US Army Corps
of Engineers®

Miami-Dade County, Florida, C-111 South Dade

114796 – Post Authorization Change Report (PACR)

Project Cost and Schedule Risk Analysis Report

Prepared by:

U.S. Army Corps of Engineers
Jacksonville District

January 2020

Table of Contents

Executive Summary 1
Main Report 1
1.0 Purpose 1
2.0 Background 1
3.0 Report Scope 4
3.1 Project Scope 4
3.2 USACE Risk Analysis Process 4
4.0 Cost and Schedule Risk Analysis (CSRA) Methodology 5
4.1 Identify and Assess Risk Factors 5
4.2 Risk Factors Analyzed 6
4.2.1 Costs Risks 6
4.2.2 Schedule Risks 7
5.0 Key Assumptions and Limitations 8
6.0 Results 9
6.1 Risk Register 9
6.2 Contingency 12
6.3 Sensitivity 13
7.0 Appendices 15
Appendix A – Cost Certification 15
Appendix B – Risk Register 16

List of Tables

Table 1: Project Cost and Schedule Contingency Development Summary…..…….……..ES-1
Table 2: Alternative Cost Comparison (Rough Order of Magnitude Estimates)……...3
Table 3: Cost Risk Model……..10
Table 4: Schedule Risk Model…….…….....11
Table 5: Contingency Analysis…….12

List of Figures

Figure 1: Sensitivity Analysis – Cost Contingency……..…..……..……14
Figure 2: Sensitivity Analysis – Schedule Contingency…….……...15

Executive Summary

The US Army Corps of Engineers (USACE), Jacksonville District, presents this cost and schedule risk analysis (CSRA) report regarding the risk findings and recommended contingencies for the Miami-Dade County, Florida, C-111 South Dade Post Authorization Change Report (PACR). In compliance with Engineer Regulation (ER) 1110-2-1302 Civil Works Cost Engineering, dated June 30, 2016, a formal risk analysis, Monte-Carlo based-study was conducted by the Project Development Team (PDT) on remaining costs. The CSRA was developed with tools provided by the Cost Engineering Mandatory Center of Expertise (MCX) for Civil Works. The purpose of this risk analysis study is to present the cost and schedule risks considered, those determined and respective project contingencies at a recommended 80% confidence level of successful execution to project completion. The Jacksonville District Cost Engineering Section performed the risk analysis for this project and it has been internally reviewed, as required, via the ATR process.

The project purpose as stated in the 1994 Final Integrated General Reevaluation Report (GRR) and Environmental Impact Statement (EIS) is to maintain existing flood protection and other Central & Southern Florida project purposes in developed areas east of C-111 while restoring natural hydrologic conditions in the Taylor Slough and eastern panhandle areas of Everglades National Park. Additionally, the future work includes the design, construction and replacement of pump stations S-332B and S-332C. This report presents a recommendation for the total project cost contingency for cost certification for the Miami-Dade County, Florida, C-111 South Dade PACR. The CSRA was developed to model the PACR features of work concerning scope growth, potential for mods and claims, and other concerns as seen in the risk register. The table below contains the costs, schedule and applicable contingency for the project.

Table 1: Project Cost and Schedule Contingency Development Summary

Contingency on Base Estimate	80% Confidence Project Cost
Baseline Estimate Cost (Most Likely) ->	**$80,727,543**
Baseline Estimate Cost Contingency Amount ->	$25,897,933
Baseline Estimate Construction Cost (80% Confidence) ->	**$106,625,476**
Contingency on Schedule	**80% Confidence Project Schedule**
Project Schedule Duration (Most Likely) ->	**57.0 Months**
Schedule Contingency Duration ->	22.1 Months
Project Schedule Duration (80% Confidence) ->	**79.1 Months**
Project Schedule Contingency Amount (80% Confidence) ->	**$1,919,240**
Project Contingency	**80% Confidence Project Cost**
Project Contingency Amount (80% Confidence) ->	**$27,817,173**
Project Contingency Percentage (80% Confidence) ->	**34%**
Project Cost (80% Confidence) ->	**$108,544,716**

Main Report

1.0 Purpose

This report presents a recommendation for the total project cost contingencies for the cost certification of C-111 South Dade PACR. 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.

2.0 Background

This estimate is primarily based upon the PDT discussions that occurred in August 2019, the 1994 Final Integrated General Reevaluation Report (GRR) and the Environmental Impact Statement (EIS). The project is located in Miami-Dade County, Florida. Refer to the main report for more information.

During the feasibility study the PDT evaluated five alternatives for the C-111 South Dade PACR. After several discussions the selected alternative was Alternative 3, which is a construction of a short channel with parallel weir and levee degrade. Refer to the Engineer Appendix for more information about the other screened out alternatives. The table contains the initial cost estimates for five alternatives.

Alternatives overview:

1. Alternative 1 (No Action) – The objective of this alternative is to do nothing and leave the pump stations S-332B and S-332C in place.

2. Extended (Additional) Channel Alternative – The objective of this alternative is to replace the pump stations S-332B and S-332C. The efforts for S-332B will include demolition (existing pump station, discharge pipes, outlet, etc.), a new pump station, a new channel, a new additional (extended) channel, a new lateral culvert, and a new outfall weir. The efforts for S-332C include demolition (existing pump station, discharge pipes, outlet, etc.), a new pump station, a new channel, a new additional (extended) channel and a new outfall weir.

3. Alternative 2 (Extended (Additional) Channel and Levee Degrade – The objective of this alternative is to replace the pump stations S-332B and S-332C. The efforts for S-332B will include demolition (existing pump station, discharge pipes, outlet, etc.), a new pump station, a new channel, a new additional (extended) channel, a new lateral culvert, a new outfall weir, a new levee and to degrade a levee. The efforts for S-332C include demolition (existing pump station, discharge pipes, outlet, etc.), a new pump station, a new channel, a new additional (extended) channel and a new outfall weir.

4. Short Channel Alternative – The objective of this alternative is to replace the pump stations S-332B and S-332C. The efforts for S-332B will include demolition (existing pump station, discharge pipes, outlet, etc.), a new pump station, a new channel, a

new lateral culvert, and a new outfall parallel weir. The efforts for S-332C include demolition (existing pump station, discharge pipes, outlet, etc.), a new pump station, a new channel and a new outfall parallel weir.

5. Alternative 3 (Short Channel and Levee Degrade) – The objective of this alternative is to replace the pump stations S-332B and S-332C. The efforts for S-332B will include demolition (existing pump station, discharge pipes, outlet, etc.), a new pump station, a new channel, a new lateral culvert, a new outfall parallel weir, a new levee and to degrade a levee. The efforts for S-332C include demolition (existing pump station, discharge pipes, outlet, etc.), a new pump station, a new channel and a new outfall parallel weir.

Table 2: Alternative Cost Comparison (Rough Order of Magnitude Estimates)

	Alternatives	1 (No Action)	Extended (Additional) Channel	#2 Extended (Additional) Channel + Levee Degrade (Alt 2 in report)	Short Channel	#3 Short Channel + Levee Degrade (Alt 3 in report)
S-332B	Demolition (existing pump station, discharge pipes, outlet, etc.)	zero	$1,674,000	$1,674,000	$1,674,000	$1,674,000
	New Pump Station		$40,500,000	$40,500,000	$40,500,000	$40,500,000
	New Channel		$3,169,000	$3,169,000	$3,169,000	$3,169,000
	New Additional (Extended) Channel		$2,542,000	$2,542,000	0	0
	New Lateral Culvert		$1,126,000	$280,000	$1,126,000	$280,000
	New Outfall Weir		$694,000	$694,000	0	0
	New Outfall Parallel Weir		0	0	$696,000	$696,000
	New Levee		0	$341,000	0	$341,000
	Degrade Levee		0	$157,000	0	$157,000
S-332C	Demolition (existing pump station, discharge pipes, outlet, etc.)		$1,578,000	$1,578,000	$1,578,000	$1,578,000
	New Pump Station		$40,500,000	$40,500,000	$40,500,000	$40,500,000
	New Channel		$3,012,000	$3,012,000	$3,012,000	$3,012,000
	New Additional (Extended) Channel		$2,353,000	$2,353,000	0	0
	New Outfall Weir		$694,000	$694,000	0	0
	New Outfall Parallel Weir		0	0	$696,000	$696,000
	TOTALS	**0**	**$97,842,000**	**$97,494,000**	**$92,951,000**	**$92,603,000**

*As a note the estimates contain a 25% contingency prior to the selection of alternative 3 and the completion of the CSRA.

3.0 Report Scope

The scope of this report is to facilitate a technical overview of the tentative selected plan (TSP). As a result, part of this report includes the risk analysis report (CSRA) used to calculate and present the cost contingency at the 80% confidence level. The 80% confidence level is derived from the risk analysis process 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.

3.1 Project Scope

The recommended plan (alternative 3) is to replace the pump stations S-332B and S-332C. A construction footprint of approximately 38 acres that includes the following features: a new concrete lined discharge channel that will replace the existing corrugated metal pipes to connect the S-332B and S-332C pump station releases to the South Detention Area (SDA) by a parallel weir; construction of a new culvert to maintain the connection from S-332B that allows flows from the SDA to the North Detention Area (NDA); removal of the existing underground corrugated metal pipes at S-332B and S-332C and a removal to grade for the existing overburden material; and the construction of a new levee to expand the wetland footprint of the NDA southward by approximately 7.1 acres following removal of the existing S-332B discharge pipes. The replacement pumps will be located approximately 300 feet south and 300 feet west of the current interim pump station locations.

The C-111 South Dade Project reduces flooding in South Dade County, prevents over drainage, prevents saltwater intrusion, and conveys water to Everglades National Park (ENP) when runoff is available. A hydraulic ridge is formed by combination of the Modified Water Deliveries (MWD) to Everglades National Park project, the North Detention Area (NDA), South Detention Area (SDA) and the S-332D Detention Area that extends from the MWD 8.5 Square Mile Area (SMA) to Taylor Slough, reducing groundwater seepage losses from ENP, while maintaining the current level of flood damage reduction for the C-111 Basin. The existing C-111 South Dade features will be operated as established by the Combined Operational Plan (COP). The COP is a parallel effort that provides guidance on how to operate the project while achieving the C-111 South Dade benefits determined in the 1994 GRR. The Selected Plan provides for continuation of the operations at the C-111 South Dade S-332B and S-332C pump stations through replacement of the existing interim pump stations. By continuing the pump station function to rehydrate ENP and reduce groundwater seepage losses from ENP, the Selected Plan will continue to provide appropriate hydrology for the Cape Sable Seaside Sparrow in accordance with the Biological Opinion. During construction of the new proposed permanent pump stations, the interim pump stations will continue to be operated.

3.2 USACE Risk Analysis Process

The risk analysis process for this study generally follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering Center of Expertise (MCX). The risk analysis process reflected within this report uses probabilistic cost and schedule risk analysis methods within the framework of the Oracle Crystal Ball software application. The risk analysis results are intended to serve several functions, one being the establishment of reasonable contingencies reflective of various levels of

confidence 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 support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule risk analysis 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.

4.0 Cost and Schedule Risk Analysis (CSRA) Methodology

The risk analysis process for this estimate is intended to determine the probability of various cost outcomes and to quantify the required contingency needed in the cost estimate to achieve the desired level of cost confidence. In simple terms, contingency is an amount added to an estimate 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. Contingency for the cost estimate has been developed using materials provided by the USACE Cost Center of Expertise located in Walla Walla District. The primary steps, in functional terms, of the risk analysis process are described in the following subsections.

4.1 Identify and Assess Risk Factors

Identifying risk factors is considered a qualitative process that results in establishing a risk register that serves as the basis for the resulting contingency percentage. 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. A risk brainstorming session was conducted September 12, 2019, to discuss all possible risks and impacts. The Project Delivery Team (PDT) attendees are listed on the 'Meeting Attendance' tab of the CSRA spreadsheet.

Contingency is analyzed using formulas within the spreadsheet. The complex analysis of the Crystal Ball software's Monte Carlo simulations were used in the CSRA. The project contingency is calculated according to the likelihood and impact of each factor identified in the risk register.

The CSRA was developed with input of the PDT and with the sponsor (South Florida Water Management District – SFWMD). Within the risk register there are 3 levels of risk. The levels are low, moderate and high. During the risk brainstorming session, all 3 levels were evident in this project. The risk level is determined for both the project cost and project schedule. Risk level identification is determined through the impact or consequence of occurrence and the likelihood of occurrence. The impact or consequence of occurrence classifications are the following: negligible, marginal, significant, critical and

crisis. The likelihood of occurrence classifications are the following: very unlikely, unlikely, likely, very likely and certain.

4.2 Risk Factors Analyzed

The quantitative impacts of risk factors on project plans were analyzed using a combination of professional judgment, empirical data and analytical techniques. Impact rating scales were established by the PDT during the risk register development sessions for both cost and schedule impacts. These scales were used to guide the representation of risk factor impacts as probabilistic distribution functions (density functions) for inputs into the Crystal Ball software application. The probabilistic distribution functions are used to describe the characteristic population (tendencies) of the risk factor inputs. In some cases, the risk factor impacts were modified by the risk analysts based on a closer review of the risk and the initial results of the sensitivity analysis.

Contingency was analyzed using the Crystal Ball software application. Monte Carlo analysis was performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified in the risk register. Contingencies were calculated by applying only the moderate and high level risks identified for each element. Low-level risks were not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies. The risks that were deemed to be 'Moderate' and 'High' are found below:

4.2.1 Costs Risks

1. Subcontracting Requirement (Moderate) – The primary concerns with this risk involve how the amount of subtracting can negatively affect the project cost. Typically, the government does not assume enough for subcontracting and the values can vary.
2. Contracting Vehicle (High) – Associated with the contracting vehicle of choice and if an 8a small business is the contracting vehicle of choice, the impact could be negative. Historically, the acquisition for scopes of work that entail pump stations consist of a request for proposal (RFP). The PDT does not anticipate any deviation, however the estimate assumes a competitive environment. Therefore, this can lead to an increase of the project cost.
3. Market Condition and Bidding Competition (Moderate) – Associated with potential for bids to vary and contract award to be within the statuary limit or outside; market conditions could allow for high bids and negotiations could occur and delay project. While the current bidding market remains competitive and work is planned in the near term, there is always concern for limited funds, schedule delays and bid variance between contractors. There is always a potential for bids to vary and contract award to be within the statuary limit of 25% of the IGE excluding profit. However, higher amount of bids are possible and bid amounts could be by 15% above the IGE. Therefore, market conditions could allow for high bids and negotiations could occur and delay project.
4. Modifications/Claims (High) – Associated with changes or modifications to project throughout project duration or period of performance. Generally, based on current project scope and historical data, modifications and claims are very likely.
5. Site Investigation (Moderate) – Current collected and previous data supports given analysis of the site. However, area and previous projects have been prone to issues such as large voids. In particular, when clearing for the channels, voids could be discovered and grouting is needed to correct any issues.

6. Production Rates (Moderate) – Associated with how the awarded contractor production rates can vary higher or lower than assumed IGE. The production rate for various construction tasks could be affected to a lower or higher rate. Market conditions could affect production as well.

4.2.2 Schedule Risks

7. Funding Stream (High) – Associated with the risk of there being an increase in the estimated total project cost and how that could affect appropriations and funding stream, which could delay project. Increase in estimated total project cost could affect appropriations and funding stream. If the funds are not received, it would likely affect cost, but it could push the project back to a much later date. Currently though this project is very important and other projects are dependent on its completion.
8. PACR Authorization (High) – Associated with PACR authorization not being guaranteed in 2020; Congress could not approve funding which could lead to schedule delays.
9. Contracting Vehicle (Moderate) – Captured as a cost risk as well, but the selection of an 8a small business could impact the schedule and cause delays. The PDT does not expect any deviation from past projects, however the estimate assumes a competitive environment.
10. Site Conditions (Moderate) – Associated with mainly with wet conditions during construction, previous projects in the area illustrated contractors were able to able to complete tasks, however there are risks that some areas on the project site may be more difficult to operate in based on the soil conditions in that area. Therefore, this could lead to project delays.
11. Haul road/Access road (Moderate) – Associated with congestion of haul road or access road during construction due to there being one road for tasks. Coordination is required for the haul or access road and estimate assumes there could be delays.
12. Weather (Moderate) – There is always potential for severe adverse weather delays and costs. This project is in south Florida which has a high likelihood of severe storms (hurricanes).

There were additional risks that were classified as low. All 3 types of risks were incorporated into the analysis and development of the contingency for the project. Solely the moderate and high risks were modeled in the cost and schedule analysis. Low-level risks were not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies The PDT discussions for the various risks provided essential information that could be used to establish control measures. Impact rating scales were established by the PDT during the risk register development sessions for both cost and schedule impacts. The risk register will continued to be updated during the project live cycle. The PDT meeting considered the various features of work or applicable feature code for the risks, as it is critically essential to account for the various risks throughout the analysis. The table summarizing all the risks discussed and considered are found in the appendix.

5.0 Key Assumptions and Limitations

Key assumptions and limitations are those that are most likely to significantly affect the determinations of contingency presented in the CSRA. The key assumptions and limitations are important to help ensure that project leadership and other decision makers understand the steps, logic, and decisions made in the risk analysis, as well as any resultant implications on the use of outcomes and results. The following list identifies the key risk analysis assumptions and limitations within the context of the project CSRA. For each item, the context is first provided and then followed by the key assumption or limitation.

1. Risk Identification and Assessment Process – Brainstorming is an information gathering technique frequently used for identifying and assessing risks. The goal of brainstorming is to obtain a comprehensive list of project risks. Cost Engineering Mandatory Center of Expertise (MCX) guidance identifies the use of a PDT Brainstorming Session for risk identification and assessment. The PDT did perform brainstorming as a facilitated teleconference with a multidisciplinary set of experts as well as the sponsor (SFWMD). However, throughout the project cycle, the CSRA should be updated as need to reflect any risks changes.
2. Application of Relevant Contracts and WBS Items – The CSRA is being conducted in conjunction with the Post Authorization Change Report (PACR). Therefore, the analysis only considered the two assumed contracts that will be required for construction of the pump stations (S322B and S322C).
3. Expected Cost Estimate and Schedule Accuracy – The expected accuracy of the cost estimate and schedule is independent of other risks and is generally a function of the level of effort expended for preparation. Significant variance of CSRA results from actual project costs and schedules may be experienced if the assumed cost estimate and schedule accuracy does not reflect actual accuracy.
4. Unknown Decisions or Decision Makers – The CSRA was prepared using a framework to generate contingency information that is appropriate for use by USACE decision makers for scheduling, budgeting, and project control purposes. The framework may generate results that are appropriate for use by a wide variety of decision makers or stakeholders; however, the assumed use of CSRA results is limited to scheduling, budgeting, and project control. Other uses by unknown decision makers may not be appropriate.
5. Dynamic Risks – Risk events are dynamic, not static, and should be evaluated regularly through all phases of design, construction and O&M (if required). The CSRA is based on the identification and assessment of risks as of the date of this document. Reduced utility of current CSRA results should be assumed if the likelihood and impact of risks change over time.
6. Causal Relationships – With the exception of risk events identified as correlated in the risk register, it is assumed that the impacts of risks are independent and that the realization of one risk does not cause the realization of another. Significant variance of the risk model results from actual project costs and schedules may be experienced if significant causal relationships exist between risks assumed to be independent.
7. Conservation of Market Pricing Risk – The CSRA assumes that market pricing risks are not created or destroyed but can only be transferred or shared at a price as a result of various contract acquisition strategies. As an example, it is assumed that a contractor will add a level of contingency to a fixed price bid, relative to a cost reimbursable bid, that is reflective of the risk transferred contractually from the Government to the contractor. Other aspects of contract acquisition strategies not related to market pricing, such as the management cost of modifications or claims, are not included in this assumption. Any contract acquisition strategy that actually transfers market pricing risk to a contractor at no cost to the Government is not reflected in the CSRA.

6.0 Results

6.1 Risk Register

A risk register is a tool commonly used in project planning and risk analysis. 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.

Specific to this risk register, it should be noted that there are events reported in the register, but not included in the calculation. That is, the risk register shows the risk events, but they do not contribute to the contingency calculation. These are the events with a low risk level (typical for cost and schedule events with some combination of, for example, Very Unlikely/Unlikely Likelihoods and Negligible/Marginal Impacts). The low risk level events are documented, but excluded from the calculation in order to mitigate skewed results. Under the risk level, these are showed with a zero.

As mentioned in the Executive Summary, tools and materials from the MCX were used throughout the process of acknowledging the various risks, trying to account for them, running into any possible calculation issue, and coming up with a resolution to the issue. The cost and schedule risk analysis results are provided in the following sections. In addition to contingency calculation results, sensitivity analyses are presented to provide decision makers with an understanding of variability and the key contributors to the cause of this variability. Recommended uses of the risk register going forward include:

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

Contained in this project risk register are the following risks: organizational and project management, contract acquisition, technical, lands and damages, regulatory and environmental, construction, and estimate and schedule. More specifically, there are 22 risks but only the ones that are moderate or high are inputted into the cost and schedule models. The cost risk model contained 6 risks and the schedule risk model contained 6 risks as well. The tables of the cost risk model and schedule risk model are found below:

Table 3: Cost Risk Model

Feasibility									
		Project Cost			Crystal Ball Simulation				
Risk No.	Risk/Opportunity Event	Likelihood*	Impact*	Risk Level*	Low	Most Likely	High	Cost Risk	Variance Distribution
	PROJECT & PROGRAM MGMT								
PPM-1	Cost Sharing	Unlikely	Negligible	LOW	0	0	0	0	Triangular
PPM-2	Funding Stream	Likely	Negligible	LOW	0	0	2,583,281	0	Triangular
PPM-3	PACR Authorization	Likely	Negligible	LOW	0	0	2,583,281	0	Triangular
	CONTRACT ACQUISITION RISKS								
CT-1	Subcontracting Requirement	Unlikely	Significant	MODERATE	0	0	8,636,365	0	Triangular
CT-2	Contracting Vehicle	Likely	Critical	HIGH	0	0	16,145,509	0	Triangular
CT-3	Acquisition Delays: Amendments to Solicitations	Likely	Negligible	LOW	0	0	0	0	Triangular
CT-4	Market Condition and Bidding Competition	Unlikely	Significant	MODERATE	0	0	12,109,131	0	Triangular
CT-5	Concurrent Contracts	Very Likely	Negligible	LOW	0	0	3,100,000	0	Triangular
	TECHNICAL RISKS								
TR-1	Site Investigation	Unlikely	Negligible	LOW	0	0	809,546	0	Triangular
TR-2	Road work required to construct L-357W	Unlikely	Negligible	LOW	0	0	0	0	Triangular
TR-3	Current Design	Very Likely	Negligible	LOW	0	0	3,632,739	0	Triangular
TR-4	Borrow Areas	Likely	Negligible	LOW	0	0	0	0	Triangular
TR-5	NDA Scraped Soils	Unlikely	Negligible	LOW	0	0	0	0	Triangular
	LANDS AND DAMAGES RISKS								
LD-1	Procurement of the Property	Very Unlikely	Negligible	LOW	0	0	0	0	Triangular
LD-2	Land Value	Unlikely	Negligible	LOW	0	0	0	0	Triangular
	REGULATORY AND ENVIRONMENTAL RISKS								
ENV-1	Status of Permits	Very Unlikely	Negligible	LOW	0	0	500,000	0	Triangular
ENV-2	Wetlands impact	Very Unlikely	Negligible	LOW	0	0	0	0	Triangular
	CONSTRUCTION RISKS								
CO-1	Site Conditions (Wet)	Likely	Negligible	LOW	155,306	0	189,818	0	Triangular
CO-2	Modifications/Claims	Very Likely	Significant	HIGH	0	0	12,109,131	0	Triangular
CO-3	Clearing and Grubbing	Unlikely	Negligible	LOW	0	0	0	0	Triangular
CO-4	1' Concrete Berm	Very Unlikely	Negligible	LOW	0	0	0	0	Triangular
CO-5	Site Investigation	Likely	Marginal	MODERATE	0	0	4,783,493	0	Triangular
CO-6	Site Investigation	Very Unlikely	Negligible	LOW	0	0	0	0	Triangular
CO-7	Haul road/Access road	Likely	Negligible	LOW	0	0	0	0	Triangular
	ESTIMATE AND SCHEDULE RISKS								
ESR-1	Fuel Costs	Likely	Negligible	LOW	101,450	0	202,899	0	Triangular
ESR-2	Production Rates	Very Likely	Marginal	MODERATE	-5,194,101	0	6,348,354	0	Triangular
	Programmatic Risks								
EXT-1	Weather	Very Likely	Negligible	LOW	0	0	1,650,000	0	
EXT-2	Sea Level Rise	Unlikely	Negligible	LOW	0	0	0	0	

Table 4: Schedule Risk Model

Feasibility									
		Project Schedule			Crystal Ball Simulation				
Risk No.	Risk/Opportunity Event	Likelihood*	Impact*	Risk Level*	Low	Most Likely	High	Schedule Risk	Variance Distribution
	PROJECT & PROGRAM MGMT								
PPM-1	Cost Sharing	Very Unlikely	Negligible	LOW	0	0	0	0	Triangular
PPM-2	Funding Stream	Likely	Significant	HIGH	0	0	12	0	Triangular
PPM-3	PACR Authorization	Likely	Significant	HIGH	0	0	12	0	Triangular
	CONTRACT ACQUISITION RISKS								
CT-1	Subcontracting Requirement	Unlikely	Negligible	LOW	0	0	0	0	Triangular
CT-2	Contracting Vehicle	Unlikely	Significant	MODERATE	0	0	12	0	Triangular
CT-3	Acquisition Delays: Amendments to Solicitations	Likely	Negligible	LOW	0	0	0	0	Triangular
CT-4	Market Condition and Bidding Competition	Unlikely	Negligible	LOW	0	0	0	0	Triangular
CT-5	Concurrent Contracts	Likely	Negligible	LOW	0	0	0	0	Triangular
	TECHNICAL RISKS								
TR-1	Site Investigation	Unlikely	Negligible	LOW	0	0	0	0	Triangular
TR-2	Road work required to construct L-357W	Unlikely	Negligible	LOW	0	0	0	0	Triangular
TR-3	Current Design	Unlikely	Negligible	LOW	0	0	0	0	Triangular
TR-4	Borrow Areas	Unlikely	Negligible	LOW	0	0	0	0	Triangular
TR-5	NDA Scraped Soils	Unlikely	Negligible	LOW	0	0	0	0	Triangular
	LANDS AND DAMAGES RISKS								
LD-1	Procurement of the Property	Very Unlikely	Negligible	LOW	0	0	0	0	Triangular
LD-2	Land Value	Unlikely	Negligible	LOW	0	0	0	0	Triangular
	REGULATORY AND ENVIRONMENTAL RISKS								
ENV-1	Status of Permits	Very Unlikely	Critical	LOW	0	0	18	0	Triangular
ENV-2	Wetlands impact	Very Unlikely	Negligible	LOW	0	0	0	0	Triangular
	CONSTRUCTION RISKS								
CO-1	Site Conditions (Wet)	Likely	Marginal	MODERATE	0	0	9	0	Triangular
CO-2	Modifications/Claims	Likely	Negligible	LOW	0	0	0	0	Triangular
CO-3	Clearing and Grubbing	Likely	Negligible	LOW	0	0	0	0	Triangular
CO-4	1' Concrete Berm	Likely	Negligible	LOW	0	0	0	0	Triangular
CO-5	Site Investigation	Very Unlikely	Negligible	LOW	0	0	1	0	Triangular
CO-6	Site Investigation	Very Unlikely	Negligible	LOW	0	0	1	0	Triangular
CO-7	Haul road/Access road	Likely	Marginal	MODERATE	0	0	4	0	Triangular
	ESTIMATE AND SCHEDULE RISKS								
ESR-1	Fuel Costs	Likely	Negligible	LOW	0	0	0	0	Triangular
ESR-2	Production Rates	Likely	Negligible	LOW	0	0	0	0	Triangular
	Programmatic Risks								
EXT-1	Weather	Likely	Marginal	MODERATE	0	0	4	0	Triangular
EXT-2	Sea Level Rise	Unlikely	Negligible	LOW	0	0	0	0	Triangular

6.2 Contingency

The contingency was calculated based off the likelihood and impact of the any risk concerns. Some of the major areas of concern were seen under the following elements: project and program management, contract acquisition risks, construction risks, and estimate and schedule risks. Construction Elements and External Project Risks categories. Total contingency (reflecting cost and schedule impacts) was allocated on a WBS feature level based on the dollar-weighted relative risk of each feature as quantified by Monte Carlo simulation. Standard deviation was used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of total project contingency being allocated to features with relatively higher estimated cost uncertainty.

The Cost Engineering MCX guidance generally focuses on the eighty-percent level of confidence (P80) for cost contingency calculation. For this risk analysis, the eighty-percent level of confidence (P80) was used. It should be noted that the use of P80 as a decision criteria is a moderately risk averse approach, generally resulting in higher cost contingencies. However, the P80 level of confidence also assumes a small degree of risk that the recommended contingencies may be inadequate to capture actual project costs.

Contingency was quantified as approximately $27,817,173 at the P80 confidence level (34.46% of the baseline cost estimate). For comparison, the cost contingency at the P50 and P95 confidence levels was quantified as 26.65% and 42.02% of the baseline cost estimate, respectively. Further analysis of the project development contingency can be found in the table below.

Table 5: Contingency Analysis

Most Likely Cost Estimate	$80,727,543		
Confidence Level	Project Cost	Contingency	Contingency %
0%	$83,133,295	$2,405,752	2.98%
5%	$91,557,815	$10,830,273	13.42%
10%	$93,648,007	$12,920,464	16.01%
15%	$95,260,406	$14,532,863	18.00%
20%	$96,510,472	$15,782,929	19.55%
25%	$97,647,588	$16,920,045	20.96%
30%	$98,552,479	$17,824,936	22.08%
35%	$99,505,713	$18,778,170	23.26%
40%	$100,413,739	$19,686,196	24.39%
45%	$101,322,706	$20,595,163	25.51%
50%	$102,237,650	$21,510,107	26.65%
55%	$103,183,021	$22,455,478	27.82%
60%	$104,129,673	$23,402,130	28.99%
65%	$105,057,238	$24,329,695	30.14%
70%	$106,034,108	$25,306,565	31.35%
75%	$107,243,299	$26,515,757	32.85%
80%	$108,544,716	$27,817,173	34.46%
85%	$110,017,108	$29,289,565	36.28%
90%	$111,827,092	$31,099,549	38.52%
95%	$114,645,674	$33,918,131	42.02%
100%	$130,180,330	$49,452,787	61.26%

6.3 Cost and Schedule Sensitivity

Sensitivity analysis generally ranks the relative importance of each risk. The Crystal Ball software uses a statistical measure (contribution to variance) that approximates the importance of each risk contributing to variability of cost outcomes during Monte Carlo simulation. In variance-based sensitivity analysis, expectation values have to be evaluated to generate a global sensitivity measure. Because expectation values are means (probability-weighted averages), using the importance measures to calculate the contingency associated with a risk at any given confidence level would generally not be meaningful. Furthermore, variance-based sensitivity analysis may provide misleading results for correlated risks.

Key cost drivers identified in the sensitivity analysis can be used to support development of a risk management plan that will facilitate control of risk factors and their potential impacts throughout the project lifecycle. Together with the risk register, sensitivity analysis results can also be used to support development of strategies to eliminate, mitigate, accept or transfer key risks.

The risks considered as key or primary cost drivers are ranked in order of importance in contribution to variance bar charts. Opportunities that have a potential to reduce project cost and are shown with a negative sign; risks are shown with a positive sign to reflect the potential to increase project cost. A longer bar in the sensitivity analysis chart represents a greater potential impact to total project cost.

The key cost risk drivers identified through sensitivity analysis are the following: Contracting Vehicle at 35.1%, Market Condition and Bidding Competition at 20.6%, Modifications/Claims at 17.5%, Production rates at 13.1%, Subcontracting Requirement at 9.6%, Site Investigation at 9.6%, Concurrent Contracts at 8%, and Weather at 0.2%. These cost risk drivers are contribute to the statistical cost estimate variance during Monte Carlo simulation. The figure illustrating this data can be found in the table below

The key schedule risk drivers identified through sensitivity analysis are the following: PACR Authorization at 28.9%, Funding Stream at 26.6%, Contracting Vehicle at 26.5%, Site Conditions (Wet) at 12.5%, Haul road/access road at 2.8%, and Weather at 2.8%. These cost risk drivers are contribute to the statistical cost estimate variance during Monte Carlo simulation. The figure illustrating this data can be found in the table below

Figure 1: Sensitivity Analysis – Cost Contingency

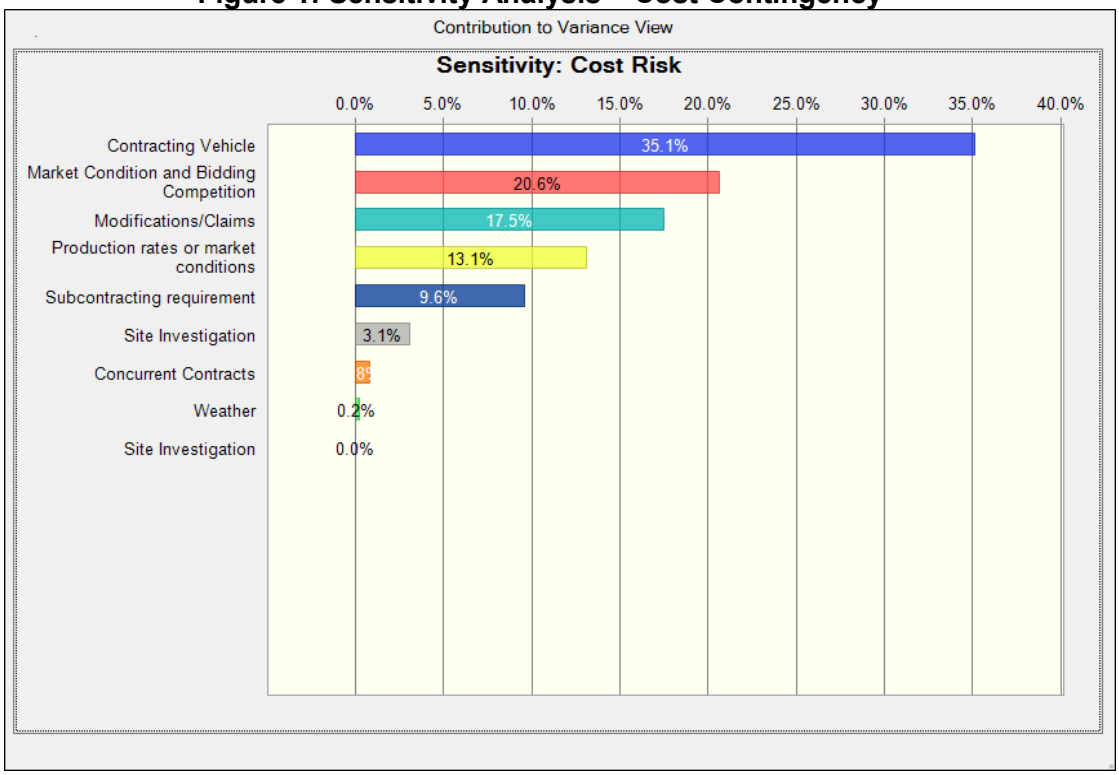
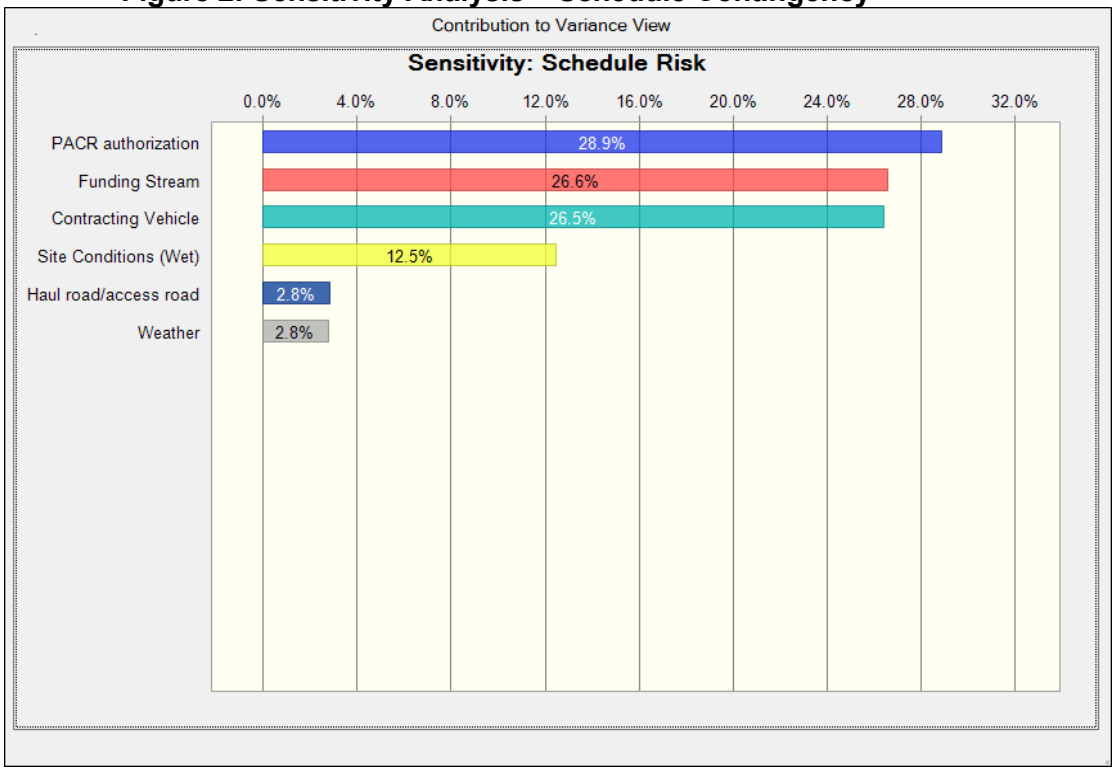


Figure 2: Sensitivity Analysis – Schedule Contingency



7.0 Appendices

Appendix A – Cost Certification

TBD

Appendix B – Risk Register

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost			Project Schedule		
				Likelihood	Impact	Risk Level	Likelihood	Impact	Risk Level
PROJECT & PROGRAM MGMT									
PPM-1	Cost Sharing	What is the current cost sharing on the project and could it change prior to the award of the contracts?	50/50 cost share for this project. It would likely not affect cost nor schedule.	Unlikely	Negligible	LOW	Very Unlikely	Negligible	LOW
PPM-2	Funding Stream	Receipt of funding in a timely manner could affect the cost (PED) and schedule.	Increase in estimated total project cost could affect appropriations and funding stream. If the funds are not received, it would likely affect cost, but it could push the project back to a much later date. Currently though this project is very important and other projects are dependent on it's completion.	Likely	Negligible	LOW	Likely	Significant	HIGH
PPM-3	PACR Authorization	PACR authorization could not be in time.	PACR authorization in 2020 is not guaranteed. Congress could not approve funding which could lead to schedule delays.	Likely	Negligible	LOW	Likely	Significant	HIGH
CONTRACT ACQUISITION RISKS									
CT-1	Subcontracting Requirement	Amount of subcontracting can negatively affect the project cost.	Project estimate assumes typical subcontracting ranges as experienced in the past.	Unlikely	Significant	MODERATE	Unlikely	Negligible	LOW
CT-2	Contracting Vehicle	If an 8a small business is the contracting vehicle of choice, the impact could be negative.	Based on the responses for a sole source sought will indicate the type of contract through an Least Price Technically Acceptable procurement method. Historically the Acquisition for pump station are RFPs. We do not anticipate any deviation. The estimate assumes a competitive environment. But if a sole source is chosen, the cost historically increases between 20 to 40%; therefore the CSRA will assume 20%.	Likely	Critical	HIGH	Unlikely	Significant	MODERATE
CT-3	Acquisition Delays: Amendments to Solicitations	Amendments to Solicitations can cause changes in specifications that cause due date changes, negative impacts	Amendments are common occurrence priority to award.	Likely	Negligible	LOW	Likely	Negligible	LOW

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost			Project Schedule		
				Likelihood	Impact	Risk Level	Likelihood	Impact	Risk Level
CONTRACT ACQUISITION RISKS									
CT-4	Market Condition and Bidding Competition	Project work allows for significant amount of work. Is possible that Contractors are busy and the market can stay competitive.	While the current bidding market remains competitive and work is planned in the near term, there is always concern for limited funds, schedule delays and bid variance between contractors. There is always a potential for bids to vary and contract award to be within the statuary limit of 25% of the IGE excluding profit. Total impact 15% on not awarded contract. Higher amount of bids possible and bid amounts could be by 15% above IGE. Market conditions could allow for high bids and negotiations could occur and delay project.	Unlikely	Significant	MODERATE	Unlikely	Negligible	LOW
CT-5	Concurrent Contracts	Concurrent sequencing.	As of now the work is assumed to be under 1 contract. However it is possible that based on previous work, there is a chance for 2 or more contracts. If this occurs, there is a chance that the work will overlap (B & C). This could lead to issues with the prime contractors. However, in the past the team has been able to establish the sequencing schedule and are aware of being able to mitigate conflicts between contractors. The main issue of concern is there is 1 haul or access road, this could lead to traffic flow issues and impact the project cost to go up. A possible solution is to review schedule and allow room for dual construction. Maintenance issues could also arise.	Very Likely	Negligible	LOW	Likely	Negligible	LOW
TECHNICAL RISKS									
TR-1	Site Investigation	Was sufficient investigation performed to insure accurate quantities?	A survey was done on the remaining borrow material, (there is some material left on L-31N). Borrow material will also be generated from excavation of the discharge canal. Construction sequencing could impact this. Material along canal near 332D that has not been processed could be used.	Unlikely	Negligible	LOW	Unlikely	Negligible	LOW
TR-2	Road work required to construct L-357W	Project accomplish intent? There will be some additional road work involved in order to complete the construction of the L-357W. Asphalt prices can increase.	Does not apply to this project.	Unlikely	Negligible	LOW	Unlikely	Negligible	LOW

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost			Project Schedule		
				Likelihood	Impact	Risk Level	Likelihood	Impact	Risk Level
TECHNICAL RISKS									
TR-3	Current Design	Current design is to be determined. Conceptual design only.	The design is not deemed complicated. Concerns could include the turning veins and no testing. Physical modeling will need to occur to ensure proper design. There will be testing that will occur at pump station. Area is not new terrain, test data of the past is available for review. Assume an increase to PED.	Very Likely	Negligible	LOW	Unlikely	Negligible	LOW
TR-4	Borrow Areas	If there is an issue with the borrow material quality or quantity, there could be a negative impact in cost and schedule.	If the material in the borrow area is deemed unsuitable it could significantly increase the cost and schedule. A new survey still needs to occur, however the MII estimates assumes 100% processed material.	Likely	Negligible	LOW	Unlikely	Negligible	LOW
TR-5	NDA Scraped Soils	Complexity of using scraped soils	Does not apply to this project.	Unlikely	Negligible	LOW	Unlikely	Negligible	LOW
LANDS AND DAMAGES RISKS									
LD-1	Procurement of the Property	If not all of the land has been procured, there could be a negative impact to cost and schedule.	Does not apply to this project.	Very Unlikely	Negligible	LOW	Very Unlikely	Negligible	LOW
LD-2	Land Value	How the land is valued (e.g. current market value, acquisition cost, or appraised value) will negatively affect the sponsors contribution (i.e. pay more money).	Does not apply to this project.	Unlikely	Negligible	LOW	Unlikely	Negligible	LOW

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost			Project Schedule		
				Likelihood	Impact	Risk Level	Likelihood	Impact	Risk Level
REGULATORY AND ENVIRONMENTAL RISKS									
ENV-1	Status of Permits	If current permits expire or need to be modified during execution, this could negatively impact cost and schedule	Water quality certification pending. All other environment (i.e. NEPA, etc.) should remain the same unless the design changes. Permits are required., SFMWD would need permits from USACE. If SFWMD builds it then the 404, DEP construction permit and 408 will be required. NEPA will need to be updated and added as well.	Very Unlikely	Negligible	LOW	Very Unlikely	Critical	LOW
ENV-2	Wetlands impact	Impact to wetlands	For alternative 2A the 2000' of additional concrete has an impact and the alternative 3 has a similar impact but not as high to project area.	Very Unlikely	Negligible	LOW	Very Unlikely	Negligible	LOW
CONSTRUCTION RISKS									
CO-1	Site Conditions (Wet)	Is water of concern regarding access to the site or operation of equipment in wet muddy conditions? This could negatively affect cost and schedule	Based on previous projects in the area, contractors were able to construct the levees without the need for dewatering by starting construction in the dry season. The material was pushed out by the dozer to create the foundation of the levees. Vibratory compactor roller was used once foundation was established. There is a risk that some areas on the project site may be more difficult to operate in based on the soil conditions in that area. There is a higher risk for 2A over 3A. However, construction during the wet season can occur. There is a chance of dewatering issues as well but it will cover in the plan and specification.	Likely	Negligible	LOW	Likely	Marginal	MODERATE
CO-2	Modifications/Claims	Is there concern of modifications/claims that might arise on this project that will have a negative affect?	Based on past performance on a similar contract for this project, modifications are very likely.	Very Likely	Significant	HIGH	Likely	Negligible	LOW
CO-3	Clearing and Grubbing	Are alternative means for clear and grubbing may be available (burning, air burner, etc.) and save time and money?	Does not apply.	Unlikely	Negligible	LOW	Likely	Negligible	LOW

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost			Project Schedule		
				Likelihood	Impact	Risk Level	Likelihood	Impact	Risk Level
CONSTRUCTION RISKS									
CO-4	1' Concrete Berm	Current design is a 6" x 18" x 12' precast sections to be used. Will there be any design changes do to environmental issues.	Does not apply.	Very Unlikely	Negligible	LOW	Likely	Negligible	LOW
CO-5	Site Investigation	Large Voids	When clearing for the channels, voids could be discovered and grouting is needed to correct any issues.	Likely	Marginal	MODERATE	Very Unlikely	Negligible	LOW
CO-6	Site Investigation	Fiber Optics	Fiber optics on site could pose a delay to construction schedule and increase cost.	Very Unlikely	Negligible	LOW	Very Unlikely	Negligible	LOW
CO-7	Haul road/Access road	Congestion due to 1 access road	Coordination is required for the haul or access road.	Likely	Negligible	LOW	Likely	Marginal	MODERATE
ESTIMATE AND SCHEDULE RISKS									
ESR-1	Fuel Costs	Unanticipated inflations in fuel, key materials?	Project uses a great amount of heavy equipment, if the price of the fuel go up the cost of the project can increase. An updated fuel price from the week of 08 July 2019 has been used within the baseline estimate.	Likely	Negligible	LOW	Likely	Negligible	LOW
ESR-2	Production Rates	Production rates or market conditions	The production rate for various construction tasks could be affected to a lower or higher rate. Market conditions could affect production as well.	Very Likely	Marginal	MODERATE	Likely	Negligible	LOW
PROGRAMMATIC RISKS (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)									
EXT-1	Weather	Potential for severe adverse weather delays and costs.	This project is in south Florida which has a high likelihood of severe storms (hurricanes).	Very Likely	Negligible	LOW	Likely	Marginal	MODERATE
EXT-2	Sea Level Rise	Sea Level Rise could cause change to project and contract conditions	The sea level risk could impact construction efforts, mostly related to quantity variations. The farther into the out-year contracts, the greater quantity variability. Time impact is low since the contracts are small annual events. Sea Level risk is covered under the EST-2 Quantities.	Unlikely	Negligible	LOW	Unlikely	Negligible	LOW