Brunswick Harbor Modifications Study, Glynn County, GA

Appendix B

Engineering and Design

U.S. ARMY CORPS OF ENGINEERS
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a. Background

Brunswick Harbor is a federally authorized navigation project located in the southeastern section of Glynn County, Georgia, adjacent to the City of Brunswick. The harbor is approximately 70 miles south of Savannah, Georgia and 60 miles north of Jacksonville, Florida. The Brunswick Navigation Channel and Harbor is used primarily for the import of new vehicles by Roll On – Roll Off (Ro/Ro) ships through Colonel's Island Terminal which is operated and maintained by the Georgia Ports Authority (GPA). Additionally, cargo ships utilize the harbor to transport bulk commodities including wood and agricultural products.

b. Hydrology and Floodplains

Brunswick Harbor is located on the Turtle and Brunswick Rivers in the Satilla River Basin. The Satilla River Basin is approximately 3,940 square miles of coastal plain composed primarily of the Satilla River, Little Satilla River, and Turtle River. The Satilla River Basin flows from the headwaters in Ben Hill County, Georgia to the Atlantic Ocean in Brunswick, Georgia. Figure 1 shows the location of Brunswick Harbor. Figure 2 shows the location of Brunswick Harbor within the Satilla River Basin.

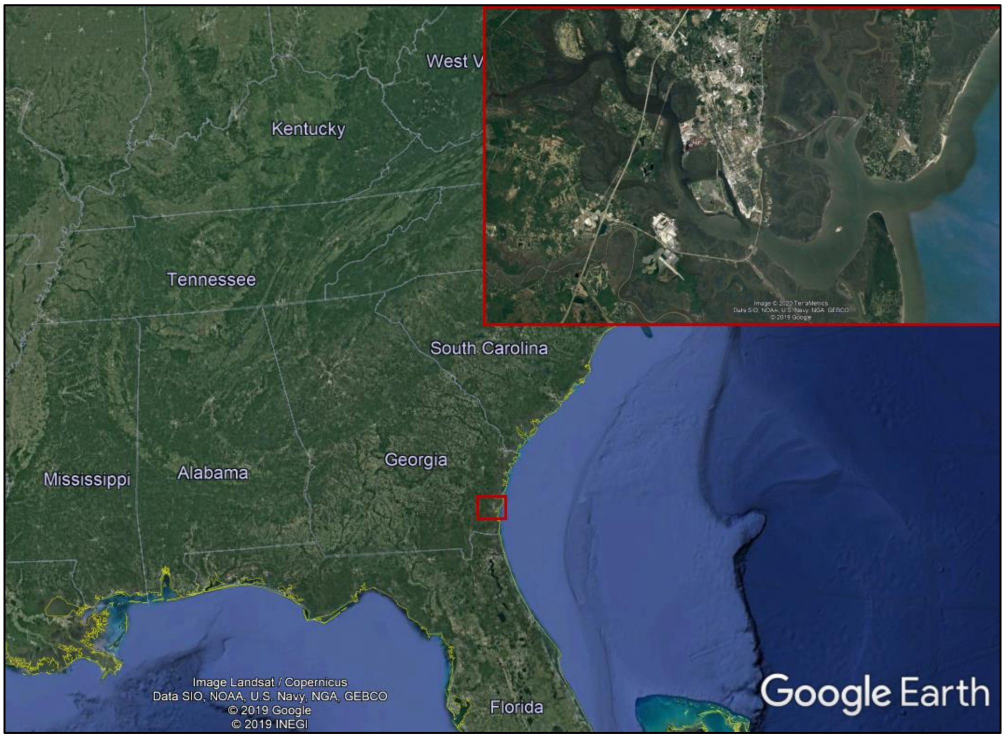


Figure 1 - Location of Brunswick Harbor

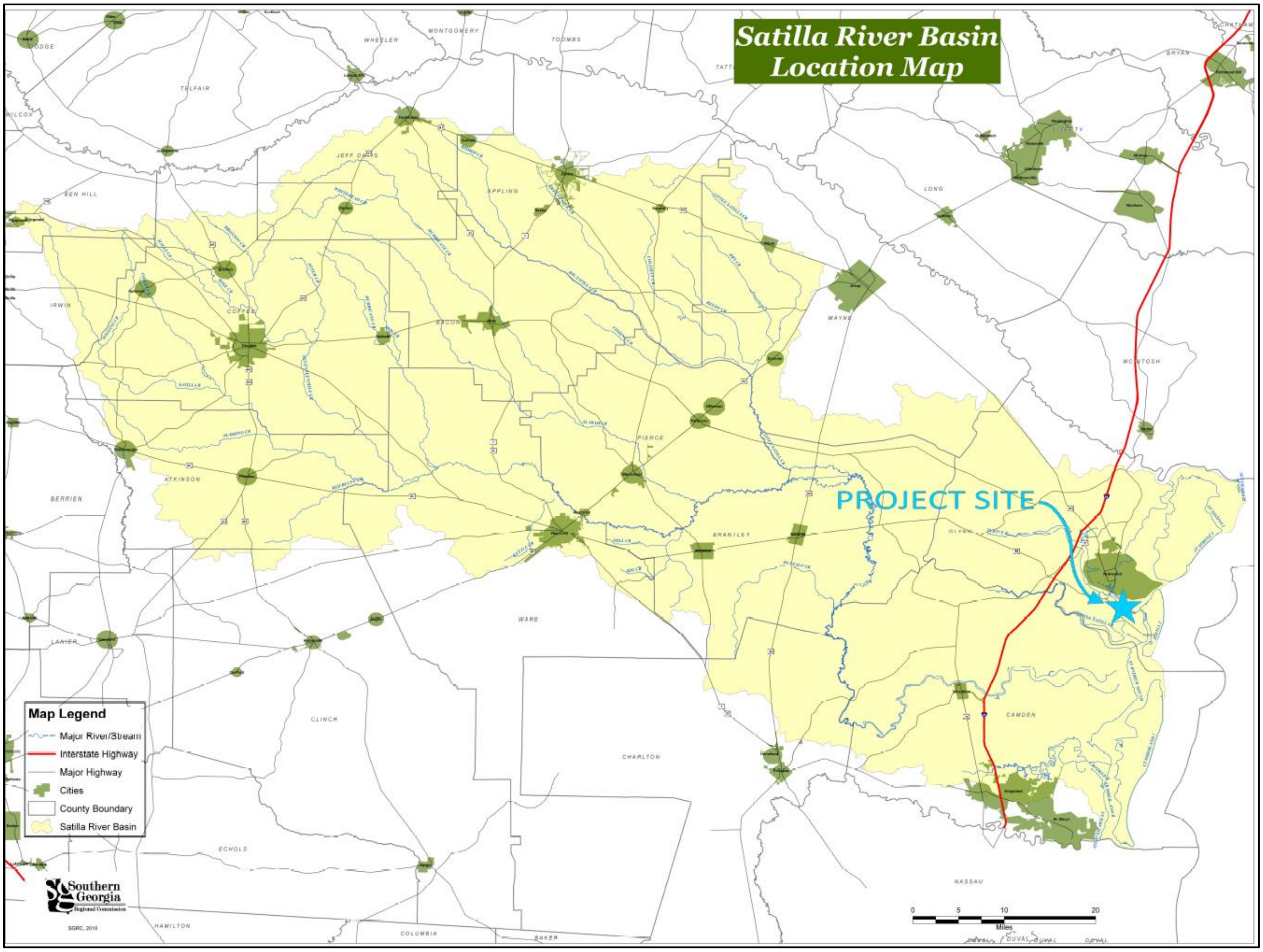


Figure 2 - Location of Brunswick Harbor Within Satilla River Watershed (Satilla Riverkeeper, 2019)

The major drainage in the project vicinity includes Turtle River and South Brunswick River. Both rivers flow from the west, merge just east of Colonel's Island, and flow through Brunswick Harbor to the St. Simon's Sound. East River is oriented in a roughly north/south direction, passing along the east side of Andrews Island before discharging into Brunswick River just upstream of the Sidney Lanier Bridge (US Highway 17.) In addition to these main streams, a complex network of small streams, creeks, and tidal sloughs dissects the entire estuarine complex *(Brunswick EIS, 1998)*.

Tides in the project area are semidiurnal (two equally proportioned high and low tides every lunar day). The mean tide range in Brunswick Harbor is approximately 6.5 feet near the St. Simon's Sound and 7.3 feet. in East River. Maximum ebb velocities usually range from 1.5 to 3.0 feet per second during mean tide conditions. Extreme Spring tides can exceed 7.5 feet near St. Simon's Sound with velocities exceeding 3.0 feet per second. While it is at the discretion of the Harbor Pilots, navigation is usually halted during sustained winds over 25 knots during max ebb and flood tide conditions.

The climate of Brunswick is generally pleasant with short mild winters and hot, humid summers. The temperate to subtropical climate of the South Atlantic Bight is influenced by the location of the Azores high-pressure system. High pressure is located offshore at is southern extent during winter months resulting in contact between polar and tropical air masses. The result is strong winter storms with gusty winds. Rainfall in the Brunswick area is typically 50 inches per year with the highest rainfall normally in August and September. Other precipitation is rare. Hurricane season generally extends from late May to late October with the coastal region of Georgia ranked as a moderately high risk zone.

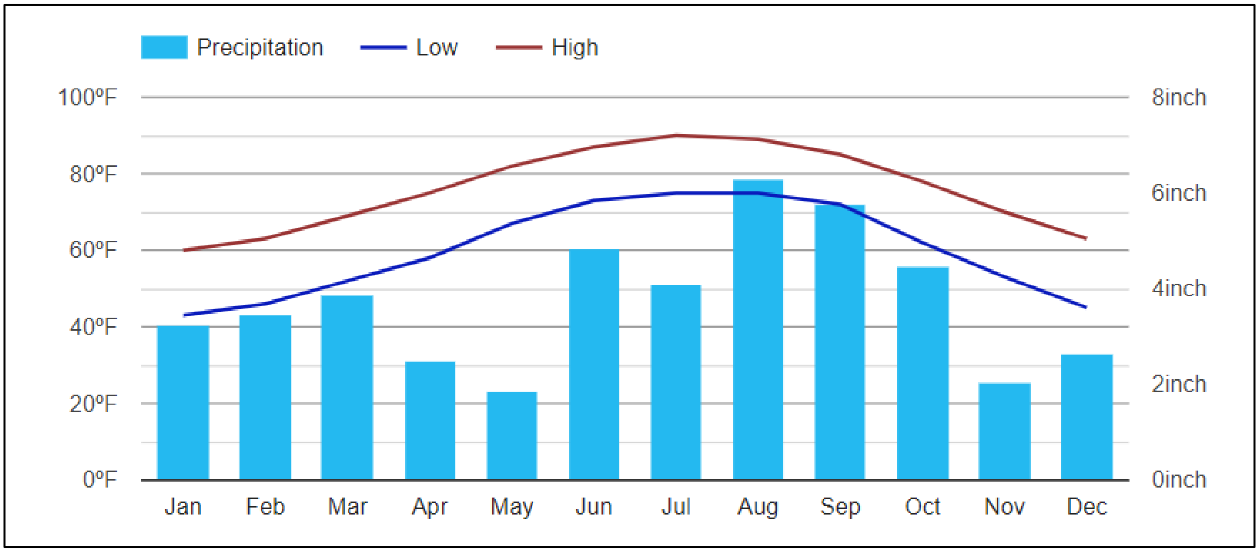


Figure 3 – Average Annual Rainfall and Temperatures for Brunswick, GA (US Climate Data, 2020)

c. Currently Authorized Project

The project area includes the 500 feet wide Brunswick River entrance channel which extends approximately 13.5 miles into the Atlantic Ocean as well as the inner harbor reaches which transit through St. Simon's Sound, Brunswick River, Turtle River, and East River. The inner harbor reaches have an authorized project depth of -36 feet mean lower low water (MLLW) and a width of 400 feet. Figure 4 and Figure 5 shows the existing channel configuration of Brunswick Harbor.

Brunswick Harbor was deepened 6 feet to -36 feet (MLW) in the inner harbor and -38 feet (MLW) in the bar entrance channel during the 1998 deepening. This authorized depth continues to be maintained. The current federal channel was deepened for a RO/RO design vessel with dimensions of 660 feet long and 106 feet wide. Table 1 shows the existing channel dimensions for the ranges within Brunswick River, South Brunswick River, and East River.

Table 1 – Existing Channel Dimensions

River	Range	Channel Width (feet)	Depth/Adv. Maintenance (feet MLLW)	Length (miles)
Brunswick	St. Simons	500	-38.0/-40.0	9.7
Brunswick	Plantation Creek	400	-36.0/-38.0	1.8
Brunswick	Jekyll Island	400	-36.0/-38.0	1.9
Brunswick	Cedar Hammock	400	-36.0/-38.0	1.4
Brunswick	Brunswick Point Cut	400	-36.0/-38.0	2.4
Brunswick	Turtle River Lower	400	-36.0/-38.0	1.8
Brunswick	Blythe Island	300	-30.0/-32.0	1.5
Brunswick	Turtle River Upper	300	-30.0/-32.0	2.7
South Brunswick	South Brunswick	400	-36.0/-38.0	1.3
East River	Entrance to Second Ave	400	-37.0/-39.0	1.2
East River	Second Ave to Mayor's Point	400	-36.0/-38.0	1.0
East River	East River Turning Basin	1100	-37.0/-39.0	0.9

Figure 4 - Existing Entrance Channel Configuration of Brunswick Harbor

Figure 5 – Existing Inner Harbor Channel Configuration of Brunswick Harbor

d. Navigation Challenges

Discussions were held with the harbor pilots who currently serve Brunswick Harbor in an effort to obtain information from those most familiar with navigation and vessel movement in the channel under the various wind, tide and current conditions. Results of these discussions are reflected below and in the Ship Simulation Report in Attachment B-1.

Large vessels transporting rolling cargo are typically referred to as “roll-on/roll-off” or Ro/Ro vessels. Ro/Ro vessels have increased in both length and width since design of the existing project. There are multiple locations within the Federal channel where vessels experience navigational challenges due to vessel size. Self-imposed transportation safety restrictions are in place such as waiting for suitable weather (including favorable tides), one-way traffic for most of the harbor, and utilizing tug boats earlier in the berthing process. Larger Ro/Ro vessels are experiencing transportation cost inefficiencies due to these restrictions at targeted areas within the confined Federal channel. The initial areas of concern, as identified by the Brunswick Harbor Pilots, include the area near U.S. Coast Guard (USCG) Buoy 24 (where Cedar Hammock Range and Brunswick Point Cut Range 4 intersect) and the existing turning basin located near the Colonel’s Island facility where Ro/Ro vessels berth. Figure 6 shows the initial areas of interest for this feasibility study.

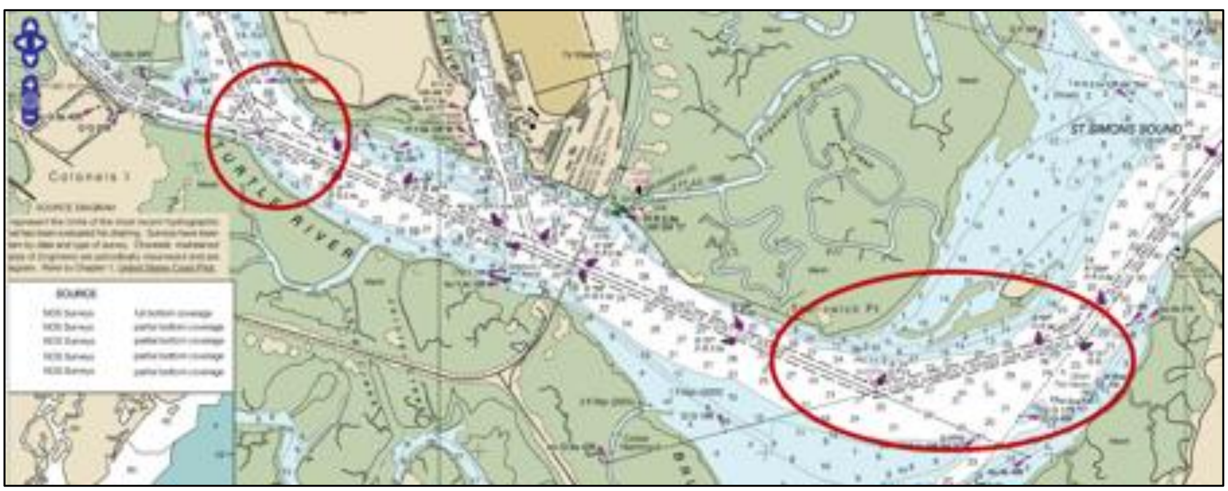


Figure 6– Initial Study Areas of Interest

Upon further discussions between the Project Delivery Team (PDT) and the Brunswick Harbor Pilots, two more areas of congestion were identified as potential meeting areas which could alleviate wait times and increase harbor transit efficiencies, allowing vessels to dock at their intended berths faster. The locations identified include a meeting area on the Turtle River Lower Range between the Sidney Lanier Bridge and the existing turning basin and as well as a meeting area at the Plantation Creek Range in the St. Simons Sound. Figure 7 shows all of the final study areas of interest for this project.

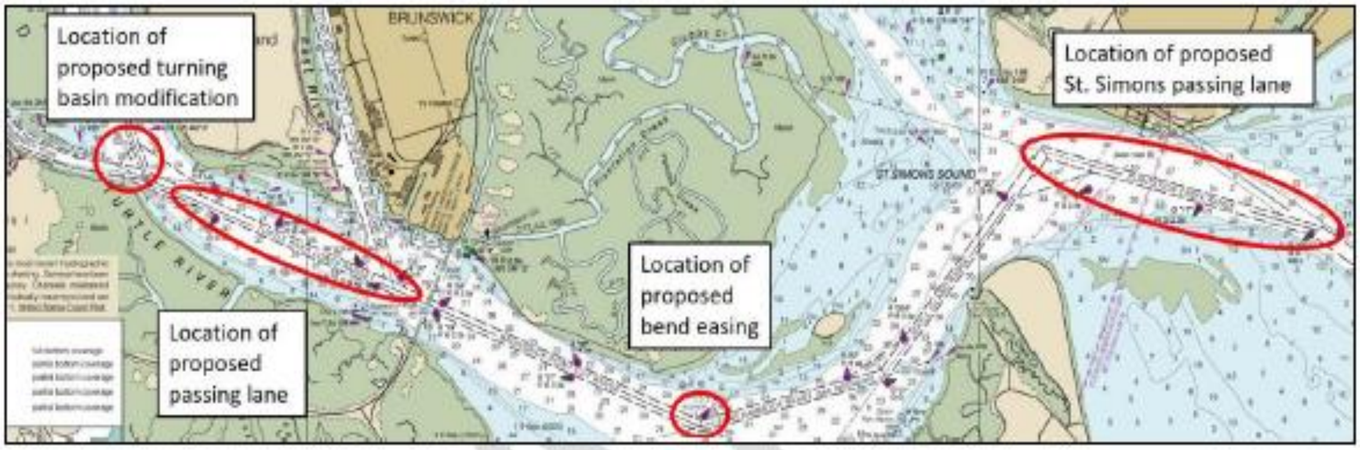


Figure 7 – Final Study Areas of Interest

The Colonels Island Terminal located on the South Brunswick River currently has three berths, but an additional berth was recently approved for construction. For this feasibility study, the proposed new berth, Berth 0, was included in all designs as well as in ship simulation, as this berth will be constructed regardless of the outcome of this study. Figure 8 shows the approximate location of Berth 0.

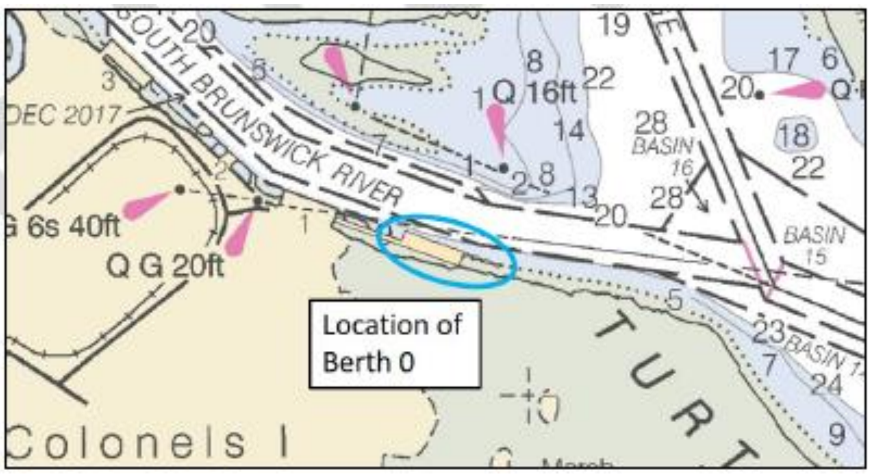


Figure 8 - Proposed Location of Berth 0

e. Existing Conditions

Bathymetry for the project study area was obtained through several different sources: multiple bathymetric surveys performed by Savannah District Survey Section (June/July 2019), the National Elevation Dataset (NED), and the Coastal Relief Model (CRM). Engineer Research and Development Center Coastal Hydraulics Lab (ERDC-CHL) performed a 13 hour field data collection effort in July 2019 to collect discharge and velocity measurements using acoustic doppler current profilers (ACDPs). Six transects were performed from the inlet to locations upstream. Figure 9 shows the ACDP transects collected along with the merged base bathymetry map created for the hydrodynamic model domain. ADCP Bathymetry and survey data were used for multiple purposes including initial alternative designs, hydrodynamic model development, ship simulation, estimated dredging quantities for informing cost estimates, as well as alternative developments and refinements.

A numerical model was developed to analyze potential modifications of the Brunswick Navigation Channel. The model was developed such that the natural driving forces of the system are included — winds, tides, and friction effects. The model results are compared to field data collected during the simulation period to ensure an accurate representation of nature.

For this study, the 2D shallow water module of Adaptive Hydraulics Model System (AdH) was applied for all simulations. This code solves for depth and depth-averaged velocity throughout the model domain. AdH version 4.6 was applied for this study.

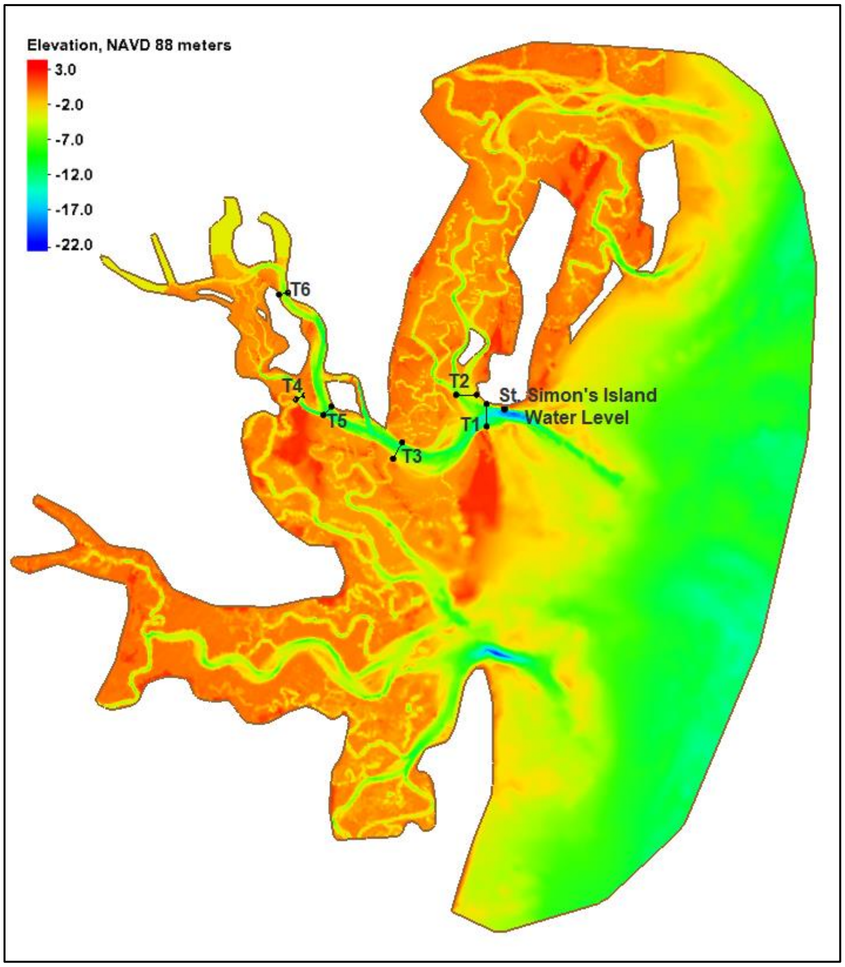


Figure 9– Six Transects Where Discharge and Velocity were collected for Hydrodynamic Modeling

Discharge comparisons were evaluated between modeled discharge and discharge at the six transects that were included in the CHL field data collection. Figure 10 through Figure 14 shows the time history discharge (positive: flood; negative: ebb) for these locations. The discharge compares well overall. There is some disagreement in the time of arrival of the peak flood at transects 2 and 4. These areas are impacted greatly by shallow backwater flow which may not be defined with enough detail as necessary to correctly reproduce the timing. The model is low on the discharge range at transect 5 and low on the ebb magnitude at transects 4 and 6. Given the good agreement of the model at transect 3, additional connectivity or roughness features in the inland area of the channel may exist beyond what could be defined in the model. Even with these differences, the model is reproducing the dynamics of the field and is suitable to for use in ship simulation analysis.

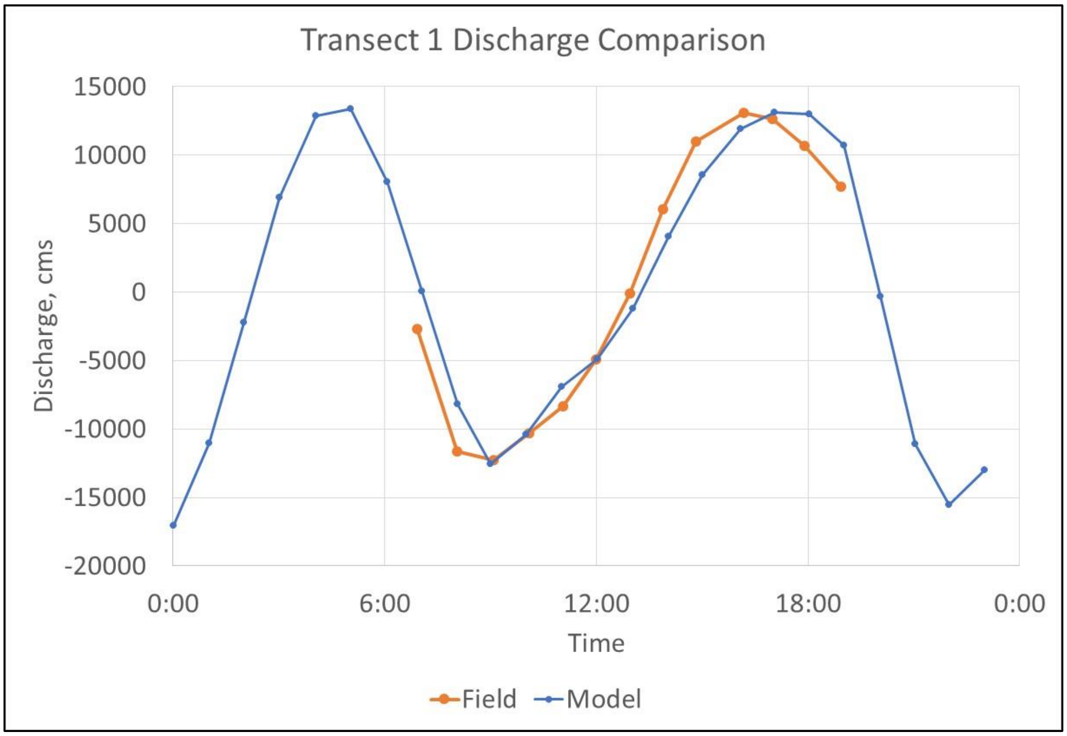


Figure 10 – Discharge Comparison at Transect 1

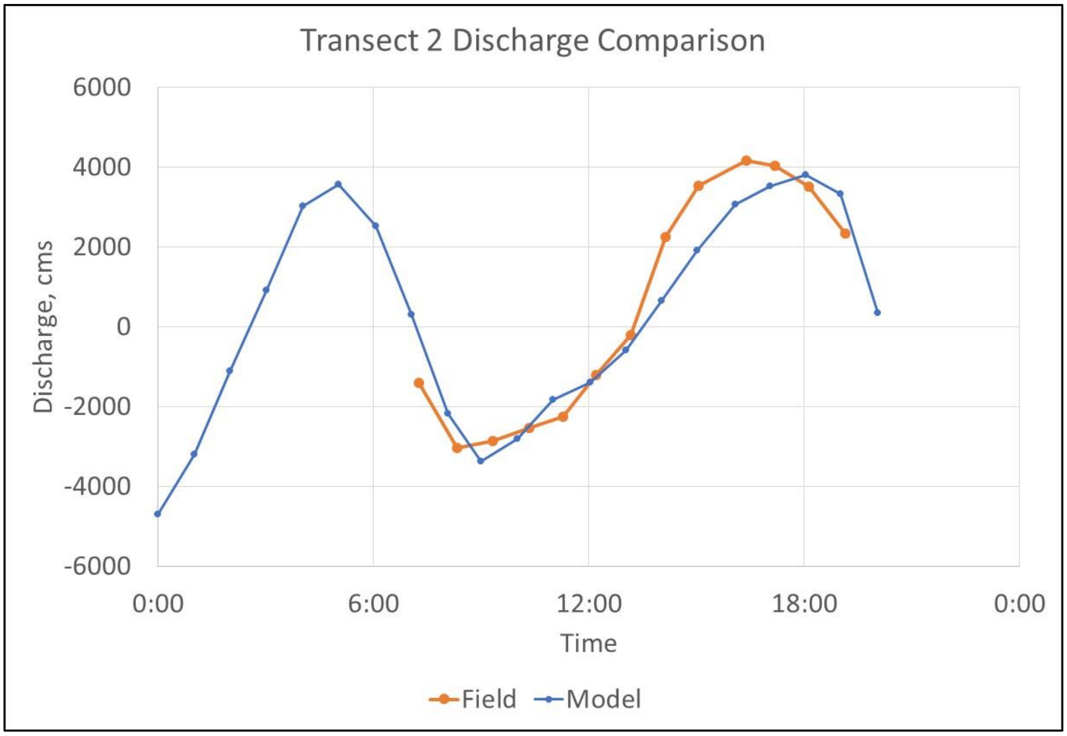


Figure 11 - Discharge Comparison at Transect 2

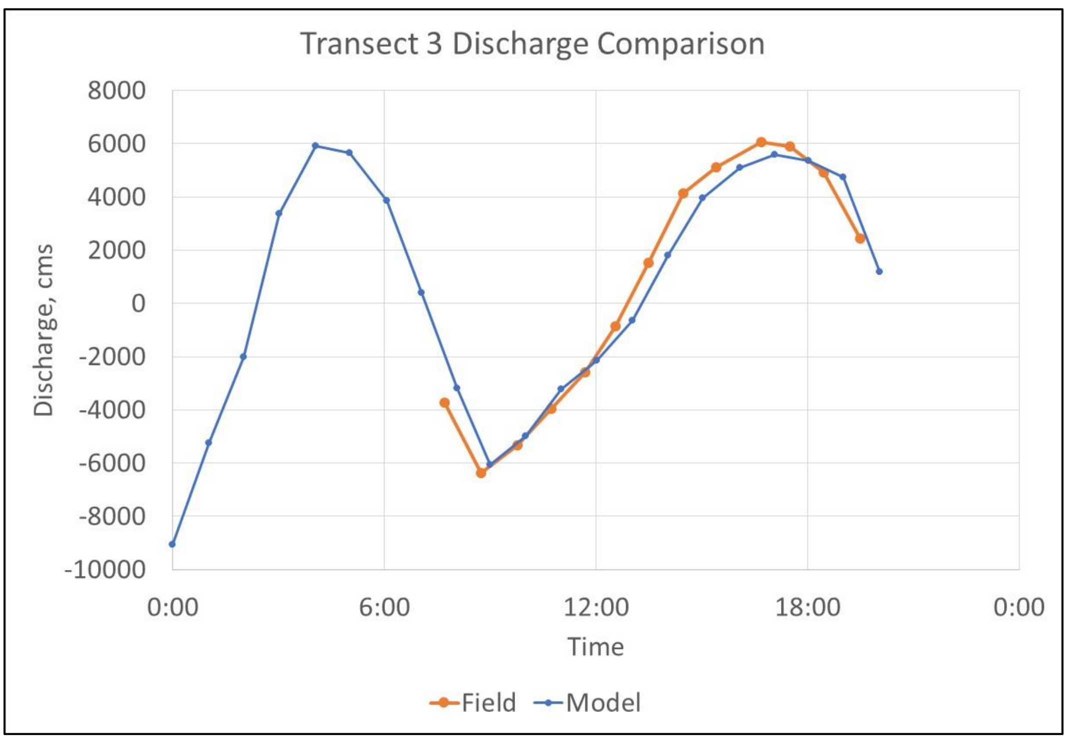


Figure 12- Discharge Comparison at Transect 3

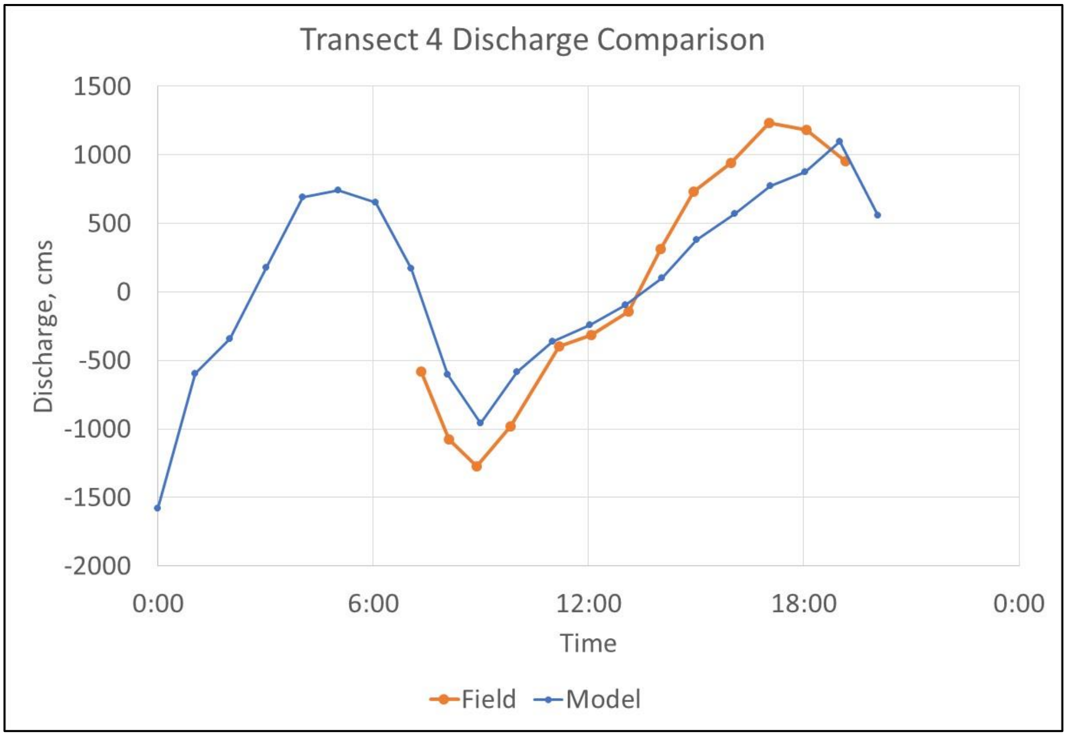


Figure 13 - Discharge Comparison at Transect 4

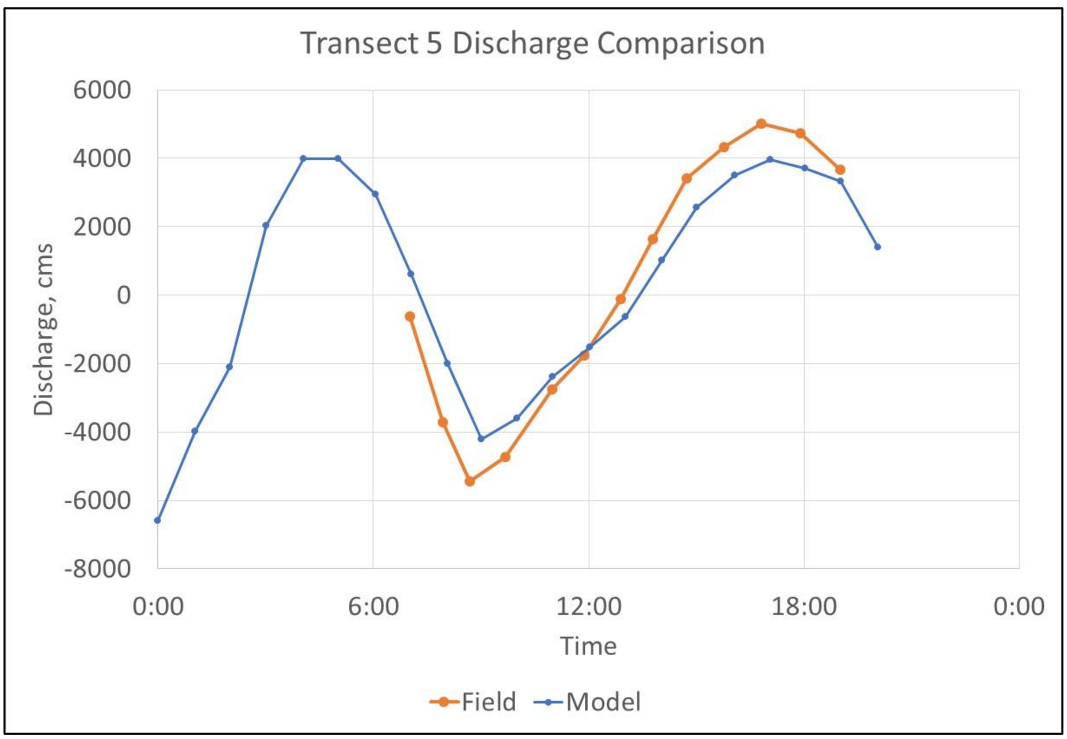


Figure 14 - Discharge Comparison at Transect 5

II. Design Considerations

The design engineer adapted the guidelines outlined in EM 2220-2-1613 (dated 31 May 2006) for improving the Brunswick Harbor deep-draft navigation project. The design goal is to provide safe, efficient, environmentally sound and cost-effective waterways for vessels to transit. The guidance presented in EM 2220-2-1613 is based on average navigation condition and situations. During the design process, the design engineer adapted these guidelines to the local, site-specific conditions of the project along with close coordination and feedback from the Brunswick Harbor Pilots. The proposed channel modifications only include widening alternatives; the overall depth of the channel will remain the same.

a. Design Vessel

Per EM 2220-2-1613, “The design ship or ships are selected on the basis of economic studies of the types and sizes of the ship fleet expected to use the proposed navigation channel over the project life.
For project improvement studies, a thorough review and analysis of ships presently using the project should be included as a part of the study (USACE EM 2220-2-1613). The design vessel was chosen with input from several team members, including engineering, economics, ERDC, Georgia Ports Authority (GPA), as well as the Brunswick Harbor Pilots. Upon extensive discussion and with careful consideration, the PDT proceeded with a HERO (High-Efficiency Ro/Ro) Class Design Vessel. HERO vessels are larger, more energy- and fuel-efficient ships capable of moving upwards of 8,000 automobiles per sailing. The chosen design vessel has the following dimensions:

- Overall length (LOA) of 656 feet (200 m)
- Beam of 120 feet (36.5 m)
- Draft of 33.8 feet (10.3 m)

Port call data was gathered from the National Navigation Operation and Maintenance Performance Evaluation and Assessment System (NNOMPEAS) as well as from the GPA and evaluated for the previous 5 years, between 2014 and 2019. According to the data gathered from 2014-2019, the design drafts (maximum summer load line draft) of HERO ships calling on Brunswick Harbor typically ranged from between 31.9 feet to 34.9 feet, while the actual recorded transit drafts ranged from 26 feet to 33.8 feet. This range in transit drafts is due to ships arriving only partially loaded. Ultimately, 33.8 feet was chosen as the design draft as it is the largest draft of a HERO vessel recorded in the previous 5 years. Figure 15 shows the ship’s particulars copied from the Pilot Card. More specific details (propulsion and steering particulars, etc) on the design vessel ship particulars can be found in the Ship Simulation Report Addendum).

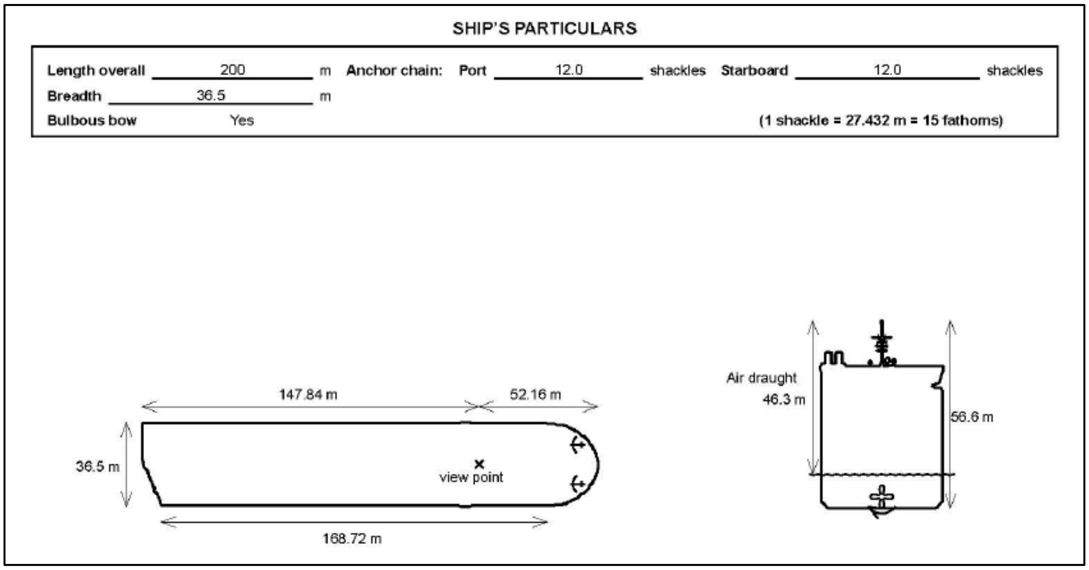


Figure 15– Pilot Card for Design Vessel

b. Bend Widener

In February 2008, GPA requested that the U.S. Army Corps of Engineers (USACE), Savannah District, investigate two areas in Brunswick Harbor identified by the Brunswick Harbor Pilots as problem areas for vessel maneuverability. The first area of concern was in the vicinity of Coast Guard Buoy 24 at the intersection of the Cedar Hammock Range and the Brunswick Harbor Range, known as Widener 13. The second area of concern was the width of the South Brunswick River Turning Basin near Colonel's Island Docks, which is discussed in a following section. Figure 16 shows the location of the proposed bend widener near Coats Guard Buoy 24.

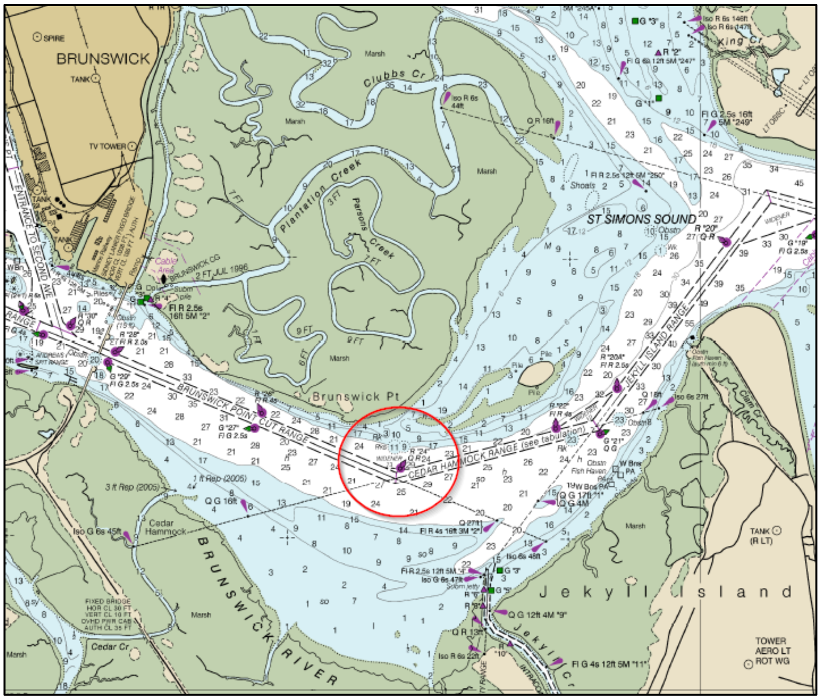


Figure 16– Location of Proposed Bend Widener

Channels with bends are more difficult to navigate compared with straight reaches because of reduction in site distance, reduced effectiveness of aids to navigation, changing channel cross-sectional area, and greater effects from varying current and bank suction forces. The width of the ship path is dependent on the following (EM 1110-2-1613 – 31 May 2006):

1. Ship yaw angle while turning
2. Length and beam of the ship
3. Ship rudder angle
4. Possible use or nonuse of kick turning by the pilot
5. Location and spacing of aids to navigation in the turn.
6. Local current and other environmental conditions.

These issues are of concern in this portion of the channel. Harbor Pilots currently traverse Widener 13 with extremely aggressive swept paths when certain environmental conditions (both winds and tides) exist. Table 2 and Figure 17 below from EM 2220-2-1613 (Table 8-4 and Figure 8-3, respectively), along with discussion with the Harbor Pilots and observed tracked plots, were used to determine the necessary additional channel width for Widener 13.

Table 2- EM 2220-2-1613 Bend Widener Recommendations

Recommended Channel Turn Configurations			
Deflection Angle, Deg	Ratio of Turn Radius/ Ship Length	Turn Width Increase Factor (* Ship Beam)	Turn Type
0 - 10	0	0	Angle
10 - 25	3 - 5	2.0 - 1.0	Cutoff
25 - 35	5 - 7	1.0 - 0.7	Apex
35 - 50	7 - 10	0.7 - 0.5	Curved
>50	>10	0.5	Circle

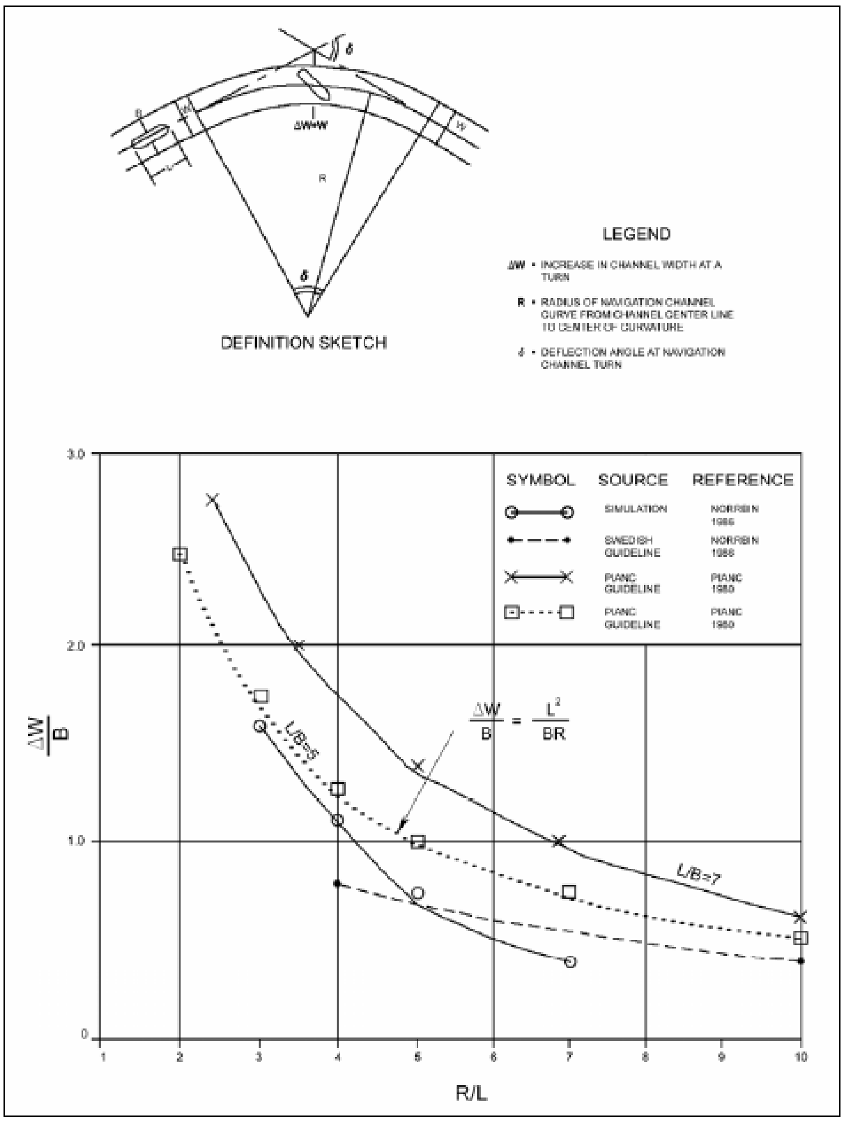


Figure 17- Channel Width Increase in Turns per EM 2220-2-1613

Bend Widener Design per EM 1110-2-1613:

Table 2 from EM 1110-2-1613 was used to determine the bend widener dimensions recommended for a HERO class vessel. The following calculations were made using the design vessel:

Deflection Angle = 38º → For a deflection angle 35º - 50º
Ratio of Turn Radius/Ship Length = 4383 feet/656 feet = 7.5 → For a Turn Width Increase Factor of 0.8
Turn Width Increase Factor* Beam = 0.8 * 120 feet = 96 feet;
Width + 96 = 562 + 96 = 658 feet→ Round up to 700 feet
Calculated Bend Width: 700 FEET

In addition to calculating the recommended width from EM 1110-2-1613, the design engineer also considered the existing channel. Located near Station 1+500, downstream of Widener 13, is another channel bend known as Widener 12. Widener 12 has the same deflection angle (38°) and a similar channel width (565 feet compared to a width of 562 feet). The bends are nearly identical in shape and width, with the exception that Widener 12 currently has additional easing, shown in the figure below. The Harbor Pilots are able to navigate Widener 12 safely and efficiently even under undesirable navigation conditions (e.g. 25 knots of wind from the NE with a max flood tide).

Further, the Harbor Pilots provided observed tracked plots from completed jobs which they store using SEAiq Pilot Tracking Software. SEAiq Pilot is a GPS enabled navigation software designed specifically for use by pilots during transits. There are many software features which benefit the Harbor Pilots during transit and are also beneficial for the Engineer in evaluation of proposed channel designs. Figure 18 shows an example of an outbound vessel transiting around Buoy 24 tracked in the SEAiq Pilot Software. Numerous tracked plots were evaluated for transits inbound and outbound near both Buoy 24 (Widener 13) and Widener 12 to help inform the bend widener width necessary for efficient and safe transit through Widener 13.

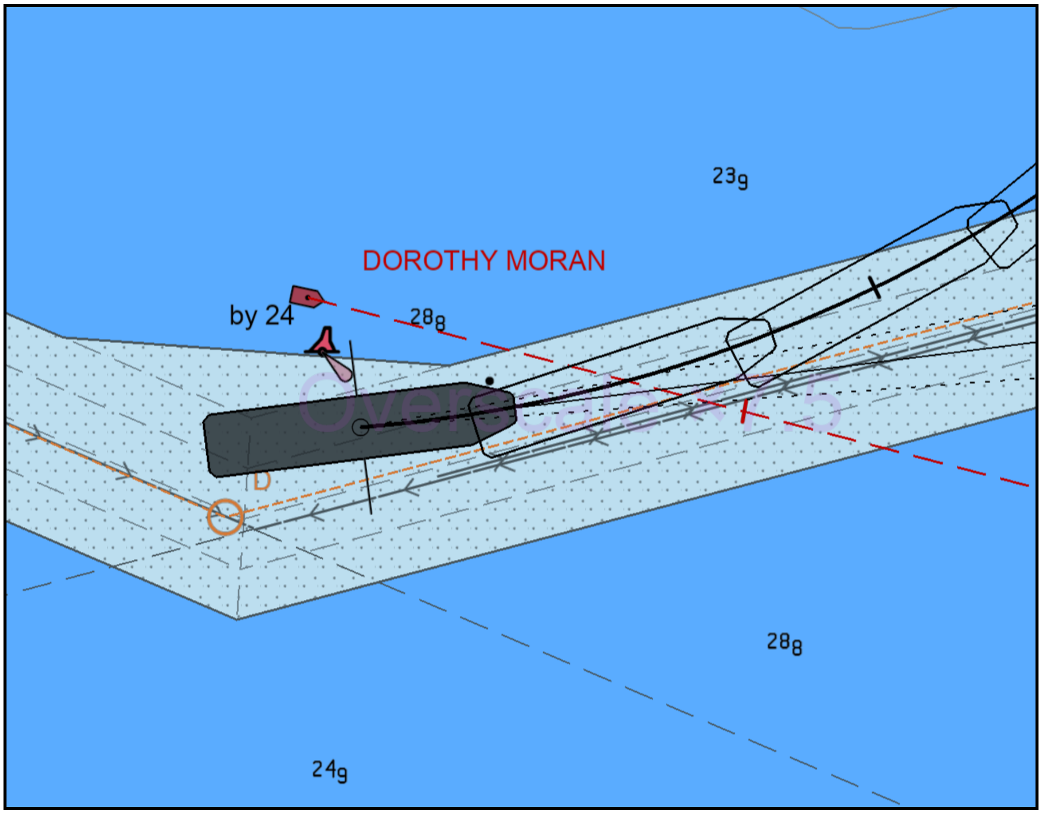


Figure 18– SEAiq Pilot Software Tracking Outbound Vessel Transit near Buoy 24

Figure 19 shows the dimensions of the bend widener at Buoy 24. The new widener portion can be seen in the shaded blue trapezoidal area with a width of 321 feet and length of 2700 feet

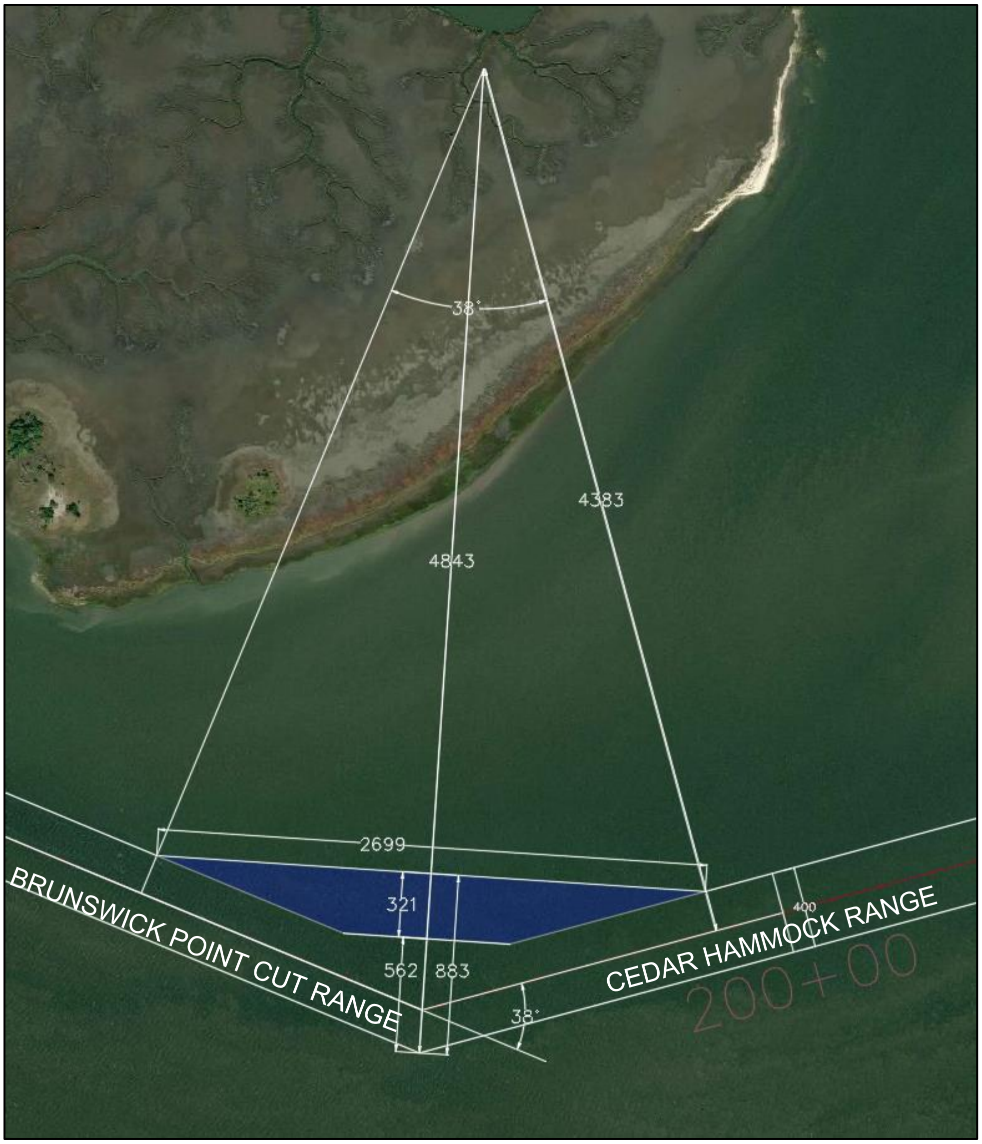


Figure 19– Dimensions of Bend Widener at USCG Buoy 24

The bend widener was tested during ship simulation multiple times with two separate Harbor Pilots and multiple environmental conditions. Each pilot provided very positive feedback on the maneuverability in the bend widener at Buoy 24. Figure 20 shows a track plot captured during ship simulation. During this particular run, the Harbor Pilot was transiting outbound during a max ebb tide condition with 25 knots of wind coming from the northeast. The Harbor Pilot was able to transit the bend efficiently and safely with no issues during these extreme environmental conditions.

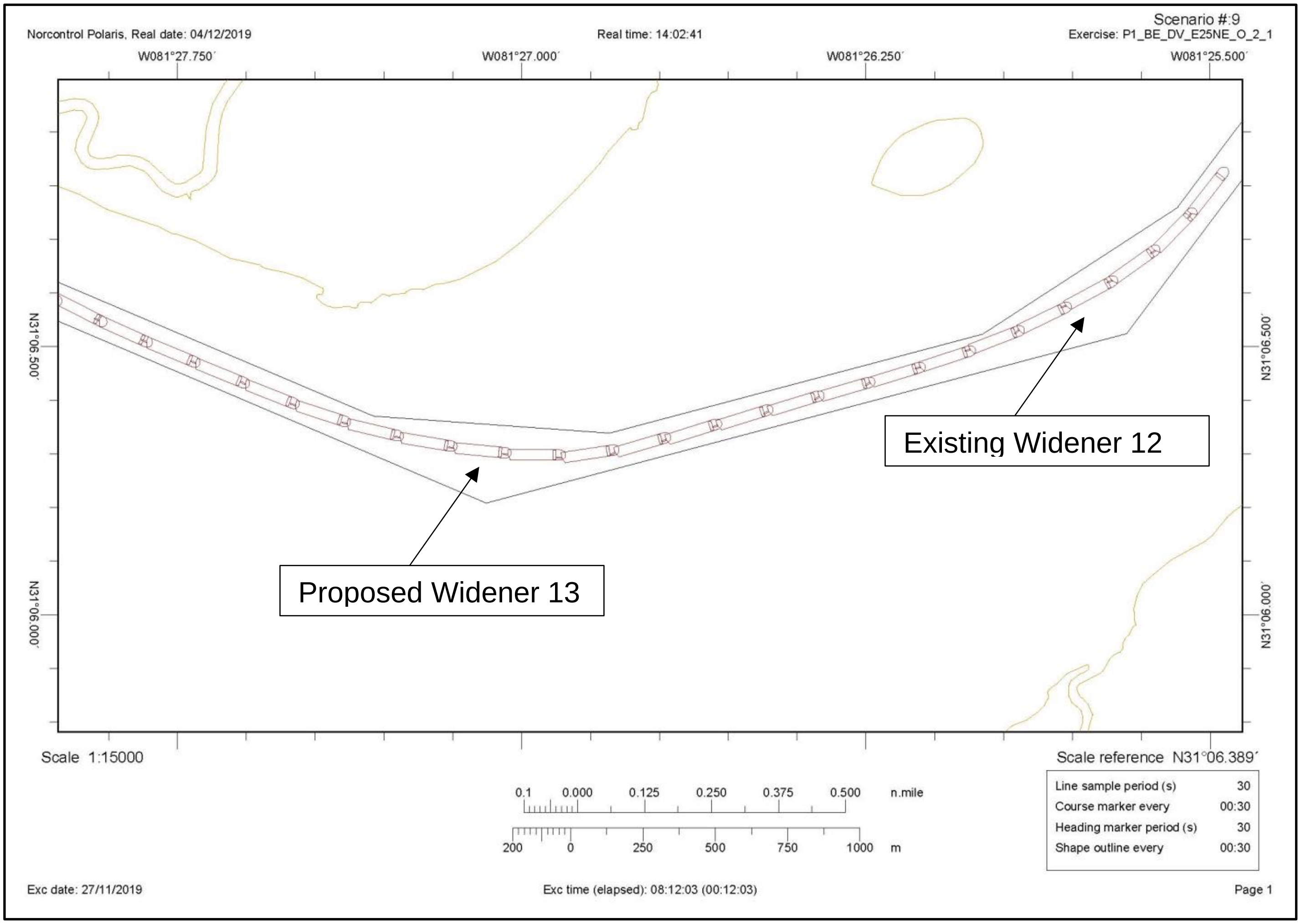


Figure 20- Track Plot of Outbound Vessel at Buoy 24 during Ship Simulation

c. Turning Basin

According to EM 1110-2-1613, the size of the turning basin should provide a minimum turning diameter of at least 1.2 times the length of the design ship where prevailing currents are 0.5 knot or less. If currents are 1.5 knots or more, the turning diameter should be designed using ship simulation. Figure 21 shows the design criteria regarding turning basins from EM 1110-2-1613.

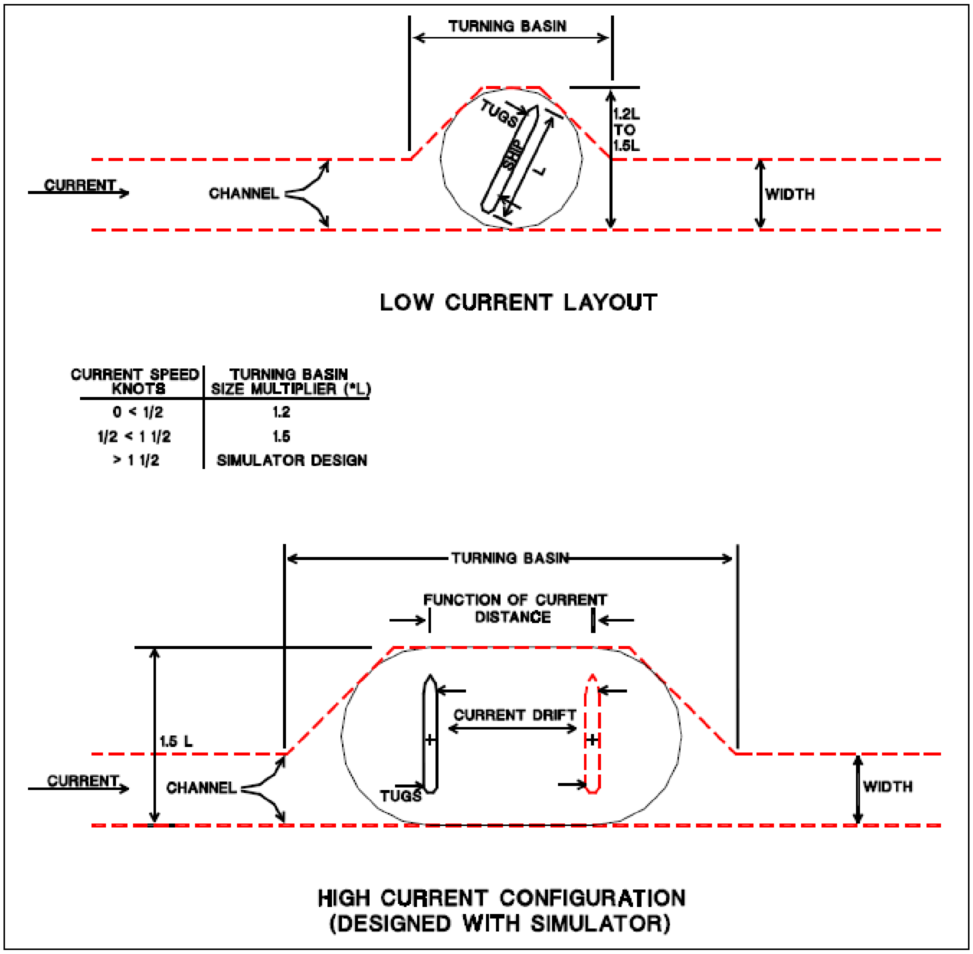


Figure 21– Turning Basin Design Standards from EM 1110-2-1613

The currents are more than 1.5 knots within the Brunswick Harbor Shipping Channel. Therefore, the High Current Configuration is applicable to the Brunswick Harbor Turning Basin. Ship simulation is necessary in this location because the turning basin is situated in an open unprotected area that is exposed to cross wind from all directions and experiences strong cross currents (> 1.5 knots) due to the confluence of the South Brunswick and Turtle Rivers. The current turning basin has a diameter of 1300 feet and was designed to accommodate vessels up to 660 feet long and 106 feet wide, which is inadequate for the larger vessels calling on the Port now. Figure 22 shows the existing configuration of the turning basin and its location at the confluence of South Brunswick and Turtle Rivers.

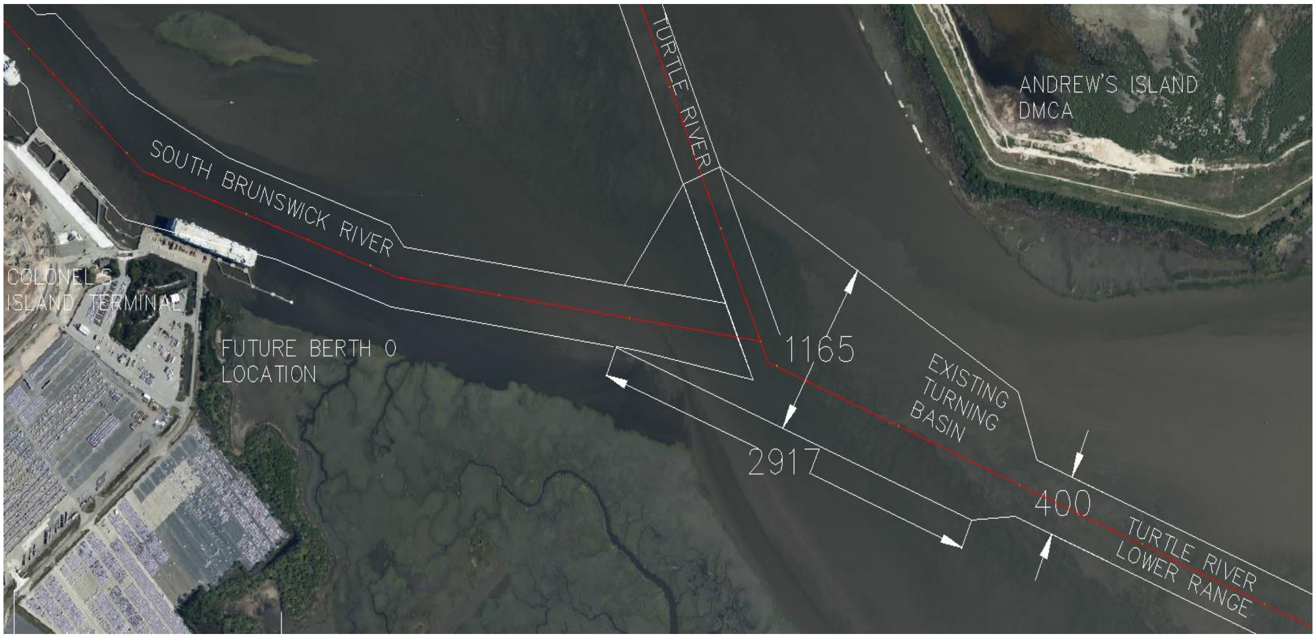


Figure 22– Existing Turning Basin Configuration

Four turning basin alternatives were designed for further evaluation during ship simulation. Ultimately, the chosen design should allow the project to serve a fleet dominated by vessels with a length of 870 feet (106 feet wide) as well as the increasing number of High Efficiency Ro/Ro vessels measuring 660 feet in length and up to 134 feet in beam width, which more accurately represent vessels currently calling on Brunswick Harbor. Harbor Pilots expressed concerns with the existing turning basin configuration when several environmental conditions exist: strong winds (~25-knot) from the northeast during either ebb or flood tide or strong winds from the south during flood tides. The following four turning basin options were further evaluated.

i. Turning Basin Option 1

Turning basin option 1 was developed during the Continuing Authorities Program (CAP) Section 107 for Brunswick Harbor Improvements in 2011. This options was proposed by the Harbor Pilots as the minimum acceptable design which would alleviate navigation problems in the turning basin. This alternative consists of extending the existing northwest side of the turning basin. The south side of the turning basin is defined by the south side of the existing turning basin and south toe of the South Brunswick River. There is no change to the existing northeast side of the turning basin. The northwest side would be defined by a line beginning at the north toe of the South Brunswick River near Station 3+200 and ending at the south toe of the Lower Turtle River near Station 46+375. The new work dredging area encompasses an area of approximately 18 acres. Figure 23 shows Turning Basin Option 1. The blue shaded area represents new work dredging to -36 feet MLLW.

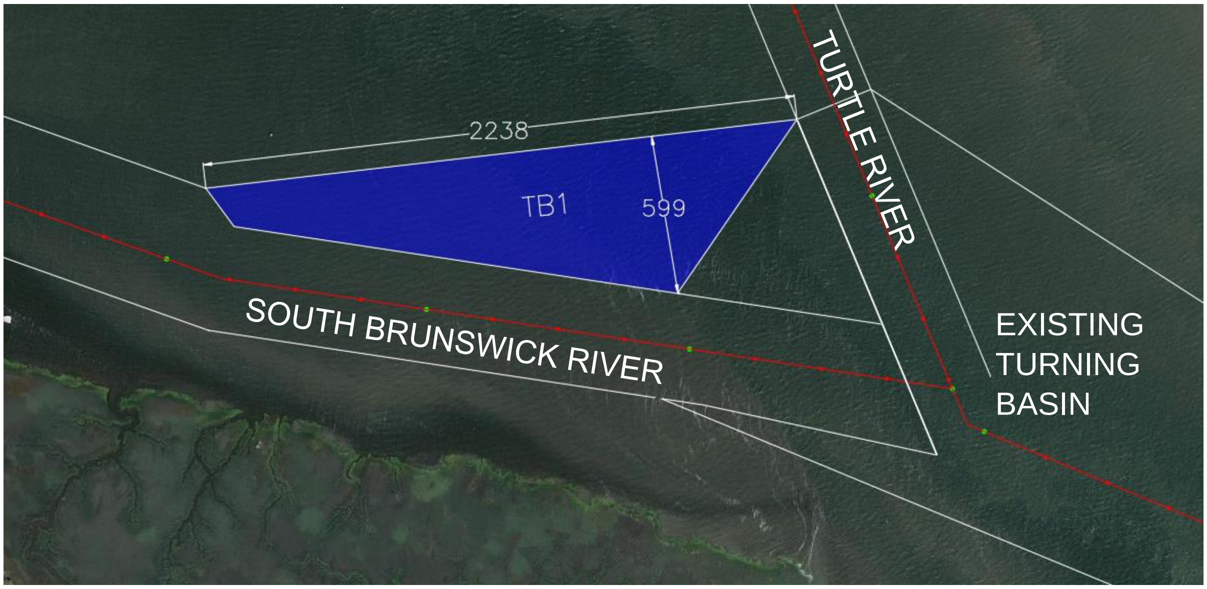


Figure 23 – Turning Basin Option 1

Turning Basin Option 1 was tested during ship simulation. The Harbor Pilots expressed concerns with lack of additional maneuvering space near or upstream of Berth 0. Harbor Pilots also indicated a large portion of Option 1 being unutilized space. Figure 24 shows the Turning Basin Option 1 track plot of an inbound transit during a flood tide with 25 knots of wind from the south.

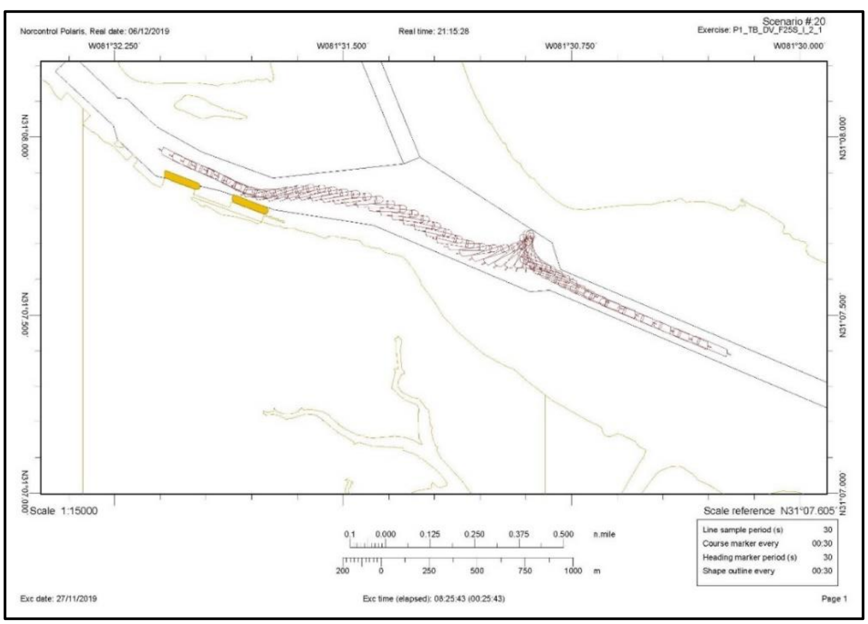


Figure 24- Track Plot of Inbound Vessel through Turning Basin Option 1 during Ship Simulation

ii. Turning Basin Option 2

Turning Basin Option 2 was also developed during the Continuing Authorities Program (CAP) Section 107 for Brunswick Harbor Improvements in 2011. Turning Basin Option 2 was the preferred design proposed by the Pilots during the 2011 CAP Study. This alternative consists of extending the existing northwest side of the turning basin. The south side of the turning basin is defined by the south side of the existing turning basin and south toe of the South Brunswick River. There is no change to the northeast side of the turning basin. The northwest side is defined by a line beginning at the north toe of the South Brunswick River near Station 3+200 and ending at the south toe of the Lower Turtle River near Station 46+750. The new work dredging area encompasses an area of approximately 28 acres that includes the approximate 18-acre area comprising Alternative 1. Turning Basin Option 2 was not tested during ship simulation due to Harbor Pilots' concerns of no additional maneuvering space near or upstream of Berth 0. Similar to Option 1, Harbor Pilots indicated a large portion of Option 2 being unutilized space. Figure 25 shows Turning Basin Option 2. The blue shaded area represents new work dredging to -36 feet MLLW. The blue shaded area represents new work dredging to -36 feet MLLW.

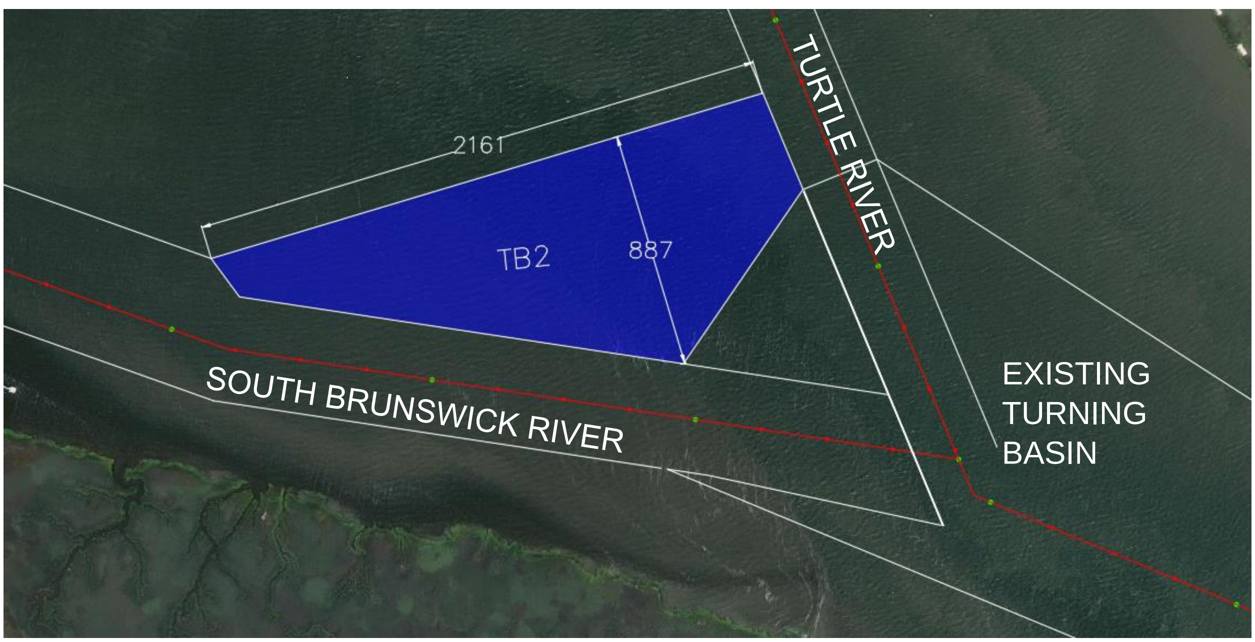


Figure 25– Turning Basin Option 2

iii. Turning Basin Option 3

Turning Basin Option 3 is proposed by the Harbor Pilots as a viable turning basin option which provides for additional maneuverability on the north toe of the South Brunswick River Channel. This additional maneuverability is particularly important for vessels transiting to and from the proposed Berth 0. Turning Basin Option 3 extends from the middle of the upstream extent of the existing turning basin to approximately South Brunswick River Station 4+250. Turning Basin Option 3 extends approximately 3200 feet upstream from the west edge of the existing turning basin and provides approximately 360 feet of additional width adjacent to the South Brunswick River Channel. The new work dredging area encompasses an area of approximately 19 acres. Figure 26 shows Turning Basin Option 3. The blue shaded area represents new work dredging to -36 feet MLLW.

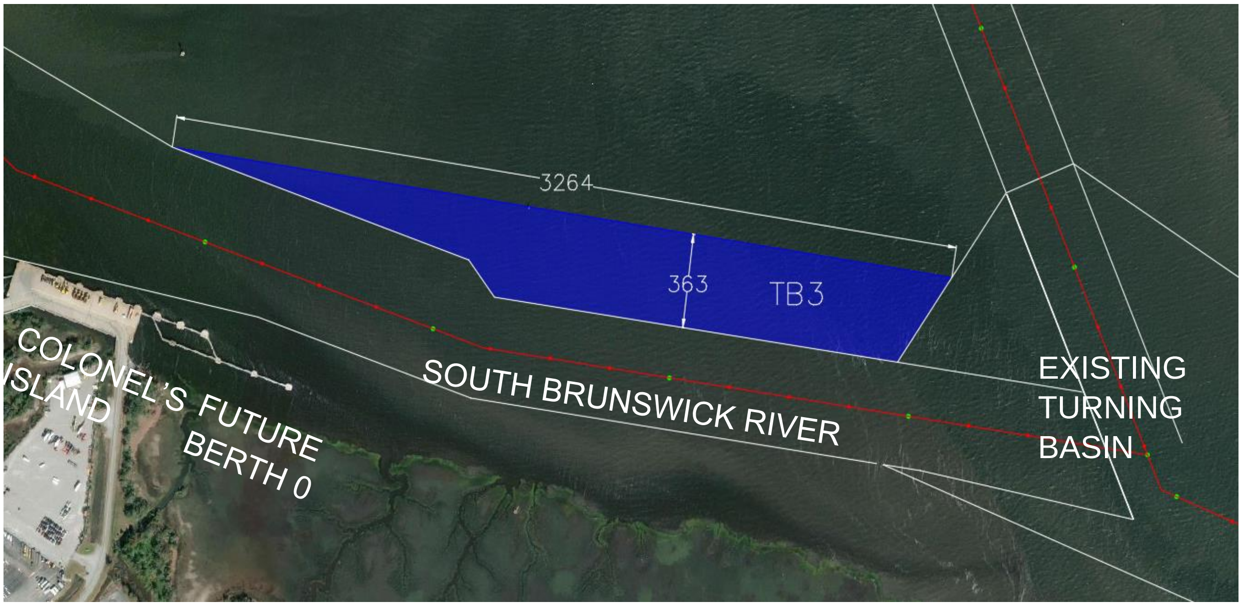


Figure 26– Turning Basin Option 3

Turning Basin Option 3 was tested during ship simulation multiple times with two separate Harbor Pilots and multiple environmental conditions. Each pilot provided very positive feedback on the maneuverability of Option 3, however expressed concerns with lack of extended width passed Berth 0. Figure 27 shows a track plot captured during ship simulation. During this particular run, the Harbor Pilot was transiting inbound during a max flood tide condition with 25 knots of wind coming from the northeast. The Harbor Pilot was able to transit the bend efficiently and safely with no issues during these extreme environmental conditions, even with a vessel docked at Berth 0.

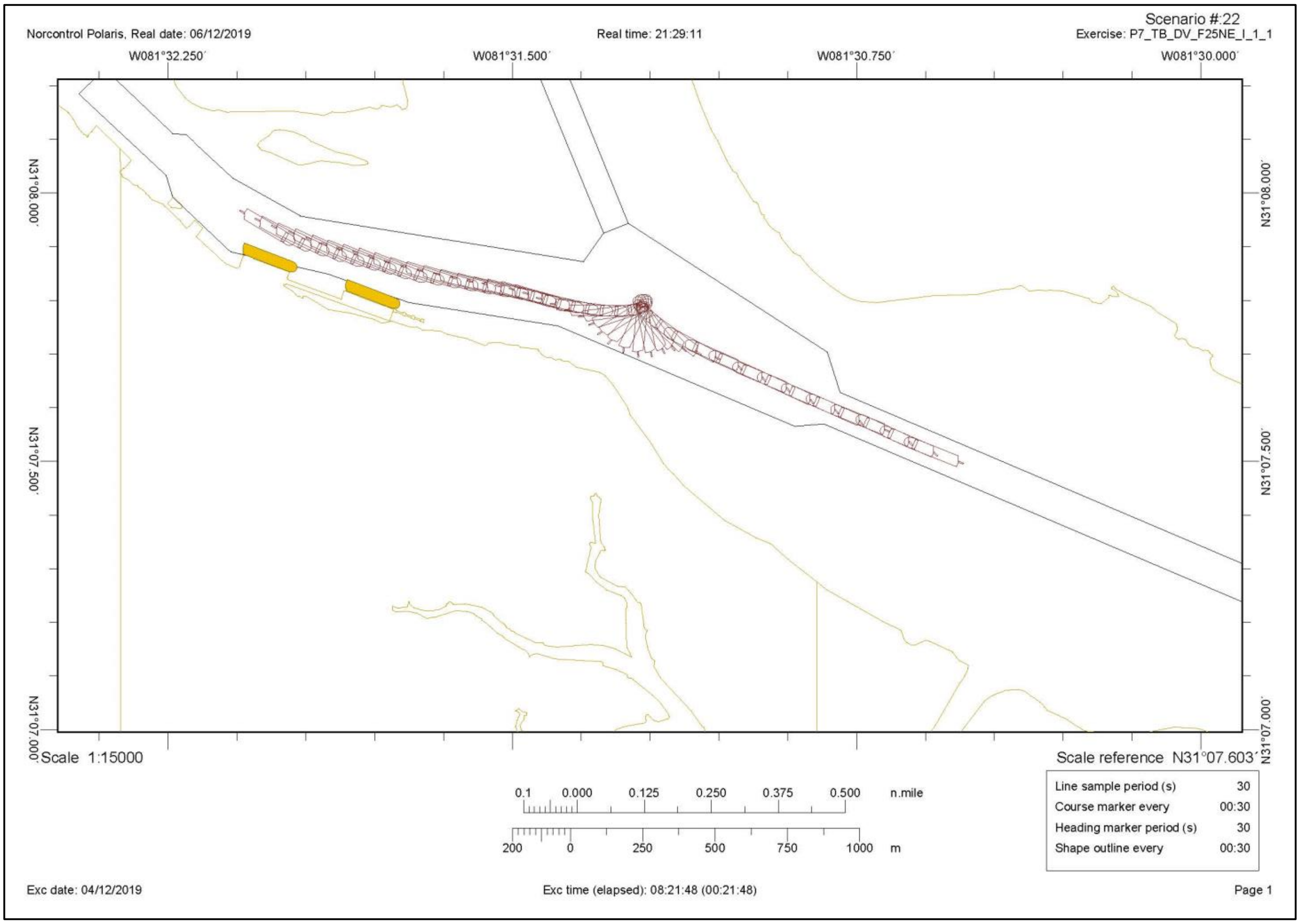


Figure 27- Track Plot of Inbound Vessel through Turning Basin Option 3 during Ship Simulation

Tracked plots from SEAiq Pilot Software illustrate the need for additional channel width on the north toe of the South Brunswick River just upstream of the existing turning basin. Transit delays often occur while vessels are navigating astern towards existing berths in the South Brunswick River, especially during high winds and max currents. The use of tug assist is greatly needed in this area. Maneuverability will further decrease with the addition of Berth 0, making additional channel width near the turning basin more imperative for efficiency. Figure 28 through Figure 30 are tracked plots captured by the SEAiq Pilot Software which show the need for additional channel width near the north toe of the South Brunswick River.

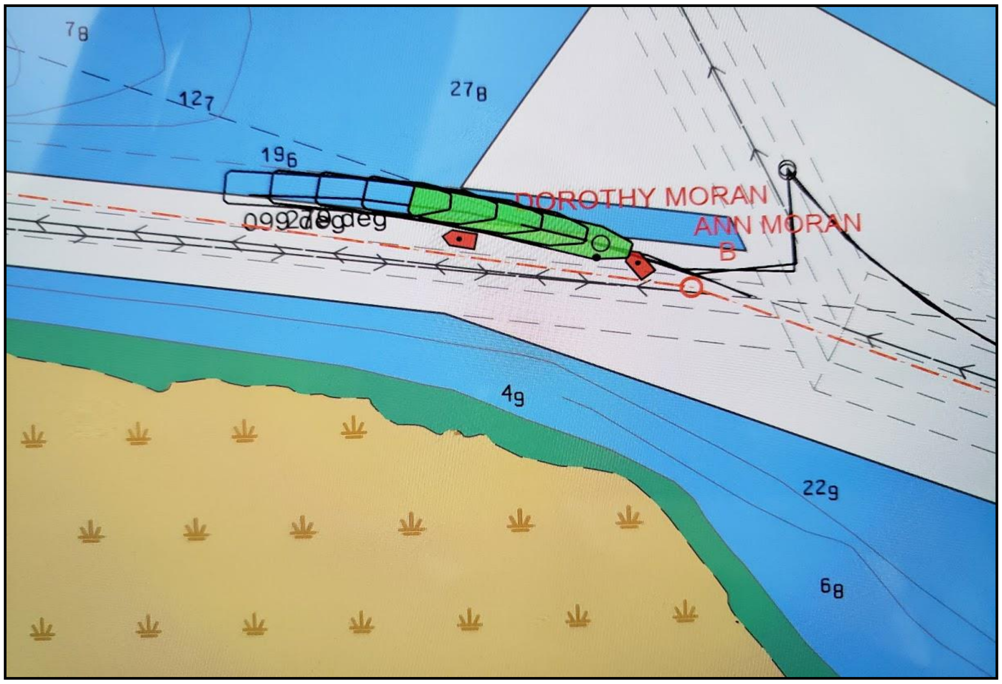


Figure 28- SEAiq Pilot Software Tracking Inbound Vessel Transit through Turning Basin

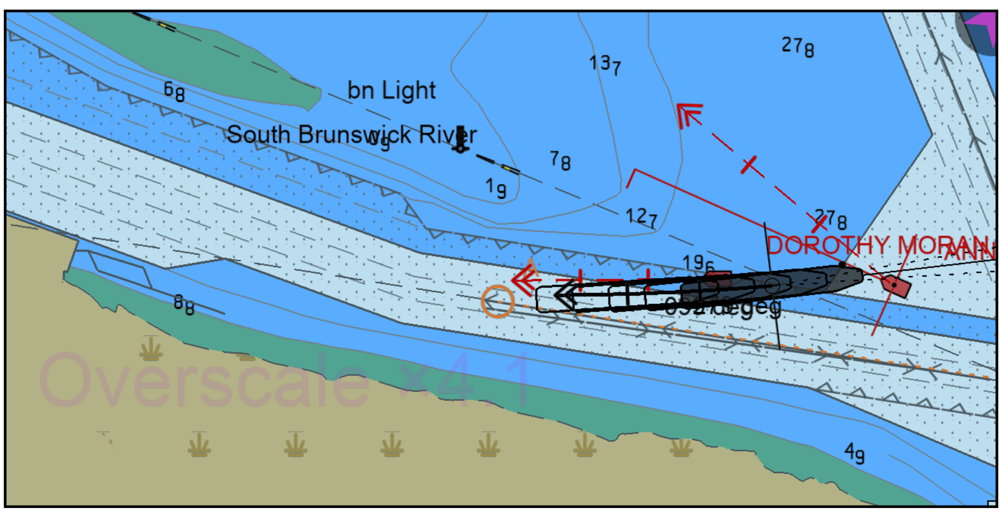


Figure 29- SEAiq Pilot Software Tracking Inbound Vessel Transit through Turning Basin

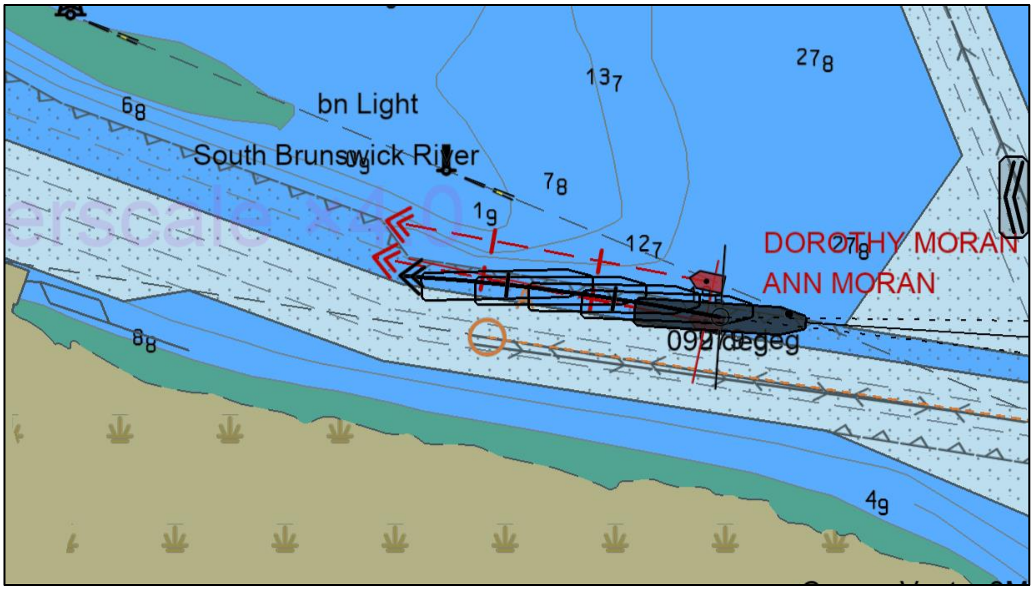


Figure 30- SEAiq Pilot Software Tracking Inbound Vessel Transit to Berth 1

iv. Turning Basin Option 4

Similarly to Turning Basin Option 3, Option 4 provides additional space for vessel maneuverability across from Berth 0. Turning Basin Option 4 incorporates less total width than Turning Basin Option 3, with widths between 100 feet and 170 feet versus up to 360 feet with Turning Basin Option 3, however Option 4 provides nearly 1000 feet of additional length upstream versus Option 3. Turning Basin Option 4 extends from the middle of the upstream extent of the existing turning basin to approximately South Brunswick River Station 5+250. Option 4 extends approximately 4100 feet upstream from the west edge of the existing turning basin and provides between 105 and 400 feet of additional width adjacent to the South Brunswick River Channel. The new work dredging area encompasses an area of approximately 12 acres. Figure 31 shows Turning Basin Option 4. The blue shaded area represents new work dredging to -36 feet MLLW.

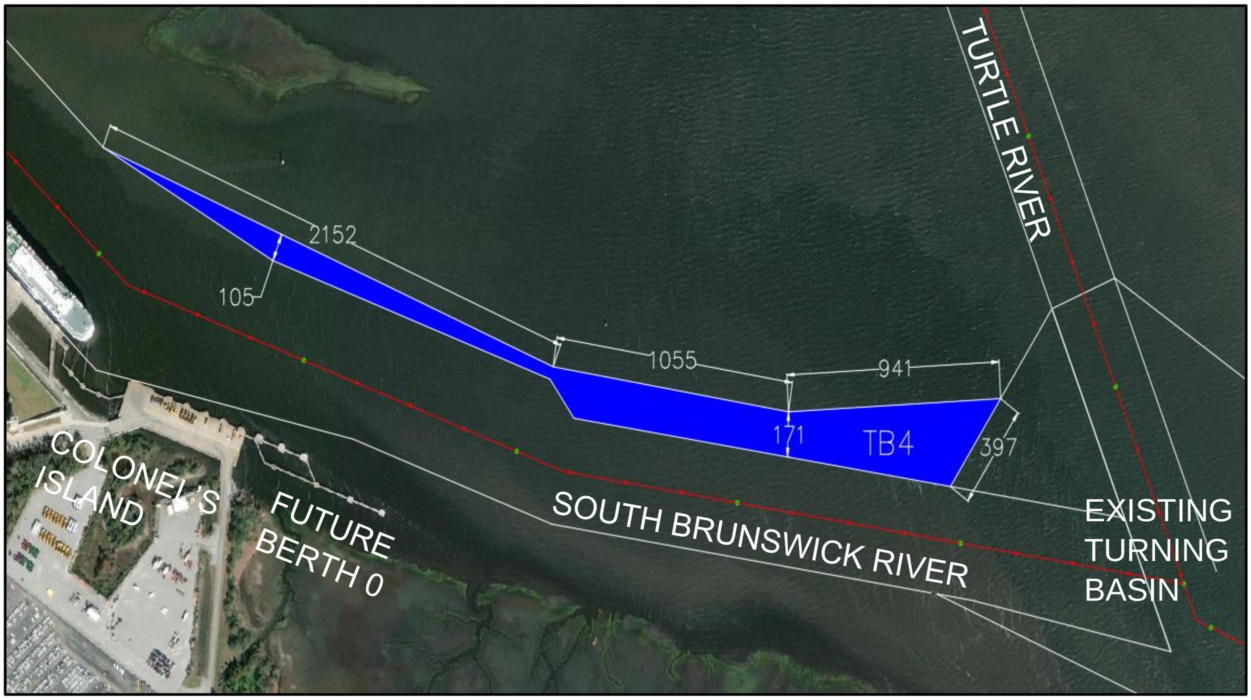


Figure 31– Turning Basin Option 4

Turning Basin Option 4 was tested during ship simulation multiple times with two separate Harbor Pilots and multiple environmental conditions. Each pilot provided very positive feedback on the maneuverability of Option 4. The additional width of approximately 100 feet upstream of Berth 0 allowed for easier maneuverability to Berth 0 and upstream of Berth 0 compared to Turning Basin Option 3. Figure 32 shows a track plot captured during ship simulation. During this particular run, the Harbor Pilot was transiting inbound during an ebb tide condition with sustained winds of 10 knots coming from the northeast in addition to 15 knot gusts coming from the northeast. The Harbor Pilot was able to transit the bend efficiently and safely with no issues during these extreme environmental conditions, even with a vessel docked at Berths 1 and 2.

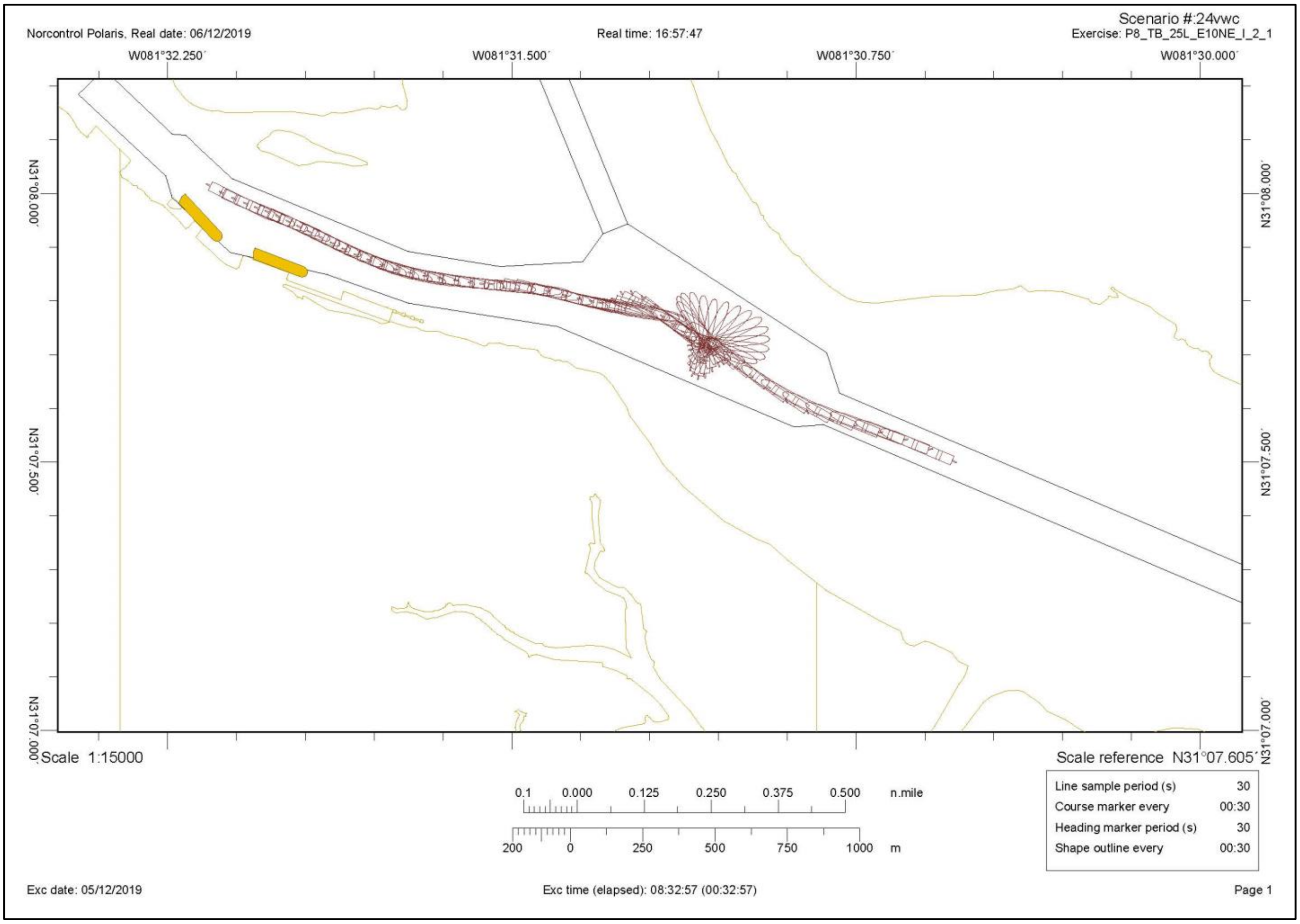


Figure 32 - Track Plot of Inbound Vessel through Turning Basin Option 4 during Ship Simulation

Since Turning Basins 3 and 4 are the only options that allow for efficient navigability with the addition of Berth 0, Turning Basin Options 1 and 2 were not evaluated further. Turning Basin Option 4 was the only basin used in the alternatives because it requires less acreage and dredging then Option 3, but has all the benefits of Option 3.

d. Meeting Areas

Two meeting area locations are being designed and evaluated during this study. A meeting area west of the Sidney Lanier Bridge and a meeting area in the St. Simon's Sound. Both meeting area designs satisfy minimum channel width requirements established in EM 1110-2-1613. Design for two-way ship traffic channel width is dependent upon several criteria including design vessel beam, traffic vessel beam, maximum current, and aids to navigation. Figure 33 and Table 3 from EM 1110-2-1613 were used to develop both meeting areas.

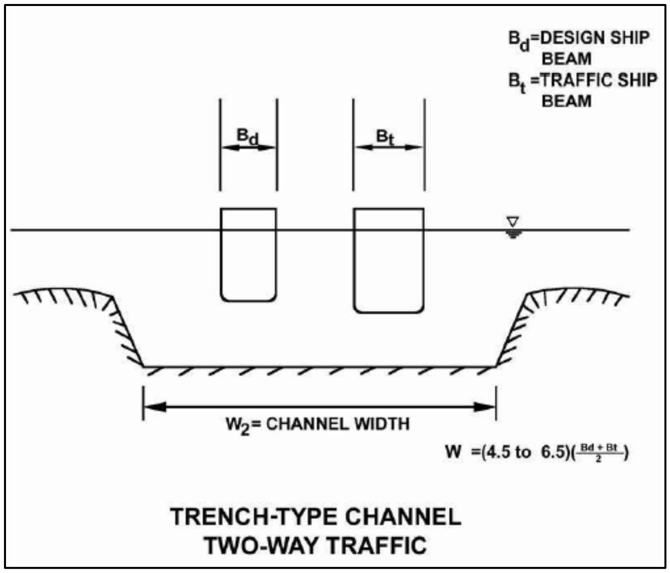


Figure 33– Channel Design Width Guidelines for Two-Way Traffic

Table 3 – Two-Way Traffic Channel Design Criteria

Two-Way Ship Traffic Channel Width Design Criteria			
	Design Ship Beam Multipliers for Maximum Current, Knots (ft/sec)		
Uniform Channel Cross Section	0.0 to 0.5 (0.0 to 0.8)	0.5 to 1.5 (0.8 to 2.5)	1.5 to 3.0 (2.5 to 5.0)
Best Aids to Navigation			
Shallow	5.0	6.0	8.0
Canal	4.0	4.5	5.5
Trench	4.5	5.5	6.5

i. Sidney Lanier Bridge Meeting Area

The Sidney Lanier Bridge Meeting Area is a two-way ship traffic channel intentionally located close to Colonels Island. This meeting area aids in alleviating congestion near the Colonels Island terminal and diminishes existing wait times for vessels departing Colonels Island while inbound vessels are in transit. The meeting area begins approximately 1,000 feet upstream of the Sidney Lanier Bridge at the confluence of East River and South Brunswick Rivers and extends 8,740 feet upstream to the base of the existing turning basin.

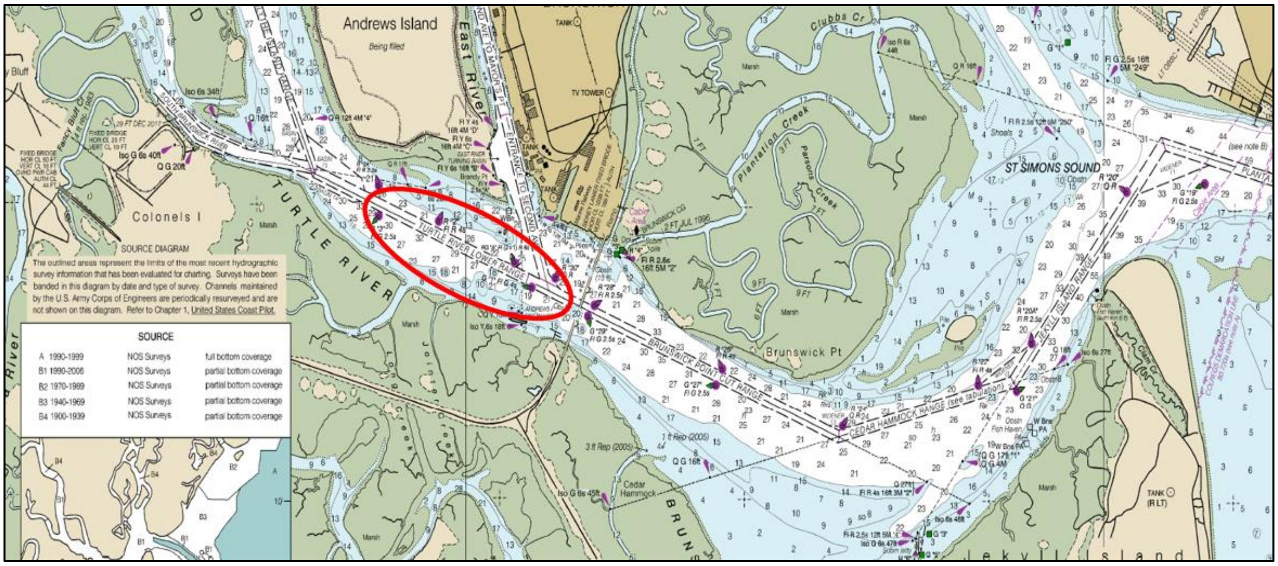


Figure 34– Location of Sidney Lanier Bridge Meeting Area

The meeting area is designed such that an inbound vessel can meet an outbound vessel and safely maneuver around one another. This two-way ship channel would also allow for ship passing (i.e. one ship overtaking another transiting the same direction), however this is much less common than meeting. EM 2220-2-1613 provides general guidelines for minimum channel width criteria based on numerous studies but recommends numerical modeling such as those used in a ship simulator. The dimensions of this meeting area were tested and refined during ship simulation.

The length of the Sidney Lanier Bridge Meeting Area was designed through consultation with the Harbor Pilots. The channel width was designed based on criteria in EM 2220-2-1613. Both the length and width channel dimensions were tested thoroughly during ship simulation (see Ship Simulation Attachment B-1 for more detail). Currents in the South Brunswick Harbor were modeled using Adaptive Hydraulics (AdH) numerical modeling and reach approximately 2.5 knots in this portion of the South Brunswick River. Per EM 2220-2-1613:

Maximum Current = 2.5 knots, Trench Cross Section→ multiplier of 6

$W = 6 * \frac{Bd+Bt}{2}$ = 6 * $(120 + 106)/2$ = 678 feet → **Round to 700 feet**

The 300 feet of necessary width was split evenly equidistant from the existing center line, with 150 feet of width added to each side of the channel. Consultation with the Harbor Pilots confirmed that equal widths on either side of the existing centerline is desired. The inbound approach angle of 27º matches the same existing angle at the confluence of East River and South Brunswick Rivers. The new work dredging area encompasses an area of approximately 53.5 acres and does not include the portion of East River currently at the existing project depth of -36 feet mean lower low water (MLLW). Figure 35 shows the Sidney Lanier Bridge Meeting Area.

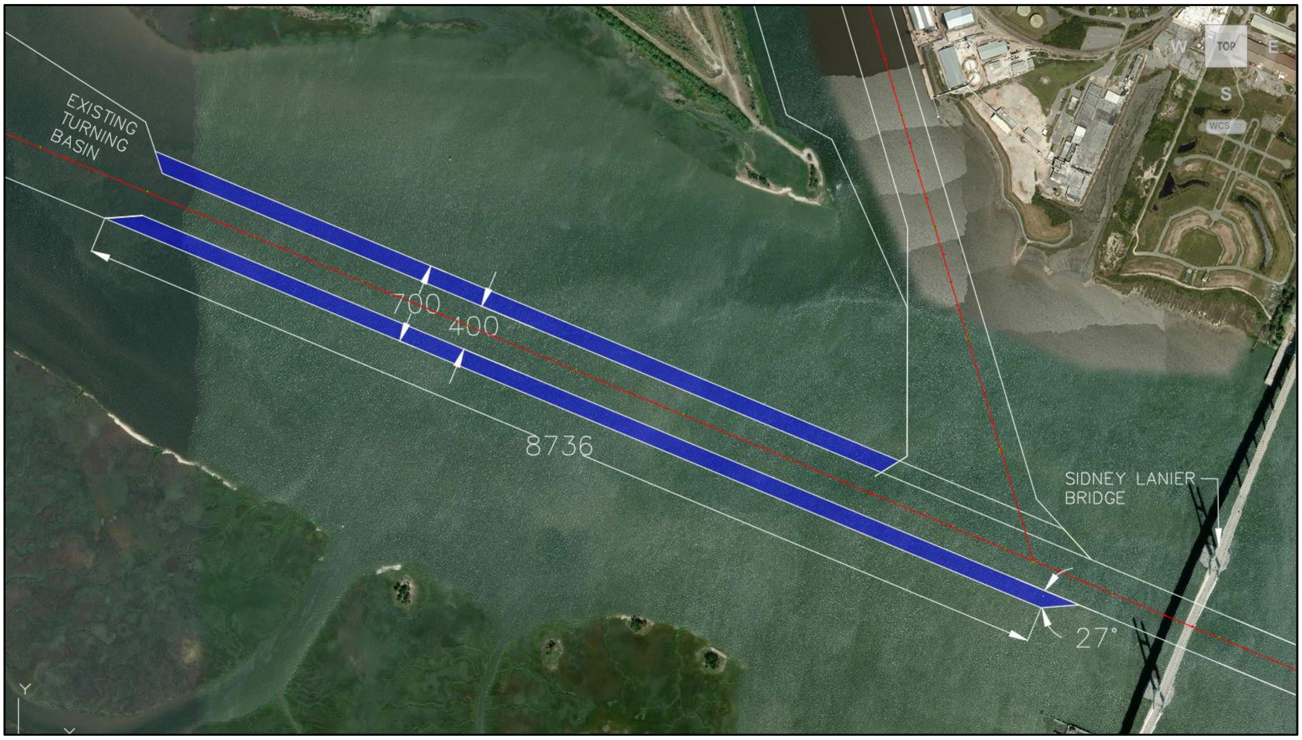


Figure 35 – Sidney Lanier Bridge Meeting Area Dimensions

The Sidney Lanier Bridge Meeting Area was tested during ship simulation multiple times with two separate Harbor Pilots and multiple environmental conditions. Each pilot transited both inbound and outbound. Both Pilots provided very positive feedback on the maneuverability of the meeting area. The additional channel width of 300 feet was adequate for safe meeting and navigating passed the other. Ship simulation confirmed the length of 8700 feet to be adequate and necessary for the meeting area. Figure 36 shows a track plot captured during ship simulation. During this particular run, one Pilot was transiting inbound while the other was transiting outbound and the two maneuvered passed one another in the Sidney Lanier Bridge Meeting Area. The environmental conditions during the simulations included 25 knots of wind from the south during a max flood tide condition. The Harbor Pilots were able to transit the meeting area efficiently and safely with no issues during these extreme environmental conditions. The HERO design vessel was used for both the inbound and outbound transits.

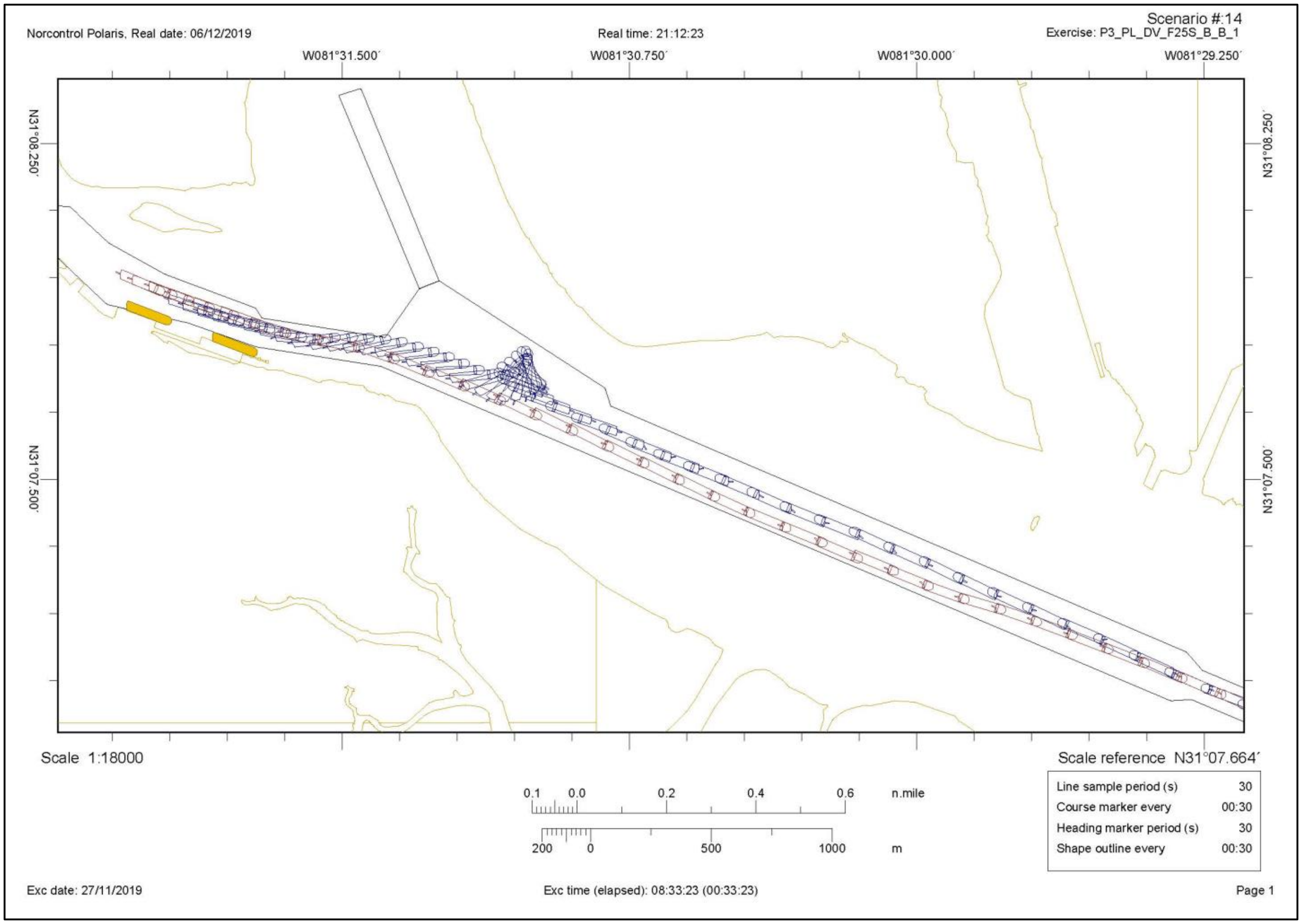


Figure 36 - Track Plot of Vessels Meeting near Sidney Lanier Bridge during Ship Simulation

ii. St. Simon's Sound Meeting Area

The St. Simon's Sound Meeting Area utilizes naturally deep water in the St. Simon's Sound Plantation Creek Range. The area proposed for this meeting area is currently used by Harbor Pilots regularly. The configuration for this meeting area was designed through consultation with the Harbor Pilots and verified per EM 2220-2-1613 as well as ship simulation.

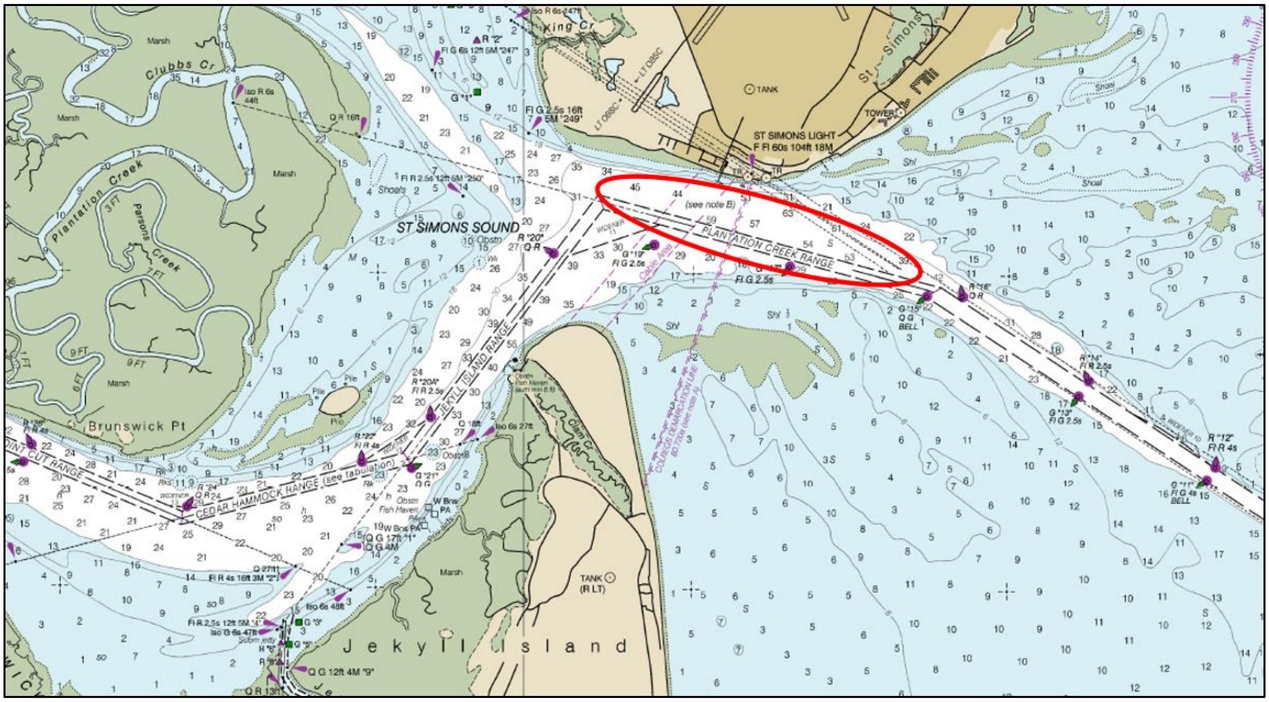


Figure 37 – Location of St. Simon's Sound Meeting Area

SEAiq Pilot tracked plots are useful for ensuring adequate width of a meeting area in the St. Simon's Sound. Figure 38 is a SEAiq Pilot track plot showing an inbound vessel transiting approximately 700 feet north of the existing channel in the Plantation Creek Range. Water depths range from 50-65 feet MLLW in this area. While Harbor Pilots occasionally use this space for meeting and passing, there is currently no authorized meeting area in St. Simon's Sound.

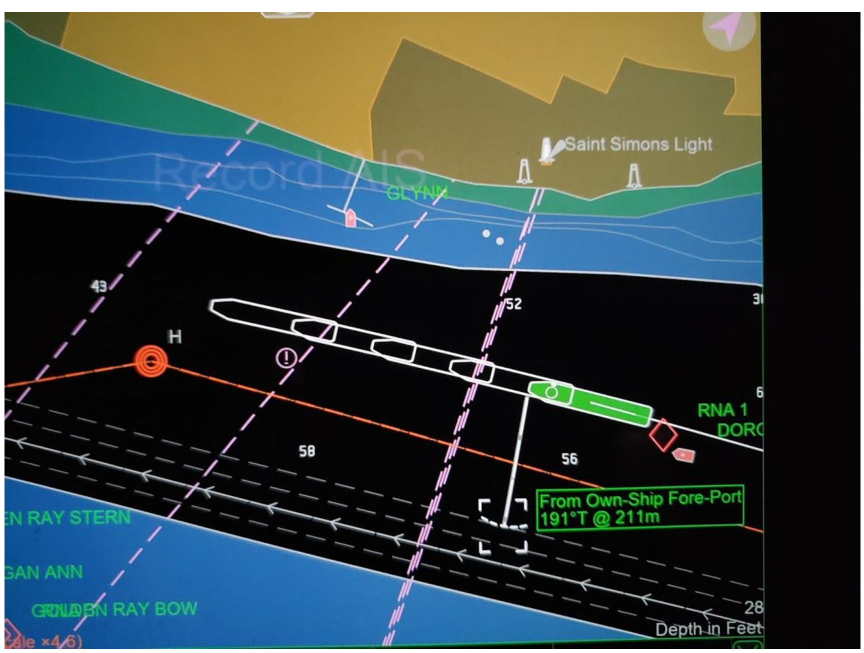


Figure 38- SEAiq Pilot Software Tracking Inbound Vessel Transit through St. Simon's Sound

Figure 39 is a SEAiq Pilot track plot showing an inbound vessel meeting an outbound vessel in the St. Simon's Sound Area. Prior to the capsizing of the Golden Ray Vessel on September 8, 2019, Harbor Pilots would occasionally utilize the naturally deep waters of the St. Simon's Sound to meet and pass other vessels, as seen in Figure 39. Note both vessels are north of the existing channel during this maneuver.

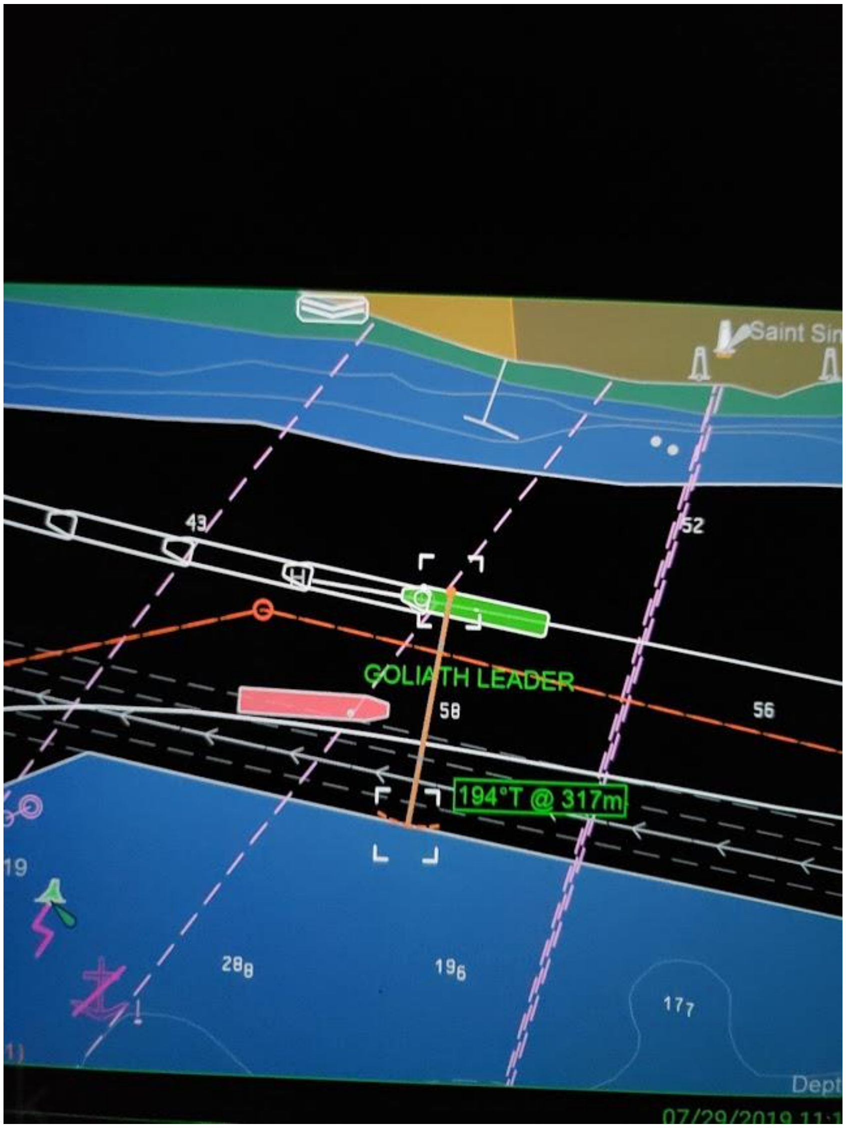


Figure 39- SEAiq Pilot Software Tracking Vessel Meeting through St. Simon's Sound

As seen in Figure 40, the north toe of the St. Simon's Range was extended approximately 3,600 feet into the St. Simon's Sound area, creating an additional 800 feet of channel width north of the existing 400 feet channel in the Plantation Creek Range. The existing centerline of the Plantation Creek Range is not altered. The meeting area also provides a total width of approximately 1525 feet at the confluence of

Plantation Creek Range and Jekyll Island Range at Widener 11. The area encompasses 173 acres and requires no dredging, as this is naturally deep water with no shoaling. Hydrodynamic modeling confirms velocities are higher in this area, causing sediments to deposit on the inside bend, closer to Jekyll Island.

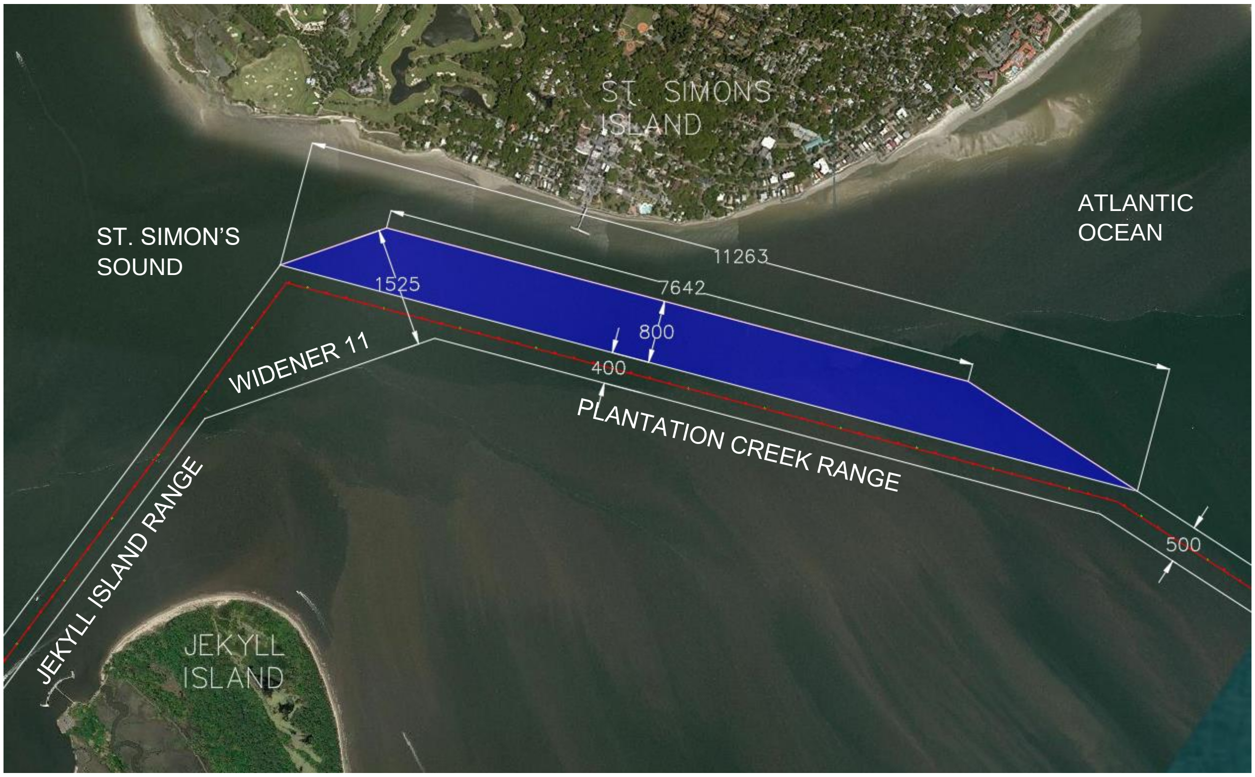


Figure 40 – Dimensions of St. Simon's Sound Meeting Area

The St. Simon's Sound Meeting Area was tested during ship simulation multiple times with two separate Harbor Pilots and multiple environmental conditions. Each pilot transited both inbound and outbound. Both Pilots provided very positive feedback on the maneuverability of the meeting area. Again, this area is used regularly by Harbor Pilots and they are very familiar with depths and currents in this area. The additional channel width of 800 feet was adequate for safe meeting and navigating passed the other. Ship simulation confirmed the length to be adequate for the meeting area. Figure 41 shows a track plot captured during ship simulation. During this particular run, one Pilot was transiting inbound while the other was transiting outbound and the two maneuvered passed one another in the St. Simon's Sound Meeting Area. The environmental conditions during the simulations included 25 knots of wind from the northeast during a max ebb tide condition. The Harbor Pilots were able to transit the meeting area efficiently and safely with no issues during these extreme environmental conditions. The HERO design vessel was used for both the inbound and outbound transits.

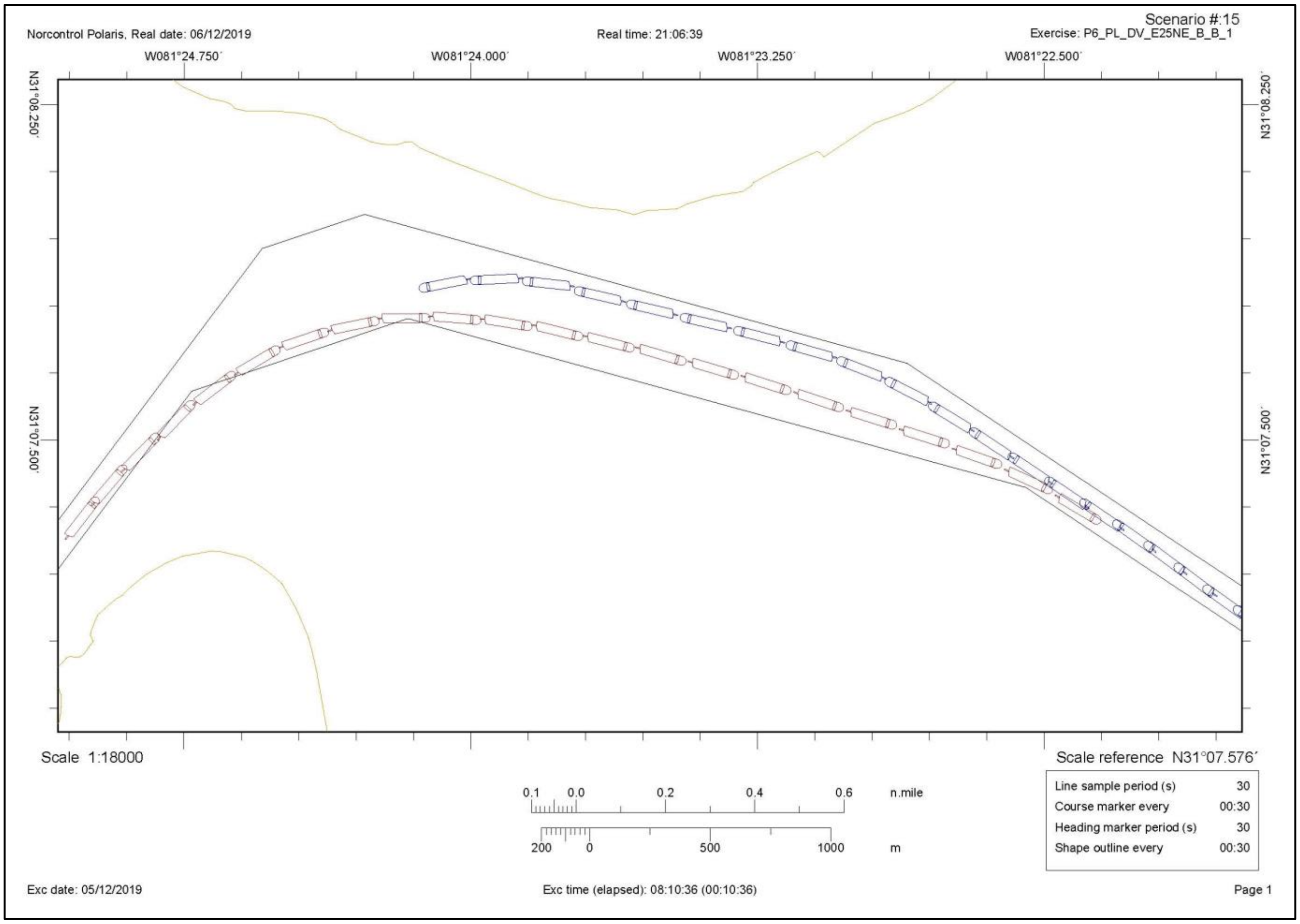


Figure 41- Track Plot of Vessels Meeting in St. Simon's Sound during Ship Simulation

III. Quantities

a. New Work

Estimated new work quantities were calculated for each individual navigational feature using Autodesk Civil 3d. The quantities for each navigational feature were calculated to -36 feet MLLW and -38 feet MLLW using the June/July 2019 bathymetric data. The depth of -36 feet MLLW represents the current authorized project depth and -38 feet MLLW represents the allowable overdepth during dredging. All new work channel edges will be cut on a 3h:1v slope, which is included in the dredging calculations. Table 4 shows the cut quantities in cubic yards for each navigation feature, including allowable overdepth. There is no fill necessary for any navigational feature.

Table 4 – Estimated Dredging Quantities per Navigational Feature

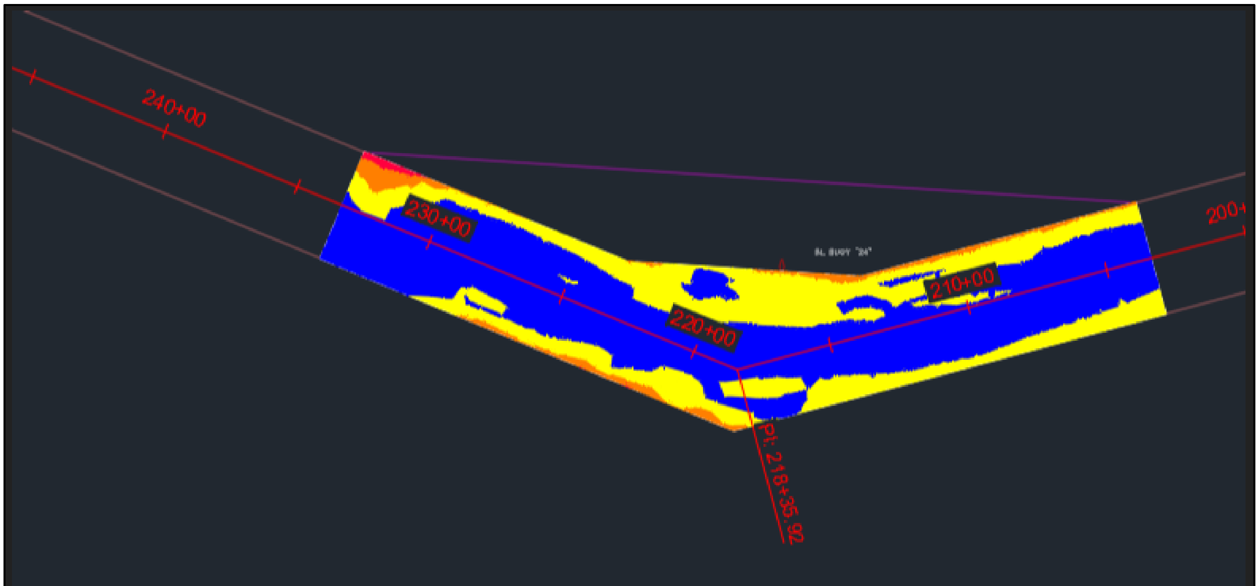
Navigational Feature	Depth (feet MLLW)	Cut (CY)
Bend Widener	-38	205,159
Turning Basin 1	-38	458,087
Turning Basin 2	-38	693,488
Turning Basin 3	-38	623,948
Turning Basin 4	-38	346,462
Sidney Lanier Meeting Area	-38	800,074
St. Simon's Sound Meeting Area	-38	0

b. O&M Quantities

Future O&M quantities were estimated for each project feature using previous Brunswick Harbor O&M dredging records provided by Operations Division, Savannah District. Dredging records from 2014 – 2019 were evaluated. A more detailed hydrodynamic analysis of the selected alternative will be performed during the PED Phase.

i. Bend Widener

O&M dredging records were available and evaluated from 2014 – 2020 for the Brunswick Point Cut Range and Cedar Hammock Range near Buoy Station 24. January 2018 and January 2020 surveys were available for evaluation in this location. The January 2018 survey was compared to an elevation of -38 feet MLLW using Autodesk Civil 3d, resulting in approximately 15,000 CY of shoaling. The same procedure was followed using the January 2020 survey compared to an elevation of -38 feet MLLW, resulting in approximately 19,000 CY of shoaling. There was no dredging in the location between the January 2018 survey and January 2020 survey. The shoaling rate was calculated to be approximately (19,000 CY – 15,000 CY)/2 years = 2,000 CY/year for this location. More detailed estimates of shoaling rates in this location will be performed during the PED Phase. Figure 42 and Figure 43 show the January 2018 and January 2020 surveys used for shoaling analysis, respectively.



ELEVATIONS TABLE

NO.	MINIMUM CHANGE IN ELEV.	MAXIMUM CHANGE IN ELEV.	VOLUME (CY.)	COLOR
1	-7.00	-4.00	110	
2	-4.00	-2.00	1,370	
3	-2.00	0.00	13,841	
4	0.00	6.00	31,830	

Figure 42 – January 2018 Bathymetric Survey near Bend Widener

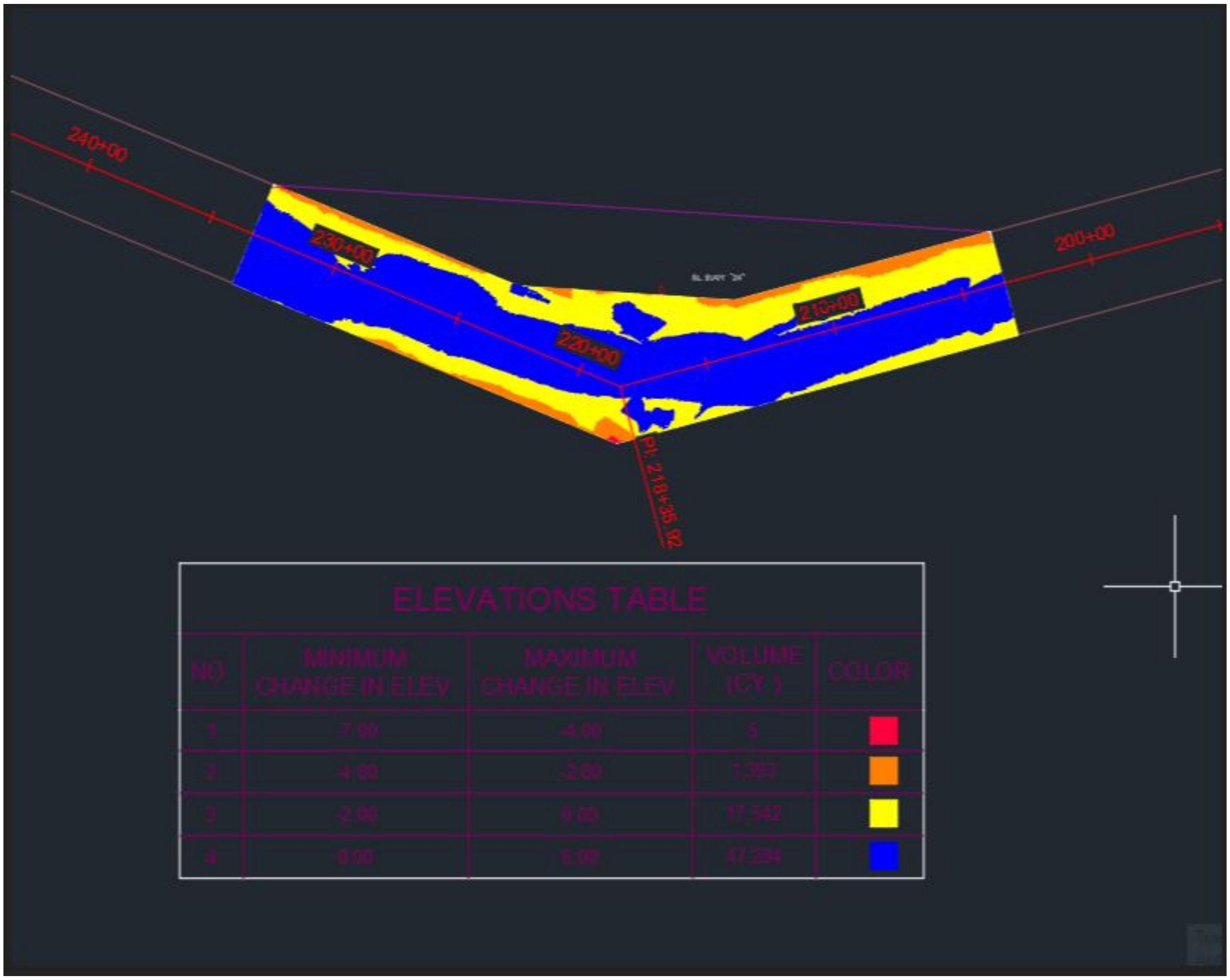


Figure 43– January 2020 Bathymetric Survey near Bend Widener

ii. Turning Basin

O&M dredging records were available and evaluated from 2015 – 2019 for the South Brunswick River near the existing turning basin. Dredging records show approximately 16,000 CY of material was dredged in FY15, 58,000 CY of material was dredged in FY16, and no material was dredged in FY17, FY18, or FY19 near the existing turning basin due to lack of funding. The average shoaling rate for this five year period is approximately 14,900 CY and will be assumed as the future annual shoaling rate for the turning basin until further hydrodynamic analysis is completed during the PED Phase.

iii. Sidney Lanier Bridge Meeting Area

There has been no O&M dredging in the Turtle River Lower Range, which is the location for the Sidney Lanier Meeting Area. Velocities are relatively high (>2.5 knots) in this location and shoaling is not expected to occur in the future. No O&M is expected in the Sidney Lanier Bridge Meeting area, however further hydrodynamic analysis will be completed during the PED Phase.

iv. St. Simon's Sound Meeting Area

There has been no O&M dredging in the Plantation Creek Range, which is the location for the St. Simon's Sound Meeting Area. Velocities are relatively high (>2.5 knots) in this location, depths range from 40 – 60 feet MLLW, and shoaling is not expected to occur in the future. No O&M is expected in the St. Simon's Sound Meeting area, however further hydrodynamic analysis will be completed during the PED Phase.

IV. Material Characteristics

The sediments to be removed for these channel improvements are principally unclassified new work dredging and consist predominantly of undisturbed soils that have not previously been dredged. Information on material to be removed has been extracted from nearby existing borings drilled in 1999 during the previous Brunswick Harbor Deepening. Logs for three existing borings in the Cedar Hammock and Brunswick Point Cut Ranges were used to determine material types for the proposed Bend Widener at the intersection of Cedar Hammock and Brunswick Point Cut Ranges. Logs for fourteen existing borings near the South Brunswick River Turning Basin were used to determine material types for the proposed South Brunswick River Turning Basin modification.

In the area of the proposed South Brunswick River Turning Basin Widener, nearby boring logs indicate the soils consist of high liquid-limit clay (CH), low liquid-limit clay (CL), low liquid-limit silt (ML), poorly-graded sand (SP), silty sand (SM), clayey sand (SC), and poorly-graded gravel (GP). Laboratory analyses indicated that well-graded sand (SW), well-graded silty sand (SW-SM), poorly-graded silty sand (SP-SM), silty clayey sand (SM-SC), and high liquid-limit clayey sand (SC-H) were also encountered. Figure 44 shows the soil borings used for analysis near the South Brunswick River Turning Basin. Figure 45 shows the interpolated profile of soil characteristics near the South Brunswick River Turning Basin.

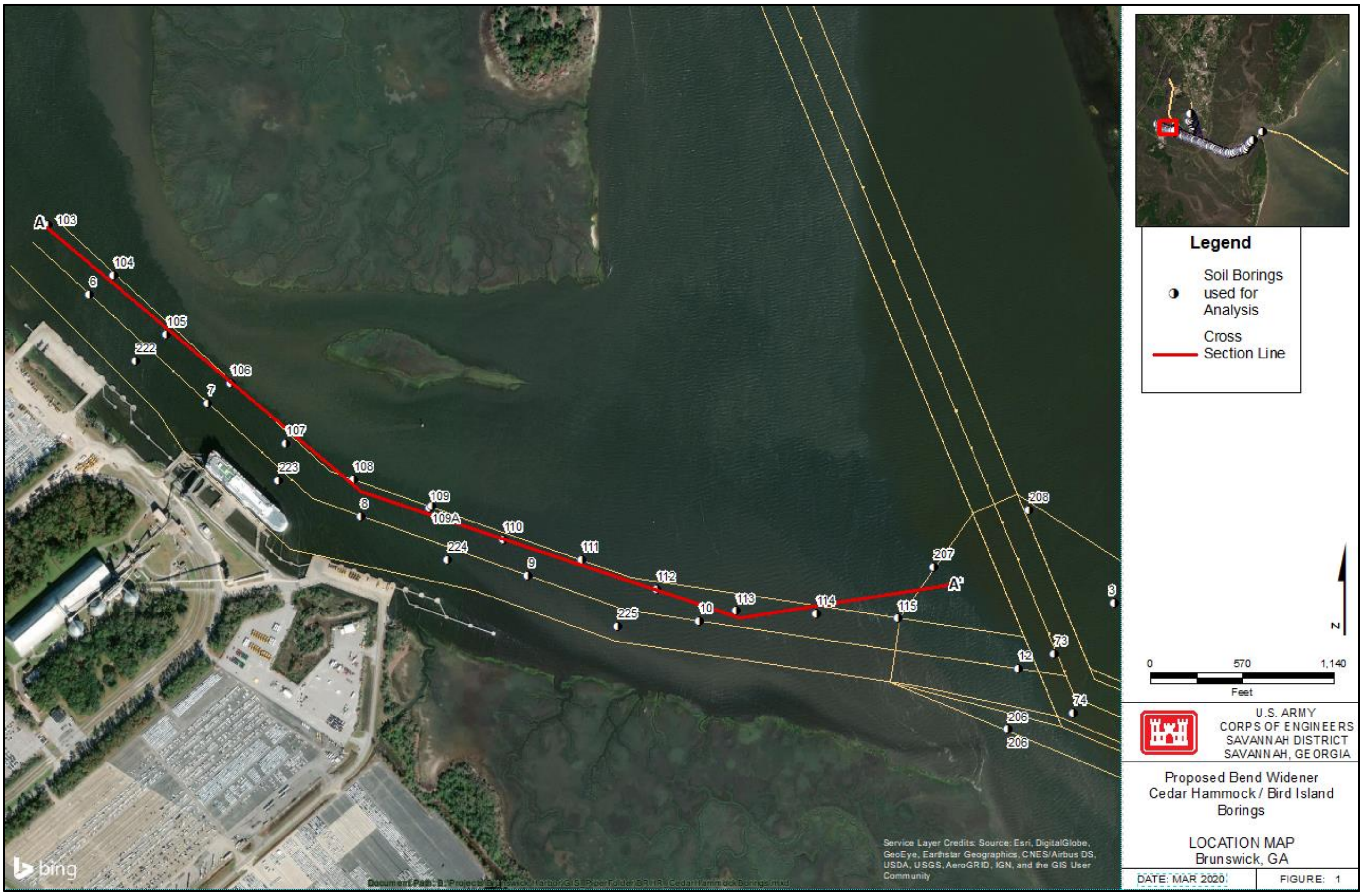


Figure 44- Soil Borings Evaluated for Turning Basin Alternatives

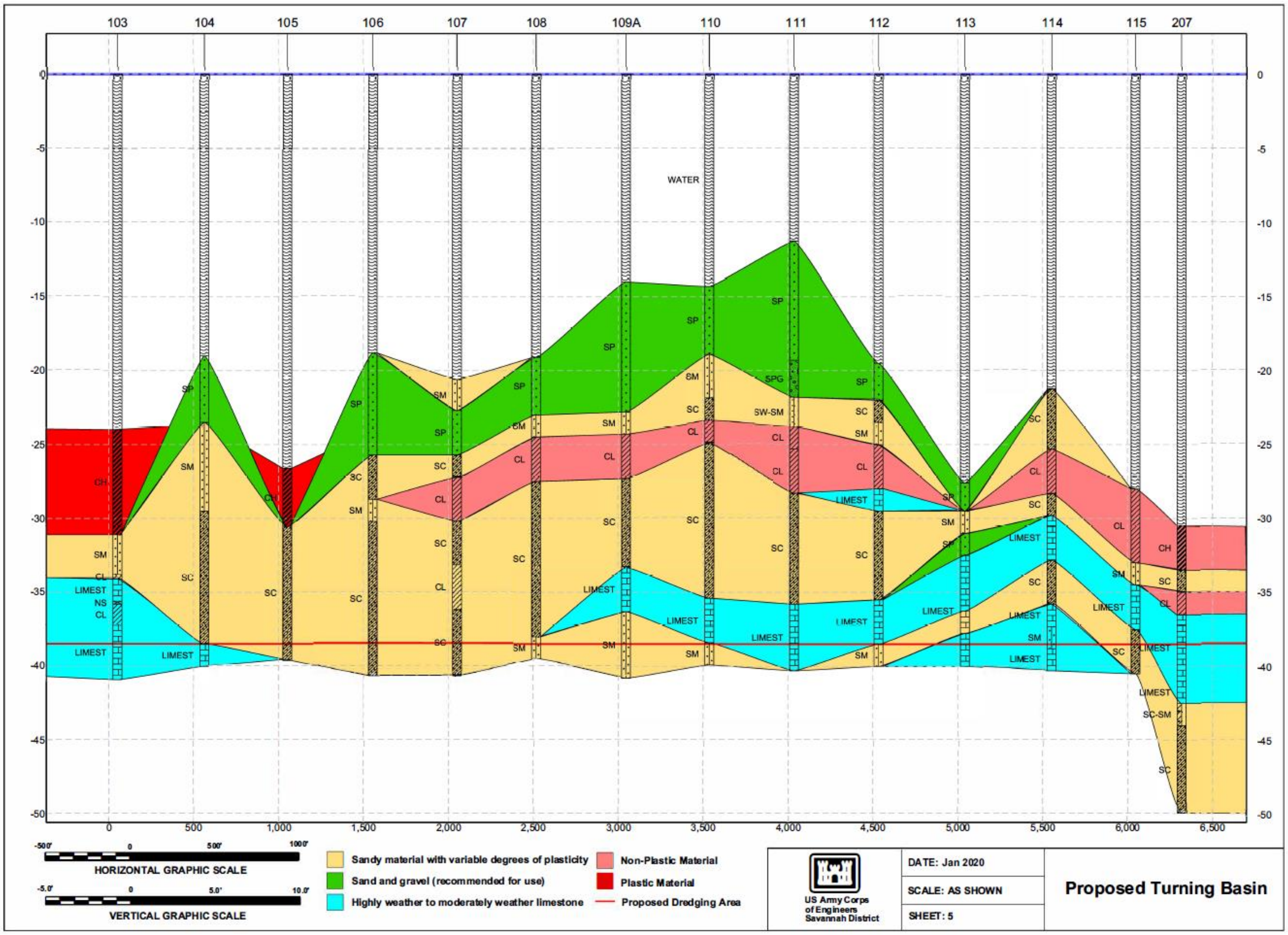


Figure 45– Soil Profile Interpolation near Turning Basin, A-A'

Very dense material was identified in some of the nearby borings within the required depths of the project and is described as ranging from hard to soft limestone, and is sometimes found in layers ranging from about 1 inch to 1 foot in thickness. Sediments similar to those that would be removed as part of this project have successfully been removed under previous projects.

Borings indicate the materials within the required depths and any allowable overdepth consist predominantly of soil. At some locations, the drilling action of the splitspoon sampler penetrated and broke apart less competent rock layers so they had the appearance of soil. The descriptions of these soils may indicate rock fragments or nodules of cemented or indurated soils are contained in the soil matrix of the sample. Sediments in the project area are largely a result of varying depositional environments and are discontinuous both vertically and horizontally. For this reason, variations in the characteristics of the subsurface material can be anticipated within relatively short distances.

In the area of the proposed Bend Widener at the intersection of Cedar Hammock and Brunswick Point Cut Ranges, nearby boring logs indicate the soils to be dredged consist of: high liquid-limit clay (CH), low liquid-limit clay (CL), high liquid-limit silt (MH), low liquid-limit silt (ML), poorly-graded sand (SP), silty sand (SM), high liquid-limit silty sand (SM-H), clayey sand (SC), silty-clayey sand (SC-SM), poorly-graded gravel (GP), silty gravel (GM), and clayey gravel (GC). Laboratory analyses indicate that poorly-graded silty sand (SP-SM), well-graded sand (SW), and well-graded silty sand (SW-SM) were also encountered. The coarse-grained soils encountered may contain varying amounts of fine to coarse sand and gravel-sized shell and rock fragments. The silt and clay constituents of these sands may be dolomitic and cohesive. Figure 46 shows the previously collected soil borings used for analysis of materials in the location of the bend widener. Figure 47 and Figure 48 show the interpolated profiles of soil characteristics near the bend widener.

Figure 46 - Soil Borings Evaluated near Bend Widener at Buoy 24

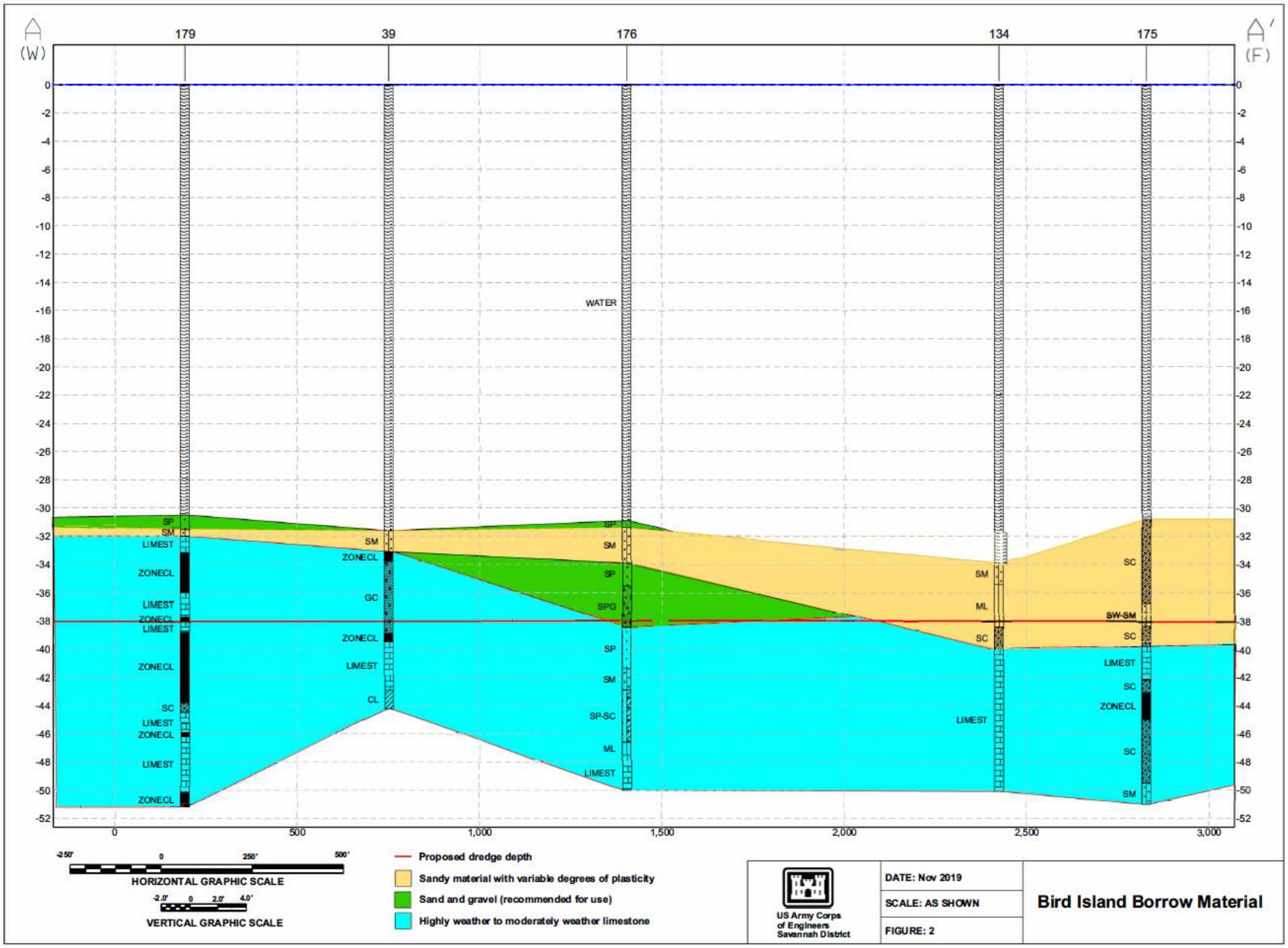


Figure 47 – Soil Profile Interpolation near Bend Widener, A-A'

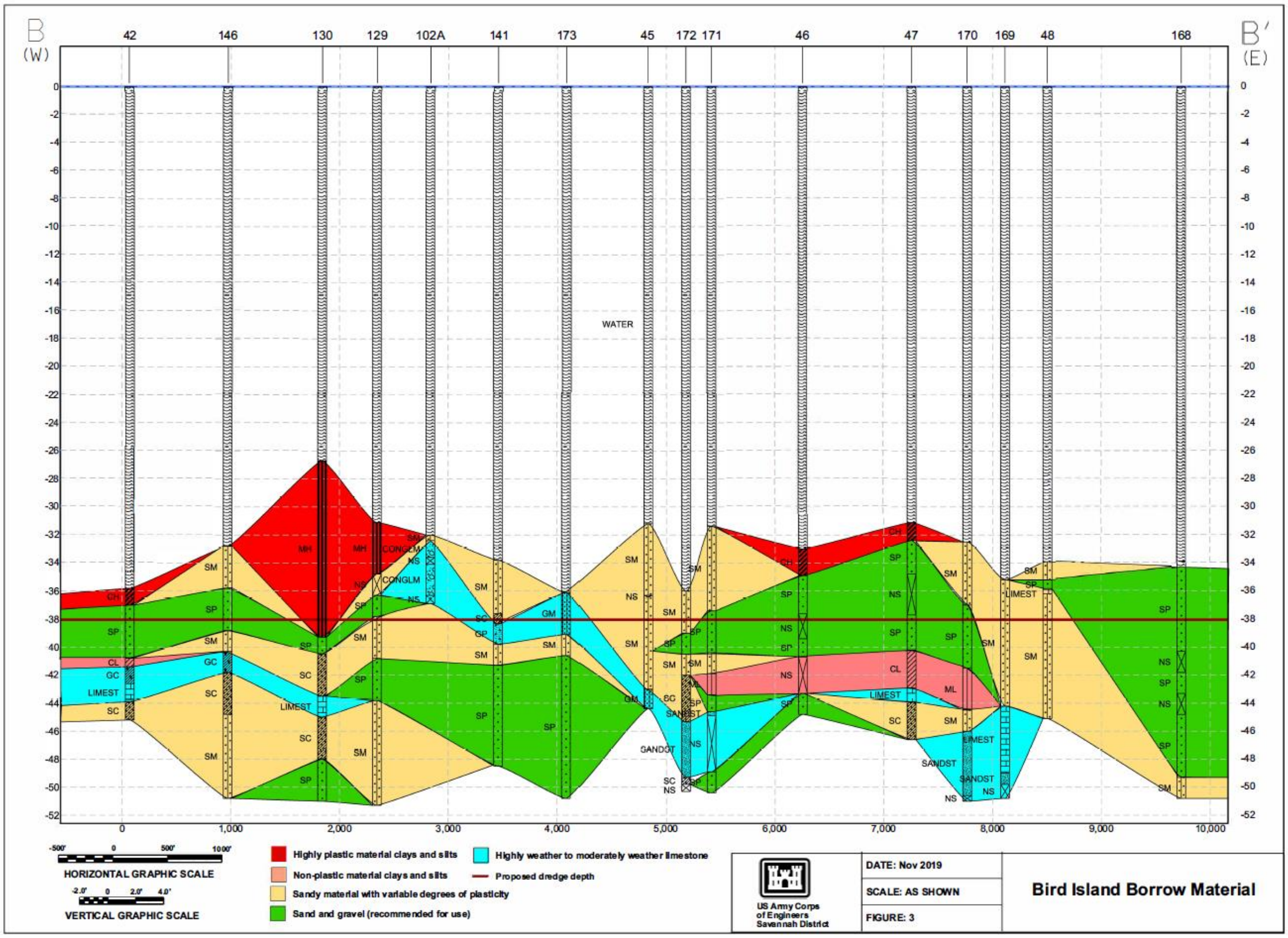


Figure 48 – Soil Profile Interpolation near Bend Widener, B-B’

In the area of the proposed Sidney Lanier Bridge Meeting Area, nearby boring logs indicate the soils to be dredged consist of: high liquid-limit clay (CH), low liquid-limit clay (CL), high liquid-limit silt (MH), low liquid-limit silt (ML), poorly-graded sand (SP), silty sand (SM), high liquid-limit silty sand (SM-H), clayey sand (SC), silty-clayey sand (SC-SM), poorly-graded gravel (GP), silty gravel (GM), and clayey gravel (GC). Laboratory analyses indicate that poorly-graded silty sand (SP-SM), well-graded sand (SW), and well-graded silty sand (SW-SM) were also encountered. Moderately to highly weathered, moderately hard to hard, highly porous limestone was also noted in this reach. The silt and clay constituents of these sands may be dolomitic and cohesive. Figure 49 shows the previously collected soil borings used for analysis of materials in the location of the bend widener. Figure 50 shows the interpolated profile of soil characteristics near the location of the Sidney Lanier Bridge Meeting Area.

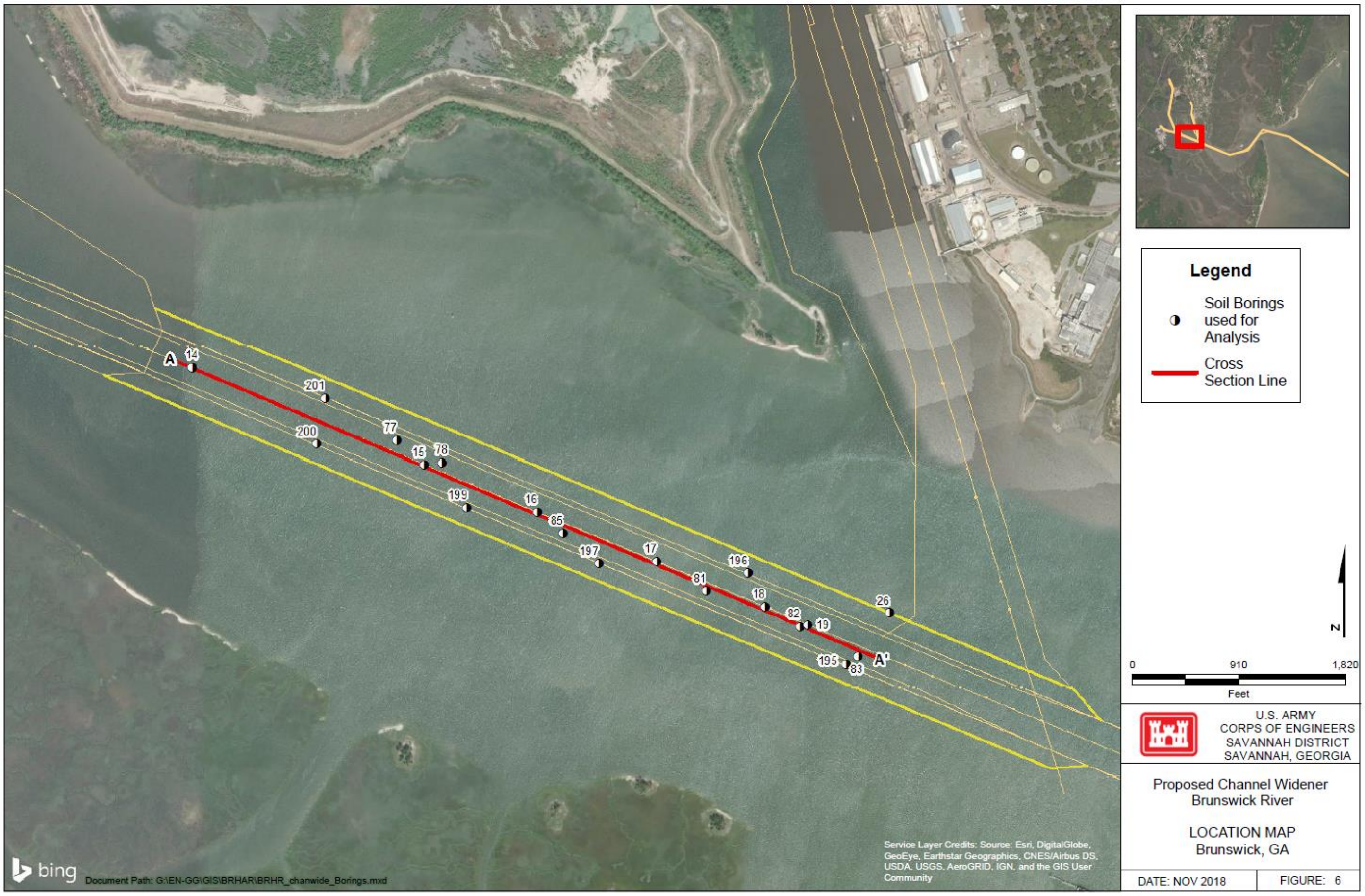


Figure 49- Soil Borings Evaluated near Sidney Lanier Bridge Meeting Area

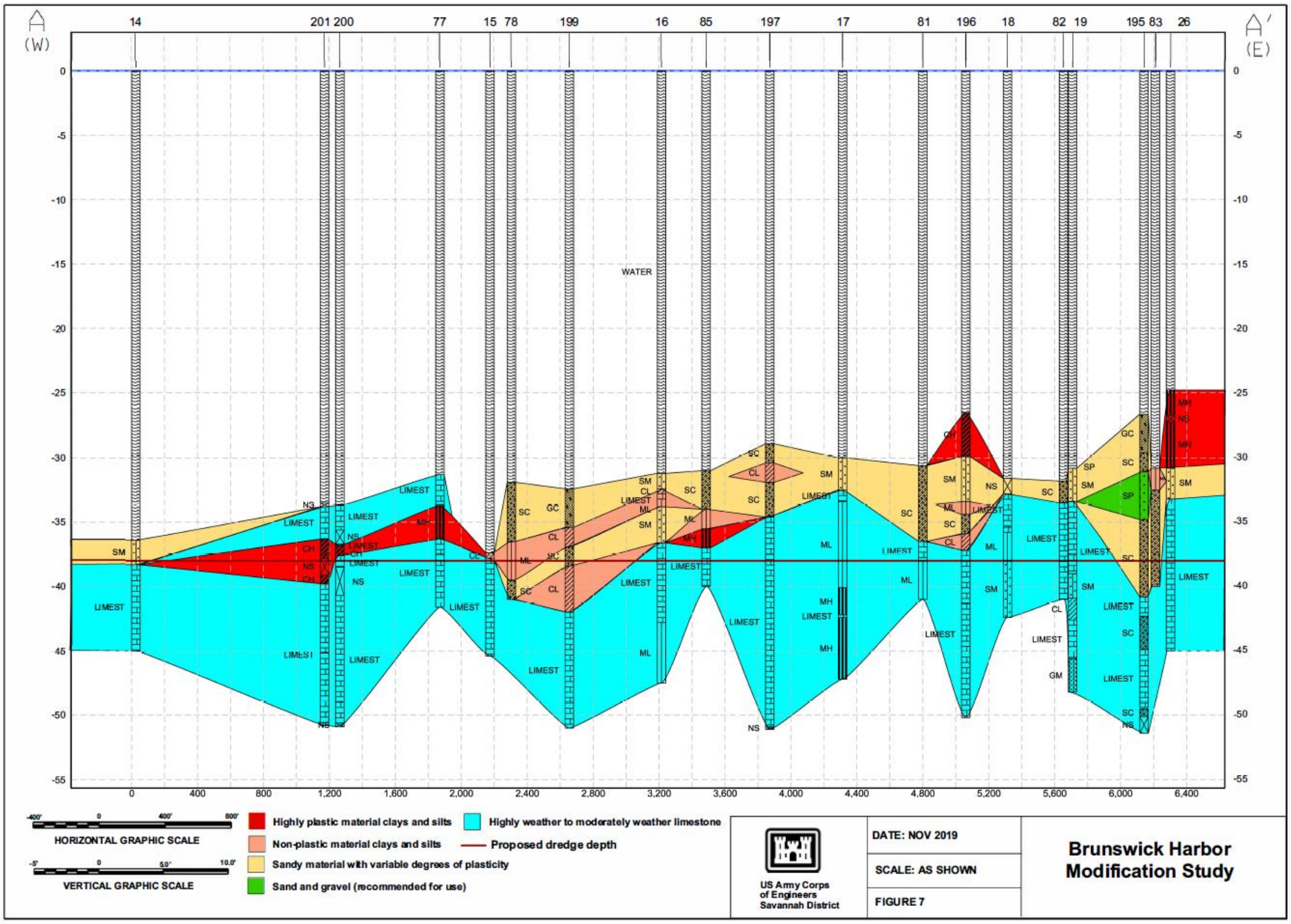


Figure 50 – Soil Profile Interpolation near Sidney Lanier Bridge, A-A'

It should be reiterated that these material descriptions are based on borings previously drilled for other work and may not be directly located in the actual areas proposed to be dredged. Also, these descriptions are in no way meant to imply the dredgeability of these materials. If the proposed wideners are funded, additional borings should be drilled accordingly. Further geotechnical investigations are scheduled to be performed during the Preconstruction Engineering and Design (PED) Phase of this project.

a. Dredging and Dredged Material Management

Material will be removed using a hydraulic cutter-head suction dredge and will be pumped into Andrews Island, an existing diked dredged material containment area (DMCA) for placement of sediments removed during maintenance dredging of Brunswick Harbor. The area is completely diked and covers about 770 acres. There are five existing weirs in the disposal area. The main weir for the DMCA is three 48-inch weirs side by side which are connected to one 60 inches HDPE outfall pipe which discharges to East River. The other two 48-inch weirs are currently not in use for maintenance dredging but are available after ditching is performed to allow water to flow to them.

The Andrews Island dikes were raised to elevation +44 feet MLW in 2009 after the 1998 Brunswick Harbor Deepening to restore capacities used during the deepening. The last dike improvement was performed by the Corps of Engineers in 2009 and will extend the remaining useful life of the site to about 50 years. Two additional future dike raisings are planned for the future. The current remaining capacity is 15,568,347 CY, according to the most recent survey, performed in November 2019. This capacity far exceeds the necessary volume of dredging for the Tentatively Selected Plan (TSP), Alternative 8, which totals approximately 550,000 CY. The average annual amount of maintenance material placed in Andrews Island DMCA is 390,000 CY. The current Dredge Material Management Plan (DMMP) was developed during the previous harbor deepening in 1998 (USACE – SAS, May 1998).

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