

FERC AFTER ACTION PANEL

ASSESSMENT OF OROVILLE SPILLWAY

INCIDENT CAUSES AND

RECOMMENDATIONS TO IMPROVE

EFFECTIVENESS OF THE FERC

DAM SAFETY PROGRAM

November 23, 2018

## **1. INTRODUCTION**

This report was prepared by the FERC AFTER ACTION PANEL (FAAP). This Panel was convened by the FERC Director of Division of Dam Safety and Inspections (D2SI), Mr. David Capka, after the Oroville Dam spillway incident of February 2017 and given the charge to evaluate FERC's dam safety program at Oroville during design, construction, and operations, including regional office annual site inspections, 5-year Part 12 safety review process and Potential Failure Mode Analyses (PFMA) exercises. Lessons learned during this review were utilized to develop recommendations to upgrade FERC's review process at the Oroville Dam Project and for all other existing and future projects.

This report also provides an assessment of the Root Causes leading to the February 2017 Service Spillway chute slab failure, the erosion downstream of the Emergency Spillway (ES) and provides comments on the DWR Independent Forensic Team (IFT) findings.

As part of the process, the FAAP made an assessment of the FERC Part 12 process and DWR's Owner's Dam Safety Program (ODSP). We also reviewed how they were implemented at Oroville Dam prior to and during the February 2017 incident. These two items along with various interactions between DWR and the California Division of Safety of Dams (DSOD) form the bulk of the dam safety programmatic efforts at the Oroville Project.

Finally, the FAAP provides suggested improvements for FERC to consider implementing in the existing Part 12 process. Our comments related to this part of the scope are not

absolute in nature but are intended to generate a conversation leading to improvements of the processes in place for both the regulators and the dam owner/licensee.

The FAAP panel members are;

Dr. Alfred Hendron, Jr. - Chairman

Dr. Nelson Pinto

Dr. Gabriel Fernandez

Dr. Nicholas Sitar

Mr. Charles Ahlgren, PE

Mr. John Northrop, PE

FERC's mandate to the FAAP is quoted below.

*“The FERC Consulting Board will review project documents and history for Oroville Dam. These documents will include but not be limited to, design documents, construction records, photographs, Part 12 Independent Consultant Reports, Potential Failure Mode Analyses, FERC Annual Dam Safety Inspection Reports, and other inspection reports by the state of California. The Board will review the performance of the FERC dam safety program at the Oroville Dam Project, which includes both work and actions by FERC staff, and the program requirements on the dam owner, such as the Part 12 process, the PFMA process, the Instrumentation and Monitoring Program, and Owners Dam Safety Program. The Board should focus on both the Service (gated) Spillway and the Emergency Spillway aspects. Failure mechanisms should be assessed if possible. The findings from the DWR Independent Forensic Team (IFT) will be provided to the Board. The Board will then make conclusions regarding any shortcomings in the FERC dam safety program*

*implementation at Oroville Dam. Additionally, if shortcomings are found, recommendations for improvement or changes to the FERC dam safety program to ensure that future incidents like Oroville can be avoided.”*

A brief description of the topics discussed in the various sections of this report is presented below.

Section 2 includes comments on the IFT Report which relate to the causes of failures at the Service Spillway chute and erosion on the downstream side of the Emergency Spillway. Where appropriate the physics of the chute slab failure mechanisms are described in detail; and, the erosion downstream of the Emergency Spillway is described. The FAAP conclusions related to the physical causes of the chute slab incident are also presented within this section.

In Section 3 we reviewed the effectiveness of dam safety activities, including the FERC Annual Inspections, the 5-year Part 12 Safety Inspection Reports, the Potential Failure Modes Analysis (PFMA) sessions from 2004 to 2014, and owners dam safety program (ODSP).

In Section 4 the Suggestions and Recommendations to improve the current FERC 5-year Part 12 Safety Inspection Reports and the PFMA sessions are given.

## **2. COMMENTS ON THE INDEPENDENT FORENSIC TEAM REPORT**

### **2.1 General Appraisal**

The Independent Forensic Team Report dated January 5, 2018, is a comprehensive 584-page document and essential reference for any further study on the February 7, 2017, Oroville Spillway incident. The principal root causes of the spillway failure proper are thoughtfully analyzed, and an overall appraisal of the many other contributing factors – physical, human, and organizational – involved during the 60-yr history of the project, are also included. As such, the IFT report covers practically all the main design, construction, inspection, operation, and maintenance activities that might have influenced the incident during the life of the project up to date of the incident.

Many lessons can be learned from the data and comments included in the IFT report.

### **2.2 Specific Comments on the IFT Report**

The IFT report “Summary” includes the following comments regarding the possible root causes of the spillway incident;

*“During service spillway operation on February 7, 2017, water injection through both cracks and joints in the chute slab resulted in uplift forces beneath the slab that exceeded the uplift capacity and structural strength of the slab, at a location along the steep section of the chute. The uplifted slab section exposed the underlying poor-quality foundation rock at that location to unexpected severe erosion, resulting in removal of additional slab sections and more erosion.*

*Responding to the damage to the service spillway chute necessitated difficult risk tradeoffs while the lake continued to rise. The resulting decisions, made without a full understanding of relative uncertainties and consequences, allowed the reservoir level to rise above the emergency spillway weir for the first time in the project’s history, leading to severe and rapid erosion downstream of the weir and, ultimately, the evacuation order.”*

*“There was no single root cause of the Oroville Dam spillway incident, nor was there a simple chain of events that led to the failure of the service spillway chute slab, the*

*subsequent overtopping of the emergency spillway crest structure, and the necessity of the evacuation order. Rather, the incident was caused by a complex interaction of relatively common physical, human, organizational, and industry factors, starting with the design of the project and continuing until the incident. The physical factors can be placed into two general categories:*

*Category 1 • Inherent vulnerabilities in the spillway designs and as-constructed conditions, and subsequent chute slab deterioration*

*Category 2 • Poor spillway foundation conditions in some locations”*

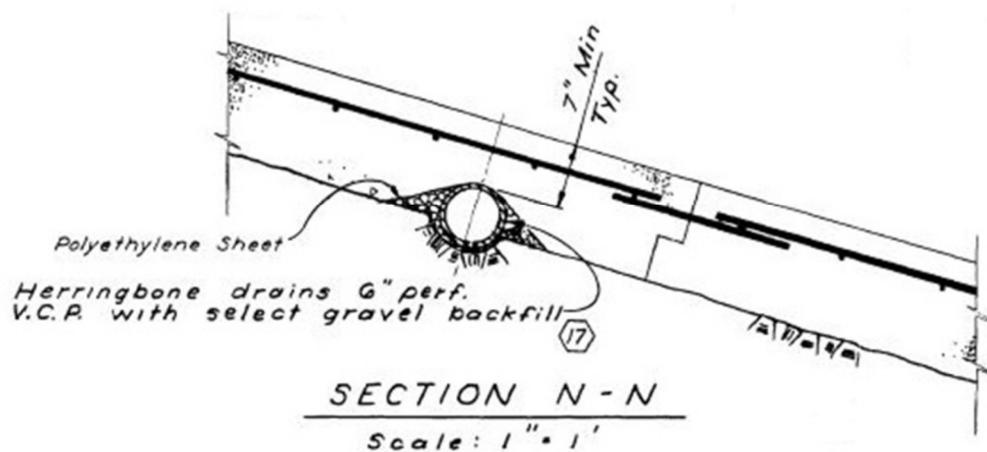
On pages 37 and 38 of the IFT Report, the inherent vulnerabilities in the spillway design as constructed were given as the first category of physical factors;

*“The IFT has also identified a number of design and construction fragilities, specific to the chute slab details, which contributed to the chute slab’s vulnerability to uplift. Specifically:*

- Underdrains intruding into the chute slab section, reducing the thickness of concrete above the drains to 7 inches or less (compared to a design minimum slab thickness of 15 inches elsewhere). This condition resulted in cracks above most of the herringbone drains. The cracks allowed water to pass through the slab and also led to a propensity for concrete delamination and spalling in the slab.*
- The formed contraction joints in the slab did not include waterstops, which facilitated water passing through the slab into the foundation. These formed joints were also too far apart to prevent wide cracks from opening over the drains.*
- The specified foundation preparation and treatment, which was followed for the headworks and emergency spillway crest structures, was relaxed during construction of the spillway chute slab. Up to 50 percent or more of the foundation in some areas was not properly treated by removal of weathered materials and cleaning of soil-like materials from the surface, with no definition of the areal extent over which this 50 percent assessment was to be applied.*
- The design included shallow rock anchorage, with only 5-foot embedment length into the foundation, and the embedment was possibly less where the slab was thicker than the minimum of 15 inches. In addition, some anchors in the initial chute failure area were installed in strongly weathered that was unlikely to develop the intended pull-out strength. The embedment of the anchors into the 15-inch thick slab was likely also inadequate to develop the full anchor bar strength. (See Fig. 2.2.1)*
- The underdrain system had numerous deficiencies, such as no filtering, possibly broken or disconnected pipes caused by the method of placement, incorrectly*

*oriented or missing drain holes in the pipe, likely inadequate collector drain capacity for the flow that ultimately occurred through the slab, and a lack of redundancy.*

- *The slab had a single layer of nominal reinforcement bars near the top of the slab, rather than two layers of more robust reinforcing, which might have helped control cracking over the drains.*
- *With the joint dowels and steel reinforcing mat both being placed near the top surface of the slab, as compared to the dowels being placed at mid-height, there is an apparent plane of weakness created near the top surface of the joint, which could have increased the potential for delamination and spalling of the concrete near the joints.*
- *The maximum aggregate size in the concrete was relatively large (6-inch size), resulting in a propensity for cracking and spalling at keys and over drains, as well as damage to drain pipes during concrete placement.”*



**Fig. 2.2.1 Herring-Bone Drain Encroaching in the Chute Slab.**



**Fig. 2.2.2 Herring-Bone Cracks Visible from the Air.**

The herringbone drainpipe system encroaching into the thin chute slab, Fig. 2.2.1, induced a reflective pattern of vertical cracks above the herringbone drains all along the slab that were first observed within a month of concrete placement and were clearly visible since the early days of operation. The crack pattern formed by these drains (blue line emphasis) as seen from the air, is shown in Fig. 2.2.2.

The second category of the physical factors identified in the IFT Report was “poor spillway foundation”, as illustrated in Fig. 2.2.3, where the initial erosion occurred at about chute Sta. 33+00. Existing original construction records contain numerous references to soil like materials that were found to be present in this area. Project specifications indicated that when such materials were encountered they should be excavated out until a competent rock foundation was located and backfilled to grade with concrete. The Contractor encountered, erodible, soil like materials in the area of Sta. 33+00 and estimated the cost to satisfy the specification requirements (reference). The field decision

to install the chute over compacted soil like materials has been clearly implicated in the failure of the chute slab.



**Fig. 2.2.3 Initial Erosion Visible on February 8, 2017.**

Specifically, on page A-43 of the IFT Report, it is noted that a question about foundation treatment in the weathered rock area around Sta. 31+00 of the service spillway chute was presented at the Consulting Board Meeting of April 19-20, 1966. Photo Fig. A-31 shown on page A-43 shows the Board of Consultants standing at the weathered area at Sta. 31+50 on February 12, 1966.

*“Of note regarding the service spillway, a memorandum [C-25] notes that the “foundation treatment in the weathered rock area around Station 31+00” was discussed in an April 1966 BOC meeting. After an exhaustive search by DWR staff, unfortunately the minutes of this meeting could not be located. However, it is apparent that during the ensuing discussions, the adequacy of the underdrain system was questioned, and this led to a Change Order (#21), issued October 16, 1967, as previously discussed. All of the drain pipe sizes were increased, the herringbone pattern was developed to provide positive*

*drainage throughout, and vertical risers were added to the longitudinal drains.” (IFT, p. C-23)*

Also, during the design stage similar decisions were made regarding the treatment of the Emergency Spillway discharge area.

With respect to the area downstream of the Emergency Spillway:

*“One interesting comment appears regarding the area downstream of the emergency spillway. Notes from a September 20, 1963 meeting [C-24] include the passage:*

*‘The Board concurs in the finding that nothing be done to minimize erosion in the natural channel downstream from the auxiliary spillway beyond ensuring that this discharge be kept away from the concrete lined chute below the flood control outlet structure.’ “ (IFT, p. C-23).*

Thus, the Board of Consultants in 1963 weighed in that they did not foresee that the area downstream of the Emergency Spillway needed to be remediated; they “concurred” with what DWR apparently presented at the September 20, 1963 meeting, ostensibly because of the low probability of use, “about once in 800 years” (Thayer and Stroppini, 1965, “Hydraulic Design for Oroville Dam Spillway”). From the IFT Report as cited below:

*“In the early to mid-2000s, as part of the Oroville Dam re-licensing process, external groups questioned [24] the safety of the emergency spillway regarding the potential for bedrock erosion, based on the original records and reports. DWR was requested by the FERC to investigate this issue, and a very brief review was undertaken (see Appendix C). The review resulted in a 2005 DWR memorandum [25] which stated:*

*‘The Emergency Spillway does not empty onto a bare dirt hillside. Instead, it empties onto a hillside composed of solid amphibolite bedrock extending from the spillway crest down to the Feather River. Where the rock is fresh, it is hard, dense, fine- to medium-grained, greenish-gray to black and generally massive. Even though this rock contains numerous narrow shears and schistose zones, variable weathering, joints and fractures, it is considered an excellent and competent spillway rock.’ “(IFT, p. 54)*

“The memorandum was concluded with the following statement:

*‘Based on the information presented in this Office Memo, as obtained from the reports in the Project Geology files, it is my belief that Emergency Spillway at*

Oroville Dam is a safe and stable structure founded on bedrock that will not erode.”  
(IFT, p. 55)

Bracketed numerals, [24], as cited above refer to the numbered reference cited within the IFT Report. In Fig. 2.2.4 the erosion is shown on the downstream side of the Emergency Spillway which occurred from February 11 to February 12, 2017 from only 1.6 ft. overtopping of the Emergency Spillway Weir.



Figure 4-10: Emergency spillway head cutting on February 12 (from DWR)

**Fig. 2.2.4 (IFT, p. 39)**

*“The principal physical factor contributing to the damage at the emergency spillway was clearly the presence of significant depths of erodible soil and rock in features orientated to allowed rapid headcutting toward the crest control structure. The erodible materials appear to be associated with geologic features such as shear zones. Other factors that contributed to the damage at the emergency spillway include:*

- *Hillside topography that concentrated flows and increased erosive forces, facilitating headcut formation*
- *Insufficient energy dissipation at the base of the spillway ogee crest structure*
- *Absence of erosion protection downstream of the crest structures*

*The ogee spillway crest structure has a relatively short toe apron, which would have provided only very limited energy dissipation before the water exited onto the natural terrain. Downstream of the crest structure toe apron, the hillside did not include any structures to provide erosion protection. If erosion had progressed to the short toe apron, the stability of the crest structure could have been compromised.” (IFT, p. 40)*

The rapid and significant erosion triggered by spilling only 1.6 ft. of water over the crest of the Emergency Spillway indicates that the previously accepted perception of the behavior of the existing geology to resist erosion was unrealistic.

### **2.3 FAAP Suggested Physical Mechanisms Responsible for the Root Causes of the Failure of the Spillway Chute**

The IFT has made good use of the opportunity for handling the extensive documentation, with ample time to analyze the information made available. Many lessons can be learned from the data and comments included in the IFT report.

The IFT report “Summary” however does not include a physical explanation for the “root cause” mechanisms responsible for the incident, preferring to attribute it to a *“long-term systemic failure of the California Department of Water Resources (DWR), regulatory, and construction industry practices, to recognize and address inherent spillway design and construction weaknesses, poor bedrock quality, and deteriorated service spillway chute conditions”*. The uplift forces beneath the slab that exceeded the uplift capacity and structural strength of the slab are simply related to *“water injection through both cracks and joints in the chute slab”*.

As for the physical causes for the increase in the uplift forces that resulted in the slab displacement, downstream of Sta. 33+00, the IFT Report does comment on the opinion of “others” (IFT, page 32) **“that suggest that the chute failure initiated when a section of the chute slab settled or sagged into a void beneath the slab.... created by piping (internal erosion) of foundation material from flow that entered the foundation through the slab and exited through the drain system.”** The IFT Report however indicates that this hypothesis is a less likely alternative to the uplift action, recognized as the destructive force.

The FAAP is of the opinion that the early settlement of a portion of the slab is not an alternate, but it is at least an additional, equally plausible hypothesis to explain how an adverse offset into the flow could be created in the first place and result in an increase of the uplift force, as discussed below.

The Oroville Dam spillway design was comprised of several potentially weak elements, (a chute slab that was too thin - a drainage system encroaching too much into the slab thickness - a defective slab anchoring system that was too short and was anchored into soil like materials instead of rock – a lack of water-stops in transverse joints - deficient keying system between concrete joints – an extensive area of soil from a weathered rock shear zone, etc.), which were main contributors to the incident. However, the combination of two factors, at distinct time scales, seem to be the main cause of the February 7, 2017 failure:

1. The first physical cause mechanism is the unnoticed long-term slow progressing internal erosion process of the foundation soils present in the area between

stations 32 to 36, which consisted of highly weathered rock materials within a wide shear zone.

The soil erosion was caused by water infiltration during spillway operation, and precipitation events that flowed through the vertical slab cracks that developed above the herringbone drain system as shown by the blue line pattern in Fig. 2.2.2. Discharge from the crack infiltration flow was manifested in the outlet holes along both spillway walls. From the very first time the spillway was operated, these flows were called to the attention of operators and engineers because of the relatively high flow volumes, clearly larger than those anticipated from reservoir seepage. These infiltration water flows gradually eroded the highly weathered materials into the drainpipe system. The slow process passed undetected in the inspections, as no visible indications of slab movements had been observed. However, the slab cracks tended to widen with time and regular repair and maintenance was being performed on an on-going basis. Hence, the rate of erosion, although slow and unnoticed for 50 years, ended up by undermining the concrete slab, at the weaker highly weathered soil foundations in the chute zone, downstream of Sta. 33+00, enough to produce a slab settlement, possibly of only a few inches, on February 7, 2017, as hypothesized in Fig. 2.3.1. Due to the slow progress of the erosion and lack of a visible slab movement until then, the phenomenon remained unnoticed until that critical date.

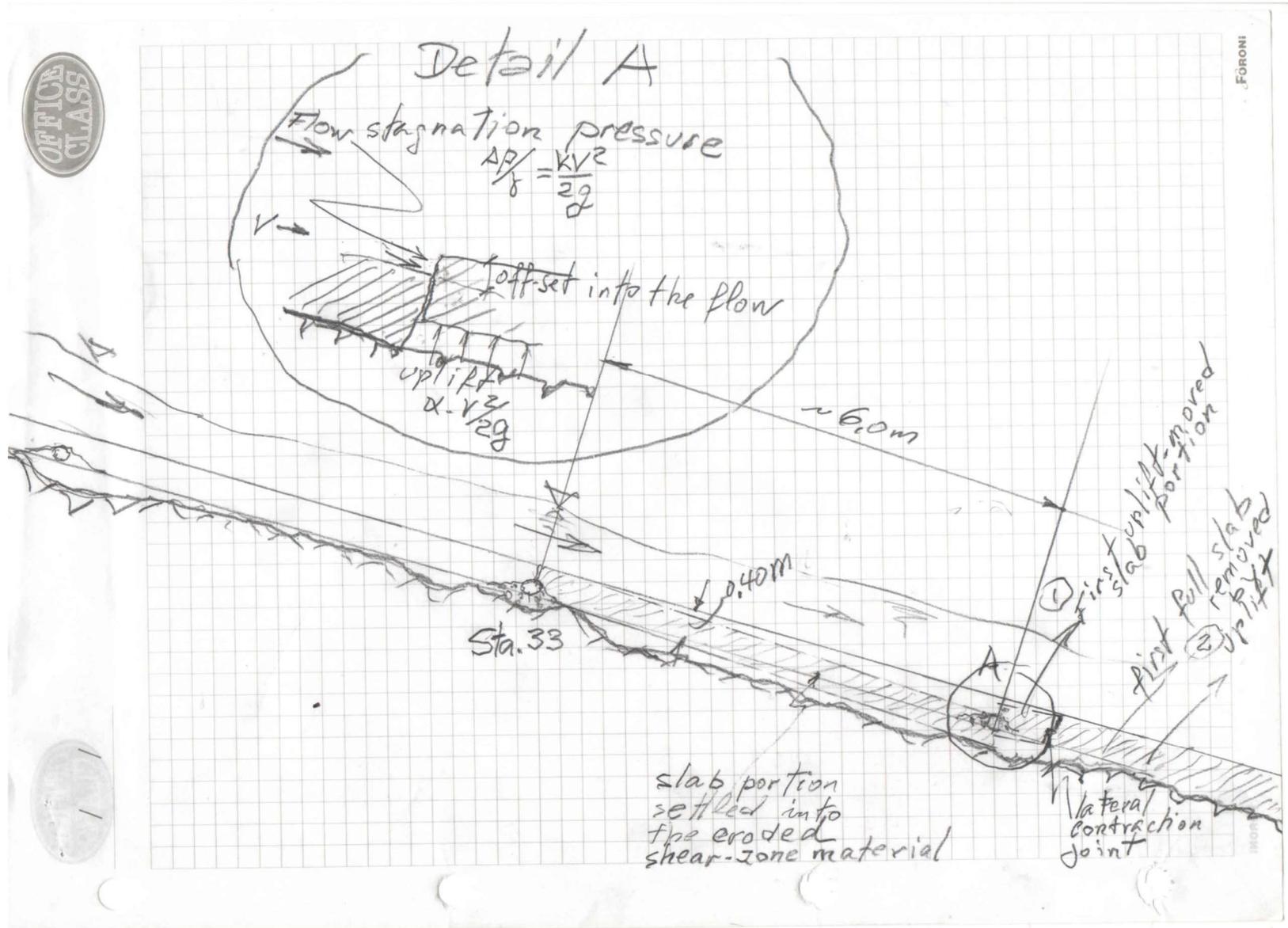


Fig. 2.3.1 Possible Slab Settlement and Resulting Offset Into Flow

There are numerous references during construction indicating the presence of soil like materials at the slab failure location which the specifications required to be excavated to competent rock, then subsequently backfilled to grade with concrete. Deliberations regarding the treatment of these soft foundation materials were carried out during construction as indicated on page A-43 of the IFT Report and on Page 8 of this report.

2. The second physical cause mechanism was the sudden increase of the uplift force under the slab, induced by an offset into the flow, resulting from the slab settlement of February 7, 2017.

The stagnation pressure of the high velocity shooting flow against this offset (a high proportion of the velocity head), propagated under the slab through vertical cracks and/or joints, producing a large uplift force that raised and dislodged part of the slab. The high stagnation pressure produced a water-splashing phenomenon captured in photos by an operator as shown in Fig. 2.3.2. The earliest photos were probably taken after the initial removal of a portion of the slab. The splashing effects were probably too small to be noticed in the early stages but became clearly visible as the slab removal process developed and the resulting offset into the flow increased.



**Fig. 2.3.2 Water Splashing against Offset Downstream from Sta. 33+00**

The removal of the slab sections further downstream was a natural domino effect, typical of chute spillway failures, which had been common in the early days of poor anchoring and inadequate slab drainage provisions in chute spillways. The extensive rock erosion that followed and progressed mostly downstream, and to a lesser degree upstream, were natural effects from the fast and turbulent water flow over the weak and unlined rock chute, Fig. 2.3.3.



**Fig. 2.3.3 Initial Erosion Visible on February 8, 2017**

## 2.4 Adverse Erosion at Emergency Spillway Discharge Area Caused by Gate Operational Decisions in Response to Chute Slab Failure

The DWR response after the Flood Control Outlet (FCO) chute slab failure is presented below.

Responding to the damage to the service spillway chute necessitated risk tradeoffs while the lake level continued to rise. The resulting decisions, made without a full understanding of relative uncertainties and consequences, allowed the reservoir level to rise 1.6 ft. above the emergency spillway weir for the first time in the project's history, leading to severe and rapid erosion downstream of the weir (See Fig. 2.2.4) and, ultimately, the evacuation order of about 180,000 people.

*“The principal physical factor contributing to the damage at the emergency spillway was clearly the presence of significant depths of erodible soil and rock in features orientated to allowed rapid headcutting toward the crest control structure. The erodible materials appear to be associated with geologic features such as shear zones. Other factors that contributed to the damage at the emergency spillway include:*

- Hillside topography that concentrated flows and increased erosive forces, facilitating headcut formation*
- Insufficient energy dissipation at the base of the spillway ogee crest structure*
- Absence of erosion protection downstream of the crest structures*

*The ogee spillway crest structure has a relatively short toe apron, which would have provided only very limited energy dissipation before the water exited onto the natural terrain. Downstream of the crest structure toe apron, the hillside did not include any structures to provide erosion protection. If erosion had progressed to the short toe apron, the stability of the crest structure could have been compromised.” (IFT, p. 40)*

As indicated previously on pages 9 and 10 of this report, the operators were informed by a DWR Memorandum [25], that the area downstream of the Emergency Spillway was not erodible.

## 2.5 Conclusion Regarding the Physical Causes of the Failure

The review of available design and construction records indicate that key aspects of the slab chute design were inadequate and decisions were made during construction, apparently without proper consultation with the design team. In the FAAP's view the implications of these modifications led to the development of unanticipated, slow progressive erosion of the foundation materials from Sta. 33+00 to 33+50 which ultimately resulted in the chute slab failure of February 7, 2017. Thus, the FAAP considered it pertinent to compare the original chute slab design with the actual slab construction, as discussed below to highlight the root causes of the observed failure.

### 2.5.1 Chute Slab Design

The original chute design called for a 15-inch-thick concrete slab resting on moderately weathered rock or better which was pressure washed to remove all mud, debris, and loose or unsound rock fragments as shown in Fig. 2.2.1. Anchor bars (#11 rebar) embedded a length of five feet into sound rock, were to be installed on a 10 ft. by 10 ft. pattern to provide resistance to uplift pressures, as shown in Fig. 2.5.1. The slab included a single layer of steel reinforcement (#5 rebars @ 12" center to center each way) with about 3 inches of cover from the top of the slab, interrupted at the transverse formed joints where connecting/sliding bars were installed as shown in Fig. 2.2.1 and Fig. 2.5.1. A second layer of steel reinforcement at the bottom of the chute slab could have provided the moment resistance to redistribute the loads after of cracking the slab. No water stops were included in designed for the formed transverse or longitudinal slab joints. Patterned herringbone drains were to be placed on top of the slab foundations at regular intervals

along the chute to capture potential seepage flow from the reservoir and minimize potential uplift pressure. See Section 2.5.2. As shown in Fig. 2.2.1 the herringbone drains reduced the effective slab thickness to 7" over the drains.

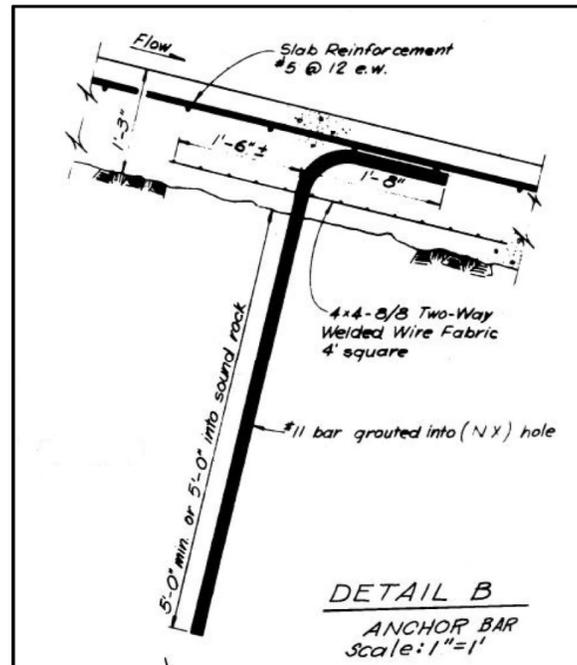


Figure 3-7: Typical anchor bar installation [5]

**Fig. 2.5.1 (IFT, p. 14)**

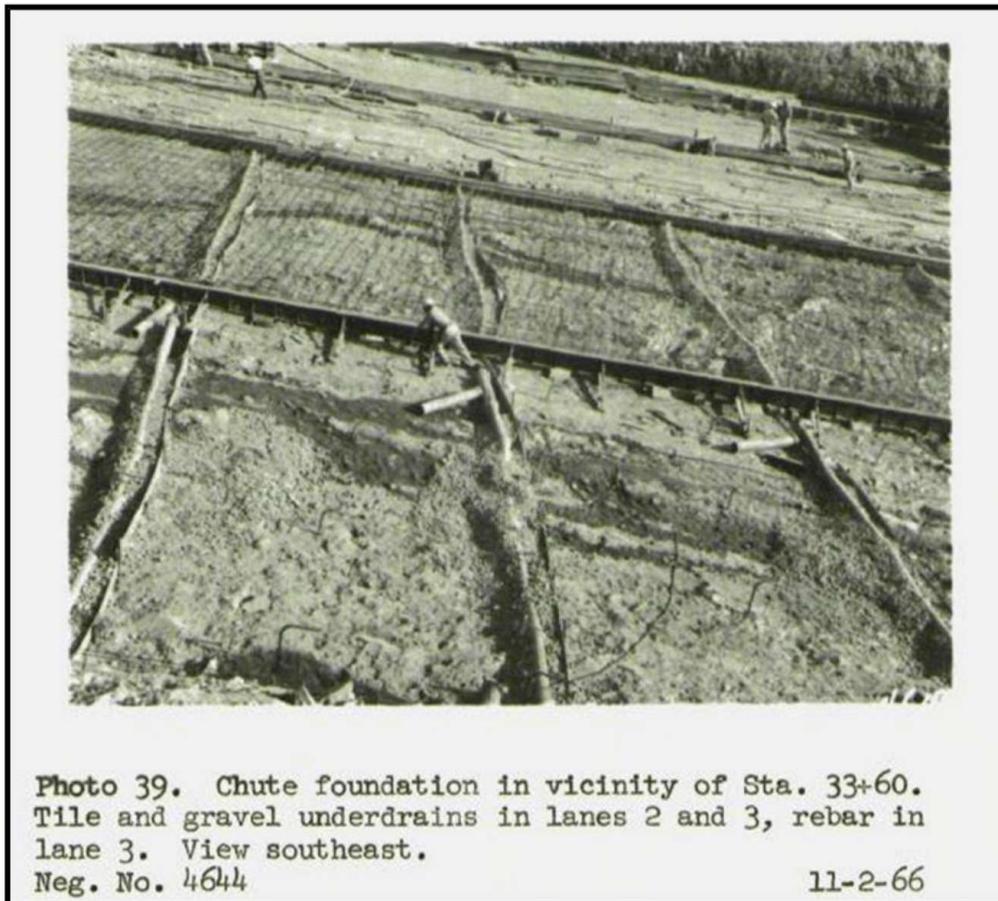
It is important to note that the dimension shown for the anchor bar length in Fig. 2.5.1 specifically indicates that the anchor bar should extend a minimum of 5 ft. from the top of the rock or 5 ft. into sound rock. This was clearly ignored, or violated, in the area of the failure where anchors were drilled into weathered rock / soil like material where the design capacity was severely compromised.

### 2.5.2 Chute Slab Construction

An initial chute alignment location was contemplated to be located in the area of the current Emergency Spillway discharge and a significant number of borings were carried out during the design stage to explore this option. A significant number of borings indicated the presence of deep weathered zones (60 ft. to 80 ft. to the top of rock) and the chute was subsequently shifted towards the East to the actual location. Only a limited number of borings were drilled along the new alignment.

A comprehensive geological mapping of the excavated spillway alignment was carried out during construction to assess the depth of the chute foundations, and its findings are documented in the “as built”, 1970 Geological Map of the Spillway Foundations. A review of this mapping, DSOD memorandums, and other information indicates that the chute slab foundations in the flat section of the chute, from the FCO structure to Sta. 29+00, were placed on hard, irregular surfaces with a variable thickness of the chute slab. Isolated pockets, of highly weathered rock were left at some location along the chute, i.e. ~Sta. 20+00. However, in an area just upstream of Sta. 33+00, in the inclined portion of the chute, a 75 ft wide zone of steeply inclined, highly weathered shears intersecting the alignment were encountered. The depth of the highly weathered rock was reported to be about 60 to 75 ft on the geology map of the spillway foundations. Although the foundations in this area were judged (by DSOD) to be the “softest in the whole chute” the excavation and clean up extended only 1 to 2 ft below design grade and the slab was placed on clayey materials. The chute anchors were embedded 5 ft. within the soft materials, not 5 ft. into sound rock as specified in the design and shown on Fig. 2.5.1. This modification is considered significant and this led to the foundation condition shown

in Fig. 2.5.2 at Sta. 33+60 on Nov. 2, 1966, where extensive areas of soil like materials are shown in the foundation.



**Figure 3-11: Lane 3 downstream from Sta. 33+00 being prepared for placement. [9]**  
**Note what appears to be extensive areas of soil-like materials in the foundation.**

**Fig. 2.5.2 (IFT, p. 17)**

The presence of the soil-like materials within the foundations and lack of anchors being extended 5 ft. into sound rock resulted in the poor performance of the as constructed chute slab foundation/anchor system shown in Fig. 2.5.3.



**Figure A-19: Anchor bars on the underside of the slab upstream of Sta. 33+00 (on right edge). Note the smooth underside of the chute slab that was to have been placed on a rock foundation which would have been expected to be irregular. (Photo DSCF9788)**

**Fig. 2.5.3 (IFT, p. A-27)**

In addition, the irregular nature of the excavation below the chute slab resulted in the practice of leveling the grade below the slab foundations placing the herringbone drains on the leveled grade which resulted in drain encroachment into the designed 15-inch slab thickness. The intact slab thickness above the drains was reduced to 7 in. to 5 in. This phenomenon was exacerbated at the shear zone locations below Sta. 33+ 00 by the Board of Consultants recommendation on April 1, 1966, to modify the design by increasing the diameter of the herringbone drains from 4 inches to 6 inches in the soft

foundation materials. Persistent shrinkage cracks developed through the reduced concrete slab thickness along the herringbone drain alignment, and their opening increased with time triggered by seasonal temperature fluctuations.

Recorded observations made in 1969 after the first significant spillway discharge indicated large infiltration of spillway discharge into the herringbone drains via the continuous slab cracks above the alignment of the herringbone drains. Herringbone drain flow measurements taken during a field test carried out in 1969 indicate that the magnitude of the flow in the herringbone drains was directly proportional the spillway discharge flow. The velocity of the drain infiltration flows is proportional to the concrete crack width to the third power, thus large concentrated inflows could have developed into the slab foundations at the location of enhanced concrete cracking.

In our view the location of the failure along the chute is not a random occurrence and is not a surprise that it took place at the location where soft materials, susceptible to erosion were left immediately under the slab foundations. The root causes of failure in our opinion were the direct result of the three field construction modifications made to the design during 1966 as indicated below.

- 1) The deep erodible soil material left in place just downstream of Sta. 33+00, as shown in Fig. 2.5.2 in November 1966;
- 2) The installation of 5 ft. long anchorage in this area was clearly inadequate; and
- 3) The geometry and size of the herringbone drains were changed by the Board in April 1966 reducing the thickness of the slab.

These conclusions are supported by the fact that in spite of the significant flows, up to 100,000 cfs, of continuous spillway discharge for a period of about three weeks after the failure no significant slab damage was observed upstream of Sta. 29+00, where the slab was founded on more competent rock.

### **3.0 FERC PERFORMANCE DURING OPERATIONS**

#### **3.1 Part 12 Review Issues**

In our view, in nearly 45 years of operation and through 8 Part 12 safety inspection reports, significant issues related to the safety of the of the dam and discharge structures were not addressed. However, with the recent increased scrutiny of the Part 12 process by FERC, some of these issues were brought forward during the development of the most recent Part 12 safety inspection report in 2014. The inherent assumption is that the established review process, if properly implemented, will adequately address all issues that could result in a failure resulting in loss of life downstream. This has been proven several times in the past decade to not be true, as several failures have occurred because certain technical details were overlooked and not addressed in the reviews.

- a. Specifically, in the case of the Oroville spillway chute, when large water infiltration through chute cracks was observed along the underdrains (1969), the consequences of this behavior should have been investigated more thoroughly. Furthermore, the evolution of these flows with time should have been more closely monitored to assess changes within the system

and then investigate why these changes have occurred and possible root causes and their effect on structural behavior.

- b. FERC Engineering Guidelines and, in our opinion, good engineering practice would dictate that owners of significant dam structures have on file existing documentation that describes the margins of safety of their facilities. At Oroville, the original FCO and Emergency Spillway (ES) stability analyses prepared as part of the design process were not included in the existing supporting technical information document (STID) and have been reported by DWR to be unavailable. Furthermore, FERC upon their review of the pre-2014 Part 12 reports, did not press DWR to develop documents to demonstrate adequate stability of these structures, opting to approve cursory summaries of factor of safety based on historical descriptions. The need for these analyses was finally brought up by the Independent Consultants (IC) during the 2014 Part 12 process. With that said, further delays were brought on by DWR suggesting and FERC accepting a proposed schedule that dictated updating existing seismic studies prior the development of the static stability assessments. This had the effect of delaying this vital information so that it was not available for use before and during the February 2017 incident.
- c. We note that all studies must include a thorough review of all basic assumptions including potential modes of failure, material properties, and

postulated loading conditions. A preliminary review of the 2017 stability assessments of the FCO and ES monoliths recently completed by DWR's consultant (HDR) indicates that the engineers have pursued a parametric approach that appears to offer the necessary insight into structural behavior under all postulated loading conditions together with the effects of drainage, assumed shear strengths, and anchor rod efficiencies. We feel that these parametric analyses were long overdue, but there is a requirement for external independent review of assumed shear strengths and pore pressure distributions. Moreover, all analyses should be supported by independent (e.g. manual) calculations that are well documented and readily verifiable. Furthermore, the calculation packages, should be documented in a bound volume, appended to the actual engineer's stability report, and included in their entirety in the STID. Similar studies should be performed on the main and auxiliary structures within the project. It is recommended that the next Part 12 Independent Safety Inspection Report review should begin at this time, 2018, and finish in 2019, and would serve as an independent review of the final remediation of the FCO structure, Service Spillway Chute and Emergency Spillway.

- d. Prior to 2003 DWR monitored piezometric levels under the FCO using Carlson type stress meters at various locations along the concrete rock interface. These meters were installed during construction to monitor uplift and to test the effectiveness of the tendons holding the radial gate

trunnions. However, as time passed, the readings became erratic and hence, rather than pursuing a repair or replacement, these instruments were abandoned in place in 2003. Since that time no uplift under the FCO has been recorded. Piezometric data is absolutely essential to accurately assess stability. Therefore, the FAAP urges FERC to direct DWR to immediately install a system of piezometers in both the FCO and ES monoliths. These instruments will be needed to assess the effectiveness of future contemplated improvements to both the FCO and ES. In addition, improved drainage below the FCO Gate Structure should be completed during the 2018 construction season.

- e. As shown during the February 2017 incident, the erosion potential of the ES discharge path was not properly assessed. cursory reviews performed in 2005 proved to be inadequate and misleading, judging by the performance during the 1.6 ft. of overflow (12,500 cfs discharge) of the February 2017 incident. The rock mass along the emergency spillway hillside discharge zone includes significant shear zones parallel to or extending from those encountered along the FCO chute foundations. Also, during construction, a 35 ft to 75 ft wide shear zone was detected at the foundations of the emergency spillway monoliths. Installation of the recent cut-off wall has confirmed the presence of these shear zone features. In our view, treatment of the entire emergency spillway discharge path down to the river is required to provide for safe spillage conveyance in the future. This

treatment extends beyond the area envisioned in the DWR 2017/2018 scope of remediation work.

- f. Based on our review of the historical Part 12 report record, certain aspects of these reviews were treated as merely updates of existing information, rather than an independent checking of facts and a thorough review of available information and analyses. An example is the quality of the rock along the spillway chute foundation that has been characterized as competent or excellent contrary to the information available in the as-built geological map of the chute foundation, which indicates the presence of a wide, deep shear zone at the location of failure, just downstream of Sta. 33+00. Based on this information, it is clear that some or all of the past Part 12 Independent Consultants did not review original spillway geology reports to arrive at their own opinion.
- g. FERC Engineering Guidelines for the Part 12 process specifically dictate that the IC should review all available analyses and determine as to whether or not the summary of those analyses contained in the STID are accurate and sufficient for use by the owner during operation of the project. Apparently, no efforts were made to review original design calculations and intent and compare them with as built conditions, opting instead to accept past Part 12 descriptions and summary of results as adequate. The FAAP

notes that this was apparently also the case at Wanapum Dam in Washington state a few years ago.

- h. The FAAP notes that the FCO and ES, due to their close proximity to one another can be thought of as one water retention structure over 2000 feet long, and 100 feet high (NHWL to the base of the FCO) that is retaining about 1.2 MAF of reservoir water at the NHWL. Furthermore, the City of Oroville (Pop 20,000) is located immediately downstream. Therefore, it may be appropriate for the FERC to identify these spillway structures as a part of the high hazard Oroville Dam Structures and direct DWR to address it as such within the Oroville Project Part 12 safety inspection report. Thus, for the Oroville Project, the standard of care for inspection, stability and writeup for the FCO and ES spillways should be equal to that of the main dam. In fact, we note that part of the problem with this incident stems from conducting the Part 12 process as one huge report for the entire Oroville/Thermolito complex and not as separate projects. It is our opinion that too many features need to be attended to in such a report and that many important details may be omitted in such a process due to the sheer volume of details that need review, as addressed later in Section 4.1.5.

### **3.2 Inspections**

#### **a. Chute Drain Outlet Flows**

The main difficulty faced by the reservoir operator and the inspectors of the regulatory entities in assessing the potential for failure to occur was the lack of evident signs of

impending distress, although increasing chute slab crack widths were reported in the repair logs. The spillway was operated sporadically, about 10 times in 51 years for relatively short durations, a few days to a few weeks, with long periods, of 6 to 7 years between spillages, and no significant changes in the nature of the repairs were required.

In our view, an important parameter that could have given an indication of a potential deterioration of the slab foundations with time was the evolution of the magnitude and turbidity of the drain outlet flows discharging from the spillway walls. These flows were monitored in 1969 during a testing period during the first spilling event and subsequently only sporadically in 2003, but no attempt was made to systematically track their behavior. Admittedly the flows were difficult to monitor, and a correlation between their evolution and potential for slab failure would have been difficult to discern. However systematic recording of these flows could have triggered the initiative to install instrumentation in the slab foundations, i.e. piezometers that together with the flow measurements might have provided evidence of the development of the soil erosion phenomena.

- b. DWR treated all the chute slab work as a maintenance activity and thus the reports associated with this activity did not undergo a critical review process such as is done with most repair or modification work. The 1995 annual inspection report indicates that FERC (San Francisco Regional Office) verbally advised DWR they should develop a site map showing locations of all cracking, repairs, etc. in an effort to more fully characterize the problem. This was done in the ensuing years as part of the

maintenance / repair process. Also, the report entitled, FINAL CONSTRUCTION REPORT, SPILLWAY REPAIRS, Oroville Dam, Antelope Dam, Frenchman Dam and Grizzly Dam, dated August 2010, could have also alerted all parties to further examine the original spillway geologic report. No one viewed this information in context and neither the Part 12 Reviewers or FERC urged the owner to conduct more in-depth studies. The FAAP believes that a more rigorous review may have highlighted the significance of the persistent and increasing crack openings that needed to be fixed repeatedly.

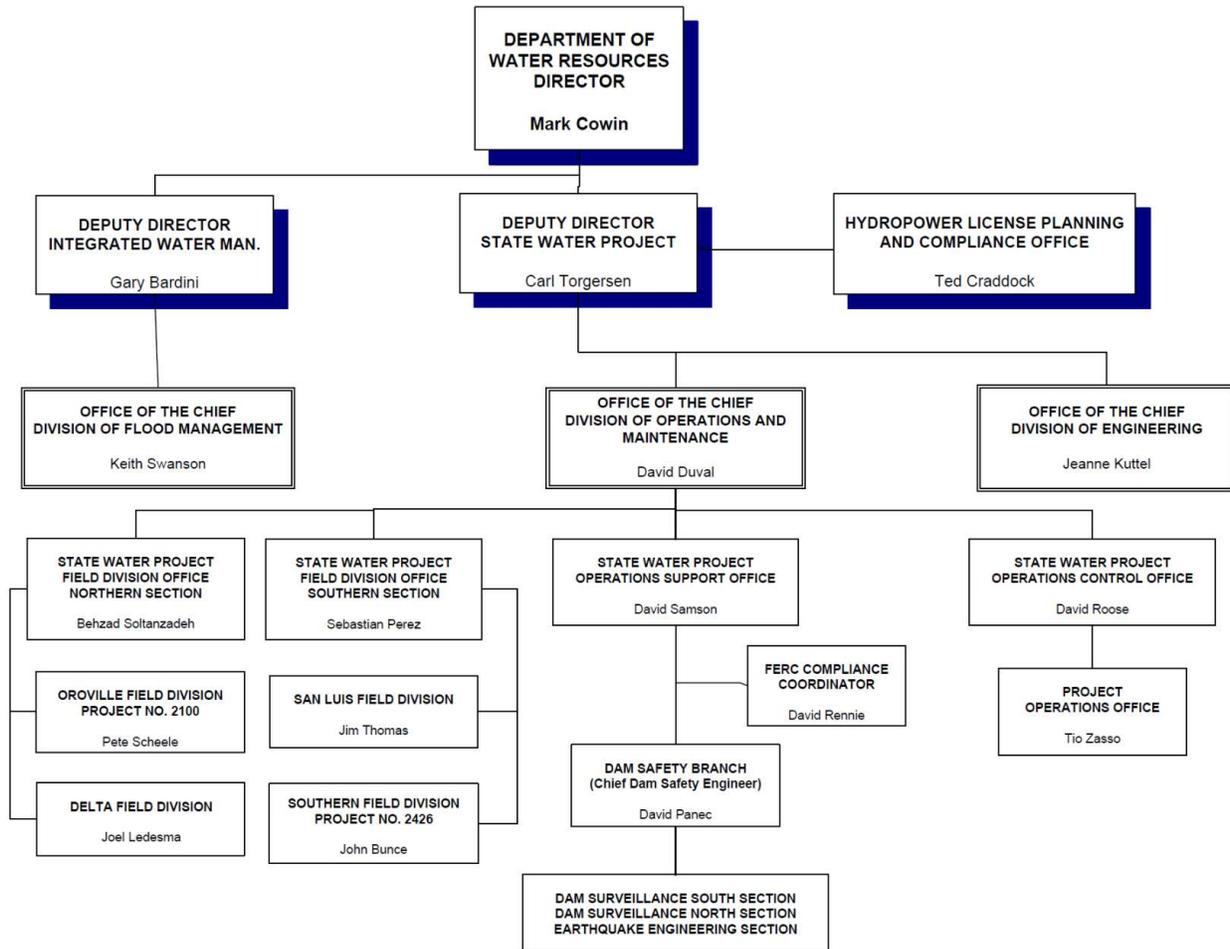
In addition, the methods used to detect and evaluate voids beneath the slab were, for the most part, outmoded (i.e. dragging chains along the slab surface and listening to the sound), and more suited for thinner slabs such as road pavements. A more appropriate method for this work may have been the use of Ground Penetrating Radar (GPR).

- c. At present, the FERC annual inspections typically focus on the operation of the project as a whole and do not go into any depth beyond items that are viewed as on-going or typical maintenance. Thus, the spillway chute slab got little attention beyond visual inspections.

### **3.3 Comments on the DWR ODSP**

The FAAP reviewed the DWR ODSP (2013), the IFT report, and IFT report Appendices J, K1, and K2 to gain an understanding of the DWR ODSP and how it was implemented prior to and during the February 2017 incident.

- a) **Background:** The California Department of Water Resources (DWR) owns and operates the State Water Project (SWP) in concert with the United States Bureau of Reclamation (USBR) and the United States Army Corps of Engineers (USACoE). The Oroville Dam and its associated structures are licensed by the FERC and as such fall under Part 12 of the Code of Federal Regulations, specifically those sections dealing with dam safety (Part 12). In addition to those requirements, the DWR also must deal with the State Water Code requirements for Dam Safety as well as those related to DSOD and USACoE. This, therefore, represents a multi-jurisdictional dam safety effort in which the DWR must satisfy different agencies, each with their specific goals.
- b) **Organization and Reporting:** The DWR Dam Safety Organization consists of multiple divisions of engineers and other technical and managerial people. The Organization chart below is taken from the FERC ODSP submitted in 2013 to formally document these efforts.



DWR has organized its dam safety efforts into 3 distinct divisions: Flood Management, Operations and Maintenance, and Engineering. However, according to the Organization Chart, the functions of Operations & Maintenance and Dam Safety report up through the O&M Division. Engineering is kept separate.

The Dam Safety Branch (DSB) led by the Chief Dam Safety Engineer, is part of the State Water Project, (SWP) Operations Support Office and is responsible for the safety and performance of all SWP dams and their appurtenant structures. Their specific activities include dam inspections (including but not limited to FERC

Part 12); instrumentation and surveillance; managing the SWP seismic monitoring program; coordinating SWP dam remediation projects; and providing guidance to the field divisions on operating and maintenance practices that affect dam integrity and performance.

The DWR Owners Dam Safety Program (ODSP) organization chart seems to indicate that all engineering (design and construction support) is the responsibility of the Office of the Chief Division of Engineering. No apparent tie or reporting responsibility exists between the Chief Dam Safety Engineer (CDSE) and the Engineering Division. Both the Chiefs, Division of Operations and Maintenance and Division of Engineering report to the Deputy Director, SWP. So, it would appear that the CDSE's role is largely that of compliance. It is curious to note, however, that the project compliance function resides with the Hydropower License Planning and Compliance Office, which also reports to the Deputy Director, SWP. Therefore, in assessing the organization chart for the Oroville Dam project, it can be concluded that the CDSE has little influence over any project decisions, save for those involved with inspections and surveillance. The FAAP believes that functionally the CDSE and the FERC Compliance Coordinator should be aligned more directly with the Office of the Chief Division of Engineering to effectively respond to FERC OSDP Guidelines.

- c) **Training:** Training outlined for DSB engineers has been identified in the following areas; USBR Safety Evaluation of Embankment Dams (SEED); Association of Sate Dam Safety Officials (ASDSO) and American Society of Civil Engineers

(ASCE) conferences and webinars; USBR dam operator training; and various DWR In-house training courses. There is no mention of FERC sponsored training such as Part 12 Inspections for owners; Risk Informed Decision Making, etc. Also, of note is that this training for DSB Engineers largely focuses on inspection and monitoring, rather than engineering evaluations.

- d) **Record Keeping**: The ODSP indicates almost all engineering documents must be kept for the “life of the facility”. The DSB is responsible for this activity and storage is accomplished by hardcopy and electronic copy. These records should include design, as-builts, and maintenance documents. It should be noted that some of these documents were not located for this investigation.
  
- e) **Succession Planning**: The ODSP summarizes succession planning steps for DSB staff, senior, and supervising engineers, but is silent on how these functions are related to succession planning for the CDSE. For example, we see no position such as a Deputy CDSE from which a qualified candidate could step into the CDSE role when needed. Furthermore, a lot of the qualifications seem to be tied toward successfully passing different levels of civil service exams, rather than on experience directly applicable to evaluating and managing the risks of major dams.
  
- f) **Assessments and Audits**: Internally assessments are conducted annually by the O&M Chief and his staff through review of various documents to confirm compliance commitments are being met. The success of such endeavors is

measured by the success rate in meeting compliance deadlines related to FERC Part 12D reports and initiatives; inspection reports; and specific internal DWR schedules. Training is also considered and is the responsibility of the CDSE. Independent dam safety audits are conducted by third-party consultants with dam safety expertise on a 5-year interval but remain separate from the FERC Part 12 D and State Dam Safety Review Board (DSRB) cycle. Thus far, we don't believe any ODSP audits have been conducted for Oroville.

g) **Conclusion(s):** This ODSP is set up to ensure compliance with any and all FERC directives. Therefore, we would deem this program to be a compliance program, rather than a safety program. Little information in the plan offers any of the following:

- i. How would the DWR investigate various aspects of dam safety related to the SWP if a particular concern were not raised by FERC or DSOD? Who would be responsible? Who would direct the work? And more importantly, who would be responsible to determine the proper mitigation (if required), report it to upper management (Director, DWR) and take it through to completion. Furthermore, the plan lacks any discussion of how DSB engineers would be encouraged to look into various aspects of the dams they inspect and monitor. This may have been a key issue with regard to how the incident at Oroville was allowed to happen.

- ii. The CDSE should be an experienced dam engineer with responsibility of assuring the owner / licensee's dams are safe. Part of that responsibility is to assure that the design of new dams and the modifications of existing dams and appurtenant structures meet or exceed standards in use by the profession. It is hard to see how that is accomplished with the DWR CDSE's responsibilities and reporting structure so far removed from the actual engineering being performed at DWR. Further exasperating this issue is the almost complete absence of participation of the DWR CDSE in the design and rebuilding process currently on-going for the Oroville spillways.
  
- iii. Per FERC's definition and their guidelines, the CDSE of such a large organization whose projects have an extreme impact on the safety of large downstream populations, should have significant and proven experience before being allowed to be in the CDSE position. We see no opportunity for that mapped out in the Oroville Dam ODSP. Furthermore, we see as a missed opportunity, the participation of the CDSE in the current re-build project could have offered an opportunity for another qualified engineer to sit in as temporary CDSE in the interim learning about the position and building DWR's bench strength for response to possible future incidents. However, since the CDSE has apparently gone on with his normal duties and has not been significantly involved in the current project, this training opportunity has essentially been missed.

h) **Project Certifications by CDSE:** Standard FERC procedures for project design or modifications now includes the requirement to submit notarized documents that attest to the completion of the project on the basis of 3 guiding principles: 1) The project scope has been carried out without significant changes from that agreed to with FERC. 2) The project has been designed and built to conform to industry standards consistent with FERC Engineering Guidelines and other applicable documents. 3) The project has been constructed in accordance with the drawings and specifications approved by FERC and other agencies as applicable. These documents must be certified by the CDSE or his authorized representative prior to submittal to FERC. If the CDSE has not been involved with the project, as we are seeing in the current project execution at Oroville, we cannot see how this requirement could be fulfilled, without delegating this responsibility to others.

#### **4.0 SUGGESTIONS AND RECOMMENDATIONS TO IMPROVE THE PART 12 AND PFMA REVIEW PROCESSES**

While the FAAP acknowledges that every dam owner must face the inevitable trade off of spending budget dollars on engineering studies and safety improvements against fixed generation (thus income and profit). It is the opinion of this panel that all those involved, Regulators, Owners, and their Consultants have an obligation to understand these facilities and their potential impact on the safety of the public and infrastructure downstream. Therefore, there should be motivation toward achieving adequate safety, rather than a complacency tending toward achieving compliance instead of project safety.

The Owner and the Part 12 IC's hold the ultimate responsibility for project safety and must assure that there is sufficient knowledge to make informed decisions to reduce risk.

#### **4.1 Observations Specific to Oroville Project**

It is now evident that the problems with the Oroville Spillway chute slab have been ongoing since the project was commissioned in 1967. In general, the FAAP has found the following shortcomings related to the Oroville Dam Part 12 process. These shortcomings, although gleaned from a review of the Oroville documentation, including the IFT report, may be significant to other Part 12 dams as well:

1. There was an overall lack of rigor in the performance of the Part 12 reviews and their follow up. Too much emphasis seems to have been placed on the process and not enough on detailed engineering reviews aimed at understanding the performance of critical structures. Examples of which are:
  - 1) Over reliance on previous analyses without reviewing whether such analyses were appropriately representative and used tools and methods that would satisfy current (at the time of evaluation) state of the art. In that context we note that some of the original analyses could not be located by the owner, DWR, until prompted by the 2014 Part 12 review;
  - 2) The apparent contradiction between the poor geology actually mapped along the spillway chute during construction, and the statements in the part 12 and PFMA reports that the rock along the chute was very competent;
  - 3) The lack of urgency/ concern about the very large outflows from the spillway chute drains throughout its operational life.

2. There was a gradual loss of institutional memory because of normal replacement of personnel in key positions, and the lack of a rigorous maintenance of valuable instrumentation data. As an example, flow measurement records for the spillway drains at Oroville could not be located as were some of the original design analyses and calculations.
3. There appears to have been a lack of critical thinking in the implementation of the Owners Dam Safety Program as evident by the apparent lack of involvement of the CDSE in anything beyond surveillance and inspections programs, i.e. license compliance activities. Thus, it seems that this job became an "administrative" task after several years of successful, trouble free operation even though the operational conditions did not come close to the upper limits operational capacity. At Oroville, outside of 'routine maintenance', it is apparent that DWR did only what the FERC and DSOD directed; wrongly assuming, in the FAAP's opinion, that regulatory compliance was equivalent to safety.
4. A contributing factor was an apparent lack of recognition and appreciation of the probability and consequences (i.e. risk) in the evaluation of the FCO chute and ES failure modes and a lack of rigor in reviewing existing project documents. Specifically, even though DWR conducted an extensive PFM analysis in 2009 and then in 2014, the potential failure of the FCO chute was dismissed due to an assumed low probability of occurrence because it was founded "on solid rock", although construction data, including photographs, documented the presence of shear zones and erodible clay material below the

- chute slab. Similarly, the potential for failure of the Emergency Spillway and the impact of potential erosion was repeatedly dismissed outright, based on the assumption that this structure would be used only in the rarest of circumstances (i.e. very low probability) but not necessarily a low risk event, as amply demonstrated.
5. Another factor in the apparent low effectiveness of the Part 12 and PFM analyses may have been the fact that in case of Oroville only one Part 12 safety inspection report was required for a project with multiple large dams and other critical infrastructure. Thus, the sheer volume of project data may have led to a cursory review process in order to concentrate on perceived “critical” aspects of the project. Therefore, future Part 12 and PFMA evaluations should be confined to the Oroville Dam project elements that impound the Oroville Reservoir, specifically the ES, FCO, FCO Chute, Oroville Dam Proper, Bidwell Bar Saddle Dam, Parish Camp Saddle Dam and the Oroville Hyatt Power House. Thermalito structures should be separated out and evaluated by other IC’s in another Part 12 D Report.

#### **4.2 Recommendations for Improvements in the FERC Part 12 Review Guidance**

In recent years, there has been a number of dam safety related incidents all or most of which could be tied directly to design and operational deficiencies not detected in the Part 12 review process. Therefore, it should be noted that this oversight appears to be of a systematic or cultural nature that needs to be somehow overcome through direction by

FERC to motivate dam owners to dig deeper for a better understanding of their structures and operational risks. Thus, the FAAP believes that following modifications in the Part 12 review process on FERC's part are warranted. To achieve this goal the FERC should convene an Independent Board of Consultants to act as a Dam Safety Engineering Review Board (DSERB) for the FERC, with the on-going charge of reviewing the Part 12 program, assessing the performance and offering suggested improvements. The FERC DSERB would be comprised of one prominent individual from their respective fields of; Engineering Geology, Geotechnical Engineering, Structural Engineering, Construction Specialist, Hydraulic Engineering and Hydrology. One of the DSERB Members should have been involved in the aspects of dam safety/design/remediation from an Owner's perspective. The DSERB should have a minimum of 5 members, with a greater number at the discretion of FERC to allow some overlap in the disciplines and to ease scheduling constraints. Each member would be seated on a rotating basis for a period of 5-10 years; thus, the DSERB could evolve over time rather than remain stagnant. The FERC DSERB program could work as follows:

- a) Each year, FERC would select each year a small number of significant, high hazard dams (5 – 10) in their portfolio that have recently completed the Part 12 process (including review and approval by FERC).
- b) FERC would then engage the DSERB to review the selected Part 12 reports and develop recommendations based on the results of the reports. The FERC could then direct the owners to attend a review meeting with FERC and the DSERB wherein the Owner and/or IC would present their Part 12 report and discuss results and conclusions. By doing this, a meaningful dialogue between the FERC and the

owner / licensee could very well result in positive motivation leading to a better understanding of the project on both sides. The discussion should focus on some or all of these topics:

- Review of original the design intent
- Review of hydrology/hydraulics
- Review of geology
- Detailed review of calculations on stability of the dam and appurtenance structures, such as spillway chutes and gate structures
- Comparison of design drawings versus “as built” conditions
- Review of construction and maintenance records
- Evaluation of instrumentation data from construction to date to assess if pertinent parameters, indicative of behavior are being monitored, and detect potential trends. Survey results and piezometer readings are very important.

#### **4.3 Recommended Guidelines for Part 12 Review Process**

- a) Given the above, FERC D2SI (Washington, DC) should issue a set of priority topics to its regional offices to be addressed in all Part 12 reviews. This would set a more uniform, process across FERC for evaluation of key elements of each project that must be addressed in a Part 12 report. In that context, the STID for all dams should include complete copies of all engineering reports in order of importance, as follows:

- Priority 1: Static Stability Analyses: Static stability analysis that clearly show assumptions, geometry of cross section, loads applied, and results. The analysis should as a minimum provide knowledge of the inherent margin of failure and NHWL based on working and ultimate strengths of the materials.
- Priority 2: Surveillance Data: This section should properly document the physical behavior of the dam. Any unusual findings should be highlighted and dealt with on a priority basis.
- Priority 3: Strength of materials and available surveillance information. The report should document the behavior of the dam and foundation materials. It should also document surveillance items such as piezometric levels and uplift pressures.
- Priority 4: PMF studies: The report should include engineering assessments as to the reliability of the operating equipment (gates and valves) under normal conditions.
- Priority 5: Evaluation and documentation of the dam stability under flood loading condition. It should give results in terms of strength mobilized versus strength of materials; thus, giving an accurate depiction of margin against failure for this case.
- Priority 6: Evaluation and update of the seismicity for the project.
- Priority 7: Stability analyses for the seismic and PMF loading cases based on the most recent studies that are deemed appropriate.
- Priority 8: Structural analysis of all ancillary structures.

- b) To overcome the potential effects of the “Silo” mentality that isolated and still isolate the design and construction departments in projects, the “as built” structure should be evaluated to make sure that it meets the design intent. Furthermore, all parties involved in the Part 12 reviews/PFMA process or who are involved in remediation, operation and maintenance should be aware of the original design and operational intent of the project components and changes made during original and subsequent construction activities.
- c) The number of voting participants in the PFMA exercise should be limited, preferably to the immediate parties that bear the responsibilities if an incident were to occur. Furthermore, there should be a greater recognition that the Part 12 ICs can and should have the final authority as to how the failure modes are vetted in the PFMA.
- d) FERC engineers should concentrate on Dam Safety issues and proper review of auxiliary/ancillary structures. This could be accomplished by creating a separate FERC division solely responsible for security aspects and other non-dam safety issues.
- e) Licensees/Owners often designate repair work items to project structures as “routine maintenance”. These items that are designated as “routine maintenance” should undergo a rigorous review process to determine if they truly fall under that category or if the proposed work is a significant modification or improvement for the function of a particular structure related to safety. For example, the maintenance of the Oroville Service Spillway chute was considered “routine maintenance” and thus it was possible that FERC did not receive a repair plan to review and did not

actively press DWR to provide a plan for FERC review when it was referred to as “maintenance”. Although FERC at one time urged DWR to map the different crack locations and determine whether or not these “localized repairs” were signs of other more impending issues, there was apparently not adequate follow up in that regard by either FERC or DWR. To eliminate this from happening, the Licensee/Owner should submit to FERC all repair work items prior to the start of the repair work so that the FERC can review and comment on the adequacy of the planned work.

Finally, we recommend that, in addition to the Part 12 Safety Inspections and Evaluations, FERC develop a list of the highest dams and spillways which could be of significant hazard to downstream populations, independent of dam type.

For each of these highest hazard dams FERC should assign a team of FERC engineers to conduct FERC annual inspections. This engineering team should be supplemented with outside individual consultants with appropriate experience to provide additional expertise needed to evaluate these critical projects. These evaluations would provide FERC with an independent assessment in addition and separate from the Part 12 Safety Inspection Report evaluations. This process would permit FERC Engineers to gain experience and improve their ability to supervise the Part 12 IC’s and to participate more effectively in the PFMA exercises of the Part 12 process. In addition, this approach would provide an invaluable opportunity for training of FERC’s staff and upgrade their level of expertise. In addition, along the lines of mentoring and succession planning, the FAAP would recommend that on certain projects, practical institutional knowledge could be

relayed to younger staff in a working environment in the form of utilizing experienced individuals or retired FERC Engineers as consultants to the present FERC D2SI staff.

Furthermore, the entire FERC D2SI may benefit by having a yearly internal conference where presentations can be given to attendees from all regional offices, of certain case histories that would be instructive on particular technical, operational or remediation issues.

Respectfully submitted,

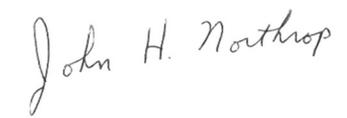
The FERC After Action Panel Members,

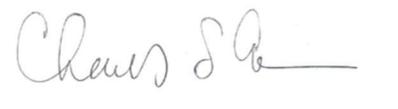
  
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