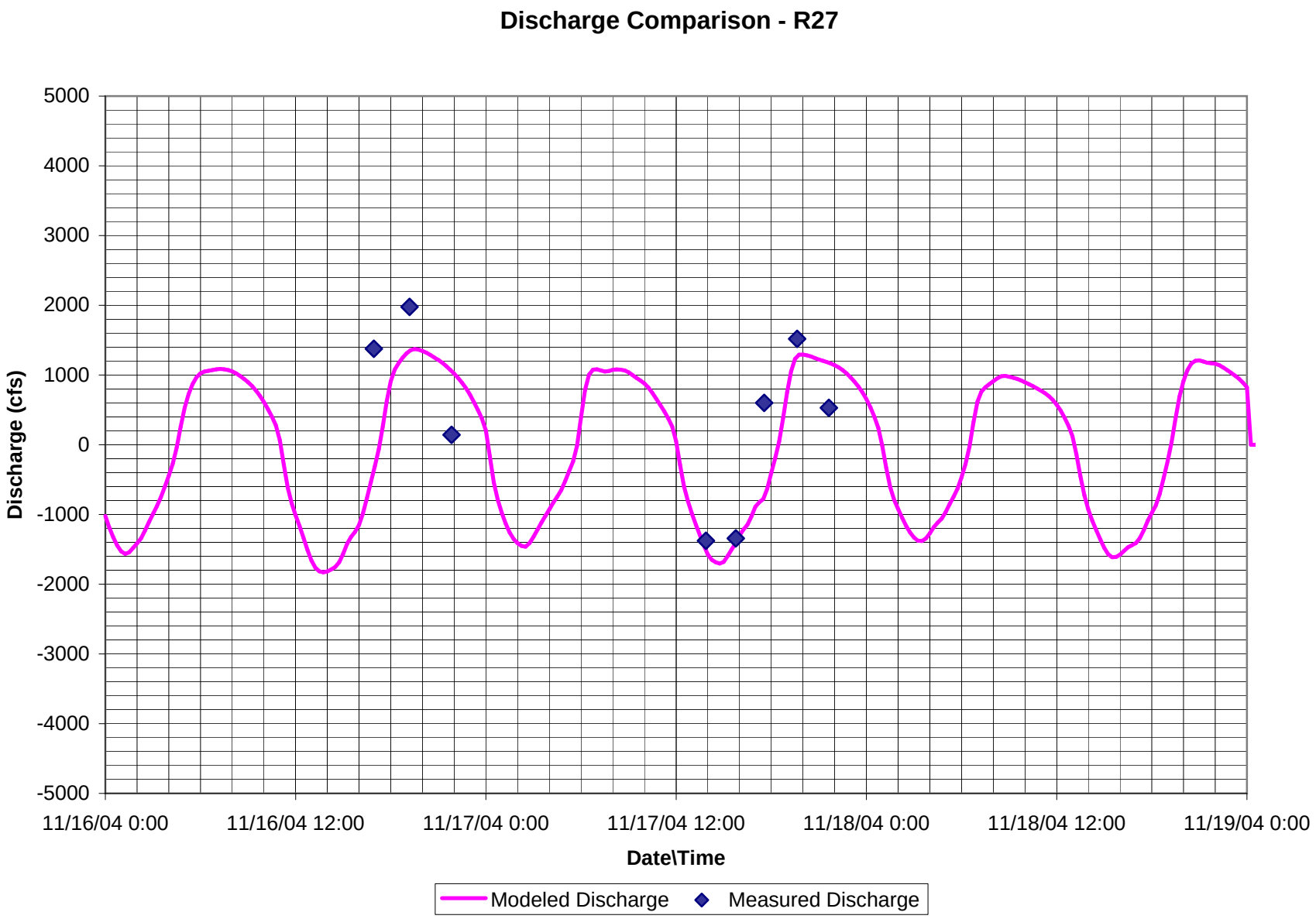

Discharge Comparison - R23
20000
16000
12000
8000
4000
0
-4000
-8000
-12000
-16000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

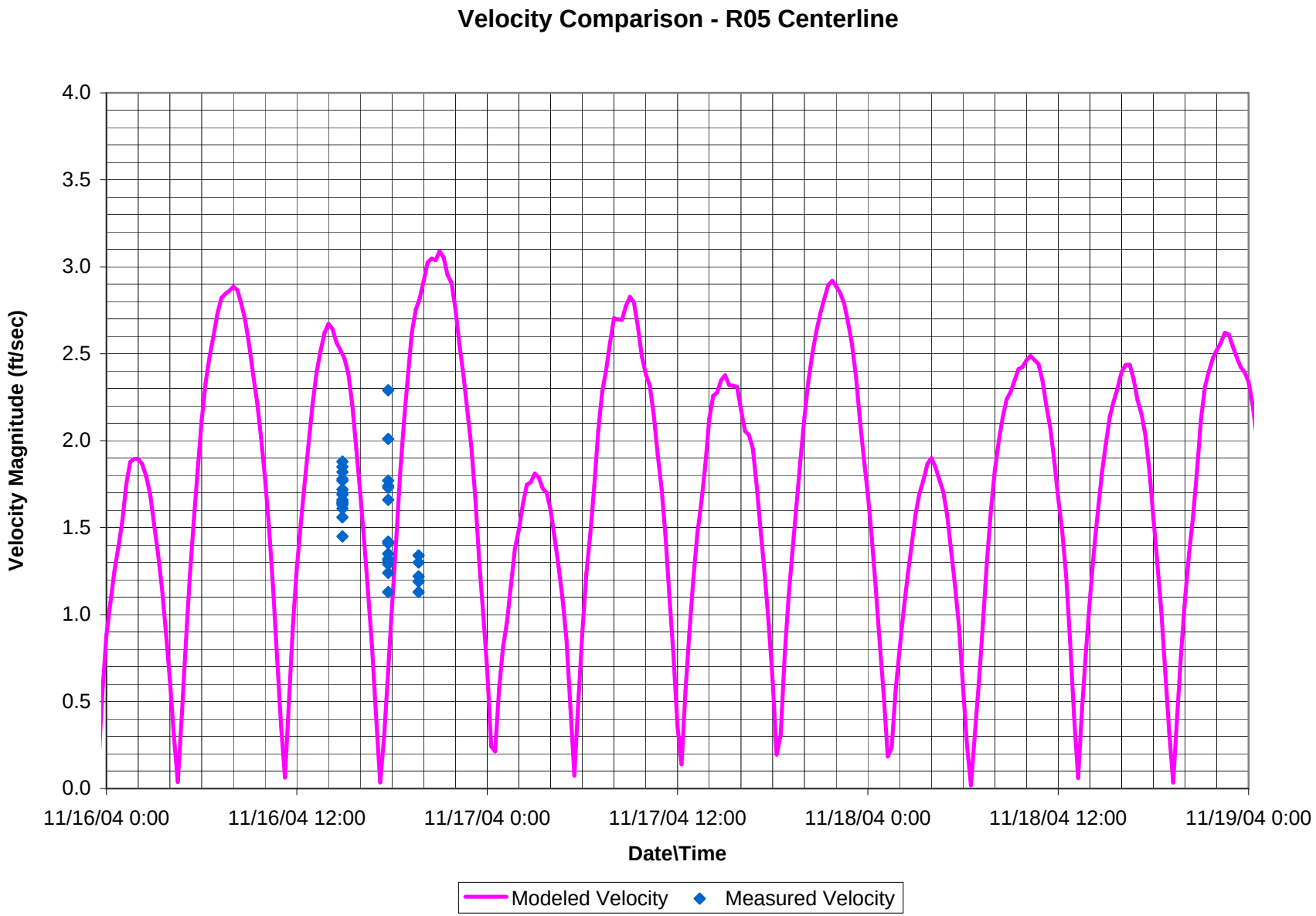

Discharge Comparison - R23a
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge

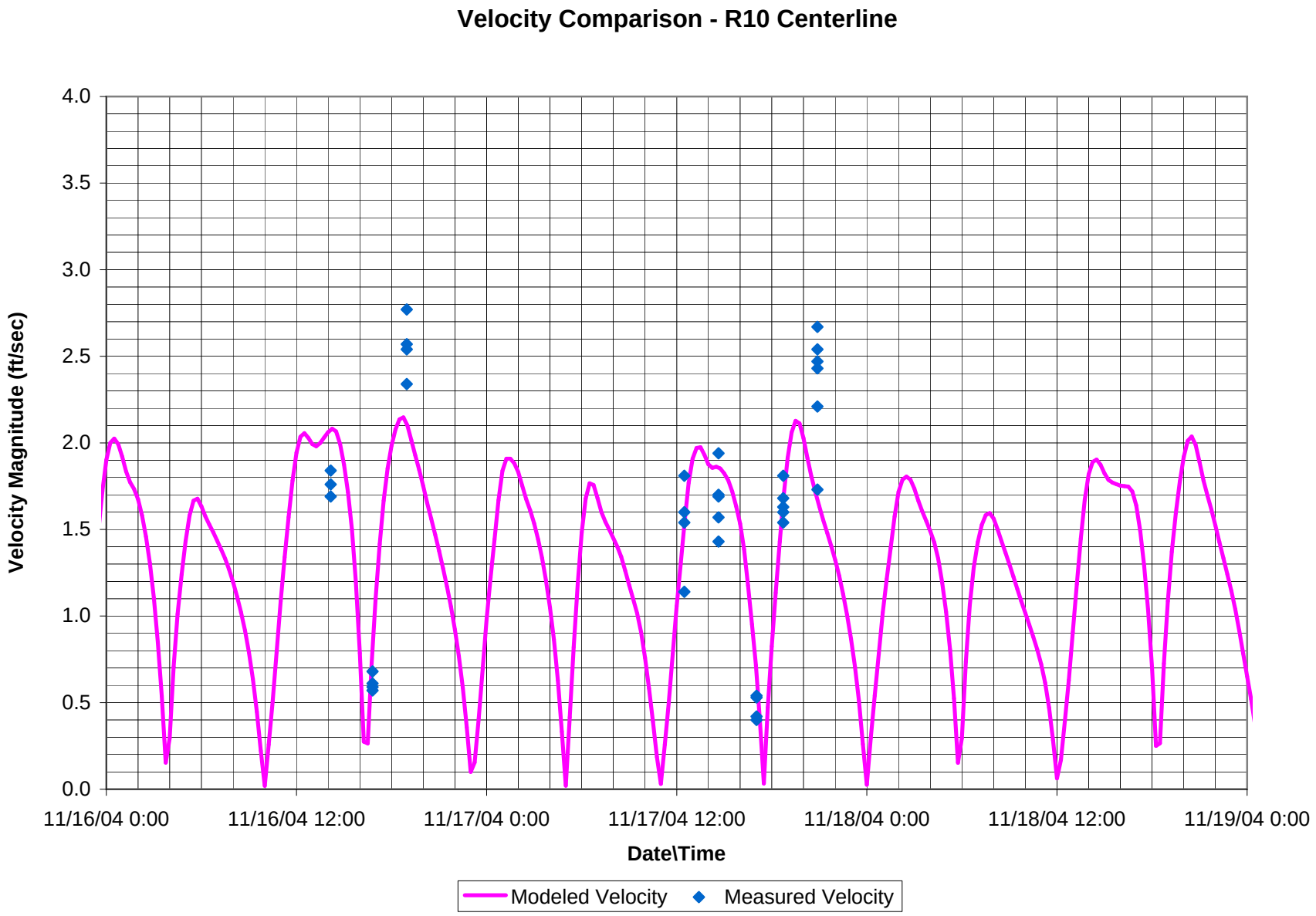

Discharge Comparison - R24
20000
16000
12000
8000
4000
0
-4000
-8000
-12000
-16000
-20000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge


Discharge Comparison - R25
60000
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge


Discharge Comparison - R26
60000
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge


Discharge Comparison - R27
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
Discharge (cfs)
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Discharge
Measured Discharge


Velocity Comparison - R05 Centerline
Velocity Magnitude (ft/sec)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Velocity
Measured Velocity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Velocity Magnitude (ft/sec)
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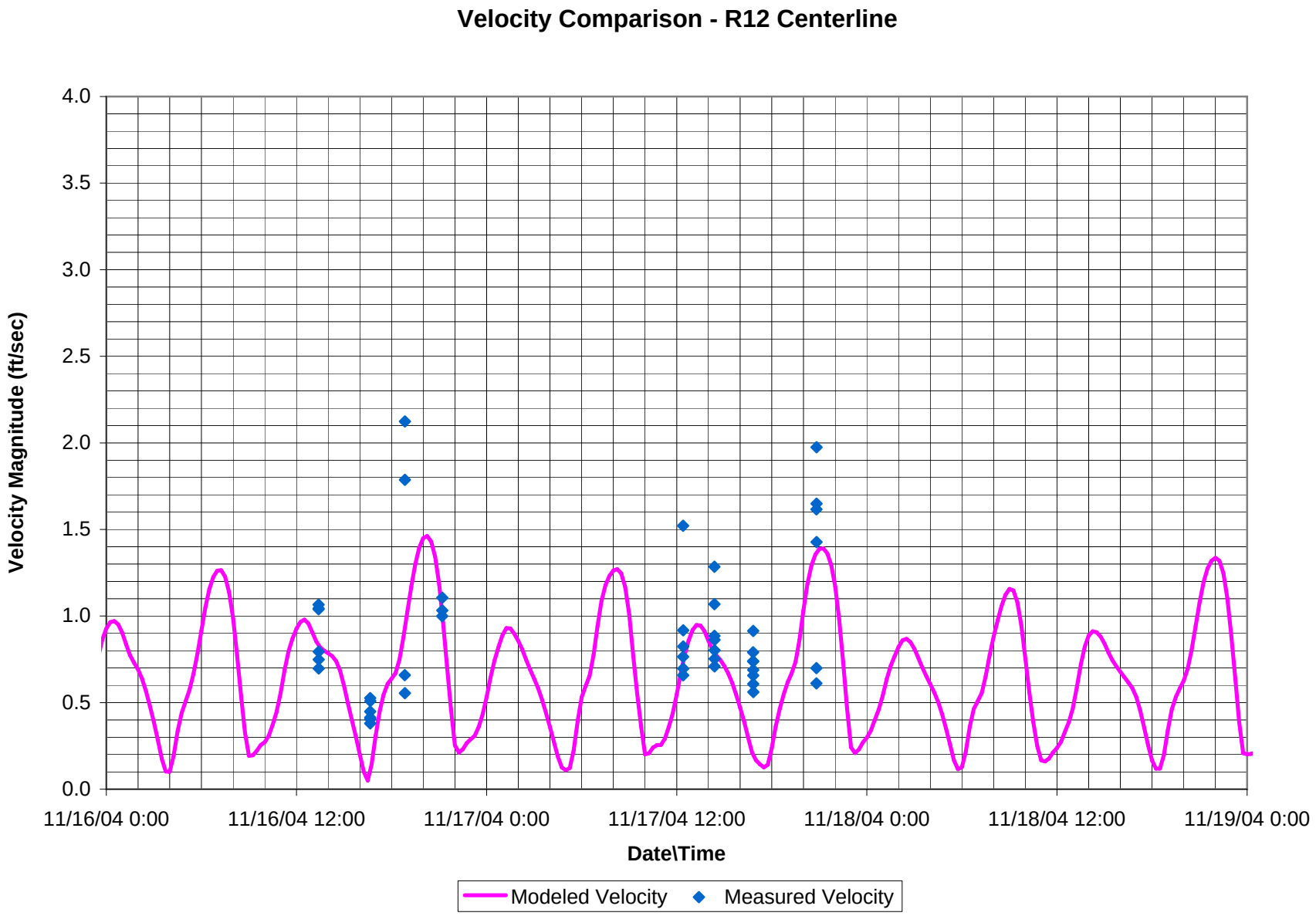
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Velocity
Measured Velocity


Velocity Comparison - R12 Centerline
Velocity Magnitude (ft/sec)
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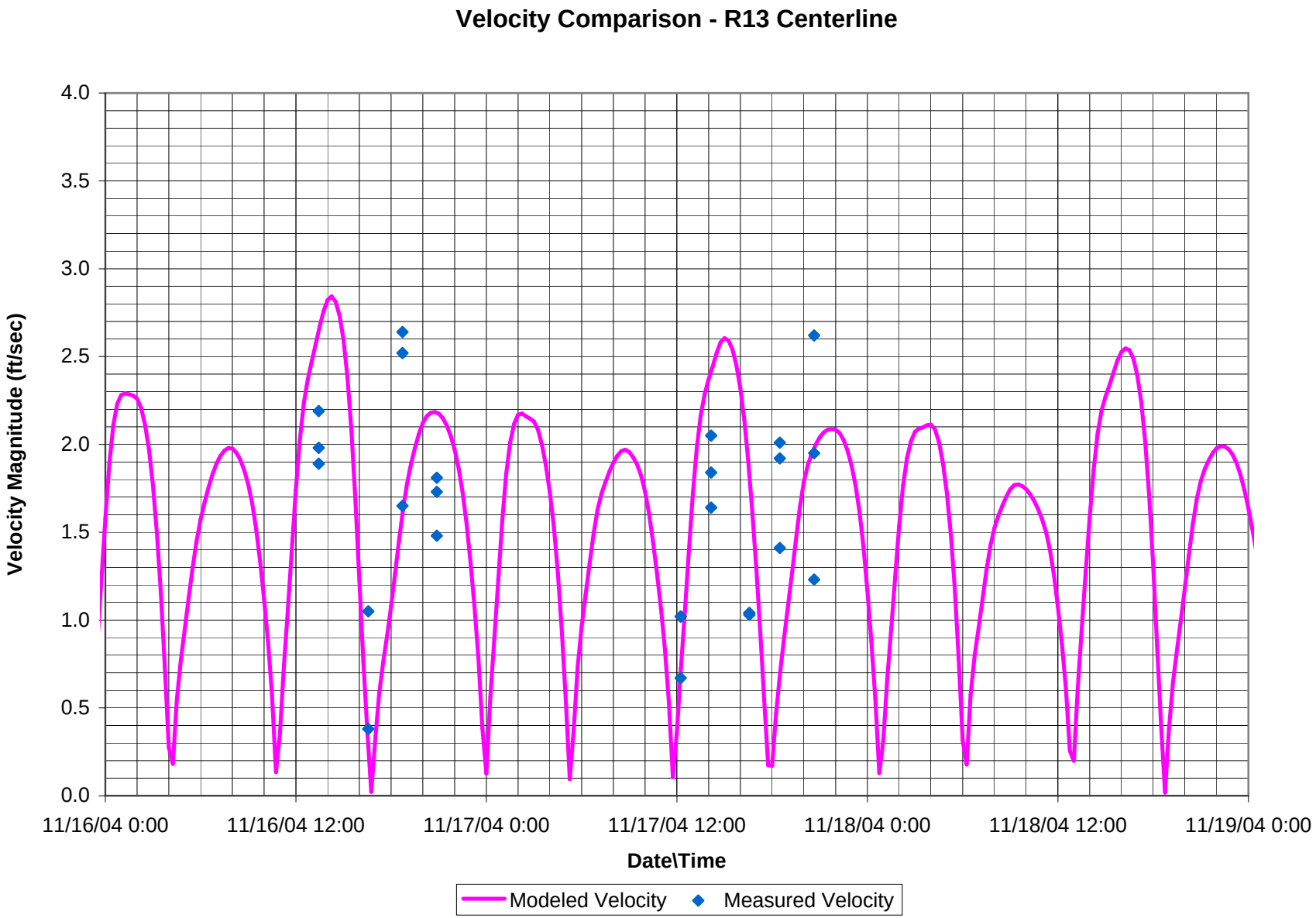
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Velocity
Measured Velocity


Velocity Comparison - R13 Centerline
Velocity Magnitude (ft/sec)
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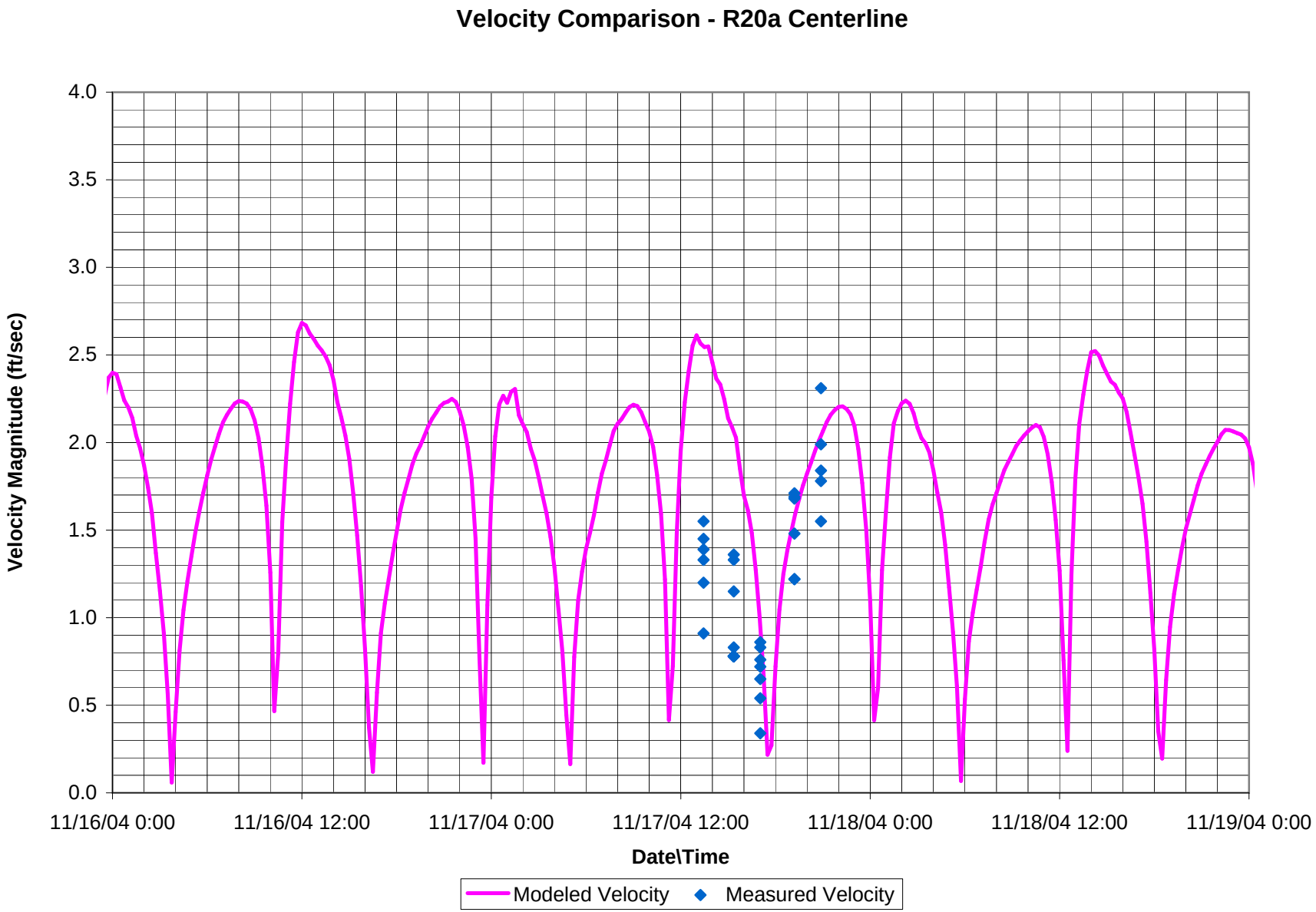
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Velocity
Measured Velocity


Velocity Comparison - R20a Centerline
Velocity Magnitude (ft/sec)
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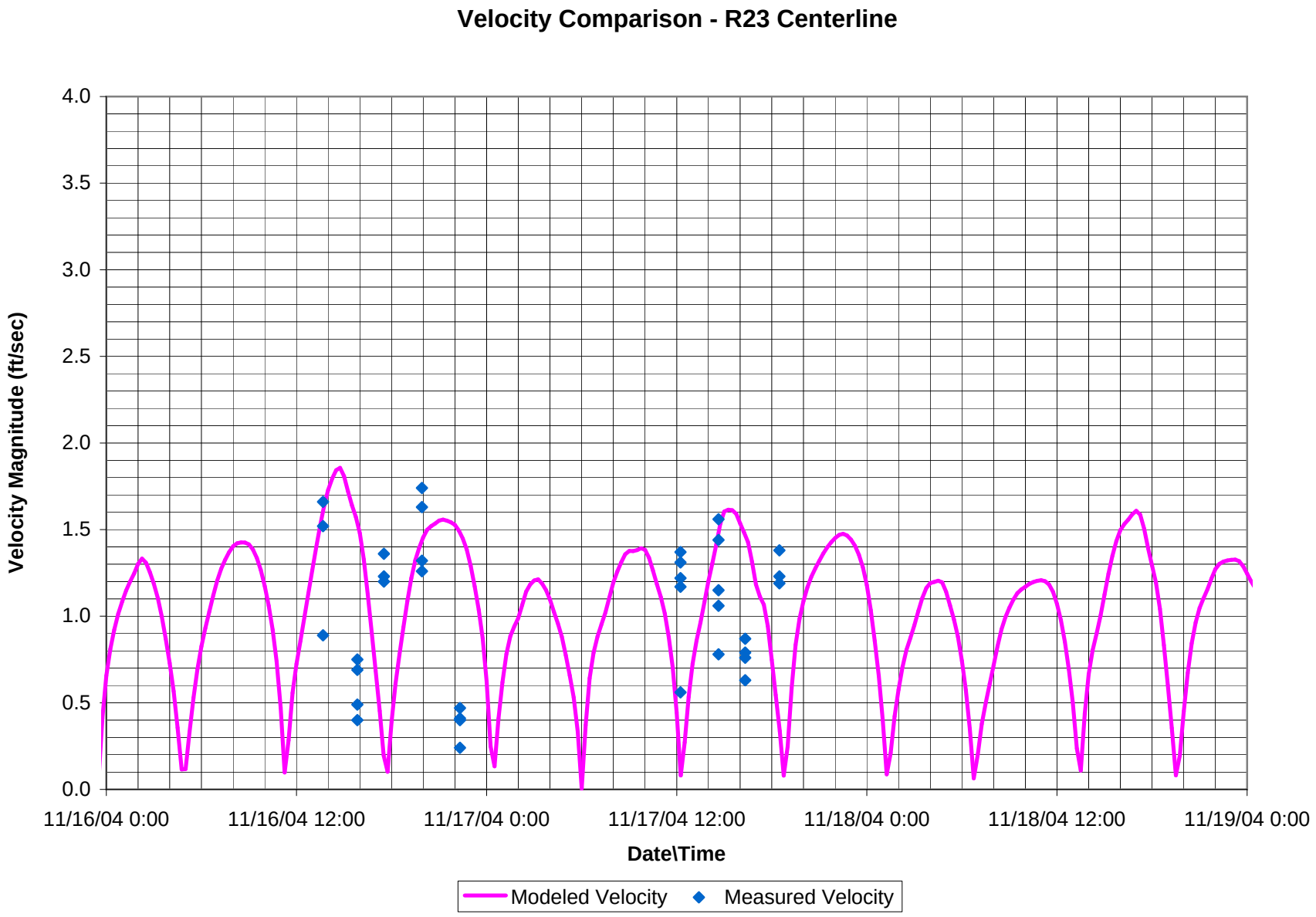
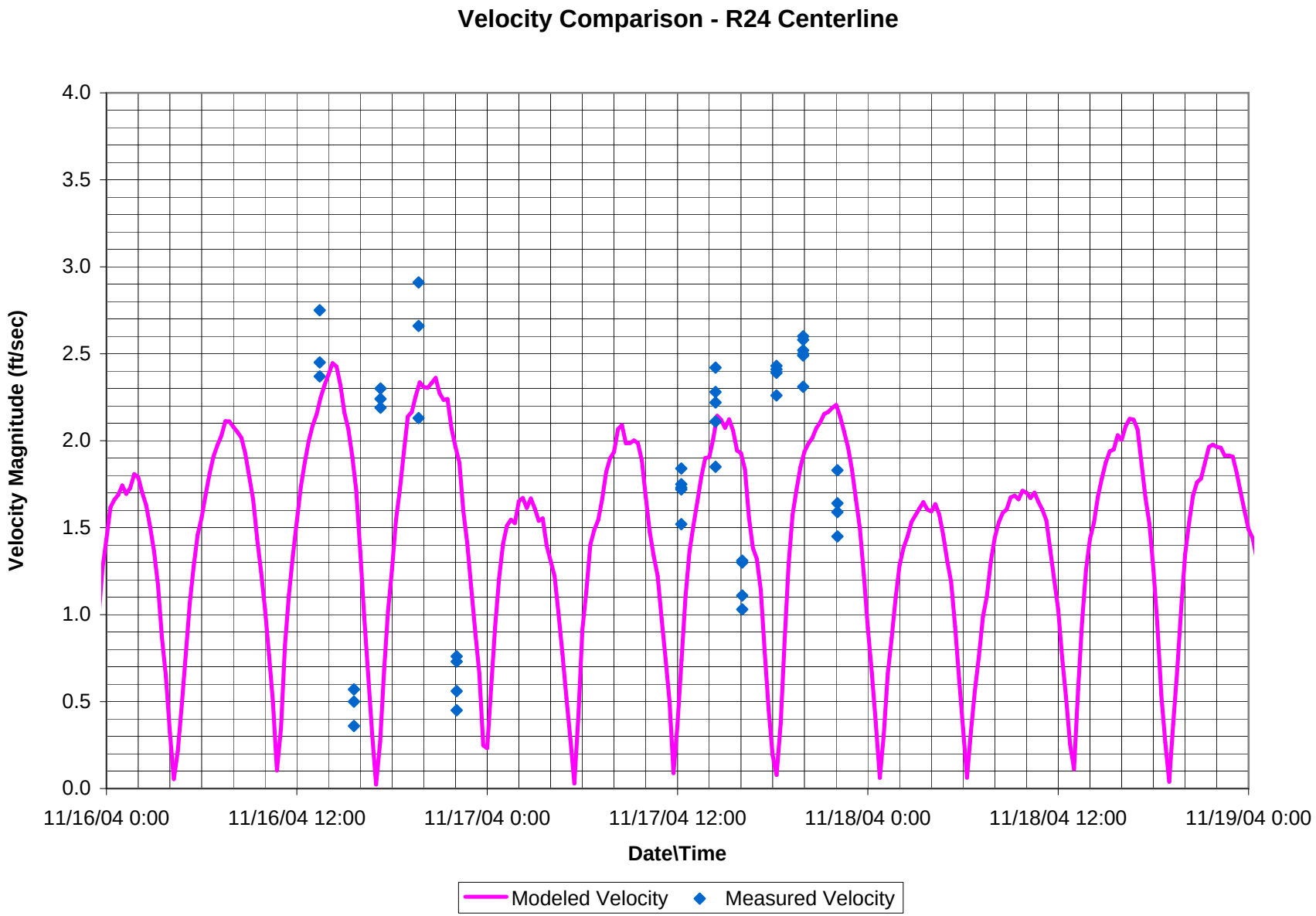
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Velocity
Measured Velocity


Velocity Comparison - R23 Centerline
Velocity Magnitude (ft/sec)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Velocity
Measured Velocity


Velocity Comparison - R24 Centerline
Velocity Magnitude (ft/sec)
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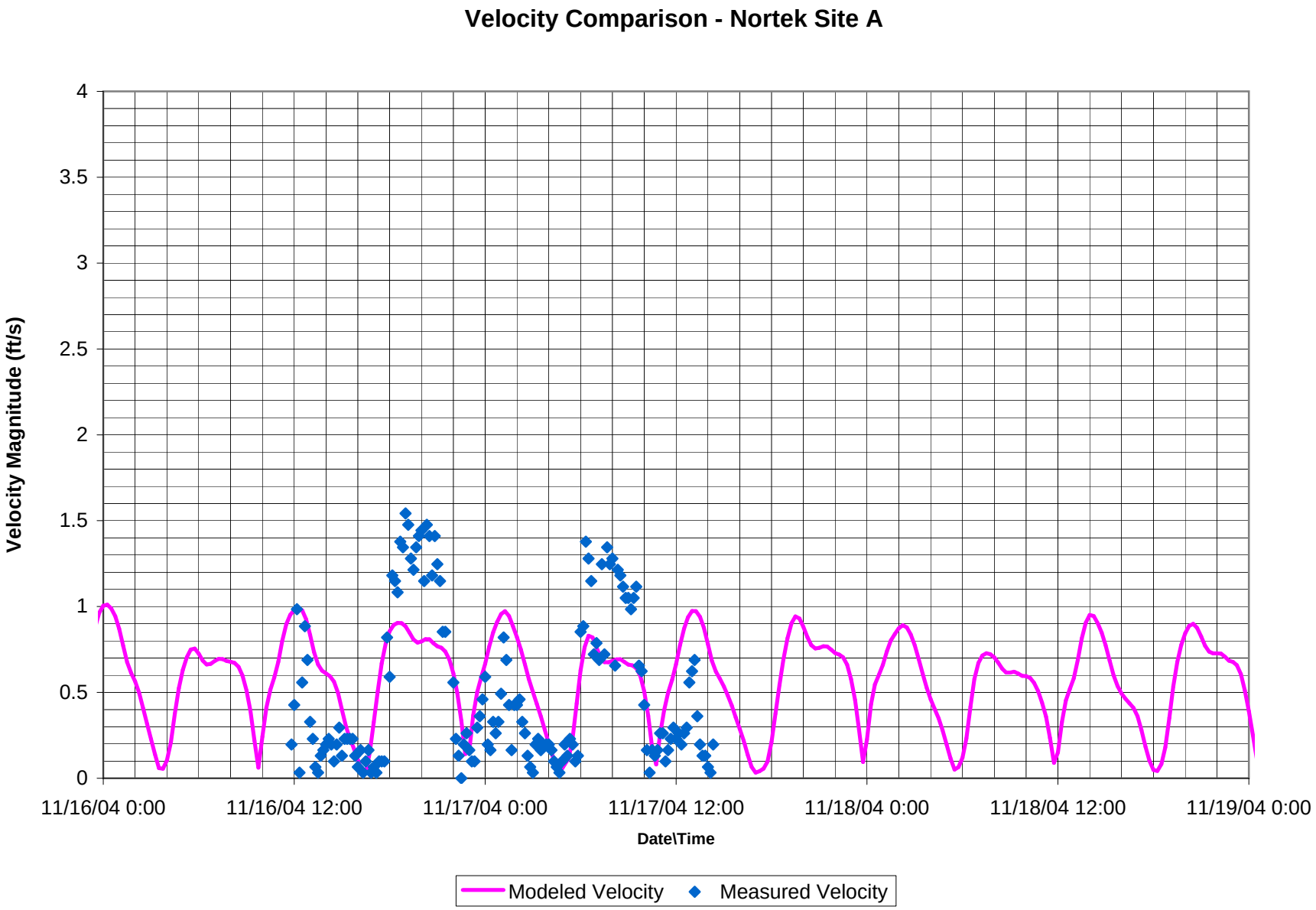
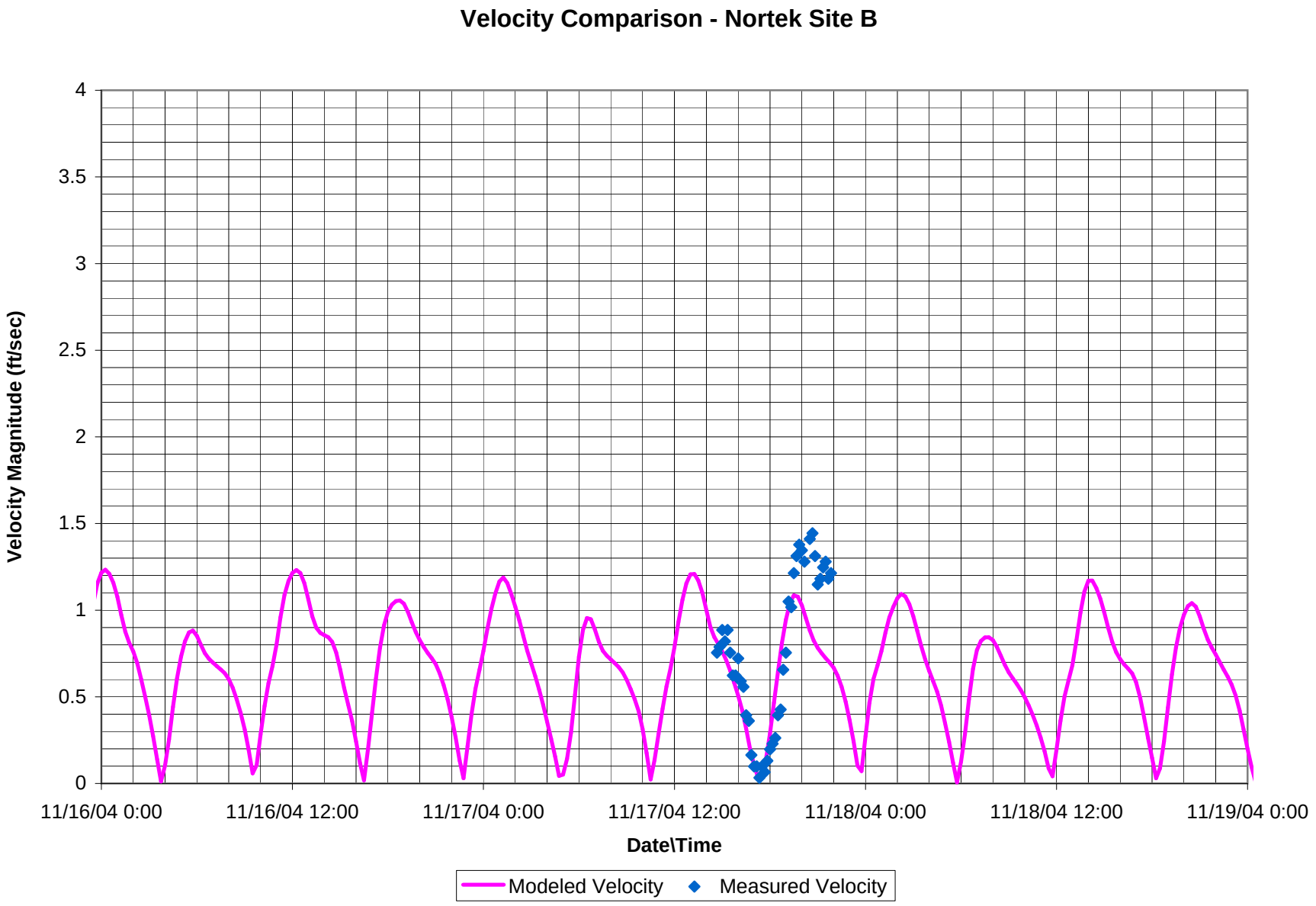
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Velocity
Measured Velocity


Velocity Comparison - Nortek Site A
Velocity Magnitude (ft/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Velocity
Measured Velocity


Velocity Comparison - Nortek Site B
Velocity Magnitude (ft/sec)
4
3.5
3
2.5
2
1.5
1
0.5
0
11/16/04 0:00
11/16/04 12:00
11/17/04 0:00
11/17/04 12:00
11/18/04 0:00
11/18/04 12:00
11/19/04 0:00
Date\Time
Modeled Velocity
Measured Velocity

Appendix D

Conceptual & Maximum Alignment Analysis

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INTRODUCTION

The following analysis reviews the hydraulic modeling of the conceptual and maximum design alternatives for the Sunset Beach 2016 Pre-dredge Analysis. The modeling addresses potential concerns expressed by the North Carolina Division of Coastal Management (DCM) and the US Army Corps of Engineers (USACE) as provided below:

1. Potential changes created in the material shoaling patterns in the AIWW confluence with Jinks Creek.
2. Changes in the 'S' curve alignment within Jinks Creek due to increased scour potential.
3. Potential changes in material shoaling or inlet migration patterns within Tubbs Inlet.

The modeling analysis provides information on how each of the respective design alternatives may alter the tidal flows within Jinks Creek and the surrounding waters. The analysis utilizes the same software package [RMA2 software (Version 4.58)] and modeling domain as described for the preferred alternative. The analysis compares the performance of each design alternative with the velocities and flow rates calculated with the 2016 existing bathymetric conditions. The analysis simulates the tidal conditions measured during the November 2004 spring tide event to generate the velocities and flow rates. Established transects throughout Jinks Creek provide consistent measuring points for comparing the modeling results. The transect locations concentrate on the areas of concern noted during the project's environmental review. Figure 1 shows the four (4) transect locations utilized to compare the modeling results. The transect designations reference the same nomenclature (numbers) used for the preferred alternative analysis.

- Transect T3 – Jinks Creek Confluence with the AIWW
- Transect T5 - Jinks Creek 'S' Curve Alignment
- Transect T7 – Tubbs Inlet
- Transect T8 – Tubbs Inlet

The conceptual and maximum alternative analysis uses fewer transects compared to the preferred alternative analysis to provide a synopsis of the potential changes the project may generate. Due to other project related concerns, the conceptual and maximum alternatives have been removed from consideration for implementation, and therefore do not warrant a full review. However, the limited results provide insight into how different design alternatives may change the velocity and flow rates within Jinks Creek.

Similar to the preferred alternative, the conceptual design extends approximately 6,800 ft from the AIWW and terminates approximately 3,600 ft from Tubbs Inlet. However unlike the preferred alternative, the conceptual design maintains a constant bottom width of 100 ft at -7 MLW. Figure 2 shows the bathymetry of the conceptual design in planview. The maximum design alternative continues from the conceptual alignment through Tubbs Inlet and maintains the 100 ft width at – 7 MLW. The alignment follows the Jinks Creek thalweg through Tubbs Inlet and terminates in the Atlantic Ocean. Figure 3 shows the planview bathymetry for the maximum design alternative.

Figure 1. Transect Location

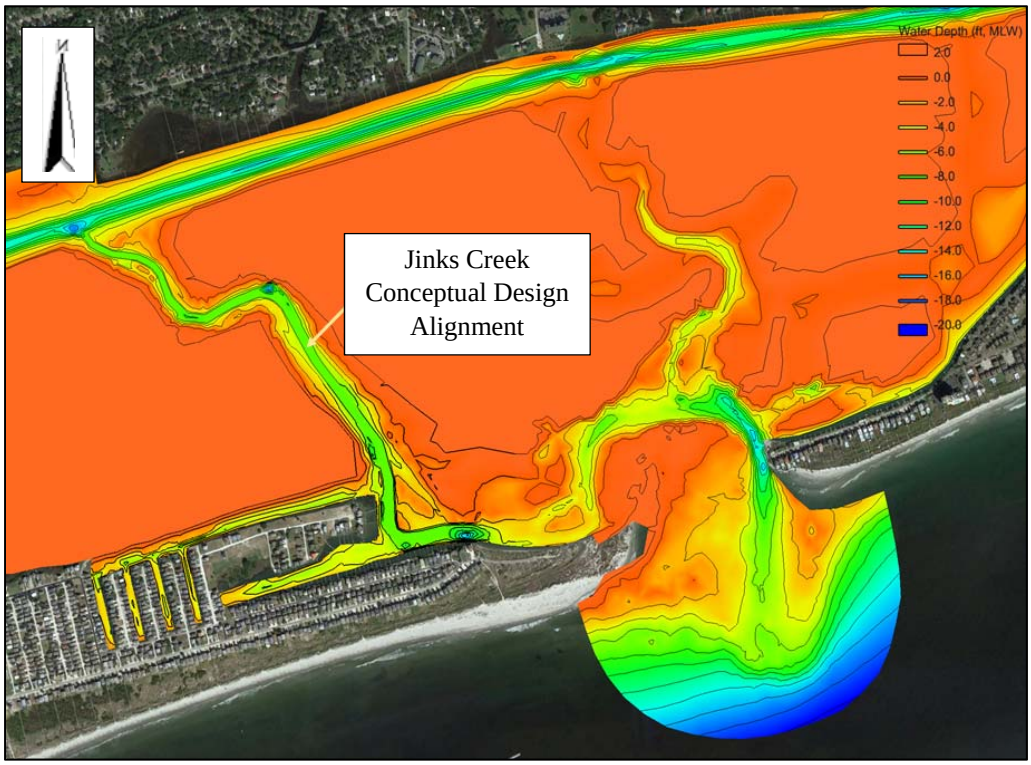


Figure 2. Bathymetry Contours for the Conceptual Design Alternative

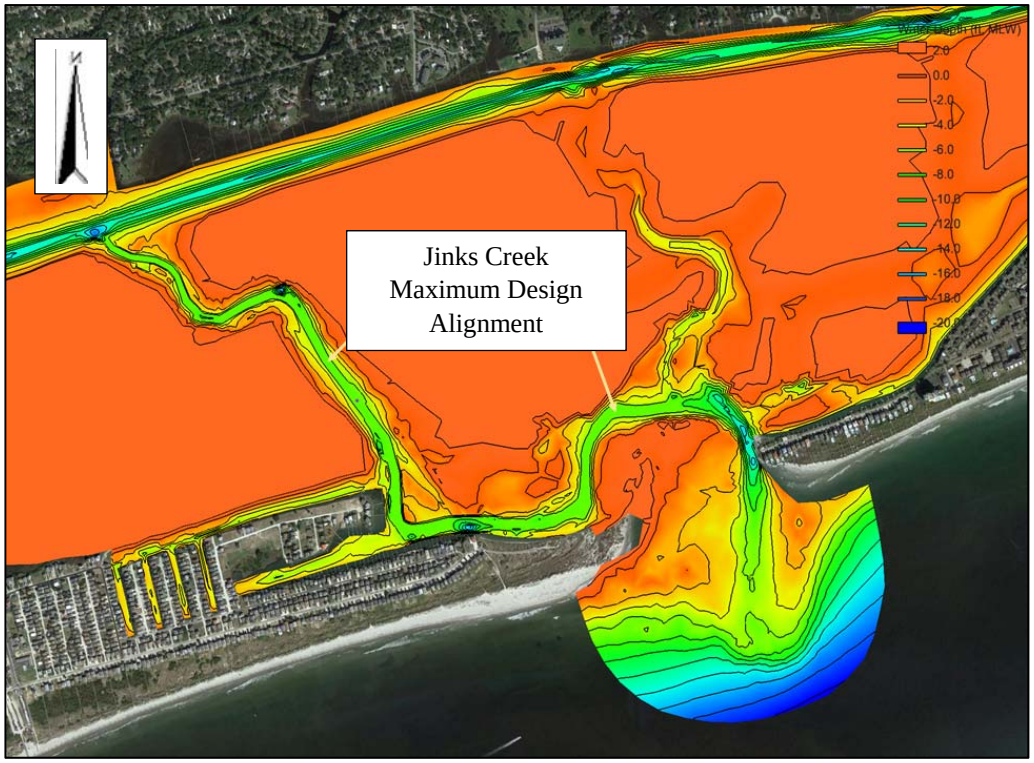


Figure 3. Bathymetry Contours for the Maximum Design Alternative

SHOALING IN THE AIWW CONFLUENCE WITH JINKS CREEK

Table 1 shows the maximum velocities expected in the AIWW confluence with Jinks Creek for each design alternative along with the 2016 existing conditions. The conceptual design analysis reflects minimal changes on the order of 2% would be expected. The maximum design analysis indicates an increase in the tidal velocities on the order of 5% ~ 6% may occur. These results suggest the hydraulic connection with Jinks Creek and the AIWW yields a lower influence on Jinks Creek compared to the Tubbs Inlet connection. The extension provided by the maximum design alignment through Tubbs Inlet entails the only difference between the conceptual and maximum alternatives. Thus, the increased tidal velocities shown in Table 1 for the maximum design must result from the improved connection between Tubbs Inlet and the Atlantic Ocean.

The increased velocities shown for the maximum design alternative most likely result from Tubbs Inlet providing a direct tidal connection to Jinks Creek. In comparison, the tidal velocities entering Jinks Creek from the AIWW must travel a longer distance and enter from Little River Inlet or Shallotte Inlet. In addition, the velocities entering through the AIWW must navigate through a constricted entrance compared to the Tubbs Inlet connection. For reference, Figure 4 shows the maximum velocities measured along Transect T3 for each respective design alternative.

Table 1. Maximum Velocities for Transect T3 (AIWW Confluence)

Design Alternative	Maximum Velocity (ft/sec)	Percent (%) Change
2016 Existing Conditions	2.75	-
Conceptual Design	2.81	2.2%
Maximum Design	2.90	5.5%

[1] Percent (%) change measured from the 2016 Existing Conditions results.

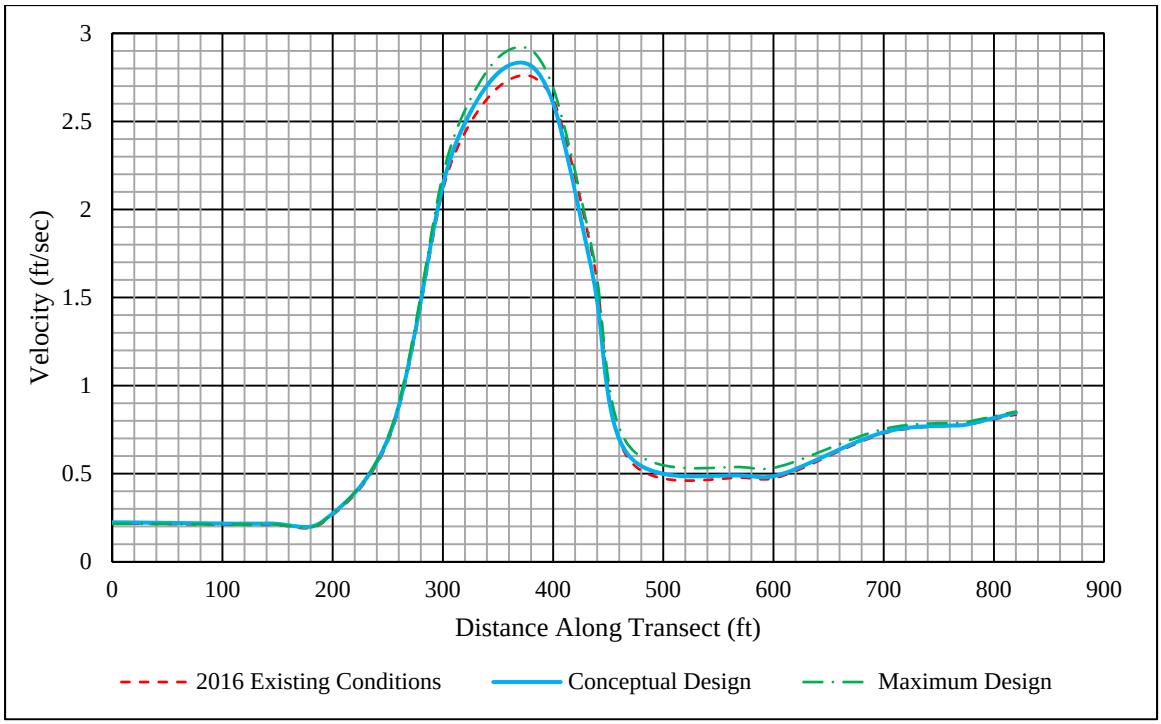


Figure 4. Maximum Velocity Measurements for Transect T3 (AIWW Confluence)

The flow rate measurements provide additional insight into the potential changes the design alternative may create. Table 2 shows the average flow rate measurements for the conceptual and maximum alternatives compared to those expected under the 2016 existing conditions. As shown in Table 2, an increase in the anticipated flow rate approaching 20% or greater could be expected with either design alignment. This suggests sediment shoaling constricts the existing flow way as the only consistent change for both design alternatives entails improving the Jinks Creek channel. For reference, Figure 5 shows the flow rate measurements for each design alternative.

Table 2. Average Flow Rates for Transect T3 (AIWW Confluence)

Design Alternative	Average Ebb Flow (Outgoing) cfs	Percent (%) Change	Average Flood Flow (Incoming) cfs	Percent (%) Change
2016 Conditions	1,440	-	2,360	-
Conceptual Design	1,710	19%	2,750	17%
Maximum Design	1,850	29%	2,870	22%

1. Values represent averaged measurements occurring from November 13, 2004 (13:15) to November 20, 2004 (13:15).
2. Percent (%) change measured from the 2016 Existing Conditions results

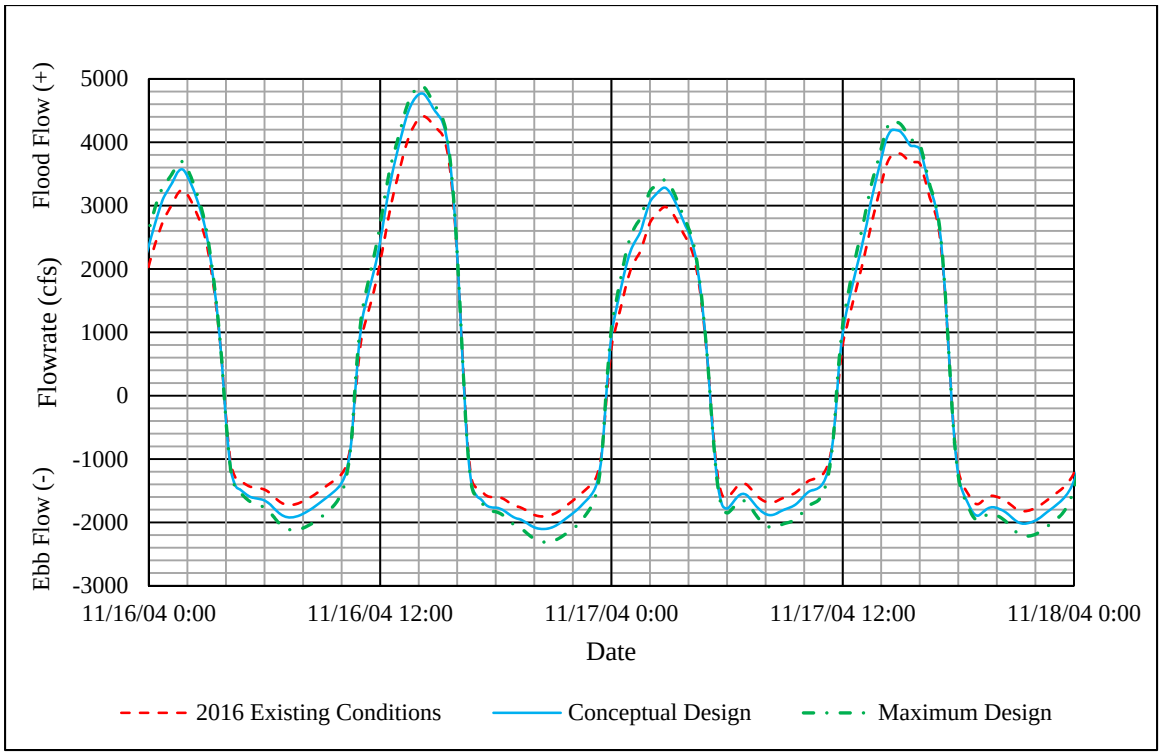


Figure 5. Flow Rate Measurements for Transect T3 (AIWW Confluence)

Review of the modeling data results also indicates tapering the channel width along northern Jinks Creek helps reduce the potential for impacts. Results shown for Transect T3 on the preferred alternative (Table 2 of the main report) indicate an approximate 2.9% change in the flood tide flow rates could be expected, compared to the approximate 17% shown for the conceptual alternative. The taper in northern Jinks Creek down to a 40 ft width comprises the main difference for the preferred alternative. The conceptual alternative maintains a 100 ft width throughout Jinks Creek.

INCREASED SCOUR POTENTIAL ALONG JINKS CREEK 'S' CURVE

Velocity and flow rate measurements recorded along Transect T5 provide the data to analyze how the proposed design alternatives would potentially impact the 'S' curve alignment in Jinks Creek. Figure 1 shows Transect T5 positioned along the primary bend in the 'S' curve and adjacent to a connecting tributary in Jinks Creek. The maximum velocity measurements indicate velocities may decrease within the 'S' curve alignment with a larger channel width and limited tidal input. Table 3 shows the conceptual design alternative provides some relief to the velocity magnitudes currently expected within the 'S' curve. The reduction in magnitude most likely results from the removal of the shoaled material within the 'S' curve alignment. Figure 6 shows the existing grade approximate to Transect T5 along Station 27+00 in the 'S' curve alignment. The 27+00 designation refers to the approximate distance from the AIWW confluence as measured along the centerline of the conceptual alternative.

Table 3. Maximum Velocities for Transect T5 ('S' Curve Alignment)

Design Alternative	Maximum Velocity (ft/sec)	Percent (%) Change
2016 Existing Conditions	2.88	-
Conceptual Design	2.85	-1.0%
Maximum Design	2.89	0.3%

[1] Percent (%) change measured from the 2016 Existing Conditions results.

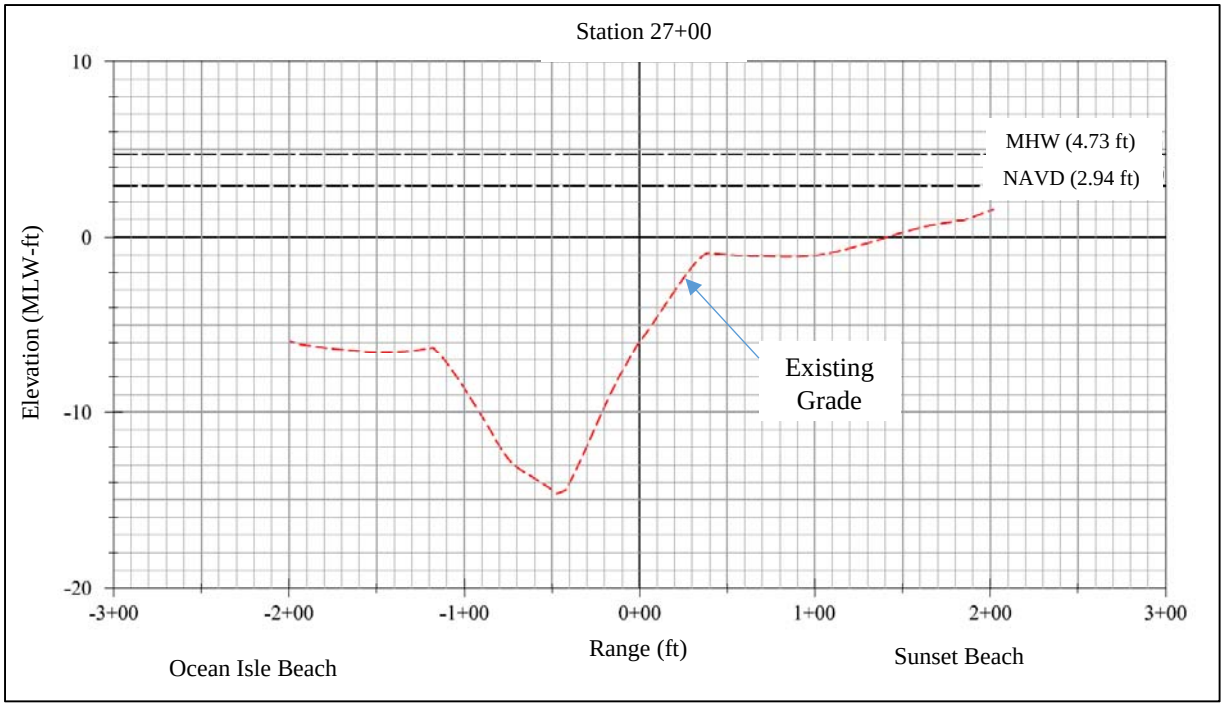


Figure 6. Cross-Section View of Station 27+00 (Transect T5)

Review of Table 3 also shows the maximum design alternative would not provide a significant change to the maximum velocities expected in the 'S' curve alignment. The anticipated maximum velocities could increase on the order of 0.3% for the maximum design alternative compared to the 2016 existing conditions. For reference, Figure 7 provides the maximum velocities recorded for each respective design alternative.

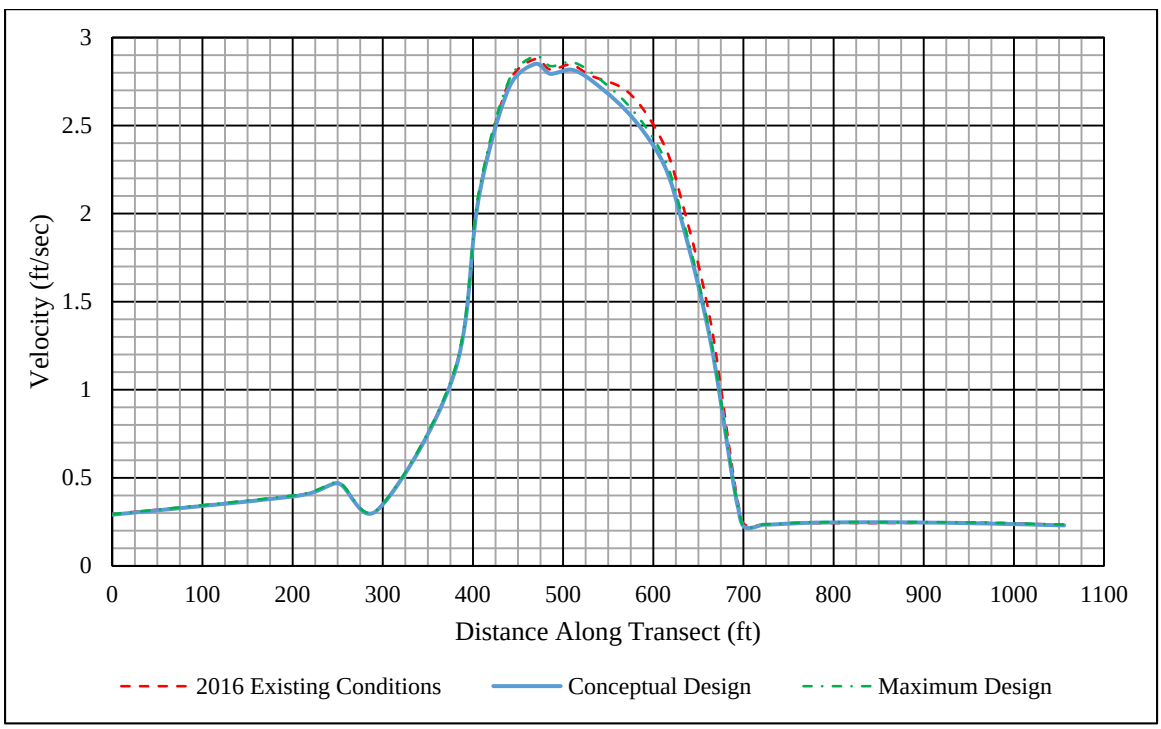


Figure 7. Maximum Velocity Measurements ('S' Curve Alignment)

The average flow rate measurements for Transect T5 show the respective design alternatives would allow a significant increase in the water volume traversing the 'S' curve alignment. Table 4 shows the conceptual and maximum design alternatives could allow approximately 10% ~ 20% more water through the 'S' curve, respectively. The results shown in Table 4 match relatively well with the flow rate increases that would be expected for the AIWW confluence shown above for either the conceptual or maximum alternatives. Figure 8 shows the modeled flow rate measurements for each respective alternative in the 'S' curve alignment.

Table 4. Average Flow Rates for Transect T5 ('S' Curve Alignment)

Design Alternative	Average Ebb Flow (Outgoing) cfs	Percent (%) Change	Average Flood Flow (Incoming) cfs	Percent (%) Change
2016 Conditions	3,120	-	2,520	-
Conceptual Design	3,530	13%	2,860	13%
Maximum Design	3,660	17%	3,050	21%

1. Values represent averaged measurements occurring from November 13, 2004 (13:15) to November 20, 2004 (13:15).
2. Percent (%) change measured from the 2016 Existing Conditions results.

TUBBS INLET SHOALING & MIGRATION PATTERNS

The analysis of Tubbs Inlet utilizes Transects T7 & T8 to gauge how the tidal velocities and flow rates may change under the conceptual or maximum design alternatives. Transect T7 provides data to estimate the potential changes at the terminus of the conceptual design alternative while Transect T8 captures data within the throat of Tubbs Inlet. Figure 1 shows the location of each transect in relation to the respective design alternatives.

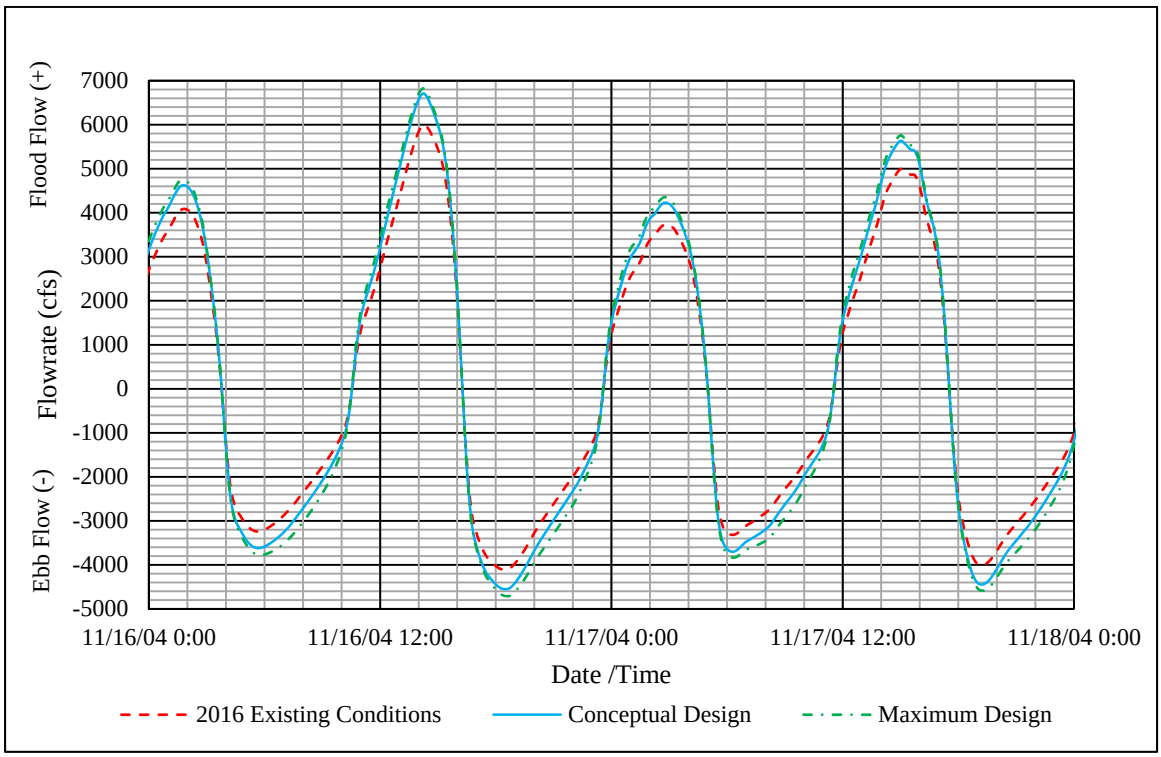


Figure 8. Flow Rate Measurements for Transect T5 ('S' Curve Alignment)

Table 5 shows the maximum velocities estimated under each design alternative for the respective transects. The velocity results for the analysis of Tubbs Inlet reflect similar variations between the existing and proposed conditions as those calculated for alternate areas of Jinks Creek. The modeling indicates the

conceptual design alternative may produce approximate 2% increase and the maximum design alternative may provide an approximate 4% ~ 5% increase in tidal velocities. In both scenarios, the tidal velocities along Transect T7 should remain well below the approximate 3.28 ft/sec[1] threshold for scour. However, in the inlet throat (Transect T8) the velocities currently exceed the scour threshold and could experience and additional increase.

The larger velocity increase observed in the maximum design analysis seems logical since the alternative would improve the hydraulic connection between Jinks Creek and the Atlantic Ocean. Accordingly, the conceptual design would not remove the perceived blockage of shoaled material within the interior complex of Tubbs Inlet. Therefore, a relative substantial increase in tidal velocities would not be expected under the conceptual alignment. For reference, Figures 9 & 10 show the maximum velocities recorded across the respective transects for the conceptual and maximum design alternatives.

Table 5. Maximum Velocities for Transects T7 & T8 (Tubbs Inlet)

Design Alternative	Transect T7		Transect T8	
	Maximum Velocity (ft/sec)	Percent (%) Change	Maximum Velocity (ft/sec)	Percent (%) Change
2016 Existing Conditions	2.29	-	4.73	-
Conceptual Design	2.33	1.7%	4.79	1.3%
Maximum Design	2.41	5.2%	4.90	3.6%

[1] Percent (%) change measured from the 2016 Existing Conditions results.

Tables 6 and 7 show the average flow rate measurements recorded for Transects T7 & T8, respectively. The measurements indicate an increase in flow would occur due to the improvement of Jinks Creek as well as the improvements to Tubbs Inlet. The measurements for Transect T7 show an approximate 4% ~ 10% increase in tidal flows could be expected within the interior of Tubbs Inlet with the conceptual and maximum designs alternatives, respectively. Also, the measurements for Transect T8, located in the mouth of Tubbs Inlet, suggests an increase of 2% ~ 3% in tidal flows for the respective alternatives.

[1] Dean, R.G. & Dalyrmple, R.A., (2002) Coastal processes with engineering applications. Cambridge: Cambridge University Press.

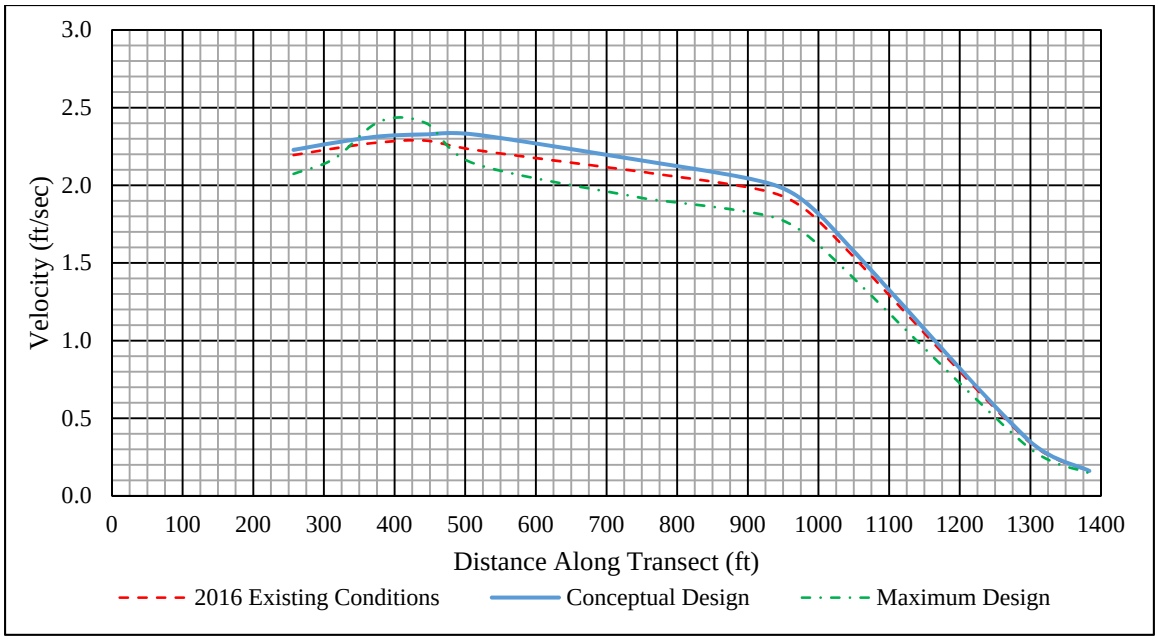


Figure 9. Maximum Velocity Measurements for Transect T7 (Tubbs Inlet)

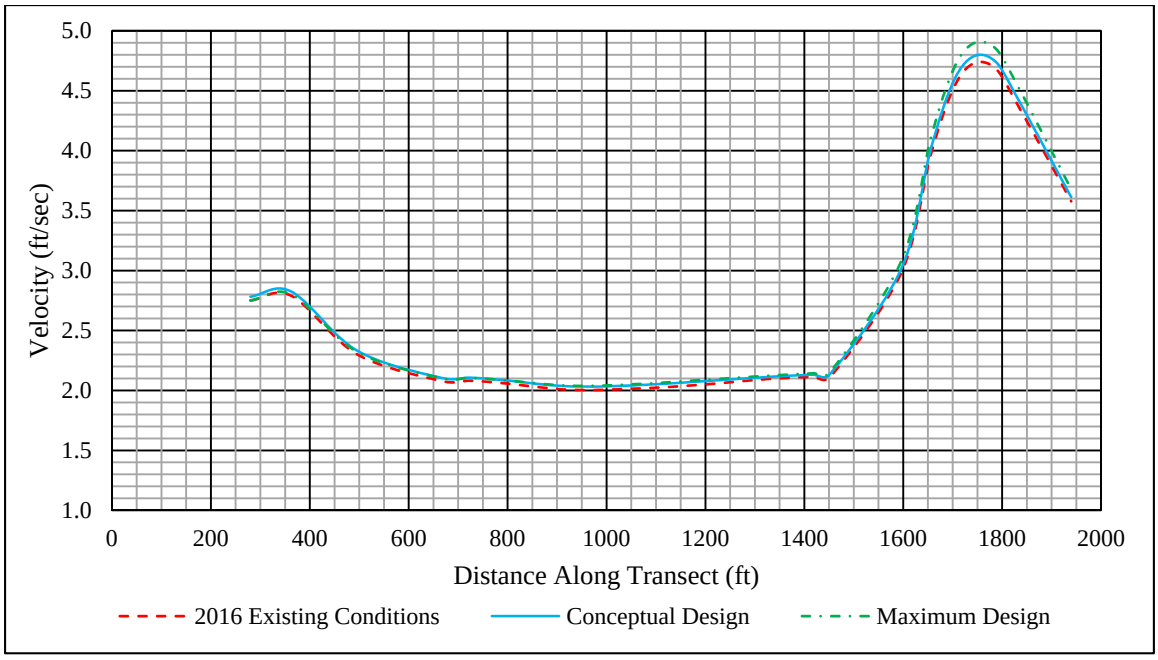


Figure 10. Maximum Velocity Measurements for Transect T8 (Tubbs Inlet)

Although the change in tidal flows would most likely be insignificant in southern Jinks Creek, the results support the preferred alternative over the conceptual or maximum design alignments. The preferred alternative analysis (shown in the main report) appears to minimize the disturbance to Jinks Creek and avoids impacting the Tubbs Inlet tidal flows or velocities. However, the results presented herein indicate the conceptual and maximum alternative may create relative changes in the tidal properties for all of Jinks Creek. For reference, Figures 11 & 12 show the flow rate measurements for Transects T7 and T8.

Table 6. Average Flow Rates for Transect T7 (Tubbs Inlet)

Alternative	Average Ebb Flow (Outgoing) cfs	Percent (%) Change	Average Flood Flow (Incoming) cfs	Percent (%) Change
2016 Conditions	4,410	-	5,800	-
Conceptual Design	4,590	4.1%	6,080	4.8%
Maximum Design	4,840	9.8%	6,080	4.8%

1. Values represent averaged measurements occurring from November 13, 2004 (13:15) to November 20, 2004 (13:15).
2. Percent (%) change measured from the 2016 Existing Conditions results.

Table 7. Average Flow Rates for Transect T8 (Tubbs Inlet)

Alternative	Average Ebb Flow (Outgoing) cfs	Percent (%) Change	Average Flood Flow (Incoming) cfs	Percent (%) Change
2016 Conditions	10,650	-	12,140	-
Conceptual Design	10,820	1.6%	12,320	1.5%
Maximum Design	10,950	2.8%	12,550	3.4%

1. Values represent averaged measurements occurring from November 13, 2004 (13:15) to November 20, 2004 (13:15).
2. Percent (%) change measured from the 2016 Existing Conditions results.

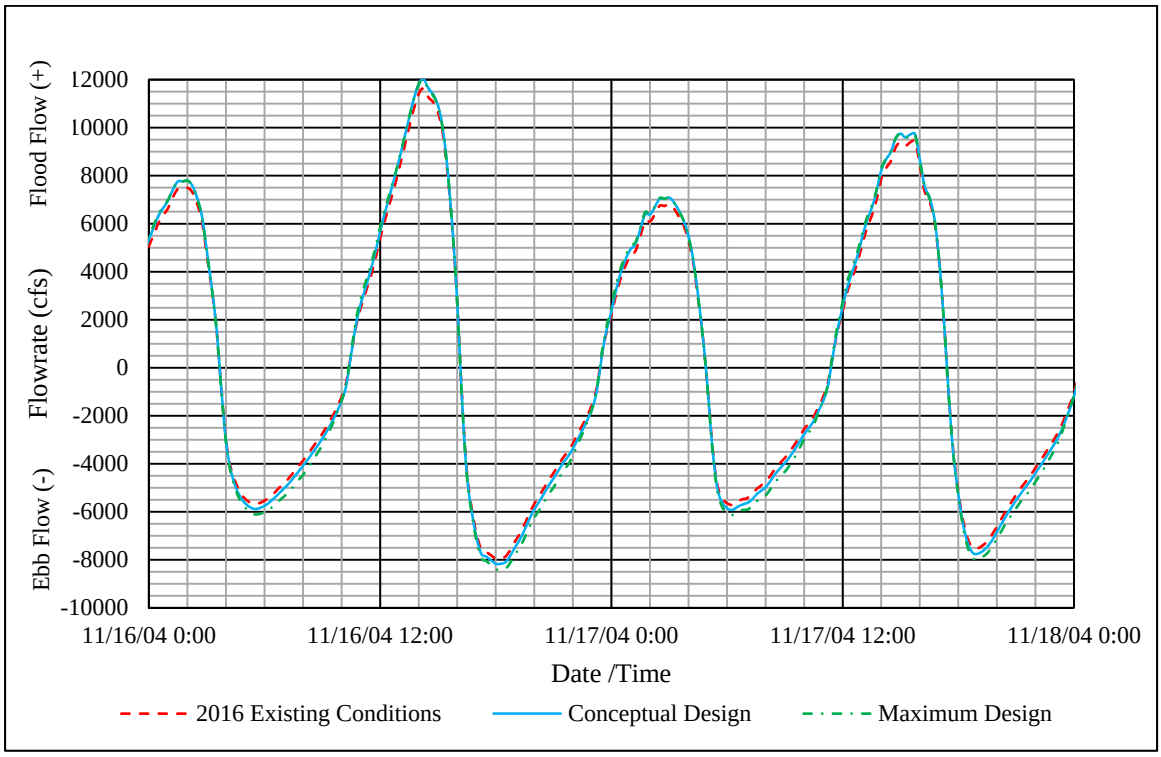


Figure 11. Flow Rate Measurements for Transect T7 (Tubbs Inlet)

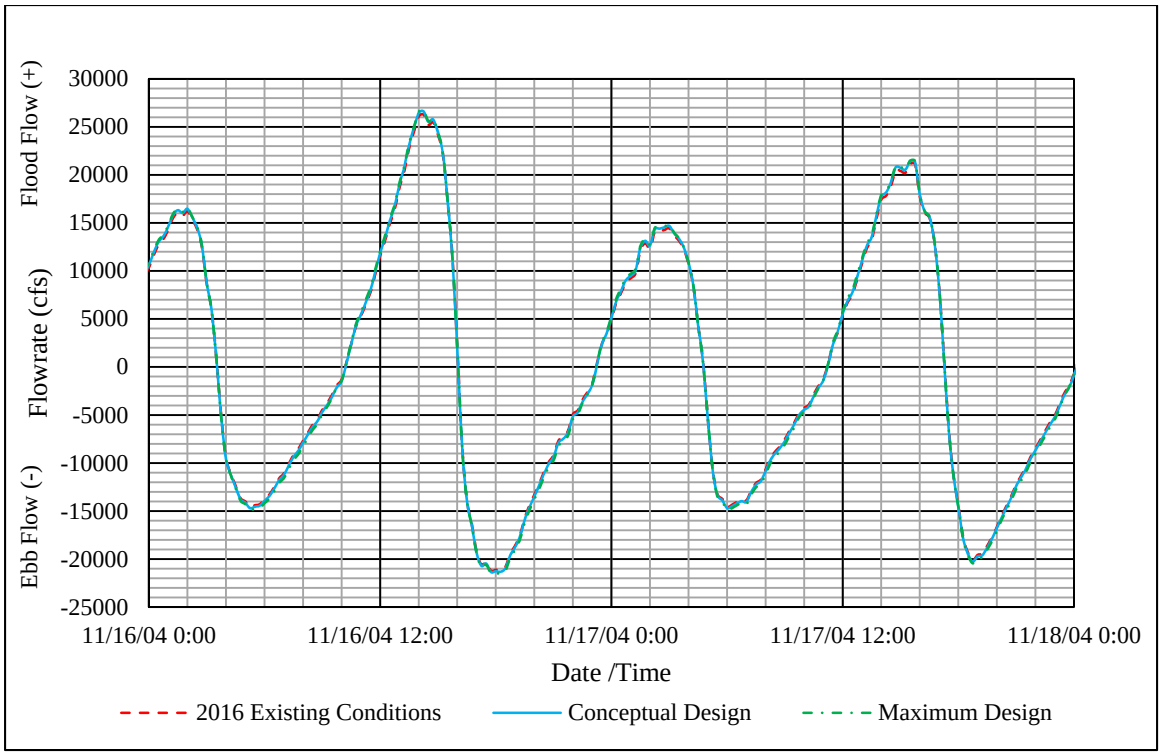


Figure 12. Flow Rate Measurements for Transect T8 (Tubbs Inlet)

CONCLUSION

The modeling analysis provides a limited evaluation of the conceptual and maximum design alternatives to gauge how each alignment may affect the existing flow patterns within Jinks Creek. Neither design option is considered a viable project alternative due to other potential concerns. Therefore, the current analysis does not fully evaluate the alternatives, but only explores the basic changes each option may create.

The analysis of the conceptual and maximum design alternatives indicates a significant increase in the average flow rates through Jinks Creek could occur with the implementation of either alternative. However, the analysis suggests the maximum tidal velocities would experience less than a 5% increase in magnitude. The increase in tidal flow rates suggested by the analysis indicates the existing shoaling within northern Jinks Creek creates an impediment to the tidal currents. Both the conceptual and maximum design alternatives would help improve the tidal flows to Jinks Creek and the AIWW. However, neither alternative appears to be the least impactive option to accomplish the navigation goals intended by the dredging project. Table 8 shows the average flow rate measurements recorded for each respective transect in the study area.

Table 8. Average Flow Rates for the Conceptual & Maximum Design Alternatives

Alternative		Average Ebb Flow (Outgoing) cfs	Percent (%) Change	Average Flood Flow (Incoming) cfs	Percent (%) Change
Transect T3 (AIWW Confluence)	2016 Existing Conditions	1,440	-	2,360	-
	Conceptual Design	1,710	19%	2,750	17%
	Maximum Design	1,850	29%	2,870	22%
Transect T5 ('S' Curve)	2016 Existing Conditions	3,120	-	2,520	-
	Conceptual Design	3,530	13%	2,860	13%
	Maximum Design	3,660	17%	3,050	21%
Transect T7 (Tubbs Inlet)	2016 Existing Conditions	4,410	-	5,800	-
	Conceptual Design	4,590	4.1%	6,080	4.8%
	Maximum Design	4,840	9.8%	6,080	4.8%
Transect T8 (Tubbs Inlet)	2016 Existing Conditions	10,650	-	12,140	-
	Conceptual Design	10,820	1.6%	12,320	1.5%
	Maximum Design	11,950	2.8%	12,550	3.4%

1. Values represent averaged measurements occurring from November 13, 2004 (13:15) to November 20, 2004 (13:15).
2. Percent (%) change measured from the 2016 Conditions results

Table 8 shows the flow rates estimated for the conceptual and maximum design alternatives increase relative to the rates expected with the 2016 existing conditions of Jinks Creek. The difference in the modeled flow rates increase from approximately 2 ~ 4% near Tubbs Inlet to approximately 20% or greater in the AIWW confluence with Jinks Creek. This suggest the channel improvements under the conceptual or maximum design alternatives may create a significant change in the tidal flows of northern Jinks Creek. Although the tidal velocities would not be expected to incur greater than a 5% increase, the volume of water traversing Jinks Creek would most likely increase. This does not necessarily indicate a negative impact or that additional scour / erosion would occur. However, reviewing the analysis of the preferred alignment suggest the navigation goals may be achieved while minimizing the anticipated change in the tidal flows of northern Jinks Creek.

For reference, Table 9 shows the maximum tidal velocities estimated for the respective design alternatives. The measurements indicate the maximum velocities estimated for the design alternative remain relatively constant through Jinks Creek compared with the 2016 existing conditions. The estimated changes range

from approximately 1% ~ 4% in near Tubbs Inlet along Transect T8, to approximately 2% ~ 6% across Transect T3 near the AIWW confluence.

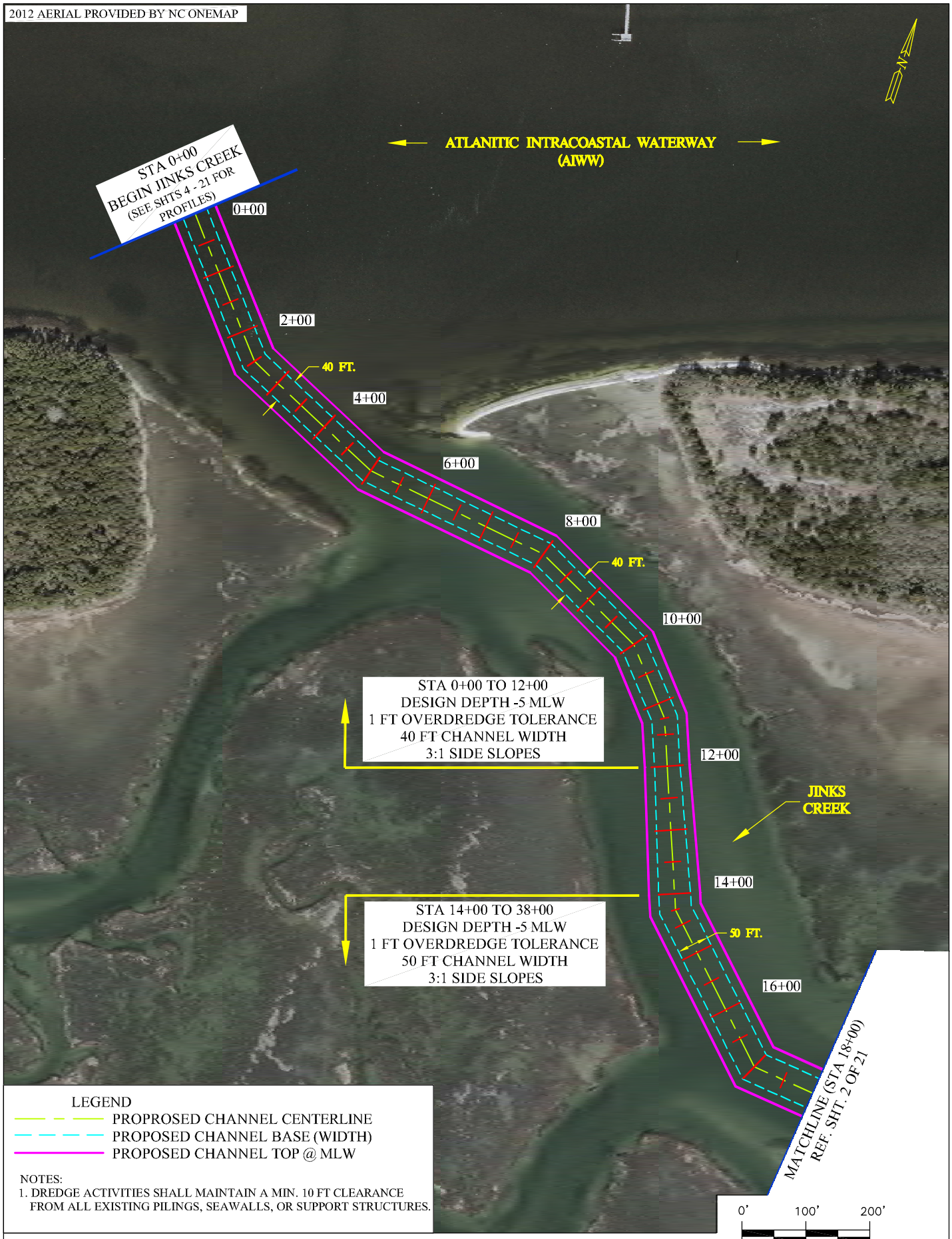
Table 9. Maximum Velocities for the Conceptual & Maximum Design Alternatives

Alternative		Maximum Velocity (ft/sec)	Percent (%) Change
Transect T3 (AIWW Confluence)	2016 Conditions	2.75	-
	Conceptual Design	2.81	2.2%
	Maximum Design	2.90	5.5%
Transect T5 ('S' Curve)	2016 Conditions	2.88	-
	Conceptual Design	2.85	-1.0%
	Maximum Design	2.89	0.3
Transect T7 (Tubbs Inlet)	2016 Conditions	2.29	-
	Conceptual Design	2.33	1.7%
	Maximum Design	2.41	5.2%
Transect T8 (Tubbs Inlet)	2016 Conditions	4.73	-
	Conceptual Design	4.79	1.3%
	Maximum Design	4.90	3.6%

[1] Percent (%) change measured from the 2016 Existing Conditions results.

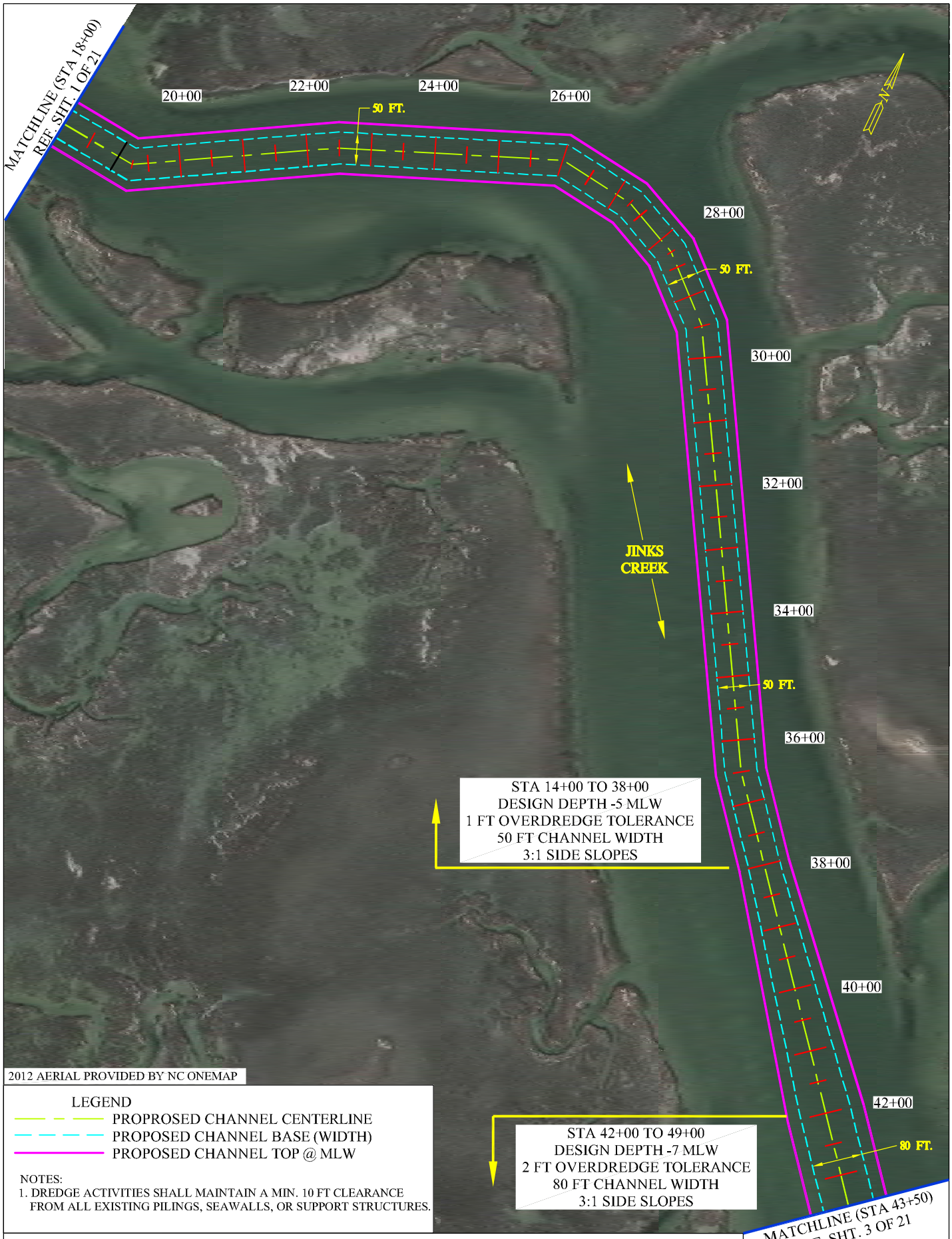
Appendix E

Preferred Alignment Plan & Profile View



TOWN OF SUNSET BEACH
PRE-DREDGE ANALYSIS
JINKS CREEK ALIGNMENT

moffatt & nichol



2012 AERIAL PROVIDED BY NC ONEMAP

LEGEND

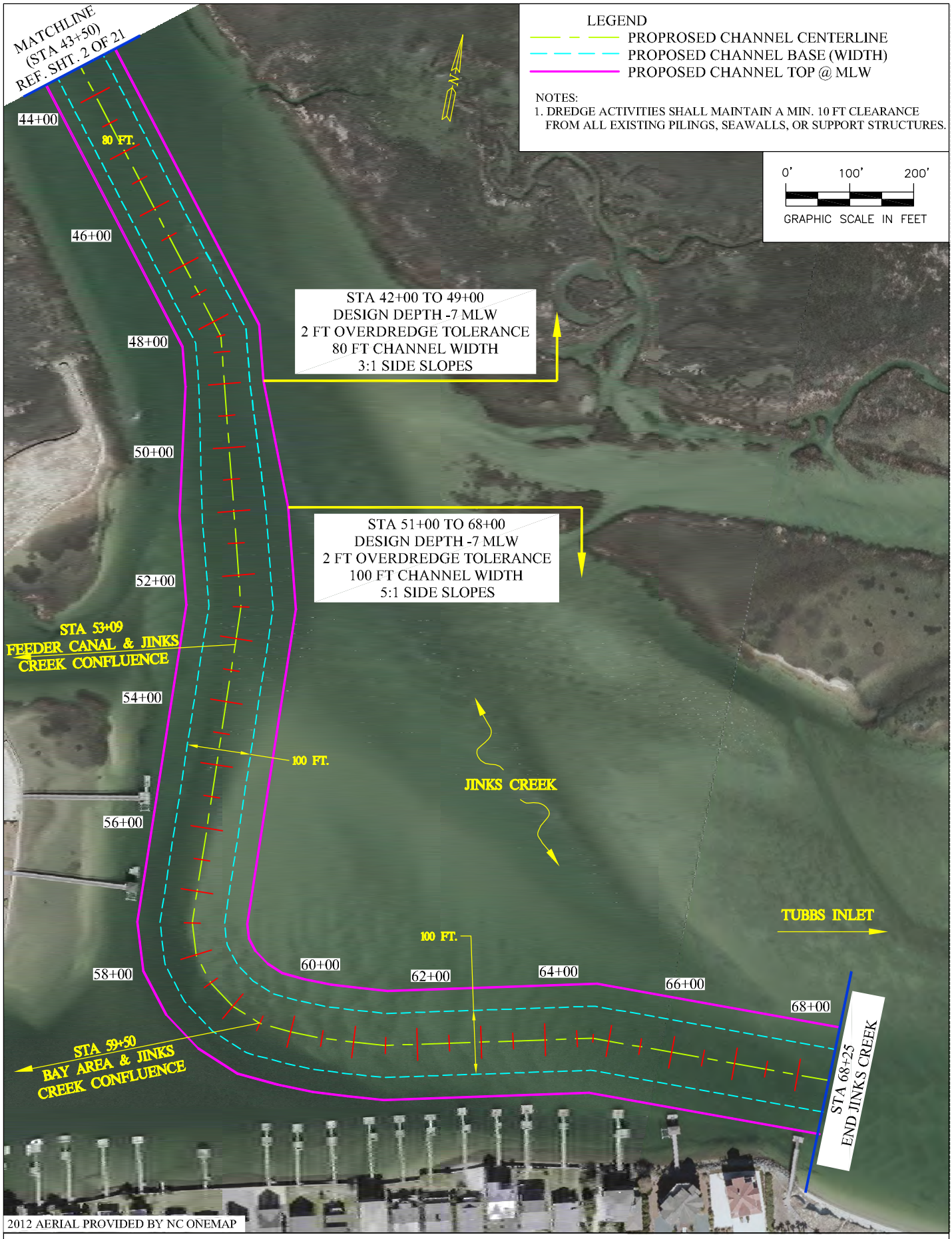
- PROPROSED CHANNEL CENTERLINE
- PROPOSED CHANNEL BASE (WIDTH)
- PROPOSED CHANNEL TOP @ MLW

NOTES:

1. DREDGE ACTIVITIES SHALL MAINTAIN A MIN. 10 FT CLEARANCE FROM ALL EXISTING PILINGS, SEAWALLS, OR SUPPORT STRUCTURES.

TOWN OF SUNSET BEACH
PRE-DREDGE ANALYSIS
JINKS CREEK ALIGNMENT

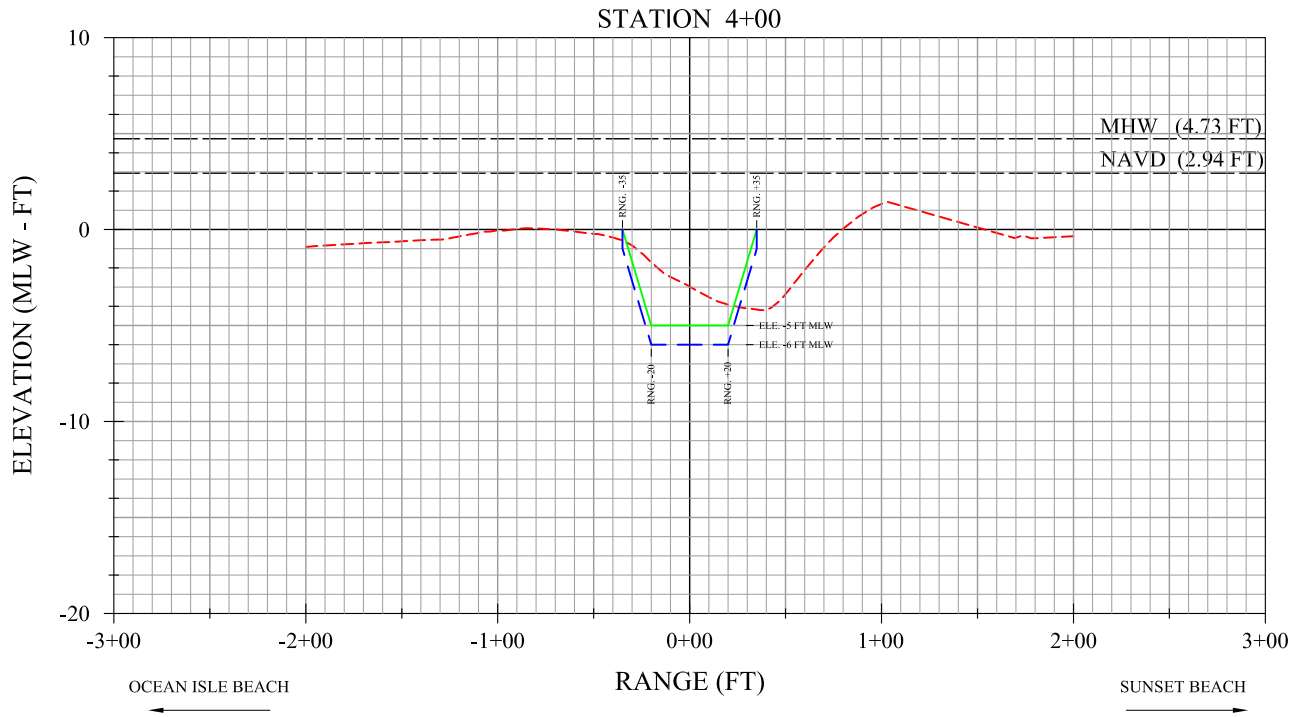
moffatt & nichol

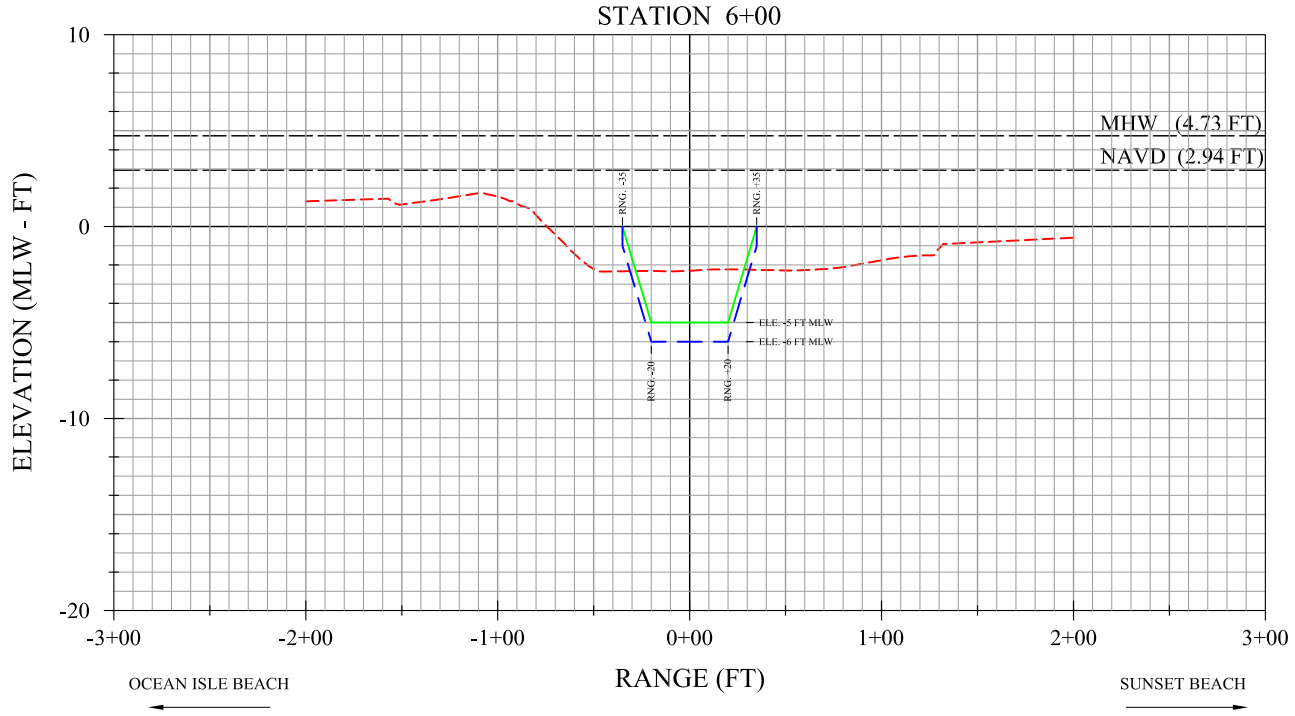


2012 AERIAL PROVIDED BY NC ONEMAP

TOWN OF SUNSET BEACH
PRE-DREDGE ANALYSIS
JINKS CREEK ALIGNMENT

moffatt & nichol





FOR REVIEW ONLY - NOT FOR CONSTRUCTION

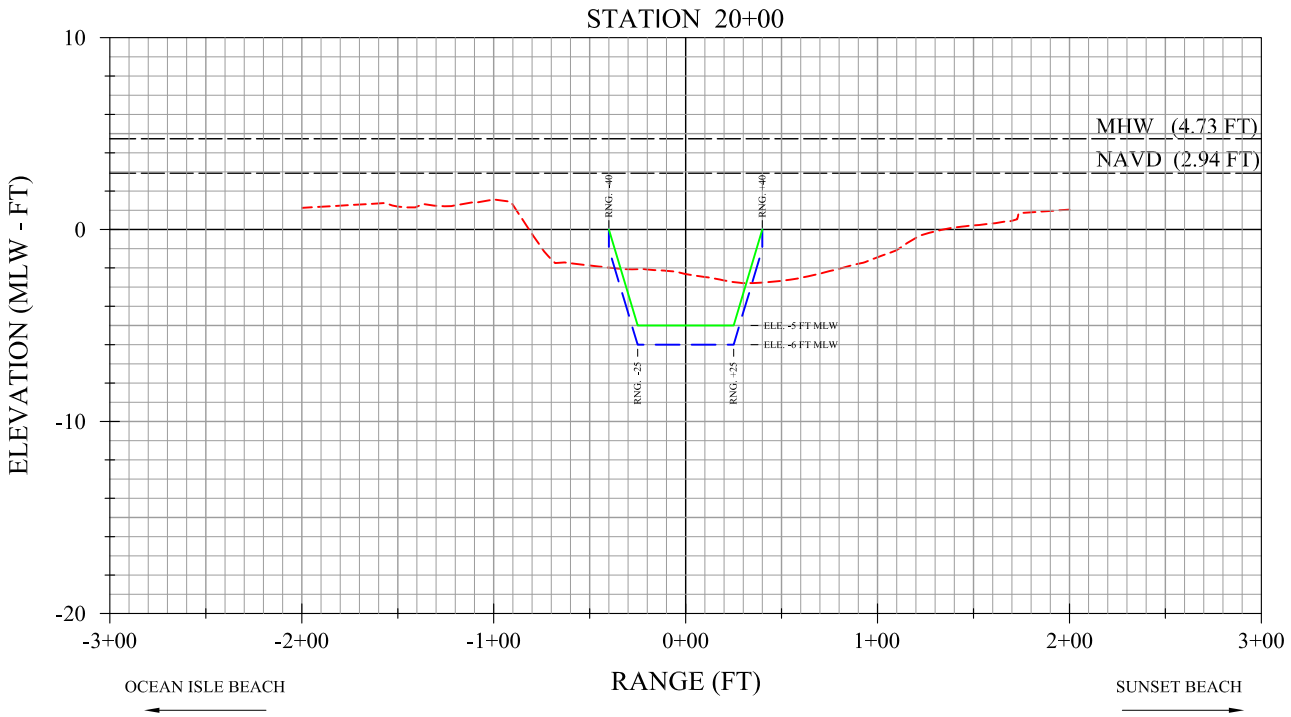
LEGEND

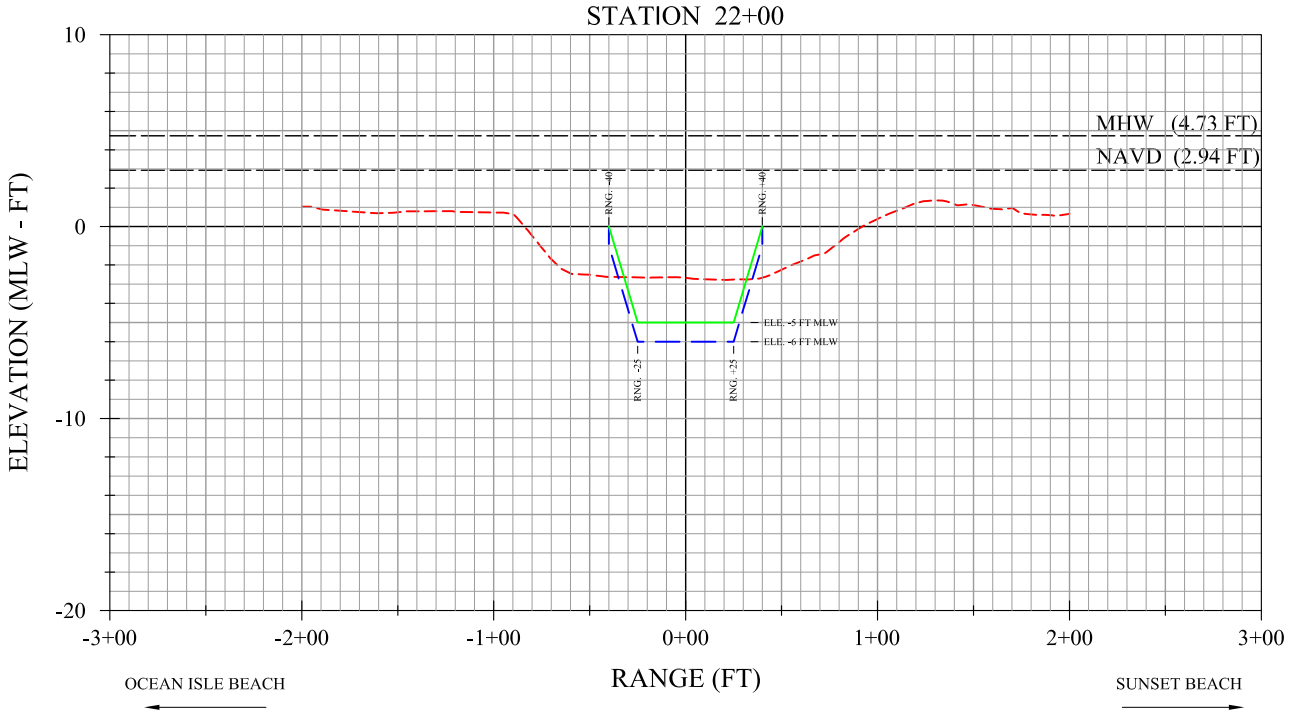
- EXISTING PROFILE (FEB. 2016)
- PROPOSED DESIGN TEMPLATE
- PROPOSED OVERDREDGE TEMPLATE

0' 5' 10'
VERTICAL SCALE: 1"=10'
0' 50' 100'
HORIZONTAL SCALE: 1"=100'

TOWN OF SUNSET BEACH
PRE-DREDGE FEASIBILITY STUDY
JINKS CREEK PROFILES
STA 4+00 & 6+00

moffatt & nichol





FOR REVIEW ONLY - NOT FOR CONSTRUCTION

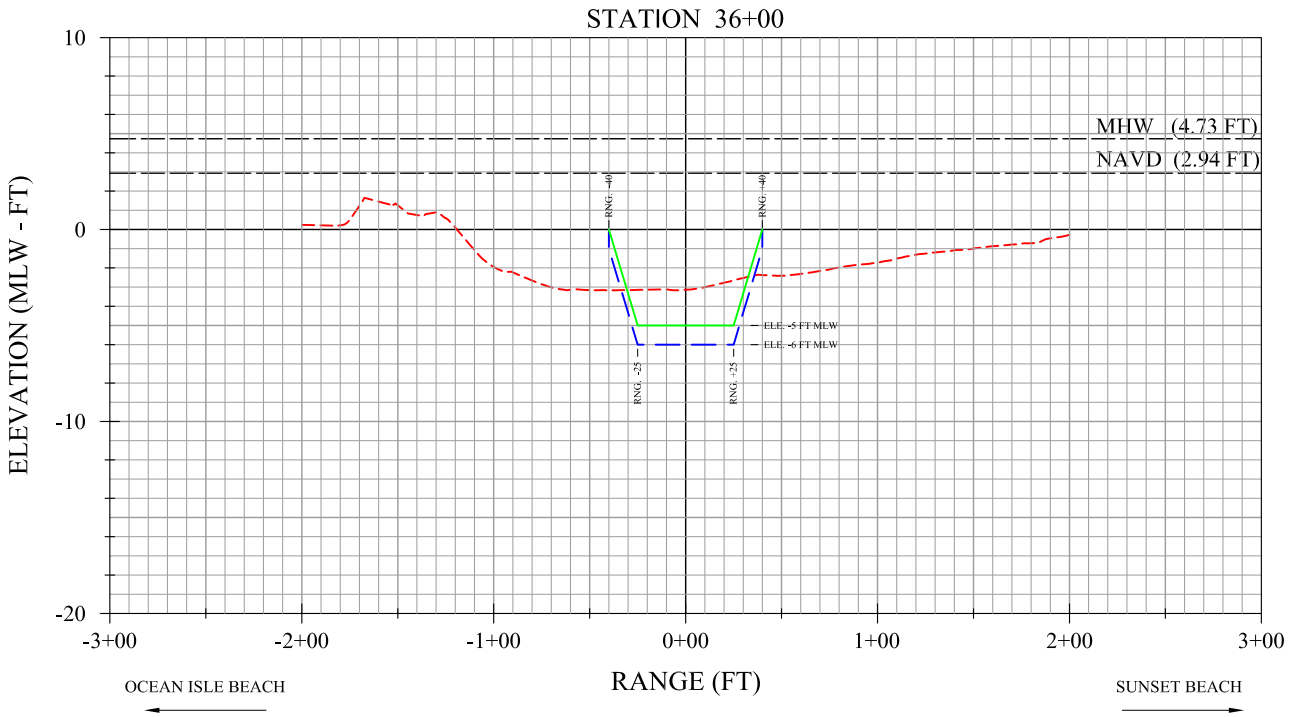
LEGEND

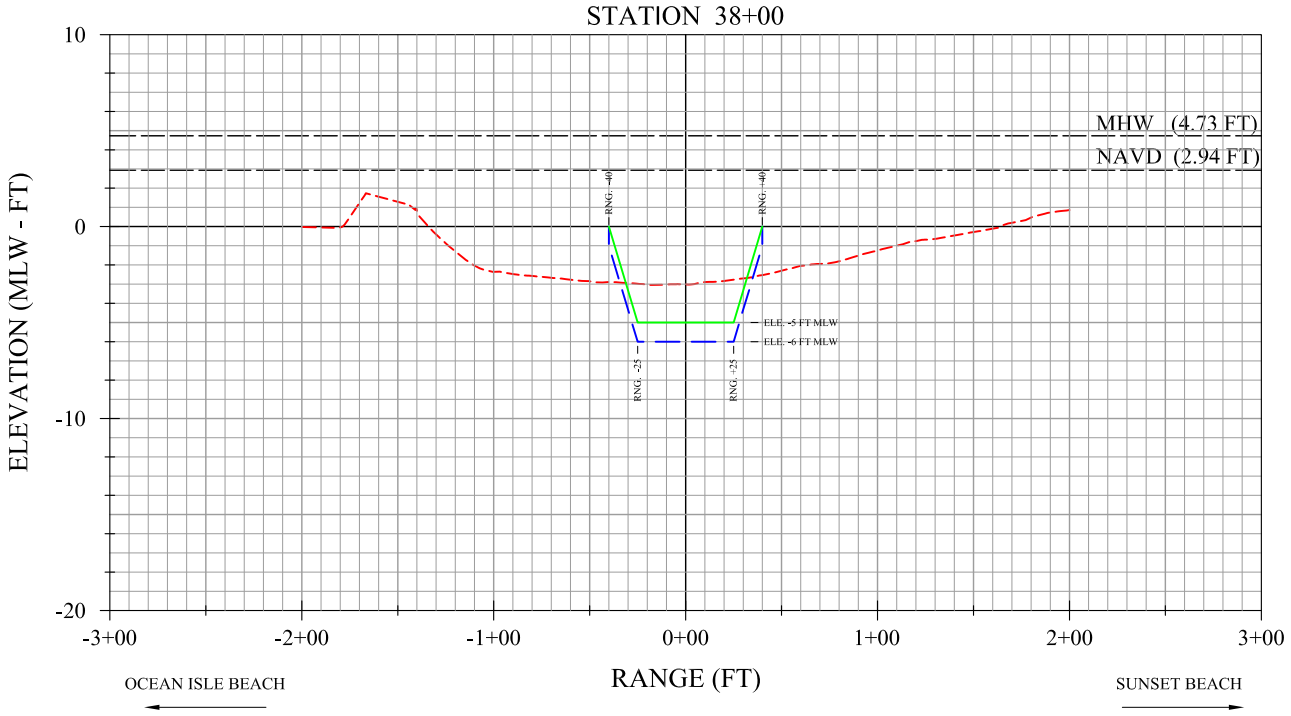
- EXISTING PROFILE (FEB. 2016)
- PROPOSED DESIGN TEMPLATE
- PROPOSED OVERDREDGE TEMPLATE

0' 5' 10'
VERTICAL SCALE: 1"=10'
0' 50' 100'
HORIZONTAL SCALE: 1"=100'

TOWN OF SUNSET BEACH
PRE-DREDGE FEASIBILITY STUDY
JINKS CREEK PROFILES
STA 20+00 & 22+00

moffatt & nichol





FOR REVIEW ONLY - NOT FOR CONSTRUCTION

LEGEND

- EXISTING PROFILE (FEB. 2016)
- PROPOSED DESIGN TEMPLATE
- PROPOSED OVERDREDGE TEMPLATE

0' 5' 10'
VERTICAL SCALE: 1"=10'
0' 50' 100'
HORIZONTAL SCALE: 1"=100'

TOWN OF SUNSET BEACH
PRE-DREDGE FEASIBILITY STUDY
JINKS CREEK PROFILES
STA 36+00 & 38+00

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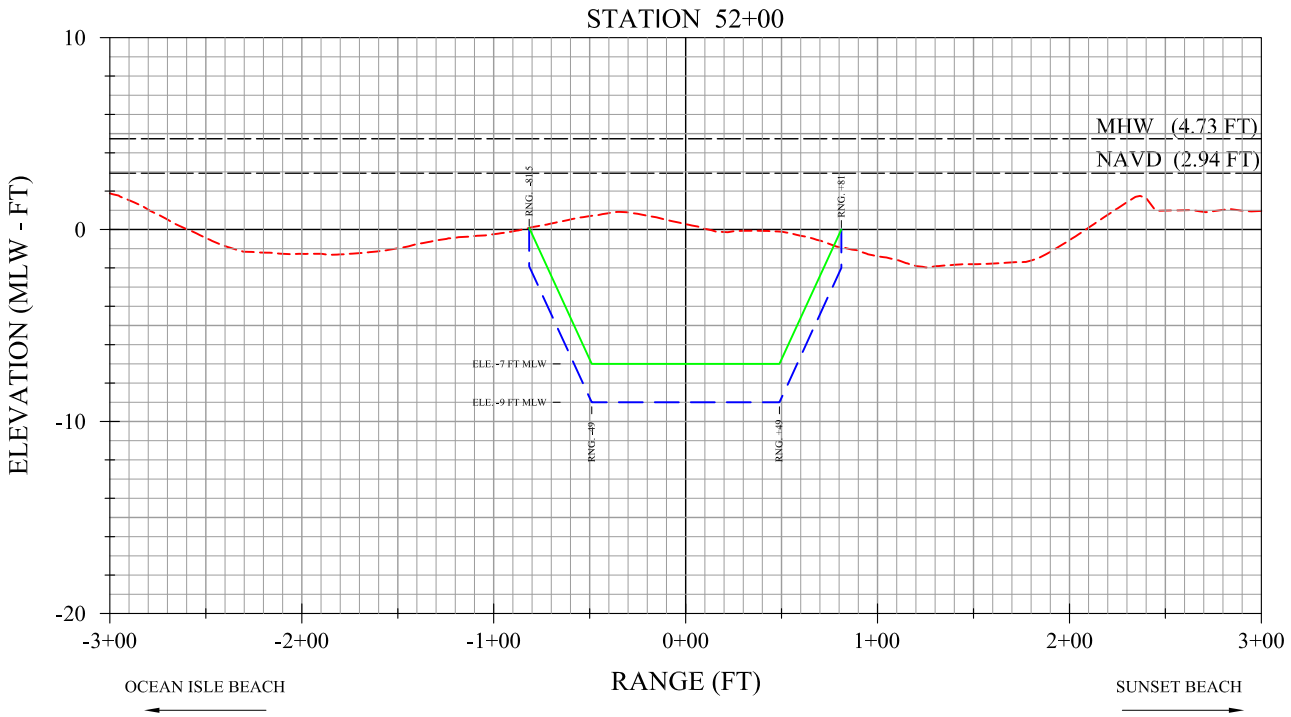

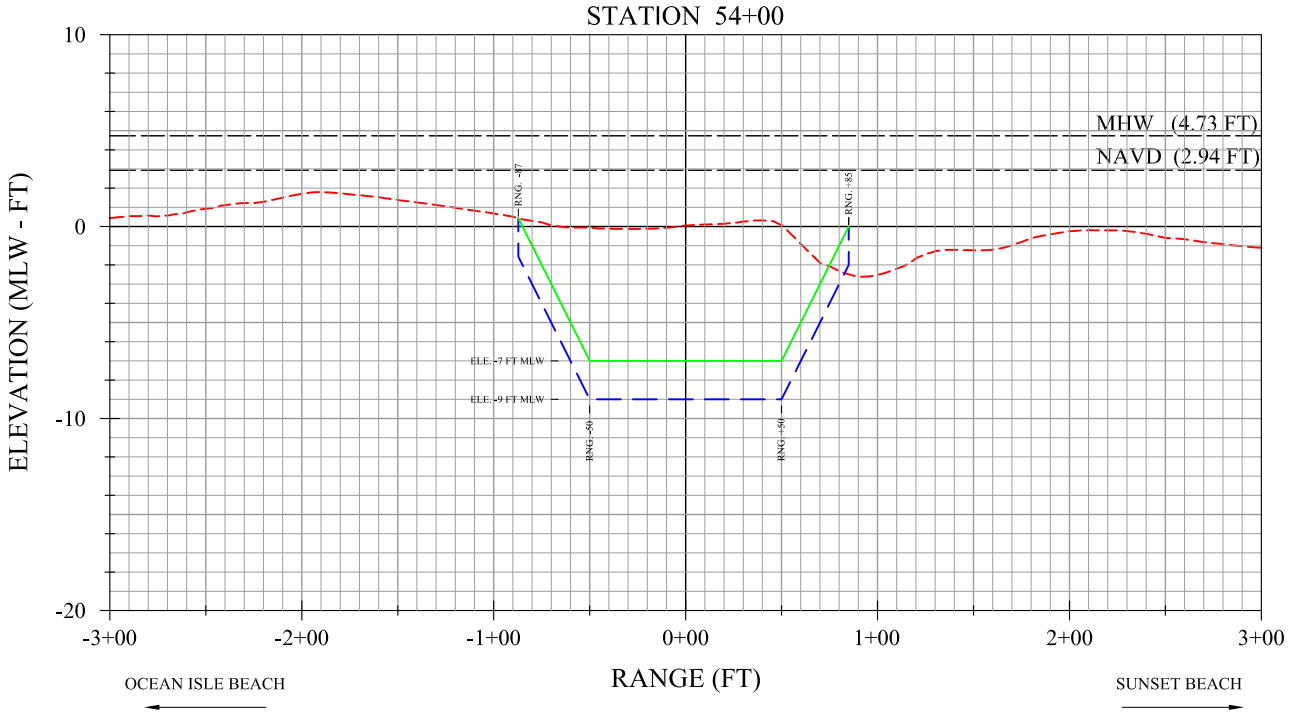

FOR REVIEW ONLY - NOT FOR CONSTRUCTION

LEGEND

- EXISTING PROFILE (FEB. 2016)
- PROPOSED DESIGN TEMPLATE
- PROPOSED OVERDREDGE TEMPLATE

0' 5' 10'
VERTICAL SCALE: 1"=10'
0' 50' 100'
HORIZONTAL SCALE: 1"=100'

TOWN OF SUNSET BEACH
PRE-DREDGE FEASIBILITY STUDY
JINKS CREEK PROFILES
STA 52+00 & 54+00

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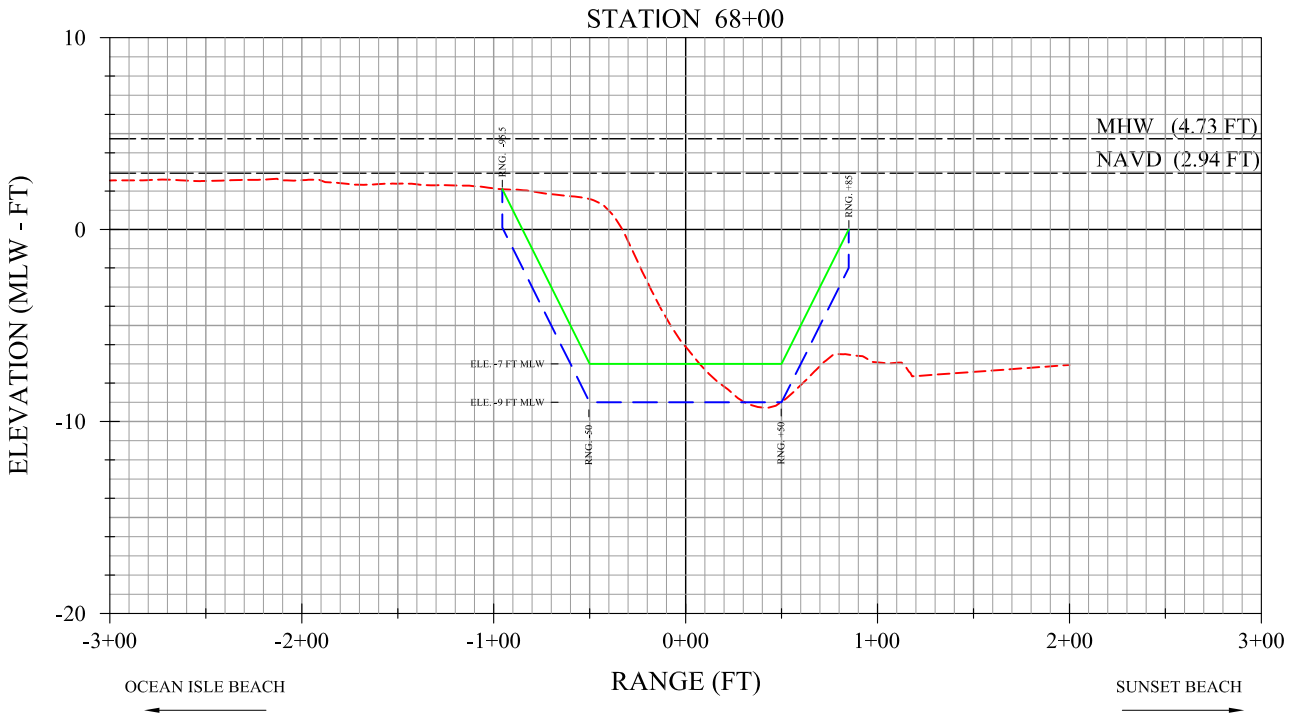

FOR REVIEW ONLY - NOT FOR CONSTRUCTION

LEGEND

- EXISTING PROFILE (FEB. 2016)
- PROPOSED DESIGN TEMPLATE
- PROPOSED OVERDREDGE TEMPLATE

0' 5' 10'
VERTICAL SCALE: 1"=10'
0' 50' 100'
HORIZONTAL SCALE: 1"=100'

TOWN OF SUNSET BEACH
PRE-DREDGE FEASIBILITY STUDY
JINKS CREEK PROFILES
STA 68+00

moffatt & nichol

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