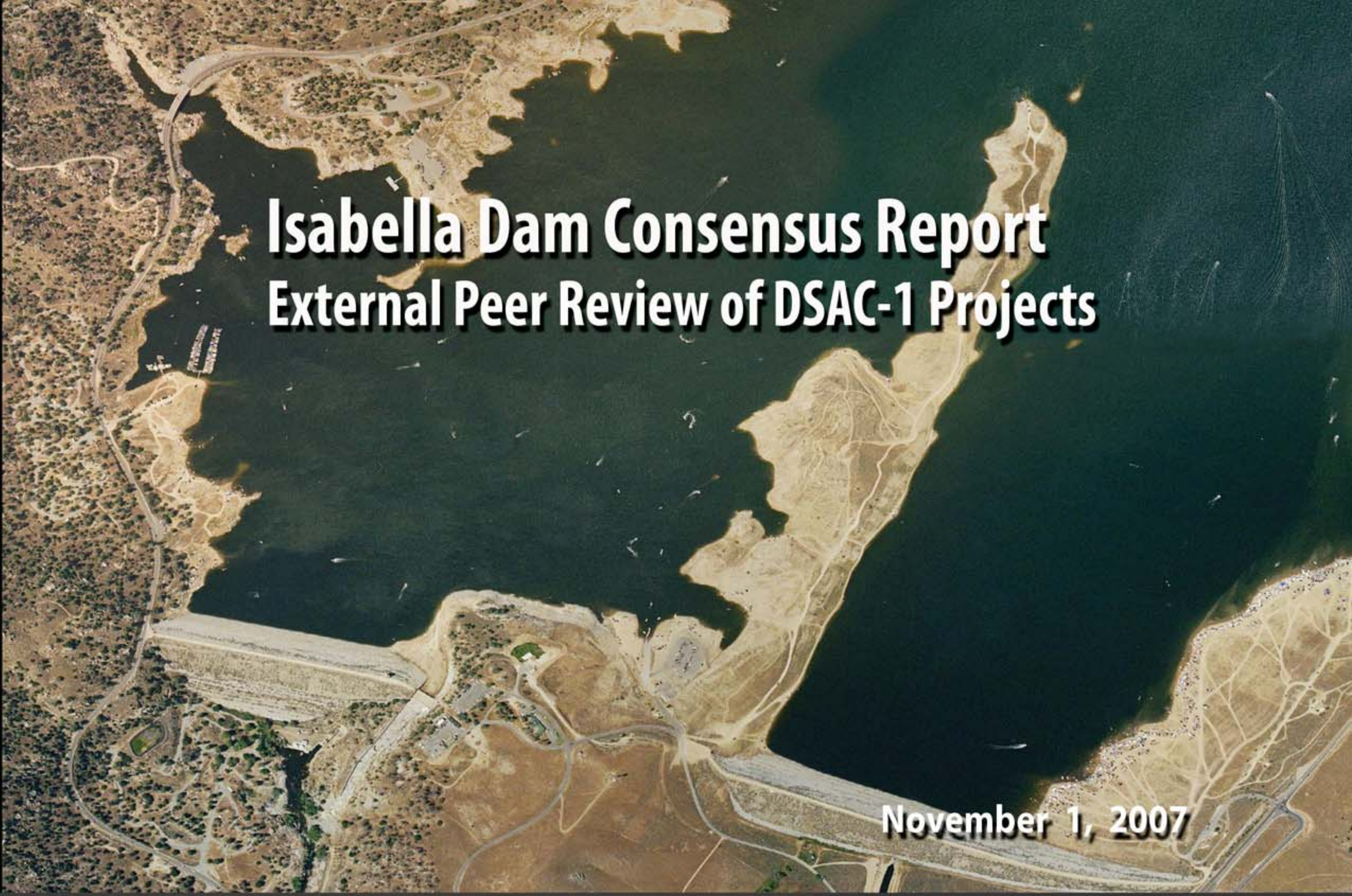
Isabella Dam Consensus Report
External Peer Review of DSAC-1 Projects



November 1, 2007

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External Peer Review Panel

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Isabella Dam (DSAC) Peer Review Team has completed its review in accordance with Contract requirements. All comments, responses, issues and concerns resulting from this Peer Review have been fully addressed.

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Executive Summary

The DSAC (Dam Safety Action Classification) External Peer Review Panel (Panel) finds that the U.S. Army Corps of Engineers (Corps) Class I designation (Urgent and Compelling) for Isabella Dam under EC 1110-2-6064 "INTERIM RISK REDUCTION MEASURES FOR DAM SAFETY" dated May 31, 2007 is appropriate.

The Panel's finding is based on the following:

- A possibility that piping is progressing along the outlet conduit of the Auxiliary Dam
- Evidence that the drain blanket of the Auxiliary Dam is not performing as intended
- Studies that find the Kern Canyon Fault, passing through the Auxiliary Dam's right abutment contact, to be active
- Evidence that the upper 20 feet of the Auxiliary Dam's foundation is loose and may be subject to significant loss of shear strength during seismic loading
- Hydrologic studies that indicate the spillway to be inadequate
- The extremely high consequences of failure associated with the foregoing dam safety issues

The Panel's major recommendations are as follows:

- Immediate Risk Reduction Measures

  Maintain the current pool restriction of Elevation 2585.5 feet, which is 20 feet below the normal pool elevation. Exceeding this reservoir elevation during significant hydrologic events is acceptable provided that every effort is made to lower the pool to the restricted level.

- Short Term Risk Reduction Measures

  Evaluate the appropriateness of restricting the pool to Elevation 2585.5 feet by considering downstream consequences and by incorporating findings of on-going studies

  Hydrologic conditions permitting, conduct a test filling to observe responses of recently installed piezometers

  Evaluate instrumentation and exploration needed for the Main and Auxiliary dams for the purpose of long term monitoring and maintenance of the dam. Install devices across the fault to monitor its movement continually.

  Assess the characteristics of the thin deposit of alluvium left in place under the downstream shell to determine its effect on the seismic stability of the Main Dam

Update the Emergency Action Plan

Conduct emergency exercises and coordinate with local officials and stakeholders

- Long Term Risk Reduction Measures

  Complete on-going investigations and studies, and initiate an Alternatives Analysis with a primary focus on a major rehabilitation of the Auxiliary Dam.

  Evaluate the overall earthquake performance of the Main Dam.

1.0 Limitation of Panel Evaluation

The Panel's evaluation, conclusions and recommendations are primarily based on information and documentation provided by USACE staff in an October 9 -13, 2006 briefing in Pittsburgh, PA as well as briefings and documentation provided during the Panel's site visit in April and May, 2007.

Additionally, the Panel has reviewed summaries and technical interpretations contained in a variety of sources of information prepared by Corps personnel, their consultants, and appointed "Panels of Experts" separate from this Panel. These documents appear to be factual and well prepared. The present Panel has relied on the accuracy of these summaries and technical interpretations and in particular the analysis of the distress indicators that have been identified, in formulating the opinions presented in this report. The Panel has carefully considered the verbal and written opinions of investigators who have been part of the ongoing investigations or who have previously reviewed and evaluated the condition of the dam.

The Panel understands that the Corps is conducting on-going studies during the preparation of this report. The Panel's evaluation is based on, and limited to the data and interpretations provided during its site visit in April and May 2007 and the October 2006 briefing.

Members of the Panel have been contractually provided a framework to express dissenting views in the form of a "Non-concurrence" report. This report represents a consensus of the Panel. There are no dissenting views by any member of the Panel.

2.0 Introduction

2.1 Project Description

Isabella Dam is located at the confluence of the north and south forks of the Kern River, 50 river miles upstream of Bakersfield, California. The drainage area is 2074 square miles. Congress authorized and appropriated funding for a dam in 1948 to prevent flooding in Bakersfield such as occurred in 1867, 1893 and in 1950 during the dam's construction. The project purposes are identified as 79 percent flood protection and 21 percent irrigation storage. Construction was completed in 1953.

The project consists of a 185-foot high Main Dam, and a 100-foot high secondary dam, called the Auxiliary Dam. Both the Main and Auxiliary Dams are compacted earth embankments, having lengths of 1700 and 3260 feet, respectively. The Main Dam is across the Kern River while the Auxiliary Dam is to the left of the Main Dam across Hot Springs Valley. The reservoir capacity is 568,000 acre-feet at full pool at Elevation 2605.5 feet. The crests of both dams are at Elevation 2633.5, providing 28 feet of freeboard above the spillway invert elevation.

2.2 Embankment Description

2.2.1 Main Dam

Based on descriptions provided in the plans, the Main Dam has a central impervious core zone and shell zones of random fill material. The core and random shell materials are comprised of clayey/silty sands and gravelly clayey/silty sands. These materials are very similar with the primary difference being that the maximum particle sizes were limited to 1 and 3 inches for the core and shell, respectively. Because of the material's similarity, the dam is, for practical purposes, homogeneous. The embankment materials were compacted in 7-inch thick loose lifts with 2-4 passes of a 92,000 pound pneumatic roller. The Corps did not indicate if moisture was controlled.

The alluvium was stripped from underneath the upstream shell zone and 200 feet downstream from the centerline of the dam, leaving a strip of alluvium approximately 250 feet wide under the downstream shell zone parallel to the downstream toe of the dam. The depth of the in place alluvium, underneath a portion of the downstream shell, is estimated by the Corps to be approximately 5 to 7 feet, maximum. Other than in this location, the embankment was placed on what is described as "sound granite." A 5-foot thick horizontal drainage blanket begins 200 feet downstream of centerline and was constructed over the in place alluvium. The horizontal drainage blanket is described as being comprised of silty gravelly sand.

A cutoff trench having a 12-foot width at the bottom and 1 on 1 side slopes was constructed at the dam's centerline. The trench varies in depth from 0 -12 feet. Grouting was carried out from the bottom of the cutoff at 20-foot centers to an approximate depth of 50 feet.

The embankment has a 3.5:1 upstream slope transitioning to 2.5:1 near the crest and a 2.5:1 downstream slope. The crest width is 20 feet. There are 7 piezometers in the embankment and no weirs to measure seepage. There are five accelerometers; one at the right abutment, one midway on the downstream slope, one on the crest near the left abutment and one in the free field downstream of the dam.

The Corps has indicated that no effective seepage collection system exists. Existing information indicates that a trench was dug with a backhoe at the toe some time before 1999 and backfilled with gravel. The information does not indicate the depth and length of the trench, although it is believed to be shallow – perhaps just 2-3 feet in depth and about 2-3 feet wide. The gravel-filled trench was not protected with filter fabric. The Corps did not indicate if this was designed as a filter.

2.2.2 Auxiliary Dam

The Auxiliary Dam is comprised of predominantly clayey/silty sands compacted by 3-5 passes with an 81,900-pound pneumatic roller in 9-inch loose lifts. A cutoff trench having a 12-foot width at the bottom was constructed in the foundation alluvium. The average depth of the cutoff trench is 5 feet. No grouting was performed and the average stripping was to a depth of only 6 inches over the entire footprint.

The embankment is described as homogeneous and impervious. A 5-foot-thick drain blanket was constructed under the downstream shell consisting of silty gravelly sands, starting about 30 feet downstream of the cutoff trench. The embankment slopes are the same as those of the Main Dam. The foundation alluvium is up to 130 feet thick and overlies deeply weathered granitic bedrock.

The geomorphology of the foundation was interpreted through seismic refraction surveys done in 2005. The Corps' assessment is that the entire foundation is an alluvial fan deposit derived from the left abutment. Below this deposit is weathered granite that grades downward into fresh granite.

The embankment was constructed in three stages. The first stage consisted of an 83.5-foot high embankment starting from left of conduit's alignment to the left abutment. This stage was completed prior to construction of the conduit. After the conduit was constructed, the second stage of the embankment was completed by infilling the area between the left of the conduit and right abutment. The third stage of construction raised the embankment height 16.5 feet by placement of fill on the upstream slope of the first stage for a final height of 100 feet.

The Corps describes the seepage collection system as follows: "An open downstream ditch was constructed soon after the project was finished for the purpose of collecting seepage. This ditch was filled with drain rock and protected with a filter fabric. A sump pump that operates automatically when the sump fills to a triggering level pumps the collected seepage via a 4-inch-diameter metal pipe to discharge over the side of the Borel Canal downstream of the dam. The free-flowing seepage from the area right of the Borel Canal is collected in the trench and flows to this sump near the maximum section of the dam. No seepage collection features exist in the area left of the Borel Canal. Seepage in this area, which only occurs at significant pools (~>elevation 2590), flows downhill via gravity to a pipe that exits into the Borel Canal."

2.3 Outlets

Downstream releases are made through (1) a 15-foot-diameter concrete lined tunnel at the Main Dam constructed in and through the granite in the left abutment, and (2) through a double barrel conduit under the Auxiliary Dam which discharges into the Borel Canal.

The Borel Canal existed prior to construction of the Auxiliary Dam and conveys water downstream to hydroelectric generating facilities owned and operated by Southern California Edison Co. (SCE). Normal maximum releases are 3,000 cubic feet per second (cfs) from the main dam and 600 cfs from the Auxiliary Dam.

Because capacity to generate power had to be maintained, the Borel conduit (at the auxiliary dam) consisting of two barrels was constructed as shown in the adjacent picture looking downstream. The inside dimensions of both barrels are 5 feet and 8 inches by 10 feet. The conduit was founded in the alluvium deposit with the top of the seepage collars slightly below original ground.

In 1956, during first filling, the embankment crest over the alignment of the conduit abruptly settled 4 inches. The reason for this abrupt settlement is unknown.

2.4 Spillway Description

The spillway consists of an uncontrolled 140-foot wide ogee-shaped weir located in the left abutment of the Main Dam. The spillway transitions to an unlined chute cut in granite below the weir.

The adequacy of the spillway was studied in June 2003 and was found to pass 33 percent of the Probable Maximum Flood (PMF), which results in a pool level with 6.5 feet of freeboard. The Corps criterion is that the design freeboard for this project of 6.5 feet not be encroached during the PMF. The peak PMF inflow overtops the dams by 8.5 feet when routed from a full reservoir.

The peak PMF inflow was calculated to be 541,900 cfs which is approximately 4.5 times the historical inflow of 120,000 cfs that occurred in 1966. Because of the extremely low reservoir level at that time, the 1966 flood runoff was entirely contained within the reservoir. Over the life the project, the reservoir has spilled 3 times. The downstream river channel capacity is limited to 8000 cfs which is governed by the levee capacity through Bakersfield. Flows in excess of this limit result in flooding of the Bakersfield metropolitan area. Thus, if the PMF were to occur, there will be significant damage and loss of life downstream and both dams would very likely fail.

3.0 Panel Site Visit (April 2007)

3.1 General

The Panel, except for Dr. Donald Bruce, inspected the Main and Auxiliary Dams on April 18 and 19, 2007. In addition to the Panel members, the following staff from the USACE were in attendance; Ronn Rose, Vinh Tran, Zach Blackwell, Jack Shamblin, Charlie Mauldin, Phil Deffenbaugh, Ken Pattermann, Dave Ricketts and Rick Britzman. Dr. Bruce inspected both the Main and Auxiliary Dams on May 30, 2007 and was accompanied by Mr. Dave Ricketts from the Corps.

The reservoir was at Elevation 2569.3 at the time of the site visit, which is 16.2 below the restricted level.

3.2 Main Dam

The embankment/spillway contact was inspected. This area is vulnerable during seismic loading whereby deformation of the embankment can result in separation of the embankment fill from the spillway wall. This separation can result in a through going transverse crack which would constitute a potential failure mode. This failure mode is mitigated by having 28 feet of freeboard, the elevation difference between the spillway crest and the crest of the dam. This freeboard is encroached about once every 7 years based on historic pool levels.

Overall, the dam appeared to be well maintained and in very good condition. The control tower was not inspected.

The spillway and the unlined chute were inspected. The unlined section is considered susceptible to plucking of the granitic rock as occurred in 1983. In that year, flow over the spillway occurred between June 15 and July 17 with a maximum of 5.35 feet corresponding to a pool elevation of 2610.84. The damage that was sustained consisted of rock being eroded out from the center of the channel with lesser erosion near the right training wall. The damage was repaired by placement of reinforced concrete in the affected areas in 1999.

The toe area was inspected and found to be dry.

3.3 Auxiliary Dam

The crest, downstream slope and toe area were inspected. These appeared to be well maintained. The toe area was found to be dry. The Borel Canal was dewatered at the time of the visit. SCE was performing scheduled maintenance on their power generating facilities permitting an inspection of the conduit. The Corps, through outside consulting services, was undertaking an evaluation of the embankment and foundation seepage and stability issues in the vicinity of the outlet conduit during this outage through an investigation program near and downstream of the outlet control structure. Conditions upstream of the control tower are not part of the current evaluation. Overall, the current evaluation includes continuous sampling and instrumentation of embankment and foundation material using Sonic drilling methods along two cross-sections approximately 50 feet left and right of the conduit, and ROV inspection of downstream portion of the conduits to evaluate joint leakage, a geophysical investigation from the inside of the conduit to look for possible voids, evaluations and surveys of the conduit alignment and conduit joints, drilling and sampling of the backfill and native foundation soils along the exterior of the conduit by coring through the conduit wall from the inside, and installation of vibrating wire piezometers along the exterior and in the interior of the conduit

The coring and soil sampling conducted from the inside of the conduit found that the backfill material adjacent to the conduit was very well compacted as evidenced by the difficulty of pushing sampling tubes. Sampling that continued beyond the compacted backfill encountered the native alluvial materials which were found to be loose. This material was saturated; measured average and peak flows were 4.8 and 9.0 gallons per minute, respectively through the holes extending through the concrete walls of the conduit and the compacted backfill into the natural material. Initially, these flows were silty and became somewhat clearer with time but never completely clear.

During previous outages and inspections of the conduit, the Corps had noted that the piezometer levels in the foundation alluvium dropped over a wide longitudinal zone of the dam when checked within 8 hours of dewatering. The extent of this zone was determined to be about 500 feet on either side of the Borel Canal at the toe. This result suggested that there is a direct link between the conduit and the surrounding alluvial zones. During the current inspection, no significant differential settlement between the monoliths was found during inspection of the conduit. The settlement gradually increased starting from the exit to a maximum of 3.5 inches near the gates in the control tower. The water stops appeared to be functioning based on a visual inspection and no direct leakage through the joints was observed. Instruments monitored prior to and during the outage, including the new Sonic borehole instrumentation did not show any significant response to the conduit dewatering.

During a previous regular inspection of the project, it was noticed by Corps personnel that the left end of the dam, at the abutment contact, does not have the requisite crest elevation. Based on a subsequent survey of the crest, it was found that the crest had been lowered by 2.2 feet as a result of highway construction by Caltrans. The Corps will be working with this agency to have the freeboard restored.

3.4 Planned Future Activities

The Corps summarized the activities planned for the future as follows:

- Expanded studies of seepage through the foundation of the Auxiliary Dam
- Geophysical testing of the Auxiliary Dam's foundation and in the vicinity where the Kern Canyon Fault crosses the right abutment contact

- Environmental assessments for subsurface investigations and the reservoir restriction
- Subsurface investigations and laboratory testing
- Additional fault studies
- Stability and deformation analysis of the embankment and foundation using software program FLAC
- Update the inundation mapping downstream of the project
- Analyze the hydraulic performance of the conduit

The Panel concurs with the scope of the foregoing future activities and recommends that these be integrated with an alternatives analysis for long term risk reduction.

4.0 Panel Observations and Findings

4.1 Auxiliary Dam Outlet Conduit

The Panel is concerned about the safety of the dam as it relates to the outlet conduit for many reasons, as discussed in the following sections of this report. It should be noted that this type of design and construction practice was commonly used in the 1940's – 1950's, the time frame of the project's design and construction. Since then, it has become clear that this design can cause an embankment dam failure due to piping of materials adjacent to the conduit.

4.1.1 Piezometric Levels and Seepage

Seepage has historically occurred on the left side of the conduit during high pool conditions. The Corps indicated that the quality of the records does not afford a determination that seepage areas or quantities have increased over time.

Piezometers were installed at the time of construction to measure conditions 20 feet into the foundation on the right and 40 feet into the foundation left of the conduit. In 1980, piezometers were placed in the drainage blanket. There are no piezometers in the embankment proper – hence, the existence of a phreatic surface within the embankment is undetermined.

Historic data from the 6 original piezometers on the right of the conduit at Station 57+75 were provided to the Panel. All six are 20 feet into the foundation; four of these under the foot print of the dam, the remaining two at and beyond the toe. Historic readings, taken at reservoir elevations of approximately 2605, showed a gradual downward trend over time. No definitive reasons were provided by the Corps for this downward trend.

The historic data for 2 of the 3 piezometers located at Station 67+10, to the left of the conduit, 40 feet into the foundation, show a similar downward trend over time. The historic data for the third piezometer, located upstream of the crest, are incomplete.

In addition to these data, the Panel was provided with the historic data of 4 piezometers installed in 1980 near the toe to monitor the drainage blanket. Two of these piezometers, P9 and P10, were located immediately adjacent to the right and left of the conduit, respectively. Two of the piezometers show a slight upward trend over time – the third shows no increase, while the fourth, P10, shows a dramatic increase when measured at near-full pool levels.

The cause for the increasing piezometer readings is unknown and may be indicative of the initiation of piping along the conduit. Therefore, the Panel finds the current investigation to assess the conditions along the conduit appropriate.

A historic aerial photograph of the project shows a darkened outline midway up the downstream slope and midway between the conduit and the right abutment. This outline has the appearance, and may be indicative of seepage and/or a perched water zone. The Panel recommends that piezometers be installed in two cross sections to monitor levels of saturation in the embankment proper and suggests that one row coincide with the aforementioned area to the right of the conduit, near Station 57+75 – the second to the left of the conduit, near Station 67+10.

4.1.2 Drainage Blanket

The design of the drainage blanket, as shown on the drawings, indicated a thickness of 5 feet. Post-construction drilling, sampling, and lab testing of this material in 1983 shows that the drain blanket material was comprised of less than 8 – 10 percent passing the #200 sieve. The currently on-going investigation has found the blanket to be of variable thickness having a 3 - foot thickness on average and a fines content of 21 percent. This percentage of fines content indicates that the drainage blanket cannot function as intended. Whether the fines are plastic is unknown at this time.

4.1.3 Hydraulic Fracturing of Adjacent Alluvial Materials

The conduit was constructed by excavating approximately 15 – 20 feet of the upper loose fan deposit. It was founded close to or in contact with the denser layer underlying the loose deposit. The recent investigation of conduit backfill has indicated that these materials were well compacted and very dense.

This set of conditions results in a positive projection for the overlying embankment materials whereby the vertical embankment load is carried by the conduit, the seepage collars and compacted backfill and is not transmitted to the adjacent alluvial materials. This in turn results in an arching condition in the loose alluvium, adjacent to the seepage collars and backfill. With an increase in pool elevation, the piezometric head can reach a point where it is greater than the minor principal stress, which would result in hydraulic fracturing of the loose alluvial deposit.

Although the Panel has made no determination that hydraulic fracturing is indeed occurring at high pool elevations, the positive projection of the conduit does, however, tend to increase the likelihood of initiation of piping. Since there is no filter/drainage zone in the downstream section of the dam or around the conduit, there is no defense against piping and/or internal erosion normally associated with embankment cracking.

4.1.4 Hydraulic Performance

The Panel understands that the hydraulic performance of the conduit is in doubt and is currently being investigated. It has been reported that project staff have noticed a surging and booming noise at the exit for decades when the conduit is flowing full. The Corps is considering the possibility that the conduit may be experiencing large pressure differentials and that the existing air venting may not be appropriate and may be causing the conduit to act as a siphon.

During the site visit, the Corps indicated that they believe that:

- The conduit may be experiencing large pressure differentials – collapsing hydraulic jump
- Soil may be being sucked through the joints into the conduit, resulting in possible voids which is a slow process and may be becoming evident now
- The situation may be serious

The Panel concurs with the Corps' investigation of the conduit's hydraulic performance and recommends that flow through the conduit be limited to less than full conditions until the current investigations conclude otherwise.

4.1.5 Anticipated Adverse Seismic Soil Structure Interaction

The embankment may undergo deformations as a result of shearing through the upper 20 feet of the loose fan/alluvial deposit due to earthquake induced loading. Such movements would result in significant distress of the conduit that may be evidenced by extensional cracking, or opening of existing joints throughout most of its length and compression buckling at the toes of the embankment. This anticipated performance is based on the performance of the outlet conduit of Upper San Fernando Dam during the 1971 San Fernando Earthquake.

Extensional cracking of the conduit can lead to formation of a sinkhole in the embankment by piping of materials into the conduit and formation of a pipe that slowly progresses upward to the face of the slope. This scenario constitutes a potential failure mode and has been observed in other cases such as Upper San Fernando Dam where a sinkhole occurred on the downstream slope above the conduit.

The connection between the tower and conduit is extremely vulnerable during an earthquake as deformation of the upstream slope will most likely result in distress in this area which could also lead to piping at this location. Because of the anticipated damage in this area, the slide gates may become inoperable. Thus, the ability to operate the gates in case of an emergency may be lost.

4.2 Seismicity and Faulting

The project is located in an area of significant background seismicity, which is associated with the Southern Sierra Nevada Seismic Zone M 6.5 and the Scodie Mountains Seismic Zone M 6.5. Active faults in the project's vicinity are the Garlock, White Wolf and San Andreas Faults.

A prominent feature is the Kern Canyon Fault (KCF), which is aligned with the Kern River and intersects the project at the Auxiliary Dam's right abutment contact. Historically, this fault has been considered inactive by the seismological community. There was strong suspicion by many, however, that this fault was indeed active. The Corps acted on this suspicion by initiating field studies in 2003. A phase of the studies has recently been concluded and documented in a September 2005 report. This report determined that the KCF is active; having a length of 160 Km and a rough, preliminary slip rate of 0.1 mm/yr. It is currently assessed to be capable of a Magnitude 7.0 earthquake. The Corps stated that the studies indicate that slip is believed to be predominately normal. Field studies on the Kern Canyon Fault are ongoing.

The evidence leading to the conclusion that the KFC is active is compelling. It consisted of offsets in recent alluvium, 50 foot offsets in Lava deposits, and a 23 foot fault scarp at Brin Creek, all north of the project and judged at one site to have occurred no later than 5,000 to 15,000 years ago. Additionally, it was found that there was “strong geomorphic evidence for late Quaternary/Holocene offsets,” when viewed from the air.

The seismic profiling along the Auxiliary Dam’s toe has suggested a discrete stepped profile in 3 – 4 locations of the granitic bedrock which may represent sympathetic faulting in association with the KCF.

Prior to these studies, the Operating Basis Earthquake (OBE), associated with a return interval of 145 years, was estimated to be 0.16g based on the USGS’ Deaggregated website which did not recognize the KCF as being active. The OBE accelerations which should now be considered may be significantly greater than 0.16g.

4.3 Foundation Investigations

4.3.1 Main Dam

A thin deposit of alluvium was left in place under the downstream shell. The characteristics of the thin deposit will have to be assessed to determine its effect on the seismic stability of the Main Dam. The depth of this alluvium is assumed to be a maximum of 5 – 7 feet, based on drawings and the characteristics of the river channel.

The criticality of this thin deposit should first be assessed using slope stability analyses and conservatively assumed shear strength parameters. Because of the limited extent of this layer, it is possible that its presence may not compromise the factor of safety of the downstream slope.

If sampling of this material is required, it is considered best to excavate a trench to expose the layer and to determine the best approach for measuring its in situ density and expected shear strength during seismic shaking.

4.3.2 Auxiliary Dam

A minimal pre-construction exploration of the Auxiliary Dam’s foundation was conducted consisting of several drill holes, of which only 4 holes were drilled to bedrock. Several trenches were also excavated. Based on this exploration, the alluvial soils were assumed to be homogeneous, dense and not subject to large seepage quantities. Review of the construction data by the Corps indicated that there appeared to have been a tendency to average the data and not differentiate specific zones or strata.

Cone penetration testing (CPT) was conducted at the toe of the dam in 2005. When coupled with the refraction survey, the Panel finds that the upper 20 feet of the fan deposit is very loose given the very low tip resistance. Below this depth, the data indicate a denser and more competent layer. Below this denser layer are the severely weathered granite and the parent granitic rock.

Recent Standard Penetration Test (SPT) data were converted to $(N_1)60$ blowcounts. The Corps compared these to plots of published correlations of cyclic strength ratio (CSR) for 50 percentile ground motions for a Magnitude 7.5 Earthquake. The Panel's experience has shown these published correlations to be erroneous. Use of these correlations will cause a significant error and result in an unreasonably conservative prediction of seismic performance.

To predict seismic performance of the foundation, the Panel recommends that in situ densities be obtained by way of sampling and trenching in conjunction with CPT, SPT and/or shear wave velocities. It is important that these data be correlated and integrated with the geomorphology of the foundation. Given these data, the undrained shear strength characteristics can then be determined for the entire foundation and the seismic performance predicted.

Exploration of the foundation as well as areas upstream of the dam may be possible during the late summer/fall of 2007 as the reservoir is anticipated to be at historically low levels due to the current very low snow pack. The Panel recommends that the Corps takes advantage of this opportunity if the reservoir reaches the expected low levels.

Given the information to date, it is the Panel's judgment that the upper 20 feet of the foundation will be susceptible to significant strength loss during seismic shaking leading to unacceptably large deformations of the embankment.

4.4 Panel Post Site Visit Questions and Review

Following the site visit, the Panel asked Corps personnel the following questions regarding the correctness of the data presented and whether the Panel should be made aware of any additional data and whether any different opinions/finding were formulated since the initial presentation in Pittsburgh on October 9 -13, 2006.

Below are the questions and the responses:

1. Is there any additional information that has not been provided to the Panel?

   Response: Yes. Sources of additional information include the following:

   - Settlement data
   - A previous panel meeting report from a meeting that occurred subsequent to the Pittsburgh meeting
   - Kern Canyon Fault seismic capability report that was completed after the Pittsburgh meeting
   - Briefing presentation
   - An exhibit of a water temperature study that was performed downstream of the auxiliary dam

The foregoing is primarily background information and was provided to the Panel for reference. The water temperature study indicated that seepage is more prevalent in the area of the conduit.

2. Is any of the previous information questionable?

   Response:

   - Previous seismic information is being updated
   - Conditions around conduit are being explored and will be updated
   - Seepage conditions in native materials immediately around the conduit are likewise being explored and will be updated.

3. Are there any fundamental changes in opinions/concepts for what needs to be done?

   Response:

   - Opinions and concepts have not been formulated. These would be delineated in a Major Rehabilitation Report/Dam Safety Assurance Program Evaluation Report which has not been completed.

4. What new initiatives are underway?

Response: (In addition to the items listed in Section 3.4 Ongoing and Future Activities)

- Project specific procurement is underway with an advertised Geotechnical Indefinite Date Indefinite Quantity (IDIQ) contract for $4 Million per year for 5 years that will include activities through the design
- Adding staff to help move the project along

4.4.1 Discussion Points and Recommendations

Following the questions, the Panel discussed the project with Corps personnel. The following list of bulleted items encapsulates the discussion points and recommendations:

- Failure Modes/risk assessment should be completed soon to help guide the development of investigation and instrumentation requirements
- Evaluate the outlet works to verify ability to perform following an earthquake including the mechanical and hydraulic systems that operate the gates
- Conduct further research of the blanket drain materials and construction to help in failure mode diagnosis
- Evaluate potential for cracking of Main Dam and determine the need for filters
- The Panel noted that a broad range of options and alternatives for overall remediation of the project exist and strongly encouraged to Corps to pursue a comprehensive and integrated solution to all dam safety concerns at one time
- The Corps asked the Panel's opinion on how to expedite the planning and permitting process. The Panel shared its experience regarding permitting
- The pool restriction seems reasonable at this time and is worth revisiting once the downstream inundation studies are complete. The Panel also discussed that it may be important to allow short-term encroachment on the restriction to evaluate instrumentation response once in place. Short term encroachment is not preventable when natural runoff becomes very large, e.g. at the peak flow of the PMF for this site. However, every effort must be made to release water well in advance if high peak flows are projected from rainfall and/or heavy snowmelt.
- Current studies are confirming that seepage and potential for piping along conduit is a significant concern. Multiple failure modes are possible, some of which (separation of joints during an earthquake) may not be permanently fixable with a downstream filter. The current investigations are answering questions and raising new ones. Additional evaluation of 1980 piezometer response to operation of the outlet needs to be performed in light of new data on the potential leakage from conduit.
- The Panel's findings and conclusions are based on information as of the site visit in April 2007. Additional information is being gathered as studies and evaluations progress. The findings and conclusions will therefore not reflect this additional information.

- Complete the inundation mapping. Consideration should be given to a sensitivity analysis around key parameters for various failure modes. These are integral to a risk assessment.
- Options for increasing the capability of the project to pass the PMF may include modification of the existing emergency spillway or outlet works to provide additional capacity. Tainter gates or a new flood control outlet may be appropriate considerations.
- Provide adequate storage and care of soil samples being taken to prevent drying of samples and allow easy access
- Try to get better descriptions of seepage and settlement of the auxiliary dam on first filling
- Evaluate progression of seepage front in embankment. To do this, develop instrumentation in a minimum of two cross sections in the Main and Auxiliary dams to evaluate piezometric surface and seepage in the embankment materials. This instrumentation would be in addition to the evaluation of seepage in the foundation of the Auxiliary Dam.
- Select locations where the quantity of potential transport of soil particles in the seepage can be measured easily and regularly, since piping usually occurs intermittently until the piping is in an advanced stage.
- Settlement monuments should be established on 25 versus 100 foot centers and special attention should be paid to the zones near the conduit and near the abutments. Horizontal movements should be measured on the dam and across the fault.
- Confirm the need to fix the crest elevation problems on the left end of the Auxiliary Dam and carry out the work as soon as practical.

Stability analyses of Main Dam, assuming complete strength loss of the recent alluvium, should be completed prior to undertaking investigations to determine potential impact and criticality of this concern. If it is determined that investigations should proceed, all holes for cross-hole shear wave testing should be performed with conventional drilling methods and sonic drilling should be avoided to minimize concerns of how sonic drilling might impact loose soils of concern. Use of sonic drilling in advance to locate materials that should be sampled is advisable. The sonic samples should be taken first so that the profile can be inspected and locations for further sampling can be selected. The additional sampling should be done at least 10 ft from the sonic holes.

5.0 Graphic Depiction of Continuum of Failure

The Panel has developed a graphical depiction of a seepage failure mode continuum for the Auxiliary Dam and has presented this depiction in a separate memorandum (DSAC Peer Review Panel, December 14, 2006). The graphical depiction is limited to a seepage failure mode and does not represent modes of failure due earthquake and/or hydrologic load conditions. The continuum is shown on the figure presented in Appendix B; the solid red arrow on this figure represents the Panel members' range of opinion of the failure timeline. The location of the arrow assumes a continuation of the same historic pool elevations in the future.

The failure continuum summarizes four stages of failure development.

a. Initiation
b. Continuation
c. Progression
d. Breach formation

Operation of the Auxiliary Dam started in 1953, but was not subject to reservoir loading until 1956. Seepage is assumed to have started soon thereafter. The first Periodic Inspection Report dated January 1970, in reference to an area near the right abutment, stated that "this area is always saturated due to under seepage and has not increased in size since completion of the project" and that it "is considered to be non-critical."

Piezometers have been installed and monitored over the course of the project's history. Piezometer P10, located adjacent to the conduit under the Auxiliary Dam, has shown a steady increase over a 20-year period – more so than the other piezometers. The sensing zone of Piezometer P10 is 10 feet long and straddles the drainage blanket. It is postulated that seepage is occurring along the conduit and that a possibility of piping in this area exists. Detection/intervention is associated with a 2006 timeline when the District convened an advisory panel to assess the criticality of this potential failure mode and initiated studies to investigate conditions along the conduit. The advisory panel concurred with the Corps' decision to restrict the reservoir.

The Panel considers that a breach formation/failure is not imminent. Seepage has occurred for a period of 53 years without any observed deleterious effects. However, the Panel notes that the pool is rarely full for sustained periods of time. Under these conditions, it is unknown if there are areas, other than at the conduit, where seepage and a potential for piping exist.

Seepage and associated piping along the conduit is currently being investigated by the District. A course of action and a timeline to failure can be better evaluated once this investigation is complete.

6.0 Safety in Context of Failure Continuum

The Panel's assessment of the Auxiliary dam's condition is shown on the seepage and piping failure mode continuum diagram in Appendix B. This diagram suggests that a seepage related failure mode has initiated. The extent of the arrow on the continuum is reflective of the confidence interval of the Panel's assessment.

The Failure Continuum is only applicable to seepage and piping failure modes. The Panel finds that the primary and dominant failure modes are associated with hydrologic and seismic events. The project is considered unsafe under these significant to extreme load conditions. The Auxiliary Dam is considered to have adequate safety against piping along the conduit so long as the reservoir restriction is maintained. The investigations currently underway will permit a more confident evaluation of the condition of this dam along the continuum and selection of appropriate remediation to reduce the risks and consequences of failure to tolerable values.

7.0 Failure Modes

7.1 Failure Modes of Primary Concern

The Panel considers the following failure modes to be of primary concern. The order of the failure modes does not necessarily represent a priority ranking. Such a ranking will be possible following the completion of a risk analysis.

1. Inadequate spillway leading to possible overtopping during extreme hydrologic conditions
2. Deformation of the Auxiliary Dam during a moderate or greater seismic event leading to loss of pool
3. Distress to the Auxiliary Dam conduit/tower during a moderate or greater seismic event leading to loss of pool
4. Faulting offsets in the foundation/embankment of the Auxiliary Dam leading to loss of pool
5. Piping along the outlet conduit that may lead to loss of pool, particularly at high pools

7.2 SPRA Failure Modes

Screening Portfolio Risk Assessment (SPRA) is an internal tool developed by USACE to perform initial risk characterization of the USACE dam inventory, and identify the highest risk projects for risk management decision making. SPRA failure modes are given four designations: Inadequate (I) Probably Inadequate (PI), Probably Adequate (PA) and Adequate (A) for three loading conditions, Extreme, Unusual and Normal.

The Panel finds that the project was properly characterized and that all failure modes had been appropriately identified in the SPRA completed by the Corps. At the time this screening was done, the Kern Canyon Fault was considered inactive. As such, a failure mode due to the fault rupture and offset near the right abutment of the Auxiliary Dam was not considered. This failure mode should now be incorporated in the list of failure modes.

The Panel generally concurs with the SPRA designations. A brief discussion is provided for those failure modes which the Panel has slightly different designations.

7.2.1 Failure Mode: Embankment – Foundation, Seepage and Piping

The Panel finds that the designation of inadequate for this failure mode, with respect to the conduit underneath the Auxiliary Dam for all load conditions, to be appropriate. However, for the foundation and embankment proper, no evidence was provided that suggests that piping is occurring or will occur under any load condition. It is recognized, however, that the maximum pool elevation was 2611 which corresponds to an estimated recurrence of approximately 120 years. Seepage conditions, therefore, for events with greater than a 120 year recurrence interval have not been observed. However, renovations must take them into account after evaluation of the probability and consequences of failure at various pool levels.

Projects with similar designs such as the Auxiliary Dam, founded on alluvial materials, perform adequately under full reservoir load. This type of design is not unusual for flood control projects and typically requires that seepage be controlled at the downstream toe.

7.2.2 Failure Mode: Embankment Stability and/or Liquefaction

Both the main and auxiliary dams are rolled earth fill. Exclusive of foundation conditions, this type of construction precludes massive instability - hence, the Panel's designation of "adequate" for this failure mode. Results of the current seismicity investigation will provide input to stability analysis. This will allow for an estimate of embankment stability and corresponding potential deformation following a seismic event in conjunction with an evaluation of density/shear strength of the foundation materials.

Based on results of the SPT and CPT of Auxiliary Dam's foundation, it is highly probable that the degree of deformation of the embankment/foundation will be unacceptable given a new evaluation of site seismicity.

7.2.3 Failure Mode: Outlet Works and Conduits – Intake/Tunnel/Conduit Structural Failure

A designation of "Inadequate" is appropriate for this failure mode given that the maximum design earthquake will probably be in excess of 1 g, since the determination that the Kern Canyon Fault is active.

7.2.4 Failure Mode: Outlet Works and Conduits – Tunnel/Conduit Joint Failure

A designation of "Inadequate" is appropriate for this failure mode given the current condition of the auxiliary dam outlet conduit and the probability of piping.

7.2.5 Embankment Seepage and Piping

The Panel considers this mode of failure to be designated as "Probably Adequate", based on the following reasons. The Panel was not presented any evidence that seepage and piping are occurring through the embankments proper. However, this conclusion is reached because the reservoir is usually not filled. Therefore, the possibility of seepage and piping and sustained periods of high pool elevations cannot be ruled out.

8.0 Risk Reduction Measures

8.1 Immediate Risk Reduction Measures

The pool was restricted on April 27, 2006 to Elevation 2585.5 to reduce the risk due to seepage and the potential for a piping failure along the outlet conduit. This restricted elevation was determined by the Corps to result in a target safety factor of 2.5 against exit seepage gradients at the toe. The Corps indicated that this restriction reduces the reservoir capacity by 36 percent and that this restricted elevation was exceeded, on average, only 40 percent of the years and 13 percent of the time that the reservoir has been operated.

In addition to the pool restriction, the project receives daily inspection and close surveillance and monitoring of the instrumentation. The Corps has aggressively instituted short-term risk reductions, as discussed next.

The panel concurs with the immediate risk reduction measures that the Corps has initiated.

8.2 Short Term Risk Reduction Measures

In addition to restricting the pool, the following risk reduction measures either have or will be taken in the short term:

- Installation of additional piezometers
- Dewatering of the conduit to allow inspection
- Investigation of conditions along the outside of the conduit
- Updating downstream inundation mapping
- Risk analyses to determine inundation at varying pool levels
- Analysis of the hydraulic performance of the outlet
- Foundation investigations and stability analyses of both dams
- Geophysical testing of the Auxiliary Dam's foundation in vicinity of the intersection of the KCF fault
- Additional fault studies
- An emergency exercise (tabletop)

The restricted level provides slightly less than 50 feet of freeboard. This significantly reduces the risk against loss of pool due to a seismic event causing a slumping of the Auxiliary Dam and/or as a result of transverse cracking. It also reduces, somewhat, the risk against loss of pool by way of a seismically induced structural failure of the conduit/tower. Although this risk is material, the Panel finds this risk acceptable in the short term considering the low slip rate of KCF in concert with the Corps aggressively pursuing long term risk reduction measures.

The Panel concurs with the foregoing short-term risk reduction measures and recommends that flood routing studies be undertaken to assess the impact of the restricted level on downstream risk and flood control. The findings of these studies should be integrated with the results of the current evaluations to determine the appropriateness of the restricted pool elevation. This effort is critical because long term risk reduction measures may not be undertaken for 10 years due to the anticipated magnitude of the rehabilitation effort.

8.3 Long Term Risk Reduction Measures for the Auxiliary Dam

The Corps indicated, during the Panel's site visit that it intends to evaluate all aspects of the project in its assessment of long term risk reduction measures. The Panel strongly concurs with this approach.

The Panel encourages the Corps to position itself and scope its current studies and evaluations in anticipation of an Alternative Analysis which considers replacing the Auxiliary Dam in its entirety. To that end, the Corps has advertised an Indefinite Date Indefinite Quantity (IDIQ) proposal for services which will include the development of an Alternatives Analysis for the project.

The Alternative Analysis may conclude that other options, other than entirely replacing the dam, are viable and appropriate. However, the Panel finds that the number and severity of the deficiencies of the Auxiliary Dam will probably require a major rehabilitation effort if not outright replacement. These deficiencies are:

1. An active fault passing through the right abutment contact
2. A drain blanket that is not functioning properly
3. An approximately 20-foot-thick loose alluvium layer over the entire footprint which is likely susceptible to significant strength loss during seismic loading
4. Excessive seepage
5. An outlet conduit along which piping may be progressing
6. An outlet conduit which will likely fail during an earthquake or during a very high pool event potentially resulting in loss of pool
7. An outlet conduit that is not properly performing (hydraulically) as designed
8. An anticipated poor seismic soil structure interaction between the embankment and the tower, especially at the tower/conduit connection which constitutes another potential for loss of pool

One critical component of the project is the spillway in the Main Dam. The Panel understands that its adequacy is being investigated. In the briefing provided to the Panel, it was noted that the definition of safely passing a storm is that the design freeboard, which is 6.5 feet for this project, not be encroached. Given this criterion, it was determined that the existing spillway could pass 33 percent of the PMF.

The Panel finds this criterion to be too conservative. It is the Panel's experience that spillway adequacy is more appropriately determined by the elevation at which embankment overtopping occurs or, if a nominal amount of residual freeboard (1 to 1.5 feet) is encroached. The Panel therefore, recommends that an evaluation of spillway adequacy consider the appropriateness of this criterion.

9.0 Service Life and Timeframe for Actions

9.1 Service Life without intervening actions

The Panel finds that the service life of the project, without intervening actions such as reservoir restrictions, has ended. Short and long term intervening actions will provide an adequate margin of safety to enable finishing current investigations and studies.

9.2 Recommended Timeframe to Implement Actions

The District plans to continue investigations. The investigations are properly focused on the critical elements, i.e. seismic, hydrologic, seepage, and stability. It is imperative that these investigations be authorized and funded and that the investigations are not hindered by inadequate funding.

9.3 Distress Indicators/Triggering Events

The District is conducting daily inspections and has added additional piezometers to monitor seepage conditions. This monitoring and surveillance will allow for emergency action if the following events are observed:

- Significant increase in seepage at the toe
- Sand boils associated with strong flow and movement of soil particles
- Sinkholes in the dam proper

10.0 Questions for External Peer Review Panel

10.1 What are some of the remediation options?

Remediation options can be better identified once the planned investigations are completed. Once competed, the most appropriate and viable remediation option can be determined through an Alternative Analysis which incorporates a formal risk analysis and integrates a cost analysis based on "best value" over a 25 – 50 year time frame.

Absent findings of the current investigations as well as an Alternative Analysis, the Panel anticipates that possible options may consist of one or more, or a combination of the following:

- Partial or total replacement of the Auxiliary Dam including construction of a modern chimney and blanket filter/drainage system capable of withstanding potential fault offsets under the dam
- Buttressing of Auxiliary Dam's slopes
- In situ treatment or removal of the alluvium in the foundations of the main and auxiliary dams
- Increasing the spillway capacity, construction of a new auxiliary emergency spillway, raising the crest of the existing dams, or some combination of the above to remove the hydrologic deficiency
- Armoring the spillway channel
- Removal, replacement, or rehabilitation of the conduit/tower under and in the Auxiliary Dam
- Permanently restricting the pool elevation
- Retrofit or replacement of the outlet towers to ensure their seismic performance
- Abandonment and removal of the Borel conduit/tower

10.2 Is a cutoff wall feasible?

A cutoff wall through the foundation of the Auxiliary Dam into the granitic bedrock is feasible. The foundation underneath the conduit can be treated by jet grouting. Such grouting will reduce seepage and may be considered in combination with other remedial actions. A cutoff wall as a single remediation option does not address the anticipated poor seismic performance of the upper 20 feet of the foundation as well as the conduit.

10.3 Should the Auxiliary Dam be replaced?

The Panel has indicated previously in this report that it anticipates that complete replacement of Auxiliary Dam will rank high among the preferred options. The alluvium in the foundation will most likely be the controlling factor with the second factor being the conduit/tower. Remediation of these conditions, indirectly by in situ treatment of the alluvium and structurally reinforcing the conduit/tower, will probably not result in a level of safety commensurate with the risk.

Buttressing the slopes, to increase seismic performance of the Auxiliary Dam, may be feasible and more cost effective than the replacement option. However, the conduit/tower would still have to be addressed. Additionally, serious consideration will have to be given to treatment of KCF intersection of the right abutment.

10.4 Is the pool restriction appropriate?

The Panel considers the level of current pool restriction to be an appropriate immediate risk reduction measure. The Panel further recommends that this level be re-evaluated once the outcome of currently on-going studies in concert with downstream inundation studies, are completed.

11.0 Summary and Recommendations

11.1 Summary

The Panel concurs with the Corps' designation of Isabella Dam as being in the DSAC Class I list of dams. The primary reason for the Panel's concurrence with this designation is the anticipated poor performance of the Auxiliary Dam during earthquake loading. This performance is anticipated because of the poor foundation conditions, which exist over the entire foot print of the dam, in concert with the poor performance of the outlet conduit.

The Panel has listed and discussed the problematical nature of the outlet conduit. The Corps' has initiated studies to ascertain whether piping is occurring along the conduit or along the contact between the compacted fill and native alluvium. At the time of the Panel's site visit in April 2007, data were being gathered in support of these studies.

The Panel concurs with the immediate risk reduction of restricting the pool to Elevation 2585. The Panel understands that the Corps is undertaking studies to define the downstream consequences, which, in conjunction with the on-going studies, will allow a re-assessment of the appropriateness of the restricted pool elevation as an immediate risk reduction measure. The Panel notes that such restriction may be required for a 10-year period of time – the time required to complete long term risk reduction measures. The ongoing studies may allow a higher pool or require a lower restricted pool.

11.2 Major Recommendations

The Panel's major recommendations are summarized as follows:

- Immediate Risk Reduction Measures

  Maintain the current pool restriction of Elevation 2585, which is 20 feet below the normal pool elevation. Exceeding this reservoir elevation during significant hydrologic events is acceptable provided that every effort is made to lower the pool to the restricted level.

- Short Term Risk Reduction Measures

  Evaluate the appropriateness of restricting the pool to Elevation 2585.5 by considering downstream consequences and by incorporating findings of on-going studies.

  Hydrologic conditions permitting, conduct a test filling to observe responses of recently installed piezometers.

Evaluate instrumentation and exploration needed for the Main and Auxiliary dams for the purpose of long term monitoring and maintenance of the dam. Install devices across the fault to monitor its movement continually.

Assess the characteristics of the thin deposit of alluvium left in place under the downstream shell determine its effect on the seismic stability of the Main Dam.

Update the Emergency Action Plan.

Conduct emergency exercises and coordinate with local officials and stakeholders.

- Long Term Risk Reduction Measures

  Complete on-going investigations and studies, and initiate an Alternatives Analysis with a primary focus on a major rehabilitation of the Auxiliary Dam.

  Evaluate the overall earthquake performance of the Main Dam.

11.3 Tactical Recommendations

In addition to the foregoing major recommendations, the Panel's more tactical recommendations are as follows:

- Assess the criticality of the alluvium on the overall performance of the Main Dam by conducting slope stability analyses. By assigning reasonably conservative shear strength parameters, it is possible that the analyses will show adequate overall earthquake performance. If analyses show otherwise, the Panel recommends a field investigation to measure the shear strength characteristics of the alluvium. If investigations proceed, all holes for cross-hole shear wave testing should be performed with conventional drilling methods and sonic drilling should be avoided to minimize concerns of how this drilling might impact loose soils of concern. Use of sonic drilling in advance to locate materials that should be sampled would be advisable.
- Complete the inundation mapping which is integral to a risk assessment. Consider sensitivity analysis around key parameters and for various failure modes. Assess the spillway adequacy in concert with an evaluation of the available freeboard criteria for the Probable Maximum Flood. Options for PMF may include lowering or modification of existing emergency spillway or outlet work to provide additional capacity. Tainter gates or a new flood control outlet may be appropriate.
- Complete the failure modes/risk assessment to help guide the development of investigation and instrumentation requirements. The historic pool elevations should not necessarily be assumed as an indicator of future conditions.
- Evaluate outlet works to verify ability to perform following an earthquake including the mechanical and hydraulic systems that operate the gates.

- Conduct further research of the blanket drain materials and construction to help in a failure mode analysis
- Evaluate the potential for cracking of main dam and determine the need for filters as a mitigating defensive measure
- Provide adequate storage and care of soil samples being taken to prevent drying of samples and store for easy access
- Attempt to get better descriptions of seepage and settlement of the auxiliary dam on first filling and measure the quantity of silt in outflow regularly
- Evaluate progression of the seepage front in the Auxiliary Dam. To do this, develop instrumentation in a minimum of two cross sections in the main and auxiliary dams to evaluate piezometric surface and seepage in the embankment materials. This would be in addition to the evaluation of seepage in the foundation.
- Establish settlement monuments on 25 versus 100 foot centers
- Confirm the need to fix the crest elevation problems on the left end of the auxiliary dam. This remediation should be done right away. An overtopping failure would start there and is inexpensive to do the work.

APPENDIX A

List of References

Appendix A

References:

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APPENDIX B

Seepage Failure Mode Continuum

Appendix B

Figure 6:
Seepage Failure
Mode Continuum