RECLAMATION

Managing Water in the West

Auburn-Folsom South Unit

Update of Cost

U.S. Department of the Interior
Bureau of Reclamation
Central California Area Office
7794 Folsom Dam Road
Folsom, CA 95630

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CFRD	concrete-faced rock-fill dam
cfs	cubic feet per second
cm	centimeter(s)
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CVP	Central Valley Project
DBE	Design Basis Earthquake
DPR	(California) Department of Parks and Recreation
DWR	(California) Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
GDPUD	Georgetown Divide Public Utilities District
HEP	Habitat Evaluation Procedure
HMR 36	Hydrometeorological Report No. 36
HMR 59	Hydrometeorological Report No. 59
IFIM	Instream Flow Incremental Methodology
M	moment magnitude
MCE	Maximum Credible Earthquake
MDE	Maximum Design Earthquake
msl	mean sea level
MW	megawatt(s)
NEPA	National Environmental Policy Act
NGA	Next Generation of Attenuation
OBE	Operating Basis Earthquake
OPCC	Opinion of Probable Construction Cost
PCWA	Placer County Water Authority
PEER	Pacific Earthquake Engineering Research
PG&E	Pacific Gas and Electric Company
PMF	probable maximum flood
PSHA	probabilistic seismic hazard analysis
RCC	roller-compacted concrete
Reclamation	United States Department of the Interior Bureau of Reclamation
RM	river mile

RTS	reservoir-triggered seismicity
SR	State Route
SWRCB	(California) State Water Resources Control Board
TM	technical memorandum
UHS	Uniform Hazard Spectra
URS	URS Corporation
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
WBS	Work Breakdown Structure
WCC	Woodward-Clyde Consultants
WRDA	Water Resources Development Act

In Section 209 of Public Law 109-103 (November 19, 2005), the Energy and Water Development Appropriations Act of 2006, the United States Congress directed the Secretary of the Interior to complete a Special Report to update the United States Department of the Interior Bureau of Reclamation's (Reclamation's) previous analyses of the costs and benefits of the Auburn-Folsom South Unit, Central Valley Project, California, as authorized under federal reclamation laws and the act of September 2, 1965, Public Law 89-161, Stat. 615. The purposes of the Special Report are as follows:

(1) Identify those project features that are still relevant;

(2) Identify changes in benefit values from previous analyses and update to current levels;

(3) Identify design standard changes from the 1978 Reclamation design [as described in Reclamation 1980a] that require updated project engineering;

(4) Assess the risks and uncertainties associated with the 1978 Reclamation design [as described in Reclamation 1980a];

(5) Update the design and reconnaissance level cost estimate for the features identified under paragraph (1); and

(6) Perform other analyses that the Secretary deems appropriate to assist in the determination of whether a full feasibility study is warranted.

The purpose of this technical memorandum (TM) is to respond to Items (3), (4), and (5) of Section 209 of Public Law 109-103, as framed and limited in the Statement of Work issued with Task Order Number 01B020210H.

To meet the Congressional directive, URS Corporation (URS) performed the following tasks:

- Task 1: Research and Review of Existing Information and Strategy Development
- Task 2: Engineering Technical Review
- Task 3: Update the Design and Reconnaissance Level Cost Estimate
- Task 4: Risk and Uncertainty Analysis

BACKGROUND

In Public Law 89-161 (September 2, 1965), the United States Congress authorized the Auburn-Folsom South Unit as an operationally and financially integrated part of the Central Valley Project in California. As authorized, the Auburn-Folsom South Unit, which was to be located on the North Fork of the American River, included:

- Auburn Dam and Reservoir to elevation 1,140 feet
- A power plant
- Folsom South Canal
- Sugar Pine Dam, Reservoir, and Conveyance
- County Line Dam, Reservoir, and Conveyance

As conceived, the Auburn-Folsom South Unit would have provided the following benefits:

- Increase the supply of water available for irrigation and other beneficial uses in the Central Valley of California
- Provide electric power
- Provide increased flood protection for the Sacramento metropolitan area
- Provide recreation and fish enhancement
- Provide a water supply for the Folsom Canal service area

The Auburn-Folsom South Unit would involve the following capital improvements: a mass concrete dam and hydraulic structures, an 800-megawatt power plant and switching facilities, approximately 16 miles of highway relocation, recreation and facilities improvements, and an allowance for impact to the environment.

Reclamation initiated construction of Auburn Dam in 1967 and construction of Folsom South Canal in 1968. However, the construction of Auburn Dam was halted and deferred, pending more studies, after an earthquake in 1975 near Oroville, California. No further construction has been performed on the dam since 1975. Construction of the first two reaches of the Folsom South Canal, totaling about 27 miles, was completed in 1973.

TASKS 1 AND 2: RESEARCH AND REVIEW OF EXISTING INFORMATION AND STRATEGY DEVELOPMENT, AND ENGINEERING TECHNICAL REVIEW

The purposes of the activities undertaken to respond to Item (3) of Section 209 of Public Law 109-103 were to collect information pertinent to the original design and review the information related to the original design to identify the design criteria used, particularly those criteria that would need to be changed or updated during the performance of a more detailed evaluation of the design. URS performed this evaluation qualitatively.

In many instances, the original documentation supporting the design was not readily available. URS reviewed the available design reports, calculations, and contract documents, including drawings and specifications. When no supporting direct documentation was available, the design was presumed to be based on the design assumptions commonly followed during that time period, as documented in contemporaneous Reclamation publications and the technical literature. Appendix A provides a list of the technical documents that URS consulted in preparing this cost update.

The Auburn-Folsom South Unit was originally designed in the early 1970s, and the design was updated in the late 1970s. Design criteria for dams and other structures have changed in the roughly 30 years since the original design was developed. The most crucial changes have occurred in the hydrologic and seismic aspects, as these are the areas where new data are always being collected, and the growing statistical population used in these disciplines results in the inclusion of larger events not sampled before. Important changes have also taken place in construction technologies and the use of materials.

It should be mentioned that not all design criteria changes necessarily result in cost increases. Many times better knowledge of a physical process results in the application of more exact procedures that allow for more efficient use of materials, and as a result, costs are reduced.

TASK 3: UPDATE THE DESIGN AND RECONNAISSANCE LEVEL COST ESTIMATE

The update of the design and the estimate of construction cost was done at an appraisal level of project development. Following Reclamation's instructions, URS did not update the design, with the exception of a highway relocation related to national security guidelines. The use and purpose of this assignment are to establish the feasibility of construction and identify areas of potential design improvement. Where applicable, URS quantified design modifications and incorporated them into its Opinion of Probable Construction Cost (OPCC), which is referred to as the "Field Cost" in Reclamation terminology. An OPCC is to be prepared without detailed engineering data. Typically, this type of OPCC would be expected to be accurate within +100 percent or –30 percent.

The OPCC makes use of a Work Breakdown Structure (WBS) for capital construction, as follows:

- Project general requirements
- Site preparation
- Concrete curved gravity dam
- Hydraulic electric power plant
- Electric power transmission, switchyards, and substations
- Highway and road relocation
- Public access and recreation

An allowance for environmental impact and mitigation was also considered and included.

Appendix B provides the complete cost estimate calculation work sheets. Appendix C provides the complete updated cost estimates.

TASK 4: RISK AND UNCERTAINTY ANALYSIS

A qualitative risk analysis methodology was employed to assess the risks associated with the 1978 Reclamation design (Reclamation 1980a) for the Auburn-Folsom South Unit. Assessing the project risk requires the use of risk factors. A risk factor is defined as an unplanned condition or event that can significantly impact the project cost. Such conditions are unplanned in that they are not included in the contingency developed for the project. However, the risk factors do identify issues of particular concern to Reclamation for this project. These factors can include anything from changes in design requirements due to improved understanding of physical process (e.g., floods or earthquakes) to changes in environmental regulatory requirements, changes in real estate costs, and changes in the economy in general.

To be considered in this analysis, a risk factor had to fall within a specified range of probabilities. The probability range for considering whether a risk factor was significant was 1:100 or 1 percent to 1:2 or 50 percent. Due to the qualitative nature of the analysis, the probabilities were broken down into five categories on a scale of 1 to 5.

To assess the cost of a given factor, the project team subjectively identified the mitigation measures that would be needed to respond to the impact of a given risk if the impact were to occur and the estimated cost of these measures. This analysis was done on a line-item basis for each project feature using the top-level (summary-level) WBS developed for this analysis. The cost impact of the risk factor had to exceed a threshold of $3 million to be considered as significant and included in the analysis. The increases in costs were then categorized on a five-point scale that was similar to the 1 to 5 probability scale.

The risk score was calculated by using the probability and cost category assessments. The result was a semi-quantitative method that could be used to rank the risk factors in terms of both probability of occurrence and cost.

Appendix D provides the complete risk analysis workbooks.

FINDINGS

Our review of the 1970s-era design criteria showed that many of the criteria were outdated and would need to be replaced by state-of-the-practice criteria during a future feasibility study for the project. Changed criteria in many areas would result in changes to quantities of materials and construction methodologies, both of which would have an important impact on costs. Changes in the following areas would likely lead to fundamental impacts to the cost of the project: the location of the dam, the type of dam selected, the cross-section geometry of the dam, the materials used in the dam, and others. Some of these impacts would increase the cost of the project, but other impacts would reduce the cost. Among the factors that have the potential to reduce the cost of the project, the use of roller-compacted concrete (RCC) is probably the easiest to identify. RCC has become the preferred method for constructing concrete gravity dams and could result in important savings in the cost of concrete for Auburn Dam. To some extent, these cost savings would be offset because it would be necessary to relocate the power plant outside of the body of the dam to optimize the use of RCC in the project, and this relocation would result in additional costs. The net effect of the savings from the use of RCC and the cost of the power plant relocation would need to be studied during the required feasibility stage for the project.

At June 2006 price levels, the cost of the dam component of the OPCC is approximately $4.5 billion, and the cost of the environmental mitigation component of the OPCC is $1.5 billion. Broken down by project feature, the cost of the concrete curved gravity dam component of the OPCC is approximately $2.5 billion, or about 56 percent of the total estimated cost.

Five risk factors are identified as having a high probability of significantly impacting the OPCC:

- Seismic design
- Real estate
- Quantities
- Market conditions
- Inflation

The potential total cost impact of these risk factors on the dam component of the OPCC is estimated at $1.5 billion, a potential increase of 32 percent over the estimated base cost of the dam component of the OPCC. The majority of the high-probability financial risk is associated with the dam, the hydroelectric power plant, and the highway relocation. The potential total cost impact of these risk factors on the environmental mitigation component of the OPCC is estimated at $520 million, a potential increase of 35 percent over the estimated base cost of the environmental mitigation component of the OPCC.

The seismic design risk factor dominates the uncertainty costs for dam construction. At a potential cost of approximately $750 million, seismic design risk issues clearly affect potential dam construction costs. A better understanding of seismic design could potentially result in changes to the quantities of materials necessary to build the dam to modern earthquake standards.

With respect to the highway relocation, the real estate risk factor accounts for 42 percent of the high-probability risk costs at $234 million. This impact is not surprising, as highway relocation is a land-intensive feature. The design uncertainty for the highway relocation is much larger than for the dam, and this difference is reflected in the high risk scores and potential costs increases for the highway relocation. Land costs have a high potential to continue to significantly impact costs if the recent growth rate in real estate prices continues.

The quantities risk factor also affects the highway relocation feature. The quantities risk factor addresses the issues of excavation, steel, and concrete and their potential impact on costs. The highway relocation feature as currently defined was not an original feature of the dam. It is being considered now because of changes in regional land use and national security issues that have developed since the dam was originally designed. Highway construction would require significant excavation and fill. Until such time as the highway alignment is identified and finalized, excavation costs will continue to have a potential impact on highway relocation costs.

The market conditions risk factor, particularly as it applies to material availability, has significant potential to affect the project costs of the dam. Although market conditions have the potential to impact costs for all construction features, this risk factor is especially important for hydroelectric power plant construction. Unit pricing is the key issue for this feature. The potential impact to the estimated cost of the hydroelectric power plant is approximately $130 million. Given recent trends in unit pricing, the volatility in pricing may not change in the near term. Thus, the impact of this risk factor could continue until such time as the dam would be built.

For the environmental mitigation component of the OPCC, the real estate risk factor, in terms of both cost and land, dominates the uncertainty, accounting for all of the high-probability risk costs. Environmental mitigation is a land-intensive feature. At this stage of design, uncertainty with regard to the types of mitigation and the amount of mitigation required is the dominant consideration.

The inflation risk factor also has a high potential to affect both the dam component and the environmental mitigation component of the OPCC. As a global risk factor, inflation has the potential to affect the estimated cost of the entire project, not just individual line items. This analysis identified 6 percent as the inflation level that has a high potential to impact total project costs.

The following risk factors/scenarios do not result in high risk scores but are of potential importance because all have a cost impact in the highest category: seismic uncertainty, borrow sources/quantity, borrow sources/quality, labor availability, and conditions related to the dam foundation. These five risk factors can be characterized as low-probability, high-consequence events. That is, these risk factors have a small likelihood of occurrence (less than 10 percent), but they could cause very high cost impacts if they do occur. These risk factors only apply to dam construction. However, these factors are potentially important because the dam is the single largest feature of the project. The dam accounts for 56 percent of the estimated costs of the project and uses the largest amount construction materials and resources of all the features of the project.

In Public Law 89-161 (September 2, 1965), the United States Congress authorized the construction of the Auburn-Folsom South Unit as an operationally and financially integrated part of the Central Valley Project. As authorized, the Auburn-Folsom South Unit, which was to be located on the North Fork of the American River, included:

- Auburn Dam and Reservoir to elevation 1,140 feet
- A power plant
- Folsom South Canal
- Sugar Pine Dam, Reservoir, and Conveyance
- County Line Dam, Reservoir, and Conveyance

The United States Department of the Interior Bureau of Reclamation (Reclamation) initiated construction of Auburn Dam in 1967 and the construction of Folsom South Canal in 1968. However, the construction of Auburn Dam was halted and deferred, pending more studies, after an earthquake in 1975 near Oroville, California. No further construction has been performed on the dam since 1975. Construction of the first two reaches of the Folsom South Canal, totaling about 27 miles, was completed in 1973.

In Section 209 of Public Law 109-103 (November 19, 2005), the Energy and Water Development Appropriations Act of 2006, Congress directed the Secretary of the Interior to complete a Special Report to update the previous analyses of the costs and benefits of the Auburn-Folsom South Unit, Central Valley Project, California, as authorized under federal reclamation laws and the act of September 2, 1965, Public Law 89-161, Stat. 615. The purposes of the Special Report are as follows:

(1) Identify those project features that are still relevant;

(2) Identify changes in benefit values from previous analyses and update to current levels;

(3) Identify design standard changes from the 1978 Reclamation design that require updated project engineering;

(4) Assess the risks and uncertainties associated with the 1978 Reclamation design;

(5) Update the design and reconnaissance level cost estimate for the features identified under paragraph (1); and

(6) Perform other analyses that the Secretary deems appropriate to assist in the determination of whether a full feasibility study is warranted.

The purpose of this technical memorandum (TM) is to respond to Items (3), (4), and (5) of Section 209 of Public Law 109-103, as framed and limited in the Statement of Work issued with Task Order Number 01B020210H.

1.1 PURPOSE

The purpose of this TM is to respond to Items (3), (4), and (5), as framed and limited in the Statement of Work issued with Task Order Number 01B020210H.

The purpose of this report is not to update the design of Auburn Dam. The design for Auburn Dam does not fully meet current requirements, so the design would need to be changed before the dam could be constructed. The current design would need to go through an update process that would follow the usual design steps of any project, as the conditions, requirements, and design criteria under which it was conceived have changed.

1.2 SCOPE

To meet the Congressional directives for the Special Report, URS Corporation (URS) performed the following four tasks:

- Task 1: Research and Review of Existing Information and Strategy Development
- Task 2: Engineering Technical Review
- Task 3: Update the Design and Reconnaissance Level Cost Estimate
- Task 4: Risk and Uncertainty Analysis

Task 1: Research and Review of Existing Information and Strategy Development

To accomplish Task 1, URS completed the following sub-tasks:

- **Task 1-1:** Review *Auburn-Folsom South Unit, Central Valley Project, Technical Memorandum: Project Description* (Reclamation 2006a) to tabulate the project features and the features requiring sub-appraisal design concepts.
- **Task 1-2:** Obtain and review engineering documents to determine the quantities and unit costs used in previous estimates for the relevant features, determine sub-appraisal design requirements, and determine the rationales and assumptions for the quantities and unit costs.
- **Task 1-3:** Develop a project strategy to update project cost estimates and an approach to use for sub-appraisal concept designs and cost estimates.
- **Task 1-4:** Develop a project strategy to perform a qualitative risk and uncertainty analysis of project cost estimates.
- **Task 1-5:** Develop a detailed scope of work for completing the cost estimate update.

Task 2: Engineering Technical Review

Activities grouped under Task 2 were required to comply with Item (3) of the Special Report: "Identify design standard changes from the 1978 Reclamation design [as described in Reclamation 1980a] that require updated project engineering."

Auburn Dam was studied and designed during the late 1960s and early 1970s. Although many pioneering techniques were used as part of these studies, important advances have occurred in the design and construction of dams and the criteria used for these purposes since the studies were performed. Therefore, the dam design does not fully meet current requirements, and therefore the design would need to be changed before the dam could be constructed. The purpose of the activities undertaken to respond to Item (3) of the Special Report are to collect information pertinent to the original design, review the information related to the original design to identify the design criteria used and, in particular, those criteria that would need to be changed or updated during the performance of a more detailed evaluation of the design. URS performed this evaluation qualitatively.

To accomplish the above purpose, URS undertook several sub-tasks:

- **Task 2-1:** Obtain and review the original *Feasibility Design Summary: Auburn Dam, Concrete Curved-Gravity Dam, Alternative (CG-3) (with 800-MW Integral Power Plant)* (Reclamation 1980a). The documentation supporting the original design in many instances was not readily available. The available design reports, calculations, and contract documents, including drawings and specifications, were reviewed. When no supporting direct documentation was available, URS presumed that the design was performed based on design assumptions commonly followed at that time, as documented in contemporaneous Reclamation publications and the technical literature.
- **Task 2-2:** Identify Current Criteria for the Original Features. Once the original design criteria were identified after reviewing the documentation obtained from Reclamation, URS compared these criteria with current design criteria for the corresponding dam site and existing conditions. Many dam design criteria have been modified since the original design of the dam, particularly the hydrologic design criteria, the hydraulic design criteria, the seismic design criteria, the dam foundation stability criteria, the dam body stability criteria, material usage, the seepage and drainage requirements, the underground excavation design criteria, the electro-mechanical criteria, the hydro-mechanical criteria, and others. URS identified changes in these criteria and assessed their potential impact on more-detailed studies in the future.
- **Task 2-3:** Develop Criteria and Assumptions for the Features Requiring Modification. URS developed design criteria for the features requiring update. The design criteria were developed to the sub-appraisal level.
- **Task 2-4:** Identify the Environmental Project Constraints, Mitigation Needs, and Strategies. To adequately address the project's environmental constraints, URS reviewed the existing data, which included the California Natural Diversity Database (CNDDB), the on-line inventory of the California Native Plant Society (CNPS), state and federal agency guidelines, and recent studies within the project vicinity. URS also consulted with experts familiar with the region. URS used the resulting data to identify the environmental constraints and to develop the mitigation needs. These mitigation needs were identified at a conceptual level (e.g., acres of oak woodland habitat) to develop a strategy for addressing them. As part of this task, URS developed the costs associated with the procurement of mitigation lands. These costs were based on recent similar mitigation programs and were taken to a conceptual level (e.g., acres of freshwater marsh habitat) to provide a basis for development of a more specific mitigation plan.

The work that URS performed in Task 2 relied on the documents listed in the reference list (Section 7), if cited, or Appendix A, if reviewed but not specifically cited in the text.

Task 3: Update the Design and Reconnaissance Level Cost Estimate

The features identified in *Auburn-Folsom South Unit, Central Valley Project, Technical Memorandum: Project Description* (Reclamation 2006a; see also Reclamation 2006b) were developed to a sub-appraisal level using as a basis the design criteria identified and/or developed in Task 2. Task 3 was performed to respond to Item (5), "Update the design and reconnaissance level cost estimate for the features identified under paragraph (1)."

To accomplish Task 3, URS completed the following sub-tasks:

- **Task 3-1:** Develop Concept-Level Designs of the Affected Features:
  - **Task 3-1A:** Develop Concept-Level (Sub-Appraisal-Level) Designs of the Affected Features. These designs had sufficient detail to allow estimation of work quantities, as required for the cost estimates.
  - **Task 3-1B:** Develop Concept-Level Drawings/Graphics, Layouts. The purpose of this sub-task was to prepare the concept-level drawings/graphics and layouts required to estimate the work quantities involved. The sub-task consisted of the preparation of office working quality sketches. The level of detail included in the sketches, drawings, graphics, and layouts was sufficient to allow estimation of work quantities for the concept level of design.
- **Task 3-2:** Reconnaissance-Level Cost Estimates: The Engineer's Opinion of Probable Construction Cost (OPPC) was prepared as seen through the eyes of a prudent and well-prepared contractor. The OPPC included direct and indirect costs with allowance for the risk that a prudent, experienced contractor would expect to incur.

Appendix B provides the complete cost estimate calculation work sheets. Appendix C provides the complete updated cost estimates.

Task 4: Risk and Uncertainty Analysis

The time available for preparation of this report was very short and did not allow for development of an appraisal-level evaluation of the design. To evaluate and mitigate the effects of partial knowledge of the project and the project site, Task 4 allowed for the qualification of risk and uncertainty in the 1978 Reclamation design and the cost estimate update (Reclamation 1980a). This task was performed to respond to Item (4), "Assess the risks and uncertainties associated with the 1978 Reclamation design [as described in Reclamation 1980a]."

This task was performed after several activities:

- Identification of project features
- Identification of cost components
- Identification of cost parameters for each component
- Identification of the relevant risk factors
- Assessing the likelihoods of those risk factors occurring
- Assessing the cost impacts of the risk factors

Appendix D provides the complete risk analysis workbooks.

1.3 BACKGROUND

Many Congressional actions relate to the Auburn-Folsom South Unit of the Central Valley Project (CVP), or Auburn Dam. Three fundamental authorizations important to the Auburn-Folsom South Unit Special Report were listed in *Auburn-Folsom South Unit, Central Valley Project, Technical Memorandum: Project Description* (Reclamation 2006a):

- Auburn-Folsom South Unit, Central Valley Project: The Auburn-Folsom South Unit was authorized in Public Law 89-161, 79 Stat, 615, dated 2 September 1965, as an operationally and financially integrated part of the CVP.
- Auburn Dam Road Relocation: Construction of an all-weather, two-lane paved road extending from old U.S. Highway 40 near Weimar across the North and Middle Forks of the American River to near Spanish Dry Diggings in El Dorado County was authorized in the Water Resources Development Act (WRDA) of 1974 (Public Law 93-251, dated March 7, 1974).
- Auburn-Folsom South Unit, Special Report: A Special Report to update the analysis of costs and associated benefits of the authorized Auburn-Folsom South Unit was authorized in Section 209(a) of Public Law 109-103, dated November 19, 2005.

1.4 ORGANIZATION OF THIS TECHNICAL MEMORANDUM

This TM consists of an executive summary, seven sections, tables, figures, and appendices. The sections are:

Section 1: Introduction

Section 2: Summary of Project Features

Section 3: Engineering Technical Review

Section 4: Updated Design and Reconnaissance Level Cost Estimate

Section 5: Risk and Uncertainty Analysis

Section 6: Findings

Section 7: References

Most of this section was taken from *Auburn-Folsom South Unit, Central Valley Project, Technical Memorandum: Project Description* (Reclamation 2006a).

2.1 DAM TYPE AND DESIGN

After authorization of the Auburn-Folsom South Unit, the required and customary levels of studies were completed, and a double-curvature concrete arch dam at river mile (RM) 20.1 was selected. Construction was initiated on this design and proceeded until the controversy created by the earthquakes centered near Oroville resulted in cessation of activities. Following cessation of major construction activities, various studies of alternative dam types and alignments were conducted. Studies conducted by Reclamation in 1977–1978 (Reclamation 1980a, 1980b) focused on two options: (1) a rock-fill embankment with central impervious core slightly downstream from the RM 20.1 site and (2) a concrete curved gravity dam (CG-3) at the RM 20.1 site. That study resulted in selection of the concrete curved gravity dam for further consideration. In the mid-1980s, Bechtel National, Inc., evaluated a number of dam types and locations for the California Department of Water Resources (DWR) (Reclamation 1986). These studies concluded that a roller-compacted concrete (RCC) dam at RM 19.0 would be less costly than other dam types and locations.

The Special Report is based on the CG-3 dam design at RM 20.1, as documented in *Feasibility Design Summary: Auburn Dam Concrete Curved-Gravity Dam, Alternative (CG-3) (with 800 MW Integral Powerplant* (Reclamation 1980a).

Under the CG-3 dam design, the dam would be founded on slightly weathered rock. Treatment of faults, shears, and weaker zones would be performed as necessary. Grout and drainage curtains would be drilled from the upstream drainage gallery to control seepage. Drill holes for the grout curtain would be completed in a single line at a spacing of 12 feet. Drill holes would range from 100 feet deep at the abutments to 280 feet deep at the maximum dam section. Holes for the drainage curtain would be drilled just downstream of the grout curtain at 12-foot centers and depths ranging from 75 to 210 feet. A downstream drainage curtain would be drilled from a second foundation gallery in the deeper portion of the dam below elevation 555 feet above mean sea level (msl) and would have holes at 12-foot centers and depths of 140 feet. The grouting program also would include consolidation grouting with holes 30 feet deep over the entire foundation on a 20-foot grid pattern.

2.2 SPILLWAY AND APPURTENANT FACILITIES

Under the CG-3 dam design, the spillway would be located on two blocks near the center of the dam and would consist of eight orifices. Each orifice would be approximately 456 square feet in area and extend from about elevation 980 feet to about elevation 1,004 feet above msl. Flow through the orifices would be controlled by 19-foot by 24-foot top seal radial gates, which would discharge into two chutes and terminate with a ski jump flip bucket on each chute. The four central gates would be the service spillway that would be used for normal flood operations. The outer two gates on each side of the service spillway would constitute the auxiliary spillway and would be opened only during extreme flood events. Each of the service spillway gates would have a capacity of 41,250 cubic feet per second (cfs) at a maximum water surface elevation of 1,135.0 feet. Each auxiliary spillway gate would have a capacity of 1,250 cfs. At the maximum water surface elevation, the auxiliary spillways and the service spillway would have a maximum discharge capacity of 330,000 cfs.

Early designs for Auburn Dam spillway operations were based on criteria that limited discharges to 115,000 cfs from Folsom Dam during passage of the Standard Project Flood through Auburn Dam, and protected Auburn Dam during passage of the Inflow Design Flood. These operations were based on a combined flood storage of 650,000 acre-feet for Auburn and Folsom Reservoirs, of which 125,000 acre-feet were interchangeable between the two reservoirs.

The plunge pool would be a two-level basin to accommodate the discharge from the service spillway and auxiliary spillways. The flow from the service spillway would be dissipated in the farthest downstream basin. This basin would be placed at elevation 410 feet above msl and the concrete would be lined to withstand impact loading at low discharges. The auxiliary spillway discharges would follow a trajectory underneath the service spillway jets and dissipate in the upstream basin. This basin would be placed at elevation 430.0 feet above msl and be unlined.

2.3 OUTLET WORKS

The outlet works would be located in a block near the center portion of the dam and consist of two bell-mouth circular intakes transitioning to two 72-inch-diameter steel pipes, followed by two 72-inch ring follower gates. The outlet pipes would drop from a centerline elevation of 625 feet above msl to elevation 485.5 feet to enter the power plant outlet bay. The outlets would discharge horizontally at a centerline elevation of 485.5 feet above msl through two 72-inch hollow jet valves.

The outlet works were designed for a discharge of 4,000 cfs at a water surface elevation of 816.5 feet above msl to provide releases for downstream requirements. The river outlets would have a capacity of 5,540 cfs at gross pool (reservoir water surface elevation of 1,131.4 feet above msl) but would be restricted to a discharge of 4,200 cfs because of possible damage to the conduits from high-velocity flow.

Diversions from Auburn Dam and Reservoir would primarily include the Placer County Water Authority (PCWA) Auburn Ravine (Ophir) Tunnel. The 0.75-mile-long Ophir Tunnel extends from near the north abutment of the dam to an outlet in Auburn Ravine. Its entrance would be inundated by about 200 feet at gross pool elevation in the 2.3 million acre-feet Auburn Reservoir. The intent was for PCWA to use the tunnel to divert some of its North Fork and Middle Fork American River water rights to western Placer County. The project would include a gated structure at the entrance to the tunnel that would be needed for PCWA to effectively manage the diversion of its water from Auburn Reservoir and for Reclamation to be able to store water above the inlet elevation to the Ophir Tunnel.

Although not initially included in the project, during construction, provisions were made for Georgetown Divide Public Utilities District (GDPUD) to have the potential to add a pipeline that would extend from the dam to near Cool, California. To allow for a cost-effective future attachment of the pipeline, a small portion was constructed near (downstream of) the south abutment of the dam. Lift stations and any other pipeline and related facilities would be the responsibility of GDPUD.

2.4 BORROW AREAS

A primary source for aggregate production is the area on the Middle Fork American River that would be inundated by the reservoir. Approximately 8 to 9 million cubic yards of tested concrete aggregate materials exist from Mammoth Bar upstream to Cherokee Bar. Additional materials could be available from development of a rock quarry near the possible site of the aggregate processing plant or from river gravel located in the Middle Fork American River above the potential Ruck-A-Chucky Bridge site and extending to PCWA's Ralston Afterbay Dam (Reclamation 1977a). Other potential borrow sites include Lake Clementine and the Knickerbocker Creek area (which could potentially impact recreation). Material for the original cofferdam came from the Salt Creek boat ramp and foundation excavation.

2.5 DIVERSION AND COFFERDAMS

The original diversion cofferdam was enlarged to a crest elevation of 715 feet above msl after suspension of construction of the dam. The cofferdam was designed to contain and safely pass through the river diversion tunnel a flood peak with a recurrence interval of 25 years. During the February 1986 flood, the cofferdam was overtopped. The diversion cofferdam would need to be reconstructed. The downstream cofferdam would also need to be reconstructed.

2.6 AMERICAN RIVER PUMP STATION REMOVAL

The American River Pump Station is currently under construction and would need to be removed if Auburn Dam were to proceed to construction.

2.7 POWER PLANT AND SWITCHING FACILITIES

The 1965 authorization (Public Law 89-161) for the Auburn-Folsom South Unit included a hydroelectric power plant at Auburn Dam; the initial installed capacity of the power plant was to be approximately 240 megawatts (MW) and was to include transmission for interconnection with the CVP power system. Provision was also made for the potential development of up to approximately 400 MW. Other power configurations have been evaluated since the authorization. According to the August 1980 Feasibility Design Summary (Reclamation 1980a), the optimum size of the CG-3 power plant was an installed capacity of 800 MW. An arrangement of four 200-MW generating units was selected due to the electrical design flexibility of having an even number of units. Each of the generating units has a minimum head of 356.5 feet, a maximum head of 626.0 feet, a rated head of 500.0 feet, and a design head of 548.5 feet. Each vertical shaft generator has a rotor diameter of about 31 feet and is directly connected to a Francis-type turbine with a spiral case width of about 44 feet. From each turbine water flows through a concrete draft tube with an exit opening of 20 feet wide by 35 feet high. At rated speed and head, the discharge through each turbine is 5,760 cfs. An additional 4-MW generating unit located in the river outlet bay would be used to generate the power needed by the dam itself.

The penstocks and their intakes would be located in the center portion of the dam. Each of the four 17-foot-diameter penstocks would have two intakes: one with a centerline at elevation 800 feet above msl and one with a centerline at elevation 625 feet above msl. This design provides multilevel intake capability for each power plant unit.

The tailrace would consist of the excavated river channel currently flowing through the floor of the canyon. Tailrace channel slopes would be protected with riprap to prevent erosion and slides.

2.8 RELOCATION OF STATE ROUTE 49

The original replacement of State Route (SR) 49 was to begin at the intersection of Lincoln and College Way in Auburn and run in a southerly direction generally parallel to and slightly west of Sacramento Street to the intersection of the Auburn-Folsom and Shirland Tract Roads. This portion of the highway relocation has been completed and is in use. From this intersection, the SR 49 replacement was to swing in a large arc toward the north (right) abutment of Auburn Dam. Maidu Drive, a part of the right abutment access road system, has been constructed in part on the eventual location for SR 49 in this area. SR 49 was to cross the North Fork American River canyon on the viaduct founded on the crest of Auburn Dam. From the south (left) abutment of the dam, the route was to continue in an easterly direction through the Salt Creek–Knickerbocker Recreation Area to an intersection with existing SR 49 near Cool. The total length of the relocation was to have been 6.5 miles, of which 1.9 miles was completed.

In the mid-1980s, the State of California considered alternative relocations for SR 49. Primarily because of national security concerns, the current project plan would not call for SR 49 to cross the American River Canyon on top of Auburn Dam. The updated plan would also include an access road from the relocated SR 49 alignment to the south and north abutments and across the dam. Much of the potential relocation route of SR 49, especially on the Auburn side of the American River Canyon, is now in residential development. Other potential routes would need to be evaluated in any future studies.

2.9 OTHER ROAD RELOCATIONS

Construction of Auburn Dam and Reservoir would also require the relocation of several county roads. Replacement of these roads is generally contained under provisions of Section 207 of the Flood Control Act of 1960, as amended by Section 208 of the River and Harbors Act of 1962 (Public Law 87-874) and Section 36 of WRDA. The Auburn-Foresthill Road and Bridge replacement was completed in 1973 and is now in operation. Another major road relocation would be the Placer/El Dorado County upstream route. Each relocation would need to be made to current State of California standards. Each of these and other minor road relocations would require significant additional evaluation.

The Special Report is also adopting the plan recommended in earlier studies to replace access in the eastern portion of Auburn Reservoir. This relocation includes a two-lane, all-weather paved road extending from Old U.S. 40 between Colfax and Weimar to the El Dorado County road near Spanish Dry Diggings. Two major bridges would be required: a 1,840-foot-long bridge crossing the North Fork (Colfax Foresthill Bridge) and a 1,900-foot-long bridge crossing the Middle Fork (Greenwood Bridge).

2.10 ACCESS ROADS

To date, nearly 12 miles of construction access roads have been completed. They include Pacific Avenue, Indian Hill Road, Auburn-Folsom Road intersection, left and right abutment access roads, a connecting road, a power plant access road, and a railhead access road. Where appropriate, these access roads, especially within the constriction area, would need to be replaced. Various additional site access roads would also be required to facilitate construction.

2.11 RELOCATION OF UTILITIES AND OTHER FACILITIES

Various other minor roads, bridges, and utilities in the Auburn Reservoir area could be candidates for relocation, including U.S. Forest Service facilities, the Ponderosa Way access road and bridge, power lines, and radio towers. However, it is not clear at this time if these and several other minor roads and bridges were included in the original project or should be considered for relocation. Therefore, this TM does not identify these facilities. A detailed inventory of these facilities would need to be developed in the future if the Auburn-Folsom South Unit were to be constructed.

2.12 RELOCATION OF RECREATIONAL FACILITIES

Numerous recreational trails used for hiking, running, biking, and equestrian purposes are located in the Auburn Reservoir area and would need to be replaced.

All cost estimates in the August 1980 Feasibility Design Summary (Reclamation 1980a) included a trail and equestrian bridge. Further efforts would be needed to identify the locations of these facilities. However, until the scope of the trail and bridge can be confirmed, URS believes that the previous cost should be adjusted to current price levels for the purposes of the Special Report.

Reclamation entered into an agreement with the California Department of Parks and Recreation (DPR) in 1966 that governed the construction and operation of recreation and fish and wildlife enhancement facilities at the Auburn-Folsom South Unit. Under that agreement, DPR agreed to pay one-half of the separable costs for the recreation and fish and wildlife facilities that Reclamation was to construct. The State of California also agreed to operate and maintain the completed facilities. In 1978, under this agreement, DPR developed a preliminary general plan for recreation facilities at Auburn and Folsom Reservoirs and Lake Natoma (DPR 1978).

DPR is in the process of developing the Auburn State Recreation Area Resource Management Plan/General Development Plan Environmental Impact Statement (EIS)/Environmental Impact Report (EIR).

2.13 ENVIRONMENTAL MITIGATION

Significant efforts went into the National Environmental Policy Act (NEPA) compliance process and documentation as part of the original project, but URS recognizes that much more work would be required should the Special Report proceed to the feasibility study phase. As described in *Auburn Dam Alternative Study* (Reclamation 1987), wildlife mitigation measures would be necessary to compensate for adverse effects on wildlife resources in the impoundment area. Through September 1986, about $400,000 in federal funds were spent to acquire lands in the Auburn Reservoir area to mitigate for impacts to wildlife resources. These lands are located on the Middle Fork American River near Volcanoville, California. The 1987 Alternative Study stated that the U.S. Fish and Wildlife Service would use funds appropriated to protect the habitat in these wildlife areas and restore plantings used by the wildlife for food and shelter (Reclamation 1987).

A multipurpose reservoir at the Auburn site could result in the loss of land for wildlife habitat. Further study may identify impacts that could occur to endangered species, primarily the valley elderberry beetle, resident fish species, cultural resources, scenic quality, geologic resources, and recreational resources. Surrounding recreational facilities and activities could also adversely impact these resources.

The Auburn Reservoir inundation area and the lands required for roads and relocations and recreational facilities contain numerous sites of cultural significance. Surveys of historic and archaeological sites in the project area have been accomplished as part of previous studies, and an archaeology recovery plan has been developed. Based on this information, URS believes that estimates of costs to implement a recovery and mitigation project element for the impacted sites have been developed in previous studies. These costs are to be updated for the Special Report, but no new surveys are planned as part of current efforts.

2.14 REAL ESTATE

This section discusses the lands to be acquired for the project and impacts on water rights.

2.14.1 Lands

It was originally estimated that the total land requirements to implement the Auburn-Folsom South Unit would be 49,265 acres. Of the lands needed in the Auburn Reservoir area, 12,820 acres would be acquired from private landowners and the remaining 36,445 acres would be withdrawn from public sources. The anticipated take line for Auburn Reservoir and the areas remaining to be acquired are shown in the 2006 Project Description (Reclamation 2006a). However, future studies may indicate that some of these remaining lands may not be required for the project because currently formulated studies now show that other, additional lands not now identified would be needed. In particular, additional lands may be required for environmental mitigation purposes.

2.14.2 Water Rights

Completion of Auburn Dam would require continued coordination with the California State Water Resources Control Board (SWRCB) regarding the storage of water in Auburn Reservoir for beneficial uses, including irrigation, power, flood control, and environmental purposes. In 1959, water right applications were filed by the United States for storage and diversion of water supplies for the Auburn-Folsom South Unit. The current status of those applications requires additional investigation. However, URS estimates that Reclamation would need to prepare additional hydrologic evaluations addressing in-stream flow conditions and other issues to demonstrate that unappropriated water is available for appropriation.

2.15 OVERLOOK FACILITIES

Reclamation constructed a temporary overlook on Pacific Avenue upstream from the dam site to serve visitors to the project. The overlook contains a parking area, a pictorial display, and related minimum facilities. URS anticipates that the completed project would include a permanent visitor center and parking areas to be located at the site of the temporary visitor center.

2.16 SECURITY

Security considerations for the dam may include features such as cameras, fencing, bollards, and a water barrier (the costs for these could be included in unlisted items). Guards may also be needed, but the annual cost of the guards will not be included in the Special Report (which will contain construction costs only).

2.17 TEMPORARY CONSTRUCTION FACILITIES

Reclamation constructed several buildings for its field staff during construction of the Auburn area facilities. These buildings include an administration building, a geology building, a materials laboratory, a field engineering building, an automotive shop and service station, and a warehouse building. Several of these buildings are currently occupied by tenants and would need to be vacated to provide space for supporting project construction.

Construction facilities, including staging areas, a batch plant, temporary power, and an office and laboratory (if separate from existing) would be required for the project. The duration of material transporting and site hauling would be influenced by hours permitted in the project area. The hours permitted would be different than those anticipated for initial construction, primarily because of the significant increase in urban development in and near the city of Auburn.

For the project, various other facilities would require removal, relocation, or modification. An additional project feature would be removal of the PCWA pump station. Existing project access roads would be maintained and may need to be improved.

Much of the reservoir area would need to be cleared of existing vegetation before filling. For the Special Report, URS uses the reservoir clearing plan adopted for the authorized project. However, future studies likely would show that a more aggressive, selective clearing program could be considered, as certain types of riparian vegetation may be allowed to remain in the upstream arms of inflowing creeks and streams.

This section examines both the engineering design issues and the environmental considerations that would apply should the Auburn-Folsom South Unit be constructed.

3.1 DESIGN ASSUMPTIONS, CRITERIA, STANDARDS, AND DECISIONS FOR ORIGINAL AND UPDATED FEATURES

The Auburn-Folsom South Unit was originally designed in the early 1970s, and the design was updated in the late 1970s. Design criteria for the dam and other structures have changed in the roughly 30 years since the original design was developed. The most crucial changes have occurred in the hydrologic and seismic aspects, as these are the areas where new data are always being collected, and the growing statistical population used in these disciplines results in the inclusion of larger events not sampled before.

It should be mentioned that not all design criteria changes necessarily result in cost increases. Many times better knowledge of a physical process results in the application of more exact procedures that allow more efficient use of materials, and as a result, costs are reduced.

3.1.1 Design Standards

Auburn-Folsom South Unit was designed according to the design standards that Reclamation followed in the 1970s. These design standards were presented in detail in several documents prepared for the Auburn-Folsom South Unit (Reclamation 1977a, 1980a, 1980b; DPR 1978) as well as other general documents and monographs about dam design (Reclamation 1976a, 1976b, 1977b, 1977c, 1977d).

Reclamation Monograph No. 19 (Reclamation 1977c) mentions Auburn Dam as one of the examples where those design standards are being implemented. The design standards or design criteria used by Reclamation aimed to provide safe, economical, functional, and durable structures. The criteria considered materials, including both the foundation and the concrete dam and its components; loading conditions; methods of analysis and design data; and construction methodologies and quality.

Significant criteria used for the design of the concrete dam in 1978 (Reclamation 1980a) related to:

- Selection of dam site
- Selection of dam type
- Selection of a curved gravity dam
- Geometry of the dam cross section
- Location of the powerhouse inside the gravity structure
- Use of conventional mass concrete placed in zones of different strengths
- Concrete characteristics
- Thermal analysis
- Foundation-concrete interface characteristics

- Foundation surface treatment
- Foundation seepage control
- Loads and loading conditions
- Factors of safety
- Methods of analysis

These criteria would need to be re-evaluated if the design of the dam is going to move to the next stage, as explained below.

3.1.1.1 Selection of Dam Site

The selection of the dam site (RM 20.1) has already been questioned in previous studies of a dam at the general location of Auburn Dam. Although this decision would probably have to be revisited, considerable investment has already been made in the RM 20.1 site, the unknowns at any other site would be larger than those associated with the RM 20.1 site, and the benefits of changing to another site would likely be too uncertain to warrant a change of site.

3.1.1.2 Selection of Dam Type

The Feasibility Design Summary favored the selection of a concrete gravity dam rather than a rock-fill dam (Reclamation 1980a). This fundamental decision would need to be revisited, as the technology of concrete-faced rock-fill dams (CFRDs) was not well developed at the time the study was done. However, several CFRDs have been built with heights that could be considered precedents for a dam of this type at the Auburn site.

A CFRD is one of the dam types considered in most projects these days, as it is economical and is easy to adapt to diverse foundation conditions. Undoubtedly, a CFRD would have to be considered with a gravity dam built using RCC as the probable two top contenders for the most appropriate dam type at this site.

3.1.1.3 Selection of a Curved Gravity Dam

The Feasibility Design Summary shows a curved gravity dam but states that the dam is being analyzed as a straight gravity dam (Reclamation 1980a). If this is the case, then the design must be reevaluated for the possibility of saving materials and reducing cost by constructing a straight dam or a curved dam with a larger radius. This design decision would likely need to be revisited and discussed, and if it changes, it would affect the volume of concrete used in the dam. It should be mentioned that the CG-3 study (Reclamation 1980a) implies arch action to re-distribute the stresses in the body of the dam, and the quantities for the project should include grouting of contraction joints to ensure the arch behavior.

The use of any arch action to re-distribute the stresses would also need to be reevaluated considering the potential foundation fault displacement and its unknown effect on the monolithic action of the dam blocks.

3.1.1.4 Geometry of the Dam Cross Section

The geometry of the dam cross section formed by a vertical upstream face and a downstream face of 0.68 horizontal to 1 vertical (0.68H:1V) could be considered slender and not particularly conservative for a high dam in a seismic zone. Shasta Dam, which is about the same height, has a heel block upstream, and its downstream slope is 0.8H:1V. Although cross sections cannot be compared directly, they do provide some guidance and indicate that further analysis of the dam stability, particularly the foundation and concrete-foundation interface could result in a change of the cross section to a wider cross section requiring an additional volume of material and potentially increasing costs.

3.1.1.5 Location of the Powerhouse Inside the Gravity Structure

Construction of the powerhouse inside the dam was considered as a cost-saving measure during the design process in the 1970s. However, the cost of form work and the additional coordination of activities required to construct the powerhouse inside the dam probably would offset any potential cost savings. Also, the openings required for the powerhouse, the access galleries, and the water conductors are located in the zone of highest stresses in the dam body and would concentrate stresses to potentially unsafe levels. This design decision would likely need to be reconsidered should the design move to the next phase. An independent underground powerhouse and water conductors would probably be the preferred solution.

3.1.1.6 Use of Conventional Mass Concrete Placed in Zones of Different Strengths

A zoned dam would have many benefits, and the use of zoned conventional mass concrete is a well-known procedure that has been successfully employed in many dams. However, conventional mass concrete has been almost completely displaced by RCC in the construction of dams since the 1970s. In the United States the highest dam constructed using RCC is Olivenhain Dam, with a height of 320 feet, but world experience with RCC dams includes heights of up to 650 feet and volumes of up to 10 million cubic yards, both of which would be comparable to the dimensions of the Auburn-Folsom South Unit. Any future studies of Auburn Dam would need to consider the use of RCC instead of conventional concrete.

3.1.1.7 Concrete Characteristics

Some of the zones used in the dam require concrete with very high compressive strength. To obtain those high compressive strengths the concrete mix would require very high cement contents that could result in high heat generation and thermal problems. This issue would require review in future studies, and the use of RCC instead of conventional mass concrete would provide a potential solution.

3.1.1.8 Thermal Analysis

Thermal analysis was not completely treated in the Feasibility Design Summary (Reclamation 1980a). This area would need to be addressed in future studies of Auburn Dam.

3.1.1.9 Foundation-Concrete Interface Characteristics

The foundation for Auburn Dam was studied exhaustively using the state-of-the-practice procedures at the time. The interpretation of the testing results and the corresponding parameters derived from the investigation, such as the shear strength of the rock mass, the strength of the concrete-foundation interface, the deformation modulus of the rock mass, and other parameters would be done differently at this time, and the resulting values could affect the stability analyses performed. The rock mechanics studies would need to be reviewed and the test data reevaluated based on the progress in this area in the last 20 to 30 years.

Of particular importance would be reevaluations of the behavior of the rock mass and of potential rock blocks using state-of-the-practice techniques.

3.1.1.10 Foundation Surface Treatment

The foundation surface treatment is not very well defined in the Feasibility Design Summary (Reclamation 1980a). Considering the size of the dam, the foundation should not only be excavated to competent rock, but foundation shaping should be performed to avoid potential stress concentrations. Foundation concrete would be required in significant quantities to obtain a regular surface for placement of the dam concrete.

3.1.1.11 Foundation Seepage Control

The rock foundation apparently is tight, as implied by the selection of one row grout curtain, with holes spaced at 12 feet. No details are given about grout mixes or grouting technology. This area would need review. Current design approaches call for split-spaced grout curtains with primary and secondary holes and intermediate tertiary and higher-level holes, as required. Grouting would be performed using one stable, thick grout mix, super-plasticizers, and real-time recording and computer-controlled equipment. Closure would be evaluated using a volume-pressure control method developed after a thorough field test.

3.1.1.12 Loads and Loading Conditions

The loads and loading conditions used in the Feasibility Design Summary (Reclamation 1980a) are the usual loads for analysis of gravity dams; however, a thorough review of the cases used would be required. The seismic loads are discussed separately below.

Particular attention would need to be given to foundation faulting and potential fault movement and their effect on the integrity of the dam. This problem was studied in 1978 and was assumed to be amenable to being treated as a linear effect (Reclamation 1980a). However, the problem involves a complex interaction between the rock mass and the dam, and it is a highly non-linear problem. Some of the new approaches of fracture mechanics, ranging from the simplest sheared crack models to more sophisticated models, such as cohesive crack modeling and cracking potential extension under static and dynamic stress fields, would need to be applied.

3.1.1.13 Factors of Safety and Methods of Analysis

The Feasibility Design Summary (Reclamation 1980a) was based on the traditional method of stability analysis called “shear friction factor” and the corresponding factors of safety. This methodology has been replaced by the limit equilibrium method and its own factors of safety, but even the limit equilibrium method is being replaced by risk-based design approaches and finite element analyses.

The stability analyses were performed using a two-dimensional approach, but the curvature of the dam and the geometry of the canyon require a three-dimensional approach to the analysis. The stability of potential and removable foundation rock blocks was not addressed in the documents reviewed. All these issues would need to be addressed in future studies.

3.1.2 Hydrologic Design

The inflow design study results were reported in *Auburn Dam Site Inflow Spillway Design Flood Study* (Reclamation 1967). This study was an extension of a previous study conducted in 1957 on the inflows to the proposed Auburn Dam reservoir. The hydrology was based on a rainfall volume that the Denver Flood Hydrology Section of the Bureau of Reclamation calculated in 1965. These calculations were not available for this evaluation. The distribution of the rainfall was based on an analysis of large storm events that occurred in 1955 and 1957.

The basis for the precipitation data used in the Auburn study is not referenced adequately in the information available for review, but URS assumed that the precipitation data were developed based on procedures similar to Hydrometeorological Report No. 36 (HMR 36), which the National Weather Service issued in 1961 (National Weather Service 1961). HMR 36 was superseded in 1999 by Hydrometeorological Report No. 59 (HMR 59) (National Weather Service 1999). HMR 59 incorporated procedures and new data on the extreme events that had occurred since publication of HMR 36. These criteria would need to be reevaluated to include the results of the revised 2001 probable maximum flood (PMF) study. Table 3-1 summarizes general storm probable maximum precipitation (PMP) values from HMR 36, HMR 59, and the design storm used in the 1967 study (Reclamation 1967). The values presented in Table 3-1 are for a general storm rather than a local storm. General storms are typically the critical event for watersheds the size of the Auburn Dam watershed, whereas local storm could be more critical for small watersheds.

According to the Auburn Dam Spillway Design Study (Reclamation 1967), the lag time for the Auburn Dam watershed is about 15 to 20 hours. This results in a time of concentration of about one day. As shown in Table 3-1, the peak 24-hour rainfall volume is about the same for all three methods. Although the distribution of the rainfall could be different in a new study, the peak inflow is likely to be similar to the inflow calculated in the existing study.

The existing design inflow study included 36 inches of snowmelt in addition to the rainfall. This assumption would need to be reviewed, and possibly a different assumption would be used in any new analysis.

The method used to convert rainfall to runoff and route the runoff to and through the reservoir would be different in any new study than what was done in the older study. How this new method would affect the spillway design flow is unknown but would probably not be significant.

Table 3-1
Comparison Between HMR 36, HMR 59, and the Reclamation 1967 Precipitation Amounts

Study	6 hour	12 hour	24 hour	48 hour	72 hour	Storm Total[1]
Auburn Flood Study (Reclamation 1967)	8.54	11.08	18.79	26.71	31.00	34.44 (45.45 including snowmelt)
HMR 36 (National Weather Service 1961)	6.48	11.43	19.39	30.25	36.99	36.99
HMR 59 (National Weather Service 1999)	6.90	11.21	17.72	29.56	34.64	34.64

Note: Unit of measure for all precipitation amounts is inches.

[1] Both HMR 36 and HMR 59 used a 72-hour storm. *Auburn Dam Site Inflow Spillway Design Flood Study* (Reclamation 1967) used a 120-hour (5-day) design storm.

In conclusion, the rainfall data used in any future study would likely be similar to what was used in the existing study but would be distributed differently. This change would probably not have a significant effect on the value of the PMF reported in the existing spillway design flood report. The previous report assumed about 36 inches of snowmelt in addition to the design storm rainfall. A different amount of snowmelt may be included in any future studies. Lastly, the routing of runoff to the reservoir in the existing spillway design report was based on information obtained from large storm events, mostly from the 1955 and 1957 events, though other events from the early 1960s were reviewed. Future studies may include these older large events but also include more recent large events and therefore may produce a different result. However, URS does not anticipate that the result for the spillway design flow would be significantly different.

Floods for designing the cofferdam and floods of lower recurrence intervals would potentially have more significant changes than the spillway design flood because of the recent hydrologic events recorded in the basin. These floods would need to be reviewed should the design process for the project advance to the next stage.

3.1.3 Seismic Design

Significant advances have been made in our understanding of seismic sources in the region surrounding the Auburn Dam site since the Woodward-Clyde Consultants (WCC) and Reclamation studies in the mid- to late-1970s. Also, the approaches used to evaluate seismic hazards and develop seismic design parameters have evolved significantly. Reclamation's approaches to addressing seismic hazards and seismic design have kept abreast of these advances. In addition, there has been a significant increase in the strong motion database, which forms the basis for both evaluating hazards and developing design motions. Hence, most of what is described in the Feasibility Design Summary (Reclamation 1980a) is now outdated and in some cases, invalid.

3.1.3.1 Seismic Hazard Evaluation Approach

Up until about 1996–1997, Reclamation used a deterministic approach for evaluating seismic hazards to develop seismic design or earthquake safety evaluation ground motions. The most severe seismic loading was defined through the concept of a Maximum Credible Earthquake (MCE), which did not consider the recurrence rates of the source of the MCE. Two other design events, the Operating Basis Earthquake (OBE) and Design Basis Earthquake (DBE), were also considered for evaluating dam response. Both of these events were assessed using recurrence relationships based on the historical earthquake record, a practice that for most regions has considerable uncertainties because of inadequate historical records. In the current terminology of agencies still using a deterministic approach, only two earthquake levels are used: the DBE (or Maximum Design Earthquake [MDE]) and OBE. The United States Army Corps of Engineers (USACE) stipulates that the MDE be equal to the MCE for high-hazard dams.

Subsequent to 1996–1997, Reclamation has gone to a fully probabilistic approach employing the probabilistic seismic hazard analysis (PSHA) methodology of Cornell (1968) for evaluating their existing dams. The evaluation of dam safety and the design of any new dams must be performance-based, requiring the evaluation of downstream risk and hence probabilistic hazard analysis (Ake 2006). Therefore, the design of any new Reclamation dam would be based on the results of a PSHA and this would be true for Auburn Dam (Ake 2006). For example, the seismic safety of the nearby Mormon Island Auxiliary Dam was evaluated probabilistically by WCC (Wong et al. 1994) for Reclamation and by Reclamation itself in 1999 (LaForge and Ake 1999). Other PSHAs include an evaluation of Folsom Dam by URS (URS 2001) for USACE, though as previously stated, USACE still generally employs a deterministic approach.

3.1.3.2 Seismic Sources Significant to Auburn Dam

Considerable new information on seismic sources has emerged in the past three decades, including new data and information on the seismogenic potential of the Foothills fault system (Page and Sawyer 2001) as well as all the faults shown in the 1978 study (Reclamation 1980a). In most cases, the MCEs presented are overestimates. The areal source zone approach is also outdated. The emphasis on seismic source characterization has evolved to characterizing discrete fault sources based on geologic and paleoseismic studies rather than areal sources, which rely on the often-deficient historical earthquake record. It should be noted that areal source zones are still used in PSHAs to account for background (random) earthquakes, but these do not exceed moment magnitude (M) 6½ ± ¼ in this portion of California, in contrast to what is shown in the Feasibility Design Summary (Reclamation 1980a).

Based on current studies, strands within the Foothills fault system would need to be considered in any hazard analysis of a proposed Auburn Dam either deterministically or probabilistically (URS 2001). Studies that Pacific Gas and Electric Company (PG&E) has made along the

Foothills fault system indicate that faults such as the Bear Mountains faults need to be incorporated into PSHAs (e.g., URS 2001).

3.1.3.3 Reservoir Triggered Seismicity

Reservoir-induced seismicity, now termed reservoir-triggered seismicity (RTS), was overemphasized in the early Auburn Dam studies due largely to the occurrence of the 1975 Oroville earthquake. Reclamation seismotectonic studies in the past 20 years have evaluated RTS at their dams in California and with the possible exception of Shasta Dam have not found it to be an issue, though RTS would still need to be considered in the design of any new dam. The probability of RTS occurrence and the maximum RTS earthquake is best addressed through a PSHA. The probabilistic approach for addressing RTS that was developed by WCC in the 1970s has also evolved considerably with a much expanded RTS database (Wong and Strandberg 1996). An analysis using this approach could be performed.

3.1.3.4 Site Ground Motions

The whole approach to evaluating seismic hazards and developing design ground motions has evolved since the 1970s, due in large part to the increase in the empirical strong motion database. In the 1970s, only a limited number of strong motion records were available, and these few records were used in techniques that required considerable judgment. Often, overconservatism was used in lieu of adequate data. Thus, the technique that Reclamation used to develop deterministic design response spectra in the mid-1980s is no longer valid. For any new dam, a PSHA would be performed and Uniform Hazard Spectra (UHS) for specified annual exceedance probabilities would be defined. The annual exceedance probabilities would be based on Reclamation’s analysis of downstream risk. New attenuation relationships from Pacific Earthquake Engineering Research’s (PEER’s) Next Generation of Attenuation (NGA) Project will soon be available to use in PSHAs. These relationships will become the state-of-the-practice based on an expanded and improved strong motion database. Relationships will be available for extensional tectonic regimes like the Sierran foothills. Preliminary review of these relationships shows significant decreases in ground motions compared to earlier relationships used for this site. The hazard should be disaggregated to evaluate the controlling earthquakes at various spectral frequency bands. Based on these results, one to two design earthquakes would be defined with their median response spectra scaled to the UHS. Time histories can be spectrally matched to the design spectra. Multiple time histories should be generated using the expanded strong motion database from the NGA Project.

The MCE ground motions from Reclamation’s Auburn study were characterized by a peak horizontal acceleration of 0.50*g*. The URS (2001) analysis of Folsom Dam, which is not far from the Auburn Dam site, recommended an MDE peak horizontal acceleration of 0.28*g* based on a PSHA with a return period of 10,000 years. The probabilistic peak horizontal acceleration for 35,000 years was 0.41*g*. This result would suggest that an MCE peak horizontal acceleration for Auburn of 0.50*g* is conservative.

3.1.3.5 Fault Displacements

Since the first studies of the proposed Auburn Dam, a number of groups have looked at the issue of surface fault displacement in the dam foundation. The deterministic estimates of fault displacement for Auburn Dam ranged from no displacement to 91 centimeters (cm) (U.S. Geological Survey, as cited in Reclamation 1980a). The DWR Consulting Board recommended that the proposed Auburn Dam be designed for a surface displacement of 13 cm. The displacement might occur on a single fault or be distributed over a zone of faulting. In the final design specified by the Secretary of Interior, 23 cm of normal-oblique displacement was selected for selected foundation features. In the event of a new dam, investigations for active faulting in the dam foundation would be mandatory. New age-dating techniques have emerged in the past three decades, and our understanding of faults in the Sierran Foothills has improved such that an assessment of the most recent displacements in bedrock faulting has a greater likelihood for success. Also, the hazard of surface faulting displacement is now being addressed probabilistically for important facilities (e.g., Yucca Mountain), and given the uncertainties of characterizing faulting of the nature that would most likely be found in a potential dam foundation, a probabilistic fault displacement hazard analysis is recommended.

3.1.4 Spillway Design

As mentioned above, the hydrologic basis for design of the spillway would probably not change much for a revised design, though the design would still need to be reviewed. However, other issues concerning the design of the spillway would have moderate impact on cost. These include updated seismic design of the spillway gates, aeration requirements for the spillway chute flows to mitigate cavitation, and the design of the spillway plunge pool, where new analysis procedures developed in recent years would result in potentially different dimensions for the plunge pools.

3.1.5 Concrete Structures Design

The design procedures for concrete structures have been subject to revision since the original design of the Auburn Dam, and the revised procedures would probably result in minor modifications to the designs. Most of the impact would be due to the seismic loading and the appropriate methodology for including the seismic loading in the design.

3.2 ENVIRONMENTAL CONSIDERATIONS

The environmental impacts of the Auburn-Folsom South Unit have been addressed at various levels in the reports discussed below.

3.2.1 Auburn Dam Feasibility Design Summary (Reclamation 1980a)

This study makes no mention of the potential environmental impacts of the dam or mitigation for these impacts (Reclamation 1980a). However, the study mention of three environmental reports produced for this project in 1972–1974. Because these three reports are all over 30 years old, they would not be considered adequate for this project.

3.2.2 American River Watershed Investigation, Volume 6, Appendix S, Part 1 (USACE 1991)

This report addressed potential environmental impacts, potential mitigation, and their associated costs. However, this report is also out of date and would need to be updated to current standards. Special-status species occur within the project area, and the mitigation requirements for impacts to special-status species have changed. Also, land prices in the region have skyrocketed since the study was conducted, and as a result, the mitigation cost estimates are extremely out of date.

3.2.3 Current Issues

To provide adequate information concerning the potential impacts and mitigation needs associated with the Auburn Dam project, the following analyses would need to be completed:

- An updated EIR would need to be completed to address the current impacts of the Auburn Dam project on biological resources.
- Impacts to special-status species and their habitats as well as impacts to aquatic and upland habitat types would need to be quantified.
- A Mitigation Plan that describes the impacts, mitigation requirements, opportunities, and costs would need to be prepared to make an adequate assessment of the information provided in the updated EIR.
  - This Mitigation Plan should address the mitigation costs associated with the project in greater detail than previously discussed. These costs should be based on an accurate description of the impacts resulting from the project, current requirements, current land prices, and the current ability to mitigate the impacts in a reasonable and effective manner.
  - Additional studies may be needed to address the impacts and potential mitigation from this project. Examples include:
    a. An Instream Flow Incremental Methodology (IFIM) study, resulting in habitat/flow relationships, may be required to determine the potential effect on aquatic species downstream of the dam.
    b. A stream temperature modeling study may be required to study the effect of the project on downstream water temperatures.

3.2.4 Review of Biological Information and Potential Mitigation Costs

URS has estimated the potential mitigation costs associated with the impacts resulting from the construction of the Auburn Dam based on the information presented in *American River Watershed Investigation, California,* Volume 6, Appendix S, Part 1 of the December 1991 Feasibility Report (USACE 1991). These costs are preliminary and are a rough estimate based on the potential impacts, the estimated area of impacted habitat types, and the recent costs of similar mitigation lands.

The USACE 1991 report is out of date, and an updated biological assessment would need to be completed to make an adequate assessment of the impacts of this project. However, to calculate the preliminary mitigation costs associated with this project, URS has used the acreage of impacted habitat types and the categorization of habitat types presented in the USACE 1991 report.

3.2.5 Environmental Setting and Biotic Resources

After reviewing *American River Watershed Investigation, California,* Volume 6, Appendix S, Part 1 (USACE 1991), URS determined that the following existing conditions occur within the project area:

3.2.5.1 Vegetation

The project area occurs within a transitional zone between the middle elevation foothill grassland, hardwood woodland–hardwood forest communities, and the higher montane, largely evergreen mixed- and conifer-dominated forest communities (USACE 1991). To evaluate the anticipated impacts to fish and wildlife of the Auburn Dam project, USACE 1991 used the United States Fish and Wildlife Service (USFWS) Habitat Evaluation Procedure (HEP) analysis to identify seven terrestrial vegetation cover types and one riverine cover type. (These cover types are based on the designations in *Terrestrial Plant Ecology* [Barbour, Burk, and Pitts 1987].) The seven cover types are as follows: evergreen hardwood forest (north slope–black oak forest), evergreen hardwood woodland (south slope–oak woodland), conifer forest, chaparral, grassland/savannah, freshwater marsh, and montane riparian. Rocky/ruderal upland habitat was also identified to account for impacts to this cover type, even though it is not listed in Barbour, Burk, and Pitts 1987.

Evergreen Hardwood Forest (North Slope–Black Oak Forest)

This cover type typically occurs on north-facing slopes and the deeper shaded canyons within the project area. This type is also prevalent on northwest- and northeast-facing slopes within the North and Middle Fork American River Canyons. Average slopes containing evergreen hardwood forest within the North Fork between riverbed elevations of 520 to 1,000 feet were about 32 percent. Average slopes of 31 percent occur on the Middle Fork between riverbed elevations of 600 to 1,000 feet. Canopy cover ranges between 50 and 100 percent, and the tree height ranges from 50 to 100 feet, with an occasional conifer up to and exceeding 200 feet. The dominant tree species within this cover type are canyon and interior live oaks. A more detailed description of this cover type is found in USACE 1991.

According to USACE 1991, approximately 4,129 acres of this cover type occur between the 490 and 1,135-foot elevation inundation zone.

Evergreen Hardwood Woodland (south slope–oak woodland)

This evergreen, largely oak dominated cover type typically occurs on drier, southwest- to south-facing slopes with shallow to moderately deep soils (USACE 1991). Similar in species composition to the evergreen hardwood forest cover type, evergreen hardwood woodland is distinguished by its more open canopy (30–50 percent cover) relative to that of the evergreen hardwood forest cover type. Canopy components vary greatly depending on the aspect, exposure, elevation, and soils, but interior and canyon live oaks are again the dominant species (USACE 1991). A more detailed description of this cover type is found in USACE 1991.

According to USACE 1991, approximately 4,206 acres of this cover type occur between the 490- and 1,135-foot elevation inundation zone.

Conifer Forest

Barbour, Burk, and Pitts 1987 classifies conifer forest vegetation as the mixed conifer phase of mid-montane conifer forest. In the lower elevations and western portions of the Auburn area, this cover type is diffuse in occurrence and highly limited in extent (USACE 1991). The dominant tree species in this community are ponderosa and grey pines. However, these species typically only occur as scattered individuals or clusters of a few ponderosa or grey pine trees, interspersed with plants of the chaparral, hardwood woodland and hardwood forest communities. A more detailed description of this cover type is found in USACE 1991.

According to USACE 1991, approximately 741 acres of this cover type occur between the 490- and 1,135-foot elevation inundation zone.

Chaparral

The chaparral cover type is composed mainly of evergreen woody shrubs that typify many of the dry, well-drained, shallow soils of the foothills and lower mountain slopes of the Sierra Nevada and elsewhere in the state (USACE 1991). Chaparral vegetation is tolerant of drought conditions and has developed adaptations to fire that enable it to occur and reproduce in the presence of fire conditions. The dominant woody species of the chaparral in the study area include chamise, manzanita, ceanothus, toyon, and shrubby forms of the interior and canyon live oaks, and, infrequently, shrubby forms of the deciduous blue oak (USACE 1991). A more detailed description of this cover type is found in USACE 1991.

According to USACE 1991, approximately 695 acres of this cover type occur between the 490- and 1,135-foot elevation inundation zone.

Grassland/Savanna

Although grassland is considered a distinct cover type, annual grasses and their common forb associates exist as the most pervasive ground cover elements throughout the Auburn study area. In areas where tree cover falls below 30 percent and shrub cover shows a corresponding drop, the ubiquitous grassland matrix begins to show a distinct presence and importance in the vegetation. Consequently, boundaries between grassland and adjoining woody vegetations frequently grade imperceptibly into one another (USACE 1991).

According to USACE 1991, approximately 218 acres of this cover type occur between the 490- and 1,135-foot elevation inundation zone.

Freshwater Marsh

Freshwater marsh habitats in the potential inundation zone exist mainly as isolated occurrences along most of the side drainages of the American River, including several notable locations along the main stem of the American River and its forks. Freshwater marshes also may occur at the low edges of moist meadows and at numerous springs and seeps, wherever water perennially accumulates at depths of less than 5 feet. Freshwater marsh is characterized by emergent vegetation, including dense stands of tules, cattails, rushes, sedges, and lesser amounts of smartweed and water-edge forbs (USACE 1991).

According to USACE 1991, only 14 acres of freshwater marsh were identified within the inundation zone. However, ground-level habitats were often obscured in aerial photos by the extensive canopy and the amount of freshwater marsh is probably much higher.

Montane Riparian

The montane riparian cover type includes palustrine scrub-shrub, emergent marsh, riparian forest, and other riparian-type features within the 490- to 1,135-foot inundation zone. A more detailed description of this cover type is found in USACE 1991.

According to USACE 1991, approximately 1,552 acres of this cover type occur between the 490- and 1,135-foot elevation inundation zone.

3.2.5.2 Fish

According to the USACE 1991, the North Fork American River supports a variety of warm-water species, including smallmouth bass, bullhead, and sunfish, on a year-round basis. Summer/fall water temperatures are generally too warm to support trout rearing habitat. The Middle Fork American River has cooler water temperatures as a result of the Middle Fork American River Project. Therefore, this reach is able to support both cold-water and warm-water fish species. A more detailed description of the fish resources within the project area is found in USACE 1991.

3.2.5.3 Wildlife

The project area occurs within a region of high wildlife species diversity (Verner and Boss 1980). Although seven broad vegetation cover types were chosen for studying the Auburn area, this limited number of cover types belies the enormously complex and diverse vegetation patterns and wildlife habitats of the area (USACE 1991). A more detailed description of the wildlife resources within the project area is found in USACE 1991.

3.2.5.4 Special-Status Species

Because of the large area of impact, the highly complex topography of the project area, and the corresponding high diversity within this topography, the Auburn Dam project provides potentially suitable habitat for 42 special-status species.

The special-status species would need to be considered and potentially mitigated for as part of the Auburn Dam project. To make an adequate assessment of the impacts of the project on special-status species, updated information on these species would need to be developed.

4.1 UPDATED FEATURES

To perform the required cost estimate, several features of the project would need to be changed, as they cannot be constructed in the location originally planned or they cannot remain at the locations where constructed. (The project features are discussed in Section 2 of this report and identified in Reclamation 1980a.) This design update was performed at a conceptual level to allow estimation of the quantities required to prepare the cost estimate. The most important project features that are updated for this analysis are SR 49 and other road relocations, demolition of the American River Pumping Station, and the public access and recreation facilities.

4.2 OPINION OF PROBABLE CONSTRUCTION COST

The Opinion of Probable Construction Cost (OPCC), which is referred to as the “Field Cost” in Reclamation terminology, is a yardstick that is used to measure cost performance for a project. The OPCC is a tool to be used as a foundation for realizing management objectives, economic analysis, and budgetary requirements. OPCCs are intended to represent “contract” construction costs and do not include contingency allowances for construction growth after contract or other noncontract costs, such as engineering, design, construction management, land acquisition, legal, environmental permitting and mitigation, or other “owner” costs. Some noncontract owner costs (notably, the environmental mitigation costs) are included in this report and added to the OPCC, as specifically noted in this memorandum.

4.2.1 Definition

An OPCC is defined as “a compilation of all the costs of the categories, features and items of a project or effort included within an agreed upon scope of work.” The construction contractor would most likely incur these costs in completing the project as defined in the construction documents. These costs include contractor internal costs as well as the costs associated with subcontractors, suppliers, and other third parties.

4.2.2 Construction Cost Estimate Classification

The reason for classifying the construction cost estimating process is to establish uniformity and set standards for the development of construction cost estimates. These classifications facilitate communications and internal review and provide a guideline for public presentation. Each class of construction cost estimate identifies a level of accuracy and provides for a contingency based on the risk associated with the level of detail, design, and accuracy.

Construction cost estimates are classified as follows:

- Class 5: Concept
- Class 4: Feasibility
- Class 3: Interim Design
- Class 2: Pre-Evaluation

- Class 1: Bid

Table 4-1 lists the five classes of construction cost estimates and for each level identifies the percentage of engineering completion, the expected accuracy, and the suggested contingencies.

4.2.3 Purpose and Use

The purpose of this OPCC is to accomplish the requirements of Public Law 109-103 for providing new sub-appraisal design concepts where necessary and upgrading a complete field construction cost estimate of the features identified in the Baseline Project Description Technical Memorandum. The use of the OPCC is designed to satisfy the following requirements of the Special Report: Item (2) of the Special Report, "Identify changes in benefit values from previous analyses and update to current levels," Item (3), "Identify design standard changes from the 1978 Reclamation design [as described in Reclamation 1980a] that require updated project engineering," and Item (4), "Assess the risks and uncertainties associated with the 1978 Reclamation design [as described in Reclamation 1980a]."

The OPCC (or Field Cost) developed in this document is of the Class 5 (Concept) type (also referred to as a reconnaissance level cost estimate) because of the limited information available. Section 3 (Engineering Technical Review) and Section 5 (Risk and Uncertainty Analysis) discuss the issues that would be affected by the limited available information and how these issues would affect the project cost.

4.2.4 Method

The following method was used to update the OPCC (Field Cost) estimate of the features identified in the 1978 design for Auburn Dam (Reclamation 1980a). This update of cost also considered the updated features.

4.2.4.1 Review of Documentation

URS reviewed the available documentation, including drawings, reports, and design criteria, to allow the construction cost estimators to gain an understanding of the project. URS also held discussions with personnel involved in the design studies as part of the information collection process. In addition, URS visited the project site to assess the logistics of the particular location, to assess the issues associated with construction, and to evaluate project execution processes through discussions with potential contractors, subcontractors, suppliers, and vendors.

4.2.4.2 Review of Other Information and Resources

URS examined and considered the following data to increase the accuracy and reliability of the OPCC (Field Cost):

Table 4-1
Matrix of Construction Cost Contingencies

Design Class (Level)	Engineering Design Completion	Expected Accuracy	Contingencies: Design	Contingencies: Procurement	Engineers Opinion Probable Construction Cost (Bid or Contract)	Contingencies: Construction	Contingencies: Non-Contract	Engineers Opinion Probable Project Cost
	%	%	%	%			%	
CONCEPT Class 5 Conceptual, Appraisal. Little or no detailed design. Involves planning, evaluation of alternatives, available resources. Has wide range of accuracy. Primary use and purpose to screen alternatives and detemine feasibility.	0 to 10	(30) to +100	15 to 20	5 to 10		15 to 30	10 to 20	
FEASIBILITY Class 4 Involves preliminary engineering, advances design, refines scope. Accuracy depends on amount and quality of available information. Primary use and purpose to determine feasibility, advance design and provide funding for continued engineering and design.	10 to 30	(15) to +50	10 to 15	5 to 10		15 to 30	10 to 20	
INTERIM DESIGN Class 3 Engineering and design becomes defined. Constructability issues identified and construction pricing refined. Drawings and construction specifications developed. Quantity takeoff and construction pricing more detailed. Primary use and purpose to form the	30 to 90	(10) to +30	5 to 10	5 to 10		15 to 30	10 to 20	
PRE-EVALUATION Class 2 Engineering and design complete. Construction drawings and specifications finalized. Detailed quantity takeoff completed and accuracy of construction pricing examined. Risk transfer identified and bidding schedule developed. Primary purpose to confirm est	95 to 100	(5) to +20	0 to 5	5 to 10		15 to 30	10 to 20	
BID Class 1 Bid Documents prepared, prequalification of bidders established and advertisement for bids issued. Quantity takeoff very detailed and construction pricing involves high level of accuracy backed by bid and performance indemnification.	95 to 100	(3) to +15	0	5 to 10		15 to 30	10 to 20	

Contingencies:

Design An allowance during advancing design that is used or eliminated. Includes unidentified or unlisted quantities or items, accomodating design for site constraints and conditions as discovered and needed for final design and final construction pricing adjustments.

Procurement An allowance to pay for cost associated with procurement other than advertising and receiving bid in an open and competitive market. Such as set aside or special construction applications and negotiated procurement.

Construction Used for construction growth after contract such as differing site conditions, uncontolled delay due to weather or available resources and other unforseen problems or conditions.

Non-Contract Owner project cost other than contract construction cost such as engineering design and construction management, land adquisition, legal and permits.

- The principal features of the project
- Completion time
- Equipment application and requirements
- Available labor and other resources
- Climate and weather
- Accessibility
- Hazards
- Risk
- Site investigation
- Comparison with similar work under construction in the area
- Available electric power
- Available water supply
- Clearing and demolition requirements
- Requirements for borrow pits and quarries
- General drainage requirements
- Environmental issues requirements
- Safety requirements
- Available local resources
- Permits and licenses needed
- Impacts of estimate evaluation, site investigation, and incomplete data
- Geographic, cultural, and demographic cost modifications
- Davis Bacon or other government-imposed costing rules
- Indirect costs
- Escalation
- Contingencies

4.2.4.3 Work Breakdown Structure

The WBS is a hierarchical presentation of the scope of work. The purpose of the WBS is to:

- Provide an organized manner of collecting project data in a standard format for cost reporting and cost tracking.
- Provide a checklist for categorizing cost
- Provide a means to maintain historical cost data is a standard format.

URS created this WBS for this analysis and report. This WBS is based on information from the 1978 feasibility design work and (Reclamation 1980a) URS' experience in projects such as this one.

The following topics constitute the WBS for developing the Class 5 OPCC (Field Cost) for the Auburn Dam features:

- **Project general requirements:** This topic includes setup and maintenance of temporary facilities, mobilization of personnel and equipment to the site, project security, submittals, insurance, bonds, and project management and controls. For this level of OPCC (Field Cost) URS is using a total allowance of approximately 10 percent for direct and indirect costs for project general requirements.
- **Site preparation:** This topic includes construction and improvement of existing access roads; layout and construction of haul roads; environmental protection; erosion and sediment control; demolition and removal of existing structures; abandonment and sealing of existing structures; stripping of excavation, foundation, and borrow areas; drying and processing of borrow areas; pre-wetting of borrow and excavation areas, as needed; and diverting and de-watering of surface water and groundwater. URS calculated quantities for these activities where design information was available. These activities are identified by units of measure in the Field Cost and have been priced using historical and database unit prices (see below). Other activities did not have adequate design and detail development. URS priced these activities as lump sum allowances in the Field Cost based on an URS' experience relative to the total estimated construction cost.
- **Concrete curved gravity dam:** Foundation work for the dam includes excavating, loading and hauling materials to stockpiles in the foundation footprint, including the abutments. URS quantified foundation excavations from the conceptual design. Materials for the concrete dam involve excavating, loading, and hauling to stockpiles; processing and conditioning the materials for mixing into concrete, including pre-placing and post-placing temperature control; all the quality control testing associated with the process; and installing, maintaining, removing, and repairing the formwork used during the construction. The layout of cranes or cable cranes and conveyor belts needs to be developed carefully to obtain an efficient placement operation. Stockpiling of materials would need to be started ahead of dam construction to be able to maintain the rates of concrete placement needed to construct the dam within the planned schedule.
- **Hydroelectric power plant:** A hydroelectric power plant is included in the Auburn Dam design. The planned installed capacity is approximately 800 MW, which is arranged as four 200-MW generating units located within the concrete dam. The power plants are part of the construction of the dam.
- **Electric power transmission:** Transmission and interconnection with the CVP power system would be accomplished with the construction of transmission lines, switchyards, substations, transformers, transformer circuits, and other electric power appurtenances.
- **Highway and road relocation:** Construction of Auburn Dam would require the relocation of SR 49 and the Placer/El Dorado county road upstream route. These relocations would involve three large bridges ranging from 400 to 600 feet high and approximately 2,000 feet

long. Each roadway relocation must meet current Caltrans standards and would require significant additional analysis.

- **Public access and recreation facilities:** Numerous trails for hiking, running, biking, and equestrian purposes are located in the Auburn Recreation area. New recreation facilities such as auto campgrounds, picnic areas, trails for various uses, camps, boat-launching ramps, swimming areas, and historic sites are planned and would be constructed during and after construction of Auburn Dam.
- **Quantities:** The level of detail associated with this Class 5 OPCC (Field Cost) estimate was based on the accuracy of the topographic maps available and provided at the time that Reclamation prepared the original construction cost estimate (August 1980). Quantities are identified and shown in industry standard units of measure. URS calculated quantities from the level of detail and design developed at that time and based on in-place volumes that do not reflect any possible quantity reductions that can be achieved through material management, balancing of cut-and-fill volumes, or changes in design. Quantity take-off involves measuring and cataloging the quantities of work derived from the WBS. This effort includes:

  - Classifying the work into features and a WBS
  - Describing each work activity
  - Determining the geometry of the work
  - Calculating volumes or other quantities that can be priced

  The installed quantities were further defined before being priced by calculating the necessary man-hours, equipment, and productivity rates, particularly for the larger volumes that make up most of the cost. The quantities for this project were taken from the 1978 design (Reclamation 1980a). The major quantity is the volume of mass concrete. This number was one of the few quantities that URS was able to check in detail. As mentioned in Section 3 (Engineering Technical Review), this quantity (and those related to it) must be revised during any future study of the project, as any change in this quantity would have an important effect on the viability of the project.
- **Pricing:** Construction pricing in the development of the OPCC (Field Cost) includes all direct labor, equipment, materials, and other costs. Indirect cost is assumed to be included in the unit prices. Unit pricing, when used, is accomplished with the use of cost indices from published and internally developed and maintained historical databases that are adjusted for location, contractor markups, and other project-specific criteria. The logic, methods, and procedures that URS used to develop costs are all typical for the construction industry.

  The costs that URS developed are not guaranteed to be accurate, and the use of unit pricing should not be deemed as an offering or proposal with respect to the cost of an activity or project. Unit price opinions are subject to change with notice. The estimates of unit prices that URS uses is not intended to predict the actual cost that results from open and competitive bidding.

  URS used the following cost indices to develop prices:

  - General purpose cost indices, including Engineering News Record, the Department of Commerce, and the Bureau of Reclamation.
  - Contractor pricing indices, including those received and maintained from previous or current projects of a similar nature.
  - Special purpose indices, including R.S. Means, the Bureau of Labor Statistics, and various state departments of transportation.

  URS gathered cost indices monthly or as available and maintained them as current and historic databases. The unit prices that URS calculated from the indices reflect average pricing for the various units of work incorporated into heavy and civil construction.

  Various limitations are built into the use of unit prices calculated from indices. These limitations include the potential for changes in technology, methods, and construction applications; the impact of short-term economic cycles impacting the cost of petroleum products, steel, and cement; the ever-present time lag in the reporting of the databases; and the fact that the cost index databases are a composite average and therefore have a range of acceptability.

  For major project features involving large quantities, URS developed unit prices from production calculations based on historical production rates for similar work. URS also applied labor and equipment hour rates, along with allowances for indirect costs, overhead, and markup. In addition, URS contacted vendors and obtained and adjusted pricing to include freight, taxes, and waste for project features requiring difficult-to-locate or large volumes of material.

- **Direct and indirect costs:** The OPCC (Field Cost) is divided into the contractor's direct and indirect costs. The sum of these two costs plus overhead and markup yields the bid or contract cost for the work.

  Direct cost includes:

  - The cost of labor wages, fringes, and burden paid to field personnel who do the work to the level of foreman.
  - The cost of the equipment used to construct the work as designed and not permanently incorporated in the work. This cost includes the cost of equipment ownership or rental, maintenance, and operating costs.
  - The cost of the permanent materials and equipment built into the work and essential to operating the facility as designed and intended.
  - The cost of the specific work performed by subcontractors.

  Indirect cost includes:

  - The cost of freight and the transportation of the construction equipment
  - The cost of job supervision, engineering, and office personnel
  - The cost of temporary buildings, utilities, and job construction
  - The cost of job transportation and material handling
  - The cost of insurance and taxes

- The cost of employee mobilization
- The cost of bonds
- The cost of quality control
- The cost of escalation
- The cost of contingencies
- The cost of demobilization
- The cost of financing

- **Overhead and markup:** An allowance for contractor overhead and markup is included in the development of construction cost. Contractor overhead is the cost or expense inherent in performing work that is not directly charged to the work. Contractor markup is the anticipated profit for doing the work that is added to the direct and indirect cost. Industry standards are to use 5 percent for overhead and 10 percent for markup.
- **Contingency:** As noted above, the OPCC (Field Cost) is classified as Class 5 (Concept). In preparing the Field Cost, URS examined and discussed constructability issues involving surface water and groundwater management, borrow area location, material processing and haul lengths, foundation conditions, and extent of grout curtain construction. The Reclamation statement of work for this task required a 30 percent contingency factor and an additional 20 percent allowance for unlisted items. URS did not apply these percentages; instead, URS followed the guidance described Table 4-1. Thus, URS used a design contingency of 20 percent, which is adequate for a Class 5 estimate and the "unlisted items," as referenced in Reclamation terminology.
- **Escalation:** For the purposes of developing construction cost, escalation is defined as a provision for an increase in the cost of labor, equipment, material, and subcontracts due to continuing price-level changes over time. Given the multi-year construction duration anticipated for this project, it is assumed that contractors would accommodate for escalation in their pricing. For the purposes of this OPCC (Field Cost), URS is pricing in current (June 2006) U.S. dollars, with no allowance for escalation or inflation.
- **Procurement:** URS assumes that procurement would be accomplished through an open and competitive bid process (i.e., ads would be published, etc.). URS also assumes that contractors are qualified and experienced in the construction of large concrete dams and that the contractors would calculate and offer construction pricing using a open and competitive approach to equipment production and material pricing and would not include allowances for changes, extra work, unforeseen conditions, or other unplanned costs. In addition, URS assumes that pricing does not include any special set-aside programs (e.g., 8a, small business, women-owned business, etc.), which could significantly increase cost. These costs are included in the contingencies, as shown in Table 4-1.
- **Documentation:** Written documentation of what is included and excluded in the OPCC (Field Cost) is complete and becomes part of the Field Cost files for Auburn Dam. The documentation for the various classes of Field Cost becomes a benchmark for future Field Cost or costs to be measured against. The following guidance lists the documentation included in the permanent files for the Field Cost:

- Purpose and use of the Field Cost: Clearly explain the purpose and use of the various classes of Field Cost.
- Scope: Provide and overview of what is included in the Field Cost.
- Assumptions and exclusions: Identify and document the assumptions and exclusions, such as constructability and constraint issues, available resources, level of design, and available data.
- Time and cost association: Define the assumptions and development of the construction schedule. Look at the impact of escalation.
- Contingency: Explain the method used to develop the contingency and the rates applied.
- Findings: Identify cost items of significant risk, identify the availability of similar projects and describe comparability, and indicate where optimization of design and value engineering can be utilized.
- Review: Implement a review of the Field Cost and identify the review participants.

4.2.5 Environmental Mitigation Costs

URS estimated the potential mitigation costs associated with impacts resulting from the construction of the Auburn Dam based on the information presented in *American River Watershed Investigation, California* Volume 6, Appendix S, Part 1, of USACE 1991. These costs are preliminary and are a rough estimate based on potential impacts, the estimated area of impacted habitat types, and the recent costs for mitigation bank credits (acres) sold in similar habitats and similar mitigation lands.

The USACE 1991 report is out of date and an updated biological assessment would need to be completed to make an adequate assessment of the impacts of the project. However, URS used USACE 1991 to calculate this preliminary estimate of the mitigation costs associated with this project, the acreage of impacted habitat types, and the categorization of habitat types.

The estimated mitigation costs provided in USACE 1991are based on 1991 average land prices. The cost of mitigation lands in California has increased significantly since 1991.

It is also possible that both operation and maintenance costs and monitoring costs would be included in the purchase of mitigation credits at an acceptable mitigation bank. These details would become clearer after the project's impacts have been reviewed.

The Auburn region has experienced tremendous growth over the last few decades, and Placer County has had the highest growth rate of any county in California for the past 5 years. The population of Placer County has increased from 117,000 people in 1980 to approximately 317,000 people in 2005. These pressures would undoubtedly have an effect on the potential for mitigating the impacts resulting from the Auburn Dam project. However, the fact that land is becoming scarcer in this region may provide a benefit to the project. The opportunity exists to protect large tracts of land from future development as mitigation for the project. Some may view this opportunity as a benefit to the resources of the region.

It is likely that mitigation for special-status species would be covered by the purchase of large tracts of land as part of the mitigation for the associated habitat types. However, additional mitigation may be required for individual species. In particular, some rare plants with extremely localized distributions that would be impacted by the project may need to be relocated or propagated and seeded in alternative locations. A more thorough review of the project's impacts would help determine the need for additional mitigation. Furthermore, the approach to calculating mitigation costs would most likely be different than the approach presented in USACE 1991. For instance, riparian habitat may be calculated on a linear basis (i.e., linear feet of impacted streamside riparian habitat) rather than in acreage of riparian forest cover.

If we assume the impacts described in USACE 1991, mitigation for the approximately 11,555 acres of riverine canyon and upland habitat that would be lost due to direct project-related impacts would most likely require the following measures:

- An updated Biological Assessment of the project's effect on the biological resources of the North and Middle Fork American Rivers and surrounding areas. A detailed analysis of water allocation for fish and wildlife would also have to be completed.
- To mitigate for the loss of about 12,000 acres of riverine canyon and upland habitat due to direct project-related impacts in and near the North and Middle Fork American River Canyons, approximately 24,000 acres of mitigation lands would likely be acquired and managed for wildlife and fisheries in perpetuity.
- In consultation with the California Department of Fish and Game and the U.S. Fish and Wildlife Service, Reclamation would need to develop a Fishery Management Plan to address impacts to fishery resources within the project area. This plan would identify the impacts and mitigation/enhancement opportunities for fishery resources as a result of the project.
- To minimize any additional impacts on the remaining wildlife lands in the project area, Reclamation would need to develop a Wildlife Management Plan in consultation with the California Department of Fish and Game, the U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers.

The cost uncertainty being considered in this analysis is based on uncertainty of the cost estimate, not on what might happen during the actual construction (e.g., unexpected or changed conditions). In other words, this analysis investigates the impact of the risk factors and the associated scenarios on the cost estimate. This analysis was developed based on the top-level (i.e., summary-level) WBS developed for the individual project features.

This update of cost concerns the development of the contract cost, what URS could expect bids to be, and what Reclamation could expect to pay the contractor for the construction of the dam and related facilities. This update of cost does not include the total project costs, though some owner costs, such as environmental mitigation, are included.

The methodology that URS followed for this analysis consisted of the following:

- Conducting a qualitative risk assessment
- Using a semi-quantitative analysis
- Ranking risk factors in order of decreasing importance
- Identifying those risk factors that have the greatest potential to impact the whole project
- Identifying those project features that present the greatest cost risks

Section 5.1 discusses the methodology that URS employed for the risk analysis. Section 5.2 discusses the specific risk factors and scenarios that URS analyzed.

5.1 METHODOLOGY

The methodology that URS used to conduct the risk and uncertainty analysis involved eight steps: assessment of base cost, development of work breakdown structure, identification of relevant risk factors, identification of risk scenarios, criteria for identifying how to include risk factors in the analysis, probability of encountering risk factors, cost impact of risk factors, and calculation of risk scores.

5.1.1 Assessment of Base Cost

URS developed the base cost of the Auburn-Folsom South Unit using the OPCC (Field Cost). The OPCC developed for this analysis is considered an appraisal-level (i.e., Class 5) cost estimate, and the primary use of this type of cost analysis is for screening and determining project feasibility.

The OPCC was developed according to the available level of detail and with the information and assumptions described in the preceding sections of this TM. The OPCC includes direct and indirect costs with an allowance for the risk that a prudent, experienced contractor would expect to incur. The OPCC was prepared on the basis of calculated quantities and unit pricing that are commensurate with the degree of design detail known and assumed. Construction was separated into incremental parts. These parts were defined as construction tasks, and these tasks make up the WBS (see below). If a significant design assumptions were necessary, pricing was developed from historical databases and from similar current and completed projects. As the details of the design become better known in the future, construction task pricing will be developed by utilizing crews made up of equipment and labor and an estimated productivity.

5.1.2 Analysis Using Work Breakdown Structure

The risk analysis was based on the WBS developed for the updated design and reconnaissance-level cost estimate. For the risk analysis, the top level (or summary level) of the WBS was used. At this level of WBS, the project was broken down into eight features:

- Project general requirements
- Site preparation
- Concrete curved gravity dam
- Hydroelectric power plant
- Electric power transmission, switchyards, and substations
- Highway and road relocations
- Public access and recreational facilities
- Environmental mitigation

For each one of these top-level WBS items, it was possible to adjust the quantities and unit prices in response to the perceived uncertainty or the cost risk factors.

5.1.3 Identification of Relevant Risk Factors

Assessing the project risk required the use of risk factors. A risk factor is defined as an unexpected and unplanned condition or event that can significantly impact project cost. A risk factor is unplanned in that it is not included in the contingencies developed for the project. However, a risk factor is an issue of particular concern for Reclamation that is specific to the project. A risk factor may be changes in design requirements due to improved understanding of physical process, (e.g., floods or earthquakes), changes in environmental regulatory requirements, changes in real estate costs, or general changes in the economy.

Eight risk factors were used for the risk analysis.

- Hydrology
- Seismicity
- Borrow sources
- Quantities
- Environmental issues
- Real estate
- Inflation
- Market conditions

5.1.4 Identification of Risk Scenarios

A risk factor identifies unexpected or unplanned adverse conditions or events. A risk factor may have several potential conditions that we may wish to evaluate. To address these conditions, we use the risk scenario. The risk scenario sets conditions on the risk factor and provides an opportunity to perform a more refined assessment of a risk factor's impact on the estimated cost of the project. For example, with regard to the potential impact of the market conditions risk factor on the cost estimate, two conditions were identified: changes in the availability of critical building materials and changes in the availability of the skilled labor necessary for the project. Each condition has the potential to impact the cost, but each reflects different aspects of the market conditions risk factor. For example, under the materials availability scenario the impacts of the market conditions risk factor on the project can be assessed separately from the impacts resulting from labor availability, though both scenarios reflect market conditions. This differentiation of the market conditions risk factor provides Reclamation with a better understanding of how potential shortages of construction materials can affect the estimated project cost.

5.1.5 Criteria for Identifying How to Include Risk Factors in the Analysis

As defined above, a risk factor is an unexpected and unplanned adverse condition or event. It needs to meet the following criteria to be considered for this analysis:

- If an adverse condition is known or anticipated with a high probability (greater than 50 percent), its cost impact should be included in the base cost.
- A risk factor should not be associated with a condition or event whose chance of occurrence is remote (defined as less than 1 in 100 for this analysis). For example, a catastrophic earthquake that could cause extensive damage in the project area was not included as a risk factor, because its chance of occurrence was judged to be less than 1 in 100. This level of exposure is usually addressed in the design of the project.
- The cost impact of the risk factor should be significant. For this analysis, a significant impact is defined as a cost impact of at least $3 million (estimated at the beginning of the study to roughly correspond to 0.1 percent [one-tenth of one percent] of the cost). Risk factors with cost impacts of less than this threshold would be included as part of the normal variation in the base cost and are captured in the contingency.

The risk factors and scenarios were selected based on Reclamation's statement of work and discussions with Reclamation.

5.1.6 Probability of Encountering Risk Factors

To be considered in this analysis, a risk factor should fall within a specified range of probabilities. Commonly encountered risk factors are not considered in this analysis, as they should be included in the contingency costs. At this stage of design, the lower threshold probability for a common risk factor is 50 percent. At a more mature design phase, this threshold would be higher. Risk factors whose probability of being encountered is small (less than 1:100 in this analysis) are considered too rare to significantly impact the project or are considered and mitigated for using other procedures (e.g., design flood or operating basis earthquake). The risk factors that lie between these two extremes (between 1 percent and 50 percent) are the ones considered in this analysis.

Because of the qualitative nature of this analysis, the probabilities were broken down into five categories, as follows:

- "1" 1:100 – 1:50 (rare events)
- "2" 1:50 – 1:10
- "3" 1:10 – 1:5
- "4" 1:5 – 1:3
- "5" 1:3 – 1:2 (likely events)

Thus, a risk factor with a probability of occurrence of 15 percent was given a "3". The probability of occurrence of each risk factor was assessed using expert judgment, based on experience with similar projects.

5.1.7 Cost Impact of Risk Factors

As discussed above, the cost impact of a risk factor should exceed a specific threshold to be considered as significant. For the purpose of this analysis, the threshold is defined as a cost impact of at least $3 million (i.e., a given risk factor that could result in an increase in the project cost of at least $3 million dollars is considered significant). Risk factors whose potential cost impacts are less than this threshold would be included as part of the normal variation in the base cost and are captured in the project contingency.

To assess the cost impact of a given risk factor, the project team subjectively identified the mitigation measures that would be needed to respond to a risk factor if it were to occur, and estimated the costs of these measures. This estimate was developed on a line-item basis for each project feature, using the top level WBS developed for this analysis. The increases in costs were then categorized on a five-point qualitative scale similar to the approach used for the probability assessment. The categories are as follows:

- "1" $3 million – $10 million
- "2" $10 million – $20 million
- "3" $20 million – $50 million
- "4" $50 million – $100 million
- "5" > $100 million

5.1.8 Calculation of Risk Scores

The risk score was calculated by multiplying the probability and cost scores for each risk factor/scenario and dividing by five (Equation 1). This provided a semi-quantitative five-point scale with which to compare the impact of the various risk factors/scenarios on the individual project elements and the project as a whole.

$$\textit{Risk Score} = (\textit{Probability} * \textit{Risk})/\ 5 \qquad \text{(Equation 1)}$$

To assess the impact of the risk factors on the estimated cost of the project, the risk factors were then ranked in descending order of the scores. Thus a risk factor with a score of “4” is identified as having a greater potential to adversely impact the project than a risk factor with a lower score (e.g., “2.4”).

The range of the potential risk scores is presented in Table 5-1.

Table 5-1
Matrix of Potential Risk Scores

Probability of Occurrence		**Consequence ($ million)**				
		$3 – $10	**$10 – $20**	**$20 – $50**	**$50 – $100**	**> $100**
	Ranking	**1**	**2**	**3**	**4**	**5**
1:100 – 1:50	**1**	.2	.4	.6	.8	1.0
1:50 – 1:10	**2**	.4	.8	1.2	1.6	2.0
1:10 – 1:5	**3**	.6	1.2	1.8	2.4	3.0
1:5 – 1:3	**4**	.8	1.6	2.4	3.2	4.0
1:3 – 1:2	**5**	1.0	2.0	3.0	4.0	5.0

The following discussion presents the risk factors and scenarios employed for this analysis. The risk factors and scenarios were selected based on Reclamation’s statement of work and discussions with Reclamation. All the risk factors and scenarios are considered to have the potential to impact the estimated cost of the dam.

5.2 RISK FACTORS AND SCENARIOS

5.2.1 Hydrologic Uncertainty

This purpose of this risk factor is to capture potential cost increases due to changes in design required to accommodate changes in flood flow. Collection of additional hydrologic data usually results in larger estimated flood flows. This has happened with the flood hydrology of the American River at Auburn. The acquisition of new hydrology data could also potentially result in additional revisions to the hydrologic design criteria. Such changes have the potential to increase the estimated cost of the dam. To assess the potential impact of such changes, two hydrologic scenarios were employed: hydrologic design and hydrologic source.

5.2.1.1 Hydrologic Design

New or updated models result in changes in the return period for floods, these changes may result in design changes for the facility. It is possible that new data could result in an increase in the PMF at the dam site, thereby requiring a larger design flood for the spillway and appurtenant works. This scenario assesses the potential impact to the project costs of a larger design flood.

5.2.1.2 Hydrologic Source

New models or information could also result in changes in predicted flood levels for given flood events. The impact of such changes could result in design changes for the facility. This scenario assesses the potential impact to the project costs of changes in flood levels.

5.2.2 Seismic Uncertainty

Seismic design criteria for dams have changed since the Auburn Dam was originally designed. The changes can be attributed to a number of different reasons, including changes due to improved methodologies that resulted from better seismic data in other areas and changes due to better seismic data in the neighborhood of the project. The acquisition of new seismic data could potentially result in additional revisions to the seismic design criteria. Such changes have the potential to impact the estimated cost of the dam. To assess the potential impact of such changes, two seismic scenarios were employed: seismic design and seismic source.

5.2.2.1 Seismic Design

New or modified seismic models could potentially result in changes in the return period for earthquakes at this location. Such changes have the potential to impact the design criteria of the dam as well as the costs of construction. This scenario assesses the potential impact to the project costs of the need to make design and construction changes in order to meet new seismic requirements.

5.2.2.2 Seismic Source

New seismic models could result in changes in predicted earthquake severity, which could results in design changes for the facility. This scenario assesses the potential impact to the project costs of such changes.

5.2.3 Borrow Sources

Construction of the dam and associated structures would necessitate the identification of borrow sources that could meet the aggregate requirements for construction. This risk factor assesses the impact to the estimated cost of construction should the identified borrow sources not meet these requirements. Two scenarios were developed to assess the impact of this risk factor: borrow source quantity and borrow source quality.

5.2.3.1 Borrow Source Quantity

For this scenario, the quantity of material available at the identified borrow sources is inadequate for the project. This requires acquiring/purchasing additional aggregate from other locations and potentially increasing project costs.

5.2.3.2 Borrow Source Quality

For this scenario, the quality of material from the identified borrow sources does not meet the design requirements for the project. This requires acquiring/purchasing higher quality aggregate from other locations, which could potentially increase project costs, or modifying mix designs, which could also impact the project costs.

5.2.4 Quantities

This risk factor reflects the impacts of modifications to the quantities due to potential changes in site conditions related to the dam foundation. In this case, two quantities have major impacts on the cost of the project: excavation and concrete. Although the foundation for the dam has already been excavated, the excavation was performed before the design had been finalized. The long exposure of this excavation to the elements may have had deleterious effects on the foundation and may require additional excavation and correspondingly more concrete. Also, changes in design specifications in the intervening years since the foundation was originally excavated may require additional excavation to meet current building standards.

5.2.5 Environmental Issues

This risk factor reflects the impact of environmental issues on the estimated construction costs. The dam and its associated features will impact a fairly large area in the Sierra foothills. Potential environmental impacts encompass woodlands, loss of riparian habitat, impacts to endangered plant and animal species, etc. Before construction of the dam and the subsequent impact to the local environment, Reclamation would be required to acquire environmental permits and implement mitigation to reduce the significance of the impacts. However, in the years between when the dam is designed and when it is built, there is some uncertainty with regard to what the final environmental permit and mitigation requirements might be. To assess the potential cost impact, two scenarios are employed: environmental permitting and environmental mitigation.

5.2.5.1 Environmental Permitting

Reclamation would be required to acquire environmental permits from both the State of California and the federal government before it would be permitted to construct the dam. These permits would specify certain requirements and conditions for the operation of the dam and its associated features. Potentially, these requirements and conditions could change or Reclamation might need to acquire additional permits. These changes or the need to acquire additional permits could delay construction and/or necessitate changes to the project features and thus increase costs.

5.2.5.2 Environmental Mitigation

For this scenario, additional mitigation would be required. The mitigation may be related to changes in dam design and the associated features (i.e., the dam footprint, the high water line, additional roads and their associated rights-of-way, etc.), changes in species status within the area of the dam, or the addition of a new endangered species. The net outcome would be the need for additional lands and/or funds to implement the mitigation changes.

5.2.6 Real Estate

Real estate was identified as a risk factor with the potential to significantly impact the estimated cost of the project. The area in the vicinity of the dam has seen a significant increase in population in the years since the dam was originally designed. This population increase has resulted in an increased demand for land and an increase in real estate values. Over the past several years, the pressures have increased within the Central Valley in general, and the Sacramento Metropolitan area in particular has exhibited significant population growth. The potential impact of these changes can be reflected in two scenarios: real estate costs and increased land quantity needed for the project.

5.2.6.1 Real Estate Cost

For this scenario, land costs have increased and are higher than planned in the contingency. Additional funds would be required to purchase the land necessary for the project and its associated features.

5.2.6.2 Real Estate Quantity

For this scenario, a change in design has resulted in the need for more land to complete the project. The change may be related to a number of issues including the dam footprint, the high water line, additional roads and their associated rights-of-way, etc. Additional funds would be required to purchase the land necessary for the project and its associated features.

5.2.7 Inflation

This risk factor reflects the impact of inflation on the estimated construction costs. Inflation represents a risk to project costs not tied to any specific changes in material availability or design standards. Rather, it is more indicative of the general state of the economy than to any single sector. Inflation is considered a global risk factor because its impact applies to all elements or features of the project, not just the individual features. Thus, the cost impact would be evaluated as it applies to the total project cost, not individual project features.

For this risk factor, two scenarios would be considered: a "low" scenario, with an inflation rate of 6 percent, and a "high" scenario, with an inflation rate of 10 percent.

5.2.8 Market Conditions

This risk factor reflects changes in market conditions not related to general inflation. The purpose of including this risk factor is to capture the effect of a robust economy, and the consequent reduced availability of resources, on the cost estimate for the dam. Such changes in market conditions can be reflected in two scenarios: changes in the availability of building materials and changes in the availability of labor.

5.2.8.1 Material Availability

The possibility exists that the availability of building materials may be limited because economic conditions are different than when the initial costing process was conducted. The causes could be that the local economy has picked up and thus more competition is occurring for the same materials or that competition from outside the local area has increased for the same materials. The effect could be an upward pressure on the unit pricing for the required construction materials, and thus an increase in costs for the whole project. It is important to note that the aggregate costs captured in the borrow sources risk factor are not counted here.

5.2.8.2 Labor Availability

When the economy is robust, increased competition for labor, particularly skilled labor, is possible for complex projects such as the Auburn Dam and its associated features. The effect could be an upward pressure on the labor costs for the required construction, and the result could be an increase in costs for the whole project. This scenario assesses the impact of such competition on the estimated cost of construction.

This section discusses the findings of the updated costing and risk analysis. The findings are broken out into three components related to the statement of work: the findings regarding changes in design standards, the findings regarding the updated project cost, and the findings regarding the risk analysis.

6.1 CHANGES IN DESIGN STANDARDS

The Auburn-Folsom South Unit was designed according to the design standards that Reclamation followed in the 1970s. These design standards were presented in detail in several documents prepared for the Auburn-Folsom South Unit (Reclamation 1977a, 1980a, 1980b; DPR 1978) as well as other general documents and monographs about dam design (Reclamation 1976a, 1976b, 1977b, 1977c, 1977d).

The design standards or design criteria used by Reclamation aimed to provide safe, economical, functional, and durable structures. The criteria considered materials, including both the foundation and the concrete dam and its components; loading conditions; methods of analysis and design data; and construction methodologies and quality. Significant criteria used for the design of the concrete dam in 1978 related to the following (Reclamation 1980a):

- Selection of dam site
- Selection of dam type
- Selection of a curved gravity dam
- Geometry of the dam cross section
- Location of the powerhouse inside the gravity structure
- Use of conventional mass concrete placed in zones of different strengths
- Concrete characteristics
- Thermal analysis
- Characteristics of the foundation-concrete interface
- Foundation surface treatment
- Foundation seepage control
- Loads and loading conditions
- Factors of safety
- Methods of analysis
- Hydrologic design
- Seismic design

As discussed in Section 3 (Engineering Technical Review), many of these criteria are outdated, and they would be replaced by state-of-the-practice criteria during a future feasibility study for the project. Changed criteria in many of these areas would result in changes to quantities of materials and construction methodologies, both of which would have an important impact on costs. Changes in the following areas would likely lead to fundamental impacts to the cost of the project: the location of the dam, the type of dam selected, the cross-section geometry of the dam, the materials used in the dam, and others. Some of these impacts would increase the cost of the project, but other impacts would reduce the cost. Among the factors that have the potential to reduce the cost of the project, the use of RCC is probably the easiest to identify. RCC has become the preferred method for constructing concrete gravity dams and could result in important savings in the cost of concrete for Auburn Dam. To some extent these cost savings would be offset because it would be necessary to relocate the power plant outside of the body of the dam to optimize the use of RCC in the project, and this relocation would result in additional costs. The net effect of the savings from the use of RCC and the cost of the power plant relocation would need to be studied during the required feasibility stage for the project.

6.2 UPDATED PROJECT COST ESTIMATE

This section presents the results of the updated costing analysis. The cost estimate is broken out into two components: the dam component and the environmental mitigation component. The estimated cost of environmental mitigation has been separated out from the dam cost estimate because environmental mitigation is not a civil engineering cost and was not a significant feature of the 1978 design (Reclamation 1980a).

6.2.1 Updated Cost Estimate of the Dam Component

The updated OPCC for the dam and appurtenant structures is presented in Table 6-1. The total cost is estimated at approximately $5.4 billion. Broken down by WBS category, one feature, the concrete curved gravity dam, accounts for 56 percent ($2.5 billion) of the total cost. Three other WBS categories account for an additional 40 percent ($1.78 billion) of the estimated project cost: project general requirements, the hydroelectric power plant, and the highway and road relocation.

Table 6-1
Estimated Project Costs Broken Out by WBS Features

Construction Costs			
WBS	**Description**	**Estimated Cost (1,000s)**	**Percentage of Total Cost**
1	General Requirements	$527,518	12%
2	Site Preparation	$94,989	2%
3	Concrete Curved-Gravity Dam	$2,510,418	56%
4	Hydro-Electric Power Plant	$693,548	15%
5	Electric Power Transmission, Switchyards and Substations	$91,241	2%
6	Highway Relocation	$562,828	12%
7	Public Access/Recreation Facilities	$39,130	1%
	Subtotal	**$4,519,672**	**100%**
	20% Contingency	$903,934	
	Construction Total	**$5,423,606**	
Mitigation Costs			
8	Environmental Mitigation	**$1,480,063**	

6.2.2 Cost Estimate of the Environmental Mitigation Component

At this phase of the design, environmental mitigation costs are estimated to be about $1.5 billion. These costs are a preliminary rough estimate based on the potential impacts, the estimated area of the impacted habitat types, and recent costs for mitigation back credits (acres) sold in similar habitats and for similar mitigation lands.

6.3 RISK ANALYSIS

For the purpose of this analysis, four categories of WBS were excluded from the risk analysis: site preparation, electric power transmission, switchyards and substations, and public access and recreation facilities. Although the estimated cost of these four categories was approximately $225 million, they accounted for only about 5 percent of the total estimate. The potential impact to the project cost from risks associated with these features is small compared to the potential impacts of the higher-cost features.

6.3.1 Risk Analysis for Project General Requirements

The results of the Project General Requirements risk analysis are presented in Table 6-2. Only two risk factor/scenario combinations are considered to have significant impact on the cost of this feature: Market Conditions/Labor Availability and Market Conditions/Material Availability. The issues of concern for the Labor Availability scenario have to do with project administration and management, quality assurance and control, temporary facilities, and construction costs with a cost impact ranking of 3. The Material Availability issues affected quality assurance and control, temporary facilities, and construction costs with a cost impact ranking of 2. The risk score for each of these two risk factors/scenarios is low at 1.2. The potential increase to project cost from the combined impact of Market Conditions risk factors/scenarios is approximately $36 million, or 7 percent of the feature cost.

Table 6-2
Ranked Risk Scores for Project General Requiremets

Risk Factor	Risk Scenario	Probability Ranking	Cost Impact Ranking	Risk Score	Costs (1,000s)
Market Conditions	Labor availability	2	3	1.2	$ 20,416
Market Conditions	Material availability	3	2	1.2	$15,330

6.3.2 Risk Analysis for the Concrete Curved Gravity Dam

The results of the Concrete Curved Gravity Dam risk analysis are presented in Table 6-3. Of the thirteen risk factor/scenarios, eight had risk scores greater than zero. These ranged from a risk score of 5 for Seismic Uncertainty/Design to 0.8 for Hydrologic Uncertainty/Design. Of the five highest ranked risk factors/scenarios, the first concerned seismic design standards for the construction of the dam based on current design standards versus those of the 1970s. This factor has a potential cost impact of approximately $750 million. Three of the other highest-ranked factors were concerned with the availability construction materials (i.e., concrete, aggregate, and steel). The fifth of the highest-ranked factors concerned labor availability. The potential cost impact was greatest for those risk factors/scenarios that were concerned with building materials. Of the eight risk factors with risk scores greater than zero, six had cost impact rankings of 5. The total potential increase to project cost if several of these risk factors/scenarios related to the Concrete Curved Gravity Dam were to occur simultaneously would be approximately $1.2 billion, or a 48 percent potential increase in the cost of the feature.

Table 6-3
Ranked Risk Scores for the Concrete Curved Gravity Dam Risk Analysis

Risk Factor	Risk Scenario	Probability Ranking	Cost Impact Ranking	Risk Score	Costs (1,000s)
Seismic Uncertainty	Design	5	5	5	$752,616
Market Conditions	Material availability	3	4	2.4	$83,086
Seismic Uncertainty	Source	2	5	2	$800,215
Quantities	Quantity	2	5	2	$139,732
Market Conditions	Labor availability	2	5	2	$104,601
Borrow Sources	Quality	2	5	2	$101,110
Borrow Sources	Quantity	1	5	1	$101,110
Hydrologic Uncertainty	Design	2	2	0.8	$13,312

6.3.3 Risk Analysis for the Hydroelectric Power Plant

The results of the Hydroelectric Power Plant risk analysis are presented in Table 6-4. Risk scores for four risk factors/scenarios were greater than zero. Of these, only one, Market Conditions/Material Availability had a moderately high risk score of 3. This scenario exhibited a potential cost increase of $130 million, an approximately 19 percent increase in cost for this feature because of potential increases in unit prices in almost all line items identified in this WBS feature. The other risk factors/scenarios had to do with seismic uncertainty and labor availability. These all had low risk scores of 1.2 and a total potential cost impact of approximately $74 million for all three scenarios combined. The total potential increase to project cost from all the risk factors/scenarios for this feature is approximately $204 million, which is 30 percent of the base cost of this feature.

Table 6-4
Ranked Risk Scores for the Hydroelectric Power Plant Risk Analysis

Risk Factor	Risk Scenario	Probability Ranking	Cost Impact Ranking	Risk Score	Costs (1,000s)
Market Conditions	Material availability	3	5	3	$130,740
Seismic Uncertainty	Design	2	3	1.2	$22,584
Seismic Uncertainty	Source	2	3	1.2	$22,584
Market Conditions	Labor availability	2	3	1.2	$28,898

6.3.4 Risk Analysis for the Highway and Road Relocation

All of the thirteen risk factor/scenarios for the Highway and Road Relocation risk analysis had risk scores greater than zero (Table 6-5). These ranged from a risk score of 5 for Real Estate/Costs to 0.2 for Borrow Sources/Quantity. Two risk factors/scenarios had risk scores greater than 2: Real Estate/Cost and Quantities. The potential increase in land costs for roads is the significant issue for this feature. At approximately $234 million, this cost accounts for 43 percent of the total potential cost impact for this feature. It should be noted that Real Estate is used as a proxy of cost impacts due to changes to the alignment of the road. The potential cost of the Quantities risk factor is significantly lower at $70 million, or 12 percent of the total for this feature. Environmental uncertainty, both permitting and mitigation, are also identified as a significant risk factor/scenario, albeit with cost impacts of only 20 percent of the real estate costs. What is probably the most surprising issue with this category is the potential total cost impact of all the risk factor/scenarios. The potential cost increase to this feature if all the risk factors were to occur is $548 million, an increase of 97 percent over the estimated cost of $562 million total for the feature. This potential cost increase corresponds with the level of detail that went into the design of the structures in this feature, as all of them are only identified at a conceptual level.

Table 6-5 Ranked Risk Scores for the Highway and Road Relocation Risk Analysis					
Risk Factor	**Risk Scenario**	**Probability Ranking**	**Cost Impact Ranking**	**Risk Score**	**Costs (1,000s)**
Real Estate	Cost	5	5	5	$ 234,512
Quantities	Quantity	4	4	3.2	$ 70,353
Environmental Uncertainty	Permits	3	3	1.8	$ 23,451
Environmental Uncertainty	Mitigation	3	3	1.8	$ 23,451
Market Conditions	Material availability	3	3	1.8	$ 46,902
Seismic Uncertainty	Design	2	3	1.2	$ 32,535
Real Estate	Quantity	2	3	1.2	$ 46,902
Market Conditions	Labor availability	2	3	1.2	$ 23,451
Hydrologic Uncertainty	Design	2	1	0.4	$ 9,380
Hydrologic Uncertainty	Source	2	1	0.4	$ 9,380
Seismic Uncertainty	Source	2	1	0.4	$ 9,380
Borrow Sources	Quality	2	1	0.4	$ 9,380
Borrow Sources	Quantity	1	1	0.2	$ 9,380

6.3.5 Risk Analysis for Inflation (Dam Component)

The results of the Inflation risk analysis are presented in Table 6-6. Of the two scenarios under consideration, both have a potential to significantly impact the cost of the dam component, as these scenarios were evaluated in terms of total project costs. Of the two scenarios, the 6 percent scenario has the highest probability of impacting the cost of the dam component with a risk score of 4. This result is probably not surprising, considering the conceptual design phase being evaluated in this analysis. If the project were to go forward, the potential effects of inflation would most likely be mitigated as the project moves closer to actual construction.

Table 6-6 Ranked Risk Scores for the Dam Inflation Risk Analysis					
Risk Factor	**Risk Scenario**	**Probability Ranking**	**Cost Impact Ranking**	**Risk Score**	**Costs (1,000s)**
Inflation	6 percent	4	5	4	$271,180
Inflation	10 percent	2	5	2	$451,967

6.3.6 Risk Analysis for Environmental Mitigation

The OPCC for environmental mitigation is $1.48 billion. Table 6-7 shows that Real Estate is the primary feature potentially affected by environmental mitigation costs. The high risk scores for both scenarios reflects the high level of uncertainty with respect to what mitigation would be required for the dam impacts, both in terms of the degree to which the land costs may change and the amount of land that may be required for mitigation. Because this analysis is being performed as part of a conceptual OPCC estimate, this factor is a significant contributor to the potential increase in costs for mitigation. The total potential cost increase associated with this feature is $431 million, an increase of 29 percent over the estimated cost of $1.48 billion.

Table 6-7
Ranked Risk Scores for the Environmental Mitigation Risk Analysis

Risk Factor	Risk Scenario	Probability Ranking	Cost Impact Ranking	Risk Score	Costs (1,000s)
Real Estate	Cost	5	5	5	$ 123,339
Real Estate	Quantity	4	5	4	$ 308,347

6.3.7 Risk Analysis for Inflation (Environmental Mitigation Component)

The results of the Inflation risk analysis are presented in Table 6-8. As with the inflation analysis of the cost of the dam component, both scenarios have the potential to significantly impact the environmental mitigation cost, as the scenarios were evaluated in terms of the total project costs. Of the two scenarios, the 6 percent scenario has the highest probability of impacting the environmental mitigation cost, with a risk score of 3.2. This ranking suggests that inflation-associated environmental mitigation land costs will continue to be a major component in cost uncertainty.

Table 6-8
Ranked Risk Scores for the Environmental Mitigation Inflation Risk Analysis

Risk Factor	Risk Scenario	Probability Ranking	Cost Impact Ranking	Risk Score	Costs (1000s)
Inflation	6 percent	4	4	3.2	$88,804
Inflation	10 percent	2	5	2	$148,006

6.3.8 Significant Risk Factors

Using a risk score of 3 as a cutoff for identifying the significant risk factors/scenarios, five risk factors are identified as having a high probability of significantly impacting the OPCC:

- Seismic design
- Real estate
- Quantities
- Market conditions
- Inflation

A risk score of 3 was selected as the cutoff because at this value, the minimum ranking that either the probability of occurrence or cost impact can have is a 3 or higher. For the purposes of this analysis, it was considered a reasonable threshold for identifying those risk factors with high potential to affect the estimated project cost. The total potential cost impacts of four risk factors on the individual WBS elements are presented in Table 6-9.

Table 6-9
Potentially Significant Risk Factors/Scenarios

WBS	Risk Factor	Risk Scenario	Probability Ranking	Cost Impact Ranking	Risk Score	Costs (1000s)
Dam						
3	Seismic Uncertainty	Design	5	**5**	5	$752,616
6	Real Estate	Cost	5	**5**	5	$234,512
6	Quantities	Quantity	4	4	3.2	$70,353
4	Market Conditions	Material availability	3	**5**	3	$130,740
All	Inflation	6 percent	4	**5**	4	$271,180
Environmental Mitigation						
8	Real Estate	Cost	5	**5**	5	$123,339
8	Real Estate	Quantity	4	**5**	4	$308,347
8	Inflation	6 Percent	4	4	3.2	$88,803

Seismic design issues dominate the uncertainty costs with respect to dam construction. At a potential cost of approximately $750 million, seismic issues clearly affect potential dam construction costs. A better understanding of seismic design could potentially result in changes to the quantities of materials necessary to build the dam to modern earthquake standards.

With respect to the highway relocation, the real estate risk factor accounts for 42 percent of the high-probability risk costs at $234 million. This impact is not surprising, as highway relocation is a land-intensive feature. The design uncertainty for the highway relocation is much larger than for the dam, and this difference is reflected in the high risk scores and potential costs increases for the highway relocation. Land costs have a high potential to continue to significantly impact costs if the recent growth rate in real estate prices continues.

The quantities risk factor also affects the highway relocation feature. The quantities risk factor addresses the issues of excavation, steel, and concrete and the potential impact on costs. The highway relocation feature as currently defined was not an original feature of the dam. It is being considered now because of changes in regional land use and national security issues that have developed since the dam was originally designed. Highway construction would require significant excavation and fill. Until such time as the highway alignment is identified and finalized, excavation costs will continue to have a potential impact on highway relocation costs.

The market conditions risk factor, particularly as it applies to material availability, has a significant potential to affect the project costs of the dam. Although market conditions have the potential to impact costs for all construction features, the risk factor is especially important for hydroelectric power plant construction. Unit pricing is the key issue for this feature. With regard to the hydroelectric power plant, unit pricing uncertainty shows an average total potential impact of 19 percent. For a number of items, including concrete reinforcement, cast-in-place concrete, steel fabrications, hydraulic gates and valves, special construction, conveying systems, mechanical, and electrical, the potential impact on unit pricing is 25 percent. Given recent trends in unit pricing, the volatility in pricing may not change in the near term. Thus, the impact of this risk factor could continue until such time as the dam would be built.

For the environmental mitigation component of the OPCC, the real estate risk factor, in terms of both cost and land, dominates the uncertainty, accounting for all of the high-probability risk costs. Environmental mitigation is a land-intensive feature. At this stage of design, uncertainty with regard to the types and amount of mitigation required is the dominant consideration. This uncertainty will only be reduced when the design is at a more mature phase, the environmental impacts from the dam are more fully characterized, and the affiliated regulatory agencies have had time to rule.

The inflation risk factor also has a high potential to affect both the dam component and the environmental mitigation component of the OPCC. As a global risk factor, inflation has the potential to affect the estimated cost of the entire project, not just individual line items. This analysis identified the 6 percent scenario (which was given a rank of 4 for the dam component and a 5 for the environmental mitigation component) as the inflation level that has a high potential to impact total project costs. The potential impact applies to both the dam component and the environmental mitigation component.

A number of risk factor/scenarios do not meet the risk score cut-off of 3, but are of potential importance because of their potentially high cost impacts. All of these scenarios have a cost impact ranking of 5 (> $100 million) (Table 6-10). These six risk factors/scenarios can be characterized as low-probability, high-consequences events. That is, these risk factors have a small likelihood of occurrence (less than 10 percent), but they could cause very high cost impacts if they do occur. These factors apply to both the dam component and environmental mitigation component.

Table 6-10
Low-Probability High-Cost Risk Factors/Scenarios

WBS	Risk Factor	Risk Scenario	Probability Ranking	Cost Impact Ranking	Risk Score	Costs (1000s)
Dam						
3	Seismic Uncertainty	Source	2	5	2	$800,215
3	Quantities	Quantity	2	5	2	$139,732
3	Market Conditions	Labor availability	2	5	2	$104,601
3	Borrow Sources	Quality	2	5	2	$101,110
3	Borrow Sources	Quantity	1	5	1	$101,110
All	Inflation	10 Percent	2	5	2	$451,967
Environmental Mitigation						
8	Inflation	10 Percent	2	5	2	$148,006

With regard to the dam component, the five risk factor/scenarios shown in Table 6-10 range in potential total cost impact from $800 million for Seismic Uncertainty/Source to $101 million for Borrow Source issues. These risk factors/scenarios only apply to one WBS feature, the dam construction. The dam is the single largest feature of the project, accounting for 56 percent of the estimated costs and consequently requires the largest amount construction materials and resources. Inflation has the potential to add approximately $450 million to the construction costs.

For the environmental mitigation component, inflation is the only risk factor of consequence, with a potential total cost impact of approximately $150 million.

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