American River Watershed Project

Post Authorization Change Report

American River Watershed Project

Folsom Dam Modification and Folsom Dam Raise Projects

Appendix G
Pertinent Correspondence

US Army Corps
of Engineers

Sacramento District
South Pacific Region

March 2007

PERTINENT CORRESPONDENCE

This appendix includes correspondence important to the Post Authorization Change Report for the American River Watershed Project. These correspondence include the following:

Date	To	From	Page
12/16/2004	Sacramento Area Flood Control Agency	Bureau of Reclamation	G -3
9/29/2006	Corps of Engineers	Federal Energy Regulatory Commission	G-5
10/05/2006	The Reclamation Board	Sacramento Area Flood Control Agency	G – 7
11/28/2006	Corps of Engineers	Bureau of Reclamation	G – 9
12/15/2006	Corps of Engineers	The Reclamation Board	G – 11
3/28/2007	Corps of Engineers	Bureau of Reclamation	G – 13

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721
For Mike

United States Department of the Interior

BUREAU OF RECLAMATION
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, California 95825-1898

IN REPLY
REFER TO:
MP-440
WTR-4.00

DEC 1 6 2004

Mr. Stein Buer
Executive Director
Sacramento Area Flood Control Agency
1007 Seventh Street, 7th Floor
Sacramento, California 95814

Subject: Contract No. 03-XC-20-0377 Between the United States and Sacramento Area Flood Control Agency Concerning the Operation of Folsom Dam and Reservoir – Central Valley Project, California

Dear Mr. Buer:

Enclosed is an executed original of the subject contract for your records. This contract is effective December 6, 2004, and will terminate on December 31, 2018, or on such earlier date as mutually agreed to between the Bureau of Reclamation and the Agency. Reclamation appreciates the effort expended by the Agency and its representatives relative to this contract.

If you have any further questions, please contact Mr. Rick Johnson, Deputy Area Manager, of our Central California Area Office, Folsom, California, at 916-989-7200 or TDD 916-989-7285.

Sincerely,

FOR John T. Davis

Kirk C. Rodgers
Regional Director

Enclosure

FEDERAL ENERGY REGULATORY COMMISSION
Office of Energy Projects
Division of Dam Safety and Inspections
888 First Street, NE Routing Code: PJ-13
Washington, DC 20426
(202) 502-6734 Office – (202) 219-2731 Facsimile

September 29, 2006

Mr. Donald L. Basham, Chief
Engineering and Construction
Directorate of Civil Works
Headquarters, U.S. Army Corps of Engineers
Attn: CECW-CE
441 G Street, N.W.
Washington, DC 20314-1000

Subject: Coordination of American River Dam Safety Studies

Dear Mr. Basham:

The L.L. Anderson Dam (French Meadows Reservoir), Project 2079-CA is under the regulatory authority of the Federal Energy Regulatory Commission (FERC) and has been identified by the FERC as having inadequate spillway capacity to pass the Probable Maximum Flood (PMF). This determination has been made by the FERC consistent with its regulatory authority, its dam safety regulations, and its dam safety engineering guidelines. L.L. Anderson Dam is upstream of Folsom Dam which we understand is undergoing a coordinated study effort by the U.S. Army Corps of Engineers (USACE) and the Bureau of Reclamation (Reclamation) to correct a dam safety deficiency and examine additional flood control for the American River basin. In addition to L.L. Anderson Dam, there are other dams in the drainage basin above Folsom Dam under FERC dam safety jurisdiction. We are currently completing spillway adequacy studies on these dams and it appears that each can safely pass the required Inflow Design Flood (IDF).

Since there are different regulatory authorities involved with different dams on the American River and its tributaries, those regulatory authorities need to collaborate and coordinate on the work being done concerning dam safety. This collaboration and coordination is in fact the subject of an issue paper being proposed to the Interagency Coordination on Dam Safety for the Federal Agencies to develop coordination guidelines.

In August of 2005 we accepted the PMF study completed by the FERC licensee, Placer County Water Agency (PCWA), for the L.L. Anderson Dam (French Meadows Reservoir). The accepted PMF inflow to the French Meadows Reservoir is 59,100 cfs. Based on our spillway adequacy study it has been determined that, considering the downstream consequences of a potential failure of L.L. Anderson dam, the required IDF is the PMF. We will require that PCWA increase the spillway capacity of L.L. Anderson Dam to safely pass the PMF. Accordingly, PCWA has been directed to summit a plan and schedule to complete the design and construction of dam safety remedial measures to safely pass this IDF.

We understand that the PMF of 59,100 cfs that we approved is slightly less than that calculated by the Corps of Engineers. We believe that given the assumptions used for the many parameters involved with developing a PMF, the difference is within the accuracy of calculations. The design of the spillway remediation at L.L. Anderson Dam will include the routing of the PMF through the French Meadows Reservoir and this will have to be reviewed by FERC before proceeding with the final design for the dam safety remediation. The opportunity remains to discuss any outstanding technical issues.

FERC will continue to keep both the USACE and Reclamation informed as we proceed with the design of the LL Anderson remediation and as we review the ongoing dam safety studies on other dams in the American River basin.

If you have any questions concerning the oversight of the dam safety remedial work for L.L. Anderson Dam or any of the FERC dams on the American River basin, please contact me at (202) 502-6734.

Sincerely,

Constantine G. Tjoumas

Constantine G. Tjoumas, P.E.
Director,
Division of Dam Safety and Inspections

SAFCA
Sacramento
Area Flood
Control
Agency

October 5, 2006

Jay Punia, General Manager
Reclamation Board
3310 El Camino Blvd.
Sacramento, CA 95821

SUBJECT: FOLSOM DAM SAFETY AND FLOOD DAMAGE REDUCTION

Mr. Punia:

The Sacramento Area Flood Control Agency (SAFCA) intends to be the local sponsor in partnership with the Reclamation Board as the non-federal sponsor with the United States Army Corps of Engineers on the Folsom Dam Safety and Flood Damage Reduction Project. SAFCA strongly supports this project and is committed to providing our community a minimum of 200-year level of protection. This project will deliver a greater than 200-year level of protection and in a timeline that will bring additional flood protection to our community within a decade.

SAFCA also agrees to work with the Reclamation Board to develop a mutually satisfactory Local Project Cooperation Agreement (LPCA) that will define the exact details of the local cost sharing, project coordination, liability, and operation and maintenance responsibilities.

Please feel free to contact Pete Ghelfi at 874-8733 if you have any questions.

Sincerely,

Stein Buer,
Executive Director

Cc: Robert Charney, DWR
Pete Ghelfi, SAFCA

Office 916-874-7606
FAX 916-874-8289

1007 - 7th Street, 7th Floor
Sacramento, CA 95814-3407

United States Department of the Interior

BUREAU OF RECLAMATION
PO Box 25007
Denver, Colorado 80225-0007

TAKE PRIDE IN AMERICA

IN REPLY REFER TO:

84-44000
PRJ-13.00

NOV 28 2006

Deputy Chief of Civil Works
Headquarters, US Army Corps of Engineers
Attn: CECW-CE
441 G Street N.W.
Washington, DC 20314-1000

Coordination of Folsom Dam Activities, Central Valley Project, California

Dear Mr. Stockton,

The partnership agreement between Reclamation and the US Army Corps of Engineers (USACE) provides for many opportunities for our organizations to collaborate on issues of mutual interest. One such opportunity is the coordination of dam safety and flood damage reduction improvements for Folsom Dam, California where Reclamation is the owner/operator and the Corps has operational flood damage reduction responsibilities under Section VII, Flood Control Act of 1944.

We are aware of Post Authorization Change studies being conducted by the Sacramento District to evaluate the addition of flood damage reduction measures in conjunction with dam safety improvements being evaluated by Reclamation. While some of the design and construction issues will involve decisions that will be local to specific features and contracts, evaluation of the flood hydrology (PMF and other events exceeding the authorized top of flood pool), freeboard and risk assessments will involve Reclamation policy and criteria with respect to the overall safety of the dam. In accordance with the provisions of Section VII, Reclamation recognizes its responsibility and authority to establish such criteria and requirements as may be appropriate for the proposed modifications to Folsom Dam.

To ensure that Reclamation's and Corps' priorities facilitate progress on work and decisions at Folsom Dam, I would like to propose a framework that would enable both agencies to proceed with studies and decisions at Folsom Dam and other American River Watershed projects:

- Reclamation has the authority to make Safety of Dams modifications to dams where the Secretary of the Interior determines such modifications to be reasonably required.

- Reclamation recognizes as a dam owner that it has a responsibility to safely accommodate floods that can be reasonably expected to occur at the dam.

- Any modifications to the dam for flood damage reduction would potentially involve the addition of spillway capacity, modifications or replacement of existing gates and raising the dam to safely pass flood events. Design criteria for such modifications would be the responsibility of Reclamation.

- Routing storm events through Folsom Lake and the existing Folsom Dam when the water surface exceeds the top of authorized flood pool would be within Reclamation's jurisdiction.

- Reclamation has responsibility to establish criteria for features that may be reasonably expected to impact long-term maintenance or operations of the project.

- Reclamation has responsibility to establish criteria for features that may be reasonably expected to impact the security of the dam and/or operating features.

- Reclamation and USACE will keep each other informed of study plans, results, schedules and decisions for Folsom Dam as they are formulated.

- Reclamation and USACE agree to cooperate to the maximum extent possible as the agencies pursue individual and joint design and construction activities.

Reclamation staff looks forward to working with USACE staff as both agencies work to select, design and construct appropriate structures at Folsom Dam. If you have any questions concerning Reclamation's Dam Safety Studies for Folsom Dam, please feel free to contact Mr. Nathan Snorteland 303- 445-2395 or Mr. Larry Hobbs 916- 978-5335.

Sincerely,

David G. Achterberg

David G. Achterberg
Director, Security, Safety and Law Enforcement

STATE OF CALIFORNIA – THE RESOURCES AGENCY

ARNOLD SCHWARZENEGGER, GOVERNOR

THE RECLAMATION BOARD
3310 El Camino Ave., Rm. LL40
SACRAMENTO, CA 95821
(916) 574-0609 FAX: (916) 574-0682
PERMITS: (916) 574-0653 FAX: (916) 574-0682

December 15, 2006

Colonel Ronald N. Light
District Engineer
Sacramento District
U.S. Army Corps of Engineers
1325 J Street
Sacramento, California 95814-2922

Dear Colonel Light:

This letter is to express The Reclamation Board's (Board) intent to sponsor the proposed Joint Federal action for Folsom Dam as presented in the December 2006 Post Authorization Change Report, American River Watershed Project, Folsom Dam Modifications and Folsom Dam Raise Projects. The Board supports this proposed Joint Federal Action, which intends to (1) reduce the flood risk along the American River, generally equivalent to the extent authorized under the Folsom Dam Modification and Folsom Dam Raise Projects, and (2) safely pass the Probable Maximum Flood at Folsom Dam.

The Board approved this letter of intent at its December 15, 2006 meeting. In a letter dated October 5, 2006 (attached), the Sacramento Area Flood Control Agency (SAFCA) has indicated its strong support and intent to be the local cost-sharing partner of the Board.

Please note that this letter of intent is not an obligation of future appropriations of State funds by the State Legislature. We look forward to working with the U.S. Army Corps, the U.S. Bureau of Reclamation, and SAFCA on this critically important Federal action.

If you have any questions, you may contact Jay Punia, General Manager of the Reclamation Board at (916) 574-0609, or your staff may contact Robert Charney, Project Engineer for the Department of Water Resources' Division of Flood Management, at (916) 574-2010.

Sincerely,

Benjamin F. Carter, President
The Reclamation Board

Attachment

cc: Stein Buer, Executive Director
Sacramento Area Flood Control Association
1007 Seventh Street, 7th Floor
Sacramento, California 95814

United States Department of the Interior

BUREAU OF RECLAMATION
Central California Area Office
7794 Folsom Dam Road
Folsom, California 95630-1799

IN REPLY REFER TO:
CC-100
PRJ-3.00

MAR 28 2007

RECEIVED
MAR 29 2007

Colonel Ronald N. Light
Commander
U.S. Army Corps of Engineers
1325 J Street
Sacramento, CA 95814

Subject: Folsom Dam Joint Federal Project Short-Term Evaluation Decision Document

Dear Colonel Light:

Enclosed for your use in the U.S. Army Corps of Engineers Post Authorization Change (PAC) Report is Reclamation's approved Folsom Dam Joint Federal Project Short-Term Evaluation Decision Document. The document represents Reclamation's technical evaluation of the Joint Federal Project and Selected Project in the PAC Report. Reclamation will complete a final technical evaluation concurrently with final design of the JFP and SP.

Sincerely,

Michael R. Finnegan
Area Manager

Enclosure

cc: Mr. Stuart Townsley
U.S. Army Corps of Engineers
1325 J Street
Sacramento, CA 95814

Mr. Charles Riardan
U.S. Army Corps of Engineers
1325 J Street
Sacramento, CA 95814
(w/encl to each)

Folsom Dam
Joint Federal Project / Selected Project Short-Term Evaluation

Dam Safety Program Decisions

I. Background

General Assumptions

All elevations are based on the original design datum (NGVD29).

- Flood control operation is prescribed by the U.S. Army Corps of Engineers (Corps). Although the current authorized Top of Flood Control Reservation is at reservoir elevation 466, a joint agreement between the U.S. Army Corps of Engineers (Corps) and Reclamation has extended flood control operations into the surcharge storage space up to pool elevation 470.

- Above pool elevation 466, the releases within the surcharge storage space are controlled by the Bureau of Reclamation (Reclamation). ***The Bureau of Reclamation will take control of flood routing operations and begin to ramp from a discharge of 160,000 ft^3/s to 360,000 ft^3/s in 50,000 ft^3/s per 30 minute increments (Joint Federal Project – JFP routings).***

- The PMF event for Folsom Dam and Lake was developed in 2001 using Hydrometeorological Report (HMR) 59. The hydrograph was developed based on a North Fork storm centering with no upstream failures. LL Anderson Dam is presumed modified in accordance with the FERC license so as to pass its PMF.

- The PMF event is preceded 8-days in advance by an antecedent flood (72-hours of rainfall) immediately followed by the main flood with a peak inflow of 905,770 ft^3/s and a 5-day volume of 3,206,000 acre-feet. The antecedent flood (50 percent PMF hydrograph) was derived using an HEC-1 model. This process required that each sub-area hydrograph ordinate be reduced by half and routed through the upstream reservoirs and reaches down to Folsom.

- Section 101(a)(6) of the Water Resources Development Act (WRDA) 1999 (Public Law 106-53) specifies that the Secretary of the Army and Secretary of the Interior shall coordinate. Upon completion and improvements to Folsom Dam, the variable space allocated to flood control within the reservoir shall be reduced from the current interim operating range of 400,000-670,000 acre-feet to 400,000-600,000 acre-feet.

Description of Alternatives

- Joint Federal Project

- No dam raise
- Existing spillway service/emergency gates not replaced.
- Controlled spillway flows are maintained throughout operation (no free flow operation).

Discharges do not increase beyond 160,000 ft^3/s until the pool elevation exceeds the jointly agreed permissible surcharge storage elevation target ***(466.0 ft).***

- Alternative Joint Federal Project (currently called the Selected Plan or SP)
  - 3.5 ft dam raise
  - Existing emergency spillway gates are replaced.
  - Existing service spillway gates are not replaced.
  - Controlled spillway flows are maintained throughout (no free flow operation).
  - Discharges do not increase beyond 160,000 ft^3/s until the pool elevation exceeds the storage elevation target ***(471.5.0 ft) at which enhanced flood protection can be provided.***
  - The service spillway gates could be overtopped for floods approaching the PMF (SP routings). The following is as noted in Reclamation's 2004 Folsom Dam Hydrologic Corrective Action Study report: Although the gates could fail under this condition, any failed gates would likely wash downstream. This is not viewed as a dam safety issue since they would not impede flows through the spillway. Any additional flow generated by failed gates would be relatively small compared to the total flow being discharged.

Recent hydraulic (physical) model studies have shown the gates begin to overtop at a reservoir water surface of about 481.0 feet. Given a 3.5 foot dam raise the maximum reservoir water surface should not be greater than 481.0 feet. If the gates are overtopped it will be by minimal depths.

Summary of Physical Constraints

- All existing-sized (5' x 9') river outlets retain their 60% gate opening restriction during concurrent service spillway gate operation up to 115,000 ft^3/s release.
- Any power units that are assumed operating would become non-functional once the tailwater discharge exceeds 250,000 ft^3/s.
- Emergency tainter gate operations can begin once the tailwater discharge reaches 240,000 ft^3/s or water surface is within 1 ft of overtopping closed emergency gates (RWS El. 470.0).
- For both emergency and service spillway gates, the gate lip cannot be raised beyond 454.5 feet. Therefore, it is physically impossible to open the existing tainter gates enough to go to a free-flow discharge.

Gates test were performed on November 15, 2006 to determine the current and maximum spillway gate openings. The gate was reportedly opened to 40 feet (elevation 457) where it contacted the first limit switch. Operators at the dam believe the gates can be easily modified to be opened to the full opening height of 459.0 feet. Reclamation agrees that orifice flow should be maintained.

- The safe long-term channel capacity of the downstream levees was assumed to be 160,000 ft^3/s.

Proposed Design Operation Criteria

- The minimum freeboard requirement is set at 3 feet per Bureau of Reclamation.
- No power is available for use in the routings. All power units are off-line.
- Releases from Folsom Dam must **not** be greater than the flows produced without the project in place.
- The dam was assumed to be releasing a minimum 2,000 ft^3/s at the start of the routing.
- Two methods are available for routing the PMF:
  - 1) use an antecedent flood starting the routing at the bottom of the flood control pool. (The initial reservoir water surface was assumed to be at elevation 399.63). This established the initial starting conditions for the PMF (around pool elevation El 401) or
  - 2) route the PMF alone starting at normal full pool (466 ft). The second option is appropriate for projects with limited release capabilities.
- All routings reflect the first method which provides 600,000 acre-feet of Flood Control Reservation (also referred to as Flood Control Space) between the initial water surface and the top of joint use at elevation 466
- The PMF event was routed assuming a 4-hour delay in determining outflows until the releases reached 115,000 ft^3/s. This simulates initial delays in computing inflow, scheduling/performing gate changes, solving mechanical problems, or delays in staffing the facility. Once releases reached 115,000 ft^3/s outflows were adjusted based on 1-hour intervals until reaching the top of the surcharge storage space.

  Reclamation used a 30-minute delay interval above RWS elevation 466.0 (JFP) and 471.5 (SP) when discharges begin to ramp above 160,000 ft^3/s. This 30-minute delay interval was used as long as the reservoir was rising.

- Discharge must **not** exceed 160,000 ft^3/s while the reservoir water surface elevation is less than the storage space elevation, ***which provides the desired level of flood protection***.

- The downstream levees were assumed to remain intact throughout the antecedent event.

Proposed Design Operation Criteria (continued)

- Ramp up Rate Limitations.

Discharge is less than or equal to 20,000 ft^3/s	no more than 10,000 ft^3/s during any 2-hour period
Discharge is less than or equal to 160,000 ft^3/s	no more than 30,000 ft^3/s during any 2-hour period
Discharge is greater than or equal to 160,000 ft^3/s	***Releases are to be ramped from 160,000 ft^3/s to 360,000 ft^3/s at 50,000 ft^3/s per 30 minute increment. Discharge above 360,000 ft^3/s should be the lesser of inflow or full discharge capacity.***

Ramp down Rate Limitation:

Outflow is less than or equal to 115,000 ft^3/s	no more than 10,000 ft^3/s during any 2-hour period.
Outflow is greater than 115,000 ft^3/s	Lesser of maximum peak release or 125 percent of inflow while pool elevation greater than 448 feet.

- Above the jointly agreed permissible surcharge storage elevation (466 feet for the JFP routing) at which the desired level of flood protection is reached,-***Discharge should be increased by no more than 50,000 ft^3/s during any 30 minute period for discharges below 360,000 ft^3/s.***

- ***For discharges greater than 360,000 ft^3/s*** releases are limited to inflow or full discharge capacity.

- Releases cannot exceed discharge capacity.

- A ramp-down rate of 10,000 ft^3/s in one hour and no ramp down the next hour is considered acceptable

- The Accelerated Transition rule maximizes use of the downstream objective flow capacity. Releases were increased from 115,000 ft^3/s to 160,000 ft^3/s as soon as the requirements of the accelerated transition zone were met. The requirements of the accelerated transition zone are as follows. Releases may be increased from 115,000 ft^3/s to 130,000 ft^3/s when the current inflow is greater than 200,000 ft^3/s and the 12-hour forecasted inflow is greater than 360,000 ft^3/s. Releases may be increased from 130,000 ft^3/s to 145,000 ft^3/s when the current inflow is greater than 250,000 ft^3/s and the 12-hour forecasted inflow is greater than 370,000 ft^3/s. Releases may be increased from 145,000 ft^3/s to 160,000 ft^3/s when the current inflow is greater than 270,000 ft^3/s and the 12-hour forecasted inflow is greater than 370,000 ft^3/s. The requirement to limit the ramp-up rate to 15,000 ft^3/s per hour or no more than 30,000 ft^3/s during any 2-hour period still applies.

- Fish and Wildlife Service Mitigation Rule. For inflows greater than or equal to 25,000 ft^3/s, less than or equal to 150,000 ft^3/s, limit the release to 60 percent of the inflow or 60 percent of the 12-hour forecasted inflow, whichever is greater. Discontinue this rule once the 12-hour forecast exceeds 150,000 ft^3/s or the reservoir rises above elevation 416.15 (20 percent encroachment).

- For a falling reservoir below elevation 448, releases were computed using an USACE drawdown algorithm which attempts to evacuate the Flood Control Reservation plus inflow in 1 day for each iteration while at the same time reduce the releases from 115,000 ft^3/s in 5,000 ft^3/s increments. The drawdown algorithm succeeds in evacuating most of the Flood Control Reservation below elevation 448 in a little more than 3 days.

- For a falling reservoir with releases at or below 15,000 ft^3/s, the ramp-down rate was limited to 1,000 ft^3/s per hour as defined in the USACE drawdown algorithm.

- Releases are not to be reduced while the reservoir is rising.

II. Decisions

An evaluation of the Joint Federal Project (JFP) Auxiliary Spillway Preliminary Design was performed by the Bureau of Reclamation's (Reclamation) Technical Service Center (TSC). The United States Army Corps of Engineers (USACE) has the lead responsibility for the JFP Auxiliary Spillway. Reclamation will contribute to the overall completion of the JFP Auxiliary Spillway and the Dam Safety Office has requested that Reclamation's TSC review the preliminary design of the JFP Auxiliary Spillway for technical adequacy in a risk framework. The purposes of the evaluation will be to insure that no significant flaws exist in the design that would compromise the safety of the structure or would result in

changes that would significantly increase the cost of the Auxiliary Spillway and that the design meets Reclamation's Public Protection Guidelines.

The short-term evaluation focused on several critical elements of the JFP Auxiliary Spillway. Flood routings were performed to verify the results of the USACE routings and to test the robustness of the Auxiliary Spillway design. An additional routing was performed to evaluate the Selected Plan (SP), which consists of the JFP Auxiliary Spillway, along with a 3.5-foot dam raise and modifications to the existing emergency spillway gates. A structural analysis of the auxiliary spillway control structure was performed, using a three-dimensional finite element model of the structure and the San Salvador earthquake record. Potential rock wedges in the area of the auxiliary spillway control structure were evaluated, based on joint data. The studies culminated in a risk analysis, which was held on November 15 – 17, 2006, and included participants from Reclamation and the USACE.

This Decision Document serves the purpose of documenting the formal evaluation of the USACE's JFP Auxiliary Spillway preliminary design in terms of meeting Reclamation requirements. Reclamation's concurrence with the JFP Auxiliary Spillway preliminary design is given with the following qualifications to be addressed during feasibility and final designs:

1. At least 3 feet of freeboard must be maintained during the 2001 Probable Maximum Flood (PMF) routing.

2. A ramping rate of 50,000 ft^3/s per 30 minute interval should be provided when increasing discharges from 160,000 ft^3/s to 360,000 ft^3/s (the ramping would occur above elevation 466.0 {elevations shown in this document are from the original dam construction and reflect the datum at that time} for the JFP). This will minimize the rate of inundation once the downstream levees fail (presently associated with prolonged releases exceeding 160,000 ft^3/s). This ramping rate matches closely to the rates indicated in the existing Emergency Spillway Release Diagram (ESRD) and rates of increase in spillway discharge that are provided for the Dam Safety Only Fuseplug Auxiliary Spillway. The introduction of a ramping rate for flows between 160,000 ft^3/s and 360,000 ft^3/s and the need to maintain 3 feet of freeboard during routing of the 2001 PMF will require an increase in the total spillway discharge capacity (i.e. discharge capacity increase for the JFP Auxiliary Spillway, the existing spillway or both).

3. A routing performed for the SP, with the assumption that releases would be limited to 160,000 ft^3/s up to reservoir water surface elevation 471.5 (at which point the ramping rate would be implemented) resulted in a maximum reservoir water surface elevation of 481.0. This would result in 3 feet of freeboard on the raised dam crest at elevation 484.0. Holding

releases to 160,000 ft^3/s will surcharge the flood control pool from elevation 466.0 to elevation 471.5.

4. Any changes to the formally allocated flood control space are to be documented and requested in writing.

5. Structural analysis results must be reconfirmed during feasibility and final design of the JFP Auxiliary Spillway control structure.

6. The excavation cut slopes on the right side of the spillway control structure should be steepened from 1.25:1 (rock) and 3.5:1 (common) to ½:1 or steeper (rock) and 1.5:1 (common). Review of the existing drill hole logs indicates that competent rock should exist along most of the cut slope height on the right side of the control structure. Steepening the cut slopes will keep a large buffer between the reservoir and the Left Wing Dam for potential seepage and piping paths associated with the B-shears. It will eliminate the need for an embankment closure section currently in the designs and the associated piping risks. It will allow extending the drainage gallery and draining the rock adjacent to the Left Wing Dam. Finally, it will reduce the excavation and concrete quantities for the JFP Auxiliary Spillway control structure and will reduce the overall cost of the structure.

The following key conclusions are reached regarding Reclamation's short-term evaluation studies for the JFP Auxiliary Spillway.

1. Flood routing studies performed by the USACE and Reclamation indicate that the 2001 PMF can be passed with 3 feet of freeboard if the delay between inflows and the allowed outflow in response to the inflow is established as 30 minutes above reservoir water surface (RWS) elevation 466. This is based on the proposed ESRD developed by the USACE, and using the existing outlet works, the existing spillway and the JFP Auxiliary Spillway (regulated by six 23-foot by 33-foot submerged tainter gates) to pass flood flows. The routing under the above conditions would result in a large jump in outflows (a jump of about 400,000 ft^3/s) above the point where discharges are increased above 160,000 ft^3/s. This increase would occur within a half hour, would result in failure of the downstream levees (estimated to occur for flows between about 160,000 ft^3/s and 200,000 ft^3/s), and would be extremely dangerous to downstream populations that had not been evacuated.

2. A more gradual ramping rate for flows above 160,000 ft^3/s will reduce the rate of inundation once the downstream levees fail. A ramping rate of 50,000 ft^3/s per 30-minute interval when increasing discharges from 160,000 ft^3/s to 360,000 ft^3/s would closely match the rates indicated in

the existing ESRD and would closely match the rate of increase in spillway discharge (for discharges between 160,000 ft^3/s to 360,000 ft^3/s) for the Dam Safety Only Fuseplug Auxiliary Spillway. The introduction of a ramping rate for flows between 160,000 ft^3/s and 360,000 ft^3/s and the need to maintain 3 feet of freeboard during routing of the 2001 PMF will require an increase in the total spillway discharge capacity (i.e. discharge capacity increase for the JFP Auxiliary Spillway, the existing spillway or both). It is estimated that the JFP Auxiliary Spillway capacity would need to be increased by about 4 percent to result in at least 3 feet of freeboard during the 2001 PMF.

3. Robustness studies were performed to test the sensitivity of the JFP Auxiliary Spillway design under a variety of assumptions. The JFP Auxiliary Spillway performed reasonably well, but some of the cases routed resulted in the dam overtopping. A complete set of initial routings was performed with releases held to 160,000 ft^3/s up to elevation 468 at which point releases were increased without a ramping rate up to the inflow value or the spillway capacity (whichever was less). The final set of sensitivity routings consisted of a limited set of scenarios, in which releases were held to 160,000 ft^3/s up to elevation 466, at which point the ramping rate was applied. Some of the final sensitivity routings resulted in dam overtopping. It will be necessary to achieve an increase in spillway capacity in final designs of the JFP Auxiliary Spillway and this will improve the results of the sensitivity routings and possibly eliminate overtopping for some cases. Results of the final sensitivity routings are provided in Table 3 in the Technical Report of Findings Section C.2.

4. A structural analysis of the JFP Auxiliary Spillway control structure performed with the San Salvador earthquake record indicated that the structure will perform well during large earthquakes. Stresses in the structure were generally within allowable limits.

5. A risk analysis was performed for the JFP Auxiliary Spillway, with participants from both Reclamation and the USACE. A comprehensive list of potential failure modes was discussed and five potential failure modes were carried into a second phase, where event trees were developed and risks were estimated.

6. Two of the seismic potential failure modes that were evaluated by event trees (Sliding at the Base of the Concrete Piers and Sliding of the Dam along the Foundation Contact) were found to have risks that were negligible.

7. The two remaining seismic potential failure modes (Failure of the Tainter Gates due to Buckling of the Radial Arms and Failure of the Submerged

Tainter Gate Trunnion Support Beam) could not be estimated directly since analysis and design details were not available. Evaluation of the risks using a hypothetical design indicates that if the design for both features is based on the P5 ground motions and a full reservoir, risks are likely to be below Reclamation's Public Protection Guidelines.

8. The expected risk from the hydrologic potential failure mode (Failure of Wedge in Right Ridge) is estimated to be 4.0E-3. This estimate is based on preliminary data and analysis but it indicates that modifications should be considered to the design to reduce the risk of this potential failure mode. Key factors that lead to this conclusion are: Excavation for the JFP Auxiliary Spillway would place the reservoir against the abutment in close proximity to the Left Wing Dam. There is a high probability that a wedge could be formed by the B and D joint sets in the right ridge to the right of the Auxiliary Spillway control structure. This failure mode requires that the reservoir be above elevation 470 (in order to develop significant uplift pressures on the joints) and that the wedge at least partially underlie the Left Wing Dam. If the wedge were to slide, it is almost certain that the Left Wing Dam would be breached.

The following technical recommendations are made based on Reclamation's short-term evaluation studies for the JFP Auxiliary Spillway and should be considered when developing final designs.

1. Provisions should be made to address a potential failure mode associated with sliding of the right abutment ridge (leading to failure of the Left Wing Dam) under flood conditions. Foundation treatment in the right ridge adjacent to the control structure should be pursued (such as grouting the ridge and extending the drainage gallery up the right abutment of the control structure). This will reduce the chance of a potential failure of a wedge in the right ridge, leading to an erosion failure of the Left Wing Dam.

2. Provisions should be made to address the potential failure of the submerged tainter gates (STG) during seismic loading, with the P5 ground motions used as a minimum design earthquake along with a full reservoir.

3. Provisions must be made to address the potential failure of the STG trunnion supports during seismic loading, with the P5 ground motions used as a minimum design earthquake along with a full reservoir.

4. Particular attention should be given to the joint and connection details between key interfaces in the JFP Auxiliary Spillway control structure during final design, including the base of the control structure piers and the connection between the trunnion support beams and the piers.

5. Provisions should be made during final designs to address the potential overtopping of the facility. During the robustness checks, some routings encroached on the 3 feet of required freeboard. The results of these routings were close enough to be acceptable at the feasibility design level recognizing that the JFP will be reviewed after final designs are complete.

The following technical recommendations are made based on Reclamation's short-term evaluation studies for the SP Auxiliary Spillway and should be considered when developing final designs.

1. Provisions should be made to address a potential failure mode associated with sliding of the right abutment ridge (leading to failure of the Left Wing Dam) under flood conditions. Foundation treatment in the right ridge adjacent to the control structure should be pursued (such as grouting the ridge and extending the drainage gallery up the right abutment of the control structure). This will reduce the chance of a potential failure of a wedge in the right ridge, leading to an erosion failure of the Left Wing Dam.

2. Provisions should be made to address the potential failure of the submerged tainter gates (STG) during seismic loading, with the P5 ground motions used as a minimum design earthquake along with a full reservoir.

3. Provisions must be made to address the potential failure of the STG trunnion supports during seismic loading, with the P5 ground motions used as a minimum design earthquake along with a full reservoir. Particular attention should be given to the joint and connection details between key interfaces in the JFP Auxiliary Spillway control structure during final design, including the base of the control structure piers and the connection between the trunnion support beams and the piers.

The Dam Safety Program Decisions and the key findings of the JFP/SP Short-Term Evaluation and Risk Analysis are summarized in the Decision Document. "Short –Term" is used to denote initial studies related to the JFP/SP Auxiliary Spillway preliminary design. These Decisions are in accordance with the Policy on Dam Safety Decision Making in the *Reclamation Manual*. The *Guidelines for Achieving Public Protection in Dam Safety Decision Making*, dated June 15, 2003, were used for this decision making process.

The following supporting documents have been prepared by Reclamation's Technical Service Center:

- Folsom Dam Joint Federal Project - Short-Term Evaluation – Flood Routings, Technical Memorandum No. FOL-8130-JFP-2006-1

- Folsom Dam Joint Federal Project - Short-Term Evaluation – 3-D LS-DYNA Analysis, Technical Memorandum No. FOL-8130-JFP-2006-2
- Folsom Dam Joint Federal Project - Short-Term Evaluation – Risk Analysis Report, Technical Memorandum No. FOL-8130-JFP-2006-3

This document concludes the work on the JFP/SP Short-Term Evaluation.

III. New SOD Recommendation(s)

There are no new SOD Recommendations resulting from this decision document.

IV. Prior Incomplete SOD Recommendation(s) Addressed by this Document

None.

V. New O&M (SOD-related) Recommendation(s)

None.

VI. Prior Incomplete O&M Recommendation(s) (SOD-related) Addressed by this Document

None

Folsom Dam
Joint Federal Project Short-Term Evaluation
Decision Maker's Concurrence

The decision makers accept the technical findings and recommendations and concur that this decision document has been prepared in accordance with the Policy on Dam Safety Decision Making (FAC P02) in the *Reclamation Manual*.

Concurred:

Michael Finnegan, Manager Central California Area Office	3/28/07 Date
Kirk C. Rodgers, Director Mid-Pacific Region	3/28/07 Date
Bruce Muller, Chief Dam Safety Office	3/26/07 Date

Technical Report of Findings

I. Summary of Results

A. Description of Joint Federal Project Auxiliary Spillway

The Joint Federal Project (JFP) consists of a proposed Auxiliary Spillway constructed on the left abutment of the existing Left Wing Dam. The new Auxiliary Spillway would regulate releases through a concrete gravity control structure with 6 submerged tainter gates (STG) into a reinforced concrete lined spillway chute and stilling basin, discharging directly into the American River downstream of the existing Folsom Dam. The concrete control structure would consist of six bays separated by five piers. Each 23-foot-wide by 33-foot-high bay would have an invert at elevation 368.0 and house a STG. The top of each pier would support a bridge across the JFP Auxiliary Spillway with a bridge deck at elevation 480.5 and the top of an upstream parapet wall at elevation 484.0. At reservoir water surface (RWS) elevation 477.5, the JFP Auxiliary Spillway has a discharge capacity of 50,800 ft^3/s per bay, or 304,800 ft^3/s for all six bays. The Selected Plan (SP) consists of the JFP Auxiliary Spillway, a 3.5-foot dam raise and modifications to the existing emergency spillway gates.

B. Consequence Assessment

1. Population at Risk - A detailed consequences of dam failure study was prepared in 2001 [1] for the existing Folsom Dam and dikes . This study evaluated downstream consequences associated with different failure modes for different Folsom Facility features. The 2000 census data were used in this study. This risk assessment concentrated on failure of the new JFP concrete structure, the JFP Auxiliary Spillway piers and gates, and the Left Wing Dam for a case where flow resulting from sliding of an abutment block in the ridge between the concrete section of the JFP and the existing wing dam could potentially cause the embankment to erode. Population at risk (PAR) for a failure of the JFP Auxiliary Spillway can be estimated from PAR determined for the existing concrete dam and wing dams. Failure of the JFP concrete section would have a much smaller breach discharge and would result in less PAR than failure of the existing concrete dam section. No PAR was estimated for a partial breach of the existing concrete dam that would simulate a breach of the JFP concrete section. Estimates of possible discharge for complete failure of one to three JFP monoliths indicated the discharge would be within the existing spillway discharge capacity, and PAR associated with current maximum spillway releases was used. Risks were estimated for sudden failure of one or more spillway gates. The PAR associated

with these scenarios is dependent on the number of gates that fail, and the reservoir elevation at the time of failure. The PAR was estimated from the risk analysis for the existing spillway gates [2] by equating scenarios with similar outflow.

2. Loss of Life Estimates – Loss of Life for failure of the Left Wing Dam was estimated to be 2007 people in the dam failure study performed in 2001. This value was used during this risk analysis. Estimates for failure of the JFP concrete section were developed using a breach outflow of between 190,000 ft^3/s and 570,000 ft^3/s, depending on the number of monoliths that failed (1 to 3). Since the range of breach discharge was within the existing discharge capacity at Folsom Dam, loss of life was estimated to be the pre-failure value associated with maximum spillway discharge. The 2001 dam failure study estimated a loss of life of between 90 and 370 people would occur from large discharges failing the downstream levees before failure of the wing dam. Loss of life values for gate failures were estimated from values used in a 2001 risk analysis [2] of the existing spillway gates at Folsom Dam. In this analysis loss of life was calculated for different discharges resulting from a variety of gate failure scenarios. The discharge versus loss of life values in the previous study were compared to discharge for differing JFP gate failure scenarios. Loss of life for gate failures varies from approximately 2 for 1 gate failing at a low RWS elevation to 250 for 6 gates failing at a high RWS elevation.

C. Loads, Analysis and Structural Response

1. Earthquake Ground Motions and Load Probabilities - In an attempt to better address residual risk at higher seismic loadings for failure modes at Folsom Dam, earthquake records were provided by Reclamation's Seismotectonic and Geophysics Group (86-68330) [3]. These records were chosen to represent a range of earthquakes and to approach the physical limit of seismic loading that could occur at Folsom Dam. These records included the P5 record, the San Salvador record and the Extreme Unfiltered record. The San Fernando record was obtained from the USACE to represent a more frequent event for which the structure would be expected to suffer little damage.

The exceedance probabilities for each of these events, based on peak ground accelerations and 0.2 second spectral accelerations, are given in Table 2 below. The natural period of the JFP structure and piers falls within this range.

Table 2 – Ground Motions

	Exceedance Probability	
Record	**PGA**	**0.2 S_A**
San Fernando	1/5,500	1/5,500
50k UHS (MCEx1.3)	-	-
P5	1/27,000	1/21,000
MCEx1.5	1/33,000	1/45,000
San Salvador	1/160,000	1/120,000
Extreme	1/990,000	1/260,000

2. Reservoir Operations – Flood routings were performed to verify the ability of the JFP to ensure that the USACE flood damage reduction goal is met (at least 200-year flood protection) and that Reclamation's goal of safely passing the PMF with at least 3 feet of freeboard is met.

Reclamation has developed an EXCEL spreadsheet to route floods through Folsom dam and to verify the USACE's reservoir operations models. The spreadsheet incorporates the discharge capacities from the JFP Auxiliary Spillway in combination with the existing spillways and outlet works. The spreadsheet allows Reclamation to route floods using the new reservoir operations proposed by the USACE as well as perform sensitivity study routings.

Presently the official top of flood pool is RWS elevation 466.0. Control of the reservoir would be transferred from the USACE to Reclamation once this elevation is exceeded. Discharge within the flood control pool is restricted, by the USACE, to the assumed long term safe downstream channel capacity of 160,000 ft^3/s. Using the six JFP STG (23-feet-wide by 33-feet-high), and the proposed reservoir operations, Reclamation has routed the PMF and 200-year recurrence flood to verify the USACE baseline JFP flood routings. The USACE baseline assumption is that there will typically be a 1 hour delay from the time the inflow into the reservoir occurs, the RWS elevation is determined and the required discharge is calculated to the time the new discharge is actually set at the dam. It was also assumed that adjustments are made each hour. This 1 hour delay was used whenever the reservoir was within the flood control pool and discharges were greater than 115,000 ft^3/s. The USACE assumes a 4 hour delay in setting the discharge for discharges below 115,000 ft^3/s. This delay was also followed during the routing. When the reservoir is above the proposed flood control pool (RWS elevation 466) smaller delays were also used. A 30-minute delay is believed to be practical during large flood events when all required operational personnel are in place and rapid operation of the gates is expected. The results are as follows:

- With 30-minute delay above RWS 466 feet (1-hour delay below RWS 466 feet), and a ramping rate above RWS 466, Reclamation's maximum RWS is 478.13 feet.

Routings with a 30-minute delay in setting discharge above the proposed flood control pool (RWS elevation 466) and no ramping rate pass the PMF with 3 feet of freeboard. There is a concern about outflow ramping up from 160,000 ft^3/s to over 500,000 ft^3/s in 1 hour or less (levee overtopping would rapidly occur with large overtopping depths).

To reduce the concerns about the very large initial ramping rate for the first few hours after discharge is allowed above 160,000 ft^3/s, a ramping rate of no more than 100,000 ft^3/s per hour below discharges of 360,000 ft^3/s is proposed. A 50,000 ft^3/s per 30-minute increase is proposed when a 30-minute delay is used in the routing. No ramping rate restriction was applied to the next time increment with discharges above 360,000 ft^3/s. The purpose of the ramping rate is to try and reduce the downstream impacts when increasing the releases from 160,000 ft^3/s to maximum discharge. It is believed that implementing a ramping rate of this type immediately after the levees begin to overtop and fail will reduce the loss of life during extreme flood events, by allowing people caught in the inundation boundaries to seek an evacuation route before being hit by even larger flows. This ramping rate restriction will allow for some of the evacuation and warning time that is incorporated in the existing Emergency Spillway Release Diagram. The existing Emergency Spillway Release Diagram has a target long term safe downstream channel capacity of 115,000 ft^3/s and a ramp up to 160,000 ft^3/s (short term safe downstream channel capacity) for extreme floods. Discharge is not allowed to exceed 160,000 ft^3/s until 6 hours have passed since discharges have risen above 115,000 ft^3/s and the RWS elevation is above 470.0 feet. When discharge is allowed above 160,000 ft^3/s it cannot be increased above 200,000 ft^3/s until the RWS is above elevation 472.0. All of these ramping restrictions allow additional time for warning and evacuation. The proposed ramping rate more closely matches previous Reclamation routings using the current ESRD. Routings were performed to investigate the effect of the proposed ramping rate on the maximum RWS elevation attained in PMF routings. Implementation of a ramping rate above discharges of 160,000 ft^3/s will require additional discharge capacity from the JFP Auxiliary Spillway. Modifications required to include a ramping rate are not expected to result in excessive changes to the JFP Auxiliary Spillway's configuration or designs (required increase in capacity for the JFP Auxiliary Spillway would be about 4 percent).

Routings were performed for the JFP Auxiliary Spillway using the current FCD and ESRD. These routings resulted in a maximum RWS elevation 480.94 using a 1-hour delay throughout routings and the ramping rate incorporated within the existing ESRD. Using a 30-minute delay and no ramping rate restriction above RWS elevation 468, the maximum RWS elevation was 477.17.

Several additional flood routings were performed to test the robustness of the JFP Auxiliary Spillway using the baseline gate size of 23 by 33 feet and to compare the JFP Auxiliary Spillway to the DSO fuseplug alternative. The results are summarized in Table 3 (reflecting the final assumptions for the JFP flood routings). Routings were performed using the proposed ramping rate above discharges of 160,000 ft^3/s. Routings were performed with a 30-minute delay.

Routings were performed for 110 percent of the PMF, the 2001 PMF with 1 service gate out of service, and for three scaled historical floods. The JFP Auxiliary Spillway as currently envisioned could not pass 110 percent of the PMF without dam overtopping. The JFP Auxiliary Spillway could not pass the PMF with 1 service spillway gate out of service without dam overtopping. Several critical scaled historic flood hydrographs were routed using the JFP Auxiliary Spillway. All of the scaled historic floods could be passed without overtopping the dam. Details of all the JFP flood routings are included in TM No. FOL-8130-JFP-2006-1 [4].

Table 3 – Additional PMF Routings

Flood Event	Initial RWS (feet)	Maximum RWS (feet)	Maximum Outflow (ft^3/s)
PMF with 30-min delay above El 466 with 1 service spillway gate out	**399.63**	**480.64***	**778,654***
110% PMF with 30-min delay above El 466	**399.63**	**481.67***	**853,851***
1963 Scaled historical event 24-hr intense storm duration 30-min delay above El 466	**399.63**	**478.42**	**822,826**
1986 Scaled historical event 24-hr intense storm duration 30-min delay above El 466	**399.63**	**478.46**	**823,425**
1997 Scaled historical event 12-hr intense storm duration 30-min delay above El 466	**399.63**	**477.99**	**815,979**

*** Does not include discharge over the existing dams and dikes.**

A routing was performed for the Selected Plan (SP), which consists of the JFP Auxiliary Spillway, a 3.5 foot dam raise and modifications to the existing emergency spillway gates. The routings were performed with the assumption that releases would be limited to 160,000 ft^3/s up to reservoir water surface elevation 471.5 (at which point the ramping rate would be implemented) resulted in a maximum reservoir water surface elevation of 481.0. This would result in 3 feet of freeboard on the raised dam crest at elevation 484.0. Holding releases to 160,000 ft^3/s will surcharge the flood control pool from elevation 466.0 to elevation 471.5.

3. **Dynamic Structural Analysis** – An analysis of the JFP Auxiliary Spillway control structure was performed using the LS-DYNA computer program

[5]. The control structure was analyzed for static loads that included gravity and normal reservoir at elevation 466. The analysis did not include reservoir load on the radial gates. It was assumed that the upstream bulkhead gates would be closed and reservoir load was applied to the entire upstream face of the structure. The ground motions from the 1986 San Salvador earthquake were used for the dynamic loading of the concrete structure. This ground motion provided the largest response for the existing concrete dam of the motions provided by Reclamation seismologists, and would be expected to cause the largest response for the new control structure.

The frequencies of the control structure in the upstream-downstream direction and of the center pier in the cross-canyon direction were determined by applying a sine pulse to the finite element model and measuring the response of selected nodes. The fundamental frequencies of the control structure (in the upstream-downstream direction) and the center pier (in the cross-canyon direction) are 7.04 and 8.21 Hz, respectively.

The dynamic analysis of the Folsom Dam Auxiliary Spillway Control Structure was performed using LS-DYNA. The maximum displacement at the crest of the dam is 0.55 inches in the upstream-downstream direction while the maximum displacement of the center pier is 0.38 inches in the cross-canyon direction. Due to the geometry of the structure stress concentrations are possible in locations where features intersect, such as the piers and headwalls, piers and slab and piers and beams. Stresses were investigated in these locations with the following results:

- Maximum tensile stresses in the piers along the downstream edge of the headwall were about 300 to 400 lb/in^2
- Maximum tensile stress in the piers along the lower edge of the headwall were about 300 lb/in^2
- Maximum vertical tensile stresses in the piers at the upstream and downstream edges of the base slab were about 400 lb/in^2 and 500 lb/in^2, respectively
- Maximum vertical tensile stress in the piers near the center of the base slab was about 50 lb/in^2
- Maximum vertical tensile stress at the heel and toe of the slab were about 100 lb/in^2 and 550 lb/in^2, respectively
- Maximum horizontal tensile stress in the upper and lower (trunnion) beams were about 400 lb/in^2 and 600 lb/in^2, respectively.

Nowhere in the structure were tensile stresses found to exceed the estimated dynamic tensile strength of the modern concrete that would be used to construct the structure. Therefore, for the loads analyzed, the elastic limit of the reinforcement would not be exceeded.

A limit-equilibrium sliding stability analysis using the computer program GRAVDAM was performed to evaluate overall structural stability under all loading conditions. This model was also used to evaluate post-earthquake

stability in the unlikely event that the base cracked completely through. A composite two-dimensional section was developed by adjusting the unit weight of the concrete material to account for the openings. Using a cohesion of 200 lb/in^2, a friction angle of 50 degrees, and a 67 percent effectiveness for the drains at the base of the structure, calculated factors of safety exceed 8 even with the reservoir as high as elevation 477. With the base cracked completely through, zero drain effectiveness, and a friction angle of 45 degrees, the estimated factor of safety exceeds 1.5 when the currently proposed 8 degree upstream slope to the base excavation is included. Thus, global sliding instability is unlikely.

D. Potential Failure Modes

The following failure modes were identified and addressed as part of the Conceptual Design Risk Analysis [6].

Failure Mode 1 - Sliding of Rock Wedge in Right Ridge Adjacent to Spillway Control Structure under Flood Loading - This potential failure mode involves the sliding of a rock wedge that could develop in the right ridge adjacent to the JFP Auxiliary Spillway control structure, potentially underlying the end of the Left Wing Dam. The wedge would form along the intersection of B and D joint sets and has the potential to daylight downstream in a steep area of the abutment slope. For this failure mode to develop, the reservoir would need to be above elevation 470. This is necessary to develop significant uplift pressures on the wedge. The wedge would need to be at least partially located underneath the left wing dam. Failure of the wedge would lead to an uncontrolled release of the reservoir through the area where the wedge was originally located, causing erosion and the rapid breach of the Left Wing Dam.

Failure Mode 2 – Seismic Failure of Spillway Tainter Gates due to Buckling of Radial Arm - This potential failure mode involves the failure of the spillway gates during seismic loading. The failure would occur as a result of gate arm buckling under hydrodynamic loading, with the buckling caused by a combination of axial and bending stresses in the radial gate arms. The gate arm buckling would be sudden and there are no mitigating factors if the critical loading occurs.

Failure Mode 3 – Seismic Cracking and Sliding at the Base of the Concrete Spillway Piers – This potential failure mode involves sliding of the spillway crest structure along the base of the spillway piers. The sliding would initiate during a large earthquake as a result of static and hydrodynamic loads in the direction parallel to the centerline of the spillway. The failure mode requires that cracking initiates at the base of the pier and eventually propagates through the entire base. Sliding would lead to an uncontrolled release through the area of the displaced monoliths.

Failure Mode 4 – Seismic Failure at the Tainter Gate Concrete Trunnion Support Beam - This potential failure mode involves the seismic failure of the trunnion support beams for the top-seal tainter gates. This could occur at the connection of the trunnion beams with the piers, or through the beams themselves.

Since design details were not available, it was unclear exactly how loads from the trunnions would be transferred to the trunnion support beam.

Failure Mode 5 – Seismic Sliding of the Dam along the Foundation Contact – This potential failure mode involves the sliding of the Auxiliary Spillway control structure concrete monoliths along the foundation contact. Cracking and sliding of monoliths could lead to the development of large uplift pressures at the base of the structure and post-earthquake instability. If monoliths continue to slide after the earthquake, a significant breach would occur through the area originally occupied by the failed monoliths.

A number of additional potential failure modes were considered by the risk analysis team but were not carried forward into the risk estimating process. A list of the additional failure modes considered can be found in the risk analysis report [6]. The failure modes were not pursued because they were not considered plausible or because it was the belief of the risk analysis team that current design practice would result in designs with risks below Reclamation's Public Protection Guidelines [7].

II. Findings

The following findings are based on the results provided in the source document(s) and summarized in this decision document. The findings are made in accordance with *The Guidelines for Achieving Public Protection in Dam Safety Decision Making*, dated June 15, 2003 [7] (refer to the attached summary f-N chart).

Reclamation's public protection guidelines for annual failure probability should be compared against the total annual failure probability based on the sum of all load categories, whereas the evaluation for annualized loss of life should be based on the total results for each load case separately. The total annual probability of failure for all load categories is estimated at 9.2E-6, well below the Guideline value. It should be noted that this probability of failure estimate is for the Auxiliary Spillway failure modes only and is not comprehensive in considering all failure modes for Folsom Dam.

The estimated mean seismic risk (annualized loss of life) for all identified potential seismic failure modes of 4.1E-4 (again, only considering failure modes for the Auxiliary Spillway) is below Reclamation's Guideline value. Key factors that lead to this conclusion are:

- The three dimensional analysis of the control structure performed by Reclamation indicated that the structure performs well for large earthquake loads with stresses that are within the capacity of the concrete structure.

- Two of the seismic failure modes that were evaluated by event trees (Sliding at the Base of the Concrete Piers and Sliding of the Dam along the Foundation Contact) were found to have risks that were negligible.

- The two remaining seismic failure modes (Failure of the Tainter Gates due to Buckling of the Radial Arms and Failure of the Tainter Gate Trunnion Support Beam) could not be estimated directly since analysis and design details were not available. Evaluation of the risks using a hypothetical design indicates that if the design for both features is based on the P5 earthquake ground motions and a full reservoir, risks are likely to be well below Reclamation's Public Protection Guidelines.

The risk from the hydrologic failure mode (Failure of Wedge in Right Ridge) is estimated to be 4.0E-3 (again only considering failure modes for the Auxiliary Spillway). This estimate is based on preliminary data and analysis but it indicates that modifications should be considered to the design to reduce the risk of this failure mode. Key factors that lead to this conclusion are:

- There is a high probability that a wedge could be formed by the B and D joint sets in the right ridge to the right of the Auxiliary Spillway control structure.

- If large uplift forces develop on continuous wedge planes as a result of reservoir loading caused by the Auxiliary Spillway excavation geometry, the likelihood of sliding is high.

- If the sliding wedge were to underlie the Left Wing Dam, it is almost certain that the Left Wing Dam would be breached.

The excavation cut slopes on the right side of the spillway control structure should be steepened from 1.25:1 (rock) and 3.5:1 (common) to ½:1 (rock) and 1.5:1 (common). Review of the existing drill hole logs indicates that competent rock should exist along most of the cut slope height on the right side of the control structure. Steepening the cut slopes will keep a large buffer between the reservoir and the Left Wing Dam for potential seepage and piping paths associated with the B-shears. It will eliminate the need for an embankment closure section currently in the designs and the associated piping risks. It will allow extending the drainage gallery and draining the rock adjacent to the Left Wing Dam. The combination of drainage along with grouting in the right ridge will reduce the failure probability of a wedge in this area. Finally, it will reduce the excavation and concrete quantities for the JFP Auxiliary Spillway control structure and will reduce the overall cost of the structure.

The current configuration of the JFP Auxiliary Spillway can pass the 2001 PMF with 3 feet of freeboard, provided that the delay in response to reservoir inflows is reduced in the routings from 1 hour to 30 minutes once the reservoir reaches elevation 466. This requires a large increase in spillway releases (about 400,000 ft^3/s) in the initial hour after discharges exceed 160,000 ft^3/s. This sudden jump

would be dangerous to downstream populations and as a result a ramping rate of 50,000 ft^3/s for each 30 minute interval should be provided when increasing discharges from 160,000 ft^3/s to 360,000 ft^3/s. This will minimize the rate of inundation once the downstream levees fail and more closely match warning and evacuation intervals included in the existing ESRD.

Ramping operations above elevation 466.0 will require modifications to the JFP Auxiliary Spillway to increase discharge in order to maintain 3 feet of freeboard during the 2001 PMF routing.

Robustness studies were performed to test the sensitivity of the JFP Auxiliary Spillway design under a variety of assumptions. The JFP Auxiliary Spillway performed reasonably well. Most of the routings with the JFP Auxiliary Spillway resulted in maximum RWS elevations that did not overtop the embankment dams/dikes, with some exceptions (see Table 3). Enlarging the JFP Auxiliary Spillway gates to increase discharge will likely result in less of the sensitivity routings leading to dam overtopping.

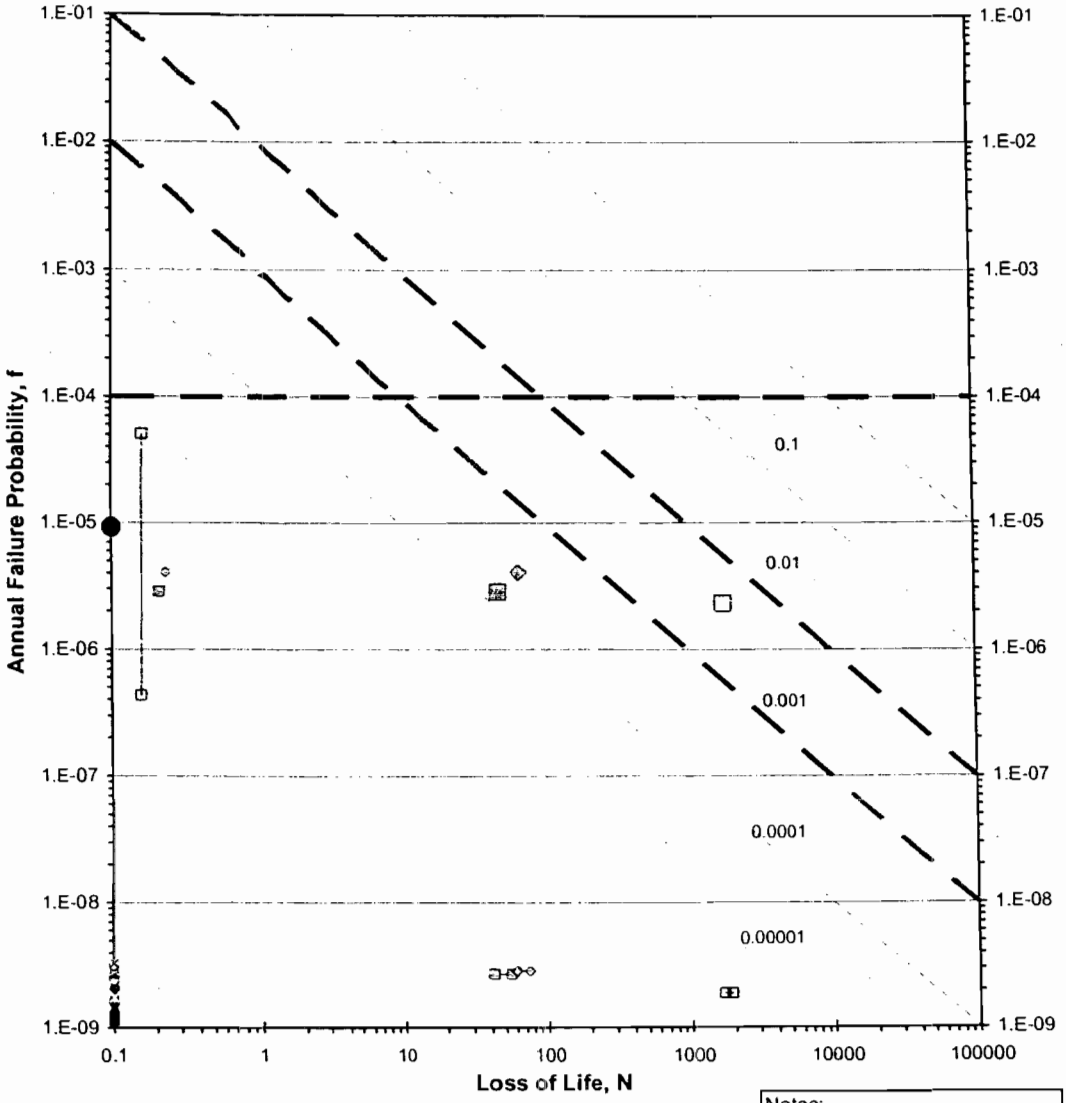
III. Benefits of New Recommendations

n/a

IV. Responses to Prior Incomplete Recommendations

n/a

Risk Estimates
Folsom Dam Joint Federal Project



- Hydrologic-Sliding Right Ridge Block
- Seismic-Radial Gate Buckling
- Seismic-Trunnion Failure
- Total Hydrologic Risk Estimate
- Total Seismic Risk Estimate
- Total Probability of Failure - All Loadings

Notes:
This f-N chart is based on the preliminary design of the Joint Federal Project and is not comprehsive in including all failure modes for Folsom Dam. Only failure modes for the Joint Federal Project are included here.

A DSAT (Dam Safety Advisory Team) Meeting was held on November 30, 2006.

The DSAT members have provided technical advice regarding the appropriateness of the proposed results, findings, and recommendations; and provided advice to the Dam Safety Office regarding the relative urgency and priority of implementing the recommendations or other follow-on activities. This advice was provided for the purpose of obtaining a level of consistency between projects.

Participants in the DSAT meeting are provided below.

DSAT meeting participants	Organization	Organization code	Role
William Fiedler	Waterways & Conc Dams	86-68130	Presenter
Ernie Hall	Waterways & Conc Dams	86-68130	Presenter
Phoebe Percell	Waterways & Conc Dams	86-68130	Presenter
Thomas Hepler	Waterways & Conc Dams	86-68130	DSAT Member
Gregg Scott	Structural Analysis	86-68110	DSAT Member
Pete Shaffner	Engineering Geology	86-68320	DSAT Member
Rick Benik	Waterways & Conc Dams	86-68130	Team Member
Brian Becker	Dam Safety Office	84-44000	Decision Maker

Participants by phone	Organization	Organization code	Role
Drew Lessard	Central California Area Office		
Larry Hobbs	Mid Pacific Regional Office		

References

[1] "Folsom Dams and Dikes, California – Estimating Consequences of Dam or Dike Failure", Bureau of Reclamation, Prepared by Wayne Graham, Technical Service Center, Denver, Colorado. July 2001.

[2] "Folsom Dam Spillway Risk Analysis – Gates and Piers Under Seismic Loading," TM No. FS-8130-TM-RA-2001-1, Bureau of Reclamation, Technical Service Center, Denver, Colorado, September 2001.

[3] "Hazard Curves and Uniform Hazard Response Spectra, Folsom Dam, Auburn-Folsom South Unit, American River Division, Central Valley Project, California," TM No. D-8330-2004-16, Bureau of Reclamation, Technical Service Center, Denver, Colorado, September 2, 2004.

[4] Folsom Dam Joint Federal Project, Short Term Evaluation, Flood Routings, Technical Memorandum No. FOL-8130-JFP-2006-1

[5] Folsom Dam Joint Federal Project, Short Term Evaluation, 3-D LS-DYNA Analysis, Technical Memorandum No. FOL-8130-JFP-2006-2

[6] Folsom Dam Joint Federal Project, Short Term Evaluation, Risk Analysis Report, Technical Memorandum No. FOL-8130-JFP-2006-3

[7] "Guidelines for Achieving Public Protection in Dam Safety Decision Making," Bureau of Reclamation, April 4, 1997