Draft

Attachment 6
CP4 Crystal Ball Estimate

Engineering Summary Appendix

Shasta Lake Water Resources Investigation

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Abbreviations and Acronyms

CP	comprehensive plan
IPE	International Project Estimating
MP	Most Probable
MPH	Most Probable High
MPL	Most Probable Low
OPCC	Opinion of Probable Construction Cost

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CP4 Crystal Ball Estimate

Feasibility-level most-probable construction cost estimates for the Shasta Dam and Reservoir enlargement include 3 dam raise alternatives, resulting in 5 comprehensive plans (CP). At this stage of the Federal planning and National Environmental Policy Act processes, an 18.5-foot raise of Shasta Dam has been identified as the preliminary proposed plan and likely preferred alternative. The Opinion of Probable Construction Cost (OPCC) for each comprehensive plan are detailed in Chapter 5 of the Engineering Summary Appendix. When this attachment was developed, analysis showed that CP4 provided the greatest net National Economic Development economic benefits. For this reason, CP4 is used as an example in the following attachment to characterize the Crystal Ball cost risk analysis of the preliminary proposed plan and likely preferred alternative.

Monte Carlo Simulation

Monte Carlo Simulation is a problem solving technique used to approximate the probability of certain outcomes by running multiple trials using random variables, called simulations. It is based on a computerized mathematical technique that accounts for risk in quantitative analysis and decision making. Monte Carlo Simulations furnishes the decision maker with a range of possible outcomes and the probabilities with which they would occur for any choice of action.

For each uncertain variable in a simulation, the possible values are defined using probability distributions. The type of distribution selected depends on the factors surrounding the variable. Some of the commonly used distributions are normal, triangular, uniform and lognormal.

Monte Carlo Simulation performs risk analysis by building models of possible results by substituting a range of values (probability distributions) for any factor that has inherent uncertainty. Values are sampled at random from the input probability distributions during simulation runs. Each set of samples is called an iteration, and the resulting outcome from that sample is recorded. The simulation does this hundreds or thousands of times, and the result is a probability distribution of possible outcomes.

Major Crystal Ball Components and Assumptions

For this project, the Monte Carlo Simulation and risk analysis has been performed using Oracle Crystal Ball software. The software uses inputs, or

assumptions, to define the range of uncertainties associated with variables and outputs, or forecasts, to calculate results based on simulations. A triangular distribution was selected to model risks and assumptions that were assigned for unit prices and quantities associated with individual cost items. Deterministic methods were used to estimate the range of possible values for the unit prices and quantities of each item. The final input values were modeled in the Crystal Ball tool and can be defined as:

- **Most Probable Estimate (MP)** – The unit price / quantity cost of an item based on realistic effort assessment for the required work and any predicted expenses.

- **Most Probable Low Estimate (MPL)** – The unit price / quantity cost of an item based on analysis of best-case scenario for the item.

- **Most Probable High Estimate (MPH)** – The unit price / quantity cost of an item based on analysis of the worst-case scenario for the item.

The components listed for direct cost line items, and specifically factors used to determine indirect costs, are critically important to the overall accuracy of the estimate. Depending on the level of study, it is often impractical to identify all items associated with a project. Accordingly, feasibility design estimates should contain a percentage allowance shown as a separate line item for unlisted items (i.e., design, construction contingencies).

Percent based allowances (e.g., contingencies, non-contract costs) were modeled within each features' Monte Carlo simulation. Non-percent based allowances, such as land acquisition and water use efficiency actions costs, were modeled separately. See Chapter 5 of the Engineering Summary Appendix for additional explanation on these allowances.

Competitive Market Conditions at the Time of Bid Tender

Estimates assume that Builder's Risk Insurance would be available to the contractor. If Builder's Risk Insurance is not available to the contractor because of the scope, security implications, or magnitude of the project, increased bid margins can be expected because the contractor would need to assume additional risks.

Price Level

Monte Carlo Simulation was performed on feasibility-level cost estimates developed at April 2010 price levels for the Shasta Lake Water Resources Investigation Preliminary Draft Environmental Impact Statement (2011d). For this Draft Environmental Impact Statement, costs were indexed to April 2012 price levels using Reclamation's Construction Cost Trends (Reclamation 2012a); however, it was not deemed appropriate to update the Monte Carlo Simulation with indexed values. Therefore, all prices shown in this attachment are in April 2010 dollars. For subsequent drafts, or as part of the Final

Feasibility Report, cost estimates may be repriced to the current price level and Monte Carlo Simulation updated.

Most Probable Estimate

- A value of 5-10 +/- percent of direct cost subtotal was used for mobilization if it was not determined within International Project Estimating (IPE)
- A value of 10-20 +/- percent of the direct cost plus mobilization subtotal was used for design contingencies
- Allowance for procurement strategies was set at 2 +/- percent of the direct cost plus mobilization subtotal
- A value of 8-25 +/- percent of the contract cost was used for construction contingencies
- Planning, engineering design, and construction management is 20 percent of the total field cost
- Land acquisition non-contract cost (see Real Estate Appendix for detailed analysis)
- Environmental mitigation non-contract cost is 10 percent of total field cost excluding environmental restoration
- Cultural resources preservation non-contract cost is 2 percent of total field cost
- Water Use Efficiency Actions non-contract cost: This includes funding for an additional water conservation program for new water supplies created by the project, to augment current water use efficiency practices (see Environmental Impact Statement, Chapter 2 for more detail on the program).

Most Probable Low Estimate

- A value of 5-10 +/- percent of direct cost subtotal was used for mobilization if it was not determined within IPE
- A value of 8-12 +/- percent of the direct cost plus mobilization subtotal was used for design contingencies
- Allowance for procurement strategies was set at zero percent of the direct cost plus mobilization subtotal
- A value of 5-20 +/- percent of the contract cost was used for construction contingencies

- Planning, engineering design, and construction management is 20 percent of the total field cost
- Land acquisition non-contract cost: Used the low market value (see Real Estate Appendix for detailed analysis)
- Environmental mitigation non-contract cost is 8 percent of total field cost excluding environmental restoration
- Cultural resources preservation non-contract cost is 2 percent of total field cost
- Water Use Efficiency Actions non-contract cost: Same as most probable estimate as this is a fixed cost that will not change during variations in the project conditions.

Most Probable High Estimate

- A value of 5-15 +/- percent of direct cost subtotal was used for mobilization if it was not determined within IPE
- A value of 15-30 +/- percent of the direct cost plus mobilization subtotal was used for design contingencies
- Allowance for procurement strategies was set at 3 +/- percent of the direct cost plus mobilization subtotal
- A value of 10-25 +/- percent of the contract cost was used for construction contingencies
- Planning, engineering design, and construction management is 35 percent of the total field cost
- Land acquisition non-contract cost: Used 80 percent of the high market value (see Real Estate Appendix for detailed analysis)
- Environmental mitigation non-contract cost is 15 percent of total field cost excluding environmental restoration
- Cultural resources preservation non-contract cost is 3 percent of total field cost
- Water Use Efficiency Actions non-contract cost: Same as most probable estimate as this is a fixed cost that will not change during variations in the project conditions.

Major Cost Estimate Exclusions

The feasibility-level cost estimates do not include costs associated with the following:

- Loss of water and power due to construction requirements affecting dam and powerplant operation
- Impacts to downstream water intakes
- General access road maintenance
- Impacts due to multiple construction contracts, market conditions, and number of bidders

Contractor Risks

Several risk items have been identified below in an effort to alert decision-makers to important issues that could impact contractor operations and costs:

- Wing dam and spillway modifications relative to fluctuating lake levels
- Schedule slippage due to security concerns
- Schedule delays for nesting restrictions
- Blasting operations at or near dam facilities
- Stringent classification of materials to meet specification requirements
- Material transport restrictions and safety concerns
- Processing areas that are identified as not sufficient to meet required production goals
- Insurance issues in relation to dam significance
- Seasonal work restrictions imposed by phased spillway gate and lower tier outlet gate replacement schedule
- Long contract periods that expose liabilities
- Contractual risk transfer
- Minority business enterprise and miscellaneous flow-down provisions

Escalation

An allowance for escalation from the April 2010 price level to the notice to proceed milestone was not included in the estimate. The cost estimates only

include escalation during construction, which is incorporated into the unit prices.

Since escalation through notice to proceed was not included, the legislation authorizing the construction of this project should contain appropriate language to provide Reclamation the authority to adjust the appropriation ceiling to reflect future changes in costs. Future efforts are necessary to determine the appropriate escalation factor to be used for budgetary approval.

The estimates of construction costs shown, and any resulting conclusions on the project's financial requirements, economic feasibility, or funding requirements, have been prepared from the best information available at the time the estimate was performed. Final project costs and resulting feasibility would depend on actual labor and material costs, competitive market conditions, and other variable factors, and should include escalation from the published price level to notice to proceed. Accordingly, the final project cost may vary from the estimate. Therefore, project feasibility, benefit/cost analysis, risk, and funding would need to be carefully reviewed before making specific funding decisions and/or establishing the project budget.

Crystal Ball Cost Risk Analysis for CP4

A summary of the Monte Carlo simulation outputs for the construction cost of CP4 is shown in Table 1. Each feature is broken down by contract cost, field cost, non-contract cost (excluding lands non-contract cost, which is broken out into the non-percent based allowances), and construction cost. Contract cost is summation of direct costs for each feature including contingencies for mobilization, design, and allowance for procurement strategies. Field cost is the contract cost plus the construction contingency. Construction cost is the field cost plus the non-contract costs (i.e., planning, engineering design, and construction management; environmental mitigation; and cultural resources).

Table 1. Crystal Ball Cost Risk Analysis Results for CP4

Feature/Cost Component	Confidence Interval		
	0% ($ million)[2]	50% ($ million)[3]	100% ($ million)[4]
Relocations			
Vehicle Bridge Replacements			
Charlie Creek Bridge			
Contract Cost	$14.7	$16.6	$19.3
Field Cost	$15.8	$17.9	$20.7
Construction Cost[5]	$20.9	$25.1	$30.6
Didallas Creek Bridge			
Contract Cost	$2.1	$2.4	$2.8
Field Cost	$2.2	$2.5	$3.0
Construction Cost[5]	$3.0	$3.5	$4.4
Doney Creek Bridge			
Contract Cost	$13.2	$15.3	$17.9
Field Cost	$14.4	$16.5	$19.3
Construction Cost[5]	$19.4	$23.2	$28.7
Fenders Ferry & Second Creek Bridge			
Contract Cost	$2.7	$2.9	$3.0
Field Cost	$3.0	$3.1	$3.2
Construction Cost[5]	$3.9	$4.2	$4.9
McCloud River Bridge			
Contract Cost	$10.4	$11.9	$14.1
Field Cost	$11.2	$12.8	$14.9
Construction Cost[5]	$14.9	$18.0	$22.1
Doney Creek Railroad Bridge			
Contract Cost	$37.5	$41.8	$47.0
Field Cost	$46.2	$52.0	$58.1
Construction Cost[5]	$58.6	$69.8	$86.6
Sacramento River Railroad Bridge, Second Crossing			
Contract Cost	$79.8	$86.6	$95.2
Field Cost	$94.2	$106.3	$117.2
Construction Cost[5]	$124.8	$144.7	$177.2
Pit River Bridge Modifications			
Contract Cost	$20.3	$22.4	$25.0
Field Cost	$24.9	$28.1	$31.6
Construction Cost[5]	$33.0	$38.2	$46.9
UPRR Railroad Realignment			
Contract Cost	$5.7	$6.3	$7.1
Field Cost	$6.8	$7.6	$8.5
Construction Cost[5]	$8.8	$10.3	$12.9

Table 1. Crystal Ball Cost Risk Analysis Results for CP4 (contd.)

Feature/Cost Component	Confidence Interval		
	0% ($ million)[2]	50% ($ million)[3]	100% ($ million)[4]
Roads			
Contract Cost	$27.3	$31.2	$35.4
Field Cost	$29.4	$33.7	$38.7
Construction Cost[5]	$39.5	$47.1	$56.8
Utilities			
Contract Cost	$19.9	$27.2	$35.1
Field Cost	$21.5	$29.5	$38.3
Construction Cost[5]	$29.7	$41.3	$55.0
Buildings/Facilities – Recreation			
Contract Cost	$120.7	$140.7	$163.5
Field Cost	$129.8	$152.1	$178.4
Construction Cost[5]	$177.2	$213.0	$259.6
Dams and Reservoirs			
Main Concrete Dam			
Contract Cost	$53.6	$61.3	$73.3
Field Cost	$64.0	$74.4	$89.1
Construction Cost[5]	$82.2	$101.1	$136.1
Outlet Works			
Contract Cost	$18.7	$21.7	$25.5
Field Cost	$22.8	$26.1	$30.2
Construction Cost[5]	$29.2	$35.3	$46.3
Spillway			
Contract Cost	$79.3	$91.3	$110.3
Field Cost	$94.0	$109.8	$131.7
Construction Cost[5]	$121.1	$148.5	$211.3
Temperature Control Device			
Contract Cost	$22.1	$23.1	$24.6
Field Cost	$27.1	$28.3	$30.0
Construction Cost[5]	$35.5	$38.2	$45.2
Powerplant and Penstocks			
Contract Cost	$0.9	$0.9	$1.0
Field Cost	$1.1	$1.1	$1.3
Construction Cost[5]	$1.4	$1.5	$1.9
Right Wing Dam			
Contract Cost	$4.69	$5.53	$6.43
Field Cost	$5.70	$6.64	$7.93
Construction Cost[5]	$7.20	$9.01	$11.84

Table 1. Crystal Ball Cost Risk Analysis Results for CP4 (contd.)

Feature/Cost Component	Confidence Interval		
	0% ($ million)[2]	50% ($ million)[3]	100% ($ million)[4]
Left Wing Dam			
Contract Cost	$13.0	$17.5	$20.8
Field Cost	$15.9	$21.5	$26.3
Construction Cost[5]	$20.3	$29.2	$39.0
Visitor Center Replacement			
Contract Cost	$6.5	$7.1	$8.0
Field Cost	$7.7	$8.6	$9.8
Construction Cost[5]	$10.0	$11.8	$14.6
Dikes			
Contract Cost	$19.5	$22.7	$26.3
Field Cost	$21.1	$24.6	$28.6
Construction Cost[5]	$27.9	$34.7	$42.9
Reservoir Clearing			
Contract Cost	$13.5	$17.3	$21.5
Field Cost	$14.9	$18.7	$23.6
Construction Cost[5]	$21.0	$26.3	$33.7
Pit 7 Dam and Powerhouse Modifications			
Contract Cost	$0.2	$0.2	$0.3
Field Cost	$0.2	$0.2	$0.3
Construction Cost[5]	$0.3	$0.4	$0.5
Environmental Restoration			
Gravel Augmentation			
Contract Cost	$3.4	$4.3	$5.6
Field Cost	$3.6	$4.6	$6.1
Construction Cost[5]	$5.0	$6.6	$8.9
Restore Riparian and Floodplain Habitat			
Contract Cost	$1.3	$1.6	$1.9
Field Cost	$1.4	$1.8	$2.1
Construction Cost[5]	$2.0	$2.5	$3.1
Non-Percent Based Allowances			
Lands Non-Contract Cost	$55.1	$57.1	$58.8
Water Use Efficiency Actions[6]	$2.3	$2.3	$2.3
Total Construction Cost[1,7]	**$954**	**$1,143**	**$1,442**

Notes:

[1] April 2010 price level

[2] The 0% cost estimate has a zero-percent probability of not being exceeded based on the assumptions used to develop the estimate.

[3] The 50% cost estimate has a 50-percent probability of not being exceeded based on the assumptions used to develop the estimate and in general is close to but not necessarily equal to the 50% cost estimate.

[4] The 100% cost estimate has a 100-percent probability of not being exceeded based on the assumptions used to develop the estimate.

[5] Excluding Lands and Water Use Efficiency Actions non-contract costs.

[6] This is a fixed cost and will not change due to variance in project conditions.

[7] Numbers may not add due to rounding.

The total construction cost of CP4 ranges from $954 to $1,442 million with 100 percent confidence that the estimate will not exceed the high end based on the assumptions used to develop the estimate. Current feasibility estimate for total construction cost of CP4 is $1,070 million (see Chapter 5 of the Engineering Summary Appendix) and falls within the middle range of the confidence interval of the crystal ball risk analysis.

A sensitivity analysis was performed to determine the items that have the greatest impact on the overall costs for each feature. Sensitivity analyses help determine which inputs affect forecasts the most so that risk mitigation efforts can be concentrated on those factors. Crystal Ball calculates sensitivity by computing rank correlation coefficients between every assumption and every forecast while the simulation is running. Correlation coefficients provide a meaningful measure of the degree to which assumptions and forecasts change together and account for their negative and positive dependencies. The sensitivity chart ranks the assumptions from the most important down to the least important in the model. If an assumption and a forecast have a high correlation coefficient, it means that the assumption has a significant impact on the forecast, through both its uncertainty and its model sensitivity. For this analysis, the percent-based allowances (i.e., contingencies, non-contract costs) were driving factors for variation in the forecast.