Wilmington Harbor, North Carolina
Navigation Improvement Project

Integrated
Section 203 Study
&
Environmental Report

Appendix D

Cost

February 2020

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1. Introduction

The Cape Fear River Navigation Channel is a federally authorized and maintained navigation channel in southern North Carolina (NC), traversing the lower Cape Fear and Northeast Cape Fear Rivers. With approximately 38 miles of length, the channel connects the Atlantic Ocean at the mouth of the Cape Fear River to the Port of Wilmington (Figure 1-1). The Port of Wilmington is a major economic contributor to the region, providing facilities for general cargo and container vessels. The port is owned and maintained by the North Carolina State Ports Authority (NCSPA).

The channel is maintained by the United States Army Corps of Engineers (USACE) Wilmington District. Table 1-1 provides the channel dimensions, including the authorized and currently maintained dimensions of the channel resulting from the Wilmington Harbor 96 Project improvements that began in the year 2000. Existing water depths along the northern reaches are lower than the 1996 project dimensions, as these are not currently maintenance dredged due to lack of users (USACE, 2014a). Therefore, these reaches are not included in this proposed deepening project.

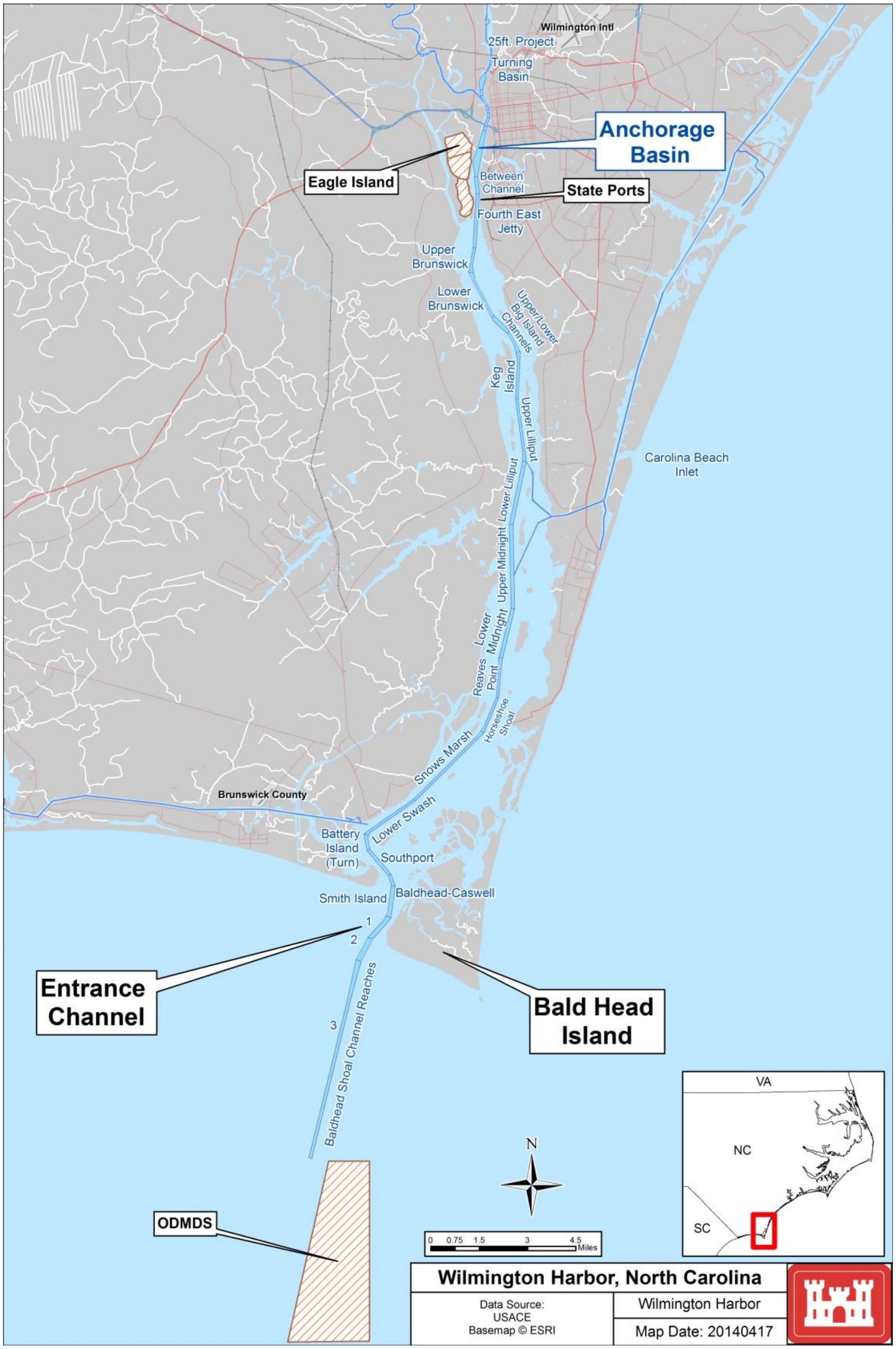

Figure 1-1: Cape Fear River Navigation Channel (USACE, 2014)

Table 1-1: Dimensions of Wilmington Harbor Navigation Channel (USACE, 2014)

Channel Name from Ocean to Upstream	Channel Length (ft)	Channel Width (ft)	Width at Turning Basin[1]	Maintained Channel Depth (ft)[2,3]	Authorized Channel Depth + Overdepth
Baldhead Shoal Reach 3	26,658	500 – 900		44	46
Baldhead Shoal Reach 2	4,342	900		44	46
Baldhead Shoal Reach 1	4,500	700 – 785		44	46
Smith Island	5,100	650		44	46
Baldhead-Caswell	1,921	500		44	46
Southport	5,363	500		44	46
Battery Island	2,589	500		44	46
Lower Swash	9,789	400		42	44
Snows Marsh	15,775	400		42	44
Horseshoe Shoal	6,102	400		42	44
Reaves Point	6,531	400		42	44
Lower Midnight[4]	8,241	600		42	44
Upper Midnight[4]	13,736	600		42	44
Lower Lilliput[4]	10,825	600		42	44
Upper Lilliput	10,217	400		42	44
Keg Island	7,726	400		42	44
Lower Big Island	3,616	400		42	44
Upper Big Island	3,533	510 – 700		42	44
Lower Brunswick	8,161	400		42	44
Upper Brunswick	4,079	400		42	44
Fourth East Jetty	8,852	500		42	44
Between	2,827	400		42	44
Anchorage Basin Station 8+00 to 84+81	7,681	550 – 1,400[5]	1,400[5]	42	44
Anchorage Basin Station 0+00 to 8+00	3,970	450 – 550		38	44
Memorial Bridge – Isabel Holmes Bridge	9,573	400	850	32	40
Isabel Holmes Bridge – Hilton RR Bridge	2,559	200 – 300		32	40
Hilton RR Bridge – Project Limit	6,718	200	700	25	36
Total Length in Feet	200,984				
Total Length in Miles	38.1				

1 Width shown is widest point at basins, and includes the channel width
2 Channel depths are at mean lower low water
3 Allowable Overdepth is two feet
4 This channel reach included the Passing Lane
5 Updated for 2016 Turning Basin Expansion

2. Project Description

2.1 Location

Figure 1-1 displays the project location and Table 1-1 includes the channel lengths, widths and currently authorized depths. The proposed deepening is to occur to the Anchorage Basin.

2.2 Existing Conditions

Refer to Section 1.2 in the Engineering Appendix for data on water levels, wind, waves, precipitation and salinity of the existing river in the project location.

2.3 Dredging Depths Considered

Within each reach, four different depths were considered for evaluation to determine the Tentatively Selected Plan (TSP). For the eight downstream reaches (closest to the Atlantic Ocean), contract depths (depths including 2 feet of advanced maintenance and overdepth) of -46 (existing), -48, -51, and -54 were estimated. For the 16 reaches upstream, depths of -44 (existing), -46, -49, -52 were estimated. The additional two feet provided for the downstream sections accounts for wave activity and the additional squat due to the speed of ships in open waters. Volumes were estimated for each of these depths, with separate rock and non-rock volumes calculated based upon historic borings and recently acquired geophysical data (see the Geotechnical Appendix).

3. Tentatively Selected Plan

3.1 Introduction

The Tentatively Selected Plan (TSP) for the Wilmington Harbor Navigation Improvement Project includes dredging to a nominal depth of -49 feet MLLW, with two feet of overdredge, for a total of -51 feet, MLLW for the first eight (8) reaches as follows:

1. Entrance
2. Baldhead Shoal Reach 3
3. Baldhead Shoal Reach 2
4. Baldhead Shoal Reach 1
5. Smith Island Reach
6. Baldhead-Caswell Reach
7. Southport Reach
8. Battery Island Reach

Upstream of Battery Island Reach, the TSP includes dredging to a nominal depth of -47 ft MLLW, with two feet of overdredge, for a total of -49 feet, MLLW. The following reaches are anticipated to be dredged to -49 feet:

1. Lower Swash Reach
2. Snows Marsh Reach
3. Horseshoe Shoal Reach
4. Reaves Point Reach
5. Lower Midnight Reach
6. Upper Midnight Reach
7. Lower Lilliput Reach
8. Upper Lilliput Reach
9. Keg Island Reach
10. Lower Big Island Reach
11. Upper Big Island Reach
12. Lower Brunswick Reach
13. Upper Brunswick Reach
14. Fourth East Jetty Reach and Berths 7-9
15. Between Reach
16. Anchorage Basin

The plan also includes widenings of the channel as summarized in Table 3-1.

Table 3-1: Summary of Existing and Proposed Channel Widths

ID	Range Name	Channel Widths [Ft]		Widening Details
		Existing Channel	Proposed	
0	Entrance	N/A	600	New
1	Bald Head Shoal Reach 3	500 - 900	600 - 900	Symmetric
2	Bald Head Shoal Reach 2	900	900	No Change
3	Bald Head Shoal Reach 1	700	900	Green Side Only
4	Smith Island	650	900	Red Side Only
5	Bald Head - Caswell	500	800	Red Side Only
6	Southport	500	800	Re-orientation Red Side then Green Side
7	Battery	500	800 - 1300	Replaced with 4000-ft Radius Curve And Green Side at Apex
8	Lower Swash	400	800 - 500	Green Side to Symmetric
9	Snows Marsh	400	500	Symmetric
10	Horseshoe Shoal	400	500	Symmetric
11	Reaves Point	400	500	Symmetric
12	Lower Midnight	600	600	No Change
13	Upper Midnight	600	600	No Change
14	Lower Lilliput	600	600	No Change
15	Upper Lilliput	400	500	Symmetric
16	Keg Island	400	500	Symmetric
17	Lower Big Island	400	500	Symmetric
18	Upper Big Island	660	660	No Change
19	Lower Brunswick	400	500	Symmetric
20	Upper Brunswick	400	500	Symmetric
21	Fourth East Jetty	500	550	Green Side Only
22	Between Channel	550	625	Green Side Only
22	Anchorage Basin	625	625 - 1509	No Change

4. Cost Estimate Assumptions

Costs included in this estimate should be considered 2019 values. Labor costs were estimated using 2019 labor rates for North Carolina using the annual statewide wage rate survey. Mean wages were typically used, with median rates used where deemed applicable. Equipment rates were escalated to 2019 using the Construction Equipment Ownership and Operating Expense Schedule Region III Economic Indexes for Construction Equipment (Appendix E), document number EP 1110-1-8, dated 30 November 2018. The full cost of money rate utilized was the published federal rate of 2.625%, covering the time period from July 1, 2019 to December 31, 2019, published biannually in the Federal Register (Volume 84, No. 208).

Fuel prices were estimated using current marine diesel fuel prices at Bald Head Island from January of 2020, with the 10% bulk discount applied, with 5% added to account for fuel price volatility. Overhead rates and production rate assumptions associated with the various dredge types are detailed in Sections 4.2 through 4.6 below.

Costs were estimated assuming that only material above the currently maintained channel was assessed for the project. Therefore, any material above the currently maintained depth was removed from the total cost of the project at the unit rate of the planned depth.

For example:

Volume above maintained depth = 2,000 CY

Volume of planned depth = 100,000 CY

Unit cost at planned depth = $20 / CY

Project Cost = $20 / CY * (100,000 CY – 2,000 CY) = $1,960,000

4.1 Dredge Type by Area

Dredge type was selected based upon which type of dredge was determined to be most efficient for the given reach based upon various factors including:

- Material type
- Wave conditions
- Haul Distance
- Production Rates

Hopper dredges operate more efficiently in open waters, but do not dredge rock well. Cutterhead dredges can dredge rock up to 4,300 PSI, but struggle to operate efficiently in rough waters. Areas with 90% sand can be placed on beaches for beneficial use in lieu of the ocean disposal site. Below is a summary of the assumed dredge type utilized in each reach:

- Entrance – Hopper

- Baldhead Reach 3 – Hopper, Cutterhead for Rock Sections
- Baldhead Reach 2 – Hopper
- Baldhead Reach 1 – Cutterhead with Beach Disposal
- Smith Island Reach - Cutterhead with Beach Disposal
- Baldhead-Caswell Reach - Cutterhead with Beach Disposal
- Southport Reach - Cutterhead with Beach Disposal
- Battery Island Reach – Cutterhead with Spider Barge
- Lower Swash Reach – Cutterhead with Spider Barge
- Snows Marsh Reach – Cutterhead with Spider Barge
- Horseshoe Shoal Reach – Cutterhead with Spider Barge
- Reaves Point Reach – Cutterhead with Spider Barge
- Lower Midnight Reach – Cutterhead with Spider Barge
- Upper Midnight Reach – Cutterhead with Spider Barge
- Lower Lilliput Reach – Cutterhead with Spider Barge
- Upper Lilliput Reach – Cutterhead with Spider Barge
- Keg Island Reach – Blasting Rig with Mechanical Dredge for Rock, Cutterhead with Spider Barge for Sand
- Lower Big Island Reach – Blasting Rig with Mechanical Dredge for Rock, Cutterhead with Spider Barge for Sand
- Upper Big Island Reach – Blasting Rig with Mechanical Dredge for Rock, Cutterhead with Spider Barge for Sand
- Lower Brunswick Reach – Blasting Rig with Mechanical Dredge for Rock, Cutterhead with Spider Barge for Sand
- Upper Brunswick Reach – Cutterhead with Spider Barge
- Fourth East Jetty Reach– Cutterhead with Spider Barge
- Between Reach - Cutterhead with Spider Barge
- Anchorage Basin - Cutterhead with Spider Barge

4.2 Hopper Dredge Assumptions

A generic medium sized hopper dredge was assumed for this project. The generic medium is assumed to have a maximum capacity of 3,800 CY, with 2 dragheads utilized for the channel dredging.

Additional assumptions for the hopper dredge included:

- 15% overhead
- 10% profit
- 1% bond
- 0.5’ overdig on average (non pay)
- 0.5’ not dug (allowable overdredge) on average

- 9 mph average speed to disposal
- 10 mph return speed
- 5 minutes gravity dump
- 10% cleanup dredging
- 621 working hours per month on average
- $3.02 / gallon fuel price (marine diesel)
- Crew of 16

4.3 Cutterhead with Spider Barge (Rock) Assumptions

The hydraulic (cutterhead) dredge utilized for dredging rock assumes a 30" dredge is used. The 30" dredge is assumed to have 8,400 HP, with a maximum capacity of 2,818 CY / Hour.

Additional assumptions for the cutterhead dredge include:

- 15% overhead
- 10% profit
- 1% bond
- 1' overdig on average (non pay)
- 0.5' not dug (allowable overdredge) on average
- 10% cleanup dredging
- 329 working hours per month on average
- $3.02 / gallon fuel price (marine diesel)
- Crew of 50, including spider barge and tending tugs
- 5,000 CY Scows
- 2,500 CY per Trip (50% full)
- 4.5 mph tow speed to disposal
- $249,000 / Month for Spider Barge Equipment
- $190,000 / Month for Tending Tug
- $300,000 / Month in Dredge Wear Due to Rock
- $450,000 / Month in Replacement Cutterhead Teeth Due to Rock

Production rates vary depending on the bank cut, but typical production rates were approximately 500 CY / Hr.

5,000 CY scows were assumed based on the industry fleet at a whole. Although one dredging company has a fleet of 6,000 CY+ scows that could be utilized, reducing trips required, the other industry leaders likely to bid on these contracts have fleets of 5,000 CY scows. This assumption of scow size is utilized consistently throughout this project (cutterhead and mechanical dredging).

4.4 Cutterhead with Spider Barge (Non-Rock) Assumptions

The hydraulic (cutterhead) dredge utilized for dredging sand with offshore disposal assumes a 30" dredge is used. The 30" dredge is assumed to have 8,400 HP, with a maximum capacity of 2,818 CY / Hour.

Additional assumptions for the cutterhead dredge include:

- 15% overhead
- 10% profit
- 1% bond
- 0.5' overdig on average (non pay)
- 0.5' not dug (allowable overdredge) on average
- 10% cleanup dredging
- 438 working hours per month on average
- $3.02 / gallon fuel price (marine diesel)
- Crew of 50, including spider barge and tending tugs
- 5,000 CY Scows
- 3,150 CY per Trip (70% full)
- 4.5 mph tow speed to disposal
- $249,000 / Month for Spider Barge Equipment
- $190,000 / Month for Tending Tug
- $75,000 / Month in Dredge Wear
- $45,000 / Month in Replacement Cutterhead Teeth

Production rates vary depending on the bank cut, but typical production rates were approximately 2,000 CY / Hr.

4.5 Cutterhead with Beach Disposal Assumptions

The hydraulic (cutterhead) dredge utilized for dredging sand with beach disposal assumes a 30" dredge is used. The 30" dredge is assumed to have 8,400 HP, with a maximum capacity of 2,818 CY / Hour.

Additional assumptions for the cutterhead dredge include:

- 15% overhead
- 10% profit
- 1% bond
- 0.5' overdig on average (non pay)
- 0.5' not dug (allowable overdredge) on average
- 10% cleanup dredging
- 475 working hours per month on average
- $3.02 / gallon fuel price (marine diesel)

- Crew of 43
- $42,000 / Month for D-6 Dozer and 980 Loader

Production rates vary depending on the bank cut, but typical production rates were approximately 2,000 CY / Hr.

4.6 Blasting with Mechanical Dredge Removal Assumptions

Blasting Costs were assumed to depend on the thickness of rock being blasted. The blasting rig was estimated to cost $75,000 per day for equipment, personnel, and supplies, with an additional $12,000 in monitoring equipment and labor. All of these are before overhead, profit, and bond. Blasting production were assumed as follows:

For 3 feet or less of rock blasting, 9,500 ft^2 per day

For 3 to 5 feet of rock blasting, 8,700 ft^2 per day

For greater than 5 feet of blasting, 8,000 ft^2 per day

These production rates resulted in the following costs after markups were added and the above production rates were applied:

- <3 ft: $112.44 / CY
- 3 to 5 ft: $74.53 / CY
- > 5 ft: $58.77 / CY

These costs represent only the costs of the drilling rig and associated monitoring. The mechanical removal of the blasted material was then estimated separately as follows. A 26 CY clamshell dredge utilizing a 14 CY bucket removes about 200 CY of blasted material per hour. Additional assumptions include:

- 15% overhead
- 10% profit
- 1% bond
- 222 Working hours per month
- 100 second bucket cycle time
- 10% cleanup
- 5,000 CY Spilt Hull Scows
- 4,000 CY / Load
- 5 mph tow speed to disposal
- $3.02 / gallon fuel price (marine diesel)

4.7 Mobilization and Demobilization

Mobilization and demobilization costs were estimated using factors including the distance the equipment must travel to reach the project, the setup time and breakdown time required for equipment, and the travel distance for the dredge plant to transit back to the home base of the dredge. These estimates were then checked with dredging bid tabs for projects on the east coast for comparison purposes. The dredge mobilization and demobilization costs were then distributed per the anticipated split in contracts, as described section 5.6 below.

4.8 Other Estimate Assumptions

Hauling distances for the scows were adjusted for each reach. The number of scows and tugs were also adjusted to prevent the dredge from waiting on the scows to return. An additional scow was assumed for the job as a spare.

Labor rates were taken from a 2019 wage rate survey for North Carolina, with mean and median wages applied as deemed applicable.

4.8.1 30 - Planning, Engineering, and Design

Code of Account 30, Planning, Engineering, and Design (PED) was estimated at $24,100,000 based upon the expected effort. This was estimated based upon estimates from Fugro for the anticipated geotechnical investigation effort, Dial & Cordy for the Environmental effort, and the maximum allowable $3 million spent on the Section 203 report to date was also included as a PED cost. In addition, $500,000 was estimated for the vessel simulation, $3,300,000 for the Section 103 Analysis based on EA estimate and an additional $5,300,000 for the engineering, planning, environmental design, mitigation design, and permitting efforts estimated by M&N, DMA, and Dial-Cordy. The breakdown of costs is included in Appendix F.

4.8.2 31 - Construction Management

Code of Account 31, Construction management costs were estimated assuming that four people would be full time in construction management overseeing the construction activities, plus $150,000 / reach in survey costs. The project schedule was then utilized to estimate the number of months that these four full time employees would work on each reach. The breakdown of costs totaling $10,800,000 is included in Appendix F.

5. Cost Summary

5.1 Construction Cost Estimate Results

The current cost estimate for the dredging of the TSP is $549.3 million. This cost does not include PED, Construction Management, O&M, IDC, or mitigation costs. Including mitigation, ATONs, relocations, PED, and Construction Management, the Total First Cost for the Project is estimated at $849.4 million, with the estimated Total Fully Funded Project Cost as $998,296,000. The Total Project Cost Summary is included below in Figure 5-1.

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
						Program Year (Budget EC):				2020					
						Effective Price Level Date:				1 OCT 19					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	**TOTAL ($K)**	Spent Thru: **1-Oct-19** ($K)	**TOTAL FIRST COST** ($K)	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*		*K*	*L*	*M*	*N*	*O*
12	NAVIGATION PORTS & HARBORS	$549,332	$117,557	21.4%	$666,890	0.0%	$549,332	$117,557	$666,890	$0	$666,890	18.5%	$651,133	$139,343	$790,476
06	FISH & WILDLIFE FACILITIES	$85,000	$18,190	21.4%	$103,190	0.0%	$85,000	$18,190	$103,190	$0	$103,190	14.3%	$97,186	$20,798	$117,984
02	RELOCATIONS	$10,975	$2,349	21.4%	$13,324	0.0%	$10,975	$2,349	$13,324	$0	$13,324	14.2%	$12,533	$2,682	$15,215
06	FISH & WILDLIFE FACILITIES	$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
07	POWER PLANT	$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
08	ROADS, RAILROADS & BRIDGES	$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
09	CHANNELS & CANALS	$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
10	BREAKWATER & SEAWALLS	$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$645,307	$138,096		$783,403	0.0%	$645,307	$138,096	$783,403	$0	$783,403	17.9%	$760,853	$162,822	$923,675
01	LANDS AND DAMAGES	$20,000	$4,280	21.4%	$24,280	0.0%	$20,000	$4,280	$24,280	$0	$24,280	12.6%	$22,526	$4,820	$27,346
30	PLANNING, ENGINEERING & DESIGN	$21,100	$4,515	21.4%	$25,615	0.0%	$21,100	$4,515	$25,615	$3,000	$28,615	9.7%	$23,154	$4,955	$31,109
31	CONSTRUCTION MANAGEMENT	$10,800	$2,311	21.4%	$13,111	0.0%	$10,800	$2,311	$13,111	$0	$13,111	23.3%	$13,316	$2,850	$16,165
	PROJECT COST TOTALS:	$697,207	$149,202	21.4%	$846,409		$697,207	$149,202	**$846,409**	$3,000	**$849,409**	17.6%	$819,848	$175,447	$998,296

Figure 5-1: TPCS Summary Costs

The 21.4% contingency was added on via the Cost and Schedule Risk Analysis completed in section 6.

5.2 Mitigation Costs

Mitigation costs have been estimated assuming multiple mitigation measures are completed to compensate for the additional area impacted by the dredging.

These measures include:

- Wetland Mitigation
- Fish and Fish Habitat Mitigation
- Vessel Wake Mitigation
- Monitoring

The estimated costs are based on preliminary analyses of project impacts and mitigation options available to consider for compensation. These estimates will be revised through coordination with interagency working groups and the USACE during the NEPA process. Risk and uncertainties as to the cost estimate prevail until full agency coordination on project impacts and analysis of mitigation needs are completed. However, the cost and schedule risk analysis does factor in the mitigation costs in the contingency developed for the project.

The estimated costs are as follows:

Wetland Mitigation	$10 million
Fish and Fish Habitat Mitigation	$61 million
Vessel Wake Mitigation	$24 million
Monitoring	$10 million
Total Cost:	$105 million

5.3 Relocation Costs

Four pipelines cross the project, with three of them shallow enough to conflict with the proposed dredging depths. One pipeline, a six inch directionally drilled pipeline owned by Exxon Mobile and Operated by Kinder Morgan requires relocation. This is estimated at $2 million. The remaining two pipelines in conflict with the project are inactive. It is anticipated that they will be removed and not replaced, at an estimated cost of $300,000. The total relocation costs are $2.3 million. These costs are included in the TPCS sheet in contract #7, under WBS #02 Relocations.

5.4 Interest During Construction (IDCs)

Interest during construction (IDC) was calculated using the FY20 federal discount rate (2.75%). The construction schedule was used to identify a schedule of costs incurred during PED and construction. The -47-foot selected plan is scheduled to be constructed during three construction years. Project costs used to calculate IDC include the 21.4% contingency determined in the Cost and Schedule Risk Analysis.

PED costs are incurred in advance of construction costs. Relocations are scheduled for the first year of construction. Land acquisition for mitigation construction is scheduled to occur in the second year of construction. Land acquisition for conservation is scheduled to occur in the third year of construction. Aid to navigation and local service facility costs are scheduled for the last year of construction. Monitoring costs during construction and construction supervision and administration costs are distributed to each year of construction. Pre-base year costs are escalated by month up to the base year to calculate the investment costs of the project. Post-construction monitoring costs are discounted back to the base year using the same method that is used to escalate pre-base year costs. These calculations resulted in a total IDC for the project of $37,287,000. Please note that this cost is not included in the total costs included in the TPCS or in Table 8-1.

5.5 Operations and Maintenance (O&M) Costs

For maintenance dredging, current annual costs are approximately:

Anchorage Basin:	$4.5 million
Inner Ocean Bar:	$3.0 million
Outer Ocean Bar:	$2.5 million
Mid-River:	$2.0 million
Total:	$12 million

The potential increase in maintenance dredging due to the project is 8% for Ocean Bars and 11% for the Anchorage Basin and Mid-River for approximately $1.2 million / year.

5.6 Aids to Navigation Costs

Recommended adjustments to the aids to navigation (ATON) and their estimated costs are presented in Table 5-1.

Table 5-1: ATON Cost Estimate Summary

	Reach (Channel Location)	ID Nos	Type	Qty.	"New" or "Relocation of Existing"	Unit Cost	Total Cost
1	New Sea Range	1	Front Range Marker	1	New	$1,250,000	$1,250,000
2	New Sea Range	2	Rear Range Marker	1	New	$1,500,000	$1,500,000
3	New Sea Range	3, 4	Lateral Marker Buoy	10	New	$85,000	$850,000
4	New Sea Range	5	Lateral Marker Buoy	1	Relocation	$20,000	$20,000
5	New Sea Range	6	Sea Buoy	1	New	$85,000	$85,000
6	Bald Head Shoal 3	7 to 13	Lateral Marker Buoy	7	Relocation	$20,000	$140,000
7	Bald Head Shoal 1	14	Front Range Marker	1	Relocation	$345,000	$345,000
8	Bald Head Shoal 1	15	Rear Range Marker	1	Relocation	$595,000	$595,000
9	Bald Head Shoal 1	16, 17	Lateral Marker Buoy	2	Relocation	$20,000	$40,000
10	Smith Island	18	Front Range Marker	1	Relocation	$345,000	$345,000
11	Smith Island	19	Rear Range Marker	1	Relocation	$415,000	$415,000
12	Southport/Battery Continuous Turn	20	Front Range Marker	1	Relocation	$365,000	$365,000
13	Southport/Battery Continuous Turn	21	Rear Range Marker	1	Relocation	$455,000	$455,000
14	Southport/Battery Continuous Turn	22, 23	Lateral Marker Buoy	2	Relocation	$20,000	$40,000
15	Southport/Battery Continuous Turn	24	Lateral Marker Buoy	1	New	$40,000	$40,000
16	Lower Swash	25	Front Range Marker	1	Relocation	$370,000	$370,000
17	Lower Swash	26	Rear Range Marker	1	Relocation	$470,000	$470,000
18	Lower Swash	27	Lateral Marker Buoy	1	Relocation	$20,000	$20,000
19	Snows Marsh	28 to 31	Lateral Marker Buoy	4	Relocation	$20,000	$80,000
20	Horseshoe Shoal	32 to 34	Lateral Marker Buoy	3	Relocation	$20,000	$60,000
21	Horseshoe Shoal	35	Lateral Marker Buoy	1	New	$40,000	$40,000
22	Reaves Point	36	Lateral Marker Buoy	1	Relocation	$20,000	$20,000
23	Upper Lilliput	37 to 40	Lateral Marker Buoy	4	Relocation	$20,000	$80,000
24	Keg Island	41, 42	Lateral Marker Buoy	2	Relocation	$20,000	$40,000
25	Keg Island	43	Lateral Marker Buoy	1	New	$40,000	$40,000

	Reach (Channel Location)	ID Nos	Type	Qty.	"New" or "Relocation of Existing"	Unit Cost	Total Cost
26	Lower Big Island	44 to 46	Lateral Marker Buoy	3	Relocation	$20,000	$60,000
27	Lower Brunswick	47 to 51	Lateral Marker Buoy	5	Relocation	$20,000	$100,000
28	Upper Brunswick	52	Lateral Marker Buoy	1	Relocation	$20,000	$20,000
29	Fourth East Jetty Range	53	Front Range Marker	1	Relocation	$325,000	$325,000
30	Fourth East Jetty Range	54	Rear Range Marker	1	Relocation	$425,000	$425,000
31	Fourth East Jetty Range	55, 56	Lateral Marker Buoy	2	Relocation	$20,000	$40,000
						Total	**$8,675,000**

5.7 Construction Sequence

The channel deepening contracts will generally occur starting from the ocean and progressing upriver, with approximately 3-4 reaches dredged in each contract. A detailed description of which reaches are included in which contracts, and the sequence of when each contract is expected to occur is included in Appendix B – Project Schedule. The schedule also factors in the regulatory windows of when dredging is allowed to occur in each reach.

6. Cost and Schedule Risk Analysis

6.1 Introduction

The United States Army Corps of Engineers (USACE) requires a risk analysis for projects over $40 million. The preliminary estimate for the Wilmington Harbor Navigation Improvement Project is over $500 million, exceeding the $40 million limit, requiring this risk analysis to be completed.

6.2 Background

The project's cost estimate is prepared using MCACES MII software in accordance with USACE policy and can be found in Appendix A. MII uses existing or custom unit cost databases and allows contingency, taxes, insurance, and profit to be added to each item as needed to create an accurate construction cost estimate. Dredging unit costs were created using CEDEP like spreadsheets that calculate the costs to the dredger to complete the project, including all overhead, life cycle costs, bond, and contractor profit. Low, middle, and high unit costs were evaluated, and a median unit cost was typically selected for the cost estimate.

6.3 Report Scope

The scope of the risk analysis report is to calculate and present the cost and schedule contingencies at the 80 percent confidence level using the risk analysis processes as mandated by USACE Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works.

6.4 USACE Risk Analysis Process

The risk analysis process follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering Directory of Expertise for Civil Works (Cost Engineering DX). The risk analysis process uses probabilistic cost and schedule risk analysis methods within the framework of the *Crystal Ball* software. The risk analysis results are intended to serve several functions, one being the establishment of reasonable contingencies reflective of an 80 percent confidence level to successfully accomplish the project work within that established contingency amount. Furthermore, the scope of the report includes the identification and communication of important steps, logic, key assumptions, limitations, and decisions to help ensure that risk analysis results can be appropriately interpreted.

Risk analysis results are also intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as provide tools to support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule risk analyses should be considered as an ongoing process conducted concurrent to, and along with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting, and scheduling.

In addition to broadly defined risk analysis standards and recommended practices, the risk analysis is performed to meet the recommendations of the following documents and sources:

- ER 1110-2-1150, Engineering and Design for Civil Works Projects.
- ER 1110-2-1302, Civil Works Cost Engineering.
- ETL 1110-2-573, Construction Cost Estimating Guide for Civil Works.
- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Engineering DX.

6.5 Methodology / Process

The purpose of the risk analysis process is to determine what can be expected for the project as a whole, allowing variation within the individual project components. Natural variation allows the simulation to mimic real-world scenarios more closely, accounting for unforeseen changes that could affect a project, but within reason for the given distributions.

As recommended in the above references, *Crystal Ball* Risk Analysis Software was selected to run the risk analysis for the project. *Crystal Ball* uses a mathematical modeling technique called a Monte Carlo Simulation that takes distributions of assumed unit costs, quantities and production rates and runs thousands of trials, taking one input from each distribution in each simulation, adding in natural variation when selecting the points. The input data was based on the Risk Register, MII Cost Estimate, Project schedule, and design team involvement.

Crystal Ball allows multiple trials (5,000 trials were used for the analysis) in order to model the distribution given to that assumption. All of the individual assumptions (i.e. cost, volumes, etc.) are then summed for each trial and plotted to show cost and schedule versus probability. The median is the most likely project cost/schedule and, based on USACE policy, the 80% confidence value is the probable upper bound cost/schedule. The software is also used to create sensitivity plots that show which risk items have the greatest impacts in the overall project cost distribution.

6.5.1 Identify and Assess Risk Factors

Risk factors are events and conditions that may influence or drive uncertainty in project performance. They may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risk factors may have either favorable or unfavorable impacts on project cost and schedule.

Checklists or historical databases of common risk factors are sometimes used to facilitate risk factor identification. However, key risk factors are often unique to a project and not readily derivable from historical information. Therefore, input from the entire design team is obtained using creative processes such as brainstorming or other facilitated risk assessment meetings. In practice, a combination of professional judgment from the design team and empirical data from similar projects is desirable and is considered. Identifying the risk factors is considered a qualitative process that results in establishing a list of risks that serves as the document for the further study using the Crystal Ball risk software.

The risk analysis process, for this project, began by gathering input from the design team. The team identified potential risks associated with each part of the project and designated each risk. In accordance with the current *Cost and Schedule Risk Analysis Guidance* (May 2009), all risks were then identified as low, moderate, or high risks based on their respective likelihoods and overall effects, as defined in the risk matrix shown below (Figure 6-1: Risk Level Matrix). These were used to identify what the design team considered to be the key risks of the project and the degree that these risks might affect the final cost and schedule.

Risk Level

Likelihood of Occurrence	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	Low	Moderate	High	High	High
Likely	Low	Moderate	High	High	High
Unlikely	Low	Low	Moderate	Moderate	High
Very Unlikely	Low	Low	Low	Low	High

Impact or Consequence of Occurrence

Figure 6-1: Risk Level Matrix

The risk register records the team's risk concerns, discussions related to those concerns, and potential impacts to the current cost and schedule estimates. The concerns and discussions are meant to support the team's decisions related to event likelihood, impact, and the resulting risk levels for each risk event.

6.5.2 Quantify Risk Factor Impacts

The quantitative impacts of risk factors on project plans are analyzed using a combination of professional judgment, empirical data, and analytical techniques. Risk factor impacts are quantified using probability distributions (density functions), because risk factors are entered into the *Crystal Ball* software in the form of probability density functions.

Similar to the identification and assessment process, risk factor quantification involved multiple project team disciplines. For each of the risks identified, quantifying risk factor impacts were determined to include:

- Maximum possible value for the risk factor.
- Minimum possible value for the risk factor.
- Most likely value (the statistical mode), if applicable.
- Nature of the probability density function used to approximate risk factor uncertainty.
- Mathematical correlations between risk factors.
- Affected cost estimate and schedule elements.

The resulting risk register includes discussion of the above.

6.5.3 Analyze Cost Estimate and Schedule Contingency

Contingency is analyzed using the *Crystal Ball* software, an add-in to the *Microsoft Excel* format of the cost estimate and schedule. Monte Carlo simulations are performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified by the design team. Contingencies are calculated by applying risks identified.

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the base cost estimate. P80 is the value that with 80% confidence one can conclude the project cost will not exceed, or 80% of the Monte Carlo simulations were less than or equal to that number. Each option-specific contingency is then allocated on a civil works feature level based on the dollar-weighted relative risk of each feature as quantified by Monte Carlo simulation. Standard deviation is used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of all the project feature cost contingency being allocated to features with relatively higher estimated cost uncertainty.

Schedule contingency is calculated as the difference between the P80 option duration forecast and the base schedule duration.

Schedule contingency is analyzed only on the basis of each option and not allocated to specific tasks. Based on Cost Engineering DX guidance, only critical path and near critical path tasks are considered to be uncertain for the purposes of schedule contingency analysis.

6.6 RISK ANALYSIS RESULTS

This section discusses the major components of the risk register, data used to develop the distributions for the risk analysis and results.

6.6.1 Risk Register – Cost Risk Analysis

During development of the risk register, risk items were discussed and evaluated by the design team. A risk register is a tool commonly used in project planning and risk analysis and serves as the basis for the risk studies and *Crystal Ball* risk models. The risk register reflects the results of risk factor identification and assessment, risk factor quantification, and contingency analysis. From this process, 14 items were determined by the team to warrant inclusion in the final risk register for the cost risk analysis (12 risks and 2 opportunities). Each of the risks was then evaluated in detail to determine the variability and distribution in quantities, cost and schedule so they could be evaluated in *Crystal Ball*. The detailed risk register is provided in Appendix C to this report and summarized in Table 6-1.

Table 6-1: Key Cost Risks Identified

Risk No.	Design Team Developed Risk/Opportunity Event
PPM-1	Congressional Funding for Construction
PPM-4	Schedule Quality
PPM-5	Additional Review Time
CA-2	Number of Contracts
T-1	Rock Hardness / Quantity
T-2	Side Slope Stability
ENV-5	Environmental Mitigation
EST-1	Dredge Number & Size
EST-2	Wood Debris
EST-4	Mid-River Dredging Expense
EST-5	Offshore Fisheries Structure*
EST-6	Beach Placement*
EXT-1	Market Conditions
EXT-2	External Opposition
EXT-6	Fuel Price

*Opportunity

Based on the above, 18 different variables were used in the Crystal Ball Cost Risk analysis to model the above risks, with CA-2 consisting of 3 variables to account for different numbers of mobilizations and demobilizations. In addition, T-1 has two variables, with a separate risk for the rock hardness requiring blasting (cutterhead → blasting) and a second for additional soft rock (cutterhead sand → cutterhead rock). These assumptions consider values from the dredging cost estimate spreadsheets, historical data and design team recommendations on individual risk items.

Following is a discussion of the more significant risks shown above, and assumptions used in developing the analysis. Crystal ball reports show details on ranges and distributions.

PM-1. Congressional Funding for Construction

The additional costs relating to delays in congressional funding were estimated as $400,000 to address additional oversight by the USACE as the project pushes into the future. It was assumed to be a uniform distribution, with a low cost of $0.

PPM-4 Schedule Quality

The aggressive schedule may not be feasible for contractors to complete given the regulatory windows and general workload of many large dredging contractors. An additional cost of $500,000 was considered for additional oversight and project management costs to cover an additional year of construction if the project duration extends longer than anticipated. This was modeled as a uniform risk with a low of $0.

PPM-5 Additional Review Time

Additional review time was estimated to push the project back as much as 16 months, with an additional cost of $200,000 for resources to review the project documents. This was modeled as a uniform distribution with a low of $0.

CA-2 Number of Contracts

The number of contracts will impact the number of mobilizations required. This was modeled as a step function, with an 80% chance for 1 additional mobilization, 50% chance for a second mobilization, and 20% chance for a third additional mobilization. Each mobilization cost was estimated at $1,444,521.

T-1 Rock Hardness / Quantity

The rock hardness / quantity was modeled in two separate ways as it can impact costs in two separate and independent risks. The first is that some of the rock that was estimated to be able to be dredged using a large cutterhead is too hard to use the cutterhead and blasting is required. This was modeled as a triangular distribution, with a high cost of 50% of the cutterhead rock volume requiring blasting, a low value assuming a 15% decrease in blasting required, with an expected value of $0 (the current estimate).

The other rock hardness risk is that some of the material estimated to be sand is actually a soft rock and requires a large cutterhead with a lower production rate and more frequent breakdowns. This was estimated using a triangular distribution with a maximum value assuming 15% of the sand is actually soft rock, a low value assuming 15% of the soft rock is sand, and an expected value of $0 (the current estimate)

T-2 Side Slope Stability

The side slope stability risk assumes that in some areas, the deepening of the channel will approach the side slopes, requiring stabilization measures to be required at the shore to keep the shore stable and avoid impacts to private or government property. This was modeled as a triangular distribution with a high value of $2 million to account for the possibility of stabilization measures such as riprap or a bulkhead required in select areas. The low and expected cost remains at $0, as no side slope stability measures are expected to be required given the analysis completed to date.

ENV-5 Environmental Mitigation

The environmental mitigation is currently estimated based on a preliminary construction estimate of specific mitigation measures but have not been confirmed by regulatory agencies at this time. The $105 million estimated in the current contract cost is considered a conservative number that may change once specific projects are determined for the mitigation effort. This risk is estimated in the model as a triangular distribution, with a high value of $10 million, a low value of -$25 million, and an expected value of $0 (the current estimate).

EST-1 Dredge Number & Size

The dredge number and size risk assumes that the contractor doesn’t have as large of a cutterhead and requires additional blasting to complete the work. It was modeled as a triangular distribution with a high value assuming 50% more blasting required, and a low and expected value of $0, matching the current estimate.

EST-2 Wood Debris

The wood debris risk assumes that in the areas that have not been previously dredged (where the widening of the channels occur) there may be significant amounts of wood debris that are not allowed to be disposed of offshore. A screen will be required to separate the wood debris and dispose of the debris in a permitted facility. This was estimated with a high value of $2 million, a low value of $0, and a uniform distribution.

EST-4 Mid-River Dredging

Historical bids for dredging in the mid-river areas have typically been higher than anticipated based on engineer estimates. Dredging costs from the Lower Lilliput Reach to the Upper Brunswick Reach were increased by 10% as a high cost, with a lower and expected cost of $0. This was modeled as a triangular distribution.

EST-5 Offshore Fisheries Structure

An opportunity was added to the model to account for the possibility of utilizing an offshore fisheries structure for disposal of the soft rock in lieu of the offshore disposal site. The Offshore fisheries site is about 2 miles closer, reducing the cycle distance for 4 miles for disposal of material. A cost savings of $1 / CY for the rock was assumed for this opportunity. This was modeled as a triangular distribution, with the high and expected value of $0, and the $1 savings represented in the low value.

EST-6 Beach Placement

A second opportunity was modeled to account for the possibility of using the Battery Island Reach, Lower Swash Reach, and Snows Marsh Reach sand on a beach in place of hauling offshore, reducing costs by $2 / CY. This was modeled as a triangular distribution, with a high and expected cost of $0, and the low value representing the $2 / CY savings for the three reaches listed.

EXT-1 Market Conditions

The market conditions risk accounts for the tight dredging market with limited equipment capable of complete the work. A uniform distribution was modeled, with a high cost estimated using a 10% increase in the project construction costs and a low value of $0 (the current estimated).

EXT-2 External Opposition

The external opposition risk relates to landowners along the channel protesting the project, fearing that it will negatively impact their property. Lawsuits could be expensive to defend. This was estimated assuming a high value of $10 million and a low of $0, with a uniform distribution.

EXT-6 Fuel Cost

The external risk of fuel prices was estimated assuming a 10% increase in fuel costs above background inflation occurs, resulting in an increase in dredging costs by approximately 3%. It was assumed that on the low end, that fuel may decrease by 3.3% (compared to background inflation), resulting in a lower dredging price. This was modeled using a triangular distribution.

The full risk register and Crystal Ball reports are included in Appendices C, D, and E and contain additional details.

6.6.1 Risk Register – Schedule Risk Analysis

Although this schedule risk register was completed at the same time for both the cost and schedule risk analysis, the key risks are displayed separately, as different risks impact the cost and schedule differently. Table 6-2 lists the key schedule risks determined for the project.

Table 6-2: Key Schedule Risks Identified

Risk No.	Design Team Developed Risk/Opportunity Event
PPM-1	Congressional Funding for Construction
PPM-4	Schedule Quality
PPM-5	Additional Review Time
CA-2	Number of Contracts
T-1	Rock Hardness / Quantity
T-2	Side Slope Stability
EST-1	Dredge Number & Size
EST-2	Wood Debris
EXT-1	Market Conditions
EXT-2	External Opposition

Based on the above risks, 10 different variables were used in the *Crystal Ball* Schedule Risk analysis to model the identified risks.

Following is a discussion of the more significant risks shown above, and assumptions used in developing the analysis. Crystal ball reports show details on ranges and distributions.

PM-1 Congressional Funding for Construction

Congressional funding is one of the largest concerns for the project relating to schedule, as funding is inconsistent and other similar projects have had issues. A Triangular distribution was estimated with a high value of 36 months and a low and expected value of 0 months was modeled for this project.

PM-4 Schedule Quality

The aggressive schedule may not be feasible for contractors to complete given the regulatory windows and general workload of many large dredging contractors. An additional 24 months was added to the project schedule to account for two additional dredging windows for the project.

PM-5 Additional Review Time

An additional 16 months was added to the schedule due to additional review time from the USACE and other Federal agencies before the project could be issued permits to begin dredging. This was modeled as a triangular distribution with an expected and low value of 0 months. It should be noted that this risk is considered concurrent with PM-1 and EXT-2 and the highest value of these risks was considered for the analysis (these risks don't add together).

CA-2 Number of Contracts

The number of contracts was considered for this schedule analysis, assuming a delay could push the project into additional regulatory windows. A triangular distribution with a high value of 16 months and a low and expected of 0 months was utilized.

It should be noted that this risk was modeled as concurrent with risks PPM-4, EST-1 and EXT-2, meaning the highest value of these risks was used in the model and they were not added together.

T-1 Rock Hardness / Quantity

Rock hardness was input into the schedule risk model using a triangular distribution. The high value assumes an additional 18 months due to additional blasting being required, taking longer. The low value assumes slightly less blasting, with a 2-month reduction in the project schedule. The expected value of 0 months corresponds to the existing schedule.

T-2 Side Slope Stability

The side slope stability risk assumes that is some areas, the deepening of the channel will approach the side slopes, requiring stabilization measures to be required at the shore to keep the shore stable and avoid impacts to private or government property. This was modeled as a triangular distribution with a high value of 3 additional months, and a low and expected duration of 0 months.

EST-1 Dredge Number & Size

The dredge number and size risk assumes that the contractor doesn't have as large of a cutterhead and requires additional blasting to complete the work. It was modeled as a triangular distribution with a high value assuming 50% more blasting required, requiring an additional 16 months to complete. The low value assumes a savings of 4 months due to an additional dredge added to a project, with an expected value of 0 months, matching the current estimate.

This risk was considered concurrent with risks PPM-4, CA-2, and EXT-2, meaning the highest value of these risks was used in the model and they were not added together.

EST-2 Wood Debris

The wood debris risk assumes that in the areas that have not been previously dredged (where the widening of the channels occurs) there may be significant amounts of wood debris that are not allowed to be disposed of offshore. A screen will be required to separate the wood debris and dispose of the debris in a permitted facility. This was estimated with a high value of 4 months, a low and expected value of 0 months, modeled as a triangular distribution.

EXT-1 Market Conditions

The market conditions risk accounts for the tight dredging market with limited equipment capable of complete the work. A triangular distribution was modeled, with a high duration estimated assuming a regulatory window is missed due to excessive contractor workload, resulting in a high value of 12 months. The expected value of 0 months was utilized, with a low value of a reduction of 4 months due to additional capacity on the market, allowing additional dredges to be utilized.

This risk was modeled concurrently with PPM-4, CA-2, and EST-1, meaning the highest value of these risks was used in the model and they were not added together.

EXT-2 External Opposition

The external opposition risk relates to landowners along the channel protesting the project, fearing that it will negatively impact their property. Lawsuits could be expensive to defend and delay the project for years. This was estimated assuming a high value of 36 months and an expected and low of 0 months, utilizing a triangular distribution.

The full risk register and Crystal Ball reports are included in Appendices C, D, and E and contain additional details.

6.7 Cost Risk Analysis - Cost Contingency Results

Using the initial base cost of $700.2 million (including all construction activities, relocating ATONs, environmental mitigation, engineering, and construction management) and a base risk within the Crystal Ball Model of $0 (corresponding to the current estimate) a distribution of risks was calculated in *Crystal Ball*. Based on the *Crystal Ball* Analysis, the most probable project risk (50 percentile) is $109.7 million. The project risk at the 80% confidence interval is $149.4 million. The confidence interval and total project distribution are shown in Figure 6-2. Detailed figures and statistical analysis from the simulation are contained in Appendix E. The range from the minimum total risk to the maximum risk is approximately $264.8 million and the range from the 80% upper limit to the minimum value is approximately $153.5 million. Please note that these are not Project First Costs or Total Project Costs as this analysis is done on the expected costs without contingency.

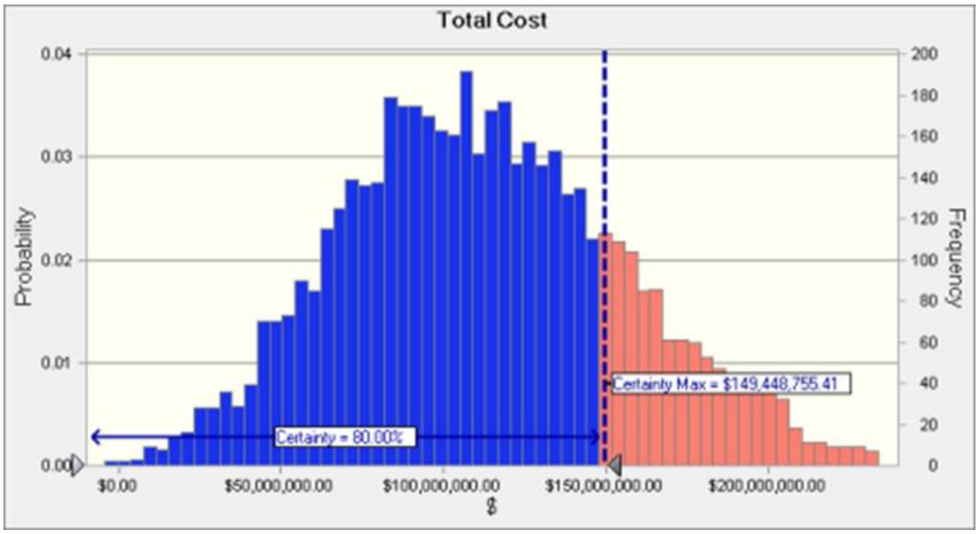

Figure 6-2: Cost Distribution with the 80% Confidence Interval Shown

A sensitivity analysis was conducted to determine which items cause the greatest change in overall project cost. The results are displayed in Figure 6-3.

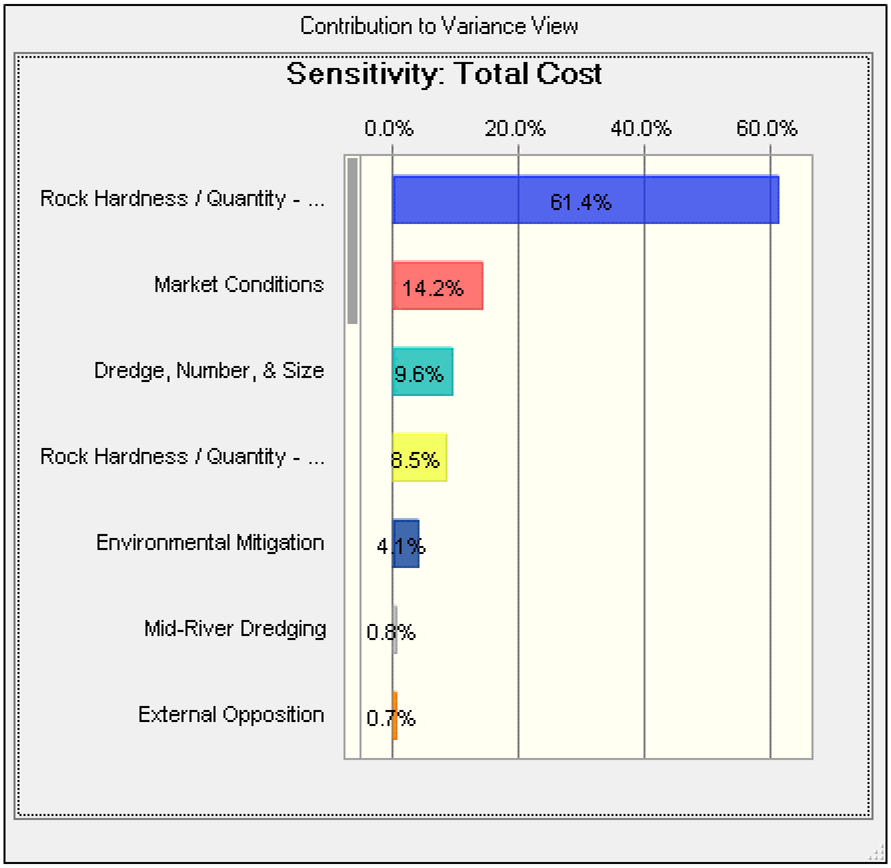

Figure 6-3: Sensitivity Analysis for Cost Risk

The sensitivity analysis showed that the quantity of rock hardness for the soft rock is the key driver of the cost of this project. An increase in the soft rock (that requires a cutterhead to work slower with more wear on moving parts) represents over 60% of the variation within the risk analysis. Other key drivers include the market conditions, which represents about 14% of the variation within the sensitivity analysis. The dredge number / size represents approximately 10%, while the rock hardness that requires blasting also represented about 8% of the variation. Note that these results reflect only those contingencies established from the cost risk analysis.

Table 6-3: Confidence Table of Total Risk

Percentiles:	Forecast values ($)
0%	$(4,062,794)
10%	$57,474,210
20%	$74,403,615
30%	$87,053,534
40%	$98,234,452
50%	$109,657,276
60%	$121,535,495
70%	$134,162,103
80%	$149,448,755
90%	$170,336,014
100%	$260,699,150

The cost risk analysis determined that a 21.4% contingency (calculated as the difference from the 80% to the base case divided by the base case of $700.2 million) should be expected for the project as a whole. These risks include the risks associated with mitigation, PED, and Construction Management. This percentage represents the funds that should be allocated to complete this project based on the risks developed by the design team. Table 6-4 shows the change in contingency with different confidence levels of the cost estimate.

Table 6-4: Project Contingencies (Base Cost plus Contingencies)

Confidence Level	Project Cost ($)	Contingency ($)	Contingency (%)
P0	$696,144,312	$(4,062,794)	-0.6%
P10	$757,681,316	$57,474,210	8.3%
P20	$774,610,720	$74,403,615	10.7%
P30	$787,260,639	$87,053,534	12.5%
P40	$798,441,557	$98,234,452	14.1%
P50	$809,864,381	$109,657,276	15.7%
P60	$821,742,601	$121,535,495	17.4%
P70	$834,369,209	$134,162,103	19.2%
P80	**$849,655,861**	**$149,448,755**	**21.4%**
P90	$870,543,120	$170,336,014	24.4%
P100	$960,906,255	$260,699,150	37.3%

7. Schedule Risk Analysis

The schedule risk analysis was dependent on many issues relating to getting the construction started, including external opposition and congressional funding, but also issues relating to the rock hardness and the aggressive schedule. The results are included below.

7.1 Results

The Monte Carlo Simulation results indicate to an 80% certainty that the project will be delayed by no more than 44 months. With an initial schedule of 67 months, the total project duration is expected to extend to 111 months, a period of over 9 years. The results are shown in Figure 7-1.

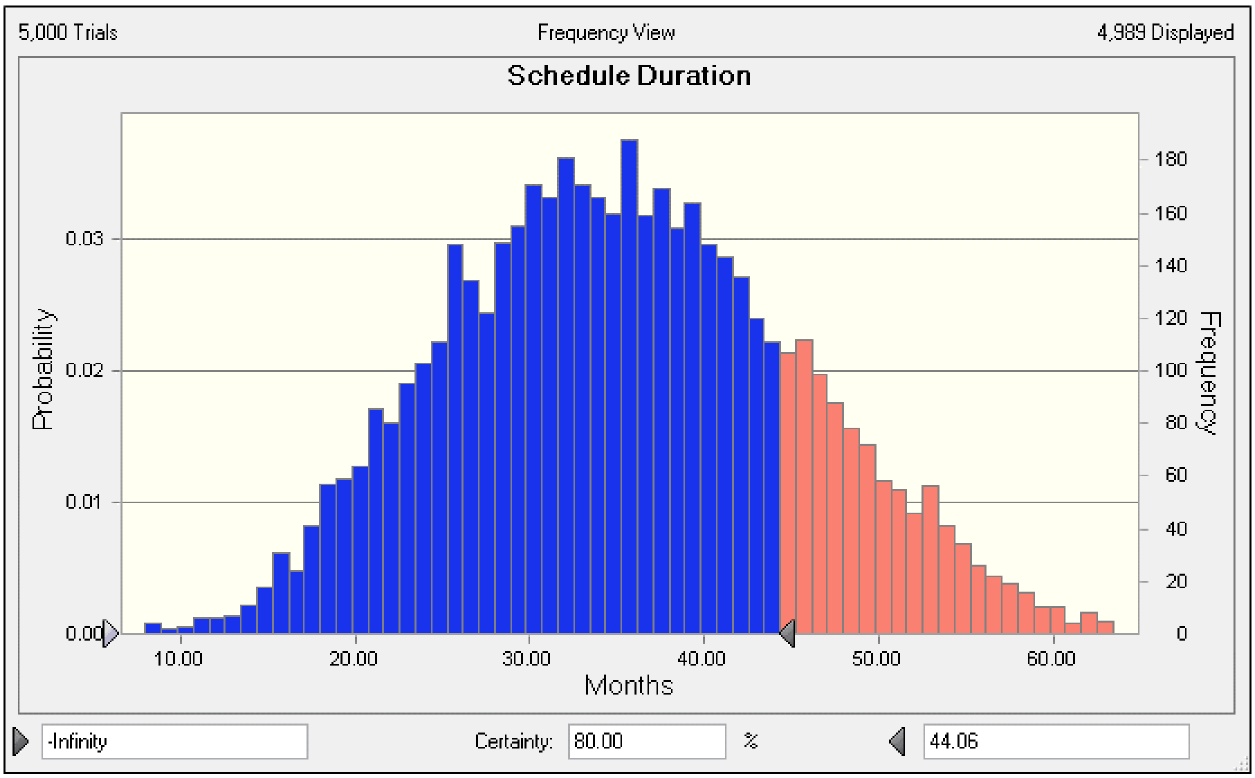

Figure 7-1: Schedule Risk Analysis Results

A sensitivity analysis was also completed for the schedule risk analysis and included in Figure 7-2.

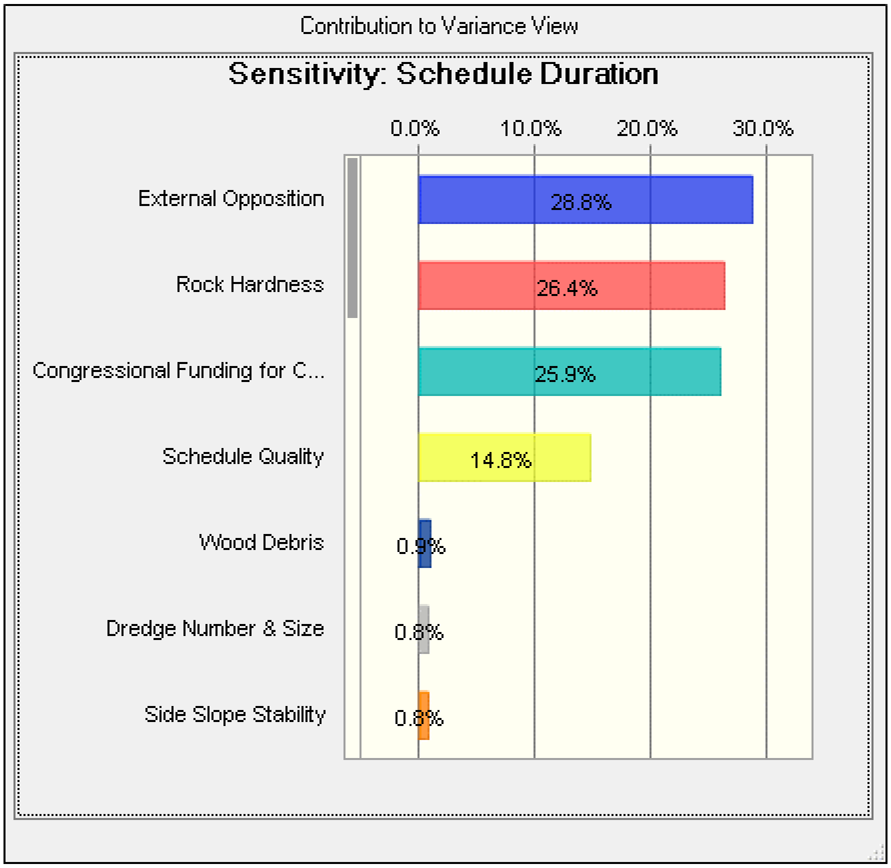

Figure 7-2: Schedule Risk Analysis Sensitivity

8. Major Findings / Observations

Based on analysis of the risk model, the most probable project cost is currently estimated to be $809.9 million with an 80% confidence interval that the cost will not exceed $849.7 million. This means the contingency to be utilized for the project is 21.4%. The project schedule is anticipated to be completed in approximately 67 months based upon the expected schedule, but is likely to be delayed due to funding, external resistance and delays in construction due to issues, with an 80% confidence that the project schedule will be completed within 111 months; a duration of just over 9 years. A summary of the costs by element are included in Table 8-1. Please note that these costs are project first costs and do not account for the Feasibility Study money that has already spent. This results in a calculated total which slightly differs from the calculation included in the TPCS sheet, which does account for the Feasibility Study as already spent.

Table 8-1: Summary of Project Costs

Element	Cost ($)
Construction	549,332,444
Mitigation	105,000,000
Utility Relocations	2,300,000
Relocation of ATONs	8,675,000
Construction Management	10,800,000
PED	21,100,000
Feasibility Study	3,000,000
Contingency	149,488,775
Total Cost	***849,696,219***

Table 8-2: Expected Project Schedule Duration

Element	Duration (Months)
Construction	67
Contingency	44
Total Cost	***111***

9. Recommendations

The identified risks for the project may be unavoidable but identifying ways to mitigate their effect on the final project cost is essential to the success of the project. Efforts to reduce risk may include:

- Further geotechnical investigations to determine the extent and hardness of rock within the dredging prism. This will greatly reduce uncertainties, although the costs may increase depending on the results of the geotechnical investigations.
- Public outreach, particularly relating to areas where the channel approaches the adjacent shores. Allowing the public to feel comfortable that the project will not negatively impact them will lower the chances that they will protest and file law suits to prevent the project from moving forward.
- Coordination with senators and other representatives for North Carolina may be beneficial to secure federal funding for the project.

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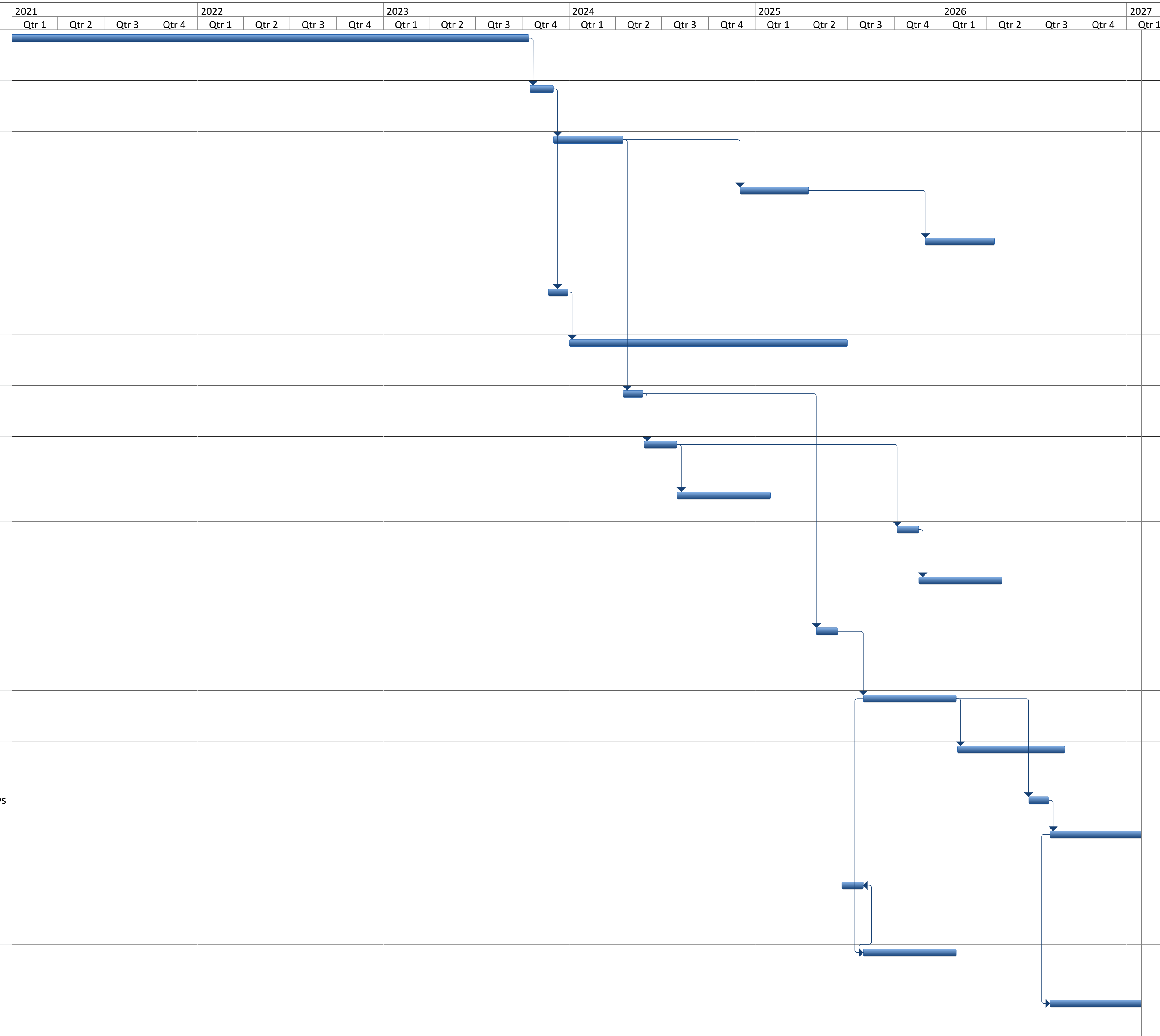
Appendix A:
MII Estimate –
(Not Included for Official Submittal)

Appendix B:
Project Schedule

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Preliminary Engineering and Design	900 days	Mon 5/4/20	Fri 10/13/23	
2		Mobilization of Contract 1 - Hopper Dredging of Entrance, Baldhead Shoal Reach 3 and Baldhead Shoal Reach 2	34 days	Mon 10/16/23	Thu 11/30/23	1
3		Contract 1 Dredging - Year 1	97 days	Fri 12/1/23	Mon 4/15/24	2
4		Contract 1 Dredging - Year 2	97 days	Mon 12/2/24	Tue 4/15/25	3FS+164 days
5		Contract 1 Dredging - Year 3	98 days	Mon 12/1/25	Wed 4/15/26	4FS+163 days
6		Mobilization of Contract 2 - Hydraulic Dredging of Baldhead Shoal 3, Battery Island, Lower Swash, and Snows Marsh Reaches	29 days	Tue 11/21/23	Fri 12/29/23	2FS-8 days
7		Contract 2 Dredging	391 days	Mon 1/1/24	Mon 6/30/25	6
8		Mobilization of Contract 3 - Hydraulic Dredging of Horseshoe Shoal, Reaves Point, Lower Midnight and Upper Midnight Reaches	29 days	Tue 4/16/24	Fri 5/24/24	3
9		Contract 3 Dredging - Horseshoe Shoal Reach	47 days	Mon 5/27/24	Tue 7/30/24	8
10		Contract 3 Dredging - Reaves Point & Midnight Reaches	132 days	Wed 7/31/24	Thu 1/30/25	9
11		Mobilization of Contract 4 - Hydraulic Dredging of Baldhead Shoal 1, Smith Island, Baldhead / Caswell, and Southport Reaches	30 days	Tue 10/7/25	Mon 11/17/25	9FS+309 days
12		Contract 4 Dredging	118 days	Tue 11/18/25	Thu 4/30/26	11
13		Mobilization of Contract 5 - Blasting and Mechanical Removal of Keg Island, Lower Big Island, Upper Big Island, and Lower Brunswick Reaches	30 days	Thu 5/1/25	Wed 6/11/25	8FS+243 days
14		Contract 5 Dredging - Blasting Operation	131 days	Fri 8/1/25	Fri 1/30/26	13FS+36 days
15		Contract 5 Dredging - Rock & Sand Removal	151 days	Mon 2/2/26	Mon 8/31/26	14
16		Mobilization of Contract 6 - Hydraulic Dredging of Lower and Upper Lilliput Reaches	30 days	Mon 6/22/26	Fri 7/31/26	14FS+100 days
17		Contract 6 Dredging	130 days	Mon 8/3/26	Fri 1/29/27	16
18		Mobilization of Contract 7 - Hydraulic Dredging of Upper Brunswick, Fourth East Jetty, Between Reach and the Anchorage Basin	30 days	Fri 6/20/25	Fri 8/1/25	19SF
19		Contract 7 Dredging - Year 1	131 days	Fri 8/1/25	Fri 1/30/26	14SS
20		Contract 7 Dredging - Year 2	130 days	Mon 8/3/26	Fri 1/29/27	17SS



Project: Wilmington Project Sched
Date: Mon 1/20/20

Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Deadline
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Progress

Appendix C:
Risk Register

Wilmington Harbor Deepening Risk Register

Risk Level

Likelihood of Occurrence	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	Low	Moderate	High	High	High
Likely	Low	Moderate	High	High	High
Unlikely	Low	Low	Moderate	Moderate	High
Very Unlikely	Low	Low	Low	Low	High

Impact or Consequence of Occurrence

Brief Scope Presentation: Provide brief scope discussion here to ensure the correct project alternative has been identified and represented within the risk discussions.

Risk No.	Risk/Opportunity Event (logic by feature, contract, responsibility)	PDT Event Concerns (include all to archive)	PDT Discussions (support the liklihood and impact)	Responsibility/POC	Project Cost: Likelihood*	Project Cost: Impact*	Project Cost: Risk Level*	Project Schedule: Likelihood*	Project Schedule: Impact*	Project Schedule: Risk Level*
ct										
	PROJECT & PROGRAM MGMT									
PPM-1	Congressional Funding For Construction	Concern is that construction funding is incremental per FY and can be impacted by budget delays such as continuing resolutions.	Based on estimated construction value, the design team feels it unlikely that total construction will be funded all at once. This could result in escalation due to schedule growth if the construction schedule extends beyond the expected schedule.		Likely	Negligible	Moderate	Likely	Critical	High
PPM-2	Stakeholder funding capability	The Port of Wilmington must provide their cost share for the project. Although the Port can issue bonds and has budgeted for the project, if funds are not available when a contract needs to be issued, it could delay the project.	Delays in issuing a contract could lead to schedule escalation, increasing costs and delaying project benefits.		Unlikely	Negligible	Low	Unlikely	Marginal	Low
PPM-3	Adequate PDT Resources	USCE will provide construction management for these contracts. If key resources leave or are unavailable, the contract may have delays or costly change orders.	USACE has overseen deepening contracts before and routinely oversees the maintenance dredging, so no impacts are expected.		Unlikely	Negligible	Low	Unlikely	Negligible	Low
PPM-4	Schedule quality	Schedule is aggressive, particularly given uncertainties relating to federal funding.	Previous deepening projects have taken more time, and federal funding is a significant unknown for this project. Delays will increase construction oversight costs and could lead to escalation due to schedule growth.		Very Likely	Marginal	Moderate	Very Likely	Critical	High
PPM-5	Additional Review Time	The 203 Process is new and not well established. The USACE review and approval of the project may take additional time.	USACE may have concerns over benefit calculations, as benefits are calculated in a unique way, as the "without project" conditions are worse than the current conditions economically, as it is assumed that ships will bypass Wilmington once the nearby Ports (Savannah and Charleston) are deeper.		Very Likely	Negligible	Moderate	Very Likely	Critical	High
PPM-6										
	Contract Acquisition									
CA-1	Contract Acquisition Strategy	The acquisition strategy could impact the construction cost and schedule.	These contract require large cutterhead and hopper dredges that are not feasible for small contracts. It is very unlikely that small businesses would be used for this project other than cultural resource surveys and minor items like that in the design work.		Very Unlikely	Significant	Low	Very Unlikely	Critical	Low

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CA-2	Number of Contracts	It is expected that the contract will be split into 7 contracts	If the project is split into more contracts, contractors may change more in mobilization fees, increasing project costs.		Unlikely	Significant	Moderate	Unlikely	Critical	Moderate
	Opportunity									
	Number of Contracts	It is expected that the contract will be split into 7 contracts	If the project is split into fewer contracts, contractors may change less in mobilization fees, decreasing project costs.		Unlikely			Unlikely		
	Technical									
T-1	Rock Hardness / Quantitiy	Rock hardness has been estimated, but splitting tensile strength isn't known to a high degree	Fugro has mapped the extent of the rock well and determined where blasting will be required vs where the cutter is sufficeint, based on rock hardness.		Very Likely	Critical	High	Very Likely	Critical	High
T-2	Side Slope Stability	Some areas along the channel currently have erosion issues, so widening and deepening the channel may exasperate these existing issues.	The channel has been widened to the opposite side in areas with known erosion issues to avoid this concern.		Likely	Marginal	Moderate	Likely	Marginal	Moderate
T-3	Utility Conflicts	Utilities may not be deep enough and require relocation to deepen the channel.	Utilities have been researched for this project and no impacts are expected.		Unlikely	Marginal	Low	Unlikely	Marginal	Low
T-4										
	Real Estate									
RE-1										
RE-2										
	Environmental									
ENV-1	Encountering UXOs	UXOs could be present in the soils, causing delays for the contractor	Area has been surveyed for UXOs, so it is very unlikely that any issues will occur.		Very Unlikely	Negligible	Low	Very Unlikely	Negligible	Low
ENV-2	Sea Turtle Site Take	If turtle take limit is reached, project could be stopped for the season.	Turtles are typically only encountered at Baldhead 3 and the Entrance reaches, so any delays would be negligible to the project as the channels could be dredged the following year when upstream channels are being dredged.		Unlikely	Marginal	Low	Unlikely	Negligible	Low
ENV-3	Bird Nesting	Birds nesting on the beaches may prevent sand from being placed for the season.	This is a common issue in the area, but one contractors are used to encountering and know how to work around birds with minimal issues		Likely	Negligible	Low	Likely	Marginal	Low

ENV-4	Right Whale Restrictions	There will likely be a take limit for Right Whales, that could shut the project down if reached.	Right Whales are not commen in the area and only a small part of the project is in an area the whales are likely to be in. It appears very unlikely that a right whale limit would be reached or exceeded.		Very Unlikely	Marginal	Low	Very Unlikely	Marginal	Low
ENV-5	Environmental Mitigation	Mitigation costs roughly estimated at this time. Costs could increase or decrease upon final design	The costs shown for mitigation are currently conservative and are unlikely to be less than the eventual costs.		Unlikely	Signficant	Marginal	Unlikely	Marginal	Low
ENV-6	Atlantic Sturgeon	Atlatnic Sturgeon are now listed as endangered and will have a take limit.	The cutterhead dredging the composes a majority of this project will not impact the sturgeon. Only the hopper dredging should pose a risk relating to Atlantic Sturgeon		Very Unlikely	Marginal	Low	Unlikely	Marginal	Low
ENV-7	Archeological	Archeological findings could prevent dredging from being permitted.	Archeological studies have already been completed. No issues are anticipated at this time.		Very Unlikely	Signficant	Low	Very Unlikely	Significant	Low
ENV-8	Salinity	Changes in salinity could impact both plants and animals in the project area.	Salinity levels have been modeled, with most changes around 1 ppm. Further impacts to be studied in detailed design.		Very Unlikely	Signficant	Low	Unlikely	Significant	Low
ENV-9	Dissolved Oxygen	Decreases in dissolved oxygen could kill off species within the river.	DO changes have also been modeled and are minimal. It is unlikely that the DO will change enough to impact marine life.		Very Unlikely	Signficant	Low	Very Unlikely	Significant	Low
ENV-10	Groundwater	Can deepening of the channel impact local groundwater?	Modeling of the impacts to the local groundwater have been analyzed and no impact area expected		Very Unlikely	Signficant	Low	Very Unlikely	Significant	Low
ENV-11										
	Estimate									
EST-1	Dredge, number & size	Large cutterhead dredges are assumed to be utilized on the project to cut through rock.	Smaller dredges may have issues cutting through rock if the large cutterhead dredges are unavailable.		Unlikely	Crisis	High	Unlikely	Significant	Moderate
EST-2	Wood Debris	Channel widenings may enter areas that have not been dredged previously that may have extensive wood debris that would need to be removed before it is hauled off for ocean disposal	This has not been accounted for in the estimate and would lead to additonal cost.		Likely	Significant	High	Likely	Marginal	Moderate
EST-3	Contaminated Material	If material is contaminedated, it could not go to the ocean disposal and would require upland disposal.	No material in the dredge area is anticipated to be contamined. Previous work completed in the area has not been contaminated.		Very Unlikely	Critical	Low	Very Unlikely	Significant	Low
EST-4	Mid-River Dredging Expense	Historically, mid-river dredging projects have been more expensive than expected.	The historical costs may have more to do with location of disposal sites relative to quantities. As this project is assumed to be using Ocean disposal, the disposal site is far away and the expected costs are higher than typical dreding projects already.		Likely	Marginal	Moderate	Likely	Negligible	Low

	Opportunity									
EST-5	Offshore Fisheries Structure	The use of the offshore fisheries structure as a disposal site for some of the harder material may be an option.	This site is closer than the ocean disposal site assumed to be utilized, saving the project money.		Unlikely					
EST-6	Beach Placement	Material from Horshoe Shoal Reach through Upper Midnight Reach may be of high enough sand quality to pump to a beach, saving cost	This is unlikely based on the available information on the sands in these reaches, but would save about $2 / CY		Unlikely					
	Construction									
CON-1	Contract Modifications	Contractors may claim existing conditions of material are different than expected.	This item is addressed in T-1, with rock hardness being the key risk.							
CON-2										

Risk

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Responsibility/POC	Project Cost			Project Schedule		
					Likelihood*	Impact*	Risk Level*	Likelihood*	Impact*	Risk Level*
EXT-1	Market Conditions	Market conditions and competing projects may impact bid competition.	The bidding climate is currently very tight, but may relax a bit once Charleston and Savannah deepening projects have been completed.		Likely	Critical	High	Likely	Significant	High
EXT-2	External Opposition	External opposition may cause scope or schedule change.	It is likely that the West Beach owners will utilize courts to block the project, as they are very sensitive towards any project near the beach.		Likely	Significant	High	Likely	Significant	High
EXT-3	Acts of God	Severe weather may impact cost or schedule.	Hurricanes do hit this area, but are infrequent and would not cause a significant impact.		Unlikely	Marginal	Low	Unlikely	Marginal	Low
EXT-4	Esc exceeds OMB rates	Over longer periods of time, the actual market may be greater than the OMB rates, impacting contract costs.	This can occur, but results in a marginal impact		Likely	Marginal	Low	Likely	Negligible	Low

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EXT-5	Climate Change	Climate change could increase sedimentation, increasing mainteance dredging costs	Any additionals due to climate change may be wholy or partially offset by the increase in water levels.		Unlikely	Marginal	Low	Unlikely	Marginal	Low
EXT-6	Fuel Price	Fuel Price has a large impact on dredging costs and could cause increases to the project cost	Fuel price has been pretty consistant for the past decade, but could always change due to global market impacts. Costs could also decrease with flobal		Unlikely	Signficant	Moderate	Unlikely	Marginal	Low

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Appendix D:
Cost Risk Analysis

Crystal Ball Report - Wilmington Harbor Navigation Improvement Project

Simulation started on 1/21/2020 at 1:48 PM
Simulation stopped on 1/21/2020 at 1:49 PM

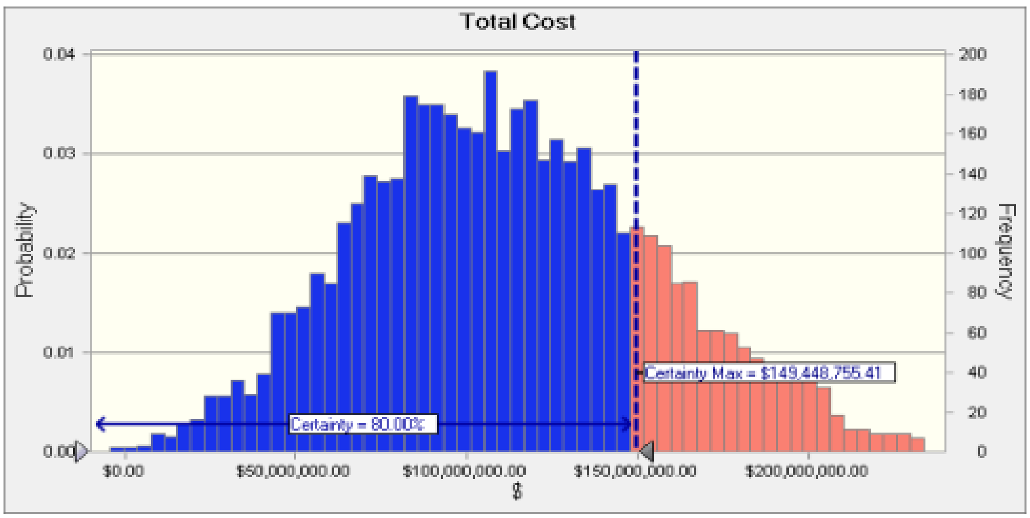
Run preferences:	
Number of trials run	5,000
Monte Carlo	
Random seed	
Precision control on	
Confidence level	95.00%
Run statistics:	
Total running time (sec)	7.19
Trials/second (average)	695
Random numbers per sec	19,466
Crystal Ball data:	
Assumptions	18
Correlations	0
Correlation matrices	0
Decision variables	0
Forecasts	1

Forecasts

Worksheet: [CSRA 20200120 Rev1.xlsx]Cost Risk Model

Forecast: Total Cost

Summary:
- Certainty level is 80.00%
- Certainty range is from -Infinity to $149,448,755.41
- Entire range is from $(4,062,793.69) to $260,699,149.71
- Base case is $0.00
- After 5,000 trials, the std. error of the mean is $613,041.82



Statistics:	Forecast values
Trials	5,000
Base Case	$0.00
Mean	$112,203,344.68
Median	$109,658,194.47
Standard Deviation	$43,348,603.03
Coeff. of Variation	0.3863
Minimum	$(4,062,793.69)
Maximum	$260,699,149.71
Range Width	$264,761,943.40
Mean Std. Error	$613,041.82

Forecast: Total Cost (cont'd)

Percentiles:	Forecast values
0%	$(4,062,794)
10%	$57,474,210
20%	$74,403,615
30%	$87,053,534
40%	$98,234,452
50%	$109,657,276
60%	$121,535,495
70%	$134,162,103
80%	$149,448,755
90%	$170,336,014
100%	$260,699,150

End of Forecasts

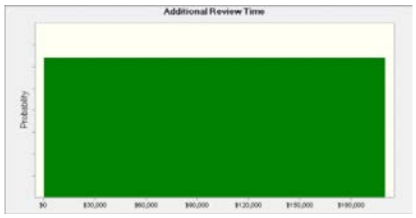
Assumptions

Worksheet: [CSRA 20200120 Rev1.xlsx]Cost Risk Model

Assumption: Additional Review Time

Uniform distribution with parameters:

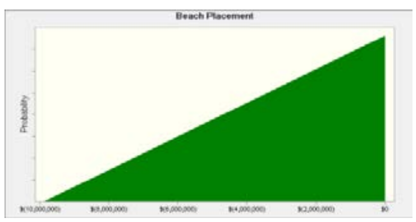
Minimum	$0
Maximum	$200,000



Assumption: Beach Placement

Triangular distribution with parameters:

Minimum	$(9,882,842)
Likeliest	$0
Maximum	$0

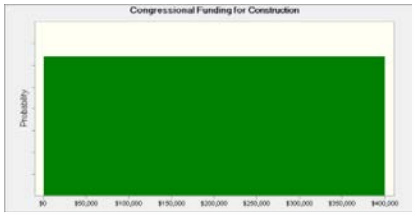


Assumption: Congressional Funding for Construction

Uniform distribution with parameters:

Minimum	$0
Maximum	$400,000

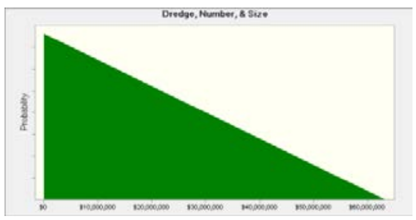
Assumption: Congressional Funding for Construction (cont'd)



Assumption: Dredge, Number, & Size

Triangular distribution with parameters:

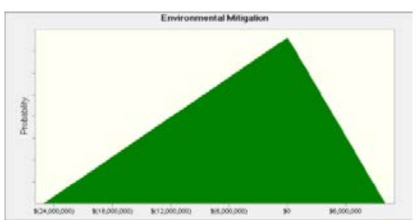
Minimum	$0
Likeliest	$0
Maximum	$63,237,682



Assumption: Environmental Mitigation

Triangular distribution with parameters:

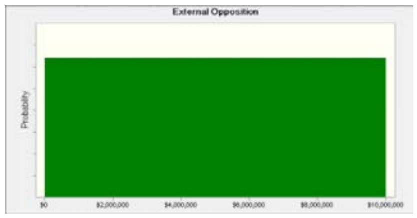
Minimum	$(25,000,000)
Likeliest	$0
Maximum	$10,000,000



Assumption: External Opposition

Uniform distribution with parameters:

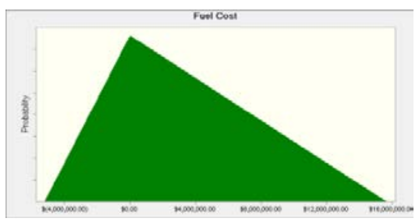
Minimum	$0
Maximum	$10,000,000



Assumption: Fuel Cost

Triangular distribution with parameters:

Minimum	$(5,208,392.22)
Likeliest	$0.00
Maximum	$15,625,176.67



Assumption: Market Conditions

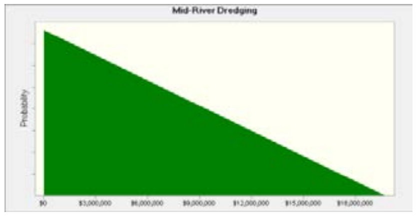
Uniform distribution with parameters:

Minimum	$0
Maximum	$54,933,244

Assumption: Mid-River Dredging

Triangular distribution with parameters:

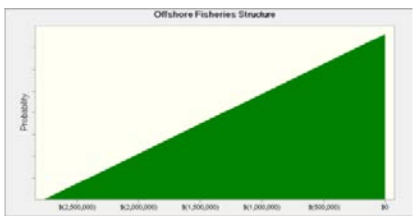
Minimum	$0
Likeliest	$0
Maximum	$19,719,757



Assumption: Offshore Fisheries Structure

Triangular distribution with parameters:

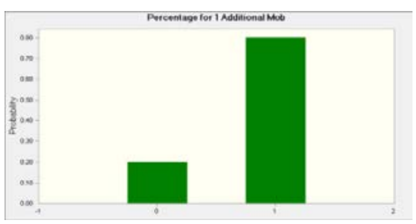
Minimum	$(2,770,303)
Likeliest	$0
Maximum	$0



Assumption: Percentage for 1 Additional Mob

Yes-No distribution with parameters:

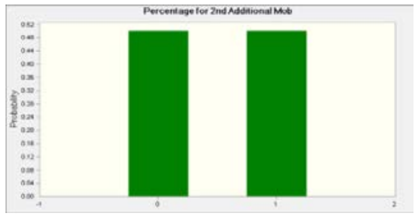
Probability of Yes(1)	0.8



Assumption: Percentage for 2nd Additional Mob

Yes-No distribution with parameters:

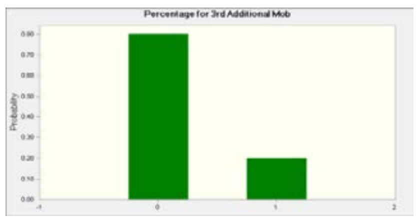
Probability of Yes(1)	0.5



Assumption: Percentage for 3rd Additional Mob

Yes-No distribution with parameters:

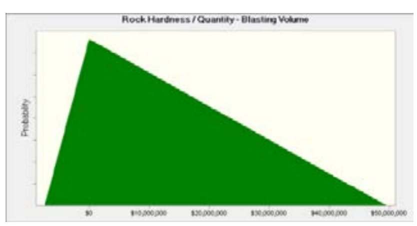
Probability of Yes(1)	0.2



Assumption: Rock Hardness / Quantity - Blasting Volume

Triangular distribution with parameters:

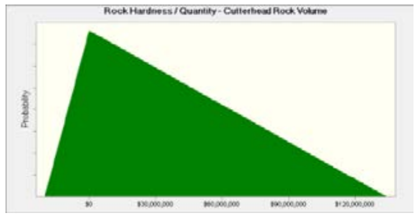
Minimum	$(7,418,002)
Likeliest	$0
Maximum	$49,453,346



Assumption: Rock Hardness / Quantity - Cutterhead Rock Volume

Triangular distribution with parameters:

Minimum	$(20,093,811)
Likeliest	$0
Maximum	$133,958,740



Assumption: Schedule Quality

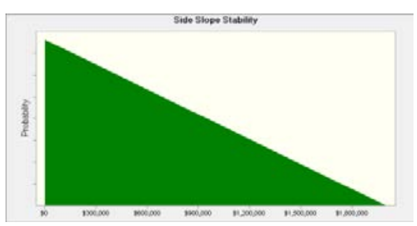
Uniform distribution with parameters:

Minimum	$0
Maximum	$500,000

Assumption: Side Slope Stability

Triangular distribution with parameters:

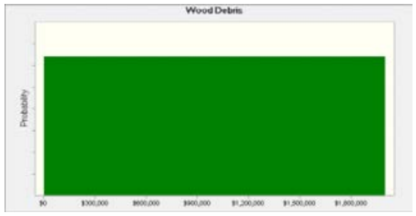
Minimum	$0
Likeliest	$0
Maximum	$2,000,000



Assumption: Wood Debris

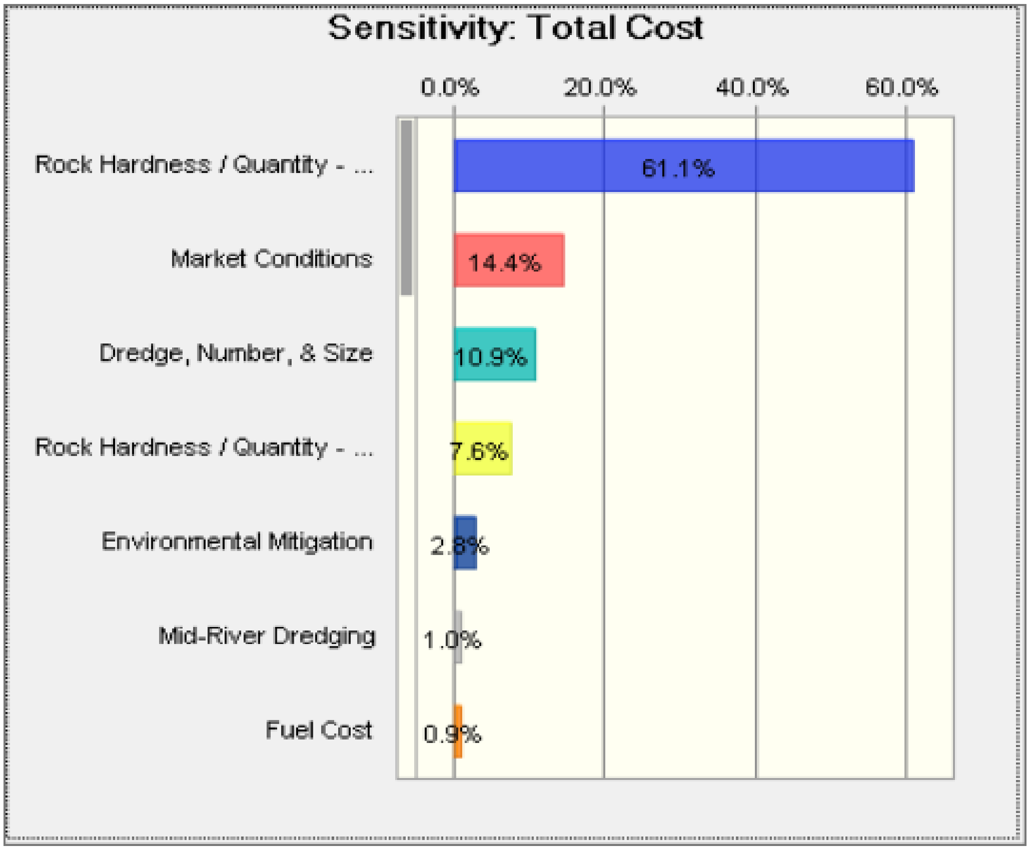
Uniform distribution with parameters:

Minimum	$0
Maximum	$2,000,000



End of Assumptions

Sensitivity Charts



End of Sensitivity Charts

Appendix E:
Schedule Risk Analysis

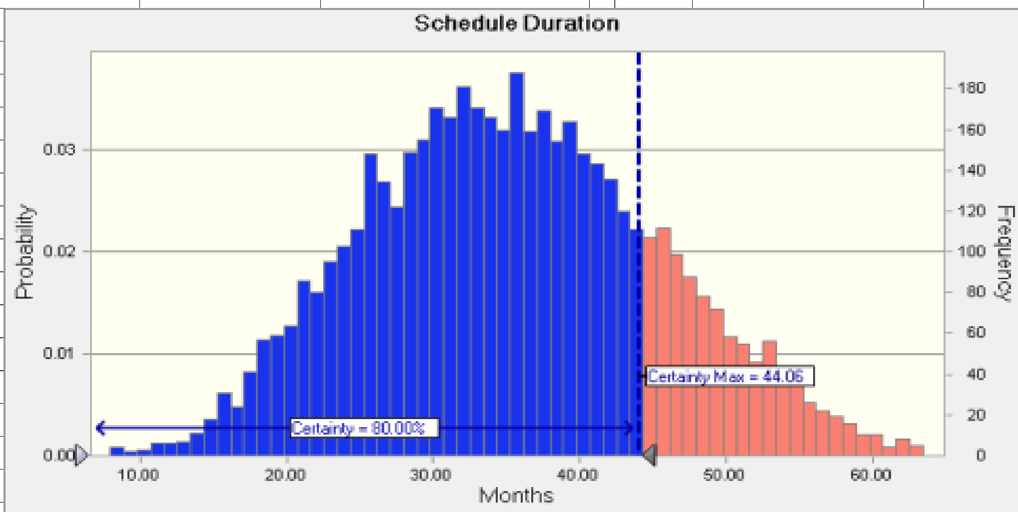
Crystal Ball Report - Wilmington Harbor Schedule Risk	
Simulation started on 5/15/2019 at 11:51 AM	
Simulation stopped on 5/15/2019 at 11:51 AM	
Run preferences:	
Number of trials run	5,000
Monte Carlo	
Random seed	
Precision control on	
Confidence level	95.00%
Run statistics:	
Total running time (sec)	7.23
Trials/second (average)	692
Random numbers per sec	18,683
Crystal Ball data:	
Assumptions	27
Correlations	0
Correlation matrices	0
Decision variables	0
Forecasts	2

Forecasts

Worksheet: [CSRA.xlsx]Schedule Risk Model

Forecast: Schedule Duration

Summary:
Certainty level is 80.00%
Certainty range is from -Infinity to 44.06
Entire range is from 8.00 to 69.91
Base case is 0.00
After 5,000 trials, the std. error of the mean is 0.14



Statistics:	Forecast values
Trials	5,000
Base Case	0.00
Mean	35.40
Median	35.08
Standard Deviation	10.00
Coeff. of Variation	0.2824
Minimum	8.00
Maximum	69.91
Range Width	61.90
Mean Std. Error	0.14

Forecast: Schedule Duration (cont'd)	
Percentiles:	Forecast values
0%	8.00
10%	22.55
20%	26.51
30%	29.69
40%	32.37
50%	35.08
60%	37.76
70%	40.61
80%	44.06
90%	48.75
100%	69.91

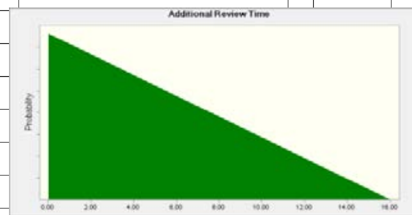
End of Forecasts

				Assumptions						
Worksheet: [CSRA.xlsx]Schedule Risk Model										

Assumption: Additional Review Time

Triangular distribution with parameters:

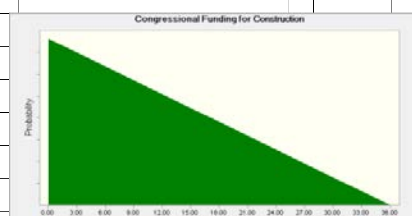
Minimum	0.00
Likeliest	0.00
Maximum	16.00



Assumption: Congressional Funding for Construction

Triangular distribution with parameters:

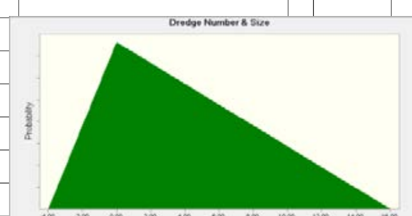
Minimum	0.00
Likeliest	0.00
Maximum	36.00



Assumption: Dredge Number & Size

Triangular distribution with parameters:

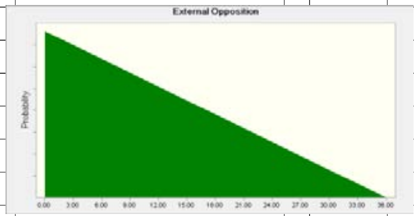
Minimum	-4.00
Likeliest	0.00
Maximum	16.00



Assumption: External Opposition

Triangular distribution with parameters:

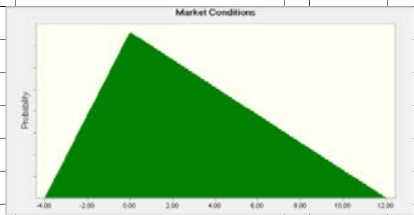
Minimum	0.00
Likeliest	0.00
Maximum	36.00



Assumption: Market Conditions

Triangular distribution with parameters:

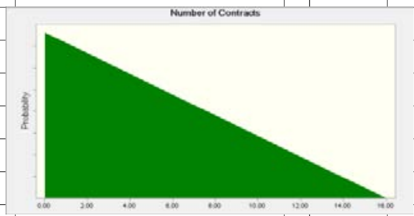
Minimum	-4.00
Likeliest	0.00
Maximum	12.00



Assumption: Number of Contracts

Triangular distribution with parameters:

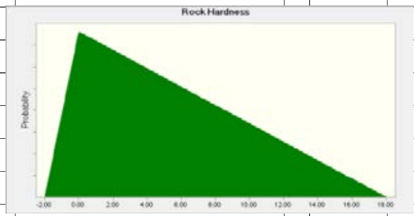
Minimum	0.00
Likeliest	0.00
Maximum	16.00



Assumption: Rock Hardness

Triangular distribution with parameters:

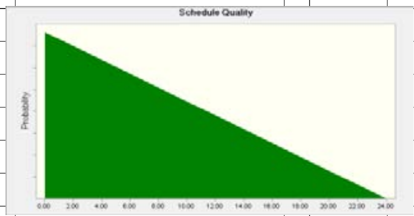
Minimum	-2.00
Likeliest	0.00
Maximum	18.00



Assumption: Schedule Quality

Triangular distribution with parameters:

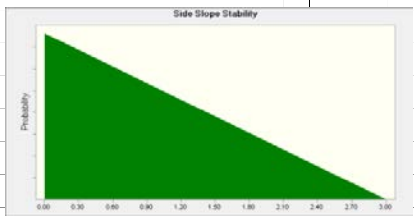
Minimum	0.00
Likeliest	0.00
Maximum	24.00



Assumption: Side Slope Stability

Triangular distribution with parameters:

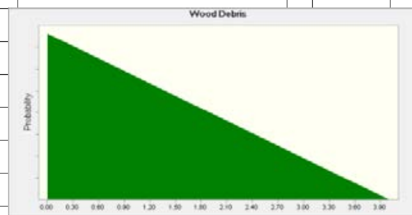
Minimum	0.00
Likeliest	0.00
Maximum	3.00



Assumption: Wood Debris

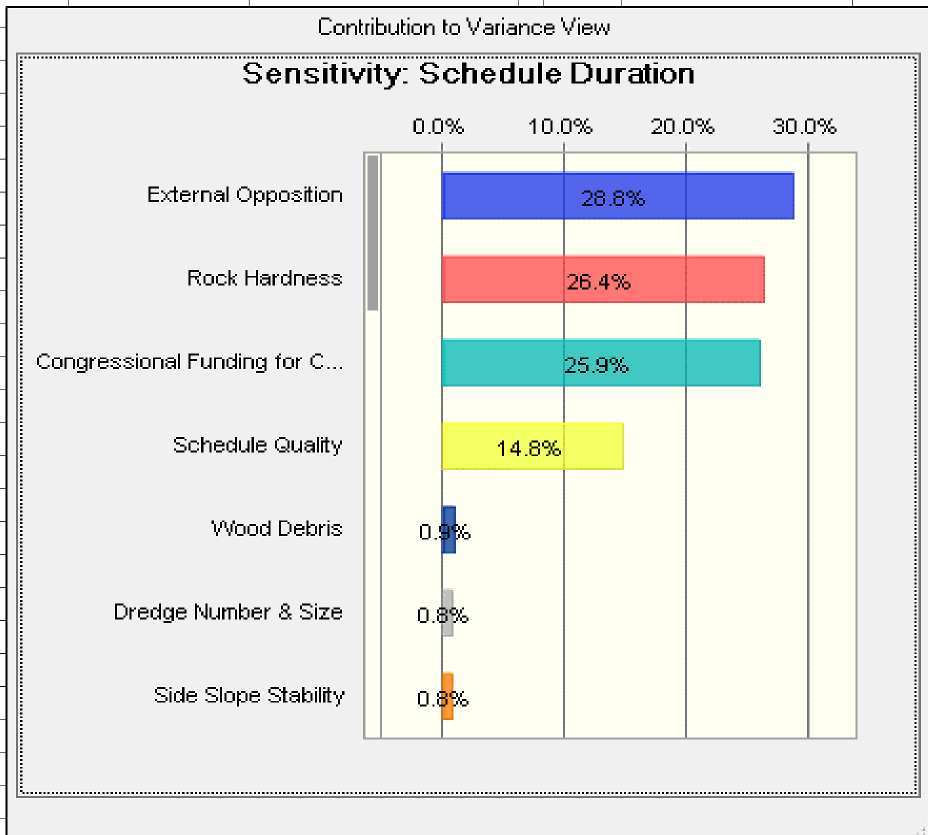
Triangular distribution with parameters:

Minimum	0.00
Likeliest	0.00
Maximum	4.00



End of Assumptions

Sensitivity Charts



End of Sensitivity Charts

Appendix F:
PED and Construction Management Estimate

	Cape Fear River
203 Study	
	$ 3,000,000
Geotechnical (includes EPA testing & cord in offshore channels)	
Entrance	$ 12,000,000
Engineering/Plans/Specs: **(1) Pre-dredge Survey and Processing and (2) Develop P&S**	
Engineering	$ 1,300,000
Planning	$ 500,000
Environmental	$ 200,000
Break Out Summary:	**$ -**
203 Study	$ 3,000,000
Geotech/Env Sampling	$ 12,000,000
Section 103 Analysis	$ 3,300,000
Vessel Simulation	$ 500,000
Engineering & Surveys	$ 2,000,000
Mitigation Modeling, Design & Permitting	$ 3,300,000
Sub-Total:	**$ 24,100,000**

Summary of Assumptions

203 Study	Based on maximum contribution for 203 Study of $3 million.
Geotech	Based on Fugro Estimate
Section 103 Analysis	Based on EA Estimate
Vessel Simulation	Based on estimate from MITAGS
Eng, Plans and Specs	Includes a condition survey for design and an estimated number of sheets at $10k per sheet (engineering estimate)
Mitigation Modeling, Design & Permitting	$300,000 for Dial-Cordy and $3 million for Design
Constr Mgmt	Function of estimated dredge/contract time for labor, and includes two surveys of the area (pre and post)

PCASE (Constr Mgmt): Progress Survey, Post Dredge Survey and PCASE labor		One Survey, field cost	Survey Processing/ Mapping Labor	Estimated Months	PCASE Labor, HRs	PCASE, Labor $
Entrance	$ 582,000	$ 30,000	$ 7,500.00	4.5	2,880	$ 432,000
Baldhead Reach 3	$ 582,000	$ 30,000	$ 7,500.00	4.5	2,880	$ 432,000
Baldhead Reach 2	$ 582,000	$ 30,000	$ 7,500.00	4.5	2,880	$ 432,000
Baldhead Reach 1	$ 270,000	$ 30,000	$ 7,500.00	1.25	800	$ 120,000
Smith Island Reach	$ 270,000	$ 30,000	$ 7,500.00	1.25	800	$ 120,000
Baldhead-Caswell Reach	$ 270,000	$ 30,000	$ 7,500.00	1.25	800	$ 120,000
Southport Reach	$ 270,000	$ 30,000	$ 7,500.00	1.25	800	$ 120,000
Battery Island Reach	$ 726,000	$ 30,000	$ 7,500.00	6	3,840	$ 576,000
Lower Swash Reach	$ 726,000	$ 30,000	$ 7,500.00	6	3,840	$ 576,000
Snows Marsh Reach	$ 726,000	$ 30,000	$ 7,500.00	6	3,840	$ 576,000
Horseshoe Shoal Reach	$ 294,000	$ 30,000	$ 7,500.00	1.5	960	$ 144,000
Reaves Point Reach	$ 342,000	$ 30,000	$ 7,500.00	2	1,280	$ 192,000
Lower Midnight Reach	$ 342,000	$ 30,000	$ 7,500.00	2	1,280	$ 192,000
Upper Midnight Reach	$ 342,000	$ 30,000	$ 7,500.00	2	1,280	$ 192,000
Lower Lilliput Reach	$ 438,000	$ 30,000	$ 7,500.00	3	1,920	$ 288,000
Upper Lilliput Reach	$ 438,000	$ 30,000	$ 7,500.00	3	1,920	$ 288,000
Keg Island Reach	$ 438,000	$ 30,000	$ 7,500.00	3	1,920	$ 288,000
Lower Big Island Reach	$ 534,000	$ 30,000	$ 7,500.00	4	2,560	$ 384,000
Upper Big Island Reach	$ 438,000	$ 30,000	$ 7,500.00	3	1,920	$ 288,000
Lower Brunswick Reach	$ 438,000	$ 30,000	$ 7,500.00	3	1,920	$ 288,000
Upper Brunswick Reach	$ 438,000	$ 30,000	$ 7,500.00	3	1,920	$ 288,000
Fourth East Jetty Reach	$ 438,000	$ 30,000	$ 7,500.00	3	1,920	$ 288,000
Between Reach	$ 438,000	$ 30,000	$ 7,500.00	3	1,920	$ 288,000
Anchorage Basin	$ 438,000	$ 30,000	$ 7,500.00	3	1,920	$ 288,000
		Assume 4 people 40hrs/wk				
		Assume $150/hr				
Total	$ 10,800,000					

Summary of Assumptions

Constr Mgmt	Function of estimated dredge/contract time for labor, and includes two surveys of the area (pre and post)