US Army Corps
of Engineers
Wilmington District®

Wilmington Harbor 403 EIS

Wilmington, North Carolina

Appendix A

General Engineering

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Draft

Prepared by U.S. Army Corps of Engineers
Wilmington District
69 Darlington Avenue
Wilmington, North Carolina 28403

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List of Figures

List of Tables

List of Attachments

APPENDIX A – GENERAL ENGINEERING

Section A.1. Introduction

A.1.1. Background

The U.S. Army Corps of Engineers (USACE), Wilmington District (SAW) initiated the Wilmington Harbor Section 403 Letter Report and Environmental Impact Statement Project (WH S403 Project) for the purpose of evaluating the technical, policy, and legal issues identified with the North Carolina State Ports Authority's (NCSPA) 2020 Water Resources Development Act (WRDA) 203 Feasibility Study. For the effort of evaluation, various engineering tasks were completed to support the WH S403 Project.

A.1.2. Project Area and Overview

The Federal Navigation System of the Wilmington Harbor is located along the Cape Fear River in New Hanover County in southeastern North Carolina. Federal Navigation System channels along the Cape Fear River connect the Port of Wilmington to the Atlantic Ocean. The overall project consists of 38 miles of channel from the entrance of the Cape Fear River at the Outer Ocean Bar to the Port of Wilmington, located at Anchorage Basin. Engineering evaluations were performed for channel deepening and channel widening, as shown in Figure 1.

A.1.3. Purpose

The purpose of the Appendix A - General Engineering is to present the general engineering analyses and design to support the WH S403 Project.

A.1.4. Datums

The following datums were used for the WH S403 Project, unless otherwise noted.

Horizontal: NAD83 North Carolina State Plane

Vertical: Mean Lower Low Water (MLLW)

Section A.2. Design and Construction

A.2.1. Background

The Federal Navigation System of Wilmington Harbor is divided into 23 separate reaches located within four maintenance segments: Upper Harbor, Mid-River, Inner Ocean Bar, and Outer Ocean Bar. The Upper Harbor Maintenance Segment includes the reaches from Anchorage Basin to Lower Brunswick. The Mid-River Maintenance Segment includes reaches from Upper Big Island to Lower Swash. The Inner Ocean Bar Maintenance Segment includes reaches from Battery Island to Baldhead Shoal Reach 2. The Outer Ocean Bar Maintenance Segment includes the reach Baldhead Shoal Reach 3. An additional reach named Baldhead Shoal Reach 4 has been proposed in the action alternatives and would be part of the Outer Ocean Bar. There are additional reaches north of the Port of Wilmington that are not considered for deepening and are therefore not discussed in this appendix. Please see Figure 1: Federal Navigation System Overview.

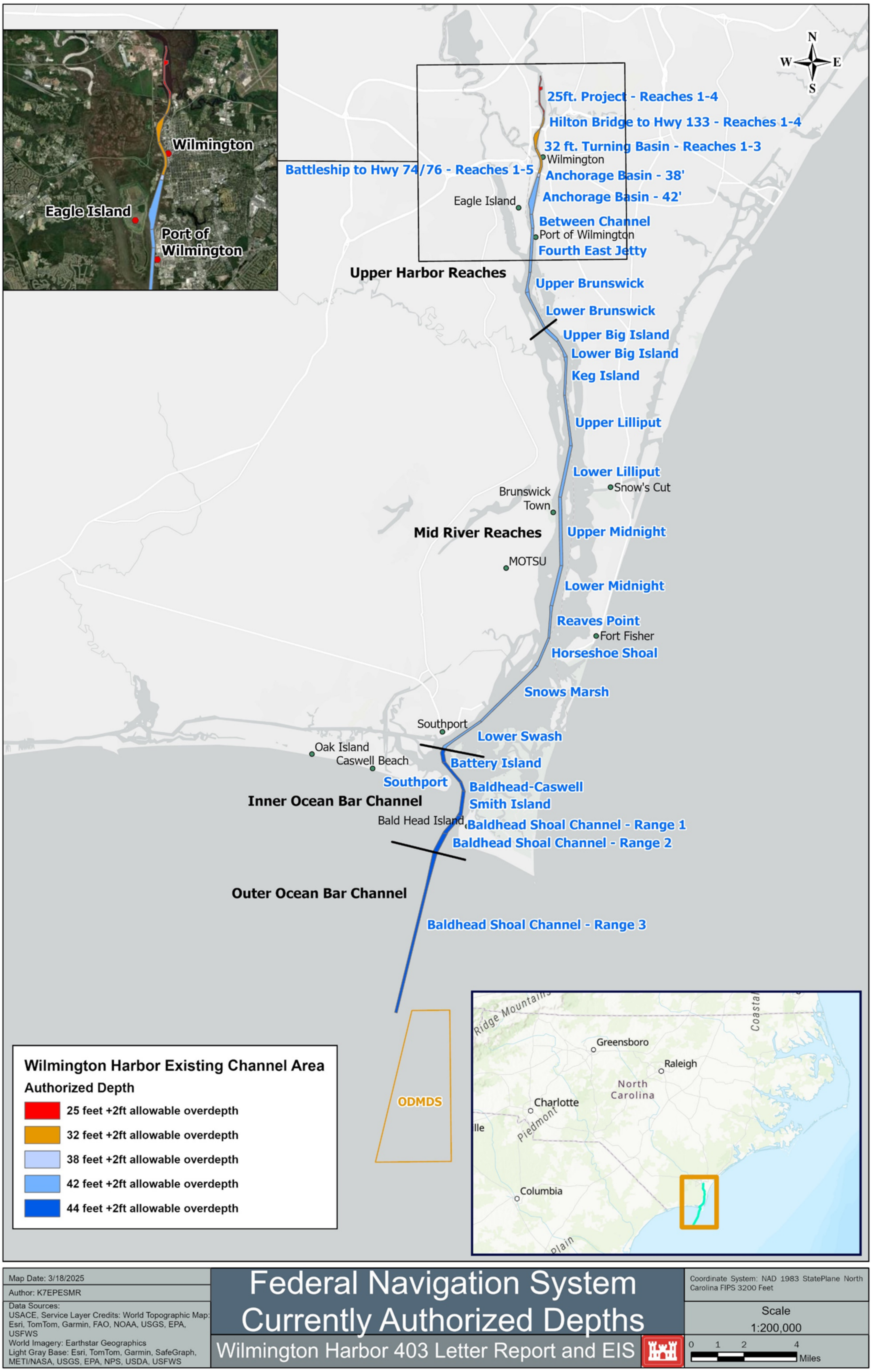

Figure 1: Federal Navigation System Overview

The reaches vary in authorized depth from 38 feet to 44 feet with an allowable overdepth of 2 feet. The reaches vary in width from 400 feet to 900 feet, with the exception of the Anchorage Basin which has a channel width of 1,200 feet to allow for the turning of vessels. Table A.1 summarizes the existing channel dimensions.

Table A.1: Existing Channel Dimensions

Reach	Channel Width (ft)	Maintained Channel Depth (ft)	Authorized Channel Depth + Overdepth (ft)
Anchorage Basin	547-1200	38/42[1]	44
Between Channel	500-550	42	44
Fourth East Jetty	450-500	42	44
Upper Brunswick	400-775	42	44
Lower Brunswick	400-775	42	44
Upper Big Island	540-700	42	44
Lower Big Island	400-700	42	44
Keg Island	400-700	42	44
Upper Lilliput	400-610	42	44
Lower Lilliput	600	42	44
Upper Midnight	600	42	44
Lower Midnight	600	42	44
Reaves Point	400-600	42	44
Horseshoe Shoal	400-610	42	44
Snows Marsh	400-610	42	44
Lower Swash	400-740	42	44
Battery Island	740	44	46
Southport	500-600	44	46
Baldhead-Caswell	500-650	44	46
Smith Island	650-895	44	46
Baldhead Shoal Reach 1	750	44	46
Baldhead Shoal Reach 2	900	44	46
Baldhead Shoal Reach 3	500-900	44	46

1. Anchorage Basin has an authorized depth of 38 feet between stations 0+00-40+00 and an authorized depth of 42 feet from station 40+00 to 84+05.

A.2.2. Channel Footprint Improvements

For this project, SAW analyzed three alternatives: a future without project (No Action Alternative, NAA), deepening the harbor to a minimum depth of 47 feet (Action Alternative 1, AA1), and deepening the harbor to a minimum depth of 46 feet (Action Alternative 2, AA2). Both AA1 and AA2 also involved widening most of the reaches. Currently, Wilmington Harbor has a minimum width of 400 feet and a maximum width of 1,200 feet. The proposed widening would increase the minimum width to 500 feet and the maximum width to 1,509 feet. Summaries of the footprint improvements can be found in Table A.2: Existing vs. Proposed Channel Widths. For more detailed information on the channel improvements, refer to **Attachment 1: Existing vs. Proposed Channel Footprints**.

Table A.2: Existing vs. Proposed Channel Footprints

Reach	Existing Channel Width (ft)	Proposed Channel Width (ft)
Anchorage Basin	547-1200	547-1509
Between Channel	500-550	575-625
Fourth East Jetty	450-500	550-575
Upper Brunswick	400-775	500-925
Lower Brunswick	400-775	500-925
Upper Big Island	540-700	560-700
Lower Big Island	400-700	500-795
Keg Island	400-700	500-795
Upper Lilliput	400-610	500-685
Lower Lilliput	600	600-660
Upper Midnight	600	600
Lower Midnight	600	600
Reaves Point	400-600	500-600
Horseshoe Shoal	400-610	500-710
Snows Marsh	400-610	500-710
Lower Swash	400-740	500-1230
Battery Island	740	1150-1300
Southport	500-600	800-1150
Baldhead-Caswell	500-650	800
Smith Island	650-895	900
Baldhead Shoal Reach 1	750	750-900
Baldhead Shoal Reach 2	900	900
Baldhead Shoal Reach 3	500-900	600-900
Baldhead Shoal Reach 4	N/A[1]	600

1. Baldhead Shoal Reach 4 does not currently exist and the reach would be added as part of AA1 or AA2.

A.2.3. Channel Dredge Depth Improvements (Action Alternative 1)

AA1 involves deepening the Federal Navigation System to a minimum depth of 47 feet. Specifically, the reaches would be deepened from an authorized depth of 42 feet to 47 feet between Anchorage Basin and Lower Swash. Battery Island to Baldhead Shoal Reach 4 would be deepened to an authorized depth of 44 feet to 49 feet. To ensure safe navigation, all reaches within the total channel length would include an additional 2 feet of overdepth, and areas with rock above the overdepth elevation would receive an additional 1 foot of overdepth for rock clearing. A summary of the proposed depths for AA1 can be found in Table A.3: AA1 Depth Improvements. A typical cross-section of the channel improvements for this alternative is illustrated in Figure 2: AA1 Typical Section.

Table A.3: AA1 Depth Improvements

Reach	Existing Authorized Depth (ft)	Proposed Authorized Depth (ft)	Initial Allowable Overdepth (ft)	Rock Clearing Overdepth (ft)	Total Depth (ft)
Anchorage Basin	42	47	+2	+1	50
Between Channel	42	47	+2	+1	50
Fourth East Jetty	42	47	+2	+1	50
Upper Brunswick	42	47	+2	+1	50
Lower Brunswick	42	47	+2	+1	50
Upper Big Island	42	47	+2	+1	50
Lower Big Island	42	47	+2	+1	50
Keg Island	42	47	+2	+1	50
Upper Lilliput	42	47	+2	+1	50
Lower Lilliput	42	47	+2	+1	50
Upper Midnight	42	47	+2	+0	49
Lower Midnight	42	47	+2	+0	49
Reaves Point	42	47	+2	+0	49
Horseshoe Shoal	42	47	+2	+0	49
Snows Marsh	42	47	+2	+1	50
Lower Swash	42	47	+2	+1	50
Battery Island	44	49	+2	+1	52
Southport	44	49	+2	+1	52
Baldhead-Caswell	44	49	+2	+0	51
Smith Island	44	49	+2	+0	51
Baldhead Shoal Reach 1	44	49	+2	+0	51
Baldhead Shoal Reach 2	44	49	+2	+0	51
Baldhead Shoal Reach 3	44	49	+2	+1	52
Baldhead Shoal Reach 4	N/A[1]	49	+2	+0	51

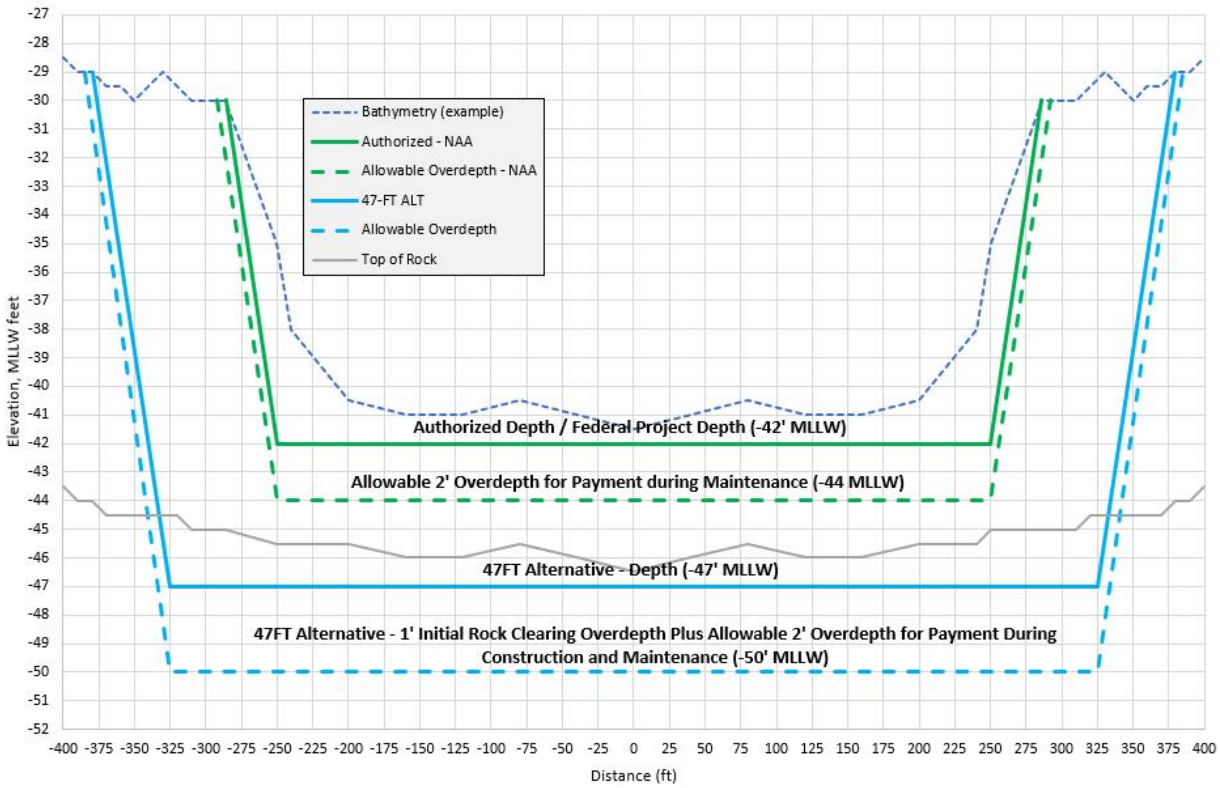

Figure 2: AA1 Typical Section

A.2.4. Channel Dredge Depth Improvements (Action Alternative 2)

AA2 involves deepening the harbor to a minimum depth of 46 feet. Specifically, the channel would be deepened from an authorized depth of 42 feet to 46 feet between Anchorage Basin and Lower Swash. Battery Island to Baldhead Shoal Reach 4 would be deepened from an authorized depth of 44 feet to 48 feet. Similar to AA1, all reaches within the total channel length would include an additional 2 feet of overdepth, and areas with rock above the overdepth elevation would receive an additional 1 foot of overdepth for rock clearing. A summary of the proposed depths for the AA2 can be found in Table A.4: AA2 Depth Improvements. A typical cross-section of the channel improvements for this alternative is illustrated in Figure 3: AA2 Typical Section.

Table A.4: AA2 Depth Improvements

Reach	Existing Authorized Depth (ft)	Proposed Authorized Depth (ft)	Initial Allowable Overdepth (ft)	Rock Clearing Overdepth (ft)	Total Depth(ft)
Anchorage Basin	42	46	+2	+1	50
Between Channel	42	46	+2	+1	50
Fourth East Jetty	42	46	+2	+1	50
Upper Brunswick	42	46	+2	+1	50
Lower Brunswick	42	46	+2	+1	49
Upper Big Island	42	46	+2	+1	49
Lower Big Island	42	46	+2	+1	49
Keg Island	42	46	+2	+1	49
Upper Lilliput	42	46	+2	+1	49

Reach	Existing Authorized Depth (ft)	Proposed Authorized Depth (ft)	Initial Allowable Overdepth (ft)	Rock Clearing Overdepth (ft)	Total Depth(ft)
Lower Lilliput	42	46	+2	+1	49
Upper Midnight	42	46	+2	+0	48
Lower Midnight	42	46	+2	+0	48
Reaves Point	42	46	+2	+0	48
Horseshoe Shoal	42	46	+2	+0	48
Snows Marsh	42	46	+2	+1	49
Lower Swash	42	46	+2	+1	49
Battery Island	44	48	+2	+1	51
Southport	44	48	+2	+1	51
Baldhead-Caswell	44	48	+2	+0	50
Smith Island	44	48	+2	+0	50
Baldhead Shoal Reach 1	44	48	+2	+0	50
Baldhead Shoal Reach 2	44	48	+2	+0	50
Baldhead Shoal Reach 3	44	48	+2	+1	51
Baldhead Shoal Reach 4	N/A	48	+2	+0	50

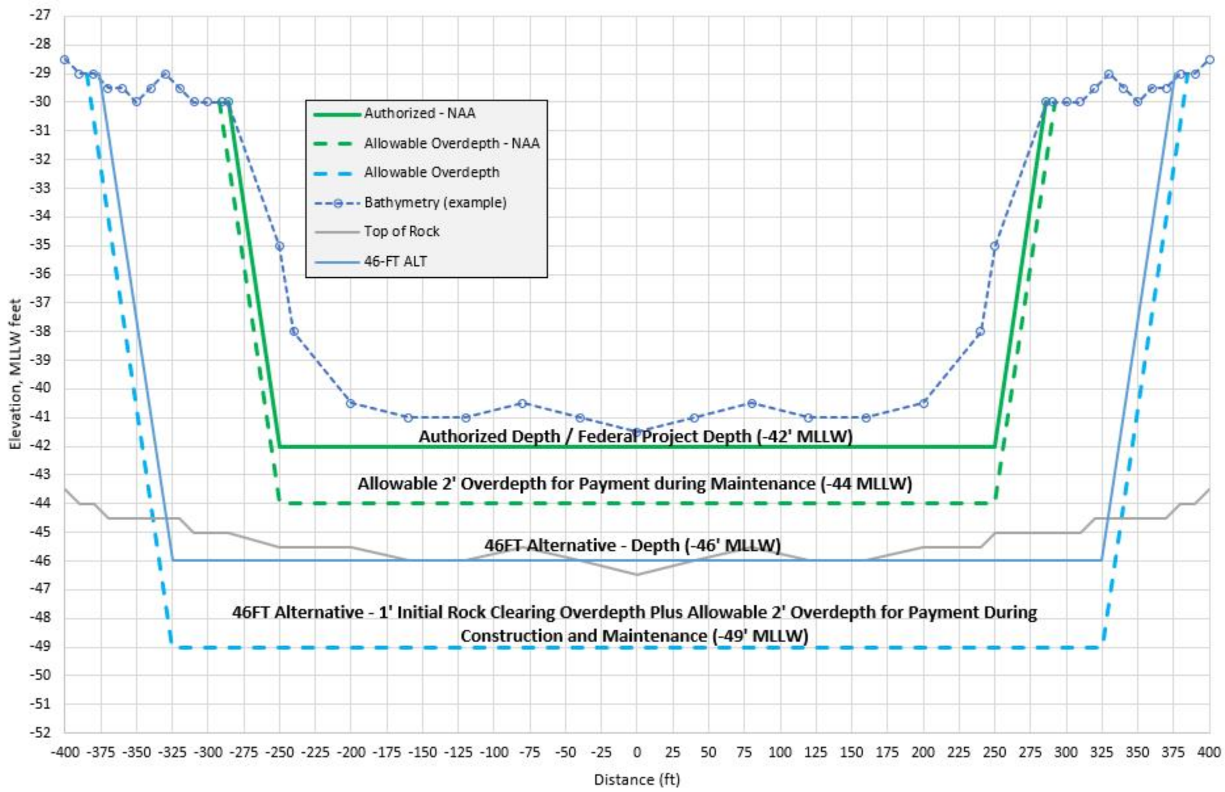

Figure 3: AA2 Typical Section

A.2.5. Construction Methodology

To achieve the desired channel improvements, it is assumed that mechanical, hydraulic pipeline and hopper dredges will be utilized. Mechanical dredges will be used to excavate and remove material from the harbor. Excavated material will then be transported to the Ocean Dredged Material Disposal Site (ODMDS) using scows for proper placement. Alternatively, hopper dredges may also be used to excavate and remove material for transport to and placement in the ODMDS. In contrast, a hydraulic pipeline dredge will be used to remove material that is suitable for beneficial use. Beneficial use could include beach renourishment or habitat restoration and will be pumped through a pipeline to designated sites where it can be repurposed. Between the Lower Brunswick and Keg Island reaches, it is expected that hard rock will be encountered. Controlled rock blasting will be used to break up the rock, allowing for its safe and efficient removal. For further detail on rock blasting, refer to *Appendix C, Geology and Geotechnical Engineering Appendix*. For further details on beneficial use sites and placement, please refer to *Appendix D, Beneficial Use Appendix*.

Section A.3. Operations and Maintenance

A.3.1. Historic Quantities

SAW currently conducts Operations and Maintenance (O&M) dredging on the Federal Navigation System each year. Some reaches such as Anchorage Basin and Outer Ocean Bar are dredged every year while most of the other reaches are dredged less frequently. Annually, approximately 2.7 million cubic yards of material are dredged from the channel. Refer to Table A.5: Federal Channel Dredging History for further details.

Table A-5: Federal Channel Dredging History

Reach	Frequency of Dredging	Yearly Average Dredging Quantity (CY)[1]	Placement Site	Dredge Type[2]
Anchorage Basin	Every Year	1,117,000	ODMDS/Eagle Island	2/3
Between Channel	Every Year	36,000	ODMDS/Eagle Island	2/3
Fourth East Jetty	When Needed	11,000	ODMDS/Eagle Island	2/3
Upper Brunswick	Every 2 to 4 Years	45,000	ODMDS/Eagle Island	2/3
Lower Brunswick	Every 2 to 6 Years	64,000	ODMDS/Eagle Island	2/3
Upper Big Island	Every 2 to 6 Years	21,000	ODMDS	1/3
Lower Big Island	Every 2 to 6 Years	10,000	ODMDS	1/3
Keg Island	Every 2 to 6 Years	19,000	ODMDS	1/3
Upper Lilliput	Every 3 to 6 Years	24,000	ODMDS	1/3
Lower Lilliput	Every 3 to 6 Years	57,000	ODMDS	1/3
Upper Midnight	Every 2 to 6 Years	40,000	ODMDS	1/3
Lower Midnight	Every 2 to 6 Years	8,000	ODMDS	1/3
Reaves Point	Every 3 to 6 Years	5,000	ODMDS	1/3
Horseshoe Shoal	Every 3 to 6 Years	30,000	Bird Island/ODMDS	1/2/3
Snows Marsh	Every 3 to 6 Years	17,000	Bird Island/ODMDS	1/2/3
Lower Swash	When Needed	0	ODMDS	1/3
Battery Island	Every 3 to 4 Years	27,000	ODMDS	1/2
Southport	Every 3 to 4 Years	6,000	ODMDS	1/2
Baldhead-Caswell	When Needed	5,000	ODMDS	1/2
Smith Island	Every 3 to 4 Years	205,000	Baldhead Island/Oak Island/ODMDS	1/2
Baldhead Shoal Reach 1	Every 5 to 6 Years	138,000	Baldhead Island/Oak Island/ODMDS	1/2
Baldhead Shoal Reach 2	Every 5 to 6 Years	127,000	Baldhead Island/Oak Island/ODMDS	1/2
Baldhead Shoal Reach 3	Every Year	714,000	ODMDS	1

1. Data is based on maintenance dredging in the Federal Channel between 2005 – 2022.
2. Dredging Method: 1 – Hopper Dredge, 2 – Pipeline Dredge, 3 – Mechanical (Clamshell)

Section A.4. Quantity Estimating

For cost estimating purposes, SAW analyzed the amount of material to be removed from the harbor for the AA1 and AA2. Dredged Material was differentiated between O&M material, New Work material, Hard Rock, and Soft Rock. O&M Material is material that is located within the existing dredge box templates. New Work material is non-rock material that is located outside of the existing dredge box, inside of the proposed dredge box of either AA1 or AA2, and above the Top of Rock surface. Soft Rock is material located within the proposed AA1 and AA2 dredge boxes, below the top of rock surface, and can be removed via standard dredging methods. Hard Rock is material located within the proposed AA1 and AA2 dredge boxes, below the top of rock surface, and requires confined blasting before it is able to be removed using standard dredging methods.

A.4.1. Program

AutoCAD Civil 3D 2021 was the program used to compute material quantities. The program utilizes a surface analysis tool to calculate the cut and fill of two overlapping surfaces. Using this tool, SAW could create a proposed surface using the designed dredge box dimensions and compare it against the existing survey surface. The surface analysis tool would compute the quantity of cut, which is the material to be dredged from the channel.

A.4.2. Bathymetry

The SAW Navigation Team was able to survey each of the reaches using the district survey vessels “Swart” and “Sanderson”, using Real Time Kinematic Global Positioning System (RTK GPS) Horizontal Positioning Equipment and 200 kilohertz (kHz) sounding equipment between April and December of 2023. The survey data was imported into AutoCAD Civil 3D 2021 and converted into a digital surface to be compared against the dredge box surfaces. All bathymetry surveys were conducted at least 7 months post dredging. SAW considers that although bathymetry may vary annually due to shoaling and O&M dredging events, the collected data offers an accurate estimate of expected quantities for construction of AA1 and AA2.

A.4.3. Top of Rock

The SAW Geotechnical Team was able to test boring samples at several points along each reach to determine the elevation of the top of the rock. These points were imported into AutoCAD Civil 3D 2021 and a surface was created by triangulating the points. Utilizing the surface analysis tool, the quantity of rock required for removal within each channel alternative reach was determined. The assessment distinguished how much of the cut for each channel alternative was rock that needed to be removed. The rock surface consists of hard rock and soft rock which were also differentiated in quantities. Hard rock generally refers to rock that needs to be blasted before dredging, while soft rock generally refers to rock that can be dredged without the need for blasting. Refer *to Appendix C- Geology and Geotechnical Engineering Appendix* for further information. A majority of the Federal Navigation System consists of soft rock with the exception of all of the Upper Big Island and the Lower Big Island reaches, the lower 1,730 feet of reach of Lower Brunswick, and the upper 2,980 feet of reach of Keg Island. Please refer to Figure 4: Hard Rock Boundary, the white line shows the area of hard rock in this area.

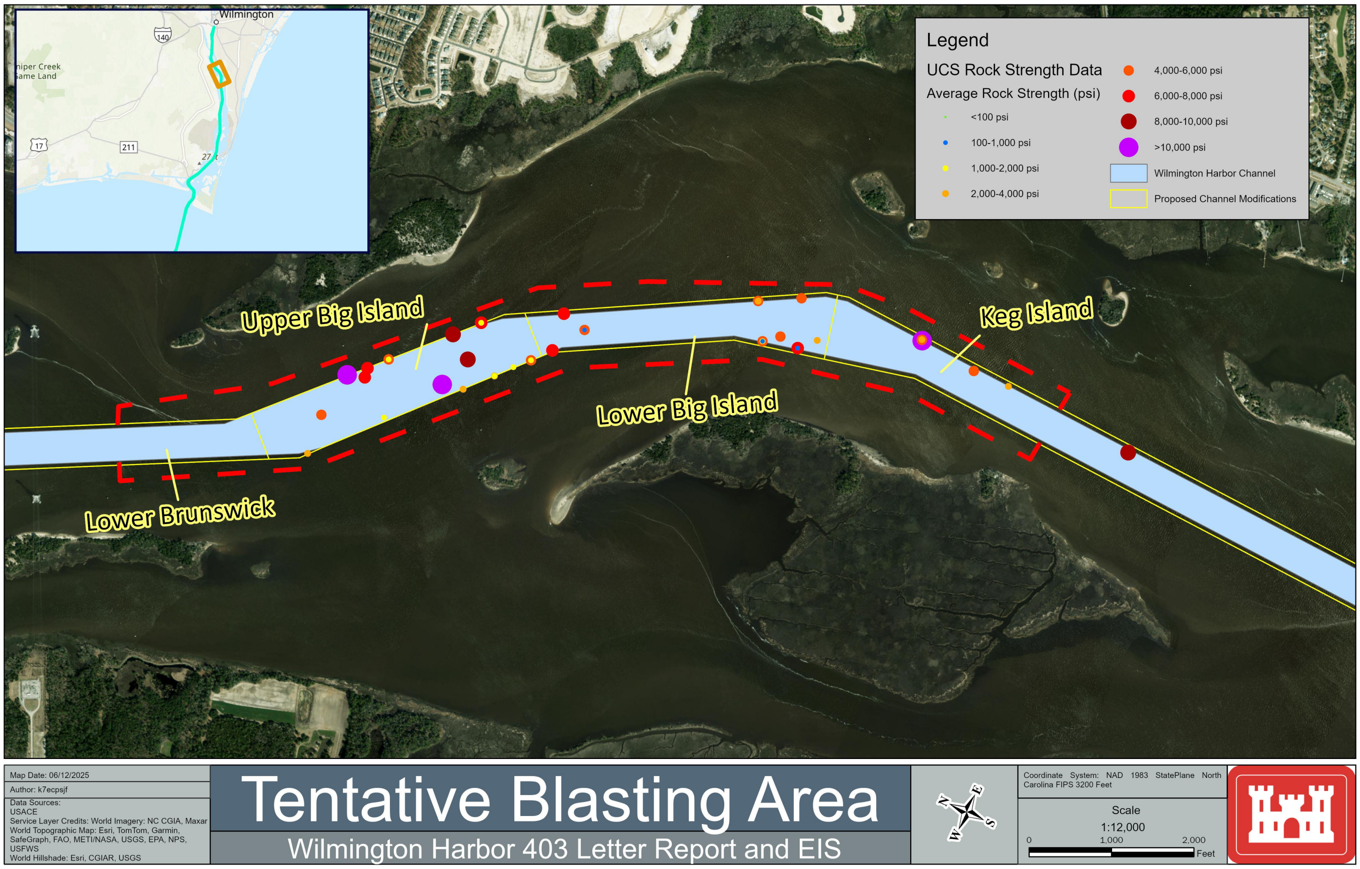

Figure 4: Hard Rock Boundary

A.4.4. Quality Control/Quality Assurance

Once SAW's Engineering Team calculated the various quantities for each reach of Wilmington Harbor, SAW's Navigation Team reviewed the results using their own quantity calculation program, Hypack. Quantities were deemed accurate if the values produced by the SAW Engineering Team had no more than a 3% difference compared to the values produced by the SAW Navigation Team. All quantities were within the acceptable range and therefore were considered accurate.

Section A.5. AA1 and AA2 Dredge Quantities

Table A.6 summarizes the dredge quantities for each reach of the Wilmington Harbor under Alternative AA1. Table A.7 summarizes the dredge quantities for each reach of the Wilmington Harbor under Alternative AA2.

Table A.6: Action Alternative 1 Dredge Quantities

Reach	Total Quantity (CY)	Maintenance O&M (CY)	New Work (Non-Rock) (CY)	Soft Rock (CY)	Hard Rock (CY)
Anchorage Basin - 8+00 to 84+85	2,948,659	1,341,184	655,649	951,826	0
Between Channel	446,318	16,075	218,109	212,134	0
Fourth East Jetty	1,165,438	80,565	580,000	504,873	0
Upper Brunswick	931,418	132,392	649,048	149,979	0
Lower Brunswick	1,556,968	139,857	1,027,851	222,654	166,605
Upper Big Island	817,838	173,172	217,380	0	427,286
Lower Big Island	897,799	121,128	386,478	0	390,193
Keg Island	1,430,867	115,010	973,994	183,344	158,518
Upper Lilliput	1,747,351	164,681	1,266,666	316,004	0
Lower Lilliput	1,940,116	402,063	1,468,120	69,934	0
Upper Midnight	1,710,712	264,794	1,445,918	0	0
Lower Midnight	986,874	112,565	874,309	0	0
Reaves Point	953,751	163,697	790,053	0	0
Horseshoe Shoal	783,187	88,667	694,521	0	0
Snows Marsh	1,959,499	99,651	1,721,621	138,227	0
Lower Swash	2,106,332	57,799	1,803,408	245,125	0
Battery Island	1,322,486	173,184	928,245	221,058	0
Southport	552,585	27,878	522,229	2,478	0
Baldhead-Caswell	172,654	51,064	121,590	0	0
Smith Island Channel	1,073,055	425,159	647,896	0	0
Baldhead Shoal Reach 1	888,939	321,027	567,911	0	0
Baldhead Shoal Reach 2	1,096,998	276,738	819,370	890	0
Baldhead Shoal Reach 3	5,444,024	294,680	4,818,665	330,679	0
Baldhead Shoal Reach 4	1,634,666	N/A	1,634,666	0	0

Table A.7: Action Alternative 2 Dredge Quantities

Reach Name	Total Quantity (CY)	Maintenance O&M (CY)	New Work (Non-Rock) (CY)	Soft Rock (CY)	Hard Rock (CY)
Anchorage Basin - 8+00 to 84+85	2,667,980	1,341,184	632,886	693,910	0
Between Channel	377,250	16,075	214,218	146,957	0
Fourth East Jetty	964,195	80,565	559,255	324,374	0
Upper Brunswick	823,173	132,392	597,786	92,995	0
Lower Brunswick	1,351,865	139,857	951,732	128,741	131,535
Upper Big Island	703,250	173,172	195,753	0	334,325
Lower Big Island	803,560	121,128	371,208	0	311,224
Keg Island	1,242,082	115,010	892,417	129,081	105,575
Upper Lilliput	1,513,754	164,681	1,123,238	225,834	0
Lower Lilliput	1,659,028	402,063	1,228,784	28,180	0
Upper Midnight	1,370,348	264,794	1,105,554	0	0
Lower Midnight	778,791	112,565	666,226	0	0
Reaves Point	809,785	163,697	646,088	0	0
Horseshoe Shoal	651,339	88,667	562,673	0	0
Snows Marsh	1,624,592	99,651	1,448,868	76,074	0
Lower Swash	1,820,937	57,799	1,619,169	143,969	0
Battery Island	1,191,910	173,184	871,341	147,385	0
Southport	438,636	27,878	409,598	1,160	0
Baldhead-Caswell	138,671	51,064	87,607	0	0
Smith Island Channel	928,205	425,159	503,045	0	0
Baldhead Shoal Reach 1	752,719	321,027	431,692	0	0
Baldhead Shoal Reach 2	925,511	276,738	648,171	603	0
Baldhead Shoal Reach 3	4,559,445	294,680	4,027,027	237,737	0
Baldhead Shoal Reach 4	966,118	N/A	966,118	0	0

The Total Quantity was computed using the surface analysis tool and calculating the difference between the bathymetry surface and the proposed dredge box. The O&M Quantity was computed using the surface analysis tool and calculating the difference between the bathymetry surface and the existing dredge boxes. The Soft Rock Quantity was computed using the surface analysis tool and calculating the difference between the top of rock surface and the proposed dredge box in areas outside the Hard Rock Boundary. The Hard Rock Quantity was computed using the surface analysis tool and calculating the difference between the top of rock surface and the proposed dredge box in areas inside the Hard Rock Boundary. Finally, the New Work (Non-Rock) Quantity was calculated by subtracting the O&M Quantity, the Soft Rock Quantity, and the Hard Rock Quantity from the Total Quantity.

Section A.6. Future Maintenance

SAW contracted Stantec to calculate the future O&M Maintenance Work for the No Action Alternative, AA1, and AA2. Stantec used the coupled FLOW/MOR/WAVE modules to simulate morphological changes due to both suspended and bed load sediment transport for three channel deepening alternatives: NAA, AA1, and AA2. This approach incorporated riverine (flow) and coastal (tidal and wave) processes and evaluated the impact of multiple sea level change (SLC) scenarios: No SLC, SLC1 (0.5 ft), SLC2 (1.28 ft), and SLC3 (3.77 ft). The results were used to develop shoaling rates, both with and without project, along each reach of the existing and proposed navigation channel. Projected O&M dredging quantities correlate with the estimated shoaling rates. While not a direct equivalence, the correlation exists because dredging occurs only when shoaling reaches the required depth and is economically justifiable. Therefore, the estimated shoaling rate provides an indication of potential dredging volumes for each reach. It is important to consider that shoaling rates are not static; factors like storm frequency and intensity, sediment composition, and adjacent land use can lead to significant variability from year to year. Please see Table A.8: Estimated Shoaling Rates in CY/YR for NAA, Table A.9: Estimated Shoaling Rates in CY/YR for AA1, and Table A.10: Estimated Shoaling Rates in CY/YR for AA2 for results. Please refer to **Attachment 2: Channel Morphology** Study for further details on the modeling.

Table A.8: Estimated Shoaling Rates in CY/YR for NAA

Reach	No SLC (CY/YR)	SLC 1 (CY/YR)	SLC 2 (CY/YR)	SLC 3 (CY/YR)
Anchorage Basin	1,549,100	1,621,000	1,742,000	1,845,000
Between Channel	401,260	416,450	425,680	381,940
Fourth East Jetty	851,100	862,650	853,410	630,220
Upper Brunswick	93,389	96,654	104,460	72,136
Lower Brunswick	53,872	51,928	46,654	13,718
Upper Big Island	56,851	52,662	45,829	9,687
Lower Big Island	34,411	32,671	25,785	2,154
Keg Island	5,780	5,558	4,472	-
Upper Lilliput	952	844	821	459
Lower Lilliput	125,610	128,120	119,050	35,330
Upper Midnight	71,727	72,473	66,736	30,119
Lower Midnight	4,900	4,824	4,821	3,933
Reaves Point	645	847	1,071	94
Horseshoe Shoal	209	267	238	30
Snows Marsh	4,227	5,395	5,887	484
Lower Swash	1,273	1,255	1,097	269
Battery Island	8,326	8,151	10,876	26,112
Southport	9,264	8,422	7,440	7,800
Baldhead-Caswell	1,663	1,444	1,251	333
Smith Island	289,031	319,816	354,365	203,287
Baldhead Shoal Reach 1	115,876	114,789	123,026	65,407
Baldhead Shoal Reach 2	110,745	114,179	117,024	115,867

Table A.9 Estimated Shoaling Rates in CY/YR for AA1

Reach	No SLC	SLC 1	SLC 2	SLC 3
Anchorage Basin	1,559,600	1,643,700	1,780,600	1,873,800
Between Channel	420,090	437,470	452,130	415,540
Fourth East Jetty	990,930	999,240	977,630	714,130
Upper Brunswick	145,600	149,240	152,280	100,500
Lower Brunswick	97,135	89,044	73,179	24,546
Upper Big Island	98,841	89,055	76,113	13,120
Lower Big Island	62,578	59,460	51,424	9,644
Keg Island	20,541	17,362	13,296	872
Upper Lilliput	5,312	4,734	4,457	1,673
Lower Lilliput	129,860	133,440	122,370	34,794
Upper Midnight	63,296	64,198	59,439	24,662
Lower Midnight	2,263	2,333	2,373	4,118
Reaves Point	1,282	1,551	1,942	262
Horseshoe Shoal	326	403	432	54
Snows Marsh	4,319	5,235	5,914	1,055
Lower Swash	397	499	625	309
Battery Island	9,218	10,889	13,304	14,149
Southport	3,115	3,719	3,933	7,322
Baldhead-Caswell	84	97	123	134
Smith Island	276,810	309,925	350,047	193,581
Baldhead Shoal Reach 1	131,506	131,413	136,866	72,510
Baldhead Shoal Reach 2	117,602	121,285	125,253	124,339

Table A.10: Estimated Shoaling Rates in CY/YR for AA2

Reach	No SLC	SLC 1	SLC 2	SLC 3
Anchorage Basin	1,544,700	1,629,200	1,764,000	1,876,900
Between Channel	414,920	432,350	444,530	405,550
Fourth East Jetty	951,880	965,030	942,830	687,240
Upper Brunswick	133,750	138,350	142,070	95,155
Lower Brunswick	84,025	77,806	64,815	23,671
Upper Big Island	86,645	77,987	68,118	16,956
Lower Big Island	57,671	56,194	48,500	8,104
Keg Island	17,768	15,740	12,264	641
Upper Lilliput	4,294	3,971	3,792	1,364
Lower Lilliput	125,480	129,870	120,230	34,087
Upper Midnight	62,566	64,071	57,777	24,615
Lower Midnight	2,243	2,388	2,319	3,816
Reaves Point	1,190	1,449	1,823	242
Horseshoe Shoal	293	369	398	49
Snows Marsh	4,244	5,153	5,847	1,041
Lower Swash	373	471	592	295
Battery Island	8,378	9,977	12,373	13,777
Southport	3,836	4,266	4,373	7,660
Baldhead-Caswell	106	127	148	160
Smith Island	277,500	310,699	350,567	195,781
Baldhead Shoal Reach 1	129,823	126,434	135,207	70,463
Baldhead Shoal Reach 2	115,952	119,505	123,606	122,361

Section A.7. Pre-construction Engineering and Design Considerations

The Pre-construction Engineering and Design (PED) phase stands as a crucial early stage in the engineering process, emphasizing planning, construction considerations, and overall project design. Below is a list of various items that will need to be considered during the PED Phase with the details following.

- Dredged Material Management
- Dredging Methodology and Equipment
- Navigation and Infrastructure Impacts

A.7.1. Dredged Material Management

USACE has a stated goal that 70% of all dredged material should be used for beneficial purposes (i.e. bank stabilization, habitat restoration, beach renourishment). Currently, most of the dredged material from Wilmington Harbor is placed in either the Eagle Island Upland Placement Facility or the ODMDS during O&M dredging operations. Neither of these placement sites are considered beneficial use. About 15 to 20 percent of the material currently dredged from the harbor during O&M activities is used for beach renourishment or bird island restoration. Several potential beneficial use sites have been identified during the feasibility phase of this project to help increase the beneficial use rate to 70% and are outlined in *Appendix D: Beneficial Use Appendix*. More detailed design considerations will be conducted in the PED phase such as determining the constructability of dredge placement based on soil material and site conditions, identifying challenges such as site access and capacity constraints, and mitigating risk through stakeholder collaboration.

A.7.2. Dredging Methodology

The selection of dredge type and placement location for dredged material are critical decisions for the Wilmington Harbor 403 Project, carrying significant environmental and economic implications. The chosen dredge type, whether mechanical, hydraulic, or hopper, must be tailored to the specific site conditions, such as sediment type, water depth, and project timeline. Simultaneously, identifying suitable placement locations for the dredged material requires careful consideration of factors like environmental impact, transportation costs, and potential beneficial reuse options. A comprehensive analysis involving geotechnical investigations, environmental assessments, and cost-benefit analyses is essential to selecting the most efficient and sustainable dredging and placement strategy, ensuring minimal disruption to the marine ecosystem and maximizing the project's long-term benefits.

A.7.3. Navigation and Infrastructure Impacts

Dredging operations can significantly impact established navigation channels, requiring careful planning of dredging sequences, placement of dredge material, and implementation of real-time vessel monitoring systems to ensure safe passage for commercial and recreational traffic. Additionally, the project's impact on existing infrastructure, such as wharves, piers, and pipelines, necessitates thorough assessments. Potential issues include undermining of structures due to dredging, increased vessel drafts affecting berthing capabilities, and the need for relocation or protection of underwater utilities. Addressing these impacts proactively through detailed engineering designs, environmental assessments, and stakeholder consultations is crucial to prevent costly delays and ensure the long-term sustainability of the Wilmington Harbor 403 project.

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US Army Corps of Engineers
Wilmington District®

Wilmington Harbor 403 Letter Report

Wilmington, North Carolina

Appendix A

Attachment 1: Channel Morphology

01/24/2025

Prepared by U.S. Army Corps of Engineers

Wilmington District

69 Darlington Avenue

Wilmington, North Carolina 28403

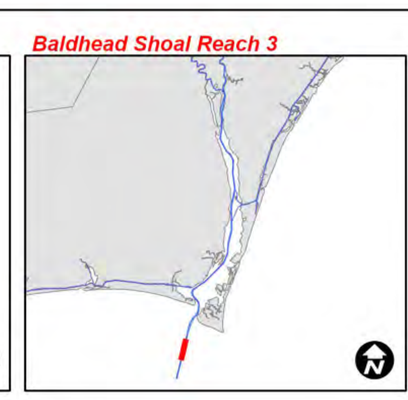
HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Baldhead Shoal Reach 3

Station 188 to 295



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Map Date: 05 May 2023

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Surveyed by: TDM,SRV
Mapped by: k7opnlac
Processed by: k7opndjm

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: LIGHT 1
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
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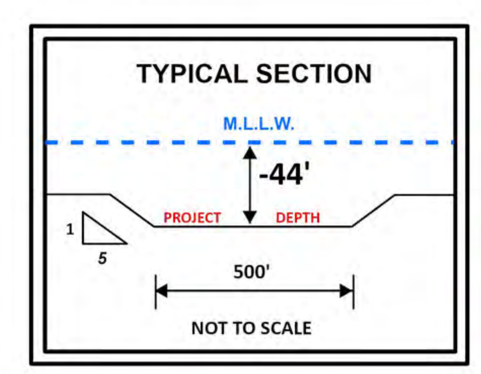


Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

- Matchlines
- Navigation Channel
- New WH403 Channel Extent

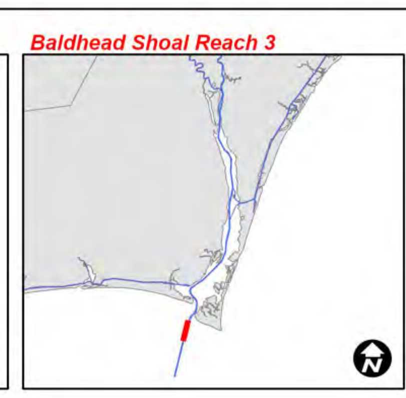
HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Baldhead Shoal Reach 3

Station 88 to 188



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Mapped by: k7opnlac
Processed by: k7opnlac

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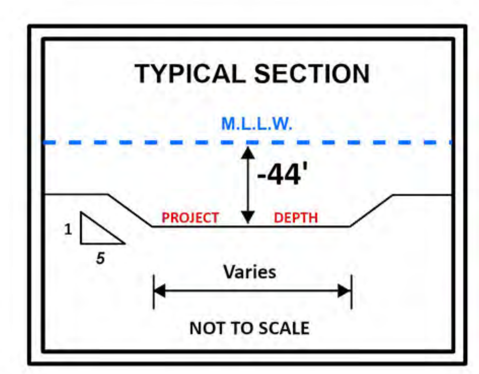

Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

- Matchlines
- Navigation Channel
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Baldhead Shoal Reach 2

NORTH CAROLINA

Baldhead Shoal Reach 2

Survey Date: 22 February; 30 March 2023
Map Date: 05 May 2023
Imagery Date: 28 January 2023

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TYPICAL SECTION

M.L.L.W.
-44'
PROJECT DEPTH
1
5
800'
NOT TO SCALE

Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

- 20 and Shallower
- 20 - 25
- 25 - 32
- 32 - 35
- 35 - 38
- 38 - 42
- 42 - 44
- 44 - 45
- 45 - 47
- 47 and Deeper

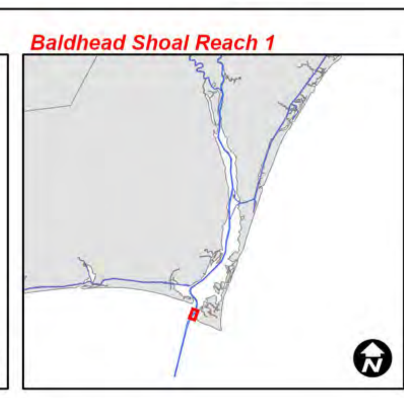
Navigation Channel
New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Baldhead Shoal Reach 1



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Imagery Date: 28 January 2023
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Mapped by: k7opndjm
Processed by: k7opndjm

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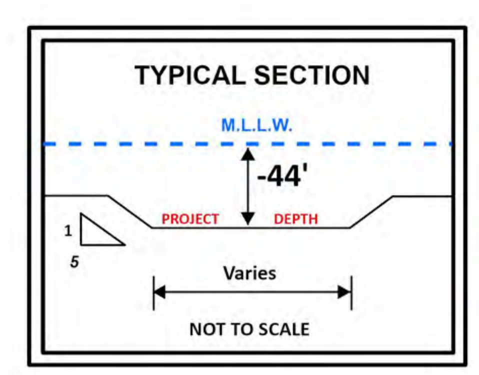

Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
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- Red Light
- Green Daybeacon
- Red Daybeacon
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- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower
20 - 25
25 - 32
32 - 35
35 - 38
38 - 42
42 - 44
44 - 45
45 - 47
47 and Deeper

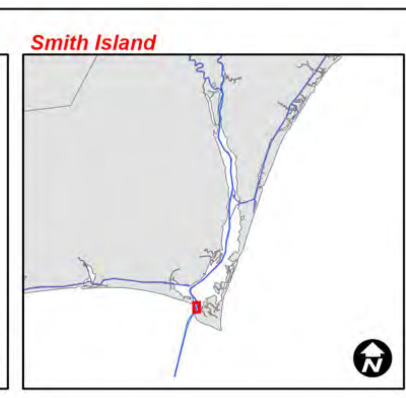
Navigation Channel
New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Smith Island



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Mapped by: k7opndjm
Processed by: k7opndjm

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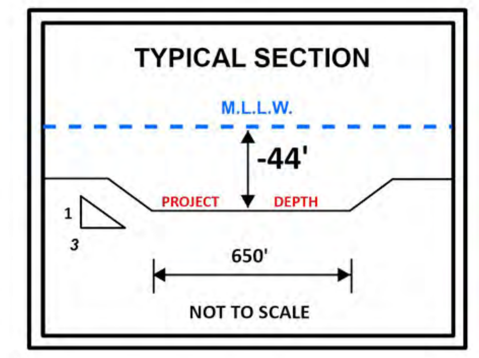
TYPICAL SECTION



Aids to Navigation

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- Red Lighted Buoy
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- Green Daybeacon
- Red Daybeacon
- Danger Sign
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- Tide Gage

Depth In Feet

20 and Shallower
20 - 25
25 - 32
32 - 35
35 - 38
38 - 42
42 - 44
44 - 45
45 - 47
47 and Deeper

Navigation Channel
New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Baldhead-Caswell

Baldhead- Caswell

Survey Date: 02 May 2023
Map Date: 05 May 2023
Imagery Date: 28 January 2023
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Scale: 1:2,000
File Name: WH_06_BHC_20230502_CS
Surveyed by: WJC,JBD
Mapped by: k7opnlac
Processed by: k7opnlac

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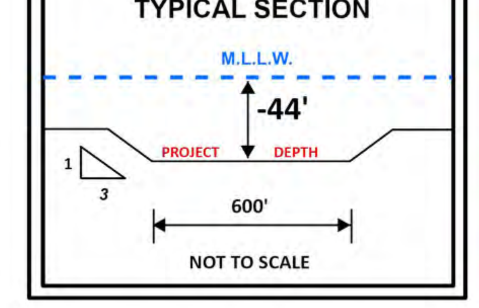

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Depth In Feet

- 20 and Shallower
- 20 - 25
- 25 - 32
- 32 - 35
- 35 - 38
- 38 - 42
- 42 - 44
- 44 - 45
- 45 - 47
- 47 and Deeper

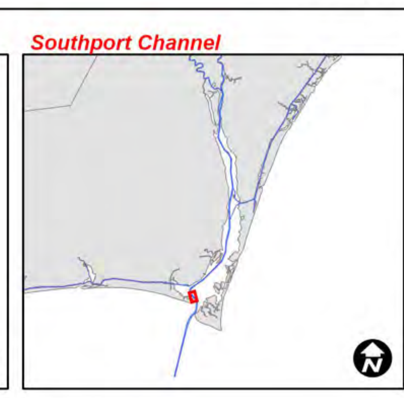
- Navigation Channel
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Southport Channel



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Mapped by: k7opndjm
Processed by: k7opndjm

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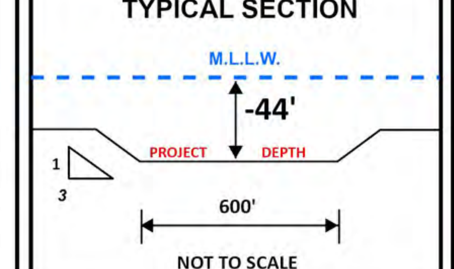
6. THE INFORMATION DEPICTED ON THIS SURVEY MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME. THESE CONDITIONS ARE SUBJECT TO RAPID CHANGE DUE TO SHOALING EVENTS. A PRUDENT MARINER SHOULD NOT RELY EXCLUSIVELY ON THE INFORMATION PROVIDED HERE. REQUIRED BY 33 CFR 209.325
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL

TYPICAL SECTION



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower
20 - 25
25 - 32
32 - 35
35 - 38
38 - 42
42 - 44
44 - 45
45 - 47
47 and Deeper

Navigation Channel
New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Battery Island

NORTH CAROLINA

Battery Island

Survey Date: 04 May 2023
Map Date: 05 May 2023
Imagery Date: 28 January 2023
© 2023 Maxar Technologies
Scale: 1:2,000
File Name: WH_08_BAT_20230504_CS
Surveyed by: JCC,TDM,SRV,DJD
Mapped by: k7opnlac
Processed by: k7opnlac

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 200 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: LIGHT 1 SOUTHPORT
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
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7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL

TYPICAL SECTION

M.L.L.W.
-44'
PROJECT DEPTH
1 3
Varies
NOT TO SCALE

Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

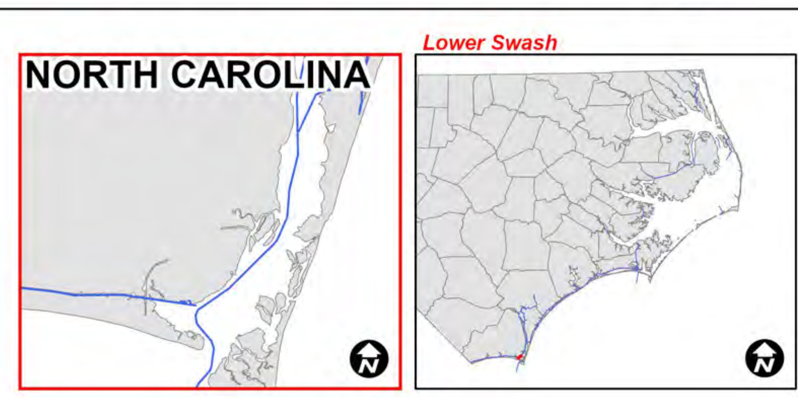
Navigation Channel
New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Lower Swash



Survey Date: 31 January & 02 February 2023
Map Date: 05 May 2023

Scale: 1:2,000
File Name: WH_09_LSW_20230131_CS
Surveyed by: TDM,SRV
Mapped by: k7opndjm
Processed by: k7opndjm

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 200 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: LIGHT 1
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
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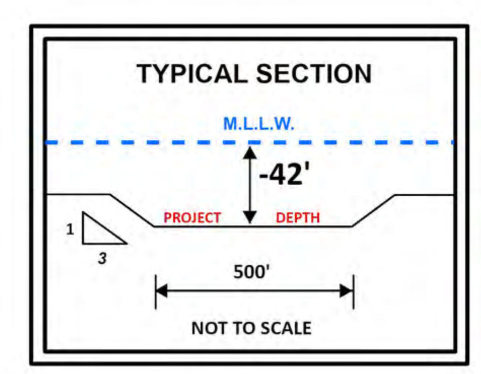
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL. ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

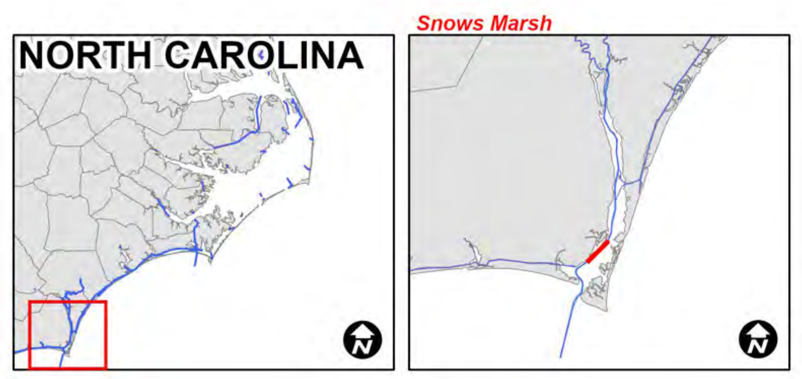
Navigation Channel
New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Snows Marsh



Survey Date: 27 February & 02 March 2023
Map Date: 04 May 2023

Scale: 1:2,000
File Name: WH_10_SNO_20230227_CS
Surveyed by: TDM,SRV
Mapped by: k7opnagf
Processed by: k7opnagf

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 200 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: REAVES POINT
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
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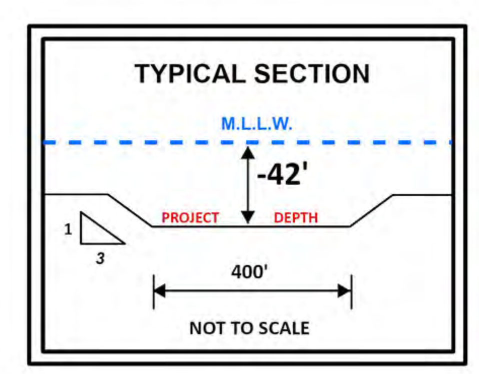
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

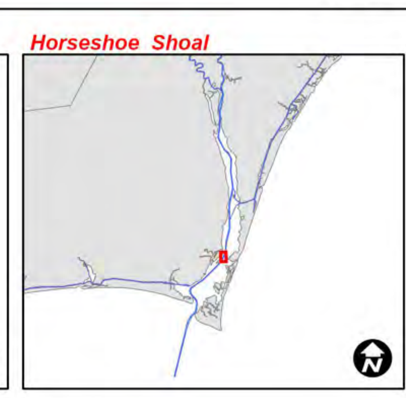
- Matchlines
- Navigation Channel
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

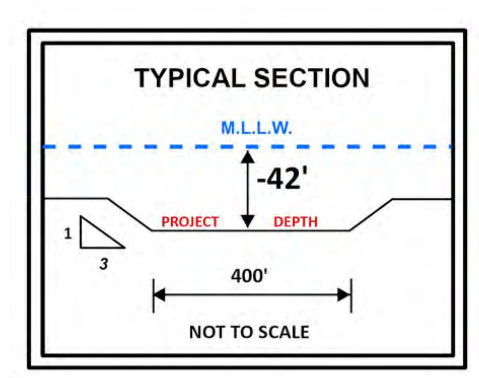
Horseshoe Shoal



Survey Date: 13 February 2023
Map Date: 04 May 2023
Imagery Date: 22 December 2022
© 2022 Maxar Technologies
Scale: 1:2,000
File Name: WH_11_HSS_20230213_CS
Surveyed by: WJC,DJD
Mapped by: k7opnlac
Processed by: K7OPNDJM

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SANDERSON ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 200 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: REAVES POINT
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
6. THE INFORMATION DEPICTED ON THIS SURVEY MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME. THESE CONDITIONS ARE SUBJECT TO RAPID CHANGE DUE TO SHOALING EVENTS. A PRUDENT MARINER SHOULD NOT RELY EXCLUSIVELY ON THE INFORMATION PROVIDED HERE. REQUIRED BY 33 CFR 209.325
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

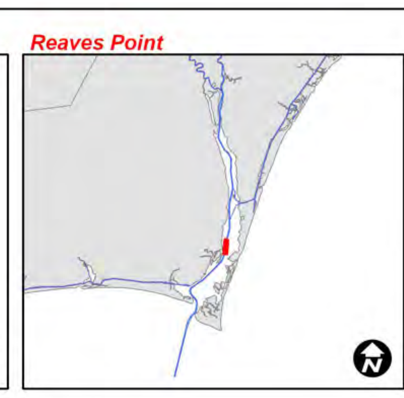
- Navigation Channel
- Placement Areas
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Reaves Point



Survey Date: 10 April 2023
Map Date: 04 May 2023
Imagery Date: 28 January 2023

Scale: 1:2,000
File Name: WH_12_RVP_20230410_CS
Surveyed by: TDM,SRV,DJD
Mapped by: k7opnlac
Processed by: k7opnlac

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: LIGHT 14
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
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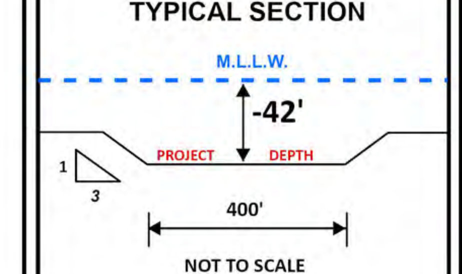
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL

TYPICAL SECTION



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower
20 - 25
25 - 32
32 - 35
35 - 38
38 - 42
42 - 44
44 - 45
45 - 47
47 and Deeper

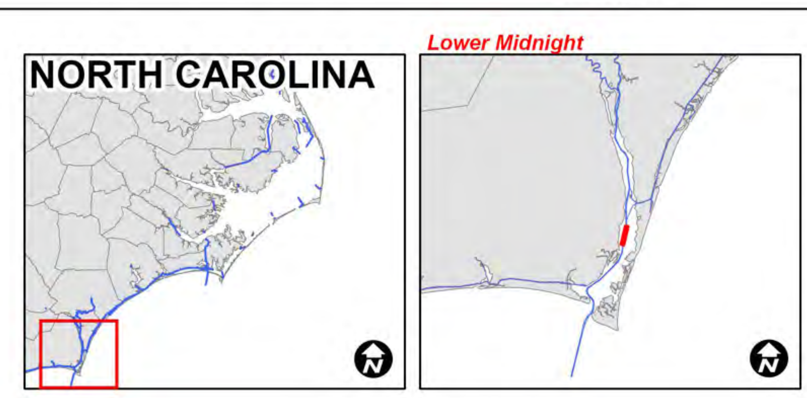
- Matchlines
- Navigation Channel
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Lower Midnight



Survey Date: 04 April 2023
Map Date: 03 May 2023
Imagery Date: 28 January 2023
© 2023 Maxar Technologies
Scale: 1:2,000
File Name: WH_13_LMI_20230404_CS
Surveyed by: TDM,SRV
Mapped by: k7opnlac
Processed by: k7opnlac

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: LIGHT 14
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
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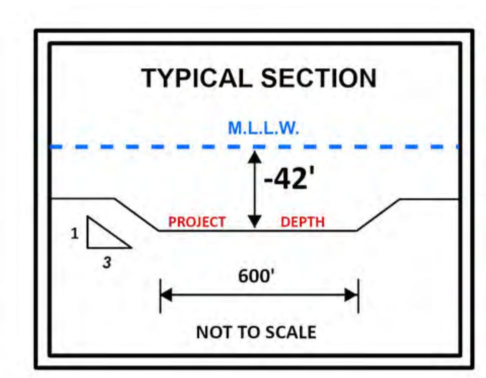
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

- Matchlines
- Navigation Channel
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA
Wilmington Harbor

Upper Midnight

Survey Date: 24 & 26 April 2023
Map Date: 03 May 2023

Scale: 1:2,000
File Name: WH_14_UMI_20230424_CS
Surveyed by: TDM,SRV
Mapped by: k7opnlac
Processed by: k7pdpsgd

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL " SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: MOTSU LIGHT 14
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
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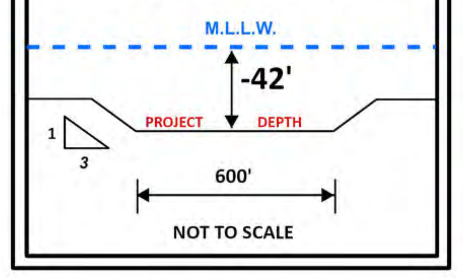
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL

TYPICAL SECTION



Aids to Navigation
Can
Nun
Green Lighted Buoy
Red Lighted Buoy
Junction Marker
Green Light
Red Light
Green Daybeacon
Red Daybeacon
Danger Sign
Mileboard
Tide Gage

Depth In Feet
20 and Shallower
20 - 25
25 - 32
32 - 35
35 - 38
38 - 42
42 - 44
44 - 45
45 - 47
47 and Deeper

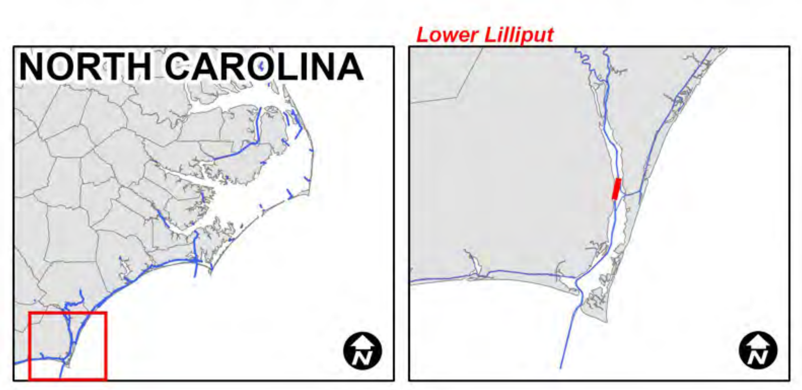
Navigation Channel
New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Lower Lilliput



Survey Date: 15-16 March 2023
Map Date: 03 May 2023

Scale: 1:2,000
File Name: WH_15_LOL_20230315_CS
Surveyed by: LMT,SRV
Mapped by: k7opnlac
Processed by: K7OPNDJM

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: KEG ISLAND
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
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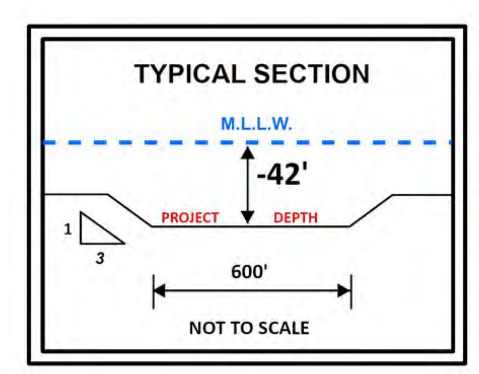
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL

TYPICAL SECTION



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower
20 - 25
25 - 32
32 - 35
35 - 38
38 - 42
42 - 44
44 - 45
45 - 47
47 and Deeper

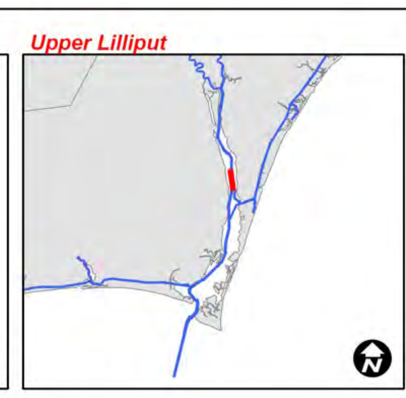
Navigation Channel
New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Upper Lilliput

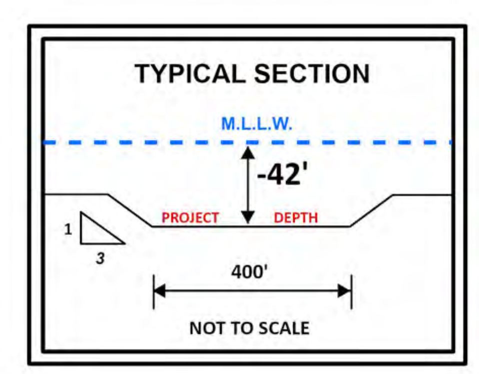


Survey Date: 15 February 2023
Map Date: 03 May 2023

Scale: 1:2,000
File Name: WH_17_UPL_20230215_CS
Surveyed by: TDM,SRV
Mapped by: k7opnlac
Processed by: K7PDPSGD

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: KEG ISLAND
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
6. THE INFORMATION DEPICTED ON THIS SURVEY MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME. THESE CONDITIONS ARE SUBJECT TO RAPID CHANGE DUE TO SHOALING EVENTS. A PRUDENT MARINER SHOULD NOT RELY EXCLUSIVELY ON THE INFORMATION PROVIDED HERE. REQUIRED BY 33 CFR 209.325
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

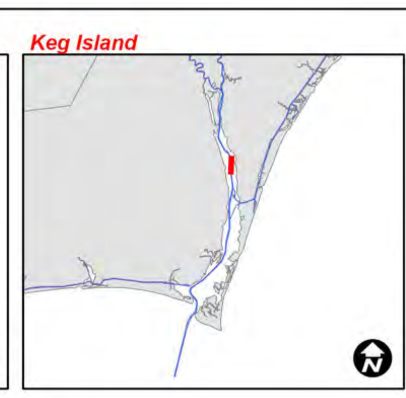
Navigation Channel
New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Keg Island

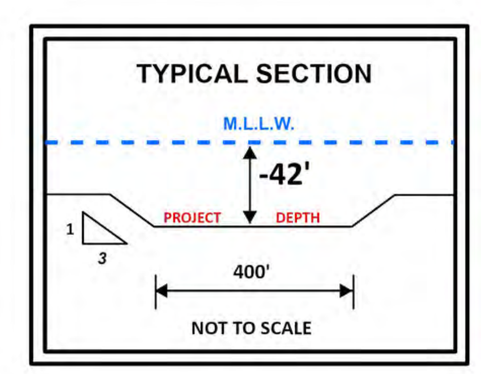


Survey Date: 16 February 2023
Map Date: 03 May 2023

Scale: 1:2,000
File Name: WH_18_KEG_20230216_CS
Surveyed by: LMT,DJD
Mapped by: k7opnlac
Processed by: K7OPNDJM

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SANDERSON ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 24 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: KEG ISLAND
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
6. THE INFORMATION DEPICTED ON THIS SURVEY MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME. THESE CONDITIONS ARE SUBJECT TO RAPID CHANGE DUE TO SHOALING EVENTS. A PRUDENT MARINER SHOULD NOT RELY EXCLUSIVELY ON THE INFORMATION PROVIDED HERE. REQUIRED BY 33 CFR 209.325
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

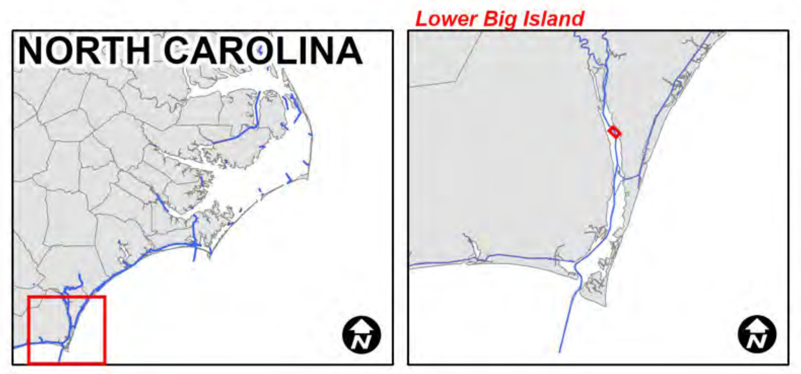
- 20 and Shallower
- 20 - 25
- 25 - 32
- 32 - 35
- 35 - 38
- 38 - 42
- 42 - 44
- 44 - 45
- 45 - 47
- 47 and Deeper

- Navigation Channel
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA
Wilmington Harbor

Lower Big Island



Survey Date: 01 May 2023
Map Date: 03 May 2023
Imagery Date: 28 January 2023
© 2023 Maxar Technologies
Scale: 1:2,000
File Name: WH_19_LBI_20230501_CS
Surveyed by: TDM,JCC,SRV
Mapped by: k7opnlac
Processed by: k7opnlac

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: LIGHT 14 MOTSU
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
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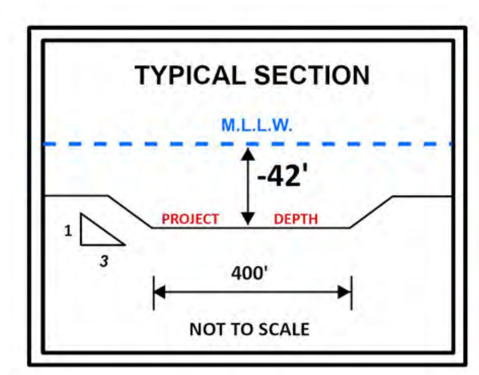
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

- Navigation Channel
- Placement Areas
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Upper Big Island

Survey Date: 13 April 2023
Map Date: 03 May 2023
Imagery Date: 28 January 2023

Scale: 1:2,000
File Name: WH_20_UBI_20230413_CS
Surveyed by: TDM,DJD,SRV
Mapped by: k7opnlac
Processed by: k7opnlac

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: KEG ISLAND
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
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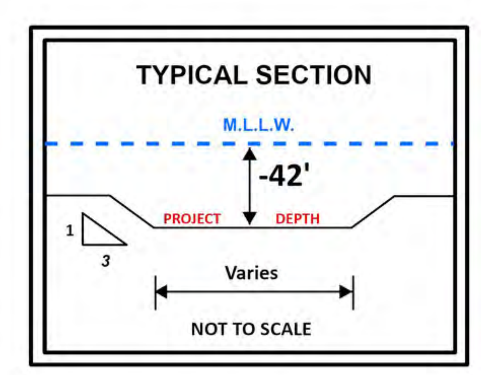


Aids to Navigation
- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet
20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

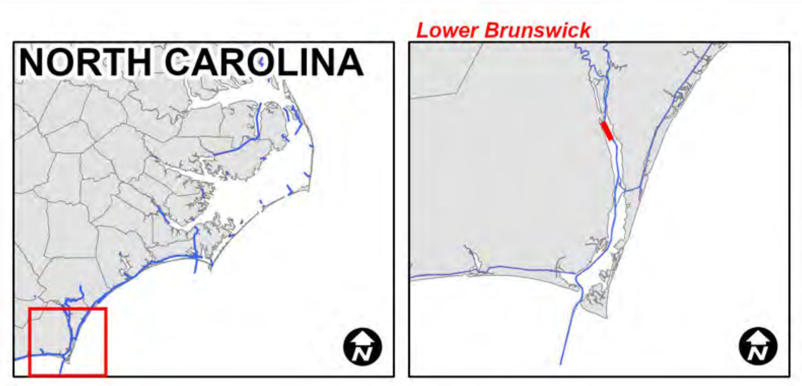
- Navigation Channel
- Placement Areas
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Lower Brunswick



Survey Date: 01 May 2023
Map Date: 03 May 2023

Scale: 1:2,000
File Name: WH_21_LBR_20230501_CS
Surveyed by: WJC,DJD
Mapped by: k7opnlac
Processed by: k7opnlac

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SANDERSON ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 24 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: LOWER BRUNSWICK
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
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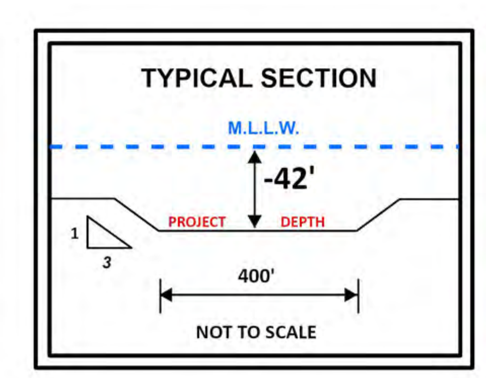
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

- 20 and Shallower
- 20 - 25
- 25 - 32
- 32 - 35
- 35 - 38
- 38 - 42
- 42 - 44
- 44 - 45
- 45 - 47
- 47 and Deeper

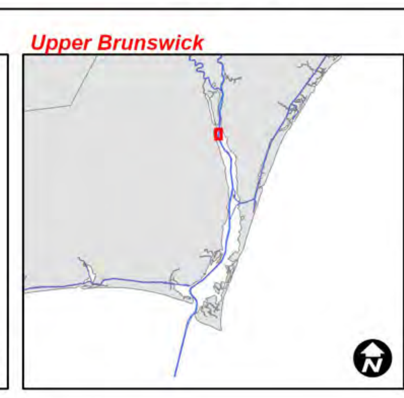
- Navigation Channel
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Upper Brunswick



Survey Date: 06 March 2023
Map Date: 03 May 2023
Imagery Date: 28 January 2023

Scale: 1:2,000
File Name: WH_22_UBR_20230306_CS
Surveyed by: WJC,SRV
Mapped by: k7opnlac
Processed by: K7OPNDJM

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: 4TH EAST JETTY
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
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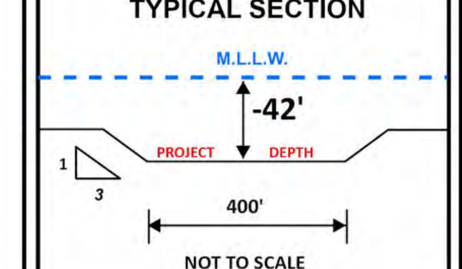
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL

TYPICAL SECTION



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

- 20 and Shallower
- 20 - 25
- 25 - 32
- 32 - 35
- 35 - 38
- 38 - 42
- 42 - 44
- 44 - 45
- 45 - 47
- 47 and Deeper

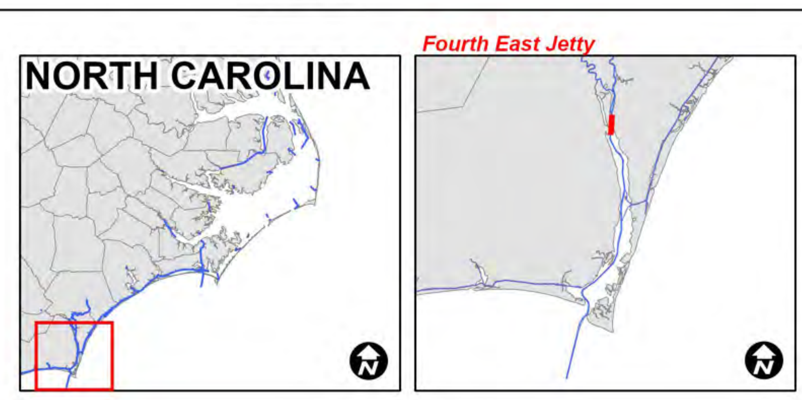
- Navigation Channel
- Placement Areas
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Fourth East Jetty



Survey Date: 28 February 2023
Map Date: 03 May 2023
Imagery Date: 28 January 2023

Scale: 1:2,000
File Name: WH_23_FEJ_20230228_CS
Surveyed by: TDM,SRV
Mapped by: k7opnlac
Processed by: K7OPNDJM

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: ENGINEER REPAIR YARD
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
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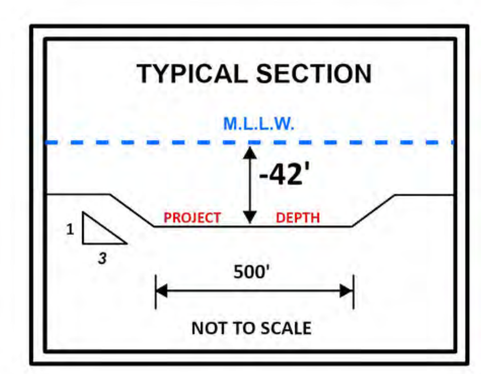
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL



Aids to Navigation
- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet
- 20 and Shallower
- 20 - 25
- 25 - 32
- 32 - 35
- 35 - 38
- 38 - 42
- 42 - 44
- 44 - 45
- 45 - 47
- 47 and Deeper

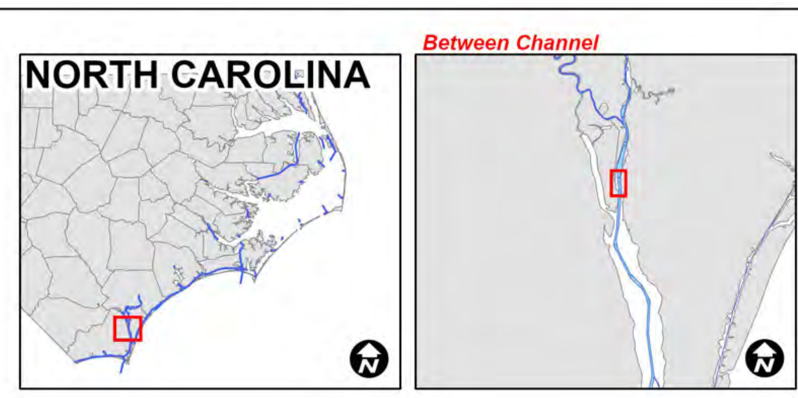
- Navigation Channel
- Placement Areas
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

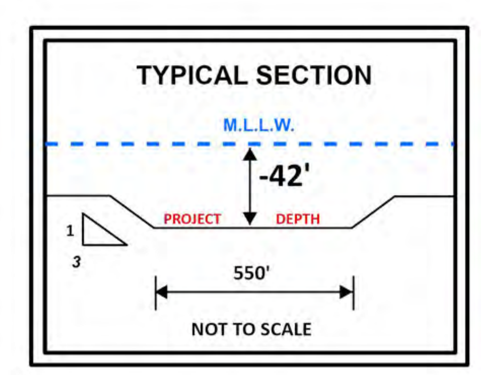
Between Channel



Survey Date: 10 February 2023
Map Date: 02 May 2023
Imagery Date: 02 December 2022
© 2022 Maxar Technologies
Scale: 1:2,000
File Name: WH_24_BTC_20230210_AD
Surveyed by: TDM,SRV
Mapped by: k7opndjm
Processed by: k7opnlac

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: ENGINEER REPAIR YARD
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
6. THE INFORMATION DEPICTED ON THIS SURVEY MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME. THESE CONDITIONS ARE SUBJECT TO RAPID CHANGE DUE TO SHOALING EVENTS. A PRUDENT MARINER SHOULD NOT RELY EXCLUSIVELY ON THE INFORMATION PROVIDED HERE. REQUIRED BY 33 CFR 209.325
7. NAVIGATION AIDS LOCATED WITH DISTRICT SURVEY VESSEL, ACCURACY +/- 3 METERS.
8. FOR THE MOST UP TO DATE INFORMATION PLEASE CHECK OUR WEBSITE AT: WWW.SAW.USACE.ARMY.MIL



Aids to Navigation

- Can
- Nun
- Green Lighted Buoy
- Red Lighted Buoy
- Junction Marker
- Green Light
- Red Light
- Green Daybeacon
- Red Daybeacon
- Danger Sign
- Mileboard
- Tide Gage

Depth In Feet

20 and Shallower, 20 - 25, 25 - 32, 32 - 35, 35 - 38, 38 - 42, 42 - 44, 44 - 45, 45 - 47, 47 and Deeper

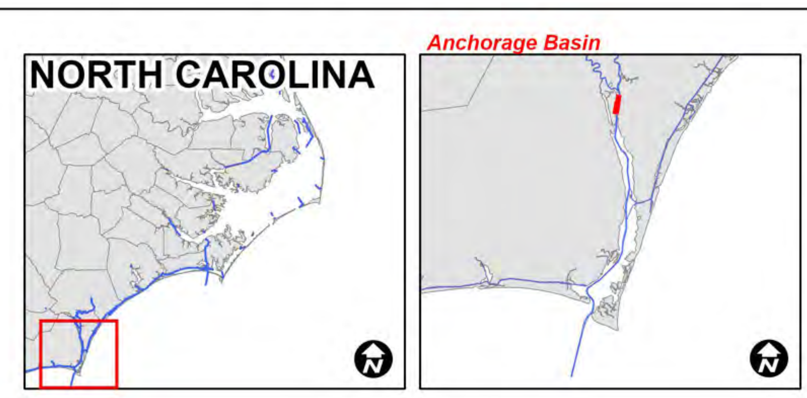
- Navigation Channel
- Placement Areas
- New WH403 Channel Extent

HYDROGRAPHIC SURVEY

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WILMINGTON, NORTH CAROLINA

Wilmington Harbor

Anchorage Basin



Survey Date: 13-14 February 2023
Map Date: 02 May 2023
Imagery Date: 28 January 2023

Scale: 1:2,000
File Name: WH_25_ANC_20230213_CS
Surveyed by: TDM,SRV
Mapped by: k7opnlac
Processed by: K7OPNDJM

200 100 0 200 400 600 Feet

1. ELEVATIONS ARE IN FEET AND REFER TO NOAA'S REPORTED MEAN LOWER LOW WATER (MLLW) RELATIVE TO THE 1983-2001 TIDAL EPOCH.
2. PROJECT SURVEYED WITH DISTRICT SURVEY VESSEL "SWART ", USING RTK GPS HORIZONTAL POSITIONING EQUIPMENT AND 28 KHZ SOUNDING EQUIPMENT.
3. HORIZONTAL DATUM NAD 1983. VERTICAL DATUM M.L.L.W..
4. TIDE GAGE LOCATED AT: ENGINEER REPAIR YARD
USE OF TIDE VALUES FOR THIS GAGE ARE RESTRICTED TO QUALITY ASSURANCE PURPOSES FOR VERIFICATION OF RTK TIDES. THE WILMINGTON DISTRICT WILL ONLY USE STAFF GAGE TIDAL VALUES FOR FINAL MAPPING AND QUANTITY CALCULATIONS IF RTK GPS IS UNAVAILABLE AT THE TIME OF SURVEY.
5. THIS PROJECT WAS DESIGNED BY THE WILMINGTON DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS AND SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER1110-1-8152.
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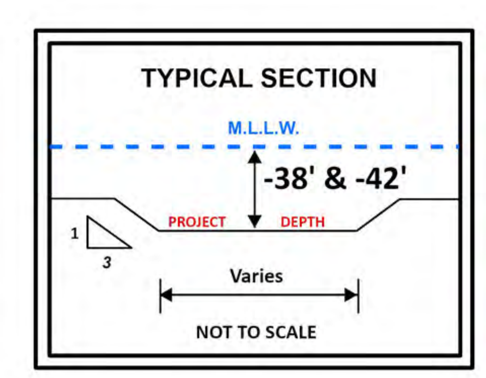

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- Matchlines
- Navigation Channel
- Placement Areas
- New WH403 Channel Extent

US Army Corps
of Engineers
Wilmington District®

Wilmington Harbor 403 Letter Report

Wilmington, North Carolina

Appendix A

Attachment 2: Hydrographic Survey

Existing Vs. New

01/24/2025

Prepared by U.S. Army Corps of Engineers
Wilmington District
69 Darlington Avenue
Wilmington, North Carolina 28403

Stantec

Memo

To:	Wilmington District U.S. Army Corps of Engineers	From:	Stantec
Project/File:	177311813	Date:	January 24, 2025

Reference: Task 11 Channel Morphology Study

1 Overview

Stantec used the coupled FLOW/MOR/WAVE modules to simulate morphological changes due to both suspended and bed load sediment transport for three channel deepening alternatives: NAA, AA1, and AA2. This approach incorporated riverine (flow) and coastal (tidal and wave) processes and evaluated the impact of multiple sea level change (SLC) scenarios: No SLC, SLC1 (0.5 ft), SLC2 (1.28 ft), and SLC3 (3.77 ft). The results were used to develop shoaling rates, both with and without project, along each reach of the existing and proposed navigation channel.

2 Study Approach

Figure 1 provides an overview of the channel morphology study approach showing the interaction between Delft3D modules, boundary conditions (e.g. Total Suspended Solids (TSS) values) and model outputs. Each component is described further in the sections that follow.

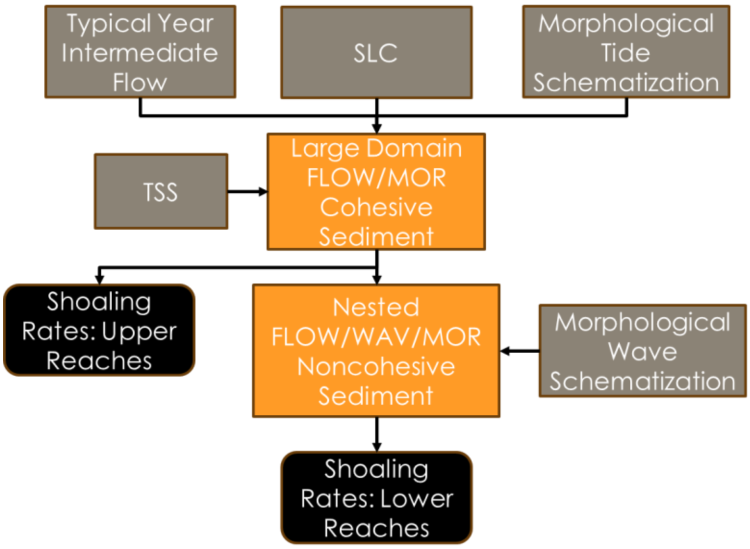

Figure 1. Flow diagram of the morphological study approach illustrating the interaction between boundary conditions (gray), Delft3D modules (orange), and outputs (black).

2.1 Model Domains

Building on the methodology used in the NCSPA Section 203 (2020) study, the channel morphology impact assessment for the current study included two model domains (Figure 2).

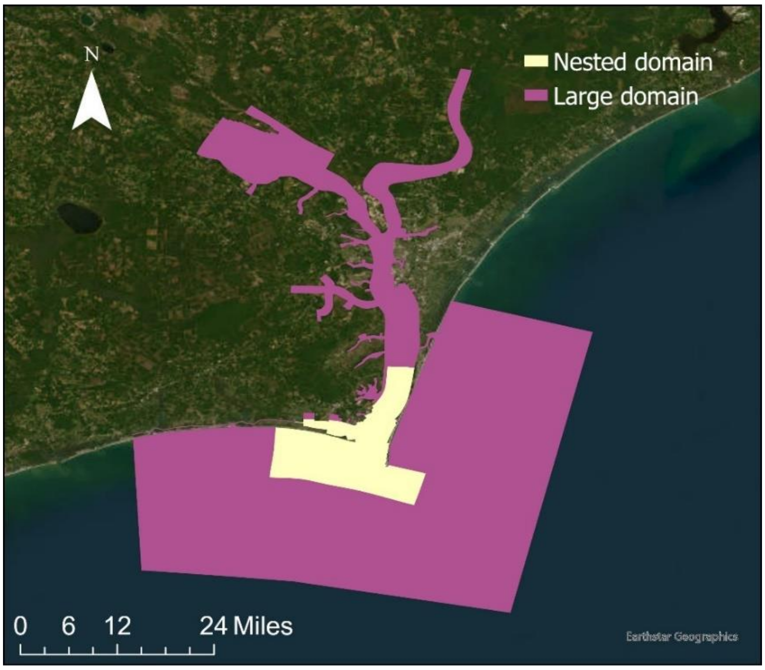

Figure 2. Map showing model domains used to assess channel morphology impacts.

2.1.1 Large domain FLOW/MOR model

To simulate the transport of cohesive sediment (mud) in the upper reaches of the Cape Fear River estuary and anchorage basin, a larger domain FLOW/MOR model was established (Figure 2). This model simulated the movement of suspended sediment and the accumulation of mud, driven by river flow and tides. Since waves have minimal impact on sediment transport in this part of the estuary, they were not included in the simulation. The grid was developed with a horizontal resolution of up to 5 meters and included 16 vertically stretched sigma layers. The bathymetries used were the same as those applied during Task 8.

2.1.2 Nested domain coupled FLOW/WAVE/MOR

To simulate noncohesive (sand) sediment transport at the inlet, a nested domain coupled flow-wave-morphology model was used. To account for wave-driven sediment transport in the lower reaches of the navigation channel near the inlets, a smaller domain model was nested within the larger, existing domain flow model. The results from the large domain flow model served as boundary conditions for the nested domain model in a one-way “offline” nested approach, where the large domain model was completed first, and the relevant boundary data was then provided to the nested domain. The nested model grid was developed with a horizontal resolution of up to 10 meters and extended from the northern limit of the Smith Island Reach to beyond the seaward limit of Bald Head Shoal segment 2, similar to the approach used in Task 9. Since vertical flow variations are anticipated to have a minor impact on noncohesive sediment transport at the coast compared to horizontal flow variations, the nested model was configured in depth-averaged mode (Lesser, Roelvink, et al. 2004). This assumption is commonly applied in coastal environments where the influence of vertical stratification is minimal, particularly in well-mixed systems with strong tidal and wave-driven currents that dominate sediment transport processes.

Following the methodology developed in the NCSPA Section 203 (2020) study, the depth-averaged approach provides a computationally efficient means of capturing the key hydrodynamic and sediment transport processes without sacrificing accuracy in areas where vertical gradients are expected to be negligible. Additionally, observational data and previous studies in similar environments indicate that depth-averaged models sufficiently capture the primary transport pathways and depositional patterns in regions with relatively shallow depths and dominant lateral flow influences.

2.2 Model Boundary Conditions

2.2.1 Discharge

The channel morphology study was focused on the impacts of the channel deepening alternatives and SLC on yearly shoaling rates. Therefore, a typical year and intermediate flow conditions were assumed for all simulations. In line with the approach taken during Task 8, constant discharge rates of 89.55 m^3/s, 13.55 m^3/s and 11.05 m^3/s were applied at the Cape Fear River (CFR), Black River (BR) and Northeast Cape Fear River (NCFR) model boundaries, respectively. The intermediate flow condition, reflecting the median discharge rates for a typical year, is considered representative of the entire year when averaged annually.

2.2.2 Total Suspended Solids at Upstream Boundary of Large Domain Model

For this study, the model input values for TSS, Total Suspended Solids, were derived using the most recent measurements available at three STORET stations (National Water Quality Monitoring Council, United States Geological Survey (USGS), Environmental Protection Agency (EPA) 2021). Table 1 provides details for each measurement station.

Table 1. Summary of STORET stations used for Discharge (Q)- total suspended solids (TSS) analysis.

STORET Station Code	Station Name	Latitude	Longitude	Date Range
B8360000	Cape Fear River at NC 11 nr East Arcadia	34.3969	-78.2675	1998 - 2013
B9000000	Black River above Thorofare	34.4312	-78.1441	
B9580000	Northeast Cape Fear River at US 117 at Castle Hayne	34.3637	-77.8965	

In a similar approach to the NCSPA Section 203 report, the synchronous measurements of TSS and discharge (Q) were first analyzed to assess correlation at the gauged locations at the model's upstream boundaries. A moderate linear correlation was found at CFR defined by the equation below,

$$TSS[mg/L] = 0.10 \cdot Q[m^3/s] + 3.57 \quad (1)$$

where $R^2 = 0.34$. However, no correlations were found for BR or NCFR ($R^2 < 0.1$). Therefore, approximations were made based on the observed scatter in the data (Figure 3). A similar approximation was made for the ungauged point sources within the model. The TSS values derived for each upstream boundary for the typical year, intermediate flow conditions simulated are summarized in Table 2.

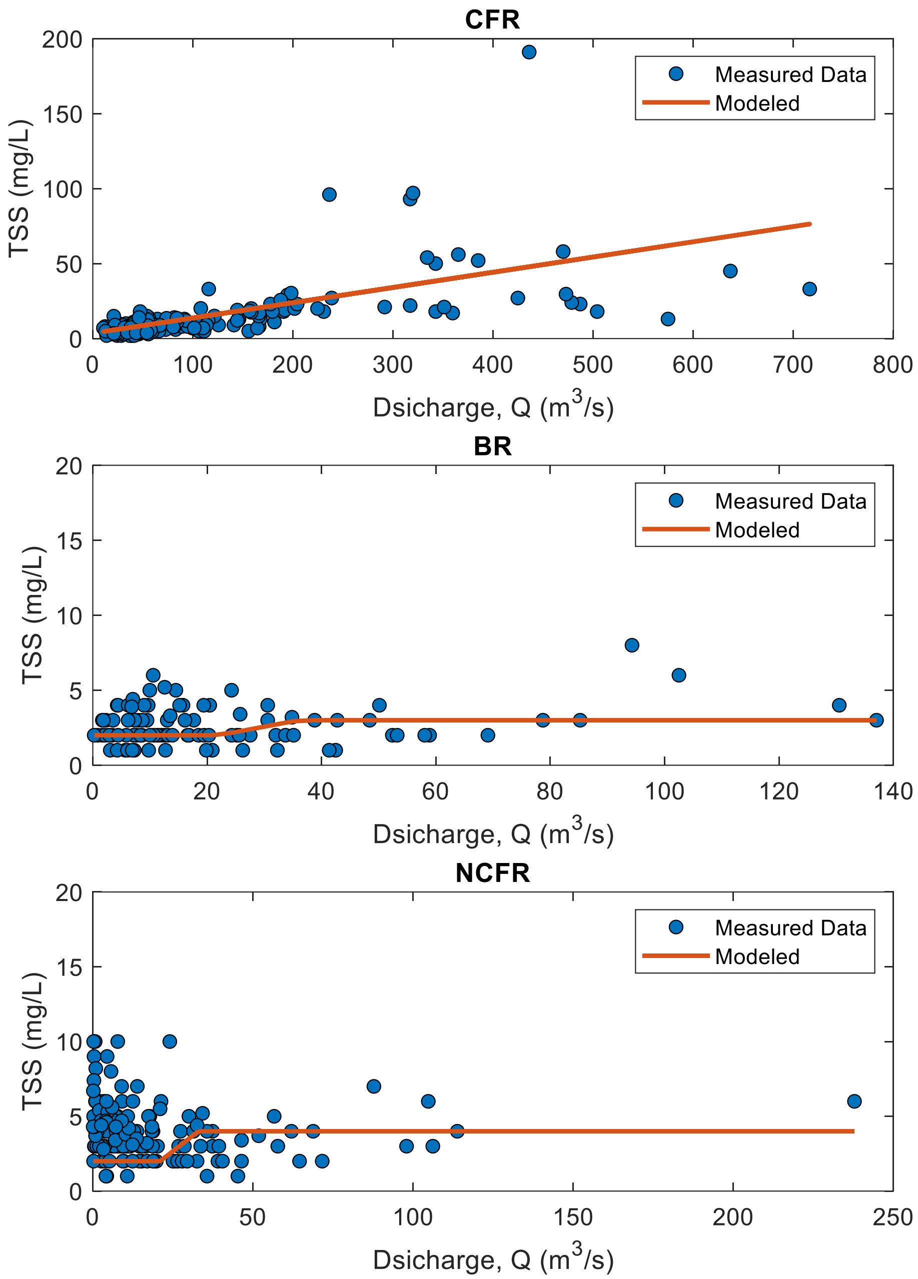

Figure 3. Relationship between total suspended solids (TSS) and discharge.

Table 2. Summary of modeled TSS values in mg/L for each upstream boundary.

Upstream Boundary	Discharge (m^3/s)	TSS (*mg/L*)
CFR	89.85	13
BR	13.55	2
NCFR	11.05	2

2.2.3 Morphological Tide Schematization

In order to practically and efficiently simulate 1 year of sediment transport, a morphological acceleration factor (morfac) was applied. This is a common approach to simulating long-term sediment transport and well supported literature (REF). The 'morfac' parameter enables the model to simulate sediment transport and morphological changes over a one-year period by scaling up (or accelerating) the results of the model for a much shorter representative timeframe.

For the cohesive sediment simulations, where the temporal variation in sediment transport is governed by the tide, a real time series of astronomical tide over 15 days was scaled to one year using a constant morfac of 24.

For the noncohesive sediment simulations, where sediment transport varies with both tide and wave climate, it was necessary to define a morphological tide that matched the wave schematization (Section 2.2.4) and captured the average monthly tidal fluctuations throughout the year. Following the approach developed by Lesser (2009), a representative tidal fluctuation was created based on input values of the M2, K1 and O1 constituents. The resulting water level (η) is then determined by Equation 2.

$$\eta = 1.08 \cdot M2\cos(\omega_{M2}t + \phi_{M2}) + C1\cos(\omega_{C1}t + \phi_{C1}), \quad (2)$$

where the diurnal astronomical tidal constituent, $C1 = \sqrt{2 \cdot O1 \cdot K1}$ and $\phi_{C1} = 0.5(\phi_{K1} + \phi_{O1})$, ω is the angular frequency of the tidal constituents, ϕ is the phase offset of the tidal constituents. The tidal periods of the $M2$ and $C1$ constituents were set to 750 minutes (semi-diurnal) and 1500 minutes (diurnal), respectively. The constant value of 1.08 is a correction factor to account for the disproportionate spring-neap contradictions to sediment transport (NCSPA Section 203 2020).

2.2.4 Morphological Wave Schematization

To capture the impact of waves on long-term inlet morphology, it was essential to define a limited yet representative set of wave conditions to optimize the model computationally. These wave classes, combined with appropriate 'morfac' values, accurately represent the wave climate throughout the year. In this approach, each wave class is simulated for a few morphological tidal cycles and multiplied by a different morfac value to represent its frequency of occurrence in a full year.

Wave climate schematization methods include the Fixed Bins Method, Energy Flux Method, Energy Flux with Extreme Wave Conditions Method, CERC Method, and the Optimum Selection or Routine Method (Opti-method). The Opti-method considers transport patterns from previous model simulations and has been reported to perform better than the other methods, especially when using a limited number of wave cases (around six) to represent an annual wave climate (Benedet, et al. 2016).

Leveraging the results of the Opti-method carried out during the NCSPA Section 203 (2020) study, Table 3 shows the representative wave classes and corresponding morfac values used as model input. These wave classes were derived from measurements at NOAA NDBC Buoy station 41013. The mean wind speed in each wave class was used as the representative wind condition, with wind directions assumed to align with the peak wave direction.

Table 3. Representative wave classes and corresponding wind speeds and morfac values used as model input.

No. Wave Class	Significant Wave Height (m/s)	Peak Wave Period (s)	Peak Wave Direction (°N)	Wind Speed (m/s)	Wind Direction (°N)	Morfac
1	2.4	8.2	157.7	9.8	157.7	12.4
2	2.4	8.0	172.6	10.4	172.6	0.5
3	3.4	9.0	173.1	13.2	173.1	8.2
4	2.4	7.6	201.7	11.9	201.7	5.2
5	1.4	5.8	217.1	9.0	217.1	19.7
6	2.4	7.0	231.1	13.4	231.1	7.4

To confirm the validity of the NCSPA Section 203 (2020) study results, a comparison was made between the wave climate at the time of the study and the present-day (year 2022) using measurements from NOAA NDBC Buoy station 41013. The analysis of wave roses (Figure 4) and histograms (Figure 5) showed negligible changes in wave climate, indicating that the representative wave classes defined during the NCSPA Section 203 (2020) study remain valid.

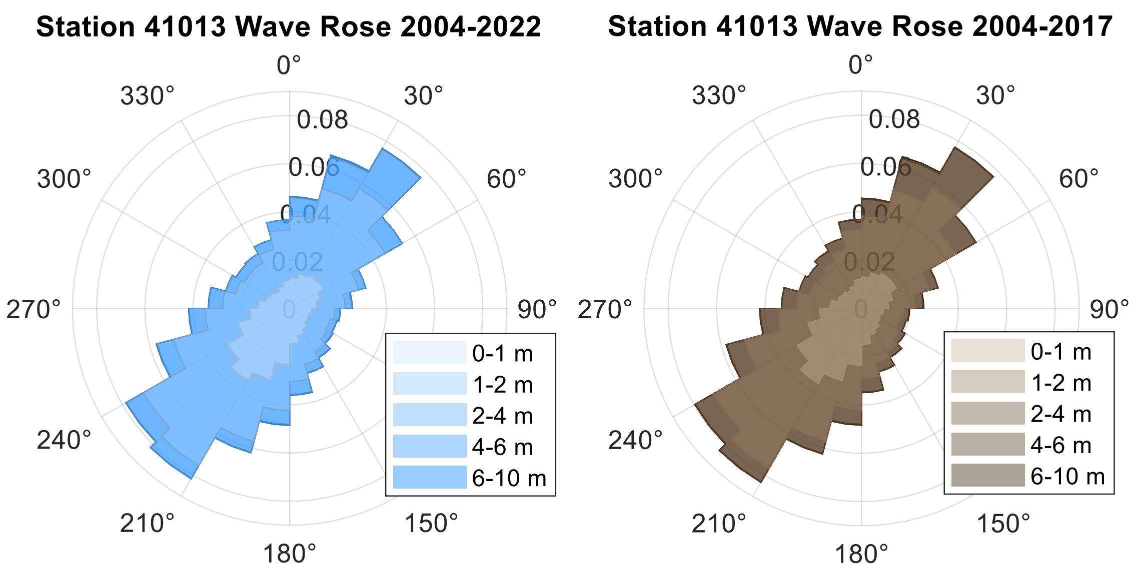

Figure 4. Wave roses derived from measurements at NOAA NDBC Buoy station 41013 for periods 2004 - 2022 and 2004 - 2017 (NCSPA Section 203 (2020) study period).

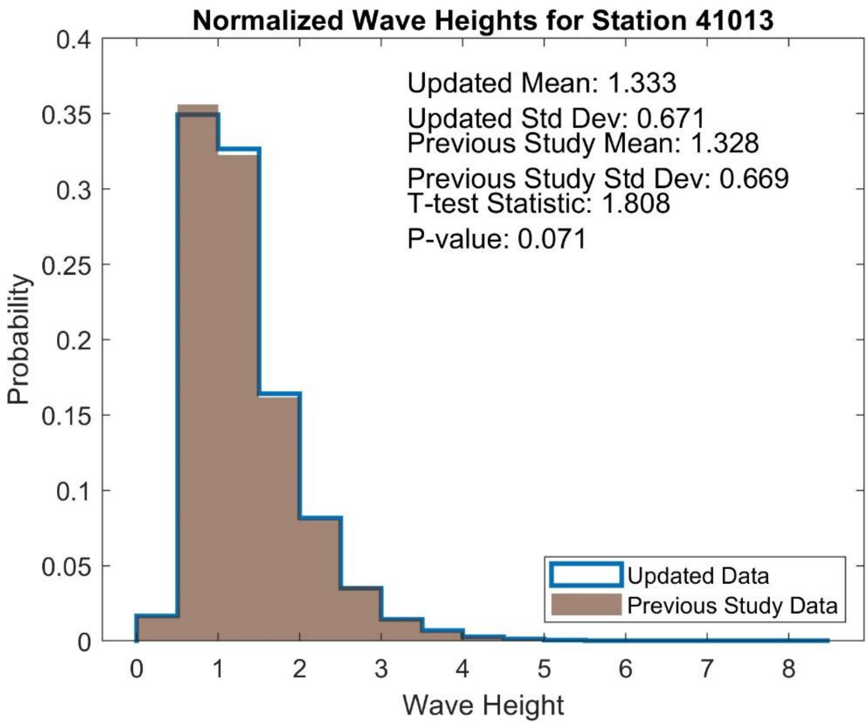

Figure 5. Histograms of significant wave heights measured at NOAA NDBC Buoy station 41013 for periods 2004 - 2022 and 2004 - 2017 (NCSPA Section 203 (2020) study period).

2.3 Model Parameter Settings

2.3.1 Cohesive Sediment Transport

The primary sediment transport parameters for the cohesive model include specific density, settling velocity, critical bed shear stress for sedimentation and erosion, dry bed density and initial layer thickness. Table 4 summarizes the model parameter settings that were applied. These settings, most of which were recommended in the NCSPA Section 203 (2020) study, were retained here following a comprehensive review and comparison of model results with measured data (Section 4).

Table 4. Summary of the model parameter settings applied to simulate cohesive sediment transport.

Parameter	Description	Value
SedTyp	Sediment Type	mud
RhoSol	Specific Density	2,650 (kg/m^3)
WS0/WSM	Settling Velocity	0.0005 (m/s)
TcrSed	Critical bed shear stress for sedimentation	0.9 (N/m^2)
TcrEro	Critical bed shear stress for erosion	0.50 (N/m^2)
EroPar	Erosion parameter	0.000005 (kg/m^2/s)
CDryB	Dry bed density	500 (kg/m^3)
MorFac	Morphological scale factor	24

Appendix R of the NCSPA Section 203 (2020) study revealed that the sediment in the channel upstream of Reeves Point consists of fines (silt and clay, together referred to as mud), whereas the lower reaches are mainly sand. Accordingly, the initial cohesive sediment thickness in the model was set to 5 meters upstream and 0 meters downstream of Reeves Point.

2.3.2 Noncohesive Sediment Transport

The default non-cohesive sediment transport formulation by Van Rijn (1993) was applied. This formulation incorporates the effects of waves by considering both wave-related and current-related transport components. It includes wave-related terms, such as: the bed shear stress due to current in the presence of waves, total wave-related friction factor based on the wave related roughness, near-bed peak orbital velocity based on the significant wave height and an estimation of suspended sediment transport due to wave asymmetry effects. For further details on the formulation and its implementation, please refer to the Delft3D model documentation (Deltares 2018).

Table 5. Summary of the model parameter settings applied to simulate noncohesive sediment transport.

Parameter	Description	Value
IopKCW	Flag for determining Rc and Rw	1
RDC	Current related roughness height (only used if IopKCW <> 1)	0.01 (m)
RDW	Wave related roughness height (only used if IopKCW <> 1)	0.02 (m)
MorFac	Morphological scale factor	Variable (Section 2.2.4)
MorStt	Spin-up interval from TStart until start of morphological changes	0.0 (min)
Thresh	Threshold sediment thickness for transport and erosion reduction	0.05 (m)
MorUpd	Update bathymetry during FLOW simulation	TRUE
EqmBc	Equilibrium sand concentration profile at inflow boundaries	TRUE
DensIn	Include effect of sediment concentration on fluid density	FALSE
AksFac	Van Rijn's reference height = AKSFAC * KS	1.0
RWave	Wave related roughness = RWAVE * estimated ripple height. Van Rijn Recommends range 1-3	2.0
AlfaBs	Streamwise bed gradient factor for bed load transport	1.0
AlfaBn	Transverse bed gradient factor for bed load transport	15.0
WetSlope	Avalanching slope sV:1H	0.2
AvalTime	Avalanching time in 1 day	86400.0 (s)
Sus	Multiplication factor for suspended sediment reference concentration	1.0
Bed	Multiplication factor for bed-load transport vector magnitude	1.0
SusW	Wave-related suspended sed. transport factor	0.0
BedW	Wave-related bed-load sed. transport factor	0.0
SedThr	Minimum water depth for sediment computations	0.1 (m)
ThetSD	Factor for erosion of adjacent dry cells	0.5
HMaxTH	Max depth for variable ThetSD	1.5 (m)

Based on information on the native beach sediment composition and recommendations noted in the NCSPA Section 203 (2020) study, the median sediment diameter was set to 0.2 mm. The initial sediment layer thickness was set to 10 m in the littoral zone and 0.5 m in the upper reaches, where the volume of noncohesive sediment is expected to be significantly lower. To evaluate the effects of sediment size and initial layer thickness on modeled shoaling rates, a sensitivity analysis was conducted (Section 4.4).

3 Shoaling Rate Estimation

Delft3D provides the cumulative sedimentation and erosion (in meters) for each grid cell at the end of the simulation. This indicates the vertical change in bed elevation, either an increase (sedimentation) or decrease (erosion), over one year (m/yr). To determine the shoaling rate (m^3/yr or cy/y), the cumulative sedimentation was multiplied by the area of each grid cell (m^2). The shoaling rate for each reach of the navigation channel was then calculated by summing the total volume of sedimentation within each polygon-defined area. Since the area considered can significantly affect the shoaling rates, with larger areas yielding greater total sedimentation volumes, the USACE navigation channel setbacks were used to define the extent of potential dredging areas (Figure 6).

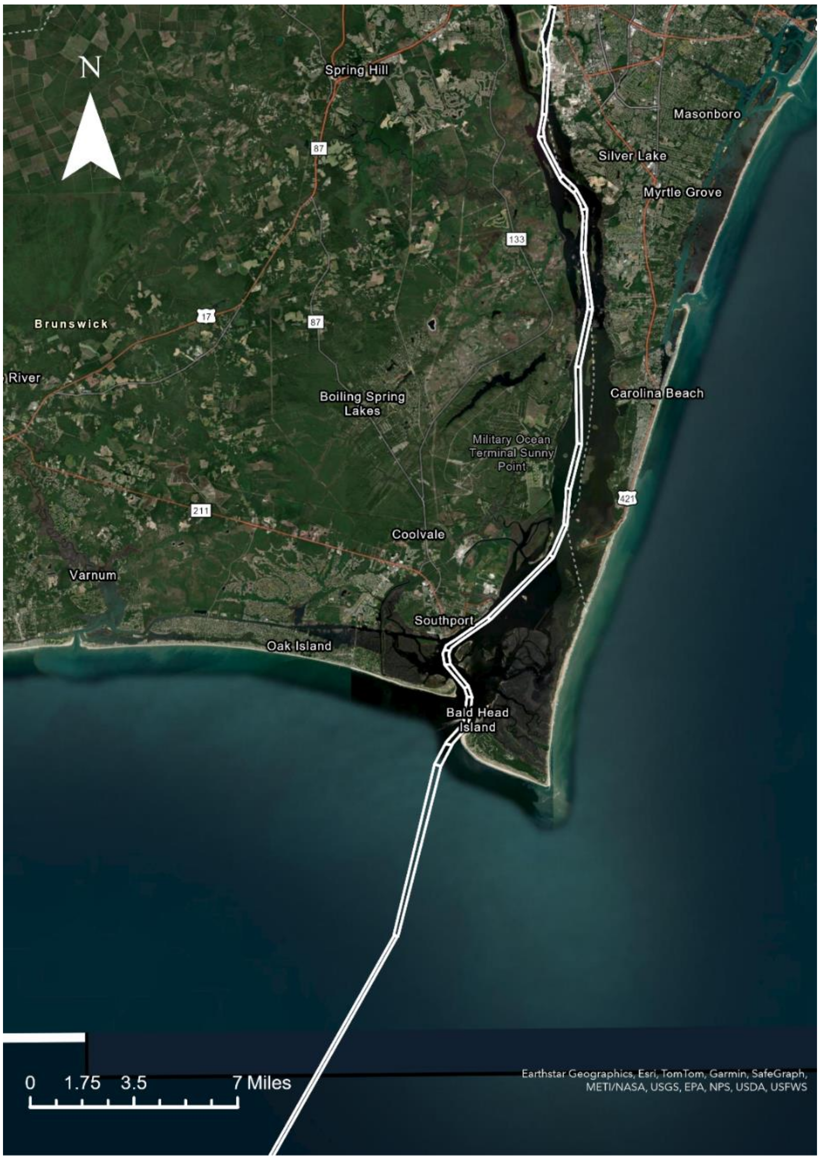

Figure 6. USACE (USACE, 2019) setback polygons (white) used to estimate shoaling rates.

4 Model Validation

4.1 Vertical Suspended Sediment Profiles

The large domain cohesive sediment model was validated by qualitatively comparing the modeled vertical variations in total sediment concentrations to measurements made during the period from March 27 to April 1, 2017. TSS casts were available at TR03, TR06, TR09, and TR11 (Figure 7 and Figure 8). Measured discharge rates from the USGS gauges were used at the upstream boundaries, and TSS values were set based on historical data. TSS values at the offshore boundary were set to zero due to the predominance of sand in those areas.

Figure 7. Transects TR01 to TR06 along Cape Fear River.

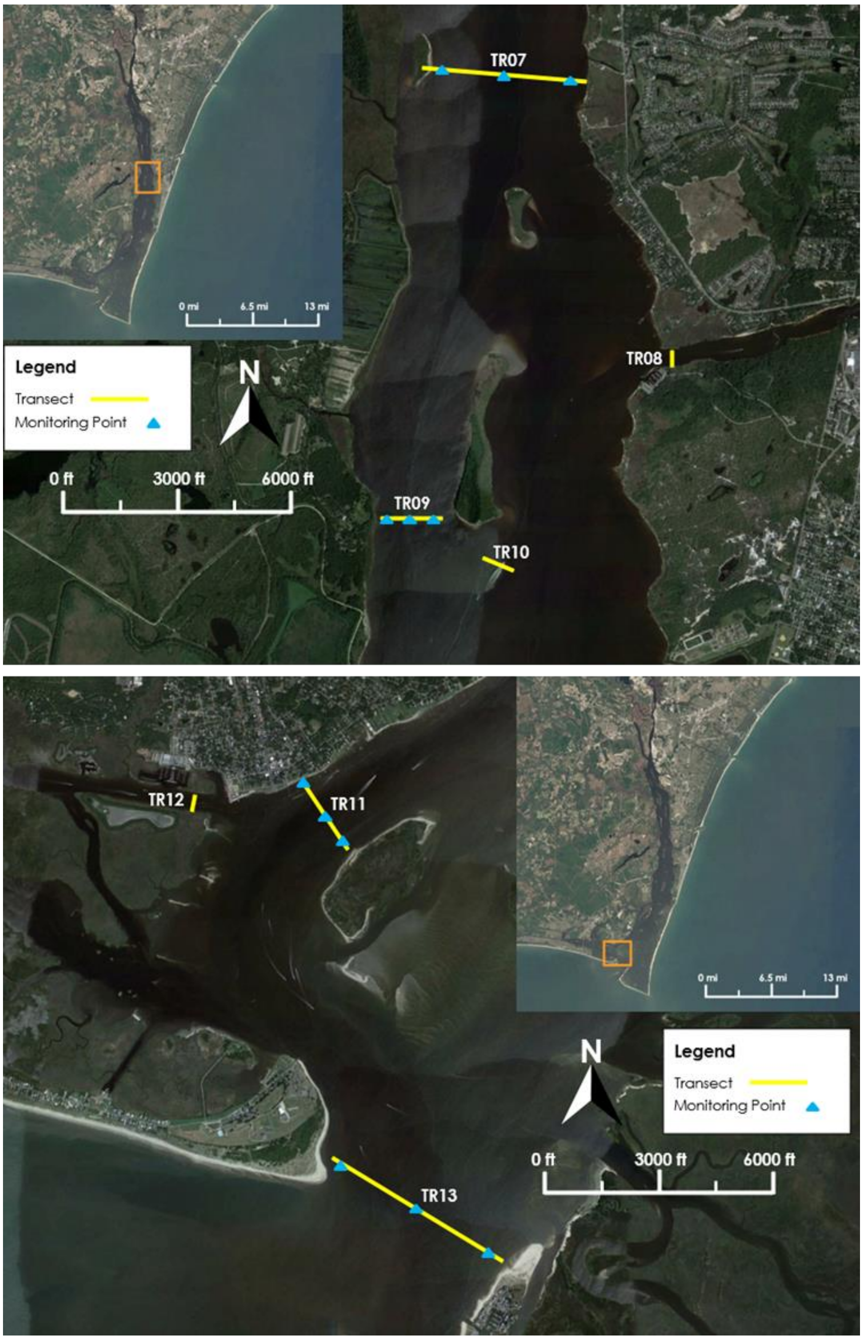

Figure 8. Transects TR07 to TR13 along Cape Fear River.

The modeled results showed reasonable agreement at each transect (Figure 9 to Figure 14). Due to the significant scatter and high variation in TSS measurements at similar depths, a third-order polynomial fit was applied to the data to represent the measurements. Given the high variability in the observations, no quantitative error statistics were used to assess model performance. The model setup was further validated quantitatively by comparing the estimated shoaling rates to historic records in Section 4.2.

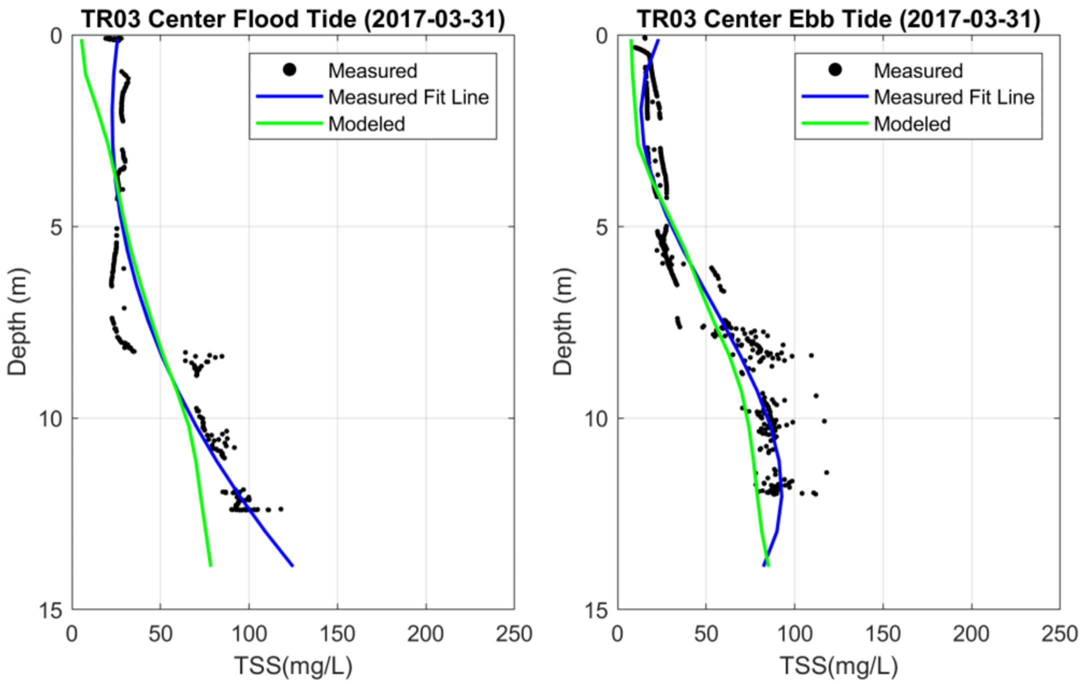

Figure 9 Modeled vs. measured TSS at the center of Transect TR03 during flood (left) and ebb (right) tides.

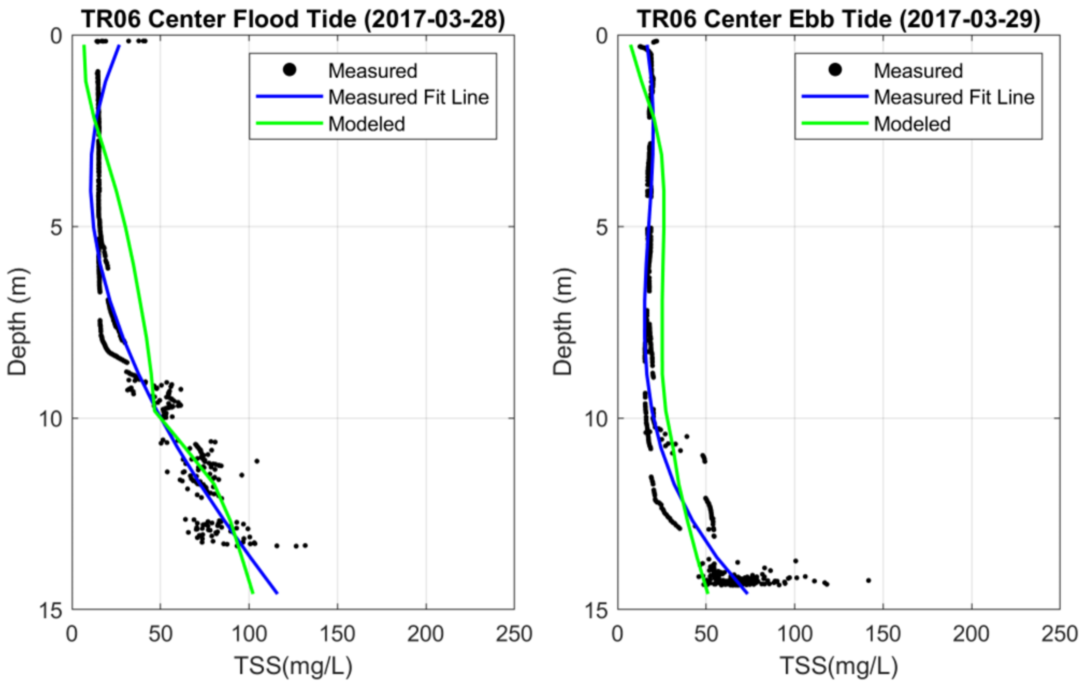

Figure 10 Modeled vs. measured TSS at the center of Transect TR06 during flood (left) and ebb (right) tides.

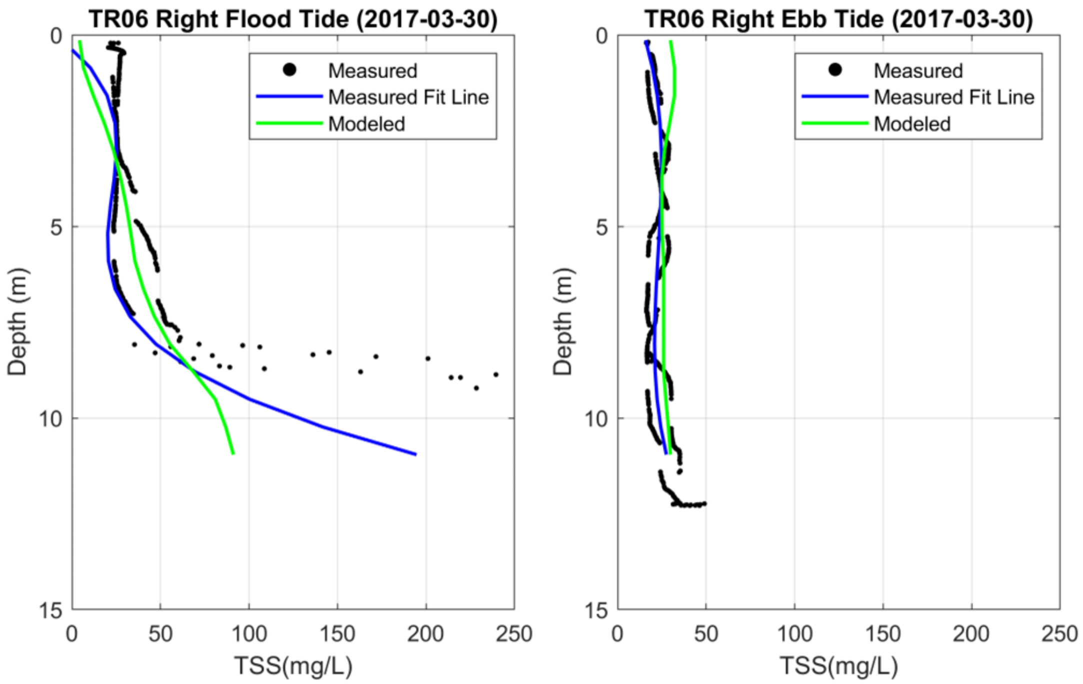

Figure 11 Modeled vs. measured TSS at the right side of Transect TR06 during flood (left) and ebb (right) tides.

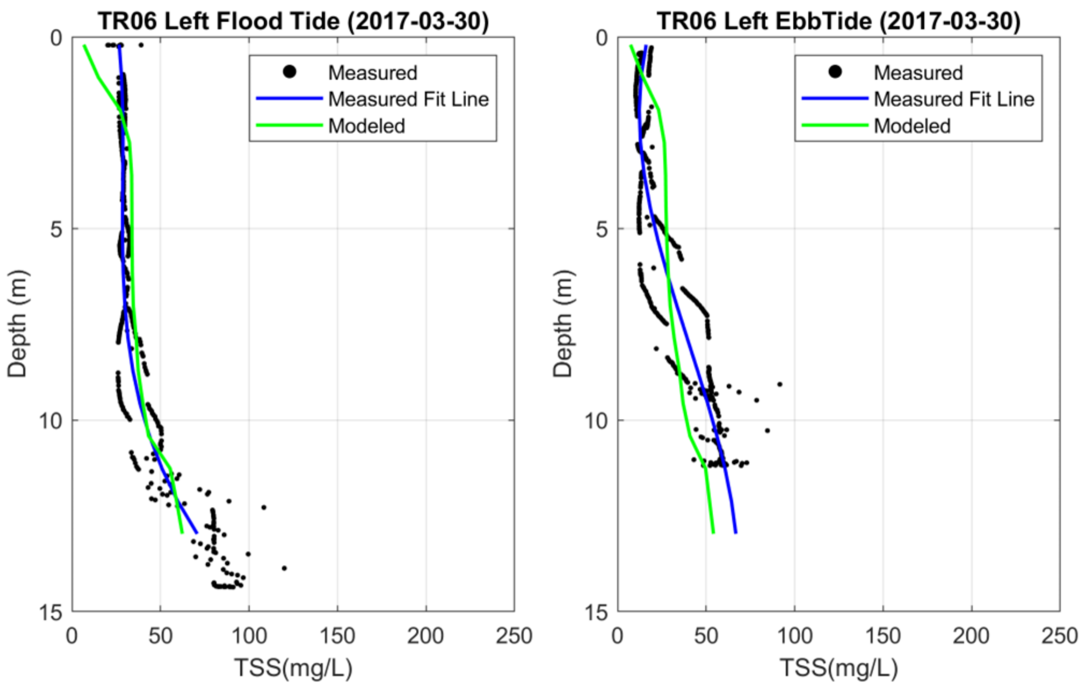

Figure 12 Modeled vs. measured TSS at the left side of Transect TR06 during flood (left) and ebb (right) tides.

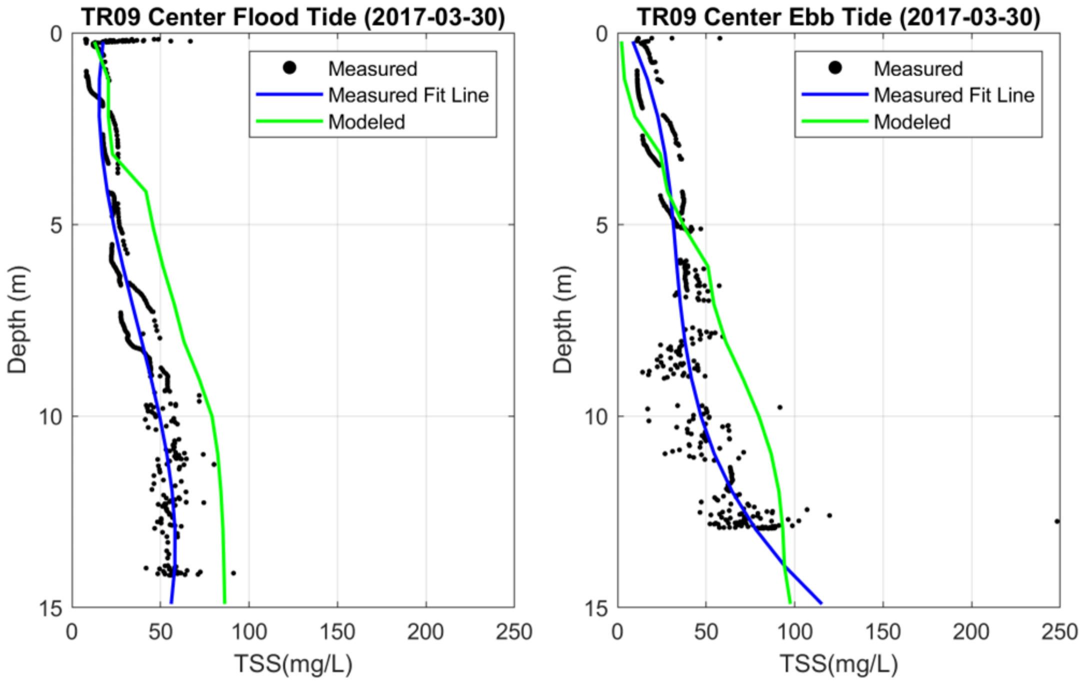

Figure 13 Modeled vs. measured TSS at the center of Transect TR09 during flood (left) and ebb (right) tides

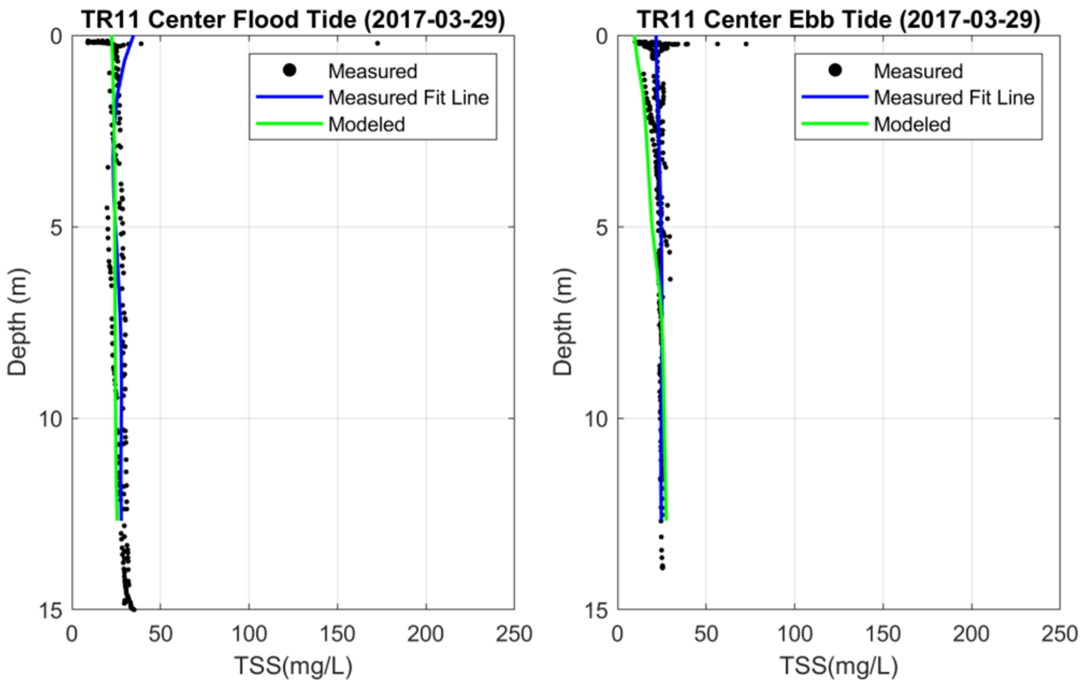

Figure 14 Modeled vs. measured TSS at the center of Transect TR11 during flood (left) and ebb (right) tides.

4.2 Shoaling at Anchorage Basin

The cohesive model was further validated by comparing the estimated shoaling rate at Anchorage Basin for the NAA No SLC scenario to historic dredging rates and the shoaling rate computed in the 2014 Feasibility and Environmental Assessment Report (USACE 2014). The modeled shoaling rate was found to be within the upper range of historic dredging volumes and within 24% of the reported shoaling rates (Table 6). Since the setback polygon used to assess shoaling rates extend beyond the navigation channel (Figure 15), the modeled shoaling rate is expected to represent an upper limit.

Table 6. Comparison of modeled shoaling rate at Anchorage Basin with reported dredge volumes from 2010 to 2023 and the computed shoaling rate from the 2014 Feasibility and Environmental Assessment Report (USACE 2014).

Dredging Reports (2010 to 2023)			2014 Feasibility and Environmental Assessment Report (USACE 2014)	Modeled
Minimum Volume Dredged per year	Average (total volume divided by 13 years)	Maximum Volume Dredged per year		
206,705	1,013,430	1,631,474	1,251,804	1,549,100

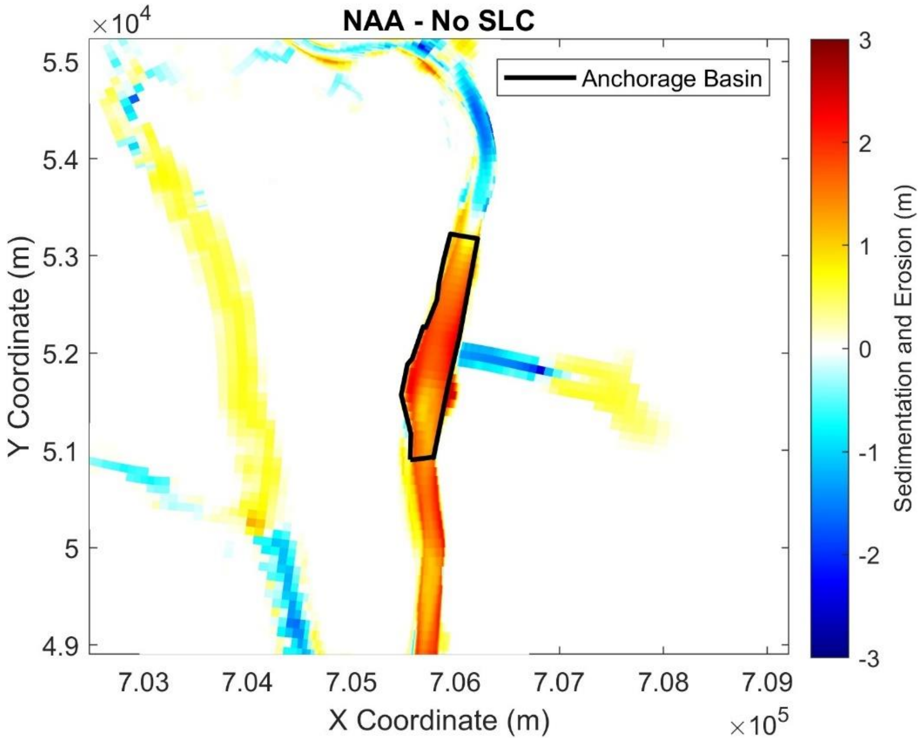

Figure 15. Modeled annual sedimentation and erosion at Anchorage Basin for NAA No SLC. Polygon represents the setback area used to estimate the shoaling rate.

4.3 Shoaling at Channel Inlet

Shoaling rates were calculated near the channel inlet for the Smith Island, Baldhead Shoal Reach 1, and Baldhead Shoal Reach 2 reaches for comparison with historical data (Figure 16). To investigate the shoaling that would occur in the navigation channel, the 1 yr cumulative sedimentation was calculated from the USACE channel setback polygons for each reach. The setbacks are indicated by the colored polygons in Figure 16.

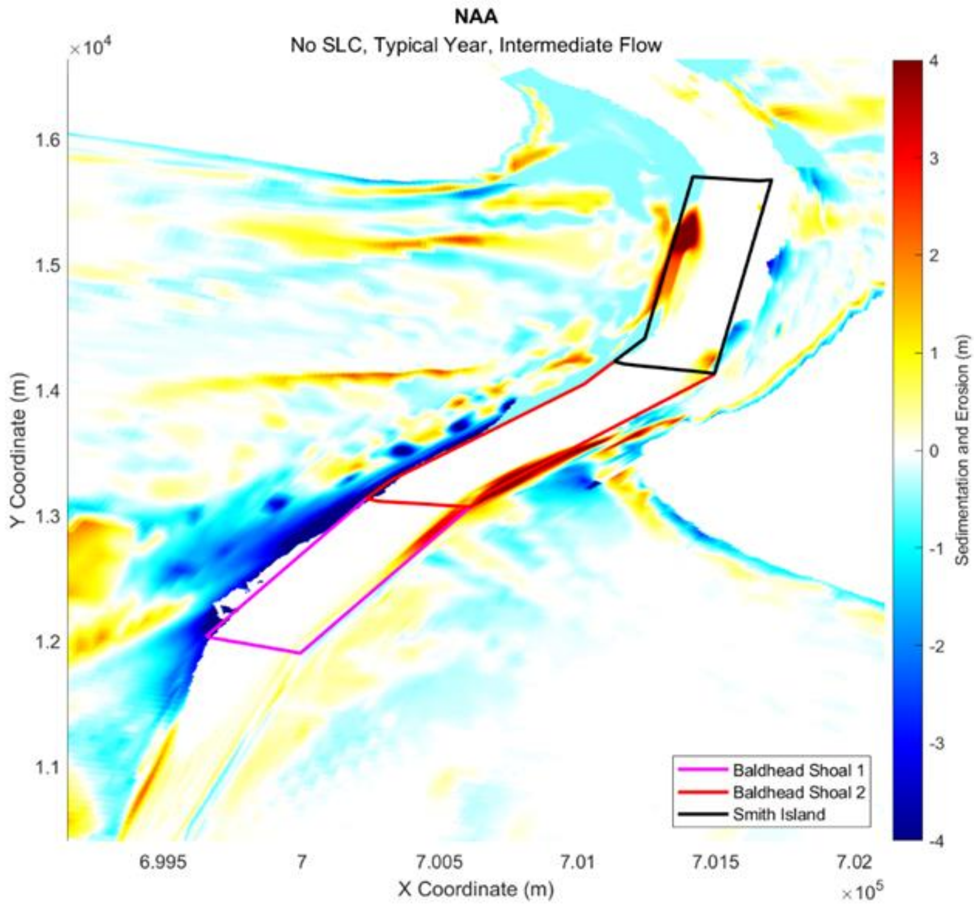

Figure 16. Modeled annual sedimentation and erosion for the Smith Island, Baldhead Shoal Reach 1 and Baldhead Shoal Reach 2 reaches of the navigation channel. Polygons show the setbacks used to estimate shoaling rates.

The total modeled shoaling volume for the three reaches of 515,660 cy for the grain size of 0.20mm was found to be within the range of historical shoaling rates (Tables 7 and 8). The modeled shoaling total is within ~12% of the weighted average shoaling reported in Table 7 and ~15% of the average of the shoaling quantities reported in Table 8. Table 7 demonstrates the variability in historical interannual shoaling rates for the combined reaches (~27%), particularly for the Smith Island Reach (~51%).

Table 7. Shoaling Rates for the Wilmington Harbor Inner Ocean Bar Channels from surveys (USACE, 2011)

Channel	1st Cycle			2nd Cycle			3rd Cycle			Weighted Average		
	Rate (cy/d)	Days	Rate (cy/yr)	Rate (cy/d)	Days	Rate (cy/yr)	Rate (cy/d)	Days	Rate (cy/yr)	Rate (cy/d)	Days	Rate (cy/yr)
Baldhead Shoal Reach 1	443	772	161,513	589	608	215,095	506	216	184,617	507	1,596	185,055
Baldhead Shoal Reach 2	517	773	188,705	712	512	259,953	322	152	117,421	566	1,437	206,554
Smith Island	431	811	157,315	591	611	215,788	878	153	320,543	537	1,575	195,859
Total			507,533			690,836			622,581			587,468

Table 8. Shoaling volume rate calibration results (cy/yr)

Phase 1	Shoaling Rate (cy/yr)			
Non cohesive model (sand) sensitivity runs	Smith Island	Baldhead Shoal 1	Baldhead Shoal 2	Total
Model Results	289,030	115,880	110,750	515,660
USACE (2011)	196,000	184,690	206,590	587,280
Condition survey (11/2015 – 11/2016)	161,180	106,090	324,600	591,870
Condition survey (11/2016 – 12/2017)	109,830	287,490	237,890	635,210

4.4 Sensitivity Analysis

A set of sensitivity runs were conducted to evaluate the impacts of grain size and initial thickness to the degree of shoaling in the model. The sensitivity runs were designed following a review of the NCSPA Section 203 (2020) study, which indicated that the model results may be sensitive to both grain sizes and initial sediment thicknesses (Figure 17). The following tests were conducted for the NAA No SLC condition:

- 0.175 mm grain size
- 0.200 mm grain size
- 0.250 mm grain size
- 0.200 mm grain size and a 20% increase in initial sediment thickness
- 0.200 mm grain size and a 20% decrease in initial sediment thickness

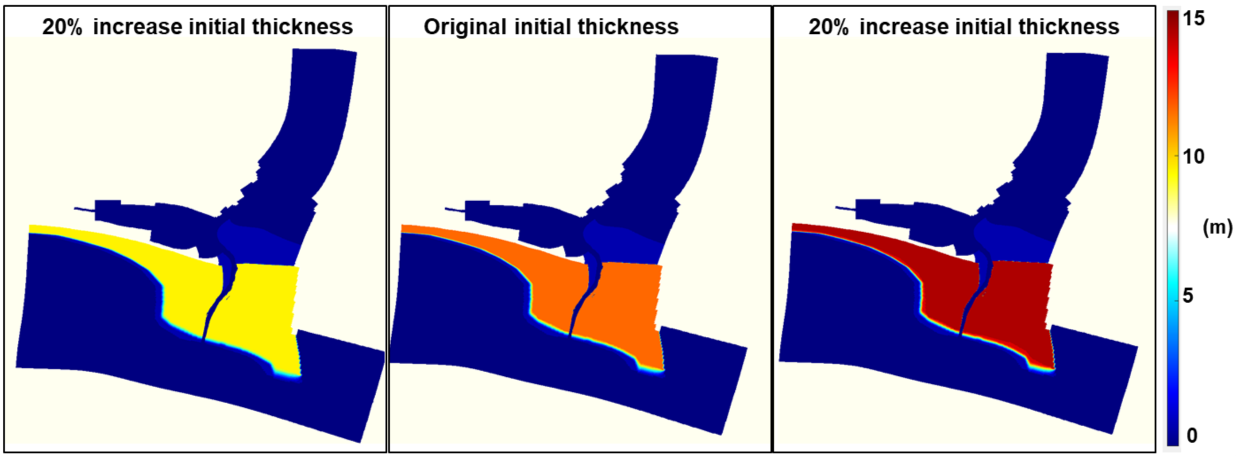

Figure 17. Delft 3D initial sediment layer thicknesses considered for sensitivity testing.

The estimated shoaling rates for each test were compared in the Smith Island, Baldhead Shoal Reach 1, and Baldhead Shoal Reach 2 areas. Table 9 contains the modeled shoaling rates for each model in the sensitivity analysis. Table 10 shows the percent deviation of the model results from the 0.20 mm, original sediment thickness layer test case.

Table 9. Sensitivity Analysis Test Results: Shoaling Rates (cy/yr)

Phase 1	Shoaling Rate (cy/yr)			
Non cohesive model (sand) sensitivity runs	Smith Island	Baldhead Shoal 1	Baldhead Shoal 2	Total
NAA No SLC – 0.175 mm	383,170	214,150	222,070	819,390
NAA No SLC – 0.20 mm	289,030	115,880	110,750	515,660
NAA No SLC – 0.25 mm	169,210	44,074	49,931	263,215
NAA No SLC - 0.2 mm increase initial thickness	311,610	115,840	111,000	538,450
NAA No SLC - 0.2 mm decrease initial thickness	265,100	115,310	110,650	491,060

Table 10. Sensitivity Analysis Test % Difference from 0.20mm, original sediment thickness layer test

Phase 1	% Difference in Shoaling Rates from NAA SLC1 0.20mm		
Non cohesive model (sand) sensitivity runs	Smith Island	Baldhead Shoal 1	Baldhead Shoal 2
NAA No SLC – 0.175 mm	33%	85%	101%
NAA No SLC – 0.20 mm	0%	0%	0%
NAA No SLC – 0.25 mm	-41%	-62%	-55%
NAA No SLC - 0.2 mm increase initial thickness	8%	0%	0%
NAA No SLC - 0.2 mm decrease initial thickness	-8%	0%	0%

The results of the sensitivity analysis support the findings from the NCSPA Section 203 (2020) study. The following conclusions were determined based on model comparison in the Smith Island, Baldhead Shoal Reach 1, and Baldhead Shoal Reach 2 areas:

1. The grain size of 0.175mm results in increased shoaling rates compared to 0.20 mm.
2. The grain size of 0.25mm results in reduced shoaling rates compared to 020 mm.
3. The grain size of 0.20mm shows agreeable estimates of shoaling rates within the range of observed shoaling rates in these areas and has the potential to demonstrate the effects of the alternatives modeled in Phase II.
4. Shoaling rates extracted from the model are highly sensitive to the delineation of the shoaling area in which they are calculated. The extents of the polygon used to extract sedimentation volumes should be carefully considered when interpreting modeled output.
5. The initial thickness layer variation does not induce significant changes in the model results for the Smith Island Reach and had negligible effects in the Baldhead Shoal Reaches 1 and 2.

Figure 18 illustrates the spatial distribution of sedimentation and erosion for each of the test cases.

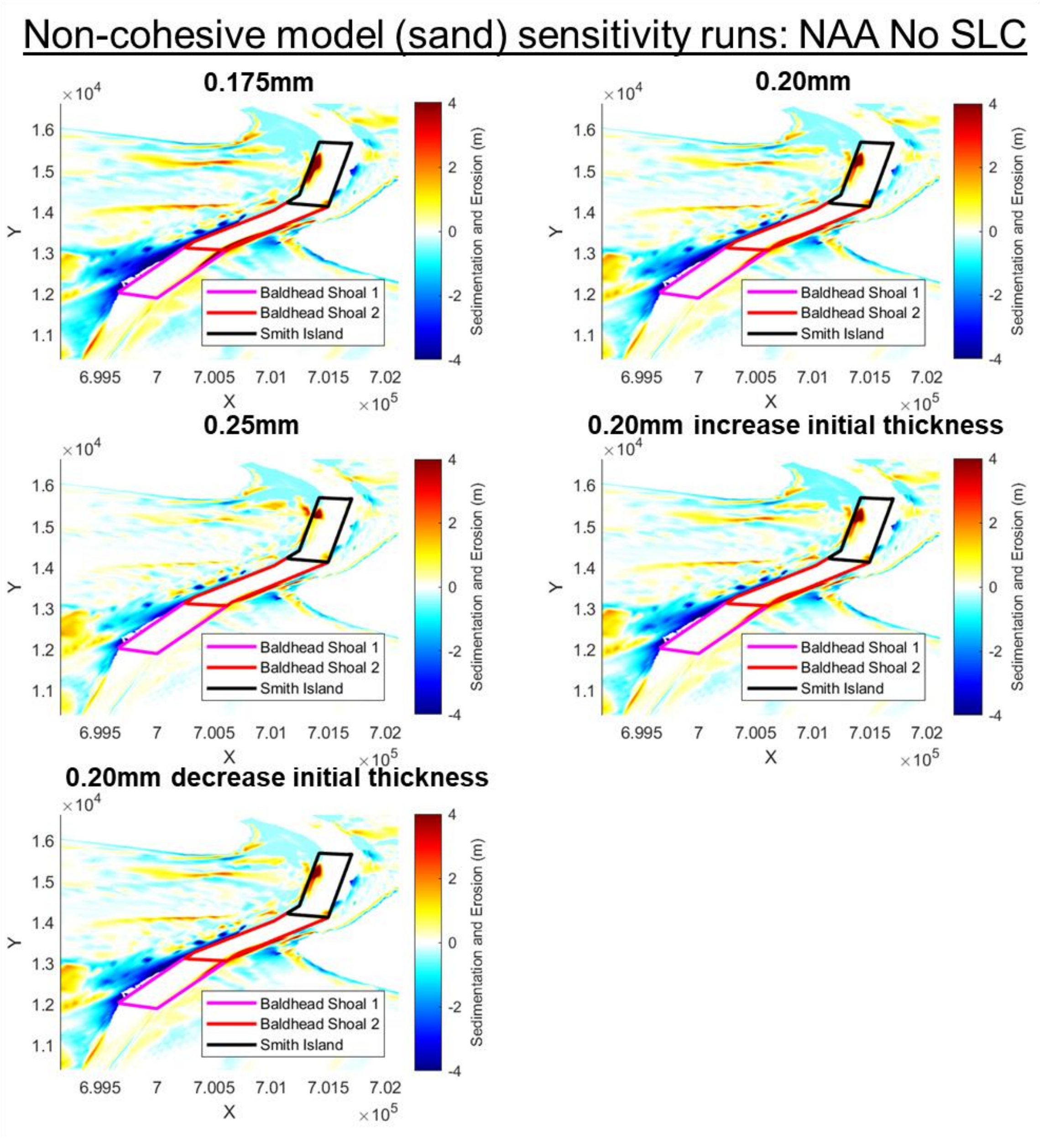

Figure 18. Cumulative 1 year Sedimentation and Erosion patterns for sensitivity analysis test cases

5 Model Results

Estimates of with and without project shoaling rates for each reach of the existing and proposed navigation channel for the three channel deepening alternatives (NAA, AA1 and AA2) and four sea level change scenarios (No SLC, SLC1, SLC2, SLC3) are provided in Table 11 to Table 16. Domain wide model output of annual sedimentation and erosion are also provided in the accompanying GIS-ready files.

Note that Reaves Point is considered the transition area between cohesive sediment in the upper estuary and non-cohesive sediment in the lower estuary. Therefore, shoaling rate estimates at Reaves Point were made using both the cohesive and non-cohesive models to represent this transition.

Table 11 Estimated shoaling rates in cy/yr for NAA – Cohesive Sediment (Upper Reaches)

Channel Reach	No SLC	SLC1	SLC2	SLC3
Anchorage Basin	1,549,100	1,621,000	1,742,000	1,845,000
Between Channel	401,260	416,450	425,680	381,940
Fourth East Jetty	851,100	862,650	853,410	630,220
Upper Brunswick	93,389	96,654	104,460	72,136
Lower Brunswick	53,872	51,928	46,654	13,718
Upper Big Island	56,851	52,662	45,829	9,687
Lower Big Island	34,411	32,671	25,785	2,154
Keg Island	5,780	5,558	4,472	-
Upper Lilliput	952	844	821	459
Lower Lilliput	125,610	128,120	119,050	35,330
Upper Midnight	71,727	72,473	66,736	30,119
Lower Midnight	4,900	4,824	4,821	3,933
Reaves Point	312	303	281	175
Total	**3,249,264**	**3,346,137**	**3,439,999**	**3,024,871**

Table 12. Estimated shoaling rates in cy/yr for AA1 – Cohesive Sediment (Upper Reaches)

Channel	No SLC	SLC1	SLC2	SLC3
Anchorage Basin	1,559,600	1,643,700	1,780,600	1,873,800
Between Channel	420,090	437,470	452,130	415,540
Fourth East Jetty	990,930	999,240	977,630	714,130
Upper Brunswick	145,600	149,240	152,280	100,500
Lower Brunswick	97,135	89,044	73,179	24,546
Upper Big Island	98,841	89,055	76,113	19,120
Lower Big Island	62,578	59,460	51,424	9,644
Keg Island	20,541	17,362	13,296	872
Upper Lilliput	5,312	4,734	4,457	1,673
Lower Lilliput	129,860	133,440	122,370	34,794
Upper Midnight	63,296	64,198	59,439	24,662
Lower Midnight	2,263	2,333	2,373	4,118
Reaves Point	1,078	943	860	330
Total	**3,597,123**	**3,690,219**	**3,766,151**	**3,223,730**

Table 13. Estimated shoaling rates in cy/yr for AA2 – Cohesive Sediment (Upper Reaches)

Channel	No SLC	SLC1	SLC2	SLC3
Anchorage Basin	1,544,700	1,629,200	1,764,000	1,876,900
Between Channel	414,920	432,350	444,530	405,550
Fourth East Jetty	951,880	965,030	942,830	687,240
Upper Brunswick	133,750	138,350	142,070	95,155
Lower Brunswick	84,025	77,806	64,815	23,671
Upper Big Island	86,645	77,987	68,118	16,956
Lower Big Island	57,671	56,194	48,500	8,104
Keg Island	17,768	15,740	12,264	641
Upper Lilliput	4,294	3,971	3,792	1,364
Lower Lilliput	125,480	129,870	120,230	34,087
Upper Midnight	62,566	64,071	57,777	24,615
Lower Midnight	2,243	2,388	2,319	3,816
Reaves Point	925	864	723	333
Total	**3,486,867**	**3,593,822**	**3,671,968**	**3,178,431**

Table 14. Estimated shoaling rates in cy/yr for NAA – Non-cohesive Sediment (Lower Reaches*)*

Channel	No SLC	SLC1	SLC2	SLC3
Reaves Point	645	847	1,071	94
Horseshoe Shoal	209	267	238	30
Snows Marsh	4,227	5,395	5,887	484
Lower Swash	1,273	1,255	1,097	269
Battery Island	8,326	8,151	10,876	26,112
Southport Channel	9,264	8,422	7,440	7800
Baldhead Caswell	1,663	1,444	1,251	333
Smith Island	289,031	319,816	354,365	203,287
BH Shoal Reach1	115,876	114,789	123,026	65,407
BH Shoal Reach2	110,745	114,179	117,024	115,867
Total	**541,260**	**574,565**	**622,274**	**419,684**

Table 15. Estimated shoaling rates in cy/yr for AA1 – Non-cohesive Sediment (Lower Reaches*)*

Channel	No SLC	SLC1	SLC2	SLC3
Reaves Point	1,282	1,551	1942	262
Horseshoe Shoal	326	403	432	54
Snows Marsh	4,319	5,235	5,914	1,055
Lower Swash	397	499	625	309
Battery Island	9,218	10,889	13,304	14,419
Southport Channel	3,155	3,719	3,933	7,322
Baldhead Caswell	84	97	123	134
Smith Island	276,810	309,925	350,047	193,581
BH Shoal Reach1	131,506	131,413	136,866	72,510
BH Shoal Reach2	117,602	121,285	125,253	124,339
Total	**544,700**	**585,017**	**638,440**	**413,986**

Table 16. Estimated shoaling rates in cy/yr for AA2 – Non-cohesive Sediment (Lower Reaches*)*

Channel	No SLC	SLC1	SLC2	SLC3
Reaves Point	1,190	1,449	1,823	242
Horseshoe Shoal	293	369	398	49
Snows Marsh	4,244	5,153	5,847	1,041
Lower Swash	373	471	592	295
Battery Island	8,378	9,977	12,373	13,777
Southport Channel	3,836	4,266	4,373	7,660
Baldhead Caswell	106	127	148	160
Smith Island	277,500	310,699	350,567	195,781
BH Shoal Reach1	129,823	126,434	135,207	70,463
BH Shoal Reach2	115,952	119,505	123,606	122,361
Total	**541,696**	**578,449**	**634,935**	**411,829**

6 Summary of Findings

The impacts of channel deepening alternatives and SLCs will be discussed in terms of the upper reaches and lower reaches. The upper reaches refer to those reaches investigated by the cohesive model (Anchorage Basin to Reaves Point), and the lower reaches refer to those reaches investigated by the noncohesive model (Reaves Point to Baldhead Shoal Reach 2). It is important to note that the shoaling quantities provided are calculated strictly within the setback polygons.

6.1 Impacts of Channel Deepening Alternatives

The channel deepening alternatives produced consistent impacts spatially along the navigation channel. In the upper reaches, AA1 resulted in the highest shoaling rates for all SLCs, exceeding the NAA by ~6-10% and AA2 by ~1-3%. In the lower reaches, AA1 produced the highest shoaling rates for all SLCs by a margin of ~1-3% compared to the NAA and ~1% compared to AA2. In the upper reaches, AA1 and AA2 showed consistent increases in shoaling compared to the NAA in all reaches except for the Upper Midnight and Lower Midnight reaches, which showed decreased sedimentation. In the lower reaches, AA1 and AA2 produced increased shoaling between Reaves Point and Snows Marsh as well as Baldhead Shoal Reaches 1 and 2, but decreased shoaling in the reaches in between.

6.2 Impacts of SLC

SLC significantly impacts channel shoaling rates by altering the hydrodynamic conditions within the estuary leading to increased sedimentation in some areas due to changes in tidal flow and wave action, while also causing increased erosion in others. Changes in tidal prism, amplitude and asymmetry due to SLC can lead to shifts in sedimentation patterns, potentially causing more sediment to be deposited in certain areas while eroding other (Jiang, et al. 2020). Furthermore, SLC allows larger waves the propagate farther inland, increasing the erosive force. As a result, the impacts of SLC on the navigation channel were found to be nonlinear and spatially varying in both the upper and lower reaches.

For example, the shoaling rate at Anchorage consistently increased with increasing SLC. On the other hand, the shoaling rates for Smith Island and Baldhead Shoal Reach 1 increased for SLC1 and SLC2 but decreased notably for SLC3. Overall, SLC2 ultimately produced the highest total shoaling rates across the entire navigation channel (upper and lower reaches), followed SLC1 and then No SLC.

7 References

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