US Army Corps of Engineers®

Directory of Expertise for Civil Works
Cost Engineering

COST AND SCHEDULE RISK ANALYSIS GUIDANCE

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COST AND SCHEDULE RISK ANALYSIS GUIDANCE

1. PURPOSE

The purpose of this document is to provide the guidance and processes recommended to perform an acceptable cost and schedule risk analysis (CSRA) that meets Headquarters (HQ), U.S. Army Corps of Engineers (USACE), requirements and successfully passes an agency technical review (ATR). This document was prepared by the USACE Cost Engineering Directory of Expertise (DX). The DX provides cost engineering guidance, performs CSRAs, ATRs, and has available both large and small business indefinite delivery, indefinite quantity (IDIQ) cost engineering contracts serving the USACE at a national level.

HQ mandates the CSRA requirement to enforce improvements in establishing the cost and schedule risk and resulting contingencies that are used within the calculation of the Total Project Cost (TPC). The CSRA is part of the greater emphasis to produce quality TPCs.

This document is not meant to serve as the risk management process. The CSRA is just a portion of a risk management strategy and should not be mistaken as the process. The CSRA is a management tool that supports the risk management process. During the course of project execution, the prudent project manager (PM) may choose to monitor and update the CSRA as the project evolves and risks change, regardless of the mandated requirements.

Many informational sources are available and recommended for the PM and the project delivery team (PDT). Among these sources is the Project Management Body of Knowledge (PMBoK) published by the Project Management Institute (PMI).

2. APPLICABILITY

This guidance applies to all HQ USACE decision documents prepared for Congressional authorization and appropriation for any project where the total project cost exceeds $40 million. It also applies to any funding document prepared where HQ USACE, Division offices, or upper management has made a request for a CSRA to support the project.

3. DISTRIBUTION STATEMENT

Approved for public release; distribution is unlimited.

4. REFERENCES

- Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works Projects.
- ER 1110-2-1302, Civil Works Cost Engineering.
- Engineer Circular (EC) 1105-2-410, Review of Decision Documents.

- Engineer Technical Letter (ETL) 1110-2-573, Construction Cost Estimating Guide for Civil Works.
- Engineer Circular Bulletin (ECB) 2007-17, Application of Cost Risk Analysis Methods to Develop Contingencies for Civil Works Total Project Costs, dated 10 Sep 2007.
- CECW-CE Memorandum, dated 3 Jul 2007 by Major General Riley.
- CECW-CP Memorandum, dated 19 Sep 2007, Initiatives to Improve Accuracy of Total Project Costs in Civil Works Feasibility Studies Requiring Congressional Authorization.
- PMBoK Guide, published by PMI.

5. GUIDANCE

In accordance with ECB No. 2007-17, dated 10 September 2007, "Cost risk analysis methods will be used for the development of contingency for the Civil Works Total Project Cost estimate. It is the process of identifying and measuring the cost and schedule impact of project uncertainties on the estimated total project cost. When considerable uncertainties are identified, cost risk analysis 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 an effective additional tool to assist in the decision making process associated with project planning and design."

The ECB further states, "A formal cost risk analysis shall be prepared for all decision documents requiring congressional authorization for projects exceeding forty million dollars. This applies to USACE commands having design and/or construction responsibilities for Civil Works."

The ECB continues by assigning the cost engineer the responsibility for conducting the CSRA for development of project contingencies. The Project Delivery Team (PDT) shall assist the cost engineer in establishing project contingencies by identifying risks and their potential impacts to cost and schedule. Crystal Ball software shall be used to conduct the CSRA.

Memorandum CECW-CE (1110), dated 3 July 2007, from Major General Don T. Riley "...directs the use of specific cost risk analysis methods for the development of contingency on Civil Works Total Project Cost. This is applicable for all decision documents requiring Congressional authorization for projects exceeding $40 million."

HQ’s intention is that any document going forward to Congress requesting funding requires a formal risk analysis if the Total Project Cost is greater than $40 million. For consistency in software usage, HQ mandates the use of Crystal Ball software to perform the CSRAs.

There are several recent HQ documents that have been updated to address this new requirement. Other regulations are currently under revision:

- EC 1105-2-410, Review of Decision Documents, dated 1 Jul 2008.
- ER 1110-2-1150, Engineering and Design for Civil Works Projects.

- ER 1110-2-1302, Civil Works Cost Engineering, dated 15 Sep 2008.
- ETL 1110-2-573, Construction Cost Estimating Guide for Civil Works, dated 30 Sep 2008.

In general, the “decision document” (as referenced in ECB No. 2007-17) typically occurs at the feasibility stage of the design process, following the reconnaissance phase. The feasibility phase includes further investigations and studies of various alternatives to determine whether a Federal project can and should solve the identified problem. The recommended solution is then sent forward to Congress with an authorization and funding request (ER 1110-2-1150), while a CSRA is mandatory for the “decision document” for project estimates above $40 million.

While HQ requires a CSRA at feasibility level or for Congressional reports and decision documents, the initial risk discussions can begin much earlier, and it is recommended that the process continue throughout the project life. HQ recommends a continuation through project completion as a prudent project risk management tool. This is especially important on large projects over extended years where project scope, costs, and risks have a greater chance of design change and evolving risks.

6. CSRA OVERVIEW

The goal of risk management is to identify project risks and develop strategies to manage those risks. In that process of managing and mitigating risks, there are likely project opportunities and benefits that are realized. Four main building blocks of the risk management process are **identification, assessment, response, and documentation**. The CSRA process addresses the “identification” and “assessment” portions of the risk management process. The activities of “response” and “documentation” are PM and PDT management efforts to mitigate, monitor, and manage the risks throughout the life of the project. On larger projects over extended years, industry chooses to continue the risk analysis process, recognizing that as the project evolves and risks are mitigated, new risks may become apparent. The CSRA process is a tool used to study the new risk potentials throughout the project life.

The CSRA identification and assessment portions focus on the total project. The outcome identifies the more critical risks to the project cost and schedule and assists in establishing contingencies to manage the project to completion. In figure 1, note the point estimate change and growth over time and scope development. The figure illustrates a common project evolution whereby the final cost is beyond the originally developed scope and the budgeted total project cost estimates. For this reason, it is important to begin this process early in project development so that the risks determined over time can be managed, planned for and mitigated as much as practical to remain within the appropriated budget. It is critical that the CSRA be performed on the best known confident scope available with the most likely cost estimate and schedule; otherwise, the contingencies developed from the CSRA may be too low and unable to capture the funding needed as the project scope is further developed.

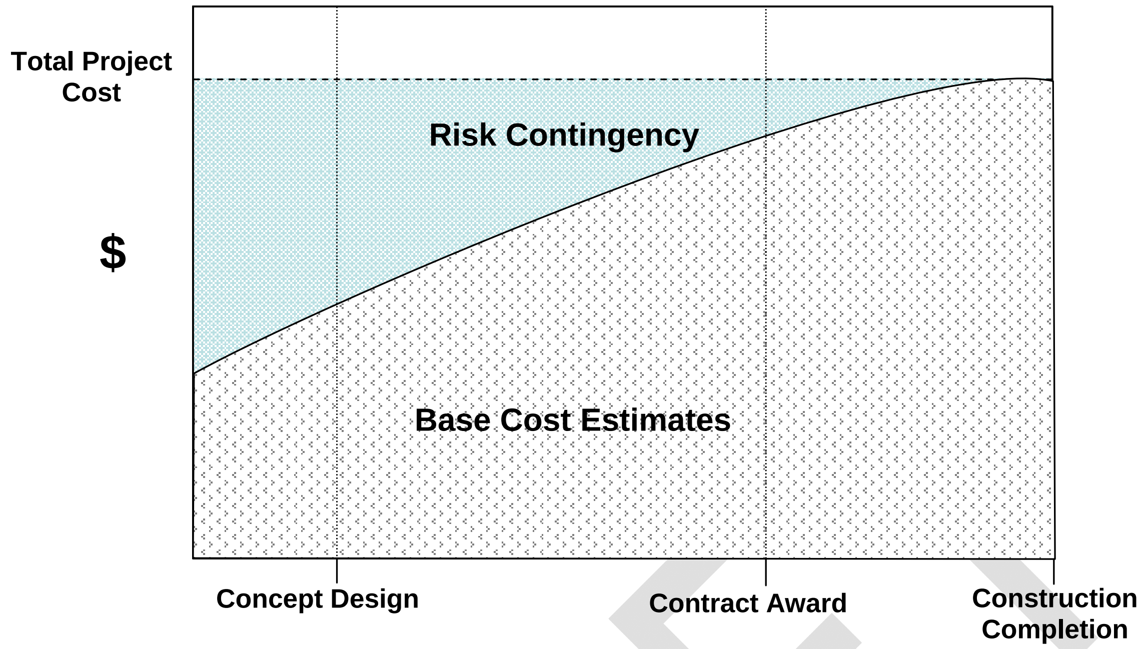

Figure 1. Project Evolution Over Time

The CSRA is the process of determining the risks associated with the studied project. The CSRA attempts to quantify potential value variance of the risks as related to the project cost and schedule. The results are expressed as contingency amounts in the form of dollars and time with reflective confidence levels for successful execution. It is a formal documented process that includes PDT involvement, utilizing nationally recognized Crystal Ball software based on the Monte Carlo principles.

To meet HQ requirements, a CSRA must be performed on the total project cost, including all features of the project, but excluding escalation and contingency. When considering total project features, refer to the USACE Civil Works Work Breakdown Structure (CWWBS) that is required for funds management (ER 1110-2-1302). Appendix A includes the higher level CWWBS). Too often, risk studies focus on just the construction activities, which can result in critical risk elements remaining unidentified and unmanaged. Through early determination of potential project risks, management can then focus efforts to mitigate those risks and realize opportunities for cost and schedule savings.

As directed in ECB 2007-17, a formal risk analysis must be accomplished as a joint analysis between the PM, the cost engineer, and the PDT members that have specific knowledge and expertise on all possible project risks for all features and internal risks as well as external risks. Internal risks are those related specifically to the project, many within the control of the PDT. External risks are those outside forces that can impact the project with little PDT control. The advantages to performing risk analyses on the more significant projects include:

- Involving PDT to share risk concerns and communicate as a team.
- Establishing contingencies supported by PDT involvement and studies.

- Defining and targeting high risk areas for management and mitigation.
- Possibly realizing cost and schedule opportunities similar to value engineering processes.

7. RESPONSIBILITIES

7.1 Project Manager

The responsibility to adhere to the CSRA process lies predominantly with the project manager (PM) that leads the project. The PM responsibilities include:

- Determining the need for a CSRA based on regulation requirements and/or what is reasonable for a healthy project execution.
- Developing a project management plan (PMP) that addresses risk management, the CSRA requirements and its execution.
- Supporting the CSRA process related to budgeting, scheduling, and team formulation to accomplish the CSRA.
- Identifying risk mitigation areas.
- Assisting management in establishing the contingency level based on the CSRA confidence curves.
- Monitoring and managing recognized risk items that may impact successful execution of the budget and schedule.
- Evaluating the need for follow-on CSRAs.

The PM can also serve as the CSRA meeting facilitator; however, it is recommended a senior cost engineer or a seasoned risk analyst perform this function. A confident facilitator, knowledgeable with the type of project work, is needed to actively engage and encourage communication amongst the PDT.

7.2 Cost Engineer/Risk Analyst

The cost engineering office is tasked to perform the CSRA as well as present the final report within the cost engineering appendix. In support of the CSRA, the cost engineer will likely lead the market research that supports the CSRA.

A senior cost engineer is typically assigned the role as the risk analyst and many times serves as a meeting facilitator to lead the PDT through the CSRA process, i.e., PDT discussions to develop the initial risk register and establish the resulting CSRA conclusions. Cost engineering personnel are trained in the CSRA process and have been provided the Crystal Ball licensed software, which is administered by the Cost Engineering Branch located at USACE, Huntsville District.

7.3 Project Delivery Team

The PDT, in support of the CSRA process, should involve all major members that have knowledge of the specific project and critical responsibility for development and management of the total project and all project features. The CSRA is to be performed on total project costs, not just construction costs. Typical PDT representatives involved with a CSRA are from the following:

- Project and planning management.
- Contracting and acquisition.
- Real estate and relocations.
- Environmental.
- Technical design.
- Estimators and schedulers.
- Risk Analyst/Facilitator.
- Construction.
- Operations.
- Sponsors.
- Others with critical input.

8. DOCUMENTS REQUIRED FOR A CSRA

The starting documents recommended for beginning a CSRA include:

- Well-developed project scope.
- Quality estimate excluding contingency and escalation.
- Schedule reflecting the estimate.
- Expended project costs and durations.
- This guidance document.*
- Crystal Ball software used to run a CSRA.
- Risk presentation to educate the PDT.*
- PDT risk checklist presenting typical risks considered.*
- Sample risk register.*
- Sample cost and schedule risk templates/models.
- Sample report of the process, outcome, and recommendations.

*These documents are maintained by the Cost Engineering Directory of Expertise (DX) at USACE, Walla Walla District. Note that this is the same DX charged with maintaining the Construction Equipment Ownership and Operating Expense Schedule (EP 1110-1-8) and the Construction Cost Indices for Civil Works Projects (EM 1110-2-1304).

The DX maintains a web site where this guidance and sample documents can be obtained by USACE and contractors.

http://www.nww.usace.army.mil/html/OFFICES/Ed/C/default.htm

9. STARTING THE CSRA PROCESS

The main building blocks of the risk management process include accomplishing a CSRA. Figure 2 illustrates the cost and schedule risk analysis process. Note the separation of the cost and schedule processes, since each requires a separate analysis.

Cost and Schedule Risk Analysis Flow Chart

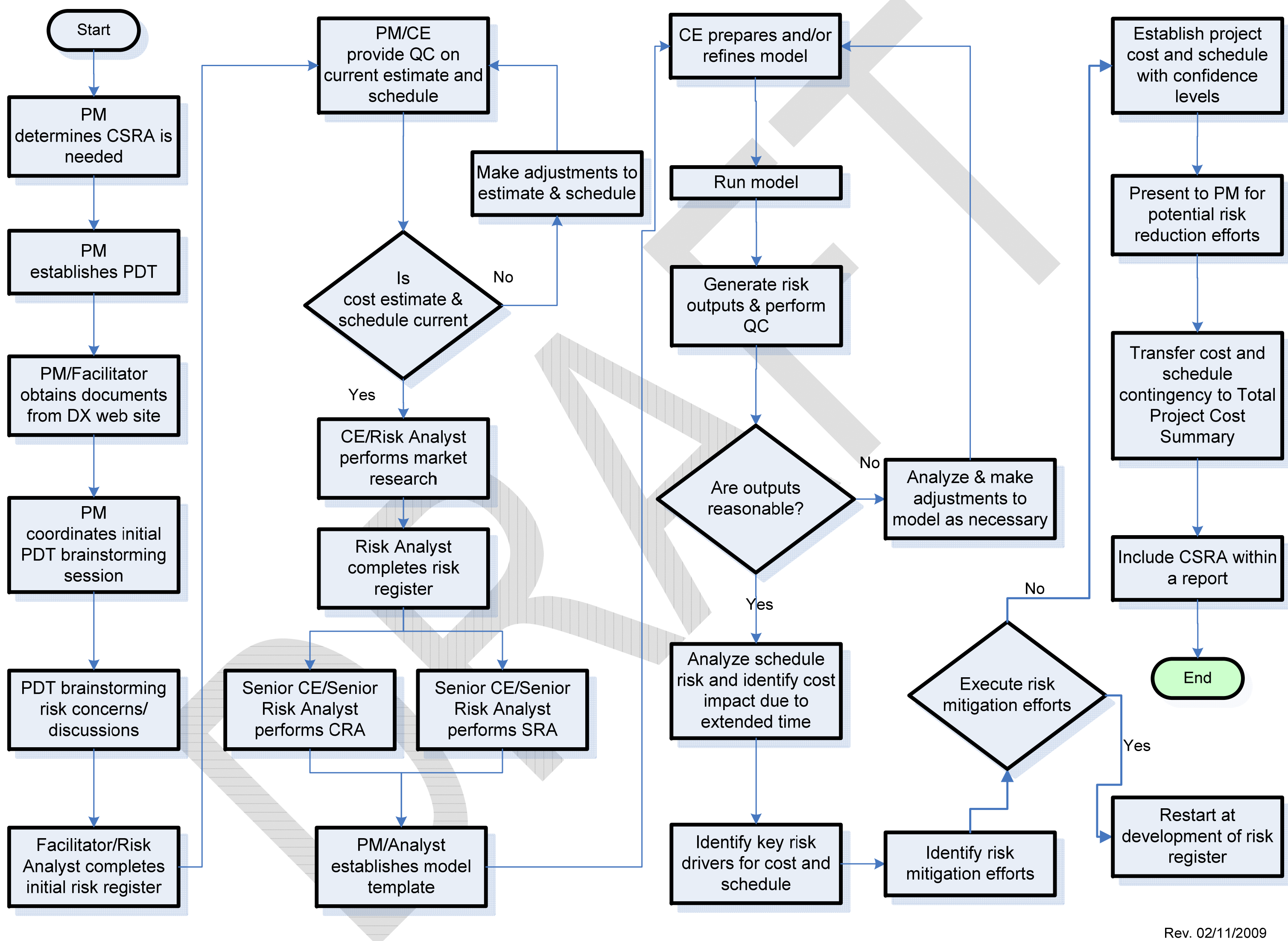

Figure 2. CSRA Flow Chart

9.1 CSRA Determination

CSRA is recommended for all projects that are large, complex, have high visibility or critical funding constraints. CSRA are required for certain projects. Based on HQ guidance, the PM must determine whether a CSRA is required or prudent for the project. The PM may consult the current USACE regulations and guidance or HQ. As a rule, well-defined scope is the critical element that then establishes the current cost estimates, and schedules. The poorer these products, the greater the risks and resulting contingencies. As scope is improved and more confident designs are developed, contingencies normally decrease.

The risk management process should be included within the PMP, which should include the four main risk management building blocks: identification, assessment, response, and documentation.

9.2 Initial CSRA Preparations

The PM should ensure an adequate total project cost estimate and reflective schedule has been prepared to support the CSRA process. The total project scope must be reflected within the two products. ER 1110-2-1150, ER 1110-2-1302, and ETL 1110-2-573 provide further guidance related to the expected quality level.

The PM must establish the PDT. The PDT is comprised of senior members with knowledge of the project scope as well as the associated potential risks, opportunities, and unknowns.

The PM must determine what project costs and durations have already been expended, since these should not be part of the CSRA.

In preparation for the initial PDT risk discussions that prepare the first risk register (the document used to support the CSRA), it is recommended that the PM distribute to the PDT a list of potential risks that are commonly encountered. A PDT risk checklist is available on the Cost Engineering DX web site. The checklist is a compilation of common risks encountered by USACE, DOE, and state Departments of Transportation. After reviewing the checklist, the PDT members will be better prepared to present their risk concerns at the PDT brainstorming meeting where the risks are discussed and captured within the initial risk register (the document used to support the CSRA).

9.3 Initial Risk Discussions

The PDT brainstorming session is the initial attempt to develop the risk register that serves as the basis for the CSRA. In order to prepare the initial risk register supporting the CSRA, certain coordination steps are recommended. These recommendations are based on experience in performing CSRAs within the USACE environment.

9.3.1 PDT Coordination

The PM will coordinate an initial risk discussion meeting, also referred to as a PDT brainstorming session. This is the first meeting where the PDT attempts to collectively capture the total project risks and place them into the risk register. It is highly recommended that the brainstorming session include the major PDT members, because the dialogue between the members typically results in scope clarification or change, findings of new risks, even possibly revising the estimates and the schedules. It is also the best opportunity to address all features of the project.

9.3.2 CSRA Presentation

To begin the PDT brainstorming session, it is recommended that the designated facilitator begin with a CSRA presentation. A confident facilitator, knowledgeable with the type of work, is needed to actively engage and encourage discussion and communication amongst the PDT. Like a value engineering study, all concerns are valid, considered, and captured within the risk register. The Cost Engineering DX has a CSRA slide show presentation available on its web site.

9.3.3 Project Scope Presentation

Following the CSRA presentation, it is highly recommended that the PM present the project scope. This presentation will lead the PDT into risk discussions. The presentation should include the major construction features.

9.3.4 PDT Brainstorming Session

The PDT brainstorming session is the opportunity to bring the PDT together to qualitatively define the risk concerns as well as potential opportunities. To lead the PDT through the discussions, an effective approach is to simply work down the PDT risk checklist. This ensures that the each major PDT member is given equal opportunity to address their concerns. As the concerns are discussed, the facilitator or risk analyst begins developing the initial risk register that supports the CSRA, capturing the PDT's concerns and discussions. This session can result in revised estimates and schedules.

9.3.5 Completing Initial Risk Register

The recommended software for risk registers is Excel (a sample risk register in Excel is available on the DX website). The risk register will serve as the basis for the CSRA model, which is run in Crystal Ball. Crystal Ball software utilizes Excel in its CSRA application. When referring to the risk register, the PDT should simply focus on the following columns:

- Risk/Opportunity – Event.
- PDT Event Concerns.
- PDT Discussions.
- Responsibility/POC.

- Project Cost: Likelihood, Impact, and Risk Level.
- Project Schedule: Likelihood, Impact, and Risk Level.

The remaining risk register columns will be completed by the risk analyst during the market research and the CSRA model development. A PDT risk register is provided in appendix A and sample risk registers are provided in appendix B.

The PDT should capture all concerns for all project features even if the risk level is considered low. The register serves as an archive of discussions and there is potential that those low-level risks may become higher following market studies, more information made available, or through time during the risk management and mitigation processes.

Within the risk register, the PDT concerns and discussions must be adequately and clearly captured, because the logic presented in those discussions must support the “likelihood” and “impact” decisions reflected within the risk register. While this product is the initial risk register, it has already captured the PDT’s greater concerns. The PDT can begin using this data to prepare for project risk management.

10. ESTIMATE AND SCHEDULE ATR

The CSRA can begin before the estimate and schedule have received an adequate review. This may be a reasonable approach if the PM is keenly interested in quantifying the potential impacts from the established risk events. However, if an ATR later determines critical changes in the estimate and schedule are needed, the CSRA may have to be adjusted.

Once the initial risk register is complete, the PM and cost engineer, responsible for the estimate and schedule, must consider whether the current estimate and schedule truly represent the most likely case. Often times, PDT discussions will present scope changes or processes that may impact the current estimate and schedule. There could be a different construction approach. There could be items such as revised productivity or crew makeup. Other PDT members may choose to revise their portions of the feature costs and schedules that reside within their area of responsibility. Remember that ER 1110-2-1302 makes the cost engineer responsible for the construction costs and schedules. Other PDT members are responsible for their portions, such as project management, real estate, relocations, contract acquisition, design studies, construction management, etc. The PM must confirm from the PDT whether these areas must be further developed or improved to reflect the most likely case estimate and schedule that serve as the basis for the market studies and the CSRA product. Those estimates must exclude contingency, because the CSRA process will establish the contingency values. The risk analyst must remove the expended costs and durations from the CSRA, since these have little to no risk.

Before the CSRA models are made ready, it is advisable that the total project cost estimate and schedule have adequately passed an internal quality control (QC) and an ATR. Should they fail, another CSRA may have to be performed.

11. MARKET RESEARCH

Once the initial risk register is completed and the PDT is confident that the total project estimate and schedule reflect the most likely case, the initial risk register is ready for the risk analyst to begin the market research. The analyst will use the risk register items as a basis for what cost and schedule items will be studied as well as use the most likely estimate and schedule as a basis of comparison and measure. The market research supports the quantitative portion of the CSRA, establishing actual values or ranges in cost and schedule. It is intended to validate the presumed risk levels within the initial risk register for both cost and schedule. The market analysis will help establish the "most optimistic" (also referred to as the "best case" or "low value"), the "most likely case" (commonly the existing estimate and schedule), and the "worst case" (also referred to as the "high value"). These three points or values will be used within the Crystal Ball risk model.

The study may require PDT interviews, historical data research, internet searches, etc. Issues may include items such as real estate fluctuations, land acquisition and easements, construction productivity concerns, significant weather impacts, fuel pricing, construction modifications, specialized equipment and material availability, local labor resources and rates, potential scope growth, bidding competition, effects resulting from the acquisition strategy, economic trends, etc.

12. RISK REGISTER COMPLETION

This section describes the completion of the risk register. Crystal Ball model preparation is described separately for cost and schedule in subsequent sections of this document.

To finalize the risk register, market research may result in the risk analyst revising the risk register as he/she prepares the final risk register for the CSRA models. Refinement may reveal similar risk events that could duplicate or double count a risk impact. It may result in adding risk/opportunity events not previously captured. It may result in revising the "likelihood" and "impact" values to support a revised risk level that reflects the research findings. Should the likelihood and impact values be revised, the PDT concerns and discussions may have to be reevaluated to ensure that they logically support the revised risk register.

The market research will enable the risk analyst to compete the risk register columns:

- Cost Impacts.
- Cost Variations (best and worst case).
- Schedule Impacts.
- Schedule Variations (best and worst case).
- Correlation of Risks to One Another.
- Affected Project Component.
- Project Implications.

12.1 Cost Impacts and Distribution

The market analysis will help establish the most optimistic (also referred to as the best case or low value), the most likely case (commonly the existing estimate), and the worst case (also referred to as the high value). These three points or values will be used within the Crystal Ball risk model and serve as the variance curves. The best and worst case impacts can be indicated in dollars or percent.

12.2 Schedule Impacts and Distribution

The market analysis will help establish the best case, the most likely case, and the worst case values. These three points or values will be used within the Crystal Ball risk model and serve as the variance curves. The impacts can be indicated in months or percent.

12.3 Correlations

Many times, risk events have a correlation or relationship to one another. A positive correlation occurs when one risk goes higher, so must the other. A negative or adverse correlation occurs when one risk increases, the other must decrease. To complete the risk register, note the correlation relationships. When preparing the model, more instructions will be provided; however, it is highly recommended to minimize correlations before running the risk model, because they may impact the resulting output. There are methods used to minimize the correlations. One can combine like correlations into one risk event. If revision is not possible, then the correlation must be modeled, based on the positive or negative event relationships.

12.4 Risk Register Quality Control Check

Upon completion of the market research, the risk analyst should complete the risk register, confident that the:

- PDT risk/opportunity events are adequately captured/conveyed.
- PDT discussions support the ”likelihood” and “impact” decisions.
- Market research supports the risk level assigned.
- Current estimate and schedule serve as the most likely case for the CSRA.
- Correlations and event duplication are minimized and addressed.
- Market research adequately defines the cost and schedule variations.

13. COST RISK MODEL DEVELOPMENT

Sections 13 and 14 are intended for readers with a basic understanding of using Crystal Ball software for the CSRA. PMs can skip to section 15. The following guidance separates the processes related to the cost risk analysis (CRA) and the schedule risk analysis (SRA), because the two are performed somewhat differently, yet use the same basic tools.

The cost risk model development and resulting CRA are most commonly performed by a trained senior cost engineer and/or a senior risk analyst. On larger projects, this may require several members to study the initial risk register, evaluate the concerns captured within the brainstorming session(s), perform market studies of those risk events, and validate whether the PDT's risk level assignments are accurate.

13.1 Cost Risk Model Template

The risk model utilizes the risk register as its basis within the Excel format. The risk analyst and the PM must determine the best modeling method that provides adequate CRA model output for the project. The result is a customized model specifically related to the project. The final product must present contingencies in the desired format for the total project cost estimate. For example, risk analyses can be performed on each contract (assuming several contracts), on each project feature, or on the total project base cost.

13.1.1 Methods

In developing the cost risk model template, two common approaches are recommended. The approaches are dependent upon what the PM prefers as the outcome when establishing the contingencies. For example, if just a single project or contract is planned, the PDT may desire a single contingency value. The PM may prefer a contingency developed for each project feature. If several projects or contracts are planned, the PM may desire a separate contingency for each project. These issues should be resolved before preparation of the CRA model. Typical approaches currently used:

- Risk event based: Develop the model to reflect the completed risk register. In a sense, the risk register becomes the model. In that way, the Crystal Ball outputs directly reflect the risk register's risk events established by the PDT. This output well supports the PDT when related to document traceability, risk management, and follow-on risk studies. The CRA output is risk based and typically presents the contingency per each project. This method can be obtained from the Cost Engineering DX.
- Cost based: This method might be used when several contracts are being studied within the program and separate contract contingencies or feature contingencies are desired. The resulting model reflects the work breakdown structure (WBS) within the estimate(s). To pursue this avenue, the CRA model is developed by downloading the most likely estimate into an Excel file at the chosen WBS level that best relates to the risk register. Once that is accomplished, refer to the market study and the various risk events, creating the best and worst case estimates, again reflecting the chosen WBS. The CRA output is cost based, because it reflects the WBS within the estimate template and is more intuitive for the cost engineer. The advantage is that the model output can better reflect multiple project features, contracts or different funding accounts. The disadvantage is that it does not directly correlate to the risk events established by the PDT and is less traceable to the risk register. If this

alternative is chosen, the report must document how the CRA outputs relate to the risk register event concerns.

Table 1 is a sample of the risk event method. Note that the model focuses on certain risk register categories and the market research values related to best case, most likely, and worst case. The entire risk register can be included; however, it can be cumbersome when producing paper documents and reports. The key risk register columns are:

- Risk No.
- Risk/Opportunity Event.
- Risk Level.
- Variance Distribution.
- Correlation to Others.

Table 1. Sample Cost Risk Model

					Crystal Ball Simulation Using $			
					Expected Values ($$$)			
Risk No.	Risk/Opportunity Event	Risk Level*	Variance Distribution	Correlation to Other(s)	Low ($ or %)	Most Likely	High ($ or %)	*Comments related to Risk Duplication or Correlation*
Internal Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)								
	PROJECT & PROGRAM MGMT							
PPM-1	Product Development by Several Sources	Moderate*	Triangular		$269,608,214	$283,798,120	$312,177,932	
PPM-5	Inefficient Contractor/Productivity of Critical Work Items	High	Triangular		$276,753,091	$283,798,120	$303,171,951	
	GENERAL AND ECONOMIC RISKS							
GE-2	Bidding Climate (Mobilization)	Moderate	Triangular*		$1,622,055	$1,908,300	$2,862,450	
GE-3	Contract Phasing/Timing of Contract Awards	Moderate	Uniform*	PR-5	$0	$0	$9,459,937	
GE-4	Design Development Stage Incomplete	Moderate*	Triangular		$241,228,402	$283,798,120	$326,367,838	

Table 1. Sample Cost Risk Model (Cont.)

GE-5	Inaccurate Design Assumptions	Moderate*	Triangular	GE-4	$255,418,308	$283,798,120	$354,747,650	***Removed From Study - Captured by GE-4***
GE-9	Negative Community Impacts	Moderate	Uniform	PR-2	$0	$0	$18,974,149	***Removed From Study - Captured by PR-2***
GE-11	Estimate Quality Related to Lesser Designed Features	Moderate*	Triangular	GE-4	$189,198,747	$210,220,830	$262,776,037	***Removed From Study - Captured by GE-4***
GE-12	Conflicts with Known/Unknown Utilities During Construction	High	Uniform		$0	$0	$21,284,859	
GE-13	Permit and Environmental Work Windows	Moderate	Uniform*		$0	$0	$8,610,591	
	Dredging/Disposal Activities							
DD-2	In-Water Work	Moderate	Triangular		$16,176,493	$17,027,887	$21,284,859	
	Cell/CDF Construction							
CD-1	Source for Stone	High	Triangular	CD-3	$146,660,050	$162,955,611	$203,694,514	***Removed From Study - Captured by CD-3***
CD-3	Material Availability and Delivery	High	Triangular		$150,382,223	$167,091,359	$200,509,630	

Table 1. Sample Cost Risk Model (Cont.)

	External Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)						
PR-1	Adequacy of Incremental Project Funding	High	Uniform		$0	$0	$29,222,415
PR-2	Local Communities Pose Objections/Loss of Public Trust/Political Factors Change	Moderate	Uniform	GE-9	$0	$0	$13,024,517
PR-3	Stakeholders Request Late Changes/Influential Stakeholders Request Additional Needs	Moderate*	Uniform		($14,189,906)	$0	$42,569,718
	OPPORTUNITIES						
PR-5	Market Conditions and Bidding Competition	High	Uniform		($56,759,624)	$0	$0
	All Other Project Costs (Placeholder)	N/A	N/A	N/A		($1,410,598,347)	
				***Changed during CSRA Study**		**$283,798,120**	

Instructions:
1) Enter all entries from the PDT risk register that were identified to be either moderate or high risk level into the cost model worksheet.
2) Create Reference Tab Worksheets for each studied item, studying and developing values, and documenting logic. This is especially important for traceability both internally and externally. If you ever have to dust the study off, you'll need a paper trail.
3) Copy and paste developed values into the cost model as numbers only -- Crystal Ball does not like formulas in assumption value data. Note that it is critical that the values from the estimate MUST NOT include contingency markups in MII.
4) Establish your assumption variable distributions on your most likely value cells. Determine the distribution type, then enter your parameters using cell references (this will eliminate going back and changing the values every time).
5) Establish your forecast value for total project cost (or total feature cost for a more complex estimate). The forecast value should be a formula, but it should equal the actual most likely project (or feature) cost. Use the placeholder line to ensure that you have correct number.

Table 1. Sample Cost Risk Model (Cont.)

6) Run the simulation, using 10,000 trials. Evaluate the result. Chances are, there will be some errors in your model, or some items that should be studied again or more closely. Rule of thumb is that for a feasibility level estimate, a healthy contingency at 80% confidence should land between 20% and 30%, or between 30% and 40% for a controversial, high-risk (and easy to document and defend) project. Utilize the Tornado Chart and the other tools to assist in the evaluation. Realistically, do the results make sense from a senior estimator’s intuitive judgment? If not, there's reason to believe the model may be in error. Look for items that might be double counted, or counted more heavily than they should be. Next, evaluate correlations -- perhaps they should be reduced, increased, or broken out into separate items. Evaluate whether the distributions chosen accurately reflect the true nature of the cost and how it behaves, and modify if necessary.
7) Rerun the simulation as many times as necessary to validate the model -- this is an iterative process. Once the result consistently validates the model, run the simulation for 100,000 trials. This enhances accuracy, but can take several minutes to complete.
8) If the results land within a reasonably expected range, then clean up the model and begin the final report, reporting the contingency and cost to the Project Manager. If the contingency is below 20%, then recommend revising the estimate, as it is "overdesigned" (already too pessimistic). If the contingency is above 40%, then recommend revising the estimate as it has some holes (too optimistic).
9) This sample was intended to serve as an example, but may be used to with some manipulation to perform an actual analysis. Two cautions: a) There will be some manipulation of the distributions and formulas required throughout the workbook -- check all the numbers and all the math! b) Every cost risk study is different and unique. It is necessary to "create" the model from scratch to suit the actual project being worked on -- one size does not fit all.
10) Remember also to study schedule separately!

13.1.2 Establishing the Risk Events for Study

It is recommended that the number of events under study within the model not exceed 8 to 15 risk items. The preferred study would include the high and moderate risks. The moderate risks are included, because their impact value may be higher than a high risk. Another decision sort could be those risks that may impact the total project estimate by at least 1 percent.

Table 1 depicts only the risk events under study; however, the risk analyst could still include all risk events within the model, simply ignoring those outside the study by not assigning a variance distribution.

13.1.3 Incorporating Market Research into Model

Once it has been established as to which risk events will be incorporated into the model, the market research findings can be added. For traceability purposes, the recommended approach is to create Excel tabs next to the risk model dedicated specifically for each risk event. The tabs will present the market findings and the logic used to determine the best and worst case values for each risk event. Those values are then placed into the model input to support the variance distribution. When assigning the distributions, the most likely case must be a hard value with no equations or links to other data. Remember that the most likely case should reflect the base estimate.

13.1.4 Establishing Variance Distribution

The variance distribution within Crystal Ball must only address those risk events under study.

Within the Crystal Ball software, the distribution gallery provides more than 20 diagram or curve choices that can represent the market research data related to best case, most likely, and worst case. The two most commonly used and recommended for first consideration are the triangular and the uniform distribution curves. Other curves may better address certain risks where better data exists and should be considered when more appropriate.

The triangular distribution (figure 3) is commonly used when the market research has established the best case, most likely, and worst cases: three distinct points, measured in dollars or percent. By definition, the most likely estimate has established what is most likely to occur. This distribution is recommended for the risks events that impact discreet areas or details of the estimate where one can determine that one cost value is more likely to occur than another value.

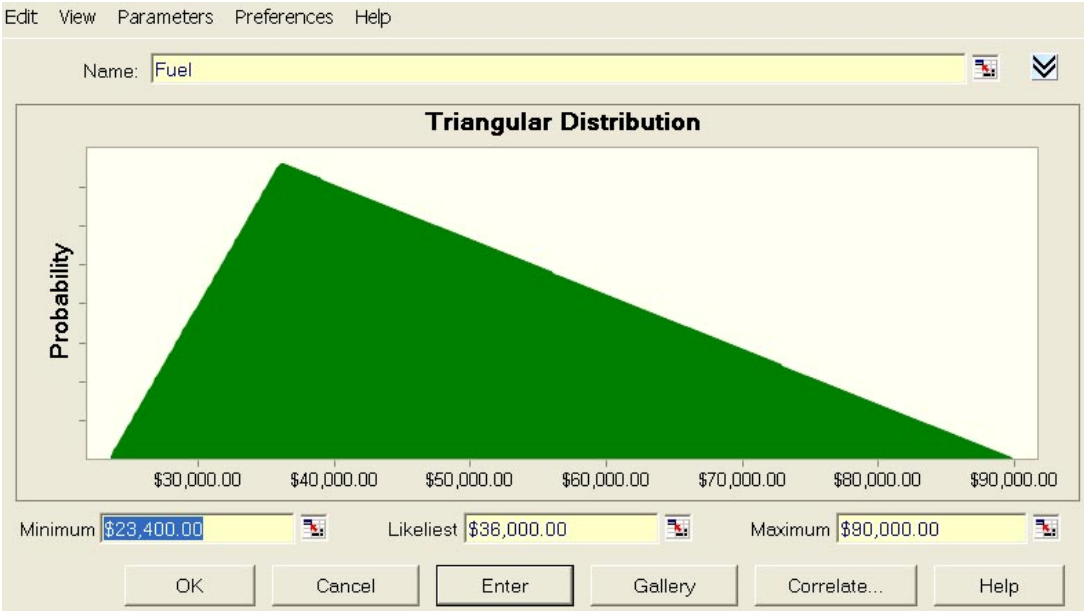

Figure 3. Example of Triangular Distribution

The uniform distribution (figure 4) is used when any value between the best case and worst case are equally likely to occur. In these instances, only two points are needed, the best and the worse case. This distribution is recommended when the risk events are more global to the project and a most likely occurrence cannot be established. Within the model, the best case is assigned a value equal-to/or less-than the most likely (cost estimate) value and the worst case is assigned a value equal-to/or greater-than the most likely (cost estimate) value.

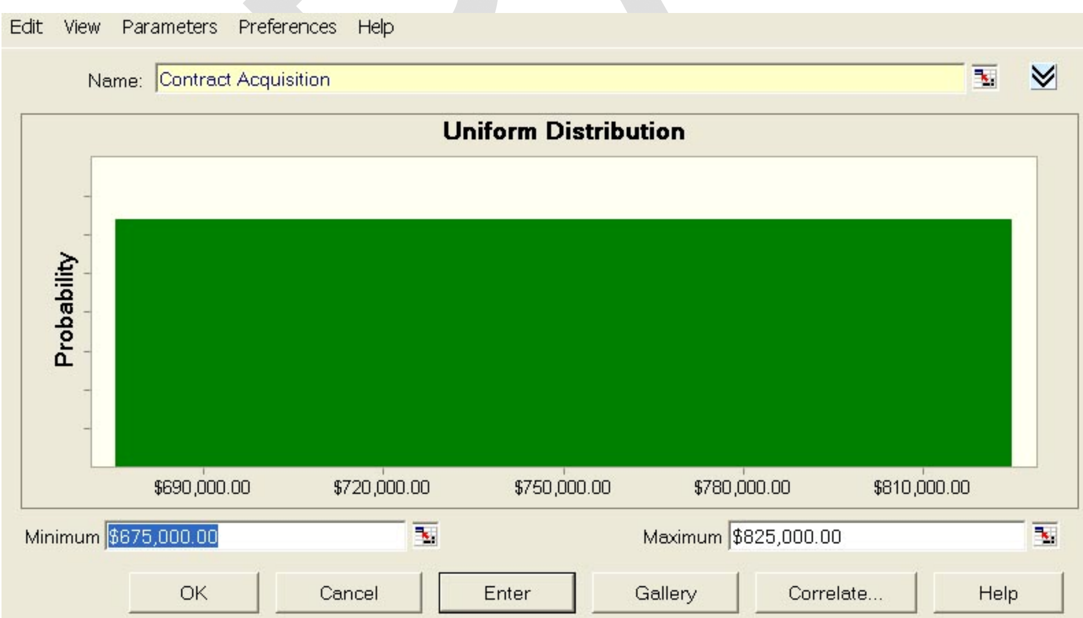

Figure 4. Example of Uniform Distribution

When assigning the variance distribution within the Crystal Ball model, for each risk event, the risk analyst must link the risk event title, the best case, most likely, and worst case values and address any correlations, both positive and negative, between the respective risk events.

13.1.5 Most Likely Cost Value

The Crystal Ball model will be run, targeting the most likely total value. Within the model, this is also referred to as the forecast value. The most likely value should reflect the most likely estimate total, encompassing all feature accounts, but excluding any escalation or contingency. The total value, or forecast value, is linked to the other most likely costs with an equation that enables the model to run and capture the variances.

Generally, the model under development at this stage does not total the most likely project estimate. An easy solution is to input a place risk event for all other project costs (placeholder). It may be a plus or minus value to bring the most likely value total to the current estimate total. Given the nature of the remaining costs, the risk analyst can choose whether a distribution variance is needed for inclusion into the risk model. For example, is the remaining placeholder cost value significant and at any significant risk?

13.2 Cost Risk Model Run

Within Crystal Ball, the risk analyst must set the model related to desired reports, decision variables, defining the forecast, establishing precisions, etc. Once the model includes the risk events under study, all distribution variances have been assigned, duplications and correlations addressed, and the most likely estimate captured, the risk analyst is ready for the initial model run.

13.2.1 Initial Model Run

By this time, the cost engineer and risk analyst should have a feel for the scope, the estimate, and the market research quality. It will be of value when reviewing the initial output data. The risk analyst evaluates the initial reports, reviewing areas of potential conflict or inaccuracy. Even if the contingency values appear reasonable, a QC check should still be performed.

Generally, several iterations will be performed as the model is studied for logic, assumptions, and values. Through several iterations, the model is corrected and improved; however, care must be given to ensure the model is not arbitrarily adjusted to output preferred results. Ultimately, the final product and report must reflect logic and pass an ATR.

13.2.2 Model Results Quality Check

After initial model or first trial is run, a quality check is required for reasonableness. The contingency calculations may seem too low or too high, based on the risk analyst's knowledge of the scope and estimate quality. If the contingency data falls significantly outside the anticipated range, there may be errors within the scope development, the most likely estimate, market research, or model development. Within the sensitivity chart (figure 5), the order of high risk events may seem unlikely or out of expected order.

Common mistakes include poor scope confidence. Perhaps the most likely estimate is actually too optimistic or too conservative. There may be similar risk events that are listed separately within the risk register, thereby measuring the risk twice. There may be critical risks absent, especially external risks. Another common error is failing to adequately consider correlation relationships between risk events. The distribution curves may have to be reevaluated. If another Excel spreadsheet is open, the software may have grabbed outside data. It is normal to run the model several times before a confident model is developed that reflects reasonable results for the known data.

13.3 Cost Risk Model Output

There are numerous Crystal Ball outputs that are helpful in presenting the data as well as supporting the CSRA report. While not all are portrayed in this guidance, the more common figures used to support the final report are presented in the following paragraphs. This data is obtained from the Crystal Ball report output after the risk simulation is run.

13.3.1 Sensitivity Chart

The sensitivity chart (figure 5) reflects the risk register areas of greatest concern (risk event based), rated in order of criticality, also referred to as the key risk drivers. It is commonly referred to as a tornado chart. Generally, the more common areas of high risk concern are scope development, contract acquisition, bidding climate, funding availability, and contract modifications.

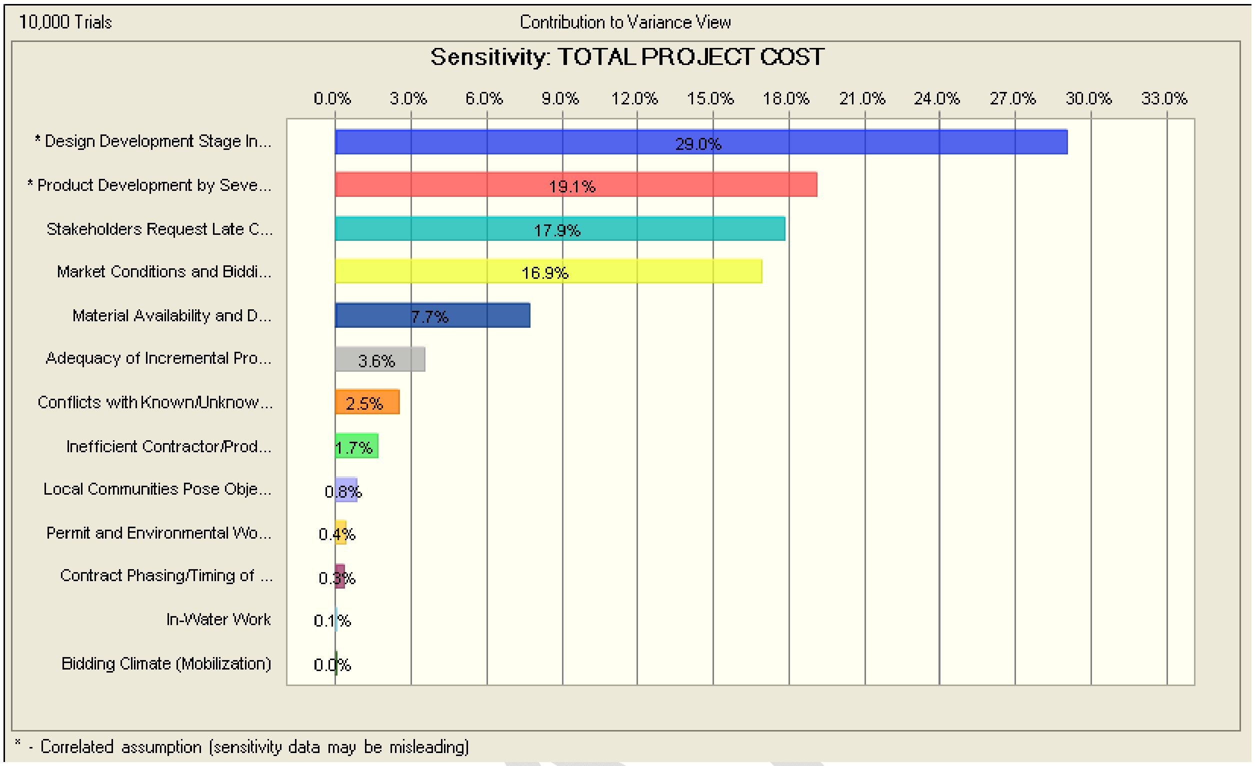

Figure 5. Sensitivity Chart for Cost

13.3.2 Total Project Contingency Analysis

The contingency analysis is measured against the most likely estimate in dollars. The output presents (table 2) the cost values based on the confidence levels for successful project execution and completion. It can be presented in tabular form and also represented graphically and termed as the confidence curve. The PM and management are left to decide what confidence level they prefer to present to Congress for authorization. Historically, Congress and the Assistant Secretary of the Army are accustomed to a contingency value with an 80 percent confidence of successful execution and completion. Examples are presented in figures 6 and 7.

Table 2. Contingency Analysis Output for Cost

Most Likely Cost Estimate	$ 283,798,120	
Confidence Level	**Value**	**Contingency**
0%	**$196,251,351**	**-30.85%**
5%	**$265,301,883**	**-6.52%**
10%	**$278,356,727**	**-1.92%**
15%	**$287,628,329**	**1.35%**
20%	**$294,426,931**	**3.75%**
25%	**$300,576,519**	**5.91%**
30%	**$306,044,712**	**7.84%**
35%	**$311,348,193**	**9.71%**
40%	**$316,463,923**	**11.51%**
45%	**$321,561,018**	**13.31%**
50%	**$325,920,859**	**14.84%**
55%	**$330,801,756**	**16.56%**
60%	**$335,990,370**	**18.39%**
65%	**$340,890,506**	**20.12%**
70%	**$346,028,517**	**21.93%**
75%	**$351,266,705**	**23.77%**
80%	**$357,691,114**	**26.04%**
85%	**$365,347,118**	**28.73%**
90%	**$373,567,089**	**31.63%**
95%	**$385,963,837**	**36.00%**
100%	**$455,670,837**	**60.56%**

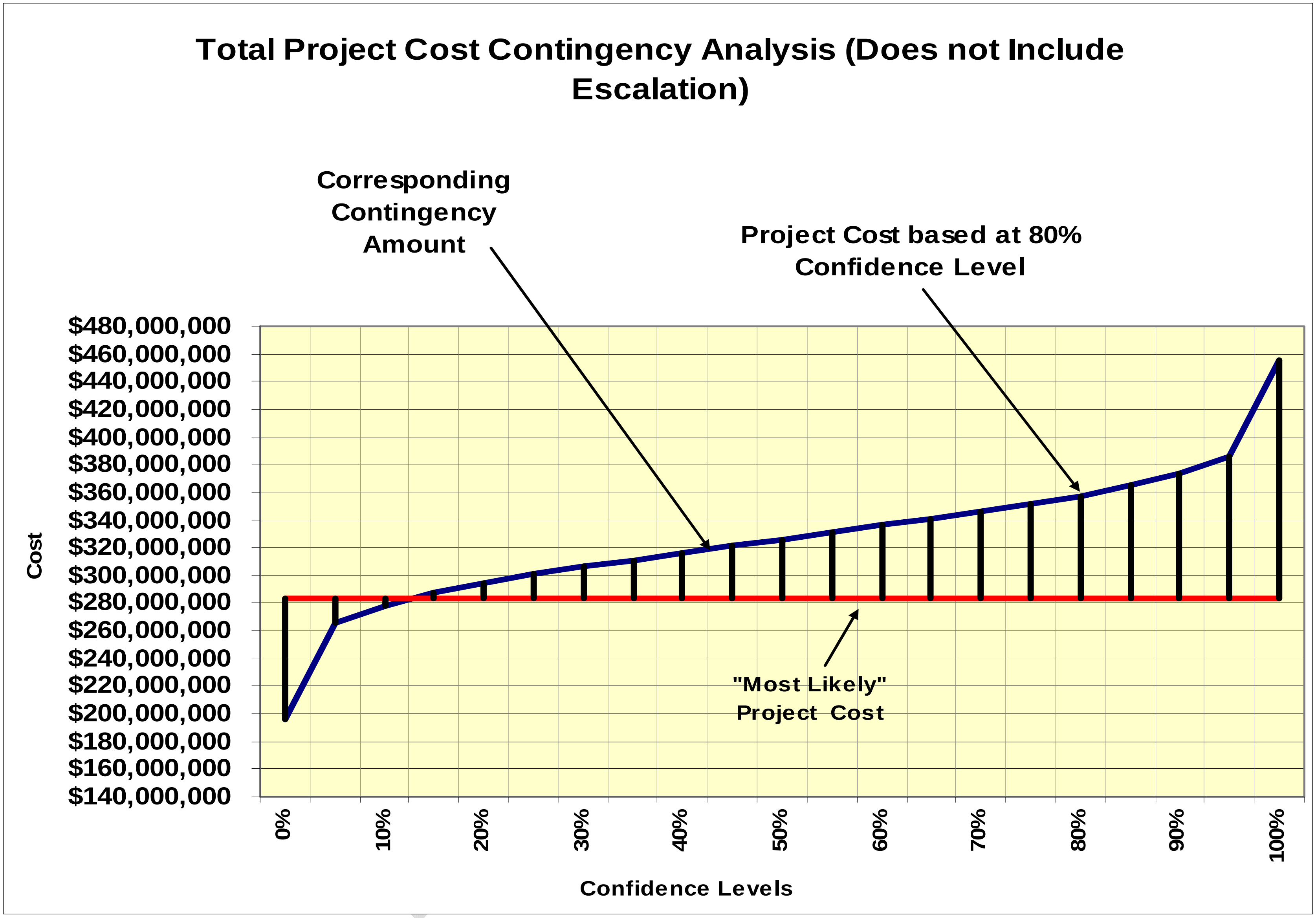

Figure 6. Total Project Cost Contingency Analysis

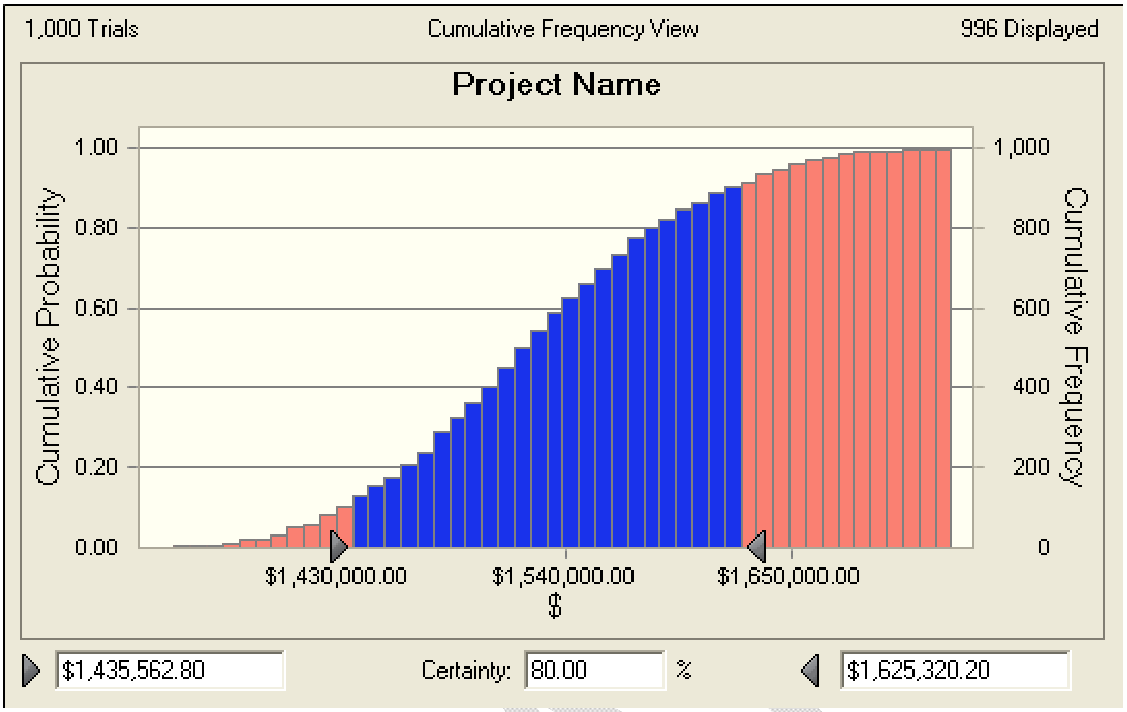

Figure 7. Cumulative Frequency View

14. SCHEDULE RISK MODEL DEVELOPMENT

The guidance prescribed for the schedule risk analysis (SRA) is treated somewhat differently than the CRA, but using the same basic tools. The output related to schedule growth in months is also portrayed as added contingency in cost when evaluating how schedule growth can affect cost. For example, added schedule growth may add escalation, it may add certain overheads to design or construction costs, etc.

The schedule risk model development and the resulting SRA are most commonly performed by a trained senior cost engineer and/or a senior risk analyst. On larger projects, this may require several members to study the initial risk register, evaluate the concerns captured within the brainstorming session(s), perform market studies of those risk events, and validate whether the PDT's risk level assignments are accurate.

To perform a reasonable SRA, an adequate schedule must be developed that reflects all project features, including the critical and near critical paths of those features. If the project is large and more complex, the construction schedule needs better development so that the risk analyst can determine what the schedule impacts would do to those durations. The construction schedule should reflect most likely estimate durations and how the PDT expects the construction to occur. Items such as site access and easements, long lead items, parallel or concurrent activities, and phasing and sequencing for the major construction and equipment items for the critical and near critical paths are critical for a confident result. Often times, the construction representatives are included in these discussions and are considered a valuable consulting asset.

14.1 Schedule Risk Model Template

The risk model utilizes the risk register as its basis within the Excel format. The risk analyst and the PM must determine the best approach to use that provides adequate SRA model output for the project. The result is a customized model specifically related to the project. The final product must present schedule growth contingencies in the desired format for the total project cost estimate. For example, risk analyses can be performed on each contract (assuming several contracts), on each project feature, or on the total project base cost.

14.1.1 Methods

In developing the schedule risk model template, two common approaches are recommended. The approaches are dependent upon what the PM prefers as the outcome when establishing the contingencies. For example, if just a single project or contract is planned, the PM may desire a single contingency value. The PM may prefer a contingency developed for each project feature. If several projects or contracts are planned, the PM may desire a separate contingency for each project. These issues should be resolved before preparation of the SRA model. The typical approaches currently used are:

- Risk event based: Develop the model to reflect the completed risk register. In a sense, the risk register becomes the model. In that way, the Crystal Ball outputs directly reflect the risk register's risk event established by the PDT. This output well supports the PDT when related to document traceability, risk management, and follow-on risk studies. The SRA output is risk based and typically presents the contingency per each project. This method can be obtained from the Cost Engineering DX.
- Cost based: This method might be used when several contracts are being studied within the program and separate contract contingencies or feature contingencies are desired. The resulting model reflects the WBS within the estimate(s). To pursue this avenue, the CRA model is developed by downloading the most likely estimate into an Excel file at the chosen WBS that best relates to the risk register. Once that is accomplished, refer to the market study and the various risk events, creating the best and worst case estimates, again reflecting the chosen WBS. The CRA output is cost based, because it reflects the WBS within the estimate template and is more intuitive for the cost engineer. The advantage is that the model output can better reflect multiple project features, contracts, or different funding accounts. The disadvantage is that it does not directly correlate to the risk events established by the PDT and is less traceable to the risk register. If this alternative is chosen, the report must document how the SRA outputs relate to the risk register event concerns.

Table 3 is a sample of the risk event method. Note that the model focuses on certain risk register categories and the market research values related to best case, most likely and worst case. The entire risk register can be included; however, it can be cumbersome when producing paper documents and reports. The key risk register columns are:

- Risk No.
- Risk/Opportunity Event.
- Risk Level.
- Variance Distribution.
- Correlations to Other(s).

Table 3. Sample Schedule Risk Model

Risk No.	Risk/Opportunity Event	Discussion and Concerns	Project Schedule			Variance Distribution	Correlation to Other(s)	Expected Values - Durations			Comments related to Risk Duplication or Correlations
			Likelihood*	Impact*	Risk Level*			Low (mo)	Most Likely (mo)	High (mo)	
Internal Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)											
I-1	Staff Turnover/Losing Staff at Critical Points	Potential to lose critical staff throughout life of project due to workload and attrition.	Very Likely	Significant	High	Triangular	I-3	10	12	16	
I-2	Inexperienced Staff Assigned	Assignment of inexperienced staff due to turnover of experienced staff and requirements dictate necessity for more staff. New staff not familiar with Corps processes and regulations.	Very Likely	Significant	High	Triangular	I-1	10	12	14	*Removed from Final Risk Study As It is Covered in Risk I-1*
I-3	Changes in SELA Priority	Pulling funding for this project -- competing with other SELA components or other HPS projects through the 2011 timeframe.	Likely	Significant	High	Uniform	I-1	-6	0	18	
I-4	Functional Resources Overloaded/Shift of Staff Priorities	Lack of internal human resources to execute project due to heavy workload, overloaded staff, and shifting priorities.	Very Likely	Significant	High	Triangular	I-1	10	12	16	*Removed from Final Risk Study As It is Covered in Risk I-1*
I-8	Control & Diversion of Water	Rain events may result in flooding. There are additional diversion and dewatering potential from rain event, storm, and/or loss of dam. Bid schedule includes flood events, but the current estimate does not.	Likely	Marginal	Moderate	Uniform		-2	0	6	
I-10	Real Estate Not Fully Defined	Real estate plan is at the feasibility level. There are risks associated with lack of scope development. Need to acquire land, easements. Local development may threaten contemplated areas for acquisition/access.	Very Likely	Marginal	Moderate	Uniform	I-11	-1	0	6	*Removed from Final Risk Study As It is Covered in Risk I-11*
I-11	Land Ownership	Uncertain ownership of several land parcels. Issues surrounding ownership of the canal. Also issues with parcels outside the canal.	Very Likely	Critical	High	Uniform		-1	0	12	

Table 3. Sample Schedule Risk Model (Cont.)

I-14	Relocations Occurring Timely	Cooperation of the utility owner and the Corps may not follow planned schedule, causing significant delays.	Very Likely	Significant	High	Triangular		59	60	64
I-23	Historical Cost Growth in Modifications	Risks associated with cost and schedule growth due to modifications, particularly with respect to the pumping stations.	Likely	Significant	High	Triangular		61	63	65
External Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)										
E-1	Incremental Funding	Impacts due to lack of funding or untimely receipt of funds.	Likely	Significant	High	Uniform		-2	0	10
E-3	Market Conditions	Risks to increased costs and schedule due to market saturation.	Likely	Significant	High	Uniform	E-4	-1	0	12
E-4	Inadequate skilled trades labor force	Many projects will occur concurrent to this project. Competing with other projects for skilled labor in a saturated market (equipment operators, cement masons, steel/bridge, pump stations etc.).	Likely	Significant	High	Uniform	E-3	-1	0	9
	All Other Project Costs	Placeholder for costs not captured in summation of risks being studied.	N/A	N/A	N/A				-77	
	PROJECT TOTAL DURATION								**82**	

14.1.2 Establishing the Risk Events for Study

It is recommended that the number of events under study within the model not exceed 8 to 15 risk items. The preferred study would include the high and moderate risks. The moderate risks are included, because their impact may be greater than a high risk.

Table 3 depicts only the risk events under study; however, the risk analyst could still include all risk events within the model, simply ignoring those outside the study by not assigning a variance distribution.

14.1.3 Incorporating Market Research into Model

Once it has been established as to which risk events will be incorporated into the model, the market research findings can be added. For traceability purposes, the recommended approach is to create Excel tabs next to the risk model dedicated specifically for each risk event. The tabs will present the market findings and the logic used to determine the best and worst case values for each risk event. Those values are then placed into the model input to support the variance distribution. When assigning the distributions, the most likely case must be a hard value with no equations or links to other data. Remember that the most likely case should reflect the base schedule.

14.1.4 Establishing Variance Distribution

The variance distribution within Crystal Ball must only address those risk events under study.

Within the Crystal Ball software, the distribution gallery provides more than 20 diagram or curve choices that can represent the market research data related to best case, most likely, and worst case. The two most commonly used and recommended for first consideration are the triangular and the uniform distribution curves. Other curves may better address certain risks where better data exists and should be considered when more appropriate.

The triangular distribution is commonly used when the market research has established the best case, most likely, and worst cases: three distinct points, measured in months. By definition, the most likely estimate has established what is most likely to occur. This distribution is recommended for the risk events that impact discreet areas or details of the schedule where one can determine that one time value is more likely to occur than another value. Two examples are provided below (figures 8 and 9).

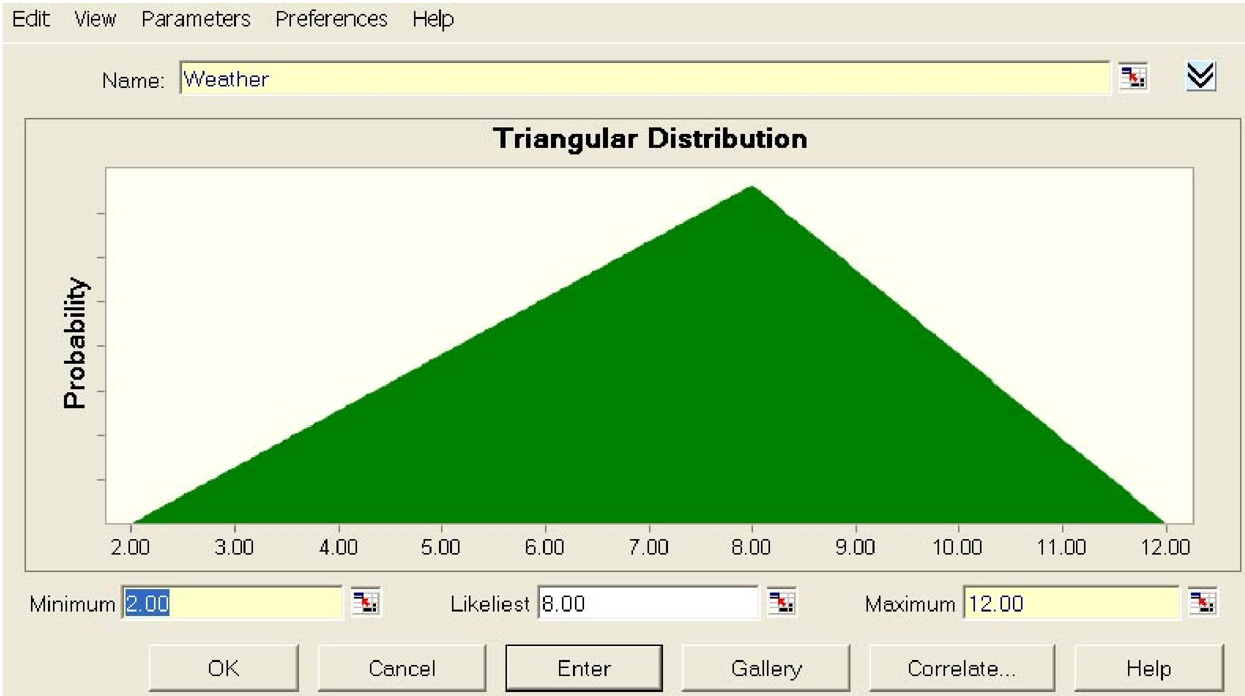

Figure 8. Example 1 of Triangular Distribution

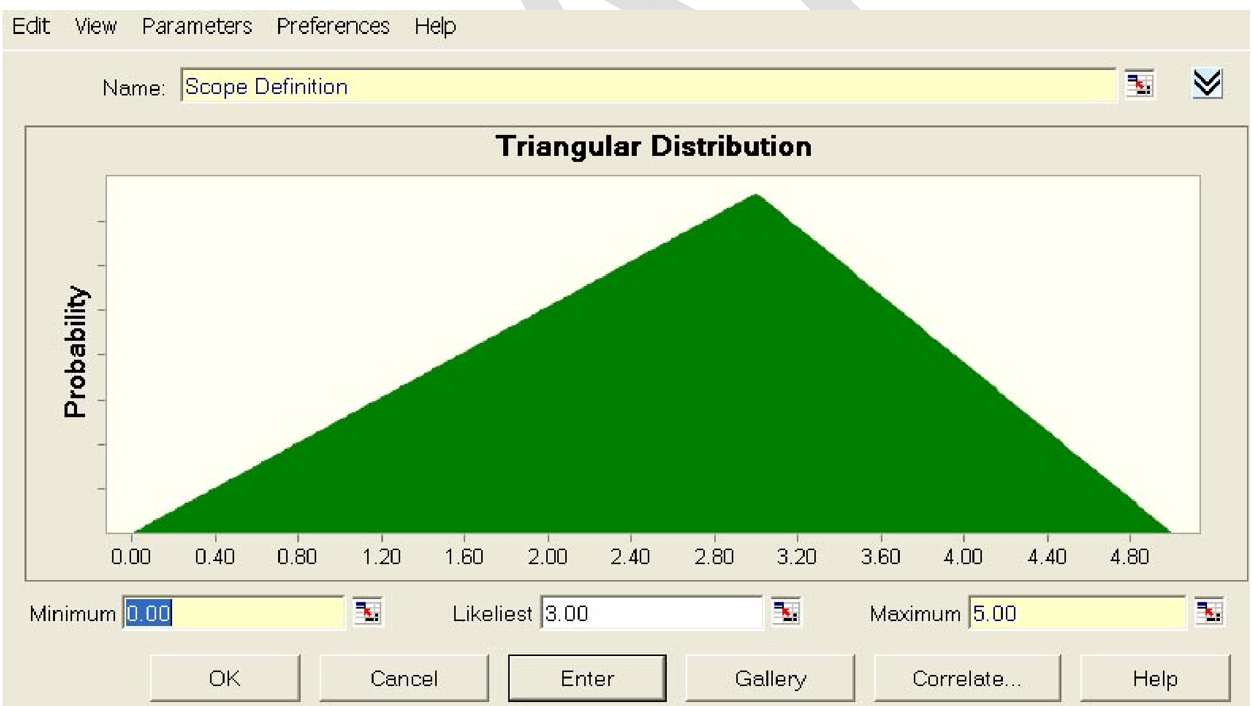

Figure 9. Example 2 of Triangular Distribution

The uniform distribution (figure 10) is used when any value between the best case and worst case are equally likely to occur. This distribution is recommended when the risk events are more global to the project and a most likely occurrence cannot be established. In these instances, only two points are needed, the best and the worse case. Within the model, the best case is assigned a value equal-to/or less-than the most likely (base) value and the worst case is assigned a value equal-to/or greater-than the most likely (base) value.

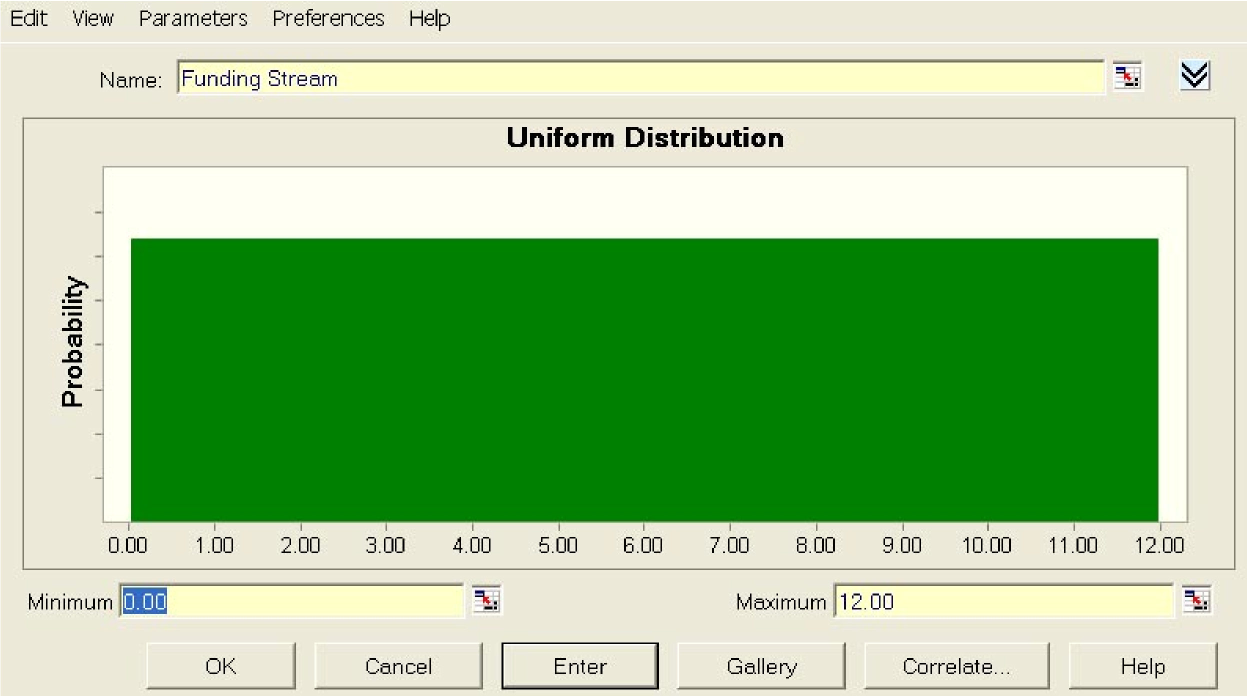

Figure 10. Example of Uniform Distribution

When assigning the variance distribution within the Crystal Ball model, for each risk event, the risk analyst must be sure to link the risk event title; the best case, most likely, and worst case values; and address any correlations, both positive and negative between the respective risk events.

14.1.5 Most Likely Duration Value

The Crystal Ball model will be run, targeting the most likely total value. Within the model, this is also referred to as the forecast value. The most likely value should reflect the most likely schedule duration total, encompassing all feature accounts, but excluding any schedule contingency. The total value, or forecast value, is linked to the other most likely durations with an equation that enables the model to run and capture the variances.

Generally, the model under development at this stage does not reflect the most likely project schedule duration. An easy solution is to input a place risk event for all other project durations (placeholder). It may be a plus or minus value to bring the most likely value to the current schedule duration. Given the nature of the placeholder durations, the risk analyst can choose whether a distribution variance is needed for inclusion into the risk model. For example, is the remaining placeholder item significant and at any significant risk?

14.2 Schedule Risk Model Run

Within Crystal Ball, the risk analyst must set the model related to desired reports, decision variables, defining the forecast, establishing precisions, etc. Once the model includes the risk events under study, all distribution variances have been assigned, duplications and correlations addressed, and the most likely schedule duration captured, the risk analyst is ready for the initial model run.

14.2.1 Initial Model Run

By this time, the cost engineer and risk analyst should have a feel for the scope, the schedule, and the market research quality. It will be of value when reviewing the initial output data. The risk analyst evaluates the initial reports, reviewing areas of potential conflict or inaccuracy. Even if the duration values appear reasonable, a QC check should still be performed.

Generally, several iterations will be performed as the model is studied for logic, assumptions, and values. Through several iterations, the model is corrected and improved; however, care must be given to ensure the model is not arbitrarily adjusted to output preferred results. Ultimately, the final product and report must reflect logic and undergo an ATR.

14.2.2 Model Results Quality Check

After initial model or first trial is run, a quality check is required for reasonableness. The risk duration calculations may seem too low or too high, based on the risk analyst's knowledge of the scope and schedule quality. If the contingency data falls significantly outside the anticipated range, there may be errors within the scope development, the most likely schedule, market research, or model development. Within the sensitivity chart, the order of high risk events may seem unlikely or out of expected order.

Common mistakes include poor scope confidence. Perhaps the most likely schedule is actually too optimistic or too conservative. Perhaps the schedule does not correlate well to the estimate productivities. There may be similar risk events that are listed separately within the risk register, thereby measuring the risk twice. There may be critical risks absent, especially external risks. Another common error is failing to adequately consider correlation relationships between risk events. The distribution curves may have to be reevaluated. If another Excel spreadsheet is open, the software may have grabbed outside data. It is normal to run the model several times before a confident model is developed that reflects reasonable results for the known data.

14.3 Schedule Risk Model Output

There are numerous Crystal Ball outputs that are helpful in presenting the data as well as supporting the CSRA report. While not all are portrayed in this guidance, the more common figures used to support the final report are presented in the following paragraphs. This data is obtained from the Crystal Ball report output after the risk simulation is run.

14.3.1 Sensitivity Chart

The sensitivity chart (figure 11) reflects the risk register areas of greatest concern (risk event based), rated in order of criticality. It is commonly referred to as a tornado chart. Generally, the more common areas of high risk concern are scope development, contract acquisition, bidding climate, funding availability, and contract modifications.

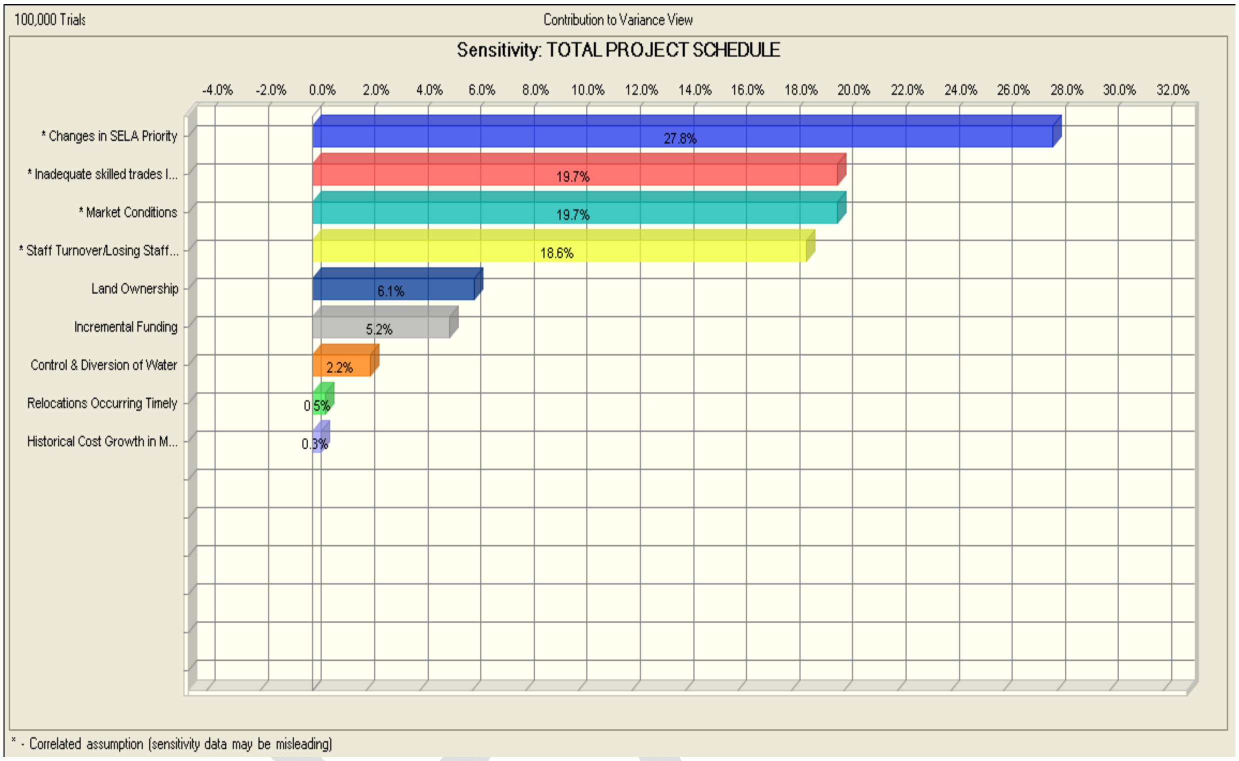

Figure 11. Sensitivity Chart for Schedule

14.3.2 Total Project Contingency Analysis

The contingency analysis is measured against the most likely schedule. The output presents (table 4) the duration values based on the confidence levels for successful project execution and completion. It can be in tabular form and also represented graphically and termed as the confidence curve. The PM and management are left to decide what confidence level they prefer to present to Congress for authorization. Historically, Congress and the Assistant Secretary of the Army are accustomed to a contingency value with an 80 percent confidence of successful execution and completion.

Table 4. Contingency Analysis Output for Total Project Schedule

Percentile	Forecast values (months)
0%	79
5%	92
10%	95
15%	98
20%	100
25%	102
30%	103
35%	105
40%	107
45%	109
50%	110
55%	112
60%	114
65%	116
70%	118
75%	119
80%	**121**
85%	123
90%	126
95%	130
100%	146

14.4 Schedule Risk Conversion to Contingency

The risk model output presents the schedule risk in months. It should demonstrate where those schedule risks are and by what monthly value. Realistically, the schedule duration also represents a cost to the project that the CRA did not capture. Schedule risk should be presented in both schedule growth and cost growth potential. When evaluating the schedule growth, consider what costs may be related to those risk events. Commonly, it could be an escalation value added by using the Office of Management and Budget (OMB) established rates. It can also include certain overhead costs, depending on whether it is design or construction risk.

Once determined, the schedule duration must be evaluated to determine if the added time results in added costs specifically related to the project and its stage in the design and construction process. Such cost impacts would be added onto the cost contingency calculations. Evaluation should consider how the time risks relate to such items as:

- Any current authorizations, appropriations, and Section 902 limits.
- Anticipated funding profiles.
- Pre-construction engineering and design risks.

- Construction risks.
- Local markets exceeding the established OMB escalation.
- Market risks impacting contractor bids related to market variability on lengthy construction activities.

15. TOTAL PROJECT COST SUMMARY

The CSRA results, both cost and schedule contingency, can now be transferred to the total project cost summary in the form of contingencies. Figure 12 is an accepted example that meets regulation requirements.

****** TOTAL PROJECT COST SUMMARY ****** PAGE 1 OF __

PROJECT: ____________ DISTRICT: ____________
LOCATION: ____________ P.O.C.: ____________

ACCOUNT NUMBER	FEATURE DESCRIPTION	CURRENT MCACES ESTIMATE PREPARED: SEE EACH FOLLOWING SHEETS. COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	AUTHORIZ./BUDGET YEAR: 2008 EFFECT. PRICING LEVEL: 1 OCT 2007 COST ($K)	CNTG ($K)	TOTAL ($K)	SPENT THRU FY 07 ($K)	FULLY FUNDED ESTIMATI COST ($K)	CNTG ($K)	FULL ($K)
04	DAMS	73,726	17,886	24%	91,612	74,572	18,091	92,663	62,989	79,793	19,396	162,178
06	FISH & WILDLIFE FACILITIES	4,885	1,735	36%	6,620	4,962	1,761	6,723		6,114	2,169	8,283
	TOTAL CONSTRUCTION COSTS ===>	78,611	19,621	25%	98,232	79,534	19,852	99,386	62,989	85,907	21,565	170,461
01	LANDS AND DAMAGES								500			500
21	RECONNAISSANCE STUDIES											
22	FEASIBILITY STUDIES											
30	PLANNING, ENGINEERING & DESIGN	3,078	880	29%	3,958	3,117	888	4,005		3,401	979	4,380
31	CONSTRUCTION MANAGEMENT	10,269	2,540	25%	12,809	10,386	2,564	12,950		11,197	2,778	13,975
	TOTAL PROJECT COSTS ========>	91,958	23,041	25%	114,999	93,037	23,304	116,341	63,489	100,505	25,322	189,316

TOTAL FEDERAL COSTS ==============>	**180,415**
TOTAL NON-FEDERAL COSTS ==========>	8,900
THE MAXIMUM PROJECT COST IS =======>	189,316
THIS TPCS REFLECTS A PROJECT COST CHANGE OF	**68,405**
THE 902 COST LIMIT IS =============>	120,911
	110%

____________ CHIEF, COST ENGINEERING, ____________
____________ PROJECT MANAGER, ____________
____________ CHIEF, REAL ESTATE ____________
____________ CHIEF, PLANNING
____________ CHIEF, ENGINEERING
____________ CHIEF, OPERATIONS
____________ CHIEF, CONSTRUCTION
____________ CHIEF, CONTRACTING
____________ CHIEF, PM-PB

NOTE: Valid only when completely signed.

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Figure 12. Total Project Cost Summary

16. REPORTS

Finally, the CSRA is included within a report (a sample risk analysis report is available at site http://www.nww.usace.army.mil/html/offices/ed/c/default.asp). The report can be added to the cost engineering appendix at feasibility stage, or it can remain a standalone report or appendix. The Cost Engineering DX provides guidance on their web site for a satisfactory report. Either way, the report should include:

- Title page with project name, date, and author.
- Table of contents.
- Executive summary reflecting the main report.
- Report purpose, background, and project scope.
- CSRA methodology/processes used including software, PDT, and market research.
- Key Assumptions, listing concerns, inclusions, and exclusions.
- Final Risk Register for the CRA and SRA.
- Crystal Ball reports such as sensitivity charts, contingency tables, and confidence curves.
- Presentation of the base cost and schedule with contingencies.
- Major findings and observations.
- Mitigation recommendations.

17. CONCLUSION

The CSRA output and resulting report contingencies serve as a management tool in establishing the total project cost. It also serves as a risk base line for PM risk management, mitigation and further CSRAs as the project moves forward and updates are deemed necessary. Later CSRAs serve to recalibrate, identify new risks as well as exclude mitigated or unrealized risks. The resulting CSRAs can also be used as a comparison to the funded amount and forecast whether the project is on target with the available funding that was appropriated.

APPENDIX A

PDT RISK CHECKLIST

PDT RISK CHECKLIST

Provided here is a checklist of risk items for consideration when performing a risk analysis. Consideration of all feature accounts is critically important 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 & 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, & Utilities
20	Permanent Operation Equipment
30	Planning, Engineering and Design
31	Construction Management

1. 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

2. The following items are a composite of several checklists from various agencies. They have been tailored to better address the more common USACE 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.

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 PM and/or management
- ❑ A/E/C 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 SDB 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, 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
- ❑ Adaptive Management features (<3% of construction cost, excluding monitoring)
- ❑ Dredge Estimate scope, quantities, equipment

Correct dredge equipment decisions (type, size, number)
Reasonable productivity (seasonal, environmental, weather)
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 L&D 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
- ☐ Adaptive Management features (<3% of construction cost, excluding monitoring)
- ☐ 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 GFE
- ☐ Permits, licenses, submittal approvals
- ☐ Permit and environmental work windows
- ☐ Environmental restrictions (equipment use, exhaust, 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, production rates

Estimate and Schedule Risks

- ❑ Estimate captures scope for all project features
- ❑ Estimate developed for current scope and design level
- ❑ Estimates developed in MCACES MII and/or CEDEP
- ❑ Estimate quality related to lesser designed features
- ❑ Estimate excludes contingency and escalation
- ❑ Estimate(s) quality when developed by others
- ❑ Estimate confidence in large and critical quantities
- ❑ Estimate include waste / drop off 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, diving)
- ❑ Prime and subcontractor structure matches likely acquisition strategy
- ❑ Adequate schedule depicting all project features
- ❑ Schedule matches PED 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)

APPENDIX B

SAMPLE RISK REGISTERS

Sample Risk Register for PDT

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

Project Name & Alternative for Study

Alternative Name and Scope: Briefly clarify the alternative under study and provide a narrative of the major construction features.

Risk No.	PDT-developed Risk/Opportunity Event (logic by feature, contract, responsibility)	PDT Event Concerns (include all to archive)	PDT Discussions (support the likelihood and impact)	Responsibility/POC	Project Cost			Project Schedule		
					Likelihood*	Impact*	Risk Level*	Likelihood*	Impact*	Risk Level*
Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)										
	PROJECT & PROGRAM MGMT									
PPM-1	Project Personnel Resources	Gov't personnel resources for project management and execution may be insufficient during peak periods of PED and Procurement. Personnel turnover and reassignments have been relatively.	The project has high visibility and a reasonable execution schedule. A majority of the effort is supported by A-E activities as well as design/build (D/B) acquisition strategy. Personnel resource levels are less of an impact with the exception of initial studies and coordination with outside stakeholders.	Project Manager Acquisition Professional	Likely	Negligible	Low	Likely	Marginal	Moderate
PPM-2	Project Experience with Civil Design/Build	Experience of USACE personnel with civil D/B construction activities is relatively limited.	Local contractor staff, A-E and the winning bidder likely have the necessary experience. Lessons learned from similar large projects are improving knowledge base.	-	Likely	Negligible	Low	Likely	Negligible	Low
PPM-3	Unanticipated Requirements and Reviews	More internal and external input and review are anticipated because of the high profile nature of the project.	The initial project plan is highly scrutinized by stakeholders who prefer different alternatives. Added coordination, study and possibly further funding needs are likely.	Project Manager	Very Likely	Marginal	Moderate	Very Likely	Marginal	Moderate
PPM-4	External Agency Resource Availability	Numerous non-federal agencies with project interest may lack resources to address issues in a timely manner.	Non-federal agencies likely have competing priorities unrelated to the project. Their priorities may differ from USACE priorities.	Project Manager	Very Likely	Negligible	Low	Very Likely	Marginal	Moderate

PPM-6	Contract Acquisition Impacts	The contract acquisition strategy may impact cost and schedule.	Current acquisition plan is a D/B FFP. Estimate is based on a D/B FFP.	-	Unlikely	Marginal	Low	Unlikely	Marginal	Low
PPM-8	Design Scope Maturity	The estimate and schedule quality could be in question because of limited 10% design.	A significant amount of the estimate and schedule are parametric-based with critical assumptions that are difficult to capture. The design team believes cost and schedule estimates are conservative in many areas. But the ITR Team feels certain areas are underestimated. Also, a complete independent technical design review of critical assumptions has not been performed; therefore, uncertainty exists regarding the current level of design. Impact assumptions are based on design team discussions.	Cost Engineering	Likely	Significant	High	Likely	Marginal	Moderate
	OPPORTUNITIES									
PPM-9	Alternate Project Delivery Method Efficiencies	Use of alternate project delivery methods similar to Early Contractor Involvement (ECI) may lower contract cost by reducing/realigning risk and providing opportunities to improve designs.	Alternative project delivery methods should provide opportunities to improve the RFP, specifically as related to pumping station design. The anticipated D/B process will involve a 2-step procurement process whereby the selected bidders will be given opportunities for RFP and design improvements, similar to an ECI process. Large contractors are growing more familiar and confident with USACE contracting methodology, processes, indemnity and risks. Design team believes there is good competitive interest in this project.	Project Manager Acquisition Professional	Very Likely	Marginal	Moderate	Likely	Negligible	Low
	GENERAL AND ECONOMIC RISKS									
GE-1	Construction Contract Modifications	Depending on level of complexity, weather impacts, and contract language, construction contract modifications can impact construction cost and	Local specifications assume higher government risk for weather concerns, thereby increasing the likelihood of construction contract modifications. Technical complexities related to the pump	Project Manager Acquisition Professional	Very Likely	Significant	High	Very Likely	Marginal	Moderate

		schedule growth.	stations and site access for the canals result in increased risk of contract modifications.							
GE-3	EIS Uncertainty	EIS impacts are expected to be social, economic and cultural primarily related to significant houses and parks. Two pump stations are on the National Register of Historic Places. Pump stations may impact wetlands. Associated mitigation costs are currently unknown.	Project schedule accommodates this potential. Most construction activities are within existing public lands. Any cost impact is small compared to overall project costs.	-	Likely	Negligible	Low	Likely	Negligible	Low
	Feature Code 02 REAL ESTATE AND RELOCATIONS									
RE-1	Real Estate Plan Uncertainty	Completion of a real estate plan is contingent on EIS and PPA execution. Environmental mitigation needs yet to be identified. Project has railroad involvement. Real Estate costs lack confidence.	Project schedule accommodates this potential. Most construction activities are within existing public lands. Any cost impact is small compared to overall project costs.	-	Likely	Negligible	Low	Likely	Negligible	Low
RE-2	Relocation Plan Uncertainty	Relocation needs are uncertain until a compensable interests report is completed.	With relocations as yet undefined, the risk analysis adds 1% to the construction estimate based on analysis of the total GNOHSDRRS program cost estimate. Impact as compared to total project cost is small.	Project Manager	Likely	Marginal	Moderate	Likely	Marginal	Moderate
RE-3	Real Estate Acquisition Needs	Additional temporary or long term land acquisition may be desired or needed. No costs have been included.	Adequate studies not yet performed. There is a likelihood of this event. Studies and coordination are required if this option occurs; however, there is a long period prior to actual construction. Overall cost impacts to the project are small.	-	Very Likely	Negligible	Low	Likely	Negligible	Low

RE-4	Impacts to High Value Habitats	Bottom land hardwoods may be impacted by the alignment.	Adequate studies not yet performed, but most efforts remain in public domain. Overall cost impacts to the project are small.	-	Unlikely	Negligible	Low	Unlikely	Negligible	Low
	Feature Code 09 CANALS									
C-2	Design Criteria	Design criteria will be subject to independent reviews, both internal and external. The outcome may be design revisions.	External reviewers have already expressed concerns related to the design, but require further studies. The outcome is yet unclear.	Civil Design	Likely	Significant	High	Likely	Marginal	Moderate
C-3	Structural and Geotechnical Uncertainty	Future studies and resulting findings could result in design changes (grout walls and floor, other stabilizations or technology). Canal lengths are long, potentially resulting in varied design parameters.	The design team believes geotechnical conditions are fairly well documented for the canals. The design and quantities are thought to be conservative, but significant opportunities for cost savings are not anticipated because of the poor soil conditions.	Civil Design	Likely	Marginal	Moderate	Likely	Marginal	Moderate
C-5	Site Access and Constructability in Canal Reaches - Wet Work	Construction access for jet grouting and DSM in certain areas may be limited, decreasing productivity for certain reaches, near obstructions or in close proximity with outside structures such as bridges, roads, and buildings.	Canal access and potential obstructions have not been studied. The estimates and schedules may not have adequately considered these unknowns related to productivity. However, price quotes used in estimate account for productivity issues related to access and were provided with local knowledge of constraints. Design team believes the schedule is conservative and provides opportunities to accelerate.	Cost Engineering	Likely	Marginal	Moderate	Very Likely	Marginal	Moderate
C-7	Unknown Utilities	Unknown utilities may impact costs. SCADA line is a special concern.	With relocations as yet undefined, the risk analysis adds 1% to the construction estimate based on analysis of the total program cost estimate. Impact as compared to total project cost is small.	Cost Engineering	Likely	Marginal	Moderate	Likely	Marginal	Moderate
C-11	Disposal of Excavated Materials	The results of environmental site assessments may result in higher than anticipated disposal costs. Disposal of some excavated materials assumed to require sanitary landfill disposal.	Estimate appears to lack disposal activities.	Cost Engineering	Likely	Marginal	Moderate	Likely	Negligible	Low

	Feature Code 13 PERMANENT PUMP STATIONS									
PPS-4	Design Criteria - Pumps	Design level is less than 10%. At pre- and post-contract award stages, design criteria will be subjected to independent reviews, internal and external. The outcome may be design revisions. Potential also exists for scope evolution within the D/B process.	Designs have not fully considered impacts of larger pumping requirements for larger weather events. Significant technical review concern regarding incorporation of discharge head in pump design.	Civil Design	Likely	Significant	High	Likely	Marginal	Moderate
PPS-6	Disposal of Excavated Materials	The results of environmental site assessments may result in higher than anticipated disposal costs. Disposal of some excavated materials assumed to require sanitary landfill disposal.	Estimate appears to lack most disposal activities.	Cost Engineering	Likely	Marginal	Moderate	Likely	Negligible	Low
PPS-8	Project Constructability	Constructability may be in question as related to in-water work, phasing and sequencing while maintaining flows and protection.	A thorough constructability review has been performed by the designer and Corps representatives. Alternate project delivery methods will minimize impacts.	-	Unlikely	Marginal	Low	Unlikely	Marginal	Low
PPS-10	Site Access Restrictions	Restricted site access, lay down and work staging areas impacting productivity and construction management.	Site access is somewhat restricted, but considered acceptable with proper site management and coordination during design period.	-	Likely	Negligible	Low	Likely	Negligible	Low
Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)										
Risk No.	**Risk/Opportunity Event**	**Concerns**	**PDT Discussions**	**Responsibility/POC**	**Project Cost**			**Project Schedule**		
					Likelihood*	**Impact***	**Risk Level***	**Likelihood***	**Impact***	**Risk Level***
PR-1	Undefined Funding Profile	Project costs are high for an extended schedule period that is not currently authorized/funded. Future full or incremental funding scenarios are unknown.	The funding profile is unknown. Design and construction delays could occur pending funding, resulting in increased escalation costs.	Project Manager	Likely	Significant	High	Unlikely	Marginal	Low

PR-2	Funding Availability	Project is not authorized/funded. Design and construction delays could occur pending funding, resulting in increased escalation costs.	This project is a large dollar amount scheduled over a period of years. Lack of funding or incremental funding that is less than needed can impact both the cost and the schedule.	Project Management	Likely	Significant	High	Likely	Significant	High
PR-3	Bidders Risk in Volatile Market	Upon solicitation, bidders may be reluctant to contract to a firm fixed price contract for an extended periods if the market conditions remain volatile in labor availability, equipment availability, and unforeseen escalation.	The extended period may cause contractors concern, because a FFP contract will not allow them financial recovery if escalation extremes occur.	Project Manager Contracting Officer	Likely	Significant	High	Likely	Marginal	Moderate
PR-4	Bid Protest Potential	Large project with significant profit potential may increase likelihood of bid protest. This may result in award to "less than" lowest price and impact the schedule.	There exists concerns related to Corps processes and potential conflicts of interest between design and construction firms.	Project Manager Acquisition Professional	Likely	Negligible	Low	Likely	Marginal	Moderate

*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. Concerns and Discussions elaborate on Risk/Opportunity Events and include any assumptions or findings (discussion to support the event rating).

3. 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.

4. Likelihood is measured as likelihood of impacting cost or schedule.

5. 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.

6. Risk Level is the resultant of Likelihood and Impact **Low**, **Moderate**, or **High**. Refer to the matrix located at top of page.

7. Variance Distribution refers to the behavior of the individual risk item with respect to its potential effects on Project Cost and Schedule. For example, an item with clearly defined parameters and a solid most likely scenario would probably follow a triangular distribution. Complete unknowns related to "it could be anywhere" would fall into the category of uniform.

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.

*** Can not assess these items**

Sample Risk Register for Risk Analyst

Risk No.	PDT-developed Risk/Opportunity Event (logic by feature, contract, responsibility)	COMPLETED BY RISK ANALYST AFTER PDT DISCUSSIONS						
		Cost Impact ($)	Variance Distribution (Cost)	Schedule Impact (mo)	Variance Distribution (Schedule)	Correlation to Others	Affected Project Component	Project Implications
Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)								
	PROJECT & PROGRAM MGMT							
PPM-1	Project Personnel Resources	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	1-6	Triangular	-	PED Procurement	Schedule
PPM-2	Project Experience with Civil Design/Build	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	-	-	-
PPM-3	Unanticipated Requirements and Reviews	Construction contingency will be applied at the same rate for PED.	Same as overall construction variance	3-6	Triangular	-	PED	Cost Schedule
PPM-6	Contract Acquisition Impacts	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	-	-	-
PPM-8	Design Scope Maturity	$400,000,000	Triangular	3-6	Triangular	-	Total Project	Cost Schedule
	OPPORTUNITIES							
PPM-9	Alternate Project Delivery Method Efficiencies	$65,000,000	Triangular	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	-	All Construction	Cost
	GENERAL AND ECONOMIC RISKS							
GE-1	Construction Contract Modifications	$50,000,000	Triangular	1-3	Triangular	PPS-13	All Construction	Cost Schedule

GE-3	EIS Uncertainty	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	-	-	-
	Feature Code 02 REAL ESTATE AND RELOCATIONS							
RE-1	Real Estate Plan Uncertainty	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	-	-	-
RE-2	Relocation Plan Uncertainty	$25,000,000	Same as overall construction variance1% added to construction	3-6	Triangular	-	All Construction	CostSchedule
RE-3	Real Estate Acquisition Needs	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	-	-	-
RE-4	Impacts to High Value Habitats	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	-	-	-
	Feature Code 09 CANALS							
C-2	Design Criteria	$40,000,000	Triangular	1-3	Triangular		Jet Grouting DSM GFM	Cost Schedule
C-3	Structural and Geotechnical Uncertainty	$10,000,000	Triangular	1-3	Triangular	-	Jet GroutingDSM	CostSchedule
C-5	Site Access and Constructability in Canal Reaches - Wet Work	$15,000,000	Triangular	3-6	Triangular	-	All Canal Construction	Cost Schedule
C-7	Unknown Utilities	$5,000,000	Triangular	3-6	Triangular	-	All Canal Construction	Cost Schedule
C-11	Disposal of Excavated Materials	less than $1,000,000	Triangular	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	PPS-6	Excavation	Cost
	Feature Code 13 PERMANENT PUMP STATIONS							
PPS-4	Design Criteria - Pumps	$45,000,000	Triangular	1-3	Triangular	-	Pumps	Cost Schedule

PPS-6	Disposal of Excavated Materials	less than $1,000,000	Triangular	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	C-11	Excavation	Cost
PPS-8	Project Constructability	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	-	-	-
PPS-10	Site Access Restrictions	N/ALow Level RisksNot Modeled	N/ALow Level RisksNot Modeled	N/ALow Level RisksNot Modeled	N/ALow Level RisksNot Modeled	-	-	-
Programmatic Risks (External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)								
Risk No.	**Risk/Opportunity Event**	**COMPLETED BY RISK ANALYST**						
		Cost Impact ($)	**Variance Distribution (Cost)**	**Schedule Impact (mo)**	**Variance Distribution (Schedule)**	**Correlation to Others)**	**Affected Project Component**	**Project Implications**
PR-1	Undefined Funding Profile	$60,000,000	Uniform	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	PR-2	Total Project	Cost
PR-2	Funding Availability	-5% - +25%	Uniform	12-18	Uniform	PR-1	Total Project	Cost Schedule
PR-3	Bidders Risk in Volatile Market	0-10% based on study		6-Mar	Triangular			Cost Schedule
PR-4	Bid Protest Potential	N/A Low Level Risks Not Modeled	N/A Low Level Risks Not Modeled	1-3	Triangular	-	PED Procurement	Schedule

APPENDIX C

SAMPLE RISK ANALYSIS REPORT

US Army Corps of Engineers®

PROJECT NAME
DESIGN LEVEL
FOR
DISTRICT NAME AND LOCATION

Prepared for:

____

Prepared by:

____

Date: ________________________

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EXECUTIVE SUMMARY

Provide a brief synopsis of the main report; keep pages of the executive summary to a minimum covering:

- Report purpose.
- Background.
- Project scope.
- Risk analysis methodology.
- Project development team (PDT) processes utilized (exclude names)
- Key project and risk assumptions.
- Contingency results to the feature level.
- Major findings/observations.
- Mitigation recommendations.

1. PURPOSE

Present report purpose, acknowledging project name, location, and design phase. The purpose for a cost and schedule risk analysis (CSRA) would briefly present discussion of the studied elements related to cost and schedule with an outcome contingency calculation at the recommended confidence level for both cost and schedule that are measured in terms of dollars and months, respectively. The most common and recommended contingency has been established at 80 percent confidence.

2. BACKGROUND

Present project background, including any related congressional appropriations, design development phase, and brief history.

3. REPORT SCOPE

The scope of the risk analysis report is to calculate and present the cost and schedule contingencies at the 80 percent confidence level using the risk analysis processes as mandated by U.S. Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The report presents the contingency results for both cost and schedule risks for all project features. The study and presentation can include or exclude consideration for operation and maintenance or life cycle costs, depending upon the program or decision document intended for funding.

3.1 Project Scope

Provide any congressional mandates and appropriations.

The report includes the project technical scope, estimates, and schedules as developed and presented by (list the name of the product developer by district or design firm). Consequently, these documents serve as the basis for the risk analysis. In general terms, the construction scope consists of the following:

- List major project features studied from the civil works work breakdown structure (CWWBS).
- Indicate the approximate design phase. Many times, various design features are at varying design stages, which impact the contingency results. If there is a design quality or scope variance between various critical features, which should be made known.

3.2 USACE Risk Analysis Process

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

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

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

- ER 1110-2-1150, Engineering and Design for Civil Works Projects.
- ER 1110-2-1302, Civil Works Cost Engineering.
- ETL 1110-2-573, Construction Cost Estimating Guide for Civil Works.
- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Engineering DX.
- Memorandum from Major General Don T. Riley (U.S. Army Director of Civil Works), dated July 3, 2007.
- Engineering and Construction Bulletin issued by James C. Dalton, P.E. (Chief, Engineering and Construction, Directorate of Civil Works), dated September 10, 2007.

4. METHODOLOGY/PROCESS

Present team makeup, including PDT members and technical positions, as well as the team makeup performing the risk analysis (both USACE and contracted members, not by name, but by position). Present timeframe of the study.

Indicate whether the cost and schedule products under analyses have successfully passed an Agency Technical Review (ATR) (if not, the risk analysis outcome is based upon an unapproved product and likely to change after an ATR is completed).

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

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

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

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

The primary steps, in functional terms, of the risk analysis process are described in the following subsections. Risk analysis results would be provided in section 6.

4.1 Identify and Assess Risk Factors

Identifying the risk factors via the PDT are considered a qualitative process that results in establishing a risk register that serves as the document for the further study using the Crystal Ball risk software. Risk factors are events and conditions that may influence or drive uncertainty in project performance. They may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risk factors may have either favorable or unfavorable impacts on project cost and schedule.

Checklists or historical databases of common risk factors are sometimes used to facilitate risk factor identification. However, key risk factors are often unique to a project and not readily derivable from historical information. Therefore, input from the entire PDT is obtained using creative processes such as brainstorming or other facilitated risk assessment meetings. In practice, a combination of professional judgment from the PDT and empirical data from similar projects is desirable and is considered.

Formal PDT meetings are held (include the name of the location in the report) for the purposes of identifying and assessing risk factors. The meetings (include the date) should include capable and qualified representatives from multiple project team disciplines and functions, for example:

- Project/program managers.
- Contracting/acquisition.
- Real Estate.
- Relocations.
- Environmental.
- Civil, structural, geotechnical, and hydraulic design.
- Cost and schedule engineers.
- Construction.
- Key sponsors

The initial formal meetings should focus primarily on risk factor identification using brainstorming techniques, but also include some facilitated discussions based on risk factors common to projects of similar scope and geographic location. Subsequent meetings should focus primarily on risk factor assessment and quantification.

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

4.2 Quantify Risk Factor Impacts

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

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

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

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

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

Table 1. Work Breakdown Structure by Feature

01	LANDS AND DAMAGES
02	RELOCATIONS
09	CHANNELS & CANALS
11	LEVEES & FLOODWALLS
13	PUMPING PLANT
30	PLANNING, ENGINEERING & DESIGN
31	CONSTRUCTION MANAGEMENT

The resulting product from the PDT discussions is captured within a risk register as presented in section 6 for both cost and schedule risk concerns. Note that the risk register records the PDT's risk concerns, discussions related to those concerns, and potential impacts to the current cost and schedule estimates. The concerns and discussions are meant to support the team's decisions related to event likelihood, impact, and the resulting risk levels for each risk event.

4.3 Analyze Cost Estimate and Schedule Contingency

Contingency is analyzed using the Crystal Ball software, an add-in to the Microsoft Excel format of the cost estimate and schedule. *Monte Carlo* simulations are performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified by the PDT. Contingencies are calculated by applying only the moderate and high level risks identified for each option (i.e., low-level risks are typically not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies as the project and risks evolve).

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the base cost estimate. Each option-specific contingency is then allocated on a civil works feature level based on the dollar-weighted relative risk of each feature as quantified by *Monte Carlo* simulation. Standard deviation is used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of all the project feature cost contingency being allocated to features with relatively higher estimated cost uncertainty.

For schedule contingency analysis, the option schedule contingency is calculated as the difference between the P80 option duration forecast and the base schedule duration. These contingencies are then used to calculate the time value of money impact of project delays that are included in the presentation of total cost contingency in section 6. The resulting time value of money, or added risk escalation, is then added into the contingency amount to reflect the USACE standard for presenting the “total project cost” for the fully funded project amount.

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

5. KEY ASSUMPTIONS

Present key assumptions in this section. Certain assumptions may be dictated by the customer. Other assumptions may be assumed by the risk analyst or cost engineer. Key assumptions are those that are most likely to significantly effect the determinations and/or estimates of risk presented in the risk analysis. The key assumptions are important to help ensure that project leadership and other decision makers understand the steps, logic, limitations, and decisions made in the risk analysis, as well as any resultant limitations on the use of outcomes and results. (Certain risks may have been excluded due to USACE or PDT guidance – these should be mentioned.)

The following is an example of key assumptions for the risk analysis that could be identified by the PDT and risk analyst.

- Address design stage.
- Address confidence in design scope.
- Address any critical inclusions or exclusions of scope or risk.
- Address any sunk or expended costs not included within the risk study.
- Address life cycle costs, whether included or excluded.
- Address operations and maintenance, whether included or excluded.
- Address major features.
- Address congressional authorization.
- Address funding profiles.
- Address contract acquisition strategy.
- Address ATR status: successfully complete, incomplete, or unsatisfactory.
- Address feature cost accounts.
- Address confidence and quality of cost estimates and project schedules.
- Address the contingency confidence level recommended within the report.
- Address which impact levels were studied or applied within the risk analysis. These relate to the high, moderate, or low risk level ratings (generally, the high and moderate risk levels are studied).

6. RISK ANALYSIS RESULTS

Present the risk products and results in narrative form as well as tables and figures including the cost and schedule risk analysis results. In addition to contingency calculation results, sensitivity analyses provide decision makers with an understanding of variability and the key contributors to the cause of this variability.

6.1 Risk Register

A risk register is a tool commonly used in project planning and risk analysis and serves as the basis for the risk studies and Crystal Ball risk models. A summary risk register that includes typical risk events studied (high and moderate levels) should be presented in a table in this section. The risk register reflects the results of risk factor identification and assessment, risk factor quantification, and contingency analysis. A more detailed risk register would be provided in appendix A. The detailed risk registers of appendix A include low level and unrated risks, as well as additional information regarding the specific nature and impacts of each risk.

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

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

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

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

- Present any risk event correlations, addressing their relationships.
- Present the final risk register or the condensed version. At a minimum include those risk events studied (an appendix can include the complete risk register):
  - ❑ Risk event identifying number.
  - ❑ Risk or opportunity event.

- ❑ PDT concerns.
- ❑ PDT discussions.
- ❑ Project cost likelihood, impact, and risk level.
- ❑ Project schedule likelihood, impact, and risk level,

Insert table containing a condensed risk register table.

6.2 Cost Risk Analysis - Cost Contingency Results

Provide a cost contingency narrative presentation of the results followed by tables presented from the Crystal Ball reports depicting the:

- Cost sensitivity chart.
- Confidence tables in 10 percent increments of confidence associated with dollars.
- Confidence curves relationship of percent confidence with contingencies in dollars (build from confidence tables).

Make note that these results reflect only those contingencies established from the cost risk analysis.

6.3 Schedule Risk Analysis - Schedule Contingency Results

Provide a schedule contingency narrative presentation of the results followed by tables presented from the Crystal Ball reports depicting the:

- Schedule sensitivity chart.
- Schedule confidence tables in 10 percent increments of confidence associated with months.
- Schedule confidence curves with contingencies (build from confidence tables).

Make note that these results reflect only those contingencies established from the schedule risk analysis.

6.4 Combined Cost and Schedule Contingency Results

Provide a brief narrative presentation of the combined cost and schedule results followed by tables depicting (combined tables of cost and schedule reports):

- Cost confidence table in percent confidence with contingencies in dollars.
- Schedule confidence table in percent confidence with contingencies in months.

7. MAJOR FINDINGS/OBSERVATIONS

Present the major findings and observations for both the cost and schedule risk analysis. It is beneficial to refer back to the key assumptions and how they relate to the findings and observations. Present the total cost summary at 10 percent confidence intervals unless otherwise directed. Provide a summary of significant risk analysis results in this section, which have been identified in the preceding sections of the report. Risk analysis results are intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as projects progress through planning and implementation. Because of the potential for use of risk analysis results for such diverse purposes, this section also reiterates and highlights important steps, logic, key assumptions, limitations, and decisions to help ensure that the risk analysis results are appropriately interpreted. Table 2 presents project contingencies, which include base cost plus cost and schedule contingencies. Figure 2 illustrates the total project cost risk analysis in confidence curve.

Table 2. Sample Project Contingencies (Base Cost Plus Cost and Schedule Contingencies)

Confidence Level	Project Cost	Contingency ($)	Contingency (%)
P0	$46,955,000	($4,875,000)	-9%
P10	$56,233,000	$4,403,000	8%
P20	$58,669,000	$6,839,000	13%
P30	$60,784,000	$8,954,000	17%
P40	$62,997,000	$11,167,000	22%
P50	$65,857,000	$14,027,000	27%
P60	$71,467,000	$19,637,000	38%
P70	$85,760,000	$33,930,000	65%
P80	$106,150,000	$54,320,000	105%
P90	$136,226,000	$84,396,000	163%
P100	$262,998,000	$211,168,000	407%

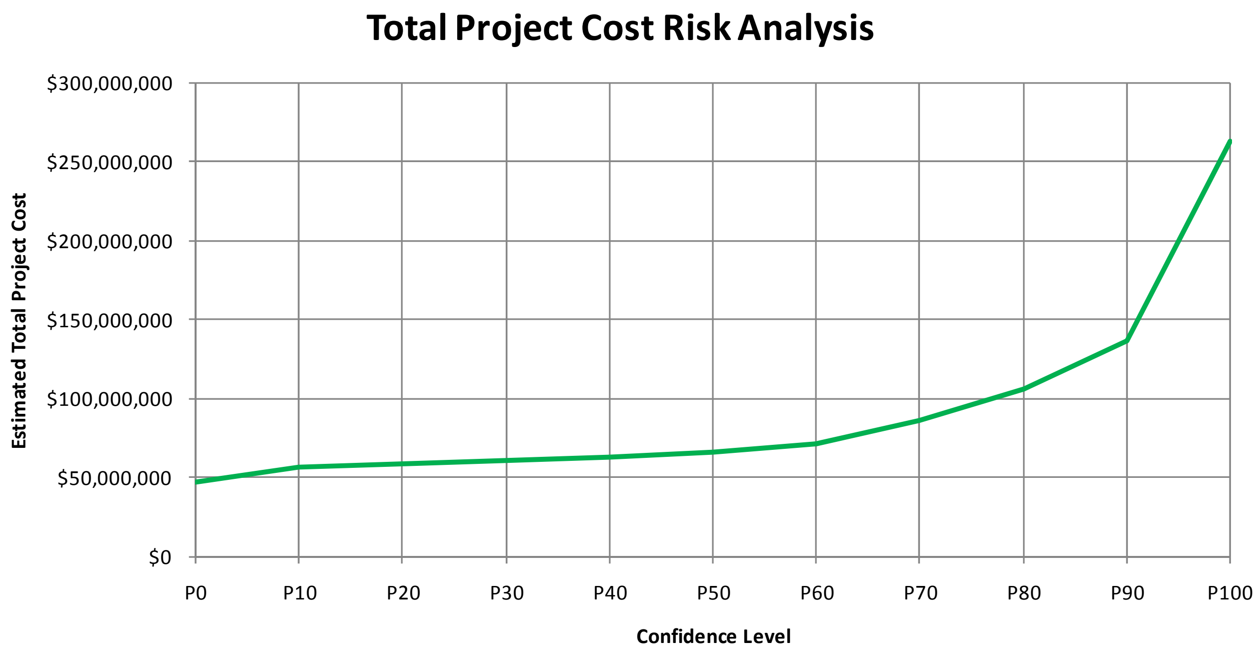

Figure 1. Sample of Project Confidence Curves

8. MITIGATION RECOMMENDATIONS

Present key recommendations that may assist in mitigating risks. Present any recommendations for opportunities for both cost and schedule.

APPENDIX A

DETAILED RISK REGISTERS

(Present the detailed Risk Register here, covering all risk events, regardless of low, medium, or high risk concerns)