Lake Oroville Spillways Emergency Recovery

Board of Consultants Memorandum No. 12 – September 22, 2017

Prepared by the Department of Water Resources

Summary & Response

Question 1

Question 1 relates to the construction schedule similar to the Board of Consultant's (BOC) questions relating to this subject and as outlined in the previous BOC meeting No. 11. As expected the Roller Compacted Concrete (RCC) production rate is higher. The BOC notes and compliments DWR's design team and the Contractor as they continue to identify and evaluate critical path issues then resolve those issues by ensuring the appropriate level of resources are procured.

The leveling concrete is placed on the foundation to level out the surface as preparation for the structural concrete. The structural concrete includes concrete and reinforcing steel and is what is placed on top of the leveling concrete. The BOC notes that placement of the final leveling concrete is nearing completion.

The secant wall is being placed under the ground downstream of the emergency spillway. The purpose of the wall is to prevent head-cutting of foundation rock towards the emergency spillway, thus protecting the emergency spillway if water were ever to flow over the emergency spillway again. The BOC endorses the modifications that DWR has made to the criteria that defines how deep the wall needs to be placed.

Question 2

Question 2 relates to Geologic mapping, the RCC borrow source, groundwater monitoring, piezometer installations and the emergency spillway weir foundation. Geologic mapping refers to information the geologists gather and document which defines and describes the foundation rock and other information related to the geology around the site. This information is for the record and also used to design the spillways.

The borrow site refers to the location where material is borrowed from to make the RCC. This material is rock material that is crushed than mixed with cement and cement to make the RCC. Additional rock material is needed for the RCC and therefore sites are being investigated to determine the appropriate borrow source.

The groundwater monitoring refers to the studies that are being conducted by DWR to understand how water flows through the ground in the vicinity of the main and emergency spillways. This information is useful to fully understand any possible affect groundwater could have on the spillways in the future.

The piezometer installations is also related to the groundwater monitoring and is the instrument that is used to help understand the water pressures under the ground. This information is used to help understand any potential affects groundwater could have on the future spillways.

The emergency spillway weir foundation discussion refers to the foundation rock that is beneath the concrete weir.

Question 3

Question 3 relates to the physical model studies being conducted in the laboratory. A 1:50 scale model is used to help engineers predict the behavior how water will flow over the new spillway. Most of the discussion relates to aeration of the water. Air is introduced into the water to help mitigate for the possibility of cavitation on the new spillway. The studies are being conducted to determine if the design needs to consider this issue.

Question 4

Question 4 relates to information that was provided by the forensic team to the BOC. The BOC is reviewing the findings of the forensic team to ensure these findings are considered as part of the new design.

Question 5

Self-Explanatory

Question 6

Since RCC is not usually as strong as structural concrete, tests are being performed to ensure any water flowing over the spillway this coming year will not damage the RCC. A test section includes constructing a very large section of the RCC. This test section is used by the engineers to investigate the potential of damage to the RCC under flowing water conditions. The BOC visited the test section and provides comments on the expected performance of the RCC. This test section is not in the same area of the new spillway and is only used for testing.

The BOC is also commenting on tests that could be performed later to monitor the drains that are under the spillway.

The BOC's recommendation regarding detailed inspections of the upper chute is self-explanatory.

OROVILLE EMERGENCY RECOVERY – SPILLWAYS
Board of Consultants Memorandum

DATE: September 22, 2017

TO: Mr. Ted Craddock, Project Manager
Oroville Emergency Recovery – Spillways
California Department of Water Resources

FROM: Independent Board of Consultants for
Oroville Emergency Recovery – Spillways

SUBJECT: Memorandum No. 12

INTRODUCTION

On Thursday September 21, 2017, the Independent Board of Consultants (BOC) met at the Department of Water Resources (DWR) Oroville Field Division Office Main Conference Room at 8:00 am for a brief progress report followed by a tour of the dam site to observe construction progress. The following construction features were observed:

- cleaning of the remaining area of exposed FCO Spillway chute rock foundation (excluding the remaining RCC foundation);
- upstream spillway chute transition from the old spillway to the new spillway near Station 20+30;
- RCC and structural concrete placement within the FCO Spillway;
- construction of the FCO Spillway slabs,
- construction of the temporary FCO Spillway RCC gravity training walls including the shotcrete treatment for the inside face of the RCC walls;
- erection of the steel reinforcement and forms for segments of the permanent FCO Spillway training walls;
- drilling and construction for the Emergency Spillway secant pile cutoff wall; and
- exposed rock foundation for the Emergency Spillway weir section located on the right side of the Emergency Spillway.

Representatives from DWR Engineering Division, the Division of Safety of Dams (DSOD), the Federal Energy Regulatory Commission (FERC), and industry consultants working on the Oroville Spillway Recovery project participated in the tour of the site.

Following the tour of the site, a meeting was convened at the DWR Oroville Field Division Office Main Conference Room beginning at 12:30 pm. Representatives from DWR Engineering Division, DSOD, FERC, and industry consultants working on the Oroville Spillway Recovery project participated in the meeting.

Presentations were made by DWR and their consultants on design and construction progress related to the following:

- FCO Spillway foundation preparation;
- placement of leveling and structural concrete within the FCO Spillway;
- RCC construction;
- Emergency Spillway weir; and
- Emergency Spillway secant pile cutoff wall.

The BOC was then updated on the progress of the hydraulic numerical modeling for both the FCO Spillway and the Emergency Spillway.

On the morning of Friday, September 22, the BOC met at the DWR Oroville Field Division Office Main Conference Room at 8:00 am for presentations by the Design Team on:

- site geology investigations and FCO Chute exploration;
- condition of the Emergency Spillway monoliths and foundation;
- site groundwater analysis;
- RCC aggregate borrow source investigations; and
- Independent Forensic Team Report.

Descriptions and comments made on the individual presentations are contained in the section that follows.

The BOC then met to deliberate and prepare their report. A reading of the BOC's draft report was made to representatives from DWR Engineering Division, DSOD, FERC, and industry consultants working on the Oroville Spillway at 3:00 pm. The meeting was adjourned at 3:30 pm.

BOC members present were Eric Kollgaard, John Egbert, Kerry Cato, Faiz Makdisi and Paul Schweiger.

QUESTIONS FOR THE BOC

1. Does the BOC have any recommendations or comments on the construction progress?

Response

1. The Contractor and the Design Team continue to aggressively monitor the construction progress and critical path work items. The Contractor and the Design Team performed an assessment of the existing concrete and RCC plants along with other essential construction equipment to identify potential replacement parts and backup equipment that may be needed to avoid delays during the final stages of the FCO spillway construction leading up to the November 1, 2017 deadline. As a result of this assessment, the Contractor has procured a backup crane, generator, secant pile drill rig and other equipment and parts.

   The Contractor has demonstrated that RCC placement production has increased as the placement area increased beyond the narrow rock crevasses, and has recently achieved RCC placement rates exceeding 5,000 cubic yards per day, resulting in the RCC placement being ahead of schedule. This is favorable given the additional quantity of RCC recently determined to be needed (~30,000 cubic yards) in the foundation of the FCO spillway. The Contractor has also increased the number of onsite workers and currently has approximately 112 full-time staff and 576 craftsmen onsite.

   The increase in the quantity of the Leveling Concrete has impacted the schedule for the Structural Concrete (Slabs and Walls). Now that the Leveling Concrete is complete, the Structural Concrete can progress unrestrained as the production from the batch plant can be dedicated solely to the Structural Concrete on both shifts. The production rate for construction of the Structural Slabs should increase as less formwork is required due to the checkerboard placement pattern of the slabs. The production rate of the Structural Wall should also increase. The number of forms has more than doubled. In addition, and as a result of initially placing every other wall section, the fill in concrete placements will not require the time-consuming bulkhead formwork. The BOC recommends careful and continuous monitoring of the progress of these critical construction items.

   The BOC compliments the Design Team and the Contractor for assessing critical path work items and pro-actively developing contingency plans to

minimize down time due to anticipated plant and equipment maintenance requirements. The BOC continues to be impressed with the organization, planning and execution of the construction work.

2. The cleaning of the FCO Spillway chute foundation areas for leveling concrete, and the placement of leveling concrete, are nearing completion. The last foundation area to receive leveling concrete under the structural slab was being cleaned at the time of the BOC site tour. The steep slope of the arena cut awaits final cleanup in advance of placement of the lifts of RCC. All of the foundation preparation work exceeded the BOC's expectations. The foundation preparation for the new FCO spillway is of the highest quality and is an important accomplishment for the success of the project.

3. RCC aggregate production which has been an ongoing concern due to higher than anticipated waste material, appears to have been resolved by mobilizing a second aggregate manufacturing plant. The aggregate production rate has increased and the total aggregate production is close to being on schedule.

4. The concerns with the low production rates for the secant pile cutoff wall installation have been addressed by mobilizing additional drill rigs. The more favorable than anticipated bedrock conditions encountered within the foundation of the secant pile cutoff wall may allow reducing the required depth of the wall at some locations. The Design Team presented modifications to the criteria for establishing the minimum depth of the piles for all panels outside of the main drainage channel (i.e. excluding Panels 95 to 118). The revised criteria will be applied to each pile to determine their as-built final depths by satisfying the following three conditions:

   (1) pile depth below original ground is 35 feet or more;

   (2) embedment of the pile is at least 15 feet into slightly weathered or fresh rock; and

   (3) a percussion rate of advancement using BG-50 drill rig is less than an average of 3 feet over a 12-hour shift.

The BOC endorses the Design Team's modifications to the secant pile cutoff wall and believes recognizing the favorable bedrock conditions is appropriate and will improve the rate of production of pile installation while satisfying the design intent.

2. Does the BOC have any recommendations or comments on the geologic conditions?

Response

1. **Geologic Mapping**. The BOC was given an update on the geologic mapping that has, for the most part, been completed in the field and is presently being compiled into As-Built completion reports. Most site mapping has been conducted at 1-inch = 5-feet scale (as compared to the original 1960's construction scale of 1-inch = 20 feet). In addition, all mapping data has been compiled onto photographs obtained through the use of Unmanned-Aerial-Vehicles (UAV or the vernacular "drones"). The detail shown on the maps and in the aerial photography is the most detailed that we are aware of on a project of this scale. Some of the derivative products that are in progress include an attempt to classify shears by their prominence and through-going nature in regards to their effect on rock quality and weathering across the site. The BOC commends the site personnel for their attention to quality and detail, and also to DWR for raising the bar in regards to project documentation.

2. **New RCC Borrow Source Area**: The BOC was informed that due to the planned RCC volumes increasing from 452,100 cubic yards to 860,000 cubic yards (an approximate 90% increase) the existing rock borrow will not be sufficient to meet the increased RCC aggregate demands. After an analysis of new offsite and onsite borrow areas, it appears the preferred borrow area will most likely be developed onsite, to the left of the FCO spillway (Station 29+00 to 36+00). This site has environmental and logistical advantages because this borrow area is located in the area of existing construction and is located near the rock crushing plant. Initial subsurface investigations show that the rock materials are of good quality and will have minimal waste. A preliminary kinematic analysis of planned quarry walls shows that several different types of slope instabilities will need to be monitored.

   The existing rock crushing plant is located several hundred feet downslope from this proposed rock borrow quarry. The slope below the rock crushing plant is currently instrumented with slope inclinometers and they show that some downslope movement has occurred. The rock crushing plant is a critical facility in terms of being able to maintain the construction schedule. Not allowing excessive RCC aggregate stockpile placement on this slope should be an operational requirement so as not to induce new slope movements. For example, when the RCC aggregate stockpiles are sufficient

to meet FCO RCC placement requirements, the additional RCC aggregate could be stockpiled downstream of the Emergency Spillway near the proposed location of the relocated RCC plant. Monitoring the slope stability below and around the rock crushing plant should be continued with the existing slope inclinometers. Consideration should also be given to the suggestion provided in the presentation by the Design Team to monitor both the proposed quarry slopes and the rock crushing plant slopes with a slope monitoring system such as the use of a ground-based LIDAR system.

3. **Groundwater Monitoring:** The BOC was given an update on the site groundwater conditions in the FCO and Emergency Spillway areas. A map of the vibrating wire and open pipe piezometers that were installed in 2017 was presented. Results from these instruments were discussed in a presentation that included graphs of results from individual instruments as well as a site groundwater surface contour map. One reason these observations were made is to address the issue of impact of groundwater flow on either spillway. These results indicate that while some groundwater can be stored in the bedrock, there does not appear to be rapid groundwater flow connectivity along shears or other discontinuities. The overall groundwater flow regime appears, as one might expect, to mimic the surface topography and to be moving downslope toward the Feather River.

   The BOC encourages the ongoing groundwater monitoring through the use and maintenance of these instruments, especially as the wet season approaches. It will be important to compare these initial "dry period" data readings with those in the future that will be recorded when the reservoir is at a higher stage or when the FCO chute experiences flows.

4. **Piezometer Installations.** The Design Team presented a plan showing the locations of piezometers installed at the FCO spillway and in the vicinity of the Emergency Spillway monoliths and secant pile cut-off wall. The purpose of this instrumentation is to provide a baseline for assessing the ground water conditions as the repair project is being completed. Piezometers installed beneath of the FCO chute slab will provide evidence of the effectiveness of the water stops and drainage system in preventing buildup of uplift pressures under the FCO slab during spill conditions. Piezometers installed upstream and downstream of the cutoff wall will provide evidence of the effectiveness of the drainage openings between the cutoff wall panels in lowering the ground water levels upstream of the secant pile cutoff wall.

5. **Emergency Spillway Weir Foundation:** During the September 21 field visit, the BOC viewed the foundation excavation for the Emergency Spillway Weir. The original design specified that the subsurface portion be embedded 14 feet into the ground and founded on slightly weathered or fresh rock. The contractor's initial excavation method used a trenching machine that was unable to penetrate the bedrock. Subsequently, an excavator with a hoe ram attachment was used to perform the foundation excavation. This resulted in a wider than planned foundation (approximately 6 to 7 feet wide instead of 2 feet), but this method was also unable to penetrate to the full 14-foot depth (measured from the top of the weir) with the current depth approximately 6 feet below the natural ground surface. The rock exposed in the foundation bottom is predominately slightly weathered to fresh rock. It should be noted that the current "ground surface" is itself an excavated surface that was created during the original 1960's construction by excavating from 5 to 40 vertical feet of amphibolite rock, and re-contouring a hill to create the approach for this part of the emergency spillway (see Figure 1). The BOC believes that the bedrock currently exposed in this foundation is of sufficient strength and quality to serve as an adequate foundation for the weir, and that requiring the contractor to continue deepening this exaction would not be meaningful.

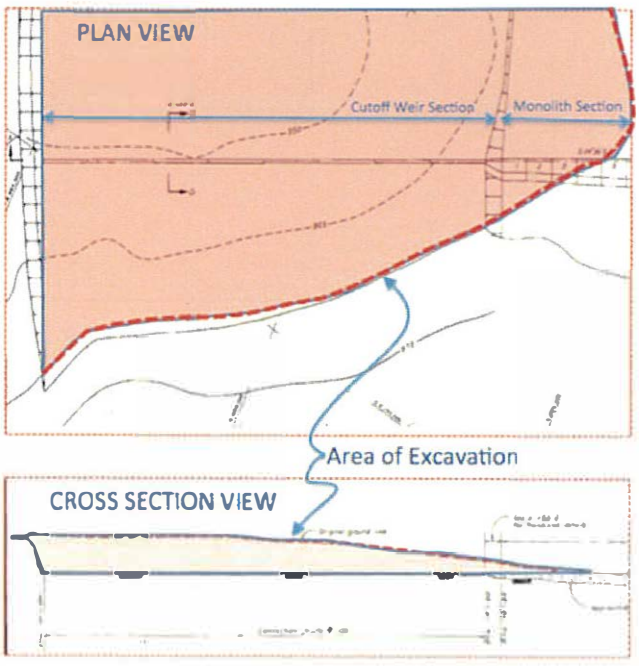

Figure 1. Plan and Section showing the original 1960's Emergency Spillway Excavation

3. Does the BOC have any recommendations or comments on the hydraulic modeling?

Response

1. On September 19, 2017, Eric Kollgaard, John Egbert and Paul Schweiger of the BOC and Marc Fortner and Tom Molls of the Design Team visited the Utah State University's Water Research Laboratory to observe the operation of the physical model of the FCO Spillway. The model study is being conducted under the direction of Dr. Michael Johnson. During the visit, Dr. Johnson and his assistants operated the model for full-scale flows representing various flows up to the maximum designed capacity of the spillway. The first runs of the model were made simulating an aerated 30-inch vertical step at Station 28+20. Then similar runs were made with the model configured for a larger air slot further downstream of the chute. The following observations were made by the BOC members who observed the model:

    a. Although the physical model provides valuable information on the flow characteristics within the FCO spillway, it does not appear to accurately replicate the actual behavior of aeration due to differences in scale and similitude for the behavior of air. It is noted that the flow velocities in the physical model are approximately one seventh of those in the actual spillway. Self-aeration and aeration from the 30-inch vertical step and air-slot further downstream are therefore approximate and appear to underestimate the actual aeration that occurs in the spillway. Self-aeration is clearly not replicated by the model.

    b. Air is definitely drawn into the underside of the flow at both the 30-inch step and the aerator further downstream. How long the air remains near the bottom boundary layer is uncertain. The observed air bubbles in the flow appeared to rise to the surface relatively quickly in the physical model, and none could be seen a short distance downstream of the air slot.

    c. The 30–inch step appears to function well at flows up to 150,000 cfs. However, at a maximum flow of 270,000 cfs, backflow from the point of jet impact was observed to partially fill the void area downstream of the

step. It appeared that air flow was intermittently blocked from a portion of the under nappe surface. The larger 9-foot air slot, placed at approximate Station [redacted], was not similarly affected at the maximum flow. If aeration is to be built into the final chute, it would appear that the step should be greater than 30-inches unless it can be demonstrated that adequate air supply is being provided.

d. The model configuration with the simulated 9-foot slot has a small ramp built into the chute slope just at the start of the step. This appeared to provide greater turbulence to the flow surface downstream of the impact point of the jet, and appeared to provide a greater mixing of air with the water. The flow downstream of the jet impact without this ramp appeared to remain laminar in appearance.

e. The physical model does not provide evidence that a single air supply slot near Station [redacted] would effectively aerate the flow to the end of the chute where the velocity of the flow is greatest, and where the beneficial effect of air entrainment is most needed.

f. It appears that final design of the air slot or slots, if aeration is decided to be built into the permanent chute surface, should be based on 3D Computational Fluid Dynamics (CFD) analytical modeling with less reliance on physical modeling using the current 1 to 50 scale model.

g. The 30-inch step to the RCC surface design should be provided for the interim period of the 2017-2018 flood season. If no FCO Spillway discharges for flood protection reasons have to be made, the BOC would advocate a test operation at 50,000 cfs and 100,000 cfs for a short period of time to verify the full-scale behavior of the flow in the spillway with the 30-inch step. Drone imagery may be able to detect any effect to flow of the aeration from the appearance of the surface.

h. The BOC is not convinced that additional aeration features are essential for the permanent FCO Spillway chute configuration. The BOC believes additional aeration may give added confidence that the chute will not be damaged due to cavitation by flows approaching the maximum discharge, if these are ever necessary. The BOC is concerned that the provision for additional aeration could result in excessive bulking of the flows and result in splash over the training

walls. The design and construction of aeration provisions also presents added complication to the Contractor's construction schedule for 2018.

i. The design of the air slot should probably have a small ramp at the takeoff point. The sloped chute surface and the landing area of the jet impact point should be made to have as small an impact angle as possible. Changes in slope from the run out surface to the 25 percent chute slope should have a curved transition.

j. There was some discussion at the model laboratory of whether it might be possible to obtain water samples from various depths within a cross-section of actual flow to measure the air content. This does not appear to be practicable.

k. Other points noted from the physical model performance include:

- [redacted]
- Similarly, no [redacted] should be designed in the spillway training walls [redacted]
- The outflows from the energy dissipater at the downstream end of the FCO Spillway chute shows that erosion of the opposite river bank could occur at high discharges approaching 270,000 cfs. The confluence of the spillway flows into the river channel is nearly perpendicular and produces upstream currents toward the dam. Although the dam appears to be far enough upstream to not be affected by these currents, the significance of these upstream flows on the dam should be evaluated using a 2D or CFD model. It would be of interest to the BOC to learn whether any problems from flow near the toe of the dam or the tailrace were experienced during prior high flow releases of the FCO spillway.
- It is expected that the access road on the near river side below the FCO Spillway energy dissipater will be removed before operation of the spillway for the 2017-2018 season. A portion of the jet from the energy dissipater was seen to impact the location of this lower access road.

4. Does the BOC have any recommendations or comments on the Forensic Report?

Response

1. The BOC appreciates the work of the Independent Forensic Team (IFT) and the important information provided in both of their publications; (1) the May 5th, 2017 memorandum presenting their preliminary findings concerning candidate physical factors potentially contributing to damage of the service and emergency spillways, and (2) the September 5th, 2017 Interim Status Memorandum. An assessment of the IFT's September 5th Memorandum has been documented in a Design Team Technical Memorandum (SRT-SPW-DOC-08_REV2) that detailed the measures taken in the current design to mitigate the physical factors identified by the IFT as likely contributors to the failure. The BOC reviewed the design and construction factors that the IFT believes likely caused the FCO Spillway chute failure and the Emergency Spillway erosion, and believes that these factors have been satisfactorily addressed by the Design Team in their current designs for both spillways.

5. Does the BOC have any recommendations or comments from the site tour?

Response

1. During the site tour, the BOC observed the following:
    a. cleaning of bedrock foundations,
    b. placement of leveling concrete,
    c. placement of RCC,
    d. placement of drain material and drain pipes,
    e. erection of steel reinforcement for spillway walls and slabs,
    f. placement of conventional concrete for walls and slabs,
    g. installation of the shotcrete lining on RCC gravity walls,
    h. construction of the secant pile cutoff wall, and
    i. relocation of the electrical power lines.

The aforementioned work observed by the BOC appeared to be in conformance with the specifications and of high quality.

6. Does the BOC have any other recommendations or comments?

Response

1. The hydro testing performed on the sloped enriched RCC test section showed that the enriched RCC provides a very durable surface and that the application of a surface hardener to improve the durability of the surface did

not demonstrate any noticeable improvement, and in the BOC's judgement may not be needed. Based on the favorable results of the hydro testing, the BOC agrees with the decision to not treat the entire surface of the RCC with a surface hardener. Instead the local area of impact of the jet at the aeration slot is proposed to be treated with the spray on surface hardener. The BOC recommends treating a limited area of the RCC surface as proposed by the Design Team.

2. The BOC noted during their tour of the FCO Spillway chute that the downstream end of the existing chute slab at Station 20+30 where the connection to the new constructed slabs will be made, has a number of areas of spalled or broken concrete on the top edge. These must be repaired by the best method of concrete patching. Photos showing the spalls along the downstream end of the existing chute slab are provided in Figure 2.

3. The BOC previously recommended that measurement of flow from individual chute under-drains be included in the surveillance and monitoring plan. The usual means to best measure small amounts of flow from individual drains is by timing the flow captured in a bucket. The configuration of the drain outflow pipes exiting high on the spillway training walls may not allow the drain flow to be easily measured using this technique as the drain pipe outlets are flush with the wall and beyond easy manual reach. Assuming the 12-inch diameter drain flow pipes have a 2 percent slope and a Manning's "n" of 0.010, a drain flow depth of 0.5 and 1.0 inches would correspond to outflows of approximately 4.5 and 27 gpm, respectively. The drains in the new chute will likely flow less than 1/2-inch depth. An accurate method of measuring the expected relatively low drain flows should be established. One approach that could be considered is to lower the backfill height behind the spillway training walls to expose the downstream end of the drain pipes and tap the pipes to allow the flow to be measured.

4. The BOC recommends that the Design Team and the Contractor perform a thorough and detailed inspection of the existing upper chute slab of the FCO Spillway that will remain in place during the 2018 flood season. The inspection should focus on any cracks, spalls, and previous repairs, to ensure that the entire surface is adequately and robustly sealed to prevent infiltration of water into the slab foundation. A detailed inspection of the existing drain system should also be performed to confirm that it will serve its intended function.

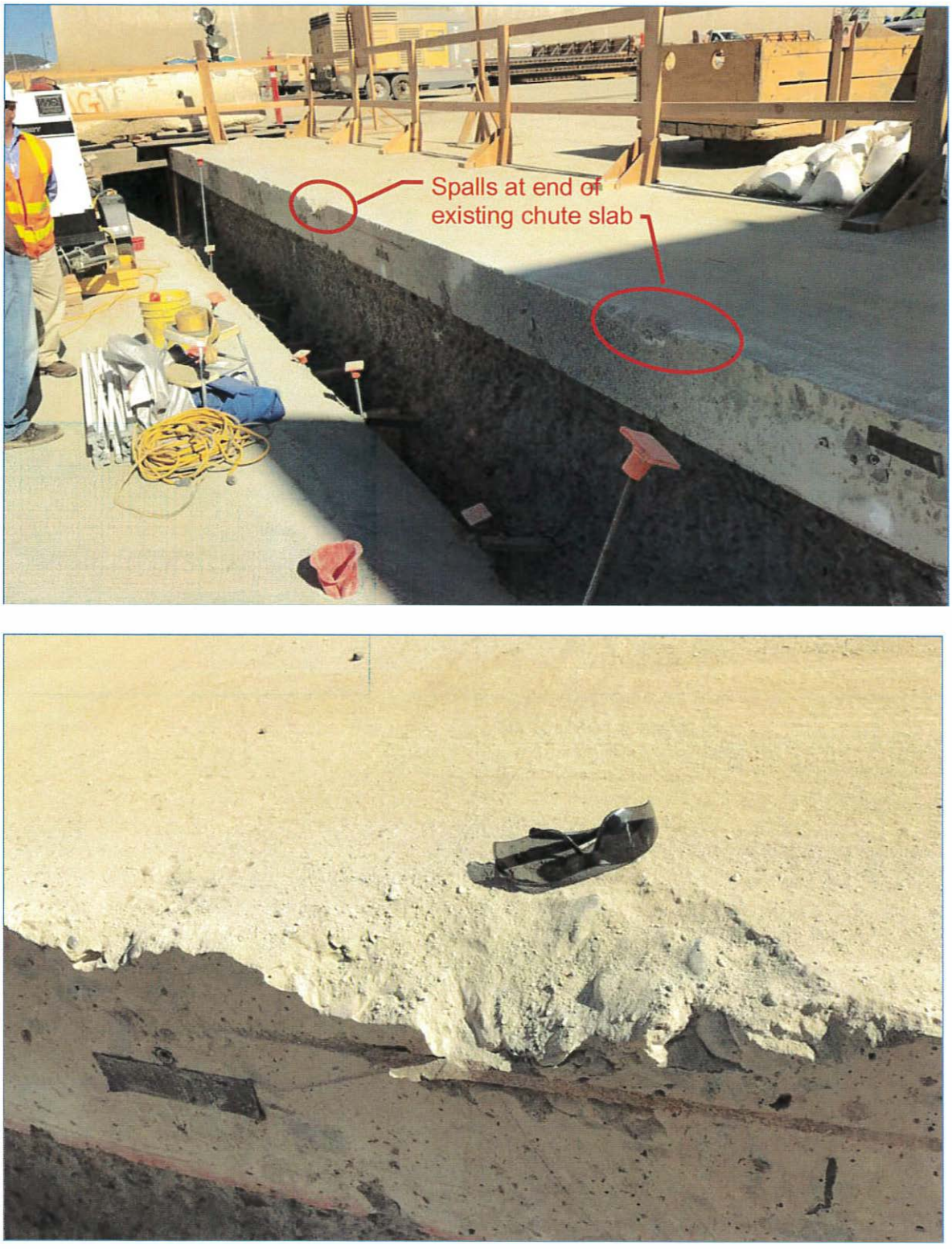

Figure 2. Photos of the downstream end of the existing chute slab showing spalls.

BOC RECOMMENDATIONS SUMMARY

M12-1 The BOC recommends careful and continuous monitoring of the progress of critical path construction items.

M12-2 The BOC endorses the Design Team's modifications to the secant pile cutoff wall design and believes recognizing the favorable bedrock conditions is appropriate and will improve the rate of production of pile installation while satisfying the design intent.

M12-3 The BOC recommends not allowing excessive RCC aggregate stockpile placement in the area of the RCC aggregate production plant as an operational requirement so as not to induce new slope movements at this location.

M12-4 The BOC recommends monitoring the proposed quarry slopes and the rock crushing plant slopes with a slope monitoring system such as the use of a ground-based LIDAR system.

M12-5 The BOC believes the bedrock currently exposed in the foundation of the Emergency Spillway weir is of sufficient strength and quality to serve as an adequate foundation for the cutoff weir.

M12-6 The BOC recommends ongoing groundwater monitoring, especially as the wet season approaches. The BOC believes it will be important to compare these initial "dry period" data readings with those in the future that will be recorded when the reservoir is at a higher stage or when the FCO Spillway chute experiences flows.

M12-7 If aeration is decided to be built into the permanent chute surface The BOC recommends that final design of the air slot or slots within the FCO Spillway chute be based on 3D CFD analytical modeling with less reliance on physical modeling.

M12-8 The BOC recommends that the 30-inch aeration step to the RCC surface be provided for the interim period of the 2017-2018 flood season.

M12-9 If no FCO Spillway discharges for flood protection reasons have to be made during the 2017-2018 flood season, the BOC recommends the aeration performance of the 30-inch step be

tested at 50,000 cfs and 100,000 cfs, if possible, for a short period of time to verify the full-scale behavior of the flow.

M12-10 The BOC recommends that the flows created by the FCO spillway discharging normal to the Feather River be evaluated using 2D or CFD modeling to determine their impact on the dam, if any.

M12-11 Based on the favorable results of the hydro testing of the slope-enriched RCC test section, the BOC agrees with the decision not to treat the entire surface of the RCC with a surface hardener. Instead, a limited area at the local area of impact of the jet at the 30-inch aeration step is proposed to be treated with the spray on surface hardener. The BOC concurs with treating this limited area of the RCC surface as proposed by the Design Team.

M12-12 The BOC recommends that the spalled areas along the downstream end of the existing FCO chute slab at Station 20+30 (where the connection to the new constructed panels will be made) be repaired by the best method of concrete patching.

M12-13 The BOC recommends that a reliable method of measuring the drain flows from the FCO Spillway be established.

M12-14 The BOC recommends that a thorough and detailed inspection of the existing upper chute slab and drain system of the FCO Spillway that will remain in place during the 2017-2018 flood season be performed to confirm that it will serve its intended function.

Respectfully submitted,

Eric B. Kollgaard **Faiz Makdisi** **Kerry Cato**

John Egbert **Paul Schweiger**