APPENDIX G

Cost and Schedule Risk Analysis

G-1. Risk Analysis Overview.

a. Cost risk analysis is the process of determining the probability of cost and schedule overruns and assigning a studied growth potential presented as a contingency percentage or value. The analysis is a formal process that includes involvement of the project delivery team (PDT) utilizing nationally recognized software based on the Monte Carlo principles.

b. A risk analysis should be provided on the total project cost, including all work breakdown structure features of the project, but excluding escalation and contingency. Too often, risk focuses on just the construction activities, which can result in critical risk elements remaining unidentified. Through early determination of potential project risks, management can then focus efforts in those areas for potential risk mitigation, resulting in cost and schedule savings. A formal risk analysis should be accomplished as a joint analysis between the cost engineer and the other PDT members that have specific knowledge and expertise on all possible project risks for all features, both internal and external project risks.

c. Beginning a Cost and Schedule Risk Analysis (Process Box 0). As part of the PDT, the project manager (PM) shall establish a risk analysis member/facilitator, their funding, and delivery schedule. The task of the PDT risk analysis facilitator is to lead the PDT in risk assessment and then produce a Cost and Schedule Risk Analysis (CSRA). In short, the CSRA begins with assembling members of the PDT to brainstorm the project's risk elements. PDT members who have the responsibility of either defining scope or the development of data would participate in the brainstorming session. Members are likely to include the PM, risk facilitator, and personnel from real estate, relocations, environmental, design, contracting, construction, scheduling, and estimating. The initial objectives are to develop:

(1) Cost risk register addressing all project features, internal and external risks.

(2) The "Most Likely" base cost estimate.

(3) The "best case" and "worst case" estimates.

(4) Cost risk assessment model using Crystal Ball.

(5) Schedule risk register addressing all features.

(6) Schedule risk assessment model using Crystal Ball.

d. All project features must be addressed within the risk analysis study to ensure total project risk has been captured. Communication is the key since the cost engineer has based the construction estimate on certain assumptions. While the cost engineer is responsible for the construction estimate, it is highly recommended that the estimate used for the risk analysis include all project costs and all feature costs. Those estimates should exclude any contingency and escalation, since those are determined after the risk analysis is complete.

e. Risk elements are any aspect of the project that could cause the cost and/or schedule to vary from the estimator's "Most Likely" cost estimate and schedule (the "Most Likely" estimate is the one presented as the base cost and base schedule). The brainstorming sessions typically last 1 day or less, during which the team identifies risk elements, their likelihood, and their potential impacts. The PDT considers internal risks within the project but also external influences. The outcome of the initial brainstorming session is a preliminary risk register(s) that displays the PDT's perceived risks and impacts to cost and schedule.

f. After the brainstorming session, the cost engineer will require several days to develop low (best case) and high (worst case) cost and schedule estimates based upon the risk elements identified by the PDT. Additional time may be required to perform local market studies on key commodities such as fuel, material cost, and labor. The studies identify the actual significance of the risk items and whether further risk study is warranted. At that time, the cost engineer can complete the risk register(s) with the identified risk items and their significance to the subsequent risk analysis. The market studies may reveal a change of impact significance and criticality related to the identified risk. The PDT risk analysis member will need several days to customize the risk model based on the data available for the CSRA. During that period, the cost engineer will assign distribution curves depicting the best, "Most Likely", and worst case for each high-risk item within the register(s). Once the CSRA model has been developed, ran, and the results analyzed, a quality check is made to assure the results are logic-based on model assumptions.

g. A typical CSRA requires 10-15 days to perform. Internal labor varies, but in general, 80-120 hours are required for the risk analysis PDT member, plus additional costs for the cost engineer and remaining PDT members who have provided support to the risk development effort. On significantly large and complex projects, labor could be as great as 1,000 hours where significant market analyses are required prior to the CSRA.

G-2. <u>Cost and Schedule Risk Process</u>.

a. Figure G-1 illustrates the steps involved in conducting a CSRA.

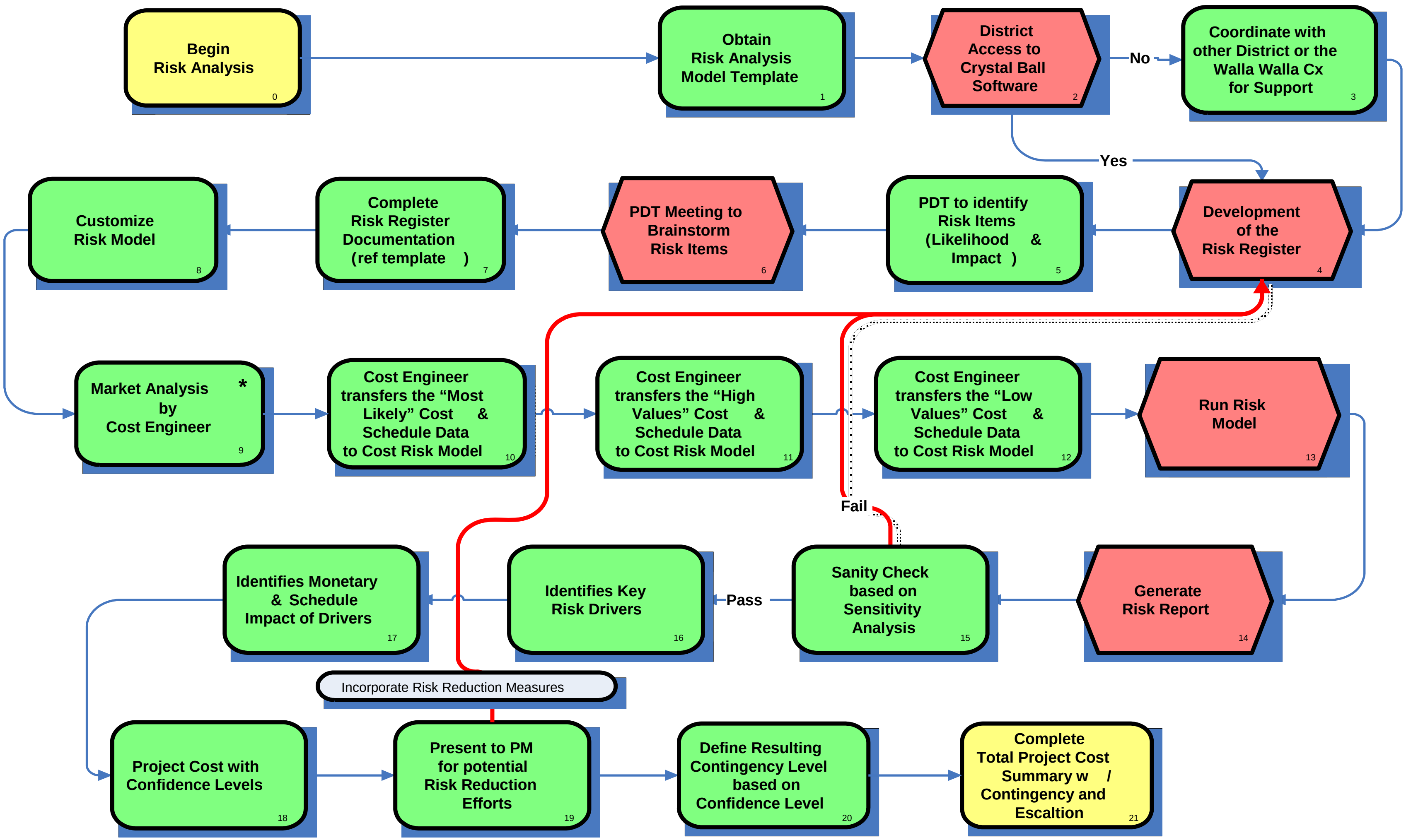


Figure G-1. Cost and Schedule Risk Process

b. Obtain CSRA Template (Process Box 1). A U.S. Army Corps of Engineers standard draft template for CSRA is available for download from the Walla Walla District, Cost Engineering Branch Center of Expertise (Cx) web page at http://www.nww.usace.army.mil/html/offices/ed/cb/cepage.htm.

c. District Access to Crystal Ball Software (Process Box 2 and 3). The CSRA template requires Crystal Ball software in order to conduct a risk analysis. This software can be obtained through coordination with another district, architect-engineer cost firm, or the Walla Walla Cost Engineering Cx to support you on the CSRA.

G-3. Development of Risk Register (Process Box 4). The first worksheet of the CSRA template, is the risk register (a sample risk register is shown in figure G-2 and addresses both cost and schedule risks). The risk register is a structured approach to communicate potential risk of the program or project and to assign risk potentials.

a. Project Delivery Team to Identify Risk Items (Process Box 5 and 6). The first step in building the risk register is for the cost engineer to identify to the PDT the basis of the cost estimate and schedule. The PDT would brainstorm and identify risks items that could potentially cause a variance to the cost estimate or schedule. Drivers, which should be discussed as a minimum, are bidding climate, saturated local market, volatile real estate values, scope definition, evolving design changes, weather, schedule constraints, labor availability/pricing, equipment availability/pricing, material availability/pricing, fuel prices, productivity, potential savings due to innovation, streamlining, acquisition strategy, and gains in efficiency.

Risk Level

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

Impact or Consequence of Occurrence

Risk No.	Risk/Opportunity Event	Discussion and Concerns	Project Cost				Project Schedule				Variance Distribution	Correlation to Other(s)	Responsibility/ POC	Affected Project Component	Project Implications
			Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)					
Internal Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)															
I-1	Scope Definition	Scope is fairly well defined for standard civil works features. The pumping plant requires considerable design and approximates 20% of the cost.	LIKELY	SIGNIFICANT	HIGH	$1,200,000	LIKELY	SIGNIFICANT	HIGH	8	UNIFORM	I-2	Project Manager/Planner	Construction Cost	Cost & Schedule
I-2	Scope Growth / Reduction	Scope is fairly well defined for standard civil works features. The pumping plant has potential of VE savings through better data and VE.	LIKELY	MARGINAL	MODERATE	($275,000)	LIKELY	MARGINAL	MODERATE	10	UNIFORM	I-1, I-16	Project Manager/Planner	Construction Cost	Cost & Schedule
I-3	Labor Availability/Pricing	$3 Billion construction will be occurring in locale over the next 5 years.	LIKELY	SIGNIFICANT	HIGH	$3,000,000	LIKELY	MARGINAL	MODERATE	9	TRIANGULAR		Project Manager/Planner	Labor/ Production Rates	Cost & Schedule
I-4	Equipment Availability/Pricing	Large cranes required, but available. Pump plant equipment long lead time.	UNLIKELY	NEGLIGIBLE	LOW	$900,000	UNLIKELY	MARGINAL	LOW	6	TRIANGULAR	I-15	Cost Engineering	Equipment/ Production Rates	
I-5	Material Availability/Pricing	Needed aggregates in short supply locally. This affects concrete, rip rap, base course and asphalt	VERY LIKELY	SIGNIFICANT	HIGH	$2,300,000	VERY LIKELY	MARGINAL	MODERATE	4	TRIANGULAR		Cost Engineering	Material Costs	Cost & Schedule
I-6	Fuel Prices	$2.65 per gallon was used in the Oct 06 MCACES, increases will effect equipment and delivery or materials	VERY LIKELY	SIGNIFICANT	HIGH	$1,750,000	VERY LIKELY	NEGLIGIBLE	LOW	0	TRIANGULAR		Cost Engineering	Equipment	Cost
I-7	Utility Relocations	Location is rural. However, several unmarked and abandoned farm related utilities are prevalent at this location.	LIKELY	MARGINAL	MODERATE	$870,000	LIKELY	MARGINAL	MODERATE	3	TRIANGULAR		Civil Design	Construction Cost	Cost & Schedule
I-8	Environmental Mitigation	Studies indicate that the area is heavily saturated with de-icing chemicals as well as agricultural fertilization and pesticide residuals.	LIKELY	SIGNIFICANT	HIGH	$1,600,000	LIKELY	SIGNIFICANT	HIGH	24	UNIFORM		Environmental Compliance Specialist	Construction Cost	Cost & Schedule
I-9	HTRW	A small portion of the project is located within the limits of an Army Chemical Depot undergoing BRAC.	UNLIKELY	MARGINAL	LOW	$400,000	UNLIKELY	SIGNIFICANT	MODERATE	18	UNIFORM		Environmental Compliance Specialist	Construction Cost	Schedule
I-10	Permits	Substantial permitting delays may occur if there are significant environmental mitigation/HTRW issues, or political opposition.	LIKELY	NEGLIGIBLE	LOW	$150,000	LIKELY	MARGINAL	MODERATE	17	TRIANGULAR	I-14, E-4	Planning/Regulatory	PED/Lands & Damages	Schedule
I-11	Environmental Windows	Project site is a natural habitat for various species of threatened wildlife that spawn during Spring months. No excavation is permitted from April 15 - June 30.	VERY LIKELY	SIGNIFICANT	HIGH	$3,500,000	VERY LIKELY	SIGNIFICANT	HIGH	30	TRIANGULAR	E-2	Project Manager/Planner	Construction Cost	Cost & Schedule
I-12	Sufficient Planning Schedule	Project is a fast-track project, although complicated. Concerns exist on obtaining appropriate schedule and funding for sufficient review and effort by specialized team members and contractors	LIKELY	MARGINAL	MODERATE	$300,000	LIKELY	SIGNIFICANT	HIGH	14	TRIANGULAR		Project Manager/Planner	Construction Cost	Cost & Schedule
I-13	Adequate Technical Staff	Due to fast-tracking, portions of design and planning effort are split between Gov't and AE specialists. Concern remains that the integration of staff may create delays.	LIKELY	NEGLIGIBLE	LOW	$200,000	LIKELY	MARGINAL	MODERATE	7	TRIANGULAR		Project Manager/Planner	PED	Schedule

I-14	Site Access	Site access is limited due to clearances required from U.S. Army installation, and local farmers remaining on property. Also, no excavation (or boring) is permitted April 15 - June 30.	VERY LIKELY	MARGINAL	MODERATE	$500,000	VERY LIKELY	NEGLIGIBLE	LOW	2	TRIANGULAR	I-10	Project Manager/Planner	Construction Cost	Cost
I-15	Special Equipment Fabrication	There are only two known manufacturers of the specialized filtration and pumping stations required on site, and neither are domestic.	UNLIKELY	NEGLIGIBLE	LOW	$1,900,000	UNLIKELY	NEGLIGIBLE	LOW	7	TRIANGULAR	I-4	Cost Engineering	Construction Cost	
I-16	Potential savings due to innovation, streamlining, and gains in efficiency	Value Engineering has already been incorporated into the project. VE remains on the pumping plant.	LIKELY	MARGINAL	MODERATE	($2,500,000)	LIKELY	NEGLIGIBLE	LOW	11	UNIFORM	I-2	Value Engineering Team	Productivity	Cost
I-17	Acquisition Plan	The estimate was based on full and open competition, with minimal tiering of contractor subs. The Acq Plan has not been finalized, therefore there is a potential for additional tiering of the contracts.	LIKELY	SIGNIFICANT	HIGH	$7,500,000	LIKELY	MARGINAL	MODERATE	16	TRIANGULAR	E-3	Acquisition Strategy Board	Construction Cost	Cost & Schedule
I-XX	Other Potentials														
External Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)															
E-1	Weather	Work will be done on the river, unpredictable, scour protection is more vulnerable	LIKELY	NEGLIGIBLE	LOW	$175,000	LIKELY	MARGINAL	MODERATE	6	TRIANGULAR		N/A	Labor/ Production Rates	Schedule
E-2	Environmental Policy Changes	There are external environmental policy changes that can change the construction work windows.	LIKELY	SIGNIFICANT	HIGH	$1,400,000	LIKELY	SIGNIFICANT	HIGH	10	TRIANGULAR	I-11	Project Manager/Planner	Construction Cost	Cost & Schedule
E-3	Bidding Climate – Saturated Local Market	$3 Billion construction will be going on in downtown Pittsburgh over the next 5 years.	LIKELY	MARGINAL	MODERATE	$2,000,000	LIKELY	NEGLIGIBLE	LOW	4	UNIFORM	I-16	Acquisition Professional	Construction Cost	Cost
E-4	Political Support/Opposition	Project is highly visible and controversial. Delays due to political ramifications are possible and could critically delay or terminate the work.	LIKELY	SIGNIFICANT	HIGH	$6,400,000	LIKELY	SIGNIFICANT	HIGH	28	UNIFORM	I-10	Project Manager/Planner	Project Cost	Cost & Schedule
E-5	Sufficient Incremental Funding	Budget constraints could limit or delay funding, creating potential sequencing delays and issues, considering the environmental window constraints.	VERY LIKELY	SIGNIFICANT	HIGH	$4,600,000	VERY LIKELY	SIGNIFICANT	HIGH	27	TRIANGULAR		Project Manager/Planner	Project Cost	Cost & Schedule
E-XX	Other Potentials														

*Likelihood, Impact, and Risk Level to be verified through market research and analysis (conducted by cost engineer).

1. Risk/Opportunity identified with reference to the Risk Identification Checklist and through deliberation and study of the PDT.
2. Discussions and Concerns elaborates on Risk/Opportunity Events and includes any assumptions or findings (should contain information pertinent to eventual study and analysis of event's impact to project).
3. Likelihood is a measure of the probability of the event occurring -- **Very Unlikely**, **Unlikely**, **Moderately Likely**, **Likely**, **Very Likely.** The likelihood of the event will be the same for both Cost and Schedule, regardless of impact.
4. Impact is a measure of the event's effect on project objectives with relation to scope, cost, and/or schedule -- **Negligible**, **Marginal**, **Significant**, **Critical**, or **Crisis.** Impacts on Project Cost may vary in severity from impacts on Project Schedule.
5. Risk Level is the resultant of Likelihood and Impact **Low**, **Moderate**, or **High**. Refer to the matrix located at top of page.

A risk item for which the PDT has little data or probability of modeling with respect to effects on cost or schedule (i.e. "anyone's guess") would probably follow a uniform or discrete uniform distribution.

7. The responsibility or POC is the entity responsible as the Subject Matter Expert (SME) for action, monitoring, or information on the PDT for the identified risk or opportunity.
8. Correlation recognizes those risk events that may be related to one another. Care should be given to ensure the risks are handled correctly without a "double counting."
9. Affected Project Component identifies the specific item of the project to which the risk directly or strongly correlates.
10. Project Implications identifies whether or not the risk item affects project cost, project schedule, or both. The PDT is responsible for conducting studies for both Project Cost and for Project Schedule.
11. Results of the risk identification process are studied and further developed by the Cost Engineer, then analyzed through the Monte Carlo Analysis Method for Cost (Contingency) and Schedule (Escalation) Growth.

Figure G-2. Example of a Risk Register

b. Complete Risk Register Documentation (Process Box 7).

(1) Once the risk events have been identified, the PDT will then assign a likelihood and potential impact to each event within a preliminary risk register. This draft risk register will identify the high cost and schedule concerns. It should also identify potential savings related to cost and schedule. This will allow the risk model to place emphasis on the events that result in the greatest potential impacts, positive and negative. The team will provide the PDT cost engineer the information required to calculate impacts of the identified driver or event. The PDT cost engineer will likely need to consult the market as well as historical data as a basis for determining certain impact potentials.

(2) Once the risk item impacts have been determined for cost and schedule, a final risk register can be completed, demonstrating the significant or high-risk items that warrant inclusion within the risk model. The final risk register is commonly completed by the cost engineer that has performed the estimate and studied the cost impacts through research. Note that during this period of study, the impact significance can change as a result of further cost and schedule study of the identified impacts.

(3) After the initial PDT brainstorming session, it is common that the "Most Likely" estimate may need revision based upon the issues learned during those discussions. To adequately address risk associated with potential design or original assumption changes, the PDT shall provide enough information for the cost engineer to develop a reasonable "Most Likely" cost estimate and schedule to reflect these potential changes. This initial process, more than any other, demonstrates that the CSRA process is a team tasking. The risk model is only as good as the data provided.

G-4. Customize Risk Model (Process Box 8).

a. Having now completed the first worksheet (the Risk Register) of the CSRA template, the second worksheet (the Risk Model) will need to be customized for the CSRA currently being developed. The risk model will include one row for every identified risk item to be included in the study within an Excel spreadsheet format. This can be accomplished in a variety of ways such as utilizing the "Most Likely" estimate work breakdown structure OR by reflecting the actual risk register. The risk model must encompass the full scope, cost and schedule of the project with all features and at an adequate detail level that clearly reflects the cost and schedule variances of the specific risk(s). The risk model must address the low (best case) estimate, the "Most Likely" estimate, and the high (worst case) estimate for those individual items that are deemed significant risks. When developing the best and worst cases, the extremes should not be included, because they can skew the results unreasonably. For this reason, the best and worst cases are commonly presented as bounded by 20 percent (best case 20 percent, worst case 80 percent). It is highly recommended that the best and worst cases are developed from the “Most Likely” estimate. In that way, any other estimates and variances reflect the same work breakdown structure OR risk register format for comparison purposes. In order to develop a traceable document, the risk model should reflect the “Most Likely” estimate, but be traceable back to the risk register.

b. The level of detail of these items, and hence the number of risk items established for further study, should be determined by the PDT risk analysis member working together with the cost engineer. Typically, risk that potentially affects the overall estimate by 1 percent or more would be addressed in the risk model. A standard number of critical risk items under study would approximate 8-12 variables. This could be just the high risk items, but may also include the moderate risks if those risks are still a considerable cost or schedule impact.

c. Market Analysis by Cost Engineer (Process Box 9). To establish the best and worst-case estimates, the cost engineer will need to perform a market analysis for the local area on the critical risk items. This would include information such as labor market, construction market, fuel cost, material cost, bidding climate, and competition. Some of this effort can begin prior to customizing the risk model, as the market conditions may uncover other risks. Various tools are used for this study, sources such as:

- Historical bid data.
- Internet research.
- Engineering news record.
- Construction records.
- Engineering and planning.
- Real estate.

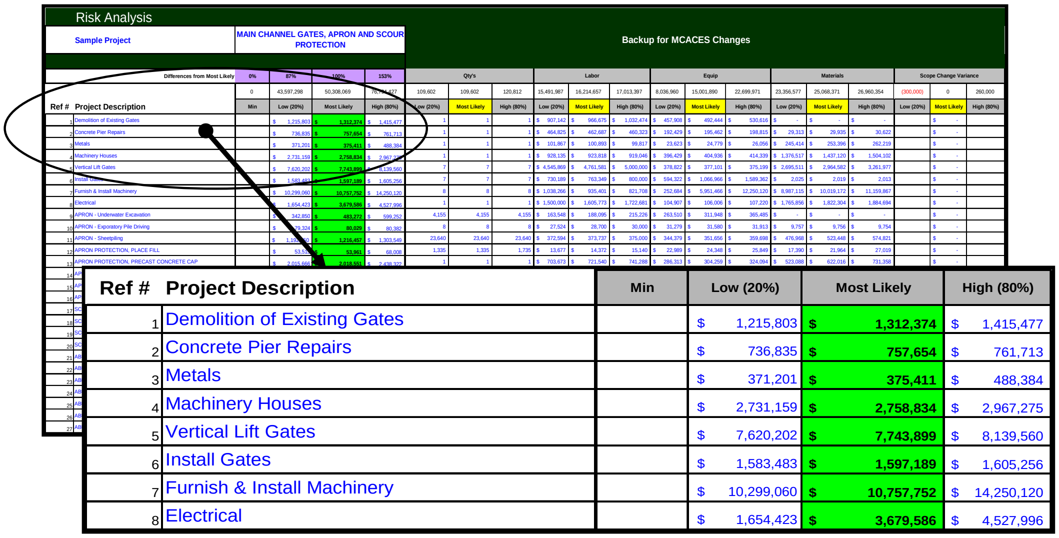
This process could start at anytime prior to running the risk model. Typically, the cost engineer may have already sought current data for the estimate development. For the risk analysis, additional data would be required such as the range of values including highs and lows.

d. Transfer the “Most Likely[1]” Cost and Schedule Data to the Risk Model (Process Box 10). The cost engineer will transfer data from the escalation and contingency-free cost estimate to the risk model’s “Most Likely” column (figure G-3). The “Most Likely” estimate is the estimate represented within the Total Project Cost Summary as presented within appendix B. The level of detail to be run in the model will vary on a project-by-project basis, and the cost engineer will be required to communicate with the PDT risk analysis member to establish the level of detail.

[1] “Most likely” is the cost developed by the cost engineer based on current project data and assumptions.

e. Transfer the “High Values” Cost and Schedule Data to Cost Risk Model (Process Box 11). The cost engineer will be required to develop the “High Cost” estimate based on the information from the risk register. It is important to have clear communications with the PDT risk analysis member to define what the high estimate should reflect. The software program allows the user to customize the model for what the “High” estimate constitutes. In figure G-3, the high estimate was based on cost that reflects an 80 percent chance of covering the item. The cost model requires this input to define the distribution (figure G-3).

f. Transfer the “Low Values” Cost and Schedule Data to Cost Risk Model (Process Box 12). The cost engineer will be required to develop the “Low Cost” estimate based on the information from the risk register. It is also important to have clear communications with the PDT risk analysis member to define what the low estimate should reflect. The software program allows the user to customize the model for what the “Low” estimate constitutes. In figure G-3, the low estimate was based on cost that reflects a 20 percent chance of covering the item. The cost model requires this input to help define the distribution (figure G-3).



Ref #	Project Description	Min	Low (20%)	Most Likely	High (80%)
1	Demolition of Existing Gates		$ 1,215,803	$ 1,312,374	$ 1,415,477
2	Concrete Pier Repairs		$ 736,835	$ 757,654	$ 761,713
3	Metals		$ 371,201	$ 375,411	$ 488,384
4	Machinery Houses		$ 2,731,159	$ 2,758,834	$ 2,967,275
5	Vertical Lift Gates		$ 7,620,202	$ 7,743,899	$ 8,139,560
6	Install Gates		$ 1,583,483	$ 1,597,189	$ 1,605,256
7	Furnish & Install Machinery		$ 10,299,060	$ 10,757,752	$ 14,250,120
8	Electrical		$ 1,654,423	$ 3,679,586	$ 4,527,996

Figure G-3. Example of Cost Model Input

g. The next step would be to assign, what are called in Crystal Ball, “assumptions” to each risk item. Assumptions are simply probability distributions, e.g., triangular, uniform, binomial, or Bernoulli. The distributions most commonly used in CSRAs are triangle and uniform, but the distribution should be tailored to best represent the determined variance potential. The distribution reflects the best, “Most Likely”, and worst-case parameters; thus, a triangular distribution is typically established. It is strongly suggested that someone who has been trained in performing a CSRA customize the risk model. Note that the study includes both a cost and a schedule risk run. Both are treated in a best, “Most Likely”, and worst-case scenario. The results can be displayed as a percentage or as a cost in dollars or schedule by months. The schedule growth can then be converted into a risk escalation and presented as part of the contingency.

h. Schedule Risk Analysis (Process Box 10, 11, and 12). A schedule risk analysis uses statistical techniques to predict the level of confidence in meeting a program’s completion date. This analysis focuses not only on critical path activities but also on activities near the critical path, since they can potentially affect program status. Like a cost estimate risk and uncertainty analysis, a schedule risk analysis relies on Monte Carlo simulation to randomly vary activity durations according to their probability distributions to develop a level of confidence in the overall integrated schedule. This analysis can provide valuable insight into “what-if” drills and quantify the impact of program changes.

(1) To develop a schedule risk analysis, probability distributions for each activity’s duration along and near the critical path must be established. (The critical path based on the schedule network identifies the specific tasks that will lead to the entire program slipping if not completed on time.) Typically, three-point estimates are used to develop the probability distributions for the duration of workflow activities, including best, “Most Likely”, and worst-case estimates.

(2) After the distributions are developed, the Monte Carlo simulation is run, and the resulting cumulative confidence diagrams display the probability associated with the range of program completion dates. If the analysis is to be credible, the program must have a good schedule network that clearly identifies the critical path that is based on a minimum number of date constraints.

(3) The risk analysis should also identify which tasks during the simulation most often ended up on the critical path, so that near–critical path activities can also be closely monitored and managed.

(4) One of the most important reasons for performing a schedule risk analysis is that the overall program schedule will always be greater than the sum of the durations for lower-level activities. This is because of schedule uncertainty, which can cause activities to lengthen. When they do, other activities can be affected by network schedule linkages. Lengthening of schedule would cause escalation increases to the estimate.

(5) Such uncertainty is typically brought on by:

- A large number of activities and tasks.

- Independent parallel tasks that have near the same completion date.
- Interdependence of two or more tasks.
- Work packages lasting longer than 3 months.
- Planning packages longer than 6 months.
- Reflection of a great deal of lag time in the schedule.

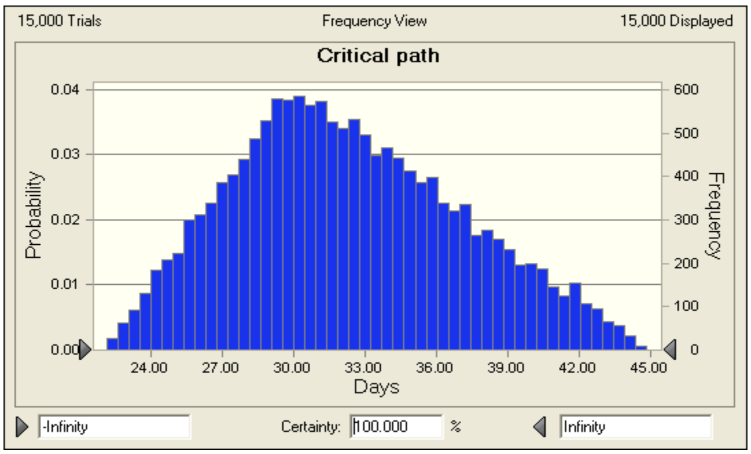


Figure G-4. Example of Critical Path Distribution

Comment [G1]: Place with Figure.

(6) Since each activity has an uncertain duration, it makes sense that the duration of the overall program schedule will also be uncertain. Therefore, unless a statistical simulation is run, the sum of "Most Likely" duration distributions will tend to underestimate the overall program critical path duration. Accordingly, because critical path activity durations are uncertain, the probability distribution of the program's total duration must be determined statistically, by adding the individual probability distributions of critical path activities.

(7) To capture the uncertainty for each critical path activity distribution, various estimates must be collected. They should be formulated by a consensus of knowledgeable technical experts and coordinated with the same people who manage the program's risk mitigation watch list. Once the distributions have been established,

the Monte Carlo simulation uses random numbers to select specific durations from each critical path activity probability distribution and calculates a new critical path. The Monte Carlo simulation continues this random selection thousands of times, creating a new program duration estimate and critical path each time. The resulting frequency distribution displays the range of program completion dates along with the probabilities that these dates will occur, as seen in figure G-4.

(8) The program schedule should satisfy the 11-point schedule assessment listed below. Questions that should be answered during a schedule risk assessment include:

- Does the schedule reflect all work to be completed?
- Are the program critical dates used to plan the schedule?
- Are the activities sequenced logically?
- Are activity interdependencies identified and logical?
- If there are constraints, lags, and lead times, what documentation is available to justify the amounts?
- How realistic are the schedule activity duration estimates?
- How were resource estimates developed for each activity and will the resources be available when needed?
- How accurate is the critical path and was it developed with scheduling software?
- How reasonable are float estimates?
- Can the schedule determine current status and provide reasonable completion date forecasts?
- What level of confidence is associated with the program schedule completion date?

(9) Other rules of thumb that can mitigate schedule risk include:

- Longer activities should be broken down to show critical handoffs. For example, if a task is 4 months long but a critical handoff is expected halfway through, the task should be broken down into separate 2-month tasks that logically link the handoff between tasks.
- Work packages should be no longer than 2 months so that work can be planned within two reporting periods.

- Lag should represent only the passing of time and should never be used to replace a task.
- Resources should be scheduled to reflect constraints, such as availability of staff or equipment.
- Constraints should be minimized, not to exceed 5 percent, because they impose a movement restriction on tasks and can cause false dates in a schedule.
- Total “float” that is more than 5 percent of the total program schedule may indicate that the network schedule is not yet mature.

G-5. Run Model, Interpret Data, and Apply Results.

a. Run Risk Model (Process Box 13). Once the model has been setup and populated with data, the PDT risk analysis member will run the risk model using the Crystal Ball software.

b. Generate Risk Report (Process Box 14). After running the risk model, there are several information reports that can be generated to help communicate the areas of cost and schedule risk on the project, and their potential impacts to the project cost development. These reports will enable management to better understand the critical risks that should be closely monitored and managed since they will reflect potential cost and schedule growth.

c. Sanity Check Based on Sensitivity Analysis (Process Box 15). An important step in the CSRA process is to check to assure the outcome fits a logical result from the data. During the data generation stage, the cost engineer has “Most Likely” had to make assumptions while generating model data. After running the risk model, the results are available to analyze, and a sanity check of the results is required. The risk result should be commensurate with the PDT confidence, a reflection of the scope development, the estimate quality, and the perceived risk impacts. A sanity check may require the team to review previous assumptions for accuracy or engage in risk reduction efforts; keep in mind that the CSRA process typically requires several passes. There is potential that the same or similar risks overly influence the outcome, thereby, unreasonably magnifying a risk. An example might be contract acquisition strategy that drives bidding competition. If both are measured separately, an undue exaggeration of risk can result. Other risks can have a similar correlation whereby, if one risk increases, the other must follow. An example might be aggregate, cement, asphalt, and concrete. Care must be given to consider and minimize these potentials. Note: This is not a step to artificially reduce the results. The PM and team must show great resolve to accurately define the risk and potential impacts of the project or to enact risk reduction measures through various means, such as more accurate information or assurance of sound acquisition strategies.

d. Identify Key Risk Drivers and Their Impact (Process Box 16 & 17). The PDT risk analysis member will be able to generate reports that identify key risk drivers and respective impacts to the project. This will allow management the ability to focus efforts on risk reduction measures for the project. These reports are called, “tornado charts.” A tornado chart is a visual attempt to sort risks in the project (figure G-5).

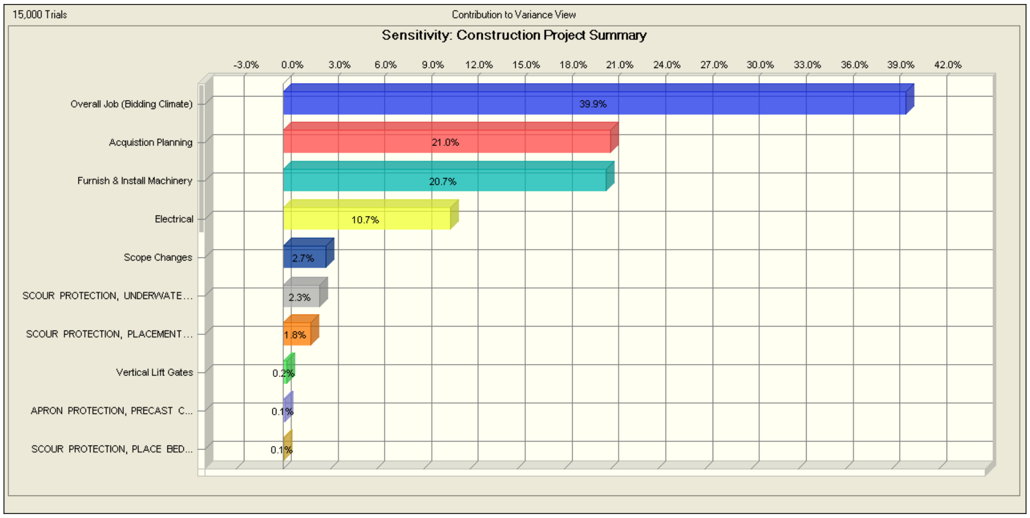


Figure G-5. Example of Sensitivity (Tornado) Chart

e. Project Cost with Confidence levels (Process Box 18). The next step is to generate a table that depicts the project cost with corresponding confidence levels. This data is generated from the risk model (figure G-6).

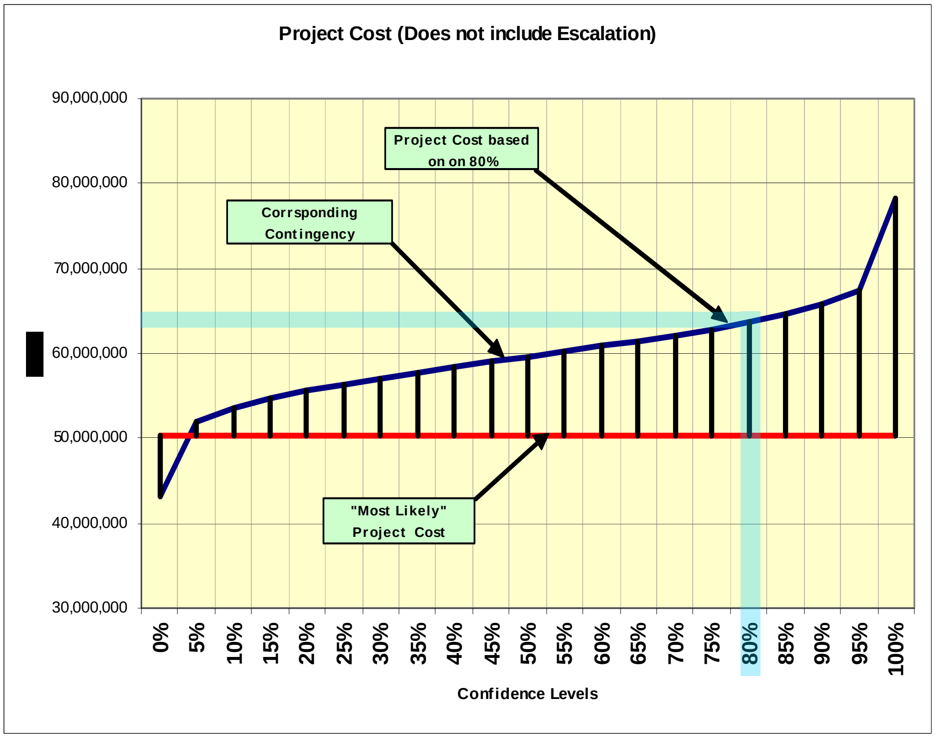


Figure G-6. Project Cost versus Confidence Levels

f. Present to Project Manager for Potential Management Risk Reduction Efforts (Process Box 19). An important outcome of the CSRA is the communication of high-risk areas, which have a high potential to affect the project cost and/or schedule. When considerable uncertainties are identified, a CSRA can establish the areas of high cost uncertainty and the probability that the estimated project cost will or will not be exceeded. This gives the management team another and effective tool in assisting the decision making process associated with project planning and design. It is highly recommended that this information is made through a report that indicates the processes used, the PDT members included, methodology such as software tools, market research, historical data. The report should present the risk register, indicate the major concerns, and the various tables and charts supporting the calculated contingencies. It is also recommended that this report be placed within the Cost Engineering Appendix of the main project report such as a Decision Document at feasibility level.

g. Define Resulting Contingency Levels (Process Box 20). The next step is to determine what confidence level and associated contingency to report. This is a management decision. The PM will be responsible to direct what confidence level will be used for final contingency development. Typically, an 80 percent confidence level is used. However, factors such as how much risk reduction the PDT will be able to generate will factor into this decision. A sample of a contingency analysis table is provided in figure G-7. It is not necessary to carry the values to the nearest dollar.

Contingency Analysis		
	Most Likely Cost Estimate	**$ 50,308,069**
Confidence Level	**Value**	**Contingency**
0%	43,155,265	-14%
5%	51,821,453	3%
10%	53,502,697	6%
15%	54,686,375	9%
20%	55,611,609	11%
25%	56,380,494	12%
30%	57,058,654	13%
35%	57,715,962	15%
40%	58,371,325	16%
45%	58,979,742	17%
50%	59,584,456	18%
55%	60,179,500	20%
60%	60,823,452	21%
65%	61,468,369	22%
70%	62,132,732	24%
75%	62,851,176	25%
80%	**63,650,172**	**27%**
85%	64,564,879	28%
90%	65,751,019	31%
95%	67,449,189	34%
100%	78,119,072	55%

Figure G-7. Example of Contingency Analysis Table

h. <u>Complete Total Project Cost Summary with Contingency</u> (Process Box 21). The last step is to generate the Total Project Cost Summary that identifies base cost by feature, project, and construction management costs; contingency cost; and escalation cost. An example of a total project cost sheet is provided in figure G-8. The confidence level is decided upon and provided to the cost member through the PM. The contingency rate is used from the contingency analysis table. Total project cost, including contingency, may differ slightly from the contingency analysis table, since the contingency rate applied is usually rounded. In addition, small changes to the estimate would not require that a complete new risk analysis be run, since the contingency rate is used and should be relative to cost. If significant changes are made to the construction cost estimate or schedule, then a new risk analysis may be required.

		Effective Price Level: 15-Jan-01			
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)
06	**Fish and Wildlife Facilities**	50,308,069	13,342,103	27%	63,650,172
	CONSTRUCTION ESTIMATE TOTALS:	50,308,069	13,342,103		**63,650,172**

PROJECT: Example Project, XXXXX
LOCATION: West Coast

DISTRICT: Walla Walla
POC: Coug Smith, Chief, Cost Engineering

PREPARED: 16-Aug-07

This Estimate reflects the scope and schedule in feasibility report; Enter the report or document this estimate is based upon.

	Estimate Prepared: 14-Aug-07 / Effective Price Level: 15-Jan-01					Program Year (Budget EC): 2007 / Effective Price Level Date: 1 OCT 07				TOTAL PROJECT COST ESTIMATE				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Spent Thru: ($K)	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
06	**Fish and Wildlife Facilities**	50,308,069	13,342,103	27%	63,650,172	3.2%	51,917,847	13,769,029	65,686,876	-	10.8%	55,741,819	14,783,177	70,524,996
	CONSTRUCTION ESTIMATE TOTALS:	50,308,069	13,342,103		**63,650,172**		51,917,847	13,769,029	65,686,876	**0**		55,741,819	14,783,177	70,524,996
01	LANDS AND DAMAGES	-	-	-	-		-	-	-	-		-	-	-
21	RECONNAISSANCE STUDIES									**100,000**				100,000
22	FEASIBILITY STUDIES	50	13	26%	63		52	13	65	-		52	14	66
30	PLANNING, ENGINEERING & DESIGN	13,331,639	3,332,910	25%	16,664,549		13,758,231	3,439,556	17,197,787	-		14,306,681	3,576,672	17,883,353
31	CONSTRUCTION MANAGEMENT	7,294,670	1,823,668	25%	9,118,338		7,528,088	1,882,022	9,410,110	-		8,082,564	2,020,642	10,103,206
	PROJECT COST TOTALS:	70,934,428	18,498,694	26%	**89,433,122**		73,204,218	19,090,620	92,294,838	100,000		78,131,116	20,380,505	**98,611,621**

ESTIMATED FEDERAL COST:	**98,611,621**
ESTIMATED NON-FEDERAL COST:	-
ESTIMATED TOTAL PROJECT COST:	**98,611,621**

_______________ CHIEF, COST ENGINEERING
_______________ Project Management, {Enter PM Name}
_______________ CHIEF, REAL ESTATE
_______________ CHIEF, PLANNING
_______________ CHIEF, ENGINEERING
_______________ CHIEF, OPERATIONS
_______________ CHIEF, CONSTRUCTION
_______________ CHIEF, CONTRACTING
_______________ CHIEF, PM-PB
_______________ CHIEF, DPM

Figure G-8. Example of Total Project Cost Sheet

G-6. Risk Register Checklist. Use the checklist of risk items for consideration when performing a risk analysis. Of critical importance is consideration of all feature codes as presented within the civil works breakdown structure.

FEATURE CODE	DESCRIPTION
01	Lands and Damages
02	Relocations
03	Reservoirs
04	Dams
05	Locks
06	Fish and Wildlife Facilities
07	Power Plant
08	Roads, Railroads, and Bridges
09	Channels and Canals

10	Breakwaters and Seawalls
11	Levees and Floodwalls
12	Navigation Ports and Harbors
13	Pumping Plants
14	Recreation Facilities
15	Floodway Control-Diversion Structure
16	Bank Stabilization
17	Beach Replenishment
18	Cultural Resource Preservation
19	Buildings, Grounds, and Utilities
20	Permanent Operation Equipment
30	Planning, Engineering and Design
31	Construction Management

a. Engineering and Construction Management Risk Document Checklist. Risk management reports vary depending on the size, nature, and phase of the project. The following are examples of risk management documents and reports that may be useful:

- Risk management plan.
- Risk information form.
- Risk assessment report.
- Risk handling priority list.
- Risk handling plan of action.
- Aggregated risk list.
- Risk monitoring documentation:
    - Project metrics.
    - Technical reports.
    - Earned value reports.
    - Watch list.
    - Schedule performance report.
    - Critical risk processes reports.

b. The following items are a composite of several checklists from various agencies. They have been tailored to better address the more common U.S. Army Corps of Engineers civil works project risks. The list, though not all encompassing, provides a valuable tool meant to serve as an aid in PDT discussions of potential risk items for a specific project.

CHECKLIST OF POTENTIAL RISK ITEMS:

Organizational and Project Management Risks

- ❑ Project purpose and objectives are poorly defined
- ❑ Project scope definition is poor or incomplete
- ❑ Project schedule in question
- ❑ No control over staff priorities
- ❑ Project competing with other projects, funding, and resources
- ❑ Functional and technical labor units not available or overloaded
- ❑ Losing critical staff at crucial point of the project
- ❑ Inexperienced or inadequate staff assigned
- ❑ Product development by several sources or entities (virtual or remote efforts)
- ❑ Coordination/communication difficulties
- ❑ Communication breakdown with project team
- ❑ Insufficient time to plan
- ❑ Timely response to critical decisions by project manager and/or management
- ❑ Architect-engineer and Construction Consultant or contractor delays
- ❑ Pressure to deliver project on an accelerated schedule
- ❑ Unanticipated project manager workload
- ❑ Internal red tape causes delay getting approvals, decisions
- ❑ Unplanned work that must be accommodated
- ❑ Local agency/regulator issues
- ❑ Priorities change on existing program

Contract Acquisition Risks

- ❑ Undefined acquisition strategy
- ❑ Lack of acquisition planning support/involvement
- ❑ Preference to Small Business Development and 8(a) contracts
- ❑ Acquisition planning to accommodate funding stream or anticipated strategy
- ❑ Numerous separate contracts
- ❑ Acquisition strategy decreasing competition
- ❑ Acquisition strategy results in higher scope risk (Design Build)

Technical Risks

- ❑ Design development stage, incomplete, or preliminary
- ❑ Confidence in scope, investigations, design, and critical quantities:
    - Geotechnical
    - Civil
    - Structural
    - Mechanical
    - Electrical
    - Architectural
    - Environmental

Controls
Other Specialized Disciplines

- ❑ Design confidence in products by others
- ❑ Consultant design not up to department standards
- ❑ Inaccurate or risky design assumptions on technical issues
- ❑ Innovative designs, highly complex, first of a kind, or prototypes
- ❑ Incomplete studies (geotech, hydrology and hydraulic, structural, HTRW, etc.)
- ❑ Surveys late and/or surveys in question
- ❑ Sufficiency/availability of as-built data/base map data
- ❑ Borrow/fill sources identified/secured
- ❑ Sufficiency/condition of borrow/fill sites
- ❑ Right-of-way analysis in question
- ❑ Lacking critical subsurface information for under-water/in-water work
- ❑ Hazardous waste concerns
- ❑ Need for design exceptions or waivers
- ❑ Dredge estimate scope, quantities, and equipment:
  Correct dredge equipment decisions
  Consideration for adequate pumping for long pipeline runs
  Adequate disposal facilities in size and number

Lands and Damages

- ❑ Real Estate plan defined
- ❑ Status of real estate/easement acquisition
- ❑ Objections to right-of-way appraisal take more time and/or money
- ❑ Ancillary owner rights, ownerships in question
- ❑ Freeway agreements
- ❑ Railroad involvement
- ❑ Relocations identified
- ❑ Records/as-built availability/inaccuracies
- ❑ Known and unknown utility impacts
- ❑ Relocations may not happen in time
- ❑ Environmental mitigation needs identified
- ❑ Vagrancy, loitering issues
- ❑ Quality of lands and damages estimates as “Most Likely” case
- ❑ Hidden estimate/schedule contingencies

Regulatory and Environmental Risks

- ❑ Established requirements for initial project studies and potential impacts
- ❑ Environmental and Water quality issues
- ❑ Conforming to the state implementation plan for air quality
- ❑ Historic/cultural site, endangered species, or wetlands present
- ❑ Project in an area of high sensitivity for paleontology
- ❑ Project in an area of high sensitivity for cultural artifacts

- ❑ Numerous exclusion zones in project area/vicinity
- ❑ Hazardous waste preliminary site investigation required
- ❑ Status of critical environmental and regulatory studies
- ❑ Status of permits
- ❑ Lack of specialized staff (biology, anthropology, archeology, etc.)
- ❑ Reviewing agency requires higher-level review than assumed
- ❑ Permits or agency actions delayed or take longer than expected
- ❑ Reviewing agency requires higher-level review than assumed
- ❑ Potential for critical regulation changes
- ❑ New permits or new information required
- ❑ Project in the coastal zone
- ❑ Project on a scenic highway, state, or national park
- ❑ Negative community impacts expected
- ❑ Pressure to compress the study and permitting activities

Construction Risks

- ❑ Accelerated contract schedule
- ❑ Inefficient contractor
- ❑ Subcontractor capabilities
- ❑ Conflicts with other contracts
- ❑ Innovative project construction
- ❑ Timely delivery of critical Government-furnished equipment
- ❑ Permits, licenses, and submittal approvals
- ❑ Permit and environmental work windows
- ❑ Environmental restrictions (equipment use, exhaust, and paint fumes)
- ❑ Site access/restrictions (highways, bridges, dams, water, overhead/underground utilities)
- ❑ Adequate staging areas
- ❑ Rural/remote locale
- ❑ Inadequate skilled trades available for labor force
- ❑ Inadequate housing/utilities to support labor force
- ❑ Special equipment and equipment availability
- ❑ Material availability and delivery
- ❑ Productivity of critical work items
- ❑ Critical fabrication and delivery
- ❑ Unknown utilities
- ❑ Survey information
- ❑ Limited transportation/haul routes available
- ❑ Transportation/haul routes constricted or unusable during periods of time
- ❑ Unusual transportation haul distances
- ❑ Regulatory/operational work windows or outage periods
- ❑ Restricted schedule, accelerated schedule impacts
- ❑ In-water work

- ❑ Control and diversion of water
- ❑ Differing site conditions
- ❑ Unidentified hazardous waste
- ❑ Historic change order or modification growth
- ❑ Consideration for standard weather impact
- ❑ Adequacy of construction schedule depicting durations, sequencing, phasing, and production rates

Estimate and Schedule Risks
- ❑ Estimate captures scope for all project features
- ❑ Estimate developed for current scope and design level
- ❑ Estimates developed in Microcomputer Aided Cost Engineering System MII and/or Cost Engineering Dredge Estimating Program
- ❑ Estimate quality related to lesser designed features
- ❑ Estimate(s) quality when developed by others
- ❑ Estimate confidence in large and critical quantities
- ❑ Estimate include waste/dropoff quantities
- ❑ Estimate reflects local market for labor and subsistence
- ❑ Estimate reasonableness of crews and productivities
- ❑ Estimate reflects local material costs and delivery
- ❑ Parametric estimates for unit prices adequate for critical items
- ❑ Consideration and local quotes for special equipment (cranes, barges, tugs, and diving)
- ❑ Prime and subcontractor structure matches likely acquisition strategy
- ❑ Adequate schedule depicting all project features
- ❑ Schedule matches preconstruction engineering and design plan
- ❑ Schedule portrays critical construction features, matching estimate productivity
- ❑ Schedule depicts logical construction sequencing, phasing, and parallel activities
- ❑ Estimate and schedule reflecting “Most Likely” occurrence
- ❑ Overall confidence in estimate and schedule

External Risks
- ❑ Adequacy of project funding (incremental or full funding)
- ❑ Priorities change on existing program
- ❑ Local communities pose objections
- ❑ Loss of public trust/goodwill
- ❑ Political factors change at local, state, or federal
- ❑ Stakeholders request late changes
- ❑ New stakeholders emerge and demand new work
- ❑ Influential stakeholders request additional needs to serve other purposes
- ❑ Political opposition/threat of lawsuits
- ❑ Stakeholders choose time and/or cost over quality
- ❑ Market conditions and bidding competition

- Unexpected escalation on key materials
- Labor disruptions
- Acts of God (seismic events: volcanic activity, earthquakes, tsunamis; or severe weather: freezing, flooding or hurricane)