US Army Corps
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APPENDIX P:
Project Costs and Schedule Risk Analysis Report

LCA CONVEY ATCHAFALAYA RIVER WATER TO NORTHERN TERREBONNE MARSHES AND MULTIPURPOSE OPERATION OF THE HOUMA NAVIGATION LOCK

FEASIBILITY STUDY
FOR
ST. LOUIS DISTRICT, ST. LOUIS, MO

Prepared for:

St. Louis District, St. Louis, MO ___

Prepared by:

Paige Scott ____________________

Date: __03 May 2010__________

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APPENDIX

APPENDIX A Detailed Risk Register

EXECUTIVE SUMMARY

This report discusses the cost and schedule risk analysis (CSRA) process and results for the Convey Atchafalaya River Water to Northern Terrebonne Marshes (ARTM) Feasibility Study. The ARTM project is located in the vicinity of Houma. A CSRA was performed to study project elements that could have an impact on the project cost and schedule. The CSRA measures that impact with a contingency calculation outcome based on an eighty (80) percent confidence level for both cost and schedule that are measured in terms of dollars and months, respectively.

The ARTM Study Area is comprised of over 500 square miles of southern Louisiana in the vicinity of Houma. The western limit of the study area is the Atchafalaya River at Morgan City in St. Mary Parish. The eastern limit of the ARTM study area is bordered by Bayou LaFourche in LaFourche Parish. A large extent of the study area lies in Terrebonne Parish adjacent to and south of State Highways 182 and 24.

The ARTM project is one of the Louisiana Costal Authority (LCA) projects, and is authorized by Title VII of the WRDA of 2007. Currently, the ARTM project is at feasibility design development phase. The ARTM diversion project involves construction of 56 structures and other water management features. There are two water diversion type structures that are at critical points in the Terrebonne Marshes. The Central Diversion Structure (CS1) which involves constructing six 10' x 10' gated box culverts on Bayou Butler under Highway 57. The Eastern Culvert #5 (EC 5) is composed of a bridge with five 83 foot spans with two 68.5 foot spans accommodating Highway 24. Associated with this bridge are five 80 foot Obermeyer gated openings, for a total flow opening width of 400 feet. The project also includes dredging, bank protection, berms, soil plugs, and other culvert structures.

- A cost and schedule risk analysis is conducted by identifying and assessing risk items for use in the risk analysis. These quantitative impacts of these risk items are then analyzed using a combination of professional judgment, empirical data, and analytical techniques. The total project cost contingency is then analyzed using the Crystal Ball software. *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 PDT. A PDT meeting was held at the RAY Building in St. Louis, Missouri, for the purpose of identifying and assessing risk factors. The meeting included the Civil Engineer, Geotechnical Engineer, Cost Engineer, and Hydraulic Engineer/Technical Manager.

Some key project assumptions were made to complete the risk analysis. To complete the schedule analysis, it was assumed that the planning, engineering, and design phase of the project would last one year, allowing the first phase of construction to start in 2012. This assumption also affects the cost estimate escalation amount used. In the cost analysis & estimate, it was assumed that the project would be constructed under multiple contracts with a prime contractor and multiple subcontractors.

The cost and schedule risk analysis resulted in a recommended cost contingency of $51,103,261 and a schedule recommended contingency of 58 months. Those two results are combined to produce a total project contingency. The recommended total project contingency is 34%, or $68,353,130, based on the 80% confidence level. This contingency was applied to the detailed estimate for the Recommended Plan (RP) for the ARTM project.

1. PURPOSE

This report discusses the cost and schedule risk analysis (CSRA) process and results for the Convey Atchafalaya River Water to Northern Terrebonne Marshes (ARTM) Feasibility Study. The ARTM project is located in the vicinity of Houma. A CSRA was performed to study project elements that could have an impact on the project cost and schedule. The CSRA measures that impact with a contingency calculation outcome based on an eighty (80) percent confidence level for both cost and schedule that are measured in terms of dollars and months, respectively.

2. BACKGROUND

The ARTM Study Area is comprised of over 500 square miles of southern Louisiana in the vicinity of Houma. The study is western limit is the Atchafalaya River at Morgan City in St. Mary Parish, eastern limit of the ARTM study area is bordered by Bayou LaFourche in LaFourche Parish. A large extent of the study area lies in Terrebonne Parish adjacent to and south of State Highways 182 and 24.

The ARTM restoration project would increase existing Atchafalaya River influence to central (Lake Boudreaux) and eastern (Grand Bayou) Terrebonne marshes via the GIWW by introducing flow into the Grand Bayou Basin. This will be accomplished by enlarging the connecting channel (Bayou L'Eau Bleu) to capture as much of the surplus flow (max. 2000 to 4000 cfs) that would otherwise leave the Terrebonne Basin. Gated control structures would be installed to restrict channel cross-sections to prevent increased saltwater intrusion during the late summer and fall when Atchafalaya River influence is typically low. Some auxiliary freshwater distribution structures may be included. The ARTM project is one of the Louisiana Costal Authority (LCA) projects, and is authorized by Title VII of the WRDA of 2007. Currently, the ARTM project is at feasibility design development phase.

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 U.S. Army Corps of Engineers (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. The report presents the contingency results for both cost and schedule risks for all project features. The study and presentation can include or exclude consideration for operation and maintenance or life cycle costs, depending upon the program or decision document intended for funding.

3.1 Project Scope

Title VII of the WRDA of 2007 authorizes the LCA program. The authority includes requirements for comprehensive coastal restoration planning, program governance, project modification investigations, a Science and Technology (S&T) program, restoration project construction, a program for beneficial use of dredged material, feasibility studies for restoration plans, and other program elements. In total the LCA program has authority for 25 elements falling into various categories including investigations, research, demonstrations, and construction.

The ARTM diversion project involves construction of 56 structures and other water management features. There are two water diversion type structures that are at critical points in the Terrebonne Marshes. The Central Diversion Structure (CS1) which involves constructing six 10' x 10' gated box culverts on Bayou Butler under Highway 57. The Eastern Culvert #5 (EC5) is composed of a bridge with five 83 foot spans with two 68.5 foot spans accommodating Highway 24. Associated with this bridge are five 80 foot Obermeyer gated openings, for a total flow opening width of 400 feet. The project also includes dredging, bank protection, berms, soil plugs, and other culvert structures.

The report includes the project technical scope, estimates, and schedules as developed and presented by the St. Louis and New Orleans Districts. Consequently, these documents serve as the basis for the risk analysis. In general terms, the construction scope consists of the following:

- Major project features studied from the civil works work breakdown structure (CWWBS) include:
- 01 LANDS AND DAMAGES
- 02 RELOCATIONS
- 08 ROADS, RAILROADS, AND BRIDGES
- 09 CHANNELS AND CANALS
- 11 LEVEES AND FLOODWALLS
- 15 FLOODWAY CONTROLS AND DIVERSION STRUCTURES
- 16 BANK STABILIZATION
- 18 CULTURAL RESOURCE PRESERVATION
- 30 PLANNING, ENGINEERING & DESIGN
- 31 CONSTRUCTION MANAGEMENT
-
- The ARTM project is currently at a feasibility study design phase with a Recommended Plan (RP) after considering several alternatives.

3.2 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 reflected within the risk analysis report 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 iteratively 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 requirements and 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.
- Memorandum from Major General Don T. Riley (U.S. Army Director of Civil Works), dated July 3, 2007.
- Engineering and Construction Bulletin issued by James C. Dalton, P.E. (Chief, Engineering and Construction, Directorate of Civil Works), dated September 10, 2007.

4. METHODOLOGY/PROCESS

The ARTM Team consists of a Civil Engineer, Geotechnical Engineer, Hydraulic Engineer, Structural Engineer, Cost Engineer, Hydraulic Modeler, Planning and Policy member, Environmental members, Real Estate, HTRW members, project managers, and oversight team members. Team members who took part in the risk analysis process include the Project Manager, Real Estate, Environmental member, Cost Engineer, and Hydraulic Engineer/Technical Manager. The ARTM study started in January 2009 and will conclude in December of 2010.

The MCASES detailed cost estimate and the construction schedule have successfully passed an Agency Technical Review (ATR). As such, the risk analysis outcome is based upon an approved product and has passed an ATR.

The risk analysis process for this study is intended to determine the probability of various cost outcomes and quantify the required contingency needed in the cost estimate to achieve any desired level of cost confidence. A parallel process is also used to determine the probability of various project schedule duration outcomes and quantify the required schedule contingency (float) needed in the schedule to achieve any desired level of schedule confidence.

In simple terms, contingency is an amount added to an estimate (cost or schedule) to allow for items, conditions, or events for which the occurrence or impact is uncertain and that experience suggests will likely result in additional costs being incurred or additional time being required. The amount of contingency included in project control plans depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans. The risk of overrun is expressed, in a probabilistic context, using confidence levels.

The Cost Engineering DX guidance for cost and schedule risk analysis generally focuses on the 80-percent level of confidence (P80) for cost contingency calculation. It should be noted that use of P80 as a decision criteria is a risk adverse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level.

The risk analysis process uses *Monte Carlo* techniques to determine probabilities and contingency. The *Monte Carlo* techniques are facilitated computationally by a commercially available risk analysis software package (Crystal Ball) that is an add-in to Microsoft Excel. Cost estimates are packaged into an Excel format and used directly for cost risk analysis purposes. Because Crystal Ball is an Excel add-in, the schedules for each option are recreated in an Excel format from their native format. The level of detail recreated in the Excel-format schedule is sufficient for risk analysis purposes that reflect the established risk register, but generally less than that of the native format.

The primary steps, in functional terms, of the risk analysis process are described in the following subsections. The key assumptions in the ARTM risk analysis are provided in section 5. The risk analysis results are provided in section 6.

4.1 Identify and Assess Risk Factors

Identifying the risk factors via the PDT are considered a qualitative process that results in establishing a risk register that serves as the document for the further study using the Crystal Ball risk software. 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 PDT is obtained using creative processes such as brainstorming or other facilitated risk assessment meetings. In practice, a combination of professional judgment from the PDT and empirical data from similar projects is desirable and is considered.

A formal PDT meeting was held at the RAY Building in St. Louis, Missouri, for the purpose of identifying and assessing risk factors. The meeting on March 1, 2010 included the Project Manager, Real Estate, Environmental member, Cost Engineer, and Hydraulic Engineer/Technical Manager Geotechnical Engineer, Cost Engineer, and Hydraulic Engineer/Technical Manager.

The first half of the formal meeting focused on risk factor identification using brainstorming techniques and some facilitated discussions based on risk factors common to projects of similar scope and geographic location. The second half of the formal meeting focused on risk factor assessment and quantification.

Additionally, numerous calls and informal meetings were conducted throughout the risk analysis process on an as-needed basis to further facilitate risk factor identification, market analysis, and risk assessment.

4.2 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 involves multiple project team disciplines and functions. However, the quantification process relies more extensively on collaboration between cost engineering, designers, and risk analysis team members with lesser inputs from other functions and disciplines.

The following is an example of the PDT quantifying risk factor impacts by using an iterative, consensus-building approach to estimate the elements of each risk factor:

- 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.

In this example, the risk discussions focused on the various project features as presented within the USACE Civil Works Work Breakdown Structure for cost accounting purposes. It was recognized that the various features carry differing degrees of risk as related to cost, schedule, design complexity, and design progress. The example features under study are presented in Table 1:

Table 1. Work Breakdown Structure by Feature

01	LANDS AND DAMAGES
02	RELOCATIONS
08	ROADS, RAILROADS, AND BRIDGES
09	CHANNELS AND CANALS
11	LEVEES AND FLOODWALLS
15	FLOODWAY CONTROL & DIVERSION STRUCTURES
16	BANK STABILIZATION
18	CULTURAL RESOURCE PRESERVATION
30	PLANNING, ENGINEERING & DESIGN
31	CONSTRUCTION MANAGEMENT

The resulting product from the PDT discussions is captured within a risk register as presented in section 6 for both cost and schedule risk concerns. Note that the risk register records the PDT'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.

4.3 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 PDT. Contingencies are calculated by applying only the moderate and high level risks identified for each option (i.e., low-level risks are typically not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies as the project and risks evolve).

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the base cost estimate. 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.

For schedule contingency analysis, the option schedule contingency is calculated as the difference between the P80 option duration forecast and the base schedule duration.

These contingencies are then used to calculate the time value of money impact of project delays that are included in the presentation of total cost contingency in section 6. The resulting time value of money, or added risk escalation, is then added into the contingency amount to reflect the USACE standard for presenting the “total project cost” for the fully funded project amount.

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 contingency analysis.

5. KEY ASSUMPTIONS

To complete the schedule analysis, it was assumed that the planning, engineering, and design phase of the project would last one year, allowing the first phase of construction to start in 2012. This assumption also affects the cost estimate escalation amount used. In the cost analysis & estimate, it was assumed that the project would be constructed under multiple contracts with a prime contractor and multiple subcontractors.

The cost estimate and risk analysis have not undergone an ATR review to date. As such, the risk analysis is based on the current detailed cost estimate for the Recommended Plan.

The risk analysis studied the high and moderate impact levels for the activities listed on the risk register. The low impact level activities were not studied because of the minimal impact of the activities on the cost or schedule duration.

6. RISK ANALYSIS RESULTS

The following sections discuss the risk register, cost risk analysis results, schedule risk analysis results, and the combined cost and schedule risk analysis results.

6.1 Risk Register

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. A summary risk register that includes the risk events studied in the ARTM Risk analysis is shown in Table 2 below. The risk register reflects the results of risk factor identification and assessment, risk factor quantification, and contingency analysis. A more detailed risk register is provided in appendix A. The detailed risk register in appendix A include low level and unrated risks, as well as additional information regarding the specific nature and impacts of each risk.

Table 2. Studied Risk Register

				Project Cost		
Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Likelihood*	Impact*	Risk Level*
(Internal Risk Items are those						
PROGRAM MGMT						
PPM-1	Congressional Funding	The concern is that the PED and Construction funding is uncertain, post feasibility	The current selected plan exceeds the congressional funding authorization. Funding may be delayed as another authorization will need to occur.	Likely	Marginal	Moderate
PPM-4	Accelerated Feasibility Schedule	Feasibility study has been delivered on an accelerated project schedule	Due to the accelerated schedule, a project item may have been overlooked that could impact the project cost or schedule	Likely	Significant	High
PPM-5	Local Agency Issues	Concern if local sponsor (state) is able to produce their funding contribution	Six LCA projects will require their funding contributions from the state at roughly the same time	Unlikely	Critical	Moderate
PPM-6	Priority Issues	Congressional priorities may change	Completion of the LCA projects may drop down on Congress's priority list, which could delay funding to the project or require design changes.	Likely	Significant	High
ACQUISITION RISKS						
CA-2	Numerous Separate Contracts	The plan has 59 elements which could be divided into separate contracts	the cost estimate, several separate contracts could potentially increase mob & Demob costs and affect unit prices for the project.	Likely	Marginal	Moderate
TECHNICAL RISKS						
TL-1	Feasibility Level Design	Design assumptions were based on existing data	Little new data was used for design on the project. Exiting data in the project area was used for the design assumptions	Likely	Marginal	Moderate
TL-3	Geotech Borings	Borings were used in the geotech that were not at the exact feature location	While some borings were located at the feature locations, others were not which could result in differing site conditions affecting design & project scope.	Likely	Marginal	Moderate
TL-4	Structural Quantities	Changes in the Geotech analysis could affect the structure foundations	If site conditions differ greatly from the borings used, piling quantities used for foundation work could increase or decrease	Likely	Marginal	Moderate
DAMAGES RISKS						
LD-3	Utilities	The project may encounter unknown pipelines in the marsh.	The unknown pipelines will have cost impacts to the project depending on who is responsible for the cost to relocate the pipelines.	Likely	Marginal	Moderate
AND ENVIRONMENT						
RE-1	Environmental & Water Quality Issues	Water quality issues related to salinity and impacts on oysters/fisheries.	Concerns by local commercial fishing/oyster interests could delay implementation of the project.	Likely	Marginal	Moderate
RE-3	Cultural Sites, Endangered species, & wetlands	There is potential for discovery of culturally significant sites throughout project area.	Discovery of site(s) could impact schedule by delaying construction.	Likely	Marginal	Moderate
CONSTRUCTION RISKS						
CON-1	Contract Modifications	There may be modification issues that have not been captured in current risks	Modifications could be issued for remobilizations, delays, and quantity assumptions	Likely	Marginal	Moderate
SCHEDULE RISKS						
EST-1	Berm Productivity	The containment berm productivity could greatly affect the estimate	The productivity assumptions can vary due to various possibilities, affecting the schedule & estimate	Unlikely	Significant	High
EST-2	Culvert Construction Productivity	The culvert construction productivity could affect the estimate & schedule	The productivity assumptions can vary due to various possibilities, affecting the schedule & estimate	Unlikely	Marginal	Moderate
EST-3	Dredging Productivity	Dredge estimating program assumes a certain productivity based on dredge size. Productivity may vary.	The productivity assumptions can vary due to various possibilities, affecting the schedule & estimate	Unlikely	Significant	High
EST-4	Fuel	Fuel Fluctuations can impact marine and land based costs.	Fuel is a major cost driver on dredging projects and has fluctuated greatly in the past 2 years.	Likely	Significant	High
Risks (External Risk Items are						
PR-1	Acts of God	Severe weather may impact cost or schedule	Hurricanes or strong storms could impact construction or cause the need for rework. Milder weather conditions have been addressed with a productivity markup in the estimate.	Likely	Critical	High
PR-2	Market Conditions	Market conditions and competing projects may affect bid competition & equipment availability	Currently, 6 other LCA marsh restoration projects are planned and there are a limited number of dredges available for the marsh area.	Likely	Significant	High
PR-3	Community Objections	Public objections may delay project	The public perceives the project as having induced flooding, some features are in urban areas, and disruption of oyster harvesting could have political implications	Likely	Marginal	Moderate
PR-4	Stakeholders	Stakeholders have differing opinions of the project size.	Some stakeholders would prefer a larger project and some stakeholders would prefer a smaller project. Objections to the project size could cause a delay	Likely	Marginal	Moderate

It is important to note that a risk register can be an effective tool for managing identified risks throughout the project life cycle. As such, it is generally recommended that risk registers be updated as the designs, cost estimates, and schedule are further refined, especially on large projects with extended schedules. Recommended uses of the risk register going forward include:

- Documenting risk mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.
- Providing project sponsors, stakeholders, and leadership/management with a documented framework from which risk status can be reported in the context of project controls.
- Communicating risk management issues.
- Providing a mechanism for eliciting risk analysis feedback and project control input.
- Identifying risk transfer, elimination, or mitigation actions required for implementation of risk management plans.

In simple terms, a correlation is a dependency that exists between two risks and may be direct or indirect. An indirect correlation is one in which large values of one risk are associated with small values of the other. Indirect correlations have correlation coefficients between 0 and -1. A direct correlation is one in which large values of one risk are associated with large values of the other. Direct correlations have correlation coefficients between 0 and 1.

Correlations are important to understand the logic used in the risk analyses. The mathematical correlations used in the *Monte Carlo* simulations are as follows:

- Present any risk event correlations, addressing their relationships.
- Present the final risk register or the condensed version. At a minimum include those risk events studied (an appendix can include the complete risk register):
- Risk event identifying number.
- Risk or opportunity event.
- PDT concerns.
- PDT discussions.
- Project cost likelihood, impact, and risk level.
- Project schedule likelihood, impact, and risk level,

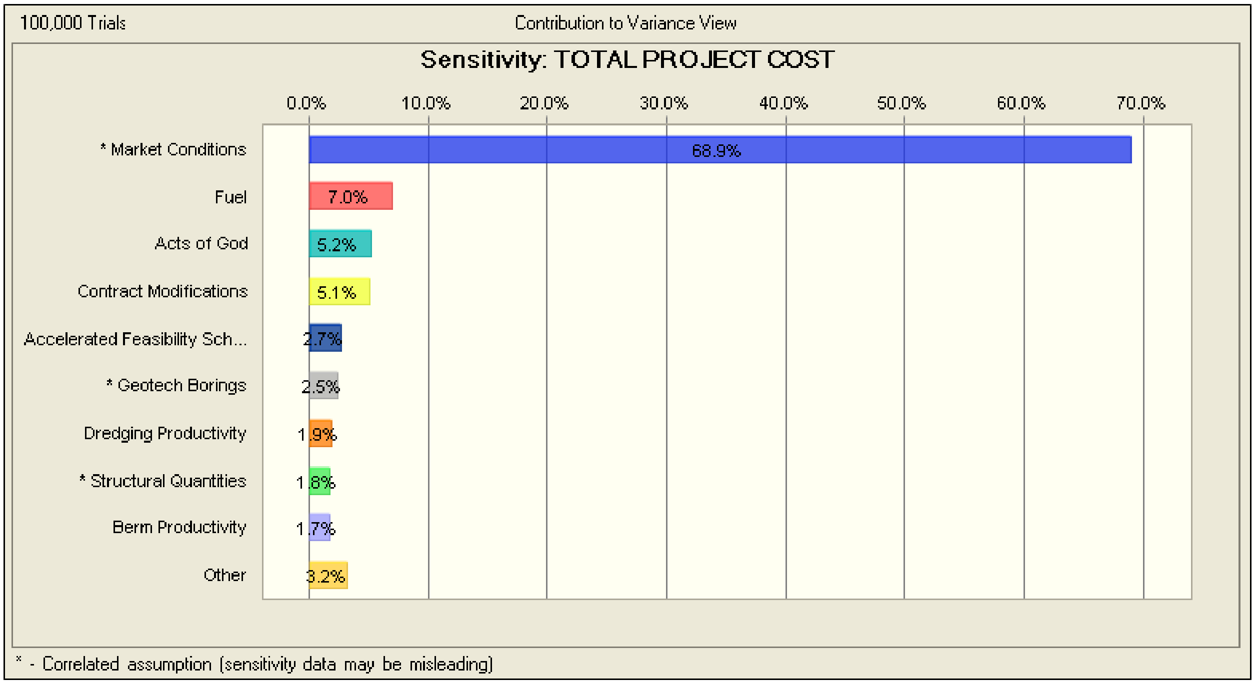
6.2 Cost Risk Analysis - Cost Contingency Results

A cost risk analysis was conducted on the twenty risks on the risk register, shown in Appendix A, which had a cost impact of moderate or high. The risk was analyzed using the low, most likely, and high estimates for each risk item and the items associated variance distribution. The analysis produced a sensitivity chart of the risk items and confidence levels from 0 to 100% and the associated contingency amount.

The cost sensitivity chart is shown in Figure 1 below. The sensitivity chart shows the influence of each risk items on the resulting cost contingency. The risk items are ranked according to their importance to the cost contingency. As shown in the Cost Sensitivity Chart, the Market Conditions item had the most influence on the cost contingency. The items that had the least amount of influence on the cost contingency are:

- Accelerated Feasibility Schedule
- Geotech Borings
- Dredging Productivity
- Structural Quantities
- Berm Productivity
- Other Risk Items

Figure 1. Cost Sensitivity Chart



The cost risk analysis also produced a confidence table in ten percent increments of project confidence associated with contingency dollars. The confidence table is shown in Table 3 below. As seen in the table, all but one of the associated contingency dollar amounts is positive. The contingency dollar amounts range from just over negative $25 million to well over $99 million. The recommended cost contingency amount is $51,103,260.

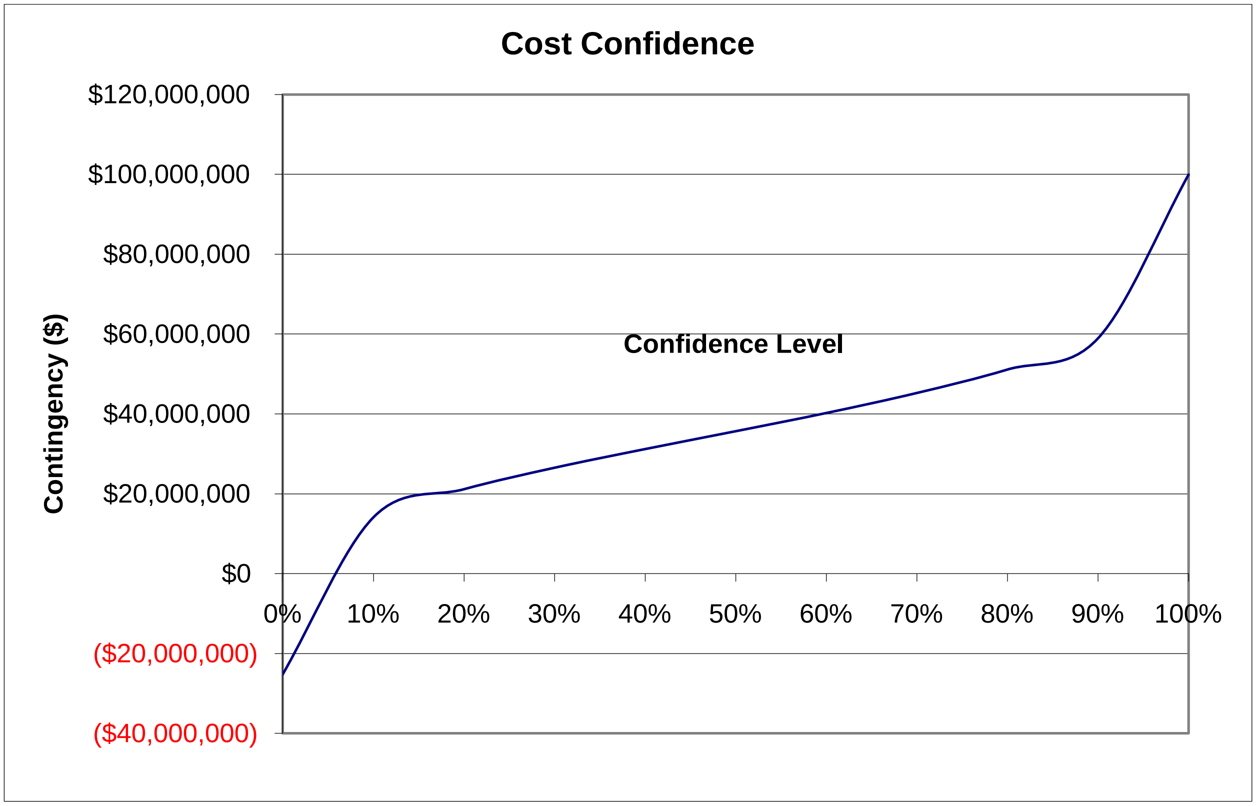
Table 3. Cost Confidence Table

Confidence Level	Contingency ($)
0%	($25,191,648)
10%	$14,077,767
20%	$21,146,527
30%	$26,524,147
40%	$31,197,091
50%	$35,666,274
60%	$40,224,992
70%	$45,238,159
80%	$51,103,261

90%	$58,917,830
100%	$99,904,260

From the table, a confidence curve was also established that shows the relationship of percent confidence with contingencies in dollars. That curve is shown in Figure 2. As seen in the curve, the contingency amount increased sharply between confidence levels 0% and 10% as well as levels 90% to 100%. All of the other confidence levels show a steady increase in the contingency amount.

Figure 2. Cost Confidence Curve



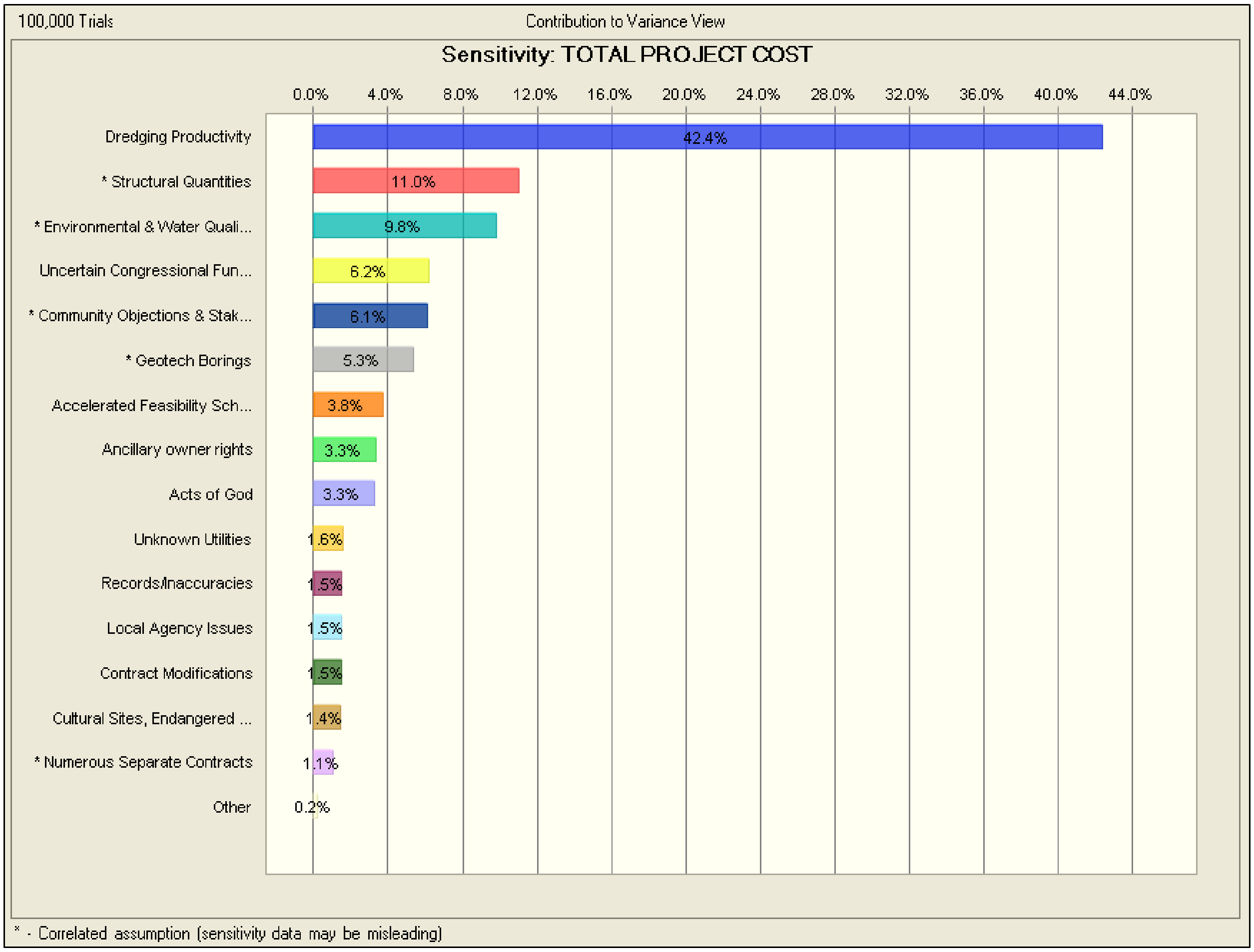
6.3 Schedule Risk Analysis - Schedule Contingency Results

A schedule risk analysis was conducted on the twenty-one risks on the risk register, shown in Appendix A, which had a schedule impact of moderate or high. The risk was analyzed using the low, most likely, and high estimates for each risk item and the items associated variance distribution. The analysis produced a sensitivity chart of the risk items and confidence levels from 0 to 100% and the associated contingency amount.

The schedule sensitivity chart is shown in Figure 3 below. The sensitivity chart shows the influence of each risk items on the resulting schedule contingency. The risk items are ranked according to their importance to the schedule contingency. As shown in the Schedule Sensitivity Chart, the Dredging Productivity item had the most influence on the schedule contingency. The items that had the least amount of influence on the schedule contingency are:

- Accelerated Feasibility Schedule
- Ancillary Owner Rights
- Acts of God
- Unknown Utilities
- Records/inaccuracies
- Local Agency Issues
- Contract Modifications
- Cultural Sites, Endangered Species, & Wetlands
- Numerous Separate Contracts
- Other items

Figure 3. Schedule Sensitivity Chart



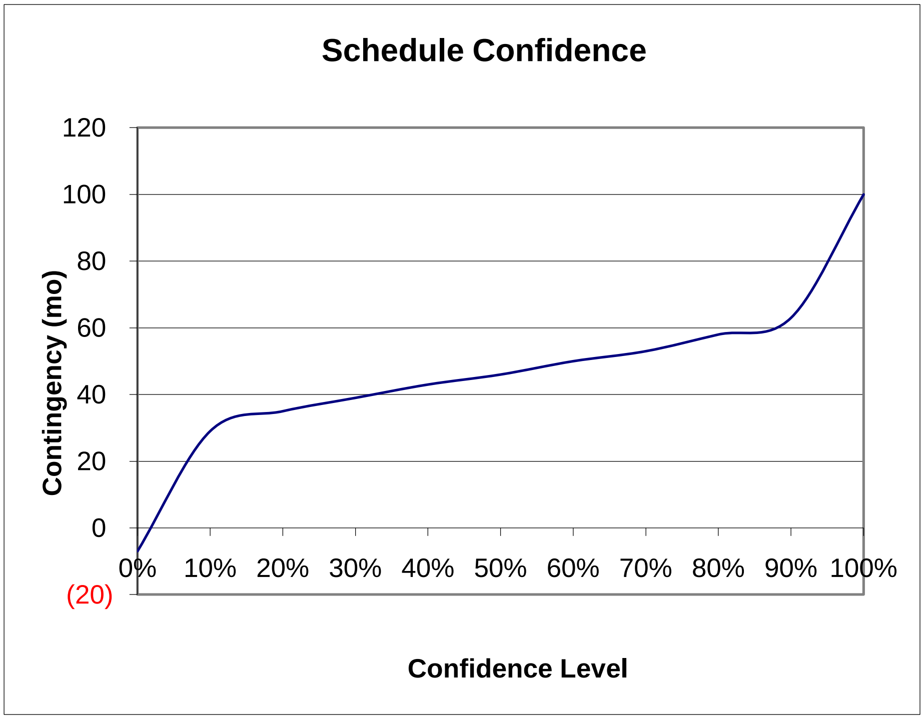
The schedule risk analysis also produced a confidence table in ten percent increments of project confidence associated with contingency months. The confidence table is shown in Table 4 below. As seen in the table, all but one of the associated contingency month amounts are positive. The contingency month amounts range from negative seven months to over eight years. The recommended schedule contingency amount is 58 months.

Table 4. Schedule Confidence Table

Confidence Level	Contingency (mo)
0%	(7)
10%	29
20%	35
30%	39
40%	43
50%	46
60%	50
70%	53
80%	58
90%	63
100%	100

From the table, a confidence curve was also established that shows the relationship of percent confidence with contingencies in months. That curve is shown in Figure 4. As seen in the curve, the contingency amount increased sharply between confidence levels 0% and 10% as well as levels 90% to 100%. All of the other confidence levels show a steady increase in the contingency amount.

Figure 4. Schedule Confidence Curve



6.4 Combined Cost and Schedule Contingency Results

The cost and schedule risk analysis resulted in a recommended cost contingency of $51,103,261 and a schedule recommended contingency of 58 months. To obtain the overall project contingency, the cost risk analysis confidence table and the schedule risk analysis confidence table are combined. That combined table is shown in Table 5. To obtain the final contingency dollar amount, the schedule contingency is converted from months into dollars by using the time value of money.

Table 5. Combined Confidence Table

Confidence Level	Contingency ($)	Contingency (mo)
0%	($25,191,648)	(7)
10%	$14,077,767	29
20%	$21,146,527	35
30%	$26,524,147	39
40%	$31,197,091	43
50%	$35,666,274	46
60%	$40,224,992	50
70%	$45,238,159	53
80%	$51,103,261	58
90%	$58,917,830	63
100%	$99,904,260	100

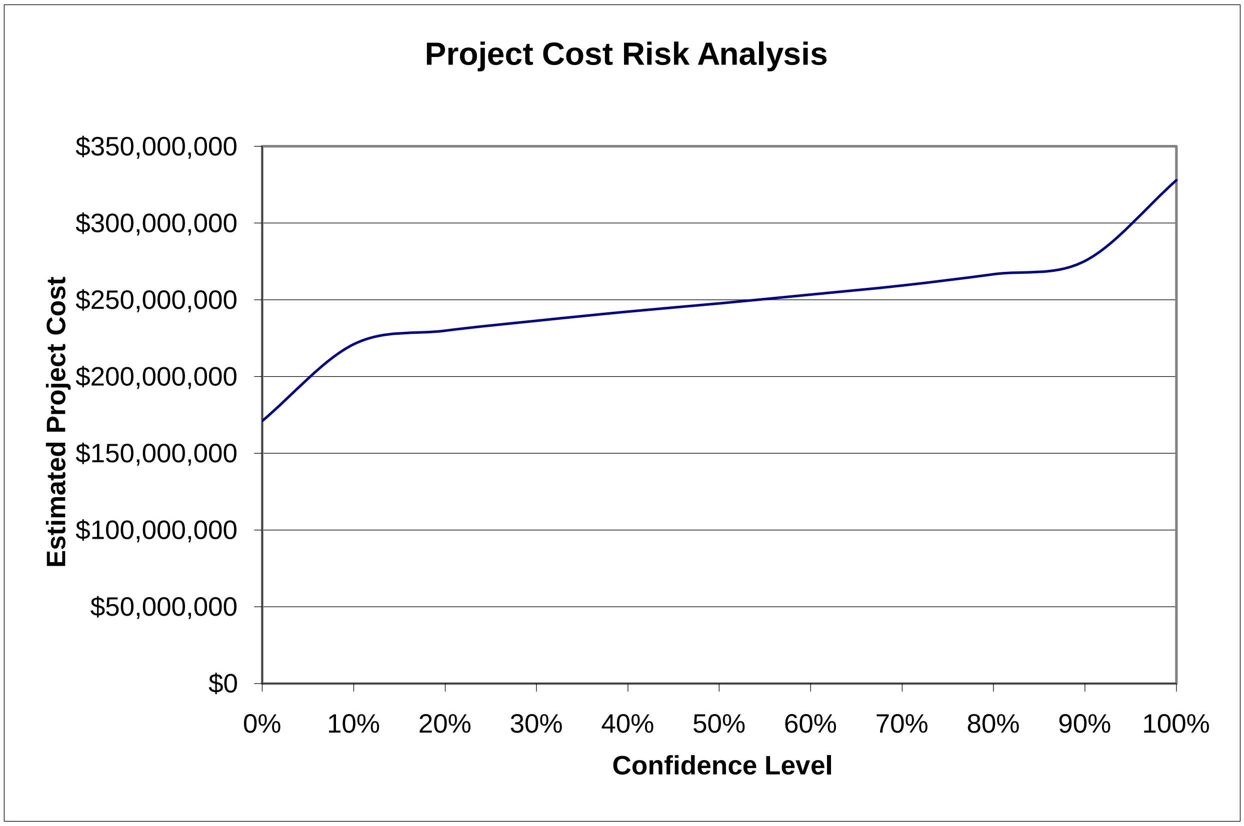
7. MAJOR FINDINGS/OBSERVATIONS

The cost and schedule risk analysis resulted in a recommended cost contingency of $51,103,261 and a schedule recommended contingency of 58 months. Those two results are combined to produce a total project contingency. The total project contingencies for confidence levels 0 to 100% are shown below. Table 6 presents project contingencies, which include base cost plus cost and schedule contingencies. Figure 5 illustrates the total project cost risk analysis in confidence curve. The recommended total project contingency is 34%, or $68,353,130, based on the 80% confidence level. This contingency was applied to the detailed estimate for the Recommended Plan for the ARTM project.

Table 6. Project Contingencies (Base Cost Plus Cost and Schedule Contingencies)

Confidence Level	Project Cost	Contingency ($)	Contingency (%)
0%	$171,000,832	($27,273,529)	-14%
10%	$220,977,063	$22,702,702	11%
20%	$229,830,292	$31,555,931	16%
30%	$236,297,559	$38,023,198	19%
40%	$242,260,148	$43,985,787	22%
50%	$247,621,533	$49,347,172	25%
60%	$253,369,930	$55,095,569	28%
70%	$259,275,332	$61,000,971	31%
80%	$266,627,491	$68,353,130	34%
90%	$275,292,118	$77,017,757	39%
100%	$327,920,775	$129,646,414	65%

Figure 5. Project Confidence Curve



The risk items that had the most influence on the resulting total project cost contingency were the Market Conditions and Dredging Productivity items. These items are discussed in more detail in the Mitigation Recommendations section.

The above risk analysis results are intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as projects progress through planning and implementation. These conclusions were reached by identifying and assessing risk items for use in the risk analysis. These quantitative impacts of these risk items are then analyzed using a combination of professional judgment, empirical data, and analytical techniques. The total project cost contingency is then analyzed using the Crystal Ball software. *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 PDT.

8. MITIGATION RECOMMENDATIONS

An important outcome of the cost and schedule risk analysis is the communication of high risk areas which have a high potential to affect the project cost and/or schedule. For the ARTM project, those risks are the Market Conditions for cost and Dredging Productivity for the schedule. These two risk items can be mitigated, reducing the risk of an increased project cost.

To mitigate the risk of the market conditions can be assessed during the planning, engineering, and design phase of the project to determine the best contract acquisition date in relation to similar scoped projects. This will enable the PDT to reduce the risks associated with the market conditions. To reduce the risk of dredging productivity, detailed productivity studies of similar sized dredges could be completed. After these studies are complete, the cost engineer will be able to more accurately calculate the dredging production rate.

APPENDIX A

DETAILED RISK REGISTERS

Register is split into two parts.

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/POC	Affected Project Component
				Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)				
	Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)														
	PROJECT & PROGRAM MGMT														
PPM-1	Congressional Funding	The concern is that the PED and Construction funding is uncertain, post feasibility	The current selected plan exceeds the congressional funding authorization. Funding may be delayed as another authorization will need to occur.	Likely	Marginal	Moderate		Likely	Marginal	Moderate				Project Manager	Project Cost & Schedule
PPM-2	Regionalized Team	The feasibility study was completed by a regionalized team.	Team members not from the New Orleans area were not familiar with marsh restoration projects before the start of the project. The PDT is concerned project aspects may have been left out.	Unlikely	Marginal	Low	<1%	Unlikely	Marginal	Low	<1%				
PPM-3	Coordination & Communication Difficulties	This project was one of the first large scale regionalized planning projects.	A learning curve was involved for all PDT members at the start of the project	Unlikely	Marginal	Low	<1%	Unlikely	Marginal	Low	<1%				
PPM-4	Accelerated Feasibility Schedule	Feasibility study has been delivered on an accelerated project schedule	Due to the accelerated schedule, a project item may have been overlooked that could impact the project cost or schedule	Likely	Significant	High		Likely	Significant	High					Project Cost & Schedule
PPM-5	Local Agency Issues	Concern if local sponsor (state) is able to produce their funding contribution	Six LCA projects will require their funding contributions from the state at roughly the same time	Unlikely	Critical	Moderate		Unlikely	Critical	Moderate				Project Sponsor(s)	Project Cost & Schedule
PPM-6	Priority Issues	Congressional priorities may change	Completion of the LCA projects may drop down on Congress's priority list, which could delay funding to the project or require design changes.	Likely	Significant	High		Likely	Significant	High					Project Cost & Schedule
	CONTRACT ACQUISITION RISKS														
CA-1	Undefined Acquisition Strategy	No acquisition strategy has been defined	Due to the large size of the project, the PDT feels the acquisition strategy will be unrestricted.	Unlikely	Marginal	Low	<1%	Unlikely	Marginal	Low	<1%			Contracting	
CA-2	Numerous Separate Contracts	The plan has 59 elements which could be divided into separate contracts	While some separate contracts have been considered in the cost estimate, several separate contracts could potentially increase mob & Demob costs and affect unit prices for the project.	Likely	Marginal	Moderate		Likely	Marginal	Moderate				Contracting	Project Cost & Schedule
	TECHNICAL RISKS														
TL-1	Feasibility Level Design	Design assumptions were based on existing data	Little new data was used for design on the project. Exiting data in the project area was used for the design assumptions	Likely	Marginal	Moderate		Likely	Marginal	Moderate				Technical Lead	Project Cost & Schedule
TL-2	Civil Quantities	Quantities for berm and culvert construction could vary	The PDT feels that the current quantities will vary very little during construction	Negligible	Marginal	Low	<1%	Negligible	Marginal	Low	<1%			Geotechnical/Civil Design	Project Cost & Schedule
TL-3	Geotech Borings	Borings were used in the geotech that were not at the exact feature location	While some borings were located at the feature locations, others were not which could result in differing site conditions affecting design & project scope.	Likely	Marginal	Moderate		Likely	Marginal	Moderate			TL-4	Geotechnical/Civil Design	Project Cost & Schedule
TL-4	Structural Quantities	Changes in the Geotech analysis could affect the structure foundations	If site conditions differ greatly from the borings used, piling quantities used for foundation work could increase or decrease	Likely	Marginal	Moderate		Likely	Marginal	Moderate			TL-3	Structural Design	Project Cost & Schedule
TL-5	Mechanical Gates	Some of the gates are very large in size as well as one gate is an Obermeyer Air Bladder Gate	Large gates are designed as sluice gates, but after talking with a manufacturer, roller gates were priced for practicality. The Air Bladder gate requires special labor to assembly which may not be available in the area	Unlikely	Marginal	Low	<1%	Unlikely	Marginal	Low	<1%			Mechanical Design	
TL-6	Dredging	Some pipe runs could be longer than estimated and quantities could vary.	The PDT feels that only a few pipelines may be longer than estimated and that the quantities may vary very little during construction	Unlikely	Marginal	Low	<1%	Unlikely	Marginal	Low	<1%			Geotechnical/Civil Design	

	LANDS AND DAMAGES RISKS														
LD-1	Ancillary owner rights	Several project features are proposed on property having multiple owners or having ownerships/interests listed as unknown.	Condemnation actions tend to be time-consuming	Very Likely	Negligible	Low	<1%	Very Likely	Significant	High	9			Real Estate	Project Schedule
LD-2	Records/Inaccuracies	Inaccuracies are anticipated in local land records at some project sites	Curative title actions tend to be time consuming	Very Likely	Negligible	Low	<1%	Very Likely	Marginal	Moderate	6			Real Estate	Project Schedule
LD-3	Utilities	The project may encounter unknown pipelines in the marsh.	The unknown pipelines will have cost impacts to the project depending on who is responsible for the cost to relocate the pipelines.	Likely	Marginal	Moderate		Likely	Marginal	Moderate				Real Estate	Project Cost & Schedule
	REGULATORY AND ENVIRONMENTAL RISKS														
RE-1	Environmental & Water Quality Issues	Water quality issues related to salinity and impacts on oysters/fisheries.	Concerns by local commercial fishing/oyster interests could delay implementation of the project.	Likely	Marginal	Moderate		Likely	Significant	High	12			Environmental Compliance	Project Cost & Schedule
RE-2	Adaptive Management Features	The project includes several features that may be adaptively managed.	Necessity of operating structures in unforeseen manner or with unforeseen frequency could increase costs for local sponsor. This cost risk does not apply to the government estimate and therefore, will not be studied in the cost or schedule model.	Likely	Significant	High		Likely	Negligible	Low	<1%			Environmental Compliance	Project Cost
RE-3	Cultural Sites, Endangered species, & wetlands	There is potential for discovery of culturally significant sites throughout project area.	Discovery of site(s) could impact schedule by delaying construction.	Likely	Marginal	Moderate		Likely	Significant	High	6			Environmental Compliance	Project Cost & Schedule
RE-4	Project in a State Park	Several features are located within boundary of or will impact Pointe au Chien Wildlife Management Area	Unforeseen impacts to WMA could delay project implementation.	Unlikely	Negligible	Low	<1%	Unlikely	Negligible	Low	<1%			Environmental Compliance	
RE-5	Negative Community Impacts	Several features will require road to be relocated during project construction	Unforeseen impacts to traffic could delay construction and/or increase costs.	Likely	Negligible	Low	<1%	Likely	Negligible	Low	<1%			Environmental Compliance	
	CONSTRUCTION RISKS														
CON-1	Contract Modifications	There may be modification issues that have not been captured in current risks	Modifications could be issued for remobilizations, delays, and quantity assumptions	Likely	Marginal	Moderate		Likely	Marginal	Moderate				Construction	Project Cost & Schedule
CON-2	Site Access & Staging Areas	The project site has limited access points and stagin areas.	The site access has been addressed in the cost estimate, but could affect the project schedule by increasing the time for transitioning equipment. Staging areas are also limited at the project site. Some staging may have to occur by barge, which has been addressed in the project estimate.	Likely	Negligible	Low	<1%	Likely	Significant	High				Construction	Project Schedule
CON-3	Limited Skilled Traes	Skilled labor for certain trades may not be available in the immediate project area	The PDT feels that contractors will bring in the skilled labor they need to complete the work, limiting the risk impacts	Likely	Negligible	Low	<1%	Likely	Negligible	Low	<1%			Construction	
	ESTIMATE AND SCHEDULE RISKS														
EST-1	Berm Productivity	The containment berm productivity could greatly affect the estimate	The productivity assumptions can vary due to various possibilities, affecting the schedule & estimate	Unlikely	Significant	High		Unlikely	Significant	High				Cost Engineering	Project Cost & Schedule
EST-2	Culvert Construction Productivity	The culvert construction productivity could affect the estimate & schedule	The productivity assumptions can vary due to various possibilities, affecting the schedule & estimate	Unlikely	Marginal	Moderate		Unlikely	Marginal	Moderate				Cost Engineering	Project Cost & Schedule
EST-3	Dredging Productivity	Dredge estimating program assumes a certain productivity based on dredge size. Productivity may vary.	The productivity assumptions can vary due to various possibilities, affecting the schedule & estimate	Unlikely	Significant	High		Unlikely	Significant	High				Cost Engineering	Project Cost & Schedule
EST-4	Fuel	Fuel Fluctuations can impact marine and land based costs.	Fuel is a major cost driver on dredging projects and has fluctuated greatly in the past 2 years.	Likely	Significant	High		Likely	Negligible	Low				Cost Engineering	Project Cost & Schedule
Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)															
PR-1	Acts of God	Severe weather may impact cost or schedule	Hurricanes or strong storms could impact construction or cause the need for rework. Milder weather conditions have been addressed with a productivity markup in the estimate.	Likely	Critical	High		Likely	Critical	High					Project Cost & Schedule
PR-2	Market Conditions	Market conditions and competing projects may affect bid competition & equipment availability	Currently, 6 other LCA marsh restoration projects are planned and there are a limited number of dredges available for the marsh area.	Likely	Significant	High		Likely	Significant	High					Project Cost & Schedule
PR-3	Community Objections	Public objections may delay project	The public perceives the project as having induced flooding, some features are in urban areas, and disruption of oyster harvesting could have political implications	Likely	Marginal	Moderate		Likely	Significant	High					Project Cost & Schedule
PR-4	Stakeholders	Stakeholders have differing opinions of the project size.	Some stakeholders would prefer a larger project and some stakeholders would prefer a smaller project. Objections to the project size could cause a delay	Likely	Marginal	Moderate		Likely	Significant	High					Project Cost & Schedule