STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY

EDMUND G. BROWN JR., *Governor*

DEPARTMENT OF WATER RESOURCES
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MAY 09 2017

Honorable Eduardo Garcia
Chair, Assembly Water, Parks & Wildlife Committee
State Capitol, Room 4140
Sacramento, California 95814

Honorable James Gallagher
Vice-Chair, Assembly Water, Parks & Wildlife Committee
State Capitol, Room 4140
Sacramento, California 95814

Dear Messrs. Chair and Vice-Chair:

I appreciate your interest in the on-going actions of the Department of Water Resources (DWR) relating to the February 7, 2017 emergency at the Oroville Reservoir Spillway, and the State's response since that date as well as the recovery plan. Your April 19, 2017 letter accurately described the situation at Oroville as highly dynamic; however, in acknowledgement of the important oversight role held by the Legislature, DWR personnel have endeavored to quickly compile the most up-to-date information in the responses. Please accept this letter as an introduction to the attached responses to those questions.

The attached packet if information includes several parts. First, a narrative responses to the questions posed in the April 19 letter; second, two attachments identifying inspection dates of the Division of Safety of Dams and the Federal Energy Regulatory Commission (FERC) over the past decade and a half; third, copies of the correspondence between DWR and FERC relating to the Board of Consultants and the investigative team of experts; and finally, a table of the last ten years of Operations and Maintenance costs of the State Water Project. I hope you find this information useful.

Should you have any questions concerning this letter or the information, please contact Kasey Schimke, DWR's Legislative Director, at (916) 653-0488.

Sincerely,

William A. Croyle
Acting Director

cc: Honorable Susan Eggman, Chair, Assembly Accountability and Administrative Review Committee
Honorable Richard Bloom, Chair, Assembly Budget Subcommittee #3
Catherine Freeman, Assembly Water, Parks & Wildlife Committee
Scott Herbstman, Assembly Accountability and Administrative Review Committee
Rachel Ehlers, Legislative Analyst's Office

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SPILLWAY INSPECTIONS

1. How often were the Oroville spillways (main and emergency) inspected, and what is done during a typical inspection?

Inspections are performed at regular intervals, describe below, by four separate groups: the Federal Energy Regulatory Commission (FERC), the California Division of Safety of Dams (DSOD), Department of Water Resources (DWR) engineers and independent FERC part 12D inspectors. A description of each is outlined below:

- **DWR Operations Staff Monthly Inspections / staff walk-downs**

  Inspections are performed by field division staff on a regular and routine basis. The staff collects instrumentation data during these inspections and views the structures more closely to detect any unusual conditions. The focus on these inspections is to detect unusual behavior and report that to the Dam Safety Group for follow-up should any anomalies be observed.

  Additionally there are observations made by field division staff as they patrol the dam and appurtenant structures on a daily basis. These observations do not qualify as inspections but they serve the purpose of providing early indications of any abnormal structural behavior. Abnormalities such as unusual seepage patterns including wet spots, unusual hydraulic patterns from discharge structures, structural defects such as cracks, offsets or embankment slips or bulges are the nature of things that might be identified through this activity.

- **DSOD Inspections**

  DSOD inspects the dam annually for the purpose of making visual observations to detect any indications of abnormal behavior of the dam. The primary focus of these inspections is on the condition of the impounding structure (embankment or concrete dam), abutments, spillways, low-level outlet, seepage conditions and instrumentation. DSOD is looking for any signs that the dam may be operating differently than expected, deterioration of any of the structural components and routine maintenance that may be needed. This inspection includes a review of the monitoring data collected by DWR operations personnel (discussed in previous answer), including the core block flow rate, toe drain, piezometers, inclinometers or other precise survey information. Following the inspection, a written report is prepared by DSOD and will make a finding and statement whether the dam is safe for continued use.

- **FERC Inspections**

  FERC also inspects the dam annually. FERC's scope also includes other parts of the hydroelectric project that are not under the jurisdiction of DSOD. The result can be that the dam is inspected twice annually, once each by FERC and DSOD. The FERC inspections of the dam include the same components as DSOD, including spillways and the instrumentation discussed previously. FERC also prepares a comprehensive written report following the inspection and, if necessary, issues a letter requesting any follow-up requirements of the owner (FERC nomenclature is Licensee).

- **FERC Part 12D and DWR Director's Safety Review Board Inspections**

  FERC and DSOD jointly conduct comprehensive dam safety reviews and inspections once every five years. This work is performed by Independent Consultant (IC) boards proposed by DWR and approved by both FERC and DSOD. These projects typically span many months of work that begins with a review by the ICs of existing technical documents, dating from initial planning, design and construction and also include all documents and technical reports following construction. Presentations to the ICs are typically made by DWR staff prior to the inspections. The presentations

include a review of surveillance monitoring, dam performance, and significant dam safety projects performed since the last five-year inspection. The comprehensive Part 12D inspection report is prepared and filed with FERC and DSOD. The Part 12D report contains statements by the consultants that the dam is safe for continued use and also makes recommendations for conducting required maintenance, repairs, or technical studies for reevaluations that may be needed.

2. Who performed inspections on the main spillway and emergency spillway and what were the dates of these inspections? Did any inspections reveal weaknesses or instability in the concrete of the spillway? Please provide copies of all available inspection reports.

- See answer #1 regarding who inspects.
- A table of DSOD inspections from 2008 through 2016 is included in **Attachment A-1**. The DSOD reports can be found on DWR's website here: http://water.ca.gov/oroville-spillway/index.cfm. A table of the dates of FERC's annual inspections and the FERC Part 12D inspections is located in **Attachment A-2**.
- No, there were no weaknesses or instabilities identified. Regularly-performed inspections do identify general maintenance issues such as the need for resealing of cracks or re-grouting of seams, or the need to address wear of the concrete surface. None of these are considered instabilities, and at no time has DSOD or FERC reported that the dam or its structures are unsafe for operation.

3. What is the geology beneath the main spillway? Was geological testing done at any point prior to construction of the main spillway and emergency spillway? What did that testing reveal, and was anything done to address geotechnical issues prior to construction?

- The geology in the vicinity of the Oroville Dam and spillways consist of Jurassic meta-volcanic rocks of the Smartville Complex. The meta-volcanic rocks are primarily amphibolite exhibiting varying degrees of weathering. The rock has prominent foliation in approximately the North-South direction, with shears, joints, and fractures crossing the foliation in approximately the same orientation as the main spillway. The intersection of these features creates the stair-stepped pattern visible in the steep cliffs adjacent to the spillway. Lower angled fractures and shears intersect the rock and lower angles (30 to 40 degrees) dipping both towards and away from the reservoir.
- Yes, geologic exploration and evaluations were completed between 1957 and 1964, prior to construction of the dam and both spillways. The following exploration methods were completed prior to construction of the spillways: geologic mapping of rock outcrops; drilling of about 40 rock core borings in the vicinity of the gated and emergency spillways; conducting about a dozen seismic lines; and excavating many shallow dozer trenches. The geologic exploration prior to construction revealed amphibolite rock of varying degrees of weathering. Where rock was fresh and not weathered, the rock was hard and tough. Where rock was heavily weathered, the rock was soft. A few areas of deep weathering were found, but generally the depth of heavily weathered rock was estimated to be about 15 to 30 feet deep.
- There were two alignments proposed for the gated spillway; ultimately, the current spillway location was chosen because the geologic conditions appeared to be more favorable. During construction of both spillways, there were several areas that were over-excavated where heavily weathered rock was encountered. Where it was not practical to remove the weathered rock, provisions were made to stabilize such zones using rock bolts or other protection measures.

- To summarize, extensive geologic exploration and analyses were completed prior to construction. The geologic and geotechnical issues arising from the analyses were provisioned for during final design and construction.

4. After construction, has there been further testing of the geology below the emergency and main spillways? If so, what did this testing reveal and what was done to address any geotechnical issues after construction?

- During construction, DWR geologists mapped the rock foundation's composition, degree of weathering, and geologic structure (fractures, joints, and shears). Since the spillways were constructed in the 1960s, one geologic rock core boring was completed in September 2016. This hole was located downstream of Monolith 18 in the emergency spillway, and was drilled for the purposes of obtaining shear wave velocity of the amphibolite rock. The drill core revealed about 18 feet of gravelly fill on top of very hard, grayish green amphibolite down to a depth of about 150 feet. The amphibolite rock had a P-wave velocity ranging between 9,500 and 18,000 feet per second. P-wave velocity is a measurement of rock density, and 9,500 to 18,000 feet per second is an indicator of dense, competent rock. An observation well was constructed in this hole, but had to be filled with grout during the emergency actions in February 2017. Additionally, as part of the independent forensics team's investigation of the cause, numerous core samples will be evaluated for usable data.

5. How extensive were any repairs to the main spillway? What were the most recent repairs to the spillway and how much did those repairs cost?

- Repairs to the gated flood control spillway structure floor slab were done in 1997 and 2009. Repairs to the spillway chute slab were also made in 1977 but appeared of a more minor nature, primarily replacing joint filler material. The contract amount for 1997 was $340,000 and for 2009 it was $776,000. Typical work under both contracts included infilling of cracks; and more extensive repairs to spalls (flaking of concrete due to wear) and deeper sections of damaged or deteriorating concrete by removal and replacement, by saw-cutting, chipping, reinforcing steel repairs and placement of new structural concrete. Overall, when excessive concrete cracks and deteriorated concrete were observed, repairs were undertaken to restore the integrity of the structure.

6. Several reports state that inspections in 2014, 2015, and 2016 found seepage on the face of the dam in addition to cracking around the gates of the main spillway. What was done to address issues found in these reports? Please provide copies of these inspection reports and any follow-up reports.

- The integrity of the Dam is not in question. Seepage is normal in all dams and can come from a variety of sources including reservoir water, groundwater from rock slopes above the dam, and infiltration from precipitation. Seepage from the reservoir and through the dam has been measured to be extremely low for a dam as high as Oroville. Seepage control measures built into the dam include a central clayey core that is almost completely impervious and rows of drill holes in the rock foundation that were grouted during the original construction to seal off joints or cracks in the rock foundation. Additional drill holes in the foundation collect some of the seepage that flows past the grout holes before it can enter the embankment fill above. In addition to the clayey core, drain zones within the dam embankment downstream of the core were placed to collect any seepage passing through the core. Seepage coming through the core or from the rock foundation downstream of the core is then channeled to a seepage collection system near the downstream

base of the dam where it is measured weekly by DWR staff. Since the original construction of the dam, this seepage has only been about 10 to 20 gallons per minute during the dry season, an extremely low value considering many dams have seepage rates of hundreds or thousands of gallons per minute. This seepage collection system also monitors the water level within the downstream portion of the dam and has found it to be very low – below the parking lot at the base of the dam and only a few feet above the river level immediately below the dam. Previous instrumentation systems in the dam have also confirmed the low water level measured by the seepage collection system.

- The inspection reports referring to seepage found on the face of the dam likely refer to one or more "*green spots*" that develop on the downstream face. The *"green spots,"* or vegetation, have been present at various times in the history of the dam, including before the reservoir was even filled. These areas are known to DWR and its inspectors and have been investigated by various independent boards, which have concluded the patches are due to rainfall in the soils of the dam.

MAINTENANCE AND OPERATION

7. Over the last ten years how much revenue has the department collected annually from the State Water Contractors for operation and maintenance of the State Water project. Please provide an annual funding breakdown for the SWP by contractor.

- Please see **Attachment C** for this response.

8. It is our understanding that the State Water Contractors are responsible for the maintenance and operation costs of the State Water Project. In 2012, DWR Director Mark Cowin commented that DWR did not have adequate resources to operate and maintain aging SWP infrastructure. How does DWR determine how much revenue is necessary for operations and maintenance? If more revenue is required, what is the process for increasing charges to the State Water Contractors?

- The 2012 statement by former Director Cowin was not in reference to funding deficiencies, rather the ability within the state pay structure to adequately retain employees within DWR's hydroelectric power utility trades and crafts classifications, which at that time was the result of significant pay disparities compared to other California water utilities. The Administration successfully resolved that issue later in 2012 with pay parity adjustments to make DWR compensation more competitive with its industry peers.
- DWR uses findings from its studies, routine monitoring, inspection, maintenance, capital, and regulatory compliance programs to identify, prioritize, and schedule operations and maintenance activities annually. These activities are developed into Annual Maintenance and Specialized O&M (capital) Plans based on the facilities' needs and availability of both internal and external (contractor) resources available to complete the work.

  These plans then form the basis for the operations and maintenance budgets which are compiled, reviewed, and costs allocated to the appropriate stakeholders based on Facility Project Purpose and Proportionate Use Factors. These are all reported in Bulletin 132: Managing the California State Water Project, found here: http://www.water.ca.gov/swpao/bulletin_home.cfm. The DWR Director approves the planned charges to the SWP contractors as outlined in the Long Term Water Supply contracts. These charges are updated annually and billed to the SWP contractors in the Statement of Charges. Should unforeseen costs arise, DWR has authority to submit supplemental bills to cover the costs.

9. What is the average annual expense for maintenance and operation of the Oroville Dam? Please provide a breakdown of how these maintenance and operation funds are spent at Oroville Dam.

- The average annual cost for operating and maintaining Oroville Dam and its appurtenances including Hyatt Powerplant is approximately $20 million per year over the last 5 years. These costs include staff, contractors, and materials as needed to monitor, inspect, operate, maintain, repair, perform studies, and coordinate those activities with our dam safety regulators (Federal Energy Regulatory Commission and California Division of Safety of Dams) that DWR funds. Numerous dam safety studies performed on the dam include evaluations of current condition of the dam, spillways and other features, maintenance, operations, structural integrity, and natural hazards such as hydrology, seepage, faulting, and seismicity.

  In addition, DWR has invested over $30 million per year over the last 5 years in capital improvements to the dam and power plant. Notable projects include work on the spillway radial

gates, refurbishing the dam's low-level outlet system, refurbishing Hyatt PP generating units, and modernization of Hyatt's fire systems with over $100 million in additional capital improvements planned for the next 5 years.

It is important to note that the costs identified above do not include the costs of the Thermalito Powerplant and its facilities, which are also part of the larger Oroville Hyatt- Thermalito Complex which necessarily operates as an integrated system. Operations & maintenance and capital costs of these associated facilities add over $50 million in annual investment to the overall Oroville facilities amounts cited for Oroville Dam, its appurtenant structures, and Hyatt Powerplant outlined above.

10. Prior to its failure, what was the expected life of the main spillway?

- It is unclear if a specific timespan was ever calculated for the gated flood control spillway, it is safe to say that, with past updates to its radial gates and regular maintenance, the expected life expectance would exceed 50 years of use.

  Civil structures such as modern dams are often referred to as "Monument Structures" and are considered as having a design life span often in excess of 100 years. Dams constructed in California are designed with codified structural factors of safety to prevent dam failure. However it is not uncommon for design/construction criteria changes to occur during a dam's lifespan (eg: seismic protections, materials, technology, etc.). If the factor of safety cannot be achieved under new analysis using updated criteria, then the dam may need remediation such is the case for Perris Dam, a state-operated dam that is nearly complete with a project to address seismic risks unknown at the time of its construction.

SPILLWAY FAILURE AND RESPONSE

11. Photos of the spillway taken on January 13th and January 27th appear to show discoloration and possible damage to the main spillway at the spot where the spillway started collapsing. Was this damage observed by DWR before February 7th, and what was done to address this issue?

- A forensic team of independent experts has been formed to study the root causes of the spillway failure, including the review of historic construction documents, inspection reports, post-incident geological surveys, and other documentation available, likely including available imagery such as is referenced in your question. These experts will be identifying the likely cause of the failure and DWR will not speculate about causes before their work is complete. The report will be provided later in 2017.

12. How much water was flowing through the main spillway at the time of failure? What is the spillway's maximum flow?

- On February 7 as water releases from the gated flood control spillway were up to 52,250 cubic feet per second (cfs). The gated flood control spillway has a maximum flow rate of 270,000 cfs at a full reservoir level of elevation 900. In the event of flood flows above that, it can pass flows in excess of 300,000 cfs. Both of these would exceed the capacity of downstream levees.

13. DWR stopped all releases after the damage was discovered on February 7th and eventually started releasing reduced flows. These releases were not enough to keep lake levels below the emergency spillway, and on February 11th water overtopped the emergency spillway. On February 10th DWR had predicted the emergency spillway would likely not have to be used. What lead to the decision not to operate the spillway earlier and at higher capacities? Why was DWR unable to predict that the emergency spillway would have to be used? Would an emergency fix have been possible while releases were stopped?

- Please see the following timeline following the damage to the gated flood control spillway, some discussion of the February 6-9 storm event, the forecasted versus observed inflow into the reservoir, the availability of Hyatt Powerplant, and the actions taken during this period. DWR is still in the midst of responding to the spillway failure and, as such, this timeline is based on the information available to date.
  - **February 8:** In collaboration with FERC and DSOD, DWR decided to run a short duration flow of 20,000 cfs down the damaged gated spillway to monitor further erosion. The spillway was re-inspected to find the initial damaged area had essentially doubled in size. As a contingency, crews from CAL FIRE and DWR began preparing for possible use of the emergency spillway by clearing the hillside of trees, rocks, and debris to the extent feasible as well as grouting and shotcreting some areas. DWR activated four 24/7 emergency interagency operations centers to study and implement responses to flood control spillway and related structures, carefully monitor weather forecasts, and coordinate operations going forward. As gated flood control spillway releases were resumed and initially ramped above 20,000 cfs, significant headward (uphill) erosion occurred as well erosion downslope towards the diversion pool. DWR, FERC, and DSOD engineers and geologists believed this would happen, but were uncertain how far upslope the erosion and damage would go. This was the primary concern at the time because if the erosion got too close to the gate control structure, preventing its use, the gated spillway would

have to be shut down and all future flows throughout the Spring would be uncontrolled over the emergency spillway. At the onset of the February 6-10 storm the reservoir had its full 750,000 acre-feet of empty space intended for flood storage. Engineers and geologists monitored the gated flood control spillway around the clock with personnel on site, as well as video from ground and drone-based cameras.

- **February 9:** Upslope erosion of the gated spillway chute had been initially severe upon re-operation on February 8, but appeared to be stabilizing some 400 feet upslope from the initial damage on February 7. DWR, FERC, and DSOD were cautiously optimistic that releases down the gated spillway chute could be increased. DWR ramped up gated spillway releases to 35,000 cfs and then 45,000 cfs, high enough to avoid spilling over the emergency spillway while utilizing all of the available flood reservation space in Lake Oroville. However, by 8 pm the forecast had changed by more than 25 percent from the previous forecast just 6 hours earlier. In response, DWR, FERC, and DSOD agreed to increase gated spillway releases in an attempt to avoid an emergency spillway release. At the same time, outflow from the Hyatt Powerplant was halted because debris buildup below the damaged spillway caused water to back up into the diversion pool thus raising water levels near Hyatt Powerplant. These elevated water levels near the generating turbine outlets, known as the tailrace, precluded DWR's ability to safely operate the power plant. DWR continued, as a contingency, to prepare for use of the emergency spillway. An additional concern emerged as the upslope erosion along the gated spillway was within approximately 100 feet of Tower #4 of PG&Es Table Mountain 230kv transmission line which serves Hyatt Powerplant. It is estimated that a loss of this tower would likely have caused a cascading failure to a multitude of adjacent towers, thereby impairing outflow capabilities at Hyatt Power plant for months.
- **February 10:** Releases down the damaged gated flood control spillway were increased to 55,000 cfs hours after midnight and then to 65,000 cfs. This operation, in response to the peak inflow of over 190,000 cfs that occurred late on February 9, was designed to reduce the likelihood of using the emergency spillway through combined outlfow and utilizing all of the available Lake Oroville flood storage space below the emergency spillway crest. The precise nature of this operation (leaving no buffer for forecasting error) represented a balancing of two risks: 1) potential spill over the emergency spillway; and 2) the risk of severely damaging all controlled outlet capabilities of the Dam with higher gated spillway releases (the gated spillway chute and the Hyatt Powerplant). The risk associated with both was perceived to be roughly equal at the time. As a safety contingency, emergency spillway preparations continued. In addition, as tailrace water elevations reached historically high levels, DWR crews shifted work at the Hyatt Powerplant to emergency flood fighting preparations inside the plant. This effort was critically important to prevent flooding of Hyatt Powerplant, which would have rendered it inoperable for up to a year or more and thus significantly limiting DWR's ability to manage lake elevations as well as to meet all beneficial water use releases from Lake Oroville including those to support Delta water quality, senior water rights, and endangered fish in the Feather River for an extended period of time – the consequences of which would be devastating to the aforementioned resources. With DWR assistance, the California Department of Fish and Wildlife evacuated millions of baby salmon from Feather River Fish Hatchery in Oroville, California to nearby fish ponds at the Thermalito Afterbay Hatchery Annex. A stall of the trailing edge of the storm over the Feather River watershed increased the total storm volume just enough so that by late on February 10, 2017 it was apparent water would flow over the emergency spillway for the first time in the operational history of Oroville Dam.

- **February 11:** As the runoff from the largest storm in twenty years (which would total more than one million acre-feet since February 6) slowly receded, Lake Oroville's level rose above 901 feet. At approximately 8:00 a.m., water flowed over the lip of the 1700-foot-long concrete weir, engaging the emergency spillway for the first time in the facility's 49-year history. Observation and monitoring of the emergency spillway and flows down the hillside to the diversion pool were carefully performed by engineers and geologists on the top of Oroville Dam, and other locations deemed safe inspection vantage points as well as through the use of drones.
- **February 12:** In mid-afternoon, anticipated erosion began progressing faster than previous observed rates near the top of the slope beneath the emergency spillway crest. After conferring with DWR, CAL FIRE, FERC, and DSOD on risk this erosion posed to a portion of the emergency spillway crest structure, the Butte County Sheriff's Office issued mandatory evacuation orders for the Oroville area, as did cities in Yuba and Sutter Counties. To more quickly cease flow over the emergency spillway, the flood control spillway outflow was increased to 100,000 cfs. At approximately 8:00 p.m., the lake level dropped below 901 feet and flows over the emergency spillway stopped. Erosion to the emergency spillway hillside was assessed via aerial and direct inspection.
- **February 12 to 15:** Flows through the flood control spillway of 100,000 cfs was maintained to lower the reservoir as fast as possible. Hyatt Powerplant remained inoperable due to the water level backed up behind the debris field. The slab failure appeared to stabilize thus allowing sustained flow.

14. Please provide a timeline of operation and water releases of the gated spillway from February 7th- February 15th. Please provide an explanation for any changes in flow.

- See answer #13.

15. When/what time was the critical erosion of the emergency spillway first noticed? To whom was this reported? When were local agencies notified of a potential danger?

- Erosion below the emergency spillway was seen almost immediately on February 11th, as was expected. Observation and monitoring of the emergency spillway and flows down the hillside to the diversion pool were carefully performed by engineers and geologists on the top of Oroville Dam, and other locations deemed safe inspection vantage points as well as through the use of drones. On the afternoon of February 12, erosion downslope of the emergency spillway became more rapid. DWR had personnel positioned onsite monitoring all aspects of the emergency spillway flows, and this was reported to the Incident Command Post in Oroville. At approximately 4:30 pm, after conferring with DWR, CAL FIRE, FERC, and DSOD on risk this erosion might pose to the emergency spillway's concrete crest, the Butte County Sheriff's Office issued mandatory evacuation orders for the Oroville area, as did cities in Yuba and Sutter Counties. To more quickly cease flow over the emergency spillway, the main spillway outflow was immediately increased to 100,000 cfs then carefully monitored.

16. What are the Department's protocols for an emergency situation like the one at Oroville?

- When an emergency situation such as Oroville occurs, the Director declares a Department emergency, which he did do on February 7th the first day the spillway hole appeared. DWR has multiple Emergency Operations Centers (EOCs) to respond to disasters: Flood Operations Center (FOC), State Water Project Operations Center (POC), the Division of Safety of Dams Operations Center (DSOD), and the Department Operations Center (DOC). The DOC is only activated when the previous three EOCs are activated at one time. During a declared Department emergency for one of the State Water Project's (SWP) dams, an Incident Command Post (ICP) at the emergency site and all four EOCs are activated and all employees in the Department are put on alert status to be called to help in the emergency (as is their duty as a disaster public worker). The Department implements the Standardized Emergency Management System/National Incident Management System (SEMS/NIMS) in each of their EOCs which incorporates the use of an Incident Command System (ICS) to improve the flow of emergency information and resources within and between agencies, to help the coordination between responding agencies, and to track and ensure rapid mobilization, deployment, and use of resources.

  SWP facilities are regulated by FERC and require Emergency Action Plans (EAPs) to be prepared and to have periodic exercises be carried out to ensure readiness. When an emergency happens on a SWP facility, FERC is immediately notified and they may include a representative within the ICS organization structure, which they did at the Oroville ICP. Depending on the severity of the situation, DWR can also request help from CalOES, US Army Corps of Engineers, and/or FEMA (all of which occurred for this particular emergency).

17. The Federal Energy Regulatory Commission (FERC) has asked that the Department create an independent Board of Consultants (BOC) and a separate independent team to investigate the cause of the main spillway failure and to determine if such failure could occur again. Please provide copies of the Department's communication with FERC regarding this request. What is the timeline for the BOC's review and the forensic analysis?

- Correspondence between DWR and FERC concerning the BOC and the forensics team is provide in **Attachment B**, and can also be found at the following site: https://www.ferc.gov/industries/hydropower/safety/projects/oroville.asp
- The BOC review is on-going until the spillway recovery is complete. There will be on-going BOC reports throughout the review. Reports of the BOC can be found here: http://www.water.ca.gov/oroville-spillway/bocreports2.cfm.
- The forensic analysis is also underway. DWR is expecting information this month from the team identifying a number of potential causes – this memo will be made available once it is received from the forensics team. This list is intended to guide new construction, ensuring that these potential causes are addressed and/or prevented in the construction. The forensic team has the benefit of being a team of experts with multiple disciplines, reviewing all available information to come to a more detailed determination. The final report is expected in the Fall of 2017.

REPAIRS AND FUTURE OPERATION

18. With a large snowpack and the potential for more storms, how does the Department propose to manage flows this coming year before the spillway can be repaired? What restrictions does the Department face with respect to flood management and what is the maximum level the Department may lower lake levels to make room for spring runoff?

- DWR has evaluated the current snowpack conditions in addition to the potential weather conditions through the year. DWR also contracted with the Corps of Engineers to complete an independent risk evaluation regarding the operation of the reservoir through the construction period to November 1, 2017. Both DWR and the Corps of Engineers independently conclude the Hyatt Powerplant will be able to manage the reservoir releases through the powerhouse even at 60% of its total capacity. Spring runoff is not nearly as severe as winter storms and can be predicted more accurately. DWR is working with FERC and DSOD in consideration of the date to close the gates for the remainder of the year and will provide the exact date soon.

19. What kind of communication structure is in place to inform local officials and the public about dam operations?

- Early in the emergency, communication with local officials and the public was not smooth. Actions were happening quickly, information was coming in, and required, in many instances, evaluation with state and federal dam safety officials before actions could be determined and information communicated. As such, and while local emergency responders were quickly brought into the incident command post, implementation of a useful communication plan for the public was delayed. DWR Acting Director Bill Croyle held a press briefing on the afternoon of February 8th, another February 9th, and subsequently through the early weeks of the emergency response. DWR, along with its state and local partners, provided regular press briefings to keep the public informed. Additionally, Natural Resources Agency Secretary John Laird, as well as leadership within DWR, CalOES, and CalFIRE participated in daily calls with state and federal legislative members and staff with updates.
- As this incident has progressed, DWR has implemented a communication plan and other strategies to keep all stakeholders informed about the dam operations in addition to the progress of the recovery of the spillways. DWR's goals for the Oroville Spillways Recovery project are to provide accurate and timely information to elected officials, partner agencies and the public; to proactively provide stakeholders with the information that may impact their businesses or organizations; and to keep Oroville residents and visitors informed about impacts caused by construction and security so they can plan accordingly. Below is a list of the communication strategies that DWR is now using and/or plans to use.
  - **Community meetings**
    - DWR is conducting several series of community meetings in a variety of locations. We will engage in community outreach by holding seven meetings, beginning in Gridley on April 27 and concluding in Sacramento on May 15. Before each meeting DWR has been meeting with and briefing local elected officials.
    - Each meeting is videotaped, and the video will be posted on DWR's webpage. We will also livestream the meetings via Facebook when adequate wifi is available. With advance request, DWR provides ASL and other language translators, as well as other ADA assistance. (This offer is publicized in the meeting notices, and a few members of the public have taken advantage of it).

- We plan to conduct a series of community meetings again in June, and meetings will be held in late summer and fall.

- **Online resources**
  - DWR has a webpage dedicated to information about the Oroville spillways, which was recently updated to make it easier for the public to find the information. This website includes the detailed timeline information provided above.
- **Media relations**
  - DWR regularly provides information to the news media about construction activities, water releases, opportunities for public engagement, and more. These updates occur in the form of electronic media advisories or news releases, press briefings at project headquarters, media conference calls to augment the press briefings, interviews, etc.
- **In-language media outreach**
  - DWR provides information about the community meetings to local print and electronic media that serve people who do not speak English.
  - We plan to follow up with in-language radio in May and June to ensure that we effectively reach this important segment of the residential population in the region.
- **Paid media (advertising)**
  - DWR will continue to place display ads in local print publications to promote the public meetings. We plan to use paid media placements through the summer to provide residents current and accurate information.
  - We are working with Stott Outdoor to use a few electronic billboards near the Lake Oroville State Recreation Area to efficiently direct visitors to boat ramps and other facilities.
- **Social media**
  - DWR is expanding use of Twitter and Facebook to keep followers informed. We regularly post content that can easily be shared, to get the information to a broader audience.
- **Video content**
  - DWR regularly creates and posts videos about the construction activity, and to record news briefings.
  - Video content will be expanded to include brief statements or visuals related to tips for visitors and other information.
- **Information distribution**
  - DWR will send information to elected officials and other interested parties, to share with their constituents and audiences. These include newsletter articles, articles to post on websites, infographic(s) and photos.
- **Email and information hotline available**
  - DWR recently established a public information hotline and an email address. The hotline is currently in English, and other languages may be added as staff resources permit.
- **Community Advisory Meetings**
  - DWR actively participates in meetings that are managed by other organizations to engage residents and community leaders in decisions related to recreation, traffic, safety, and other issues.

20. To date, what repairs have been done to secure the emergency spillway? What is the cost of these repairs? How confident is the Department that the emergency spillway would remain stable in the event of another overflow?

- The emergency work completed up to now was considered temporary and was completed for the February through April 2017 time period should there have been unforeseen changes to weather or the main spillway's condition. DWR will be breaking out the site-specific costs associated with the emergency for FEMA documentation, but does not have this breakdown at present.
- While DWR does not intend to operate the emergency spillway, the emergency spillway will be able to pass 30,000 cfs by November 1 by placing a concrete cutoff downstream of the emergency spillway. Work will continue on the emergency spillway after November 1 which will continue to increase the capacity until it meets the previous design capacity of over 400,000 cfs.

21. We understand the Department may receive cost recovery from FEMA. To the extent that this funding doesn't cover repair costs, does the Department anticipate that the State Water Contractors will pay for the emergency repair work as well as the repair to the main spillway?

- All emergency costs at Oroville are being funded under the State Water Project's (SWP) existing financing authority. DWR is working with federal agencies to seek reimbursement via all emergency disaster relief sources available, though costs that are not covered by FEMA would be the responsibility of the SWP. While the State is working to secure federal assistance on this emergency, the SWP's financing authority allows DWR to defer passing emergency response costs to the SWP rate payers.

22. Is there a timeline and/or cost estimate for reparation of the spillway? Will the spillway have to be relocated?

- The current plan is to recover the emergency spillway and the main spillway in place. The plan's timeline calls for the gated flood control spillway to be able to safely discharge 100,000 cfs by November 1, 2017, and the emergency spillway to safely discharge 30,000 cfs also by that date. The project has three components, including the upper chute, lower chute, and emergency spillway.

23. What active steps is the Department taking to ensure the safety of downstream residents and the operational integrity of Oroville Dam/spillway? What is being done to prevent this type of dam crisis in the future?

- First and foremost, maintaining an operable flood control spillway is the necessary feature to protect downstream residents and their property. So far this year, notwithstanding its damaged condition, the flood control spillway has released twice the amount of water at any time from November through April – it has continued to provide residents with that safety. The recovery plan in place will further repair the existing spillway by November 1, it will utilize current design standards, and it will continue providing the reservoir with necessary protections for the future. The work to bolster the already-improved emergency spillway offers additive protections to those at the flood control spillway.

24. Will there be a review and inspection of other critical State Water Project infrastructure? Are there other state operated dams/reservoirs that could be similarly vulnerable to what happened at Oroville?

The Dam Safety Branch of the SWP's Division of Operations and Maintenance, at the urging of the SWP Chief Dam Safety Engineer, is pursuing comprehensive inspections tailored for each SWP dam spillway. The first spillway to be inspected is Pyramid Dam's gated control spillway. Due to similarity to Oroville spillway by spilling frequency and construction as a gated spillway, Pyramid was chosen to be the first to be inspected. The inspection will include DWR and consultant engineers conducting detailed visual inspection and mapping of the concrete slabs and walls as well as below grade inspections using non-destructive methods, specifically Ground Penetrating Radar and Echo Impact to detect voids and defects in or beneath the spillway invert. The Pyramid gated spillway inspection will occur in May with a completed report in July, 2017.

Concurrently, the Dam Safety Branch is developing inspection plans for other SWP spillways including the three Upper Feather dams (Grizzly, Antelope, and Frenchman), Pyramid's emergency spillway, Castaic, Cedar Springs, Del Valle, Bethany, and Perris. These inspections will be tailored based predominantly on construction, foundation geology, and geometry. Where feasible and warranted, remote operated vehicle inspections of spillway drains will be pursued. These comprehensive inspections are aggressively planned for this summer and fall, then into next winter and spring, if necessary and feasible.

Upon completion of the planned inspections, each SWP spillway will be hydraulically and structurally reanalyzed. Where warranted, the effort will include a reassessment of the foundation geology with possible additional exploration coring.

Finally, as you are aware, in February the Governor proposed new DSOD dam safety inspection actions as well as mapping and planning requirements on dam owners. These proposed actions would increase the level of inspections at ALL dams under State jurisdiction, ensure more accurate information concerning the risks to downstream residents from different types of emergencies at a reservoir complex, and make sure dam owners have developed a local emergency plan in the event of an emergency at the dam or its facilities. These statutory changes, that are awaiting action by the Legislature, would help not only state owned facilities, but also at the more than 1200 other dams in California under State jurisdiction.

Attachment A-1

Summary of DSOD's Maintenance Inspections for Oroville Dam for the last 10 years

			Inspection Type		Duration between inspections (months)	
Count	Inspection Date(s)	Period Covered	Primary	Secondary Inspection		Comment
1	01/14/08	FY 07/08		special periodic/follow-up inspection		This special Inspection of the spillway was made in advance of the primary periodic inspection
2	05/06/08	FY 07/08	periodic		4.0	
3	06/02/09	FY 08/09	periodic		13.0	
4	8/25-27/2009	FY 09/10	periodic		3.0	multiple day inspections
5	06/01/10	FY 09/10		2nd periodic/follow-up	9.0	
6	02/02/11	FY 10/11	periodic		8.0	
7	5/16-19/2011	FY 10/11		2nd periodic/follow-up	3.5	multiple day inspections
	NONE	FY 11/12	n/a	n/a		DSOD Inspection was originally scheduled but it was deferred due to scheduling conflicts and furloughs
8	1/08-09/2013	FY 12/13	periodic		19.0	multiple day inspections
9	7/15-17/2013	FY 13/14	periodic		6.0	multiple day inspections
10	4/10-11/2014	FY 13/14		2nd periodic/follow-up	9.0	multiple day inspections
11	06/18/14	FY 13/14		Additional follow-up: saddle dams only	2.0	Inspection findings are included with August 2014 inspection report
12	8/11-12/2014	FY 14/15	periodic		2.0	multiple day inspections
13	02/03/15	FY 14/15		2nd periodic/follow-up	6.0	
14	7/20-22/2015	FY 15/16	periodic		5.5	multiple day inspections
15	08/22/16	FY 16/16	periodic		13.0	

Attachment A-2

FERC Annual Inspections and Part 12D Inspections

Inspection	Inspection Date(s)	Participants
FERC Annual	4/26/2000 - 4/27/2000	O&M, DOE, FERC, SWPAO
FERC Annual	5/25/2001	O&M, FERC, DOE
FERC Annual	3/27/2002	O&M, FERC
FERC Annual	3/26/2003	O&M, FERC
Part 12D & FERC Annual	9/21/2004	O&M, FERC, Part 12D Board
FERC Annual	8/4/2005	O&M, FERC
FERC Annual	8/15/2006	O&M, FERC
FERC Annual	8/27/2007 - 8/28/2007	O&M, FERC, DOE
FERC Annual	5/6/2008	O&M, FERC, DSOD
FERC Annual	6/2/2009	O&M, FERC, DSOD
Part 12D	8/26/2009	O&M, FERC, DSOD, DOE, Part 12D Board
FERC Annual	9/13/2010	O&M, FERC
FERC Annual	5/16/2011	O&M, FERC, DSOD
FERC Annual	6/12/2012 - 6/13/2012	O&M, FERC
FERC Annual	7/15/2013 - 7/16/2013	O&M, FERC, DSOD
Part 12D & FERC Annual	8/11/2014 - 8/12/2014	O&M, FERC, DSOD, DOE, Part 12D Board
FERC Annual	7/20/2015 - 7/21/2015	O&M, FERC, DSOD, DOE
FERC Annual	5/24/2016 - 5/25/2016	O&M, FERC

Acronyms:
O&M – State Water Project Operations and Maintenance
DOE – Department of Water Resources Division of Engineering
FERC – Federal Energy Regulatory Commission
SWPAO – State Water Project Analysis Office
DSOD – Department of Water Resources Division of Safety of Dams

Attachment B

Correspondence with FERC regarding Board of Consultants and independent investigators (forensics team)

FEDERAL ENERGY REGULATORY COMMISSION
Office of Energy Projects
Division of Dam Safety and Inspections - Headquarters Office
888 First Street, N.E., Routing Code: PJ-13
Washington, D.C. 20426
(202) 502-6025 Office - (202) 219-2731 Facsimile

February 13, 2017

In reply refer to:
P-2100

Mr. William Croyle
Acting Director
California Department of Water Resources
P.O. Box 942836
Sacramento, California, 94236-0001

Re: Emergency Repair and Board of Consultants for Oroville Dam Spillway

Dear Mr. Croyle:

Major damage occurred to the Oroville Dam Service Spillway during spillway operation on February 7, 2017. This event and subsequent operations have led to the loss of a significant portion of the spillway chute, and has reduced the amount of available spillway capacity at the project. Ongoing service spillway operations may continue to lead to additional damage to the service spillway. Additionally, due to high inflows and reduced service spillway capacity, the ungated emergency spillway saw overtopping flow beginning on February 11, 2017, for the first time which resulted in excessive erosion threatening the stability of the structure on February 12, 2017. Due to the magnitude of this event and the potential for additional issues, we are requiring California Department of Water Resources (DWR) to initiate immediate design of emergency repair to minimize further degradation of both the emergency spillway and the service spillway. In addition, DWR shall convene an Independent Board of Consultants (BOC).

The BOC shall review and assess the:

1. Current measures being implemented at the project to pass inflows.
2. Current condition of the service spillway and adjacent areas of the project.
3. Current condition and capability of the Emergency Spillway to safely pass flood flows.
4. Risk reduction measures currently implemented and any additional risk reduction measures proposed.

5. Measures to keep the Powerhouse operable during the short-term and long-term.
6. All proposed remedial options for the service spillway.
7. All proposed remedial options for the emergency spillway.
8. Long-term, permanent modifications and project operations.
9. Any additional information or analysis requested by the BOC.

In addition, DWR shall perform a forensic analysis aimed at determining the cause of the chute failure and ascertaining if the failure mode could occur again. The forensic analysis must be performed by a fully independent third party with no previous involvement in assessing the spillway structure at this project. The BOC shall also be tasked to review and comment on this analysis.

Effort must be focused on emergency repair and risk reduction actions in the short term. The forensic analysis can not be allowed to interfere with or detract from the design of emergency repair or proposed risk reduction actions. However the forensic analysis must be performed.

The BOC shall review and assess all aspects of the forensic analysis to include:

1. Review of the plan of action describing the steps that will be undertaken for the forensic analysis, to include an analysis of the root cause and contributing causes of the spillway damage.

2. Project operations, before, during and after the event.

3. A thorough review of project documents, including the emergency action plans, Potential Failure Mode Analyses, Part 12D Independent Consultant Inspection Reports and the Supporting Technical Information Documents, should be included in the analysis. This review should include an assessment of how extreme flood flows are passed at Oroville Dam.

4. Any additional information or analysis requested by the BOC.

The BOC is to consist of at least 5 members with experience that covers the following engineering disciplines: structural engineering (with specialization in concrete spillway structures), spillway hydraulics, engineering geology, geotechnical engineering, and civil engineering with extensive experience in dam design, construction and operation. By letter, a copy of each proposed Board member's resume is to be submitted to the Acting Director, Division of Dam Safety and Inspections (D2SI) for review and approval, and two copies submitted to the D2SI-San Francisco Regional Engineer.

Due to the urgency to complete assessment and manage the current situation through the Spring, we will allow some flexibility on the requirements that follow. The operation of

each BOC will normally be as follows:

1. There will be formal meetings of the BOC scheduled to review the technical areas the BOC is required to assess. The meetings should be scheduled at important milestones for the investigations and design and construction of remediations. It is anticipated that the meetings will be attended by members of the BOC, DWR, DWR's engineering consultants, and FERC.

   The BOC should convene their first meeting as soon as possible to provide any potential input into the forensic analysis.

2. At least two weeks prior to each BOC meeting, DWR shall provide to the distribution list below a data package that contains:

   a) An agenda for the meeting;
   b) A statement of the specific level of review the BOC is expected to provide;
   c) A list of the items to be reviewed and discussed with the BOC;
   d) Investigations, engineering analyses, reports, and design drawings and specifications to be reviewed by the BOC; and
   e) A discussion of significant events in the investigation that have occurred since the last BOC meeting.

   The data package, as well as all project related correspondence, should be distributed as follows:

   a) One copy to each BOC member;
   b) Three copies to the D2SI-San Francisco Regional Engineer; and
   c) Three copies to the Acting Director, D2SI, Washington DC

3. At the end of each BOC meeting, the BOC shall verbally present their conclusions and recommendations and provide DWR a copy of the BOC meeting report. An electronic copy of the report should also be included.

4. Within 15 days after each BOC meeting, DWR must submit to the Acting Director, D2SI, and to the D2SI-San Francisco Regional Engineer three copies of a plan and schedule to comply with the BOC's recommendations or a statement identifying a plan to resolve any issue(s). In the event the BOC's recommendations are not implemented, detailed reasons for not doing so should be provided. We may require additional action after we review the above information.

5. A summary of all the BOC's recommendations is to be maintained in a periodic status report folder, indicating the BOC report in which the recommendation was made, and including the current status and outcome of each recommendation.

6. The BOC shall remain in effect through the design and construction of any required remediation.

7. The final BOC meeting is to be held one year after implementation of operational changes and completion of construction of any required remediation. The final BOC report shall assess the operation of the project and if the project is performing as intended based on the engineering investigations, design report, construction reports and instrumentation performance. Within 45 days of the date of the final BOC report, three copies are to be submitted to the Acting Director, D2SI, and the D2SI-San Francisco Regional Engineer.

You must submit resumes for your proposed BOC members and your proposed forensic team, and a plan and schedule for the required actions as soon as possible, but not later than 5 days of this letter. Please contact me with any questions.

Sincerely,

David E. Capka, PE
Acting Director, Division of Dam Safety
and Inspections

cc:
Mr. David Panec
Chief, Dam Safety Branch
California Department of Water Resources
P.O. Box 942836
1416 Ninth Street, Room 604-9
Sacramento, CA 94236-0001

Ms. Sharon Tapia, Chief
Division of Safety of Dams
California Department of Water Resources
2200 X Street, Suite 200
Sacramento, CA 95818

Document Content(s)

STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY **EDMUND G. BROWN JR.**, *Governor*

DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

February 17, 2017

Mr. David E. Capka
Acting Director, Division of Dam Safety and Inspections
Federal Energy Regulatory Commission
888 First Street, NW Routing Code: PJ-13
Washington, DC 20426

Re: Emergency Repair Board of Consultants for Oroville Dam Spillway (P-2100)

Dear Mr. Capka:

The California Department of Water Resources (DWR) appreciates your arrival and initial review of the situation that has unfolded at Oroville Dam starting February 7, 2017. This is in response to your letter dated February 13, 2017 asking DWR to, among other things, create an Independent Board of Consultants (BOC) and a separate independent team to investigate the cause of the main spillway failure and ascertain if the failure mode could occur again. This letter describes our recent progress on both of those fronts.

DWR has selected five qualified experts to serve as members of the BOC:

- Kerry Cato, Ph.D., Engineering Geology; M.S., Engineering Geology; B.S., Geology
- John J. Cassidy, Ph.D., Mechanics and Hydraulics; M.S., Civil Engineering; B.S., Civil Engineering
- Eric Kollgaard, B.S., Civil Engineering
- Faiz Makdisi, Ph.D., Geotechnical and Geoenvironmental Engineering; M.A., Geotechnical and Geoenvironmental Engineering; B.E., Civil Engineering
- Larry Nuss, M.S. Civil Engineering; B.S., Architectural Engineering

The BOC will immediately engage with DWR and its emergency response partners to review and assess operations, conditions and risk reduction measures associated with the dam and appurtenant structures. The BOC will continue in this role during the repair of the main and emergency spillways.

Second, as you asked, the process to establish an independent forensic review is underway. The U.S. Society of Dams and Association of State Dam Safety Officials will identify an independent team of experts to perform this critical function. Given the immediacy of the current emergency situation and subsequent repairs, we estimate the forensic review will ensue in approximately three months. The forensic review will include an independent assessment of the conditions that led to the incident.

As you know, we face highly dynamic hydrological and engineering challenges in the context of multiple compromised appurtenances. The near-term recovery effort will

involve significant reconstruction on an accelerated time schedule to meet the demands of the 2017-18 flood season and the long-term recovery will require a thorough examination of the spillway failure causes.

As DWR representatives discussed with you this week, this dynamic situation will require BOC and FERC reviews beyond what is normally completed and in a compressed timeline. Expedited FERC and BOC reviews and approvals will be necessary in order to implement the recovery plan and construction necessary to complete a safe structure. Therefore, DWR asks FERC to provide the following assistance:

1. Full-time FERC staff who can provide immediate oversight and approval as plans and specifications are being developed.
2. Federal assistance to streamline or eliminate any permitting that normally would be required for a repair of this magnitude in order to expedite construction and provide a safe structure by the 2017-18 flood season.
3. Constant and immediate oversight of the BOC, which will require rapid input and comments as design and construction unfold.
4. Full-time FERC staff to review and approve construction activities, including any changes necessitated by conditions encountered in the field.
5. As recognized in your letter and as discussed, flexibility, including time requirements associated with meetings and data packages. As outlined in items 1, 3 and 4 above, this unprecedented situation will require immediate BOC reviews and comments in addition to a different approach to typical FERC and BOC meetings and reviews.

We look forward to coordinating with you on these requests and the governance and operational details of the BOC and on all other aspects of this emergency.

If you have any questions, please contact me at (916) 653-7007 or Ted Craddock at (916) 557-4555.

Sincerely,

William A. Croyle
Acting Director

Document Content(s)

FEDERAL ENERGY REGULATORY COMMISSION
Office of Energy Projects
Division of Dam Safety and Inspections - Headquarters Office
888 First Street, N.E., Routing Code: PJ-13
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(202) 502-6025 Office - (202) 219-2731 Facsimile

February 21, 2017

In reply refer to:
P-2100

Mr. William Croyle
Acting Director
California Department of Water Resources
P.O. Box 942836
Sacramento, California, 94236-0001

Re: Emergency Repair and Board of Consultants for Oroville Dam Spillway

Dear Mr. Croyle:

By letter dated February 17, 2017, you proposed 5 members for the Board of Consultants for the Oroville Dam Spillway project. Those members are Kerry Cato, Ph.D., CEG, John J. Cassidy, Ph.D., Eric Kollgaard, P.E, Faiz Makdisi, Ph.D., P.E., D.GE, and Larry Nuss, P.E. After reviewing these resumes, we approve Dr. Cato, Dr. Cassidy, Mr. Kollgaard, Dr. Makdisi, and Mr. Nuss for their proposed respective roles for the Oroville Dam Spillway BOC.

As detailed in our February 13, 2017, letter, the BOC will assess, at a minimum, the below:

1. Current measures being implemented at the project to pass inflows.
2. Current condition of the service spillway and adjacent areas of the project.
3. Current condition and capability of the Emergency Spillway to safely pass flood flows.
4. Risk reduction measures currently implemented and any additional risk reduction measures proposed.
5. Measures to keep the Powerhouse operable during the short-term and long-term.
6. All proposed remedial options for the service spillway.
7. All proposed remedial options for the emergency spillway.
8. Long-term, permanent modifications and project operations.

9. Any additional information or analysis requested by the BOC.

In addition, you stated that you expect the forensic analysis to ensue within three months, based on teams identified by the US Society on Dams and the Association of State Dam Safety Officials. While we understand and concur that the priority must be on the emergency operations and the remedial design, this timeframe is too long. By March 15, please identify the team who will be leading the forensic analysis and provide a plan and schedule for this effort. They should begin the forensic analysis as soon as feasible in order to ensure that the remedial designs can account for any potential issues identified by the forensic analysis. The BOC shall also be tasked to review and comment on this analysis. Steps for the forensic analysis should include but not be limited to:

1. Development of a plan of action for the forensic analysis.

2. Performing field investigations

3. Reviewing project operations, before, during and after the event.

4. Reviewing project documents, including the emergency action plans, Potential Failure Mode Analyses, Part 12D Independent Consultant Inspection Reports and the Supporting Technical Information Documents, should be included in the analysis. This review should include an assessment of how extreme flood flows are passed at Oroville Dam.

5. Developing any additional information or analysis requested by the BOC and regulating agencies.

6. Preparing and submitting the forensic analysis report. The analysis should discuss the root cause of the spillway incident, as well as any other contributing causes.

As discussed, we will provide flexibility on the typical BOC requirements that have been identified. At the first BOC meeting, we will work to formalize an expedited process to ensure that reviews are conducted as quickly as possible, while still ensuring the integrity of the BOC process. The operation of the BOC will generally be as follows:

1. There will be formal meetings of the BOC scheduled to discuss the areas of the project the BOC is required to assess. The meetings should be scheduled at important milestone markers for the design and construction of the project.

2. At the end of each BOC meeting, the BOC is to present their meeting report and provide you a copy of this report. An electronic copy of the report should also be included.

As soon as possible after each BOC meeting, DWR must submit to FERC three copies of the BOC's report (one copy to the Acting Director, D2SI and two copies to D2SI-San Francisco Regional Engineer) accompanied with a statement of intent to comply with the BOC's recommendations and a plan to resolve any issues. In the event any of the BOC's recommendations are not going to be implemented, detailed reasons for not doing so should be provided. We may require additional action after we review the above information.

A summary table of all the BOC's recommendations is to be maintained by DWR in a status table. This table must indicate the BOC report in which each recommendation was made and include the current status and outcome of each recommendation. This summary table is to be available at each BOC meeting for discussion.

Upon completion of project construction, the BOC is to prepare a report that states the BOC's opinion with respect to the investigation, design, construction, safety, and adequacy of the project structures. Two copies of the BOC's report are to be sent to the D2SI-San Francisco Regional Engineer and one copy to the Acting Director, D2SI, within 45 days of completion of project construction.

Then, one year after completion of re-construction of the Oroville spillway project, the BOC shall prepare an operation assessment report of the project. This report shall assess if the project has performed as intended by the design. DWR shall submit two copies of the BOC project operation assessment report to the D2SI-San Francisco Regional Engineer and one copy to the Acting Director, D2SI. Your submittal letter for these reports is to address how you intend to comply with any BOC recommendations and how you intend to resolve any outstanding issues. The FERC will review the BOC report and any additional information provided by DWR. FERC will then provide a final letter of our review.

Also, in response to your request, we will have dedicated FERC staff made available to provide reviews and attend meetings as required. Commission staff will, as always, make every effort to help coordinate any necessary permitting reviews. Of course, responsibility for compliance with applicable laws and regulations will rest with DWR.

Please contact me with any questions.

Sincerely,

David E. Capka, PE
Acting Director, Division of Dam Safety
and Inspections

cc:
Mr. David Panec
Chief, Dam Safety Branch
California Department of Water Resources
P.O. Box 942836
1416 Ninth Street, Room 604-9
Sacramento, CA 94236-0001

Ms. Sharon Tapia, Chief
Division of Safety of Dams
California Department of Water Resources
2200 X Street, Suite 200
Sacramento, CA 95818

Document Content(s)

FEDERAL ENERGY REGULATORY COMMISSION
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Washington, D.C. 20426
(202) 502-6314 Office - (202) 219-2731 Facsimile

March 20, 2017

In reply refer to:
P-2100

Mr. William Croyle
Acting Director
California Department of Water Resources
P.O. Box 942836
Sacramento, California, 94236-0001

Re: Forensic Review Team for Oroville Dam Spillway

Dear Mr. Croyle:

By letter dated March 15, 2017, on your behalf, Mr. Ted Craddock proposed 6 members of a core group for the independent forensic review team for the Oroville Dam Spillway project. Those members are John France, PE, D.GE, D.WRE, Henry Falvey, John Trojanowski, PE, Irfan Alvi, PE, Stephen Rigbey, and David K. Rogers, PE, CEG. After reviewing their resumes, these candidates are accepted for their proposed respective roles for the Oroville Dam Spillway forensic review team.

Mr. Craddock also provided names of technical experts who will be available to assist the team. These individuals are Dan Hertel, Erik Bollaert, Anton Schleiss, and Sultan Alam.

As detailed in our February 21, 2017, letter, the forensic review team will be responsible for:

1. Development of a plan of action for the forensic analysis.

2. Performing field investigations

3. Reviewing project operations, before, during and after the event.

4. Reviewing project documents, including the emergency action plans, Potential Failure Mode Analyses, Part 12D Independent Consultant Inspection Reports and the Supporting Technical Information Documents, should be included in the analysis. This review should include an assessment of how extreme flood flows are passed at Oroville Dam.

5. Developing any additional information or analysis requested by the BOC and regulating agencies.

6. Preparing and submitting the forensic analysis report. The analysis should discuss the root cause of the spillway incident, as well as any other contributing causes.

The forensic team should begin their work immediately. Please provide us a plan and schedule for their efforts within five days of this letter.

Please contact me with any questions.

Sincerely,

David E. Capka, PE
Director, Division of Dam Safety
and Inspections

cc:
Mr. David Panec
Chief, Dam Safety Branch
California Department of Water Resources
P.O. Box 942836
1416 Ninth Street, Room 604-9
Sacramento, CA 94236-0001

Ms. Sharon Tapia, Chief
Division of Safety of Dams
California Department of Water Resources
2200 X Street, Suite 200
Sacramento, CA 95818

STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY EDMUND G. BROWN JR., Governor

DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

March 15, 2017

Mr. David E. Capka, P.E.
Director, Division of Dam Safety and Inspections
Federal Energy Regulatory Commission
888 First Street, N.E., Routing Code: PJ-123
Washington, D.C. 20426

FERC Project No. 2100
Independent Forensic Review of the Oroville Dam Spillway

Dear Mr. Capka:

This letter is in response to the Federal Energy Regulatory Commission's (FERC) February 21, 2017 letter to the California Department of Water Resources (DWR) regarding the situation at Oroville Dam. DWR's Acting Director, Mr. William Croyle, has asked me to respond on his behalf.

DWR appreciates your continued attention to the situation at Oroville Dam. DWR has engaged the State's Division of Safety of Dams (DSOD) and FERC during weekly Board of Consultant meetings. As you know, our immediate focus is ensuring the flood control spillway can be operated safely through the spring runoff season. At the same time, we are developing a plan and schedule to ensure safe operation of the flood control and emergency spillways during the next flood season. Finally, we will establish and engage an independent forensic review team to investigate the causes of the spillway failures.

As requested in the February 21, 2017 letter from FERC, the forensic team must be identified by March 15, 2017. DWR contacted the United States Society of Dams (USSD) and the Association of State Dam Safety Officials (ASDSO) to select an independent team to conduct a forensic evaluation of the failure of the spillways.

These are the premier dam safety associations in the United States, and USSD is affiliated with the International Commission on Large Dams. USSD and ASDSO also have a long history of creating various technical committees including an ASDSO committee to study dam failures and incidents.

As a result of ongoing efforts between DWR and these organizations, an independent forensic team has been selected. It will consist of a core group with expertise in various engineering disciplines. The core team will rely on a larger team, including worldwide expertise, to provide support in specialized areas. The core group includes:

Area of Expertise	Name
Geotechnical	John France, team leader
Hydraulics	Hank Falvey
Hydraulic Structures	John Trojanowski
Operations/Human Factors	Irfan Alvi
Operations	Steven Rigby
Engineering Geology	David K. Rogers

Resumes are enclosed for each candidate.

Additional technical support will be added as required based on the ongoing investigation by the core team. The core team also will rely on the following technical expertise for specialized considerations:

Area of Expertise	Name
General Civil/Dam Construction	Dan Hertel
Scour and Erosion	Erik Bollaert
Hydraulics	Anton Schleiss
Hydraulics	Sultan Alam

Dan Wade and Lori Spragens also will be available representing USSD and ASDSO respectively.

Upon your approval of the candidates, DWR will immediately engage these experts and develop a detailed process to guide the evaluation. DWR understands the urgency of finding preliminary results to ensure the design and construction of any modifications take the results into consideration.

If you have any questions or would like to discuss this further, please contact me at (916) 502-2067.

Sincerely,

Ted Craddock

Ted Craddock, Project Manager
Oroville Emergency Recovery – Spillways
Executive Division

Enclosure(s)
Letter from USSD to Mr. William A. Croyle dated March 13, 2017
Independent forensic review team candidate resumes

cc: Sharon Tapia, Chief
Division of Safety of Dams
2200 X Street, Room 200
Sacramento, California 95818

Mr. Frank L. Blackett, P.E.
Regional Engineer
Federal Energy Regulatory Commission
100 First Street, Suite 2300
San Francisco, California 94105-3084

William A. Croyle, Director

March 13, 2017

Mr. William A. Croyle
Acting Director
California Department of Water Resources
P.O. Box 942836
Sacramento, CA 94236

Dear Mr. Croyle,

The Association of State Dam Safety Officials (ASDSO) and the U.S. Society on Dams (USSD) are pleased to offer the following experts to DWR for the Oroville independent forensic review team:

Area of Expertise	Name
Geotechnical:	John France, team leader
Hydraulics:	Hank Falvey
Hydraulic Structures:	John Trojanowski
Operations/Human Factors:	Irfan Alvi
Operations:	Stephen Rigbey
Engineering Geology:	David K. Rogers

Resumes are attached for each candidate.

The following are available for additional technical support if needed:

Dan Hertel – General Civil/Dam Construction
Erik Bollaert – Scour and Erosion
Anton Schleiss – Hydraulics
Sultan Alam – Hydraulics
Bill Fiedler (Tentative) – Hydraulic Structures
Bill McCormick – Dam Safety Regulatory

We can supply resumes for these experts upon request.

Members of the task force will continue to be available during the independent review process as needed.

Sincerely,

Dusty Myers, ASDSO President

John Wolfhope, USSD President

John W. France, PE, D.GE, D.WRE

Professional History

Years with AECOM (Legacy URS): 25
Years with other firms: 16

Academic Training

MS, Civil Engineering, Cornell University, 1976
BS, Civil Engineering, Cornell University, 1972

Areas of Expertise

Dams and Dam Safety
Geotechnical Engineering

Registration

Professional Engineer: CO, OK, MA, NC

Mr. France has more than 41 years of experience in engineering consulting and design. Most of Mr. France's technical work for the past 33 years has focused on dams and water retention structures. This experience includes dam safety inspections and analyses, detailed geotechnical and geological field and laboratory investigations, hazard classification, seepage and static stability analyses and evaluations, seismic stability/seismic deformation analyses, conceptual and final designs of new structures, rehabilitation of existing structures, and consultation during construction. He has served on numerous senior technical review boards / panels for the U.S. Army Corps of Engineers (USACE); the U.S. Department of the Interior, Bureau of Reclamation; and BC Hydro. He is listed on the Federal Energy Regulatory Commission's (FERC's) lists of approved Independent Consultants and Potential Failure Modes Analysis (PFMA) facilitators. Mr. France has been a prinicipal instructor for three presentations of a four-day Embankment Dam Design Course for the USACE and for seepage and stability analysis courses for the Association of State Dam Safety Officials (ASDSO) and for two presentations of a three-day course on Embankment Dam Seepage Remediation. In 2010, he received the prestigious President's Award from ASDSO for his contributions to dam safety in the United States.

Project Experience

Consultant Review Board, Horsetooth Dam, CO, U.S. Bureau of Reclamation: Member of a three-person CRB that provided senior technical review of dam safety evaluations, dam modification designs, and construction for four large embankment dams located near Fort Collins, CO. The principal dam safety issues were seepage-related, including solutioning of limestone and gypsum foundation rock in the left abutment of one of the dams.

John W. France, PE, D.GE, D.WRE

Principal-in-Charge, Carter Lake Dam New Outlet Works, CO, Northern Water: Principal-in-charge and senior technical reviewer for design and construction phase engineering services for the new outlet works structure at Carter Lake Dam.

Project Manager, Preliminary design of Chimney Hollow Dam, CO, Boyle Engineering and Northern Water: Project manager for evaluation of foundation data and dam types and preliminary design of the proposed new Chimney Hollow Dam for the Windy Gap Firming Project.

Risk Analysis Facilitator, Antero Dam, CO, Denver Water: Served as an facilitator for a team that completed a potential failure mode analysis and qualitative dam safety risk assessment for Antero Dam, CO. The risk analysis addressed the full range of potential failure modes for an existing embankment dam.

Risk Analysis Facilitator, Beaver Park Dam, CO, Colorado Department of Parks and Wildlife: Served as an facilitator for a team that completed a potential failure mode analysis and qualitative dam safety risk assessment for Beaver Park Dam, CO. The risk analysis addressed seepage and internal potential failure modes and potential risk reduction actions for an existing embankment dam.

Independent Consultant, Williams Fork Dam, CO, Denver Water: Independent consultant for the FERC-required five-year safety inspection of Williams Fork Dam, CO.

Independent Consultant, Dillon Dam, CO, Denver Water: Independent consultant for the FERC-required five-year safety inspection of Dillon Dam, CO.

Independent Consultant, Rampart Dam, CO, Colorado Springs Utilities: Independent consultant for two FERC-required five-year safety inspections of Rampart Dam, CO.

Board of Consultants, Chilhowee Dam, TN, Brookfield Renewable Energy.: Member of a three-person FERC-mandated Board of Consultants for evaluation of seepage concerns for an existing sloping core rockfill embankment.

Technical Advisory Panel, Wolf Creek Dam, KY, U.S. Army Corps of Engineers: Served as chairman of a Technical Advisory Panel reviewing design and construction of major dam safety modifications for Wolf Creek Dam, which is a Dam Safety Action Class (DSAC) 1 facility – the class of highest dam safety concern for the Corps of Engineers. The modifications were completed to address seepage concernms in the karstic foundation of the embankment section of the dam. The implemented solution was a deep, concrete diaphragm seepage barrier wall. Activities also included serving as an estimator for quantitative risk analyses completed during construction and after completion of the project.

Technical Advisory Panel, Center Hill Dam, TN, U.S. Army Corps of Engineers: Served as chairman of a Technical Advisory Panel reviewing design and construction of major dam safety modifications for Center Hill Dam, which is a DSAC 1 facility. The modifications were completed to address seepage concerns in the karstic foundation of the embankment section of the dam. The implemented solution was a deep, concrete diaphragm seepage barrier wall.

Independent Expert Panel, Isabella Dam, CA, U.S. Army Corps of Engineers: Served on a team that completed an idependent expert panel review of the 65 percent design of dam safety modifications for Isabella Dam, CA, which is a DSAC 1 facility. The modifications are being designed to address seismic stability and spillway capacity concerns for this existing facility.

Risk Assessment Team, Success Dam, CA, U.S. Army Corps of Engineers: Served as an estimator on a team that completed a qualitative dam safety risk assessment for Success Dam, CA, which at the time was a DSAC 2 facility. Potential dam safety concerns related to seismic stability, seepage and internal erosion, and spillway capacity.

Risk Assessment Team and Facilitator, Herbert Hoover Dike, FL, U.S. Army Corps of Engineers: Served as an estimator on a team that completed a potential failure mode analysis and qualitative dam safety risk assessment for Herbert Hoover Dike, FL, which is a DSAC 1 facility. In a later stage of this four-year long effort, Mr. France served as facilitator for one part of

John W. France, PE, D.GE, D.WRE

the risk analysis. Potential dam safety concerns for this 150 mile long embankment structure centerd on seepage and internal erosion potential failure modes.

Technical Advisory Panel, Martis Creek Dam, CA, U.S. Army Corps of Engineers: Served on a four-member Technical Advisory Panel reviewing dam safety evaluations for Martis Creek Dam, which at the time was a DSAC 1 facility. Issues of concern were seepage and seismic performance.

Technical Advisory Panel, Success Dam, CA, U.S. Army Corps of Engineers: Served on a five-member Technical Advisory Panel reviewing design and construction of major dam safety modifications for Success Dam, which is a DSAC 2 facility.

Consultant Review Board (CRB), Mormon Island Auxiliary Dam and Other Embankment Dams Associated With the Folsom Project, CA, U.S. Bureau of Reclamation: Member of Consultant Review Boards providing senior technical review of dam safety evaluations, dam modification designs, and construction for one of the embankment dams that impound Folsom Lake, CA. The principal dam safety issues are embankment and foundation seepage and piping, seismic stability concerns and inadequate spillway capacity. Modifications may include a large fuse plug spillway.

Consultant Review Board, Lauro Dam, CA, U.S. Bureau of Reclamation: Serving on a three-person CRB providing senior technical review of dam safety evaluations and dam modification designs for an embankment dam in California. The principal dam safety issue is stability and deformation during an earthquake.

Consultant Review Board, Horsetooth Dam, CO, U.S. Bureau of Reclamation: Member of a three-person CRB that provided senior technical review of dam safety evaluations, dam modification designs, and construction for four large embankment dams located near Fort Collins, CO. The principal dam safety issues were seepage-related, including solutioning of limestone and gypsum foundation rock in the left abutment of one of the dams.

Consultant Review Board, Keechelus Dam, WA, U.S. Bureau of Reclamation: Member of a three-person CRB that provided senior technical review of dam safety evaluations, dam modification designs, and construction for an embankment dam located near Cle Elum, WA. The principal dam safety issues were embankment and foundation seepage and piping concerns.

Consultant Review Board, Wasco Dam, OR, U.S. Bureau of Reclamation: Served as a single reviewer providing senior technical review of dam safety evaluations and dam modification designs for an embankment dam in Oregon. The principal dam safety issues were embankment and foundation seepage and piping concerns.

Consultant Review Board, Red Willow and Norton Dams, NE, U.S. Bureau of Reclamation: Served as a single reviewer providing senior technical review of dam safety evaluations and dam modification designs for two embankment dams in Nebraska. The principal dam safety issues were embankment and foundation seepage and piping concerns.

Consultant Review Board, Clear Lake Dam, CA, U.S. Bureau of Reclamation: Member of a two-person CRB that provided senior technical review of dam safety evaluations, dam modification designs, and construction for an embankment dam located in northern, CA. The principal dam safety issues were embankment and foundation seepage and piping concerns. The embankment dam was replaced with a new roller compacted concrete dam.

Advisory Board Member, BC Hydro: Serving on an Advisory Board for review of BC Hydro's planned dam safety modifications of Strathcona Dam.

Advisory Board Member, BC Hydro: Serving on an Advisory Board for review of BC Hydro's planned dam safety modifications of Ruskin and Blind Slough Dams. A major part of modifications at Ruskin Dam were completed to address seepage issues.

Potential Failure Modes Analysis Facilitator, Baker Project, WA, Puget Sound Energy: Facilitator for FERC-mandated potential failure modes analysis for the Baker Project, which includes two concrete dams, two powerhouses, and two embankment dams.

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Potential Failure Modes Analysis Facilitator, Noxon Rapids Project, MT, Avista Corporation: Facilitator for FERC-mandated potential failure modes analysis for the Noxon Rapids project, which includes a concrete gravity intake/powerhouse structure, a gated concrete gravity spillway structure, and two embankment dams.

Potential Failure Modes Analysis Facilitator, Blue Ridge Dam, AZ, Phelps Dodge Morenci, Inc.: Facilitator for FERC-mandated potential failure modes analysis for Blue Ridge Dam, a 170-foot high concrete thin-arch dam.

Potential Failure Modes Analysis Facilitator, Murray Hydroelectric Facility, AR, City of North Little Rock, AR.: Facilitator for FERC-mandated potential failure modes analysis for a hydro electric facility in Arkansas, located adjacent to a U.S. Army Corps of Engineers lock and dam.

Potential Failure Modes Analysis Facilitator, Ellis and Whillock Hydroelectric Facilities, AR, Arkansas Electric Cooperative Corporation.: Facilitator for FERC-mandated potential failure modes analysis for two hydro electric facilities in Arkansas, located adjacent to a U.S. Army Corps of Engineers lock and dam projects.

Potential Failure Modes Analysis Facilitator, Hydroelectric Station No. 2, AR, Arkansas Electric Cooperative Corporation.: Facilitator for FERC-mandated potential failure modes analysis for a hydroelectric facility in Arkansas, located adjacent to a U.S. Army Corps of Engineers lock and dam project.

Toker Dam, Eritrea, East Africa: Project manager for design and construction of a new, 210-foot-high RCC gravity dam, in Eritrea. The design included preparation of complete plans and specifications for solicitation of tenders from international construction firms. Dam construction was completed in the summer of 1999, at a cost of about $20 million.

Project Manager, New Construction, Elmer Thomas, USFWS, OK: Managed field investigations and conceptual and final designs of dam safety actions for an existing 97-foot-high earthfill/rockfill dam. Completed final design of a new 113-foot-high RCC replacement dam.

Project Manager, Dam Safety Modifications, McKinney Lake Dam, USFWS, NC: Managed conceptual and final designs of dam safety modifications for an earthfill embankment dam and provided engineering services during construction. The modifications included RCC embankment overtopping protection.

Project Manager, Dam Safety Modifications, Umbarger Dam, USFWS, TX: Managed conceptual designs of dam safety modifications for an earthfill embankment dam. The preferred alternative included RCC embankment overtopping protection.

Project Manager and Facilitator, Workshop on Seepage Through Embankment Dams: Organized, managed, and facilitated a workshop sponsored by the Federal Emergency Management Agency and the Association of State Dam Safety Officials. The purposes of the workshop were to identify the state-of-the-practice for analysis, evaluation and design related to seepage through embankment dams and to develop prioritized lists of recommended research and development activities to improve the state-of-the-practice.

Project Manager and Facilitator, Workshop on Dam Outlet Works: Organized, managed, and facilitated a workshop sponsored by the Federal Emergency Management Agency. The purposes of the workshop were to identify the state-of-the-practice for analysis, evaluation and design related to seepage through embankment dams and to develop prioritized lists of recommended research and development activities to improve the state-of-the-practice.

Instructor, Potential Failure Modes Workshop: Instructor for a two-day workshop developed for the Colorado Dam Safety Office.

Advisor, Risk Prioritization Workshop: Advisor for a one-day workshop on development of a dam safety risk prioritization tool for the New Mexico Dam Safety Office.

Instructor, Internal Erosion Potential Failure Modes Workshop: Instructor for a one-day workshop presented at ASDSO's National Conference.

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Instructor, Seepage Analysis for Embankment Dams Workshops: Instructor for two one-day workshops presented at ASDSO's National Conference.

Instructor, Seepage Analysis for Embankment Dams: Instructor for a two-day course for ASDSO.

Instructor, Slope Stability Analysis for Embankment Dams: Instructor for a three-day course for ASDSO.

Instructor, Embankment Dam Design: Instructor for a four-day course for the U.S. Army Corps of Engineers.

Instructor, Dam Seepage Rehabilitation: Instructor for a three-day course for the U.S. Army Corps of Engineers.

CURRICULUM VITAE RELATIVE TO SPILLWAYS

Name: Henry T. Falvey

Nationality: US citizen

Profession: Consultant in Hydraulic Engineering

Key Qualifications:

- Wrote a book on labyrinth weirs that was published by ASCE.
- Consultant for Freese Nichols for the design of the labyrinth weir on the Brazos River at Waco TX. I proposed modifications to the design, participated in physical model study and inspected installed labyrinth.
- Analyzed the flow capacity for the Flamingo Dam labyrinth spillway at Las Vegas, NV.
- Analyzed labyrinth design methods to increase spillway capacity for Los Angeles District Corps of Engineers at Prado Dam. Included site visit to evaluate existing design, development of design parameters, and advised on model studies at the Waterways Experiment station.
- Independent Technical Reviewer for Sacramento District Corps of Engineers of Isabella Dam labyrinth spillway. Included site visit and observation of physical model study at the Water Research Laboratory of Utah State University.
- Prepared an engineering monograph for the analysis of cavitation problems of chutes and spillways for Bureau of Reclamation. The monograph includes recommendations for repair, surface tolerances, aeration, and several computer programs to analyze cavitation potential and aerator design.
- Evaluated cavitation performance and recommended remedial measures on Blue Mesa, Flaming Gorge, Glen Canyon, Hoover, Kortes, and Yellowtail Dams for Bureau of Reclamation and Seven Oaks Dam for the Corps of Engineers.
- Hydraulic consultant to Hydroplus on the use of fusegates to increase spillway and reservoir capacity.
- Analyzed cavitation potential for Manenggon Hills Dam spillway for Dames & Moore.
- Analyzed spillways of Tolt, Railroad, and Smith Lake Dams, as well as the outlet works of Twin Lakes Dam for Woodward Clyde. These included investigations of existing spillways and spillways proposed to increase capacity.
- Designed baffled apron drop to control saturation at Ralston Reservoir and analyzed Dillon Dam morning glory spillway for Denver Water Board.
- Independent Technical Reviewer for US Corps of Engineers on outlet works for Folsom, Seven Oaks and Coyote Dams, spillway of Kaweah Dam and auxiliary spillway for Folsom Dam, bypass structures for Guadalupe River in San Jose, field-testing of Warm Springs Dam, fish bypass for the Dalles Dam, and spillway for Folsom Dam.

- Independent Technical Reviewer for URS Australia on Burnett (now Paradise), Eildon, Dartmouth and Hinze Dam spillways.
- Consultant for HKM Consultants in Billings Montana on the spillway and outlet works upgrade for Bair, Ruby and Nevada Creek Dams.
- Analyzed allowable surface tolerances on spillway surface for Granite Construction Company at Prado Dam.
- Directed physical model study of the double curvature arch dam Eagle Nest Dam for overtopping in NM for URS.
- Analyzed erosive damage potential for spillway flow from Warragamba Dam in Australia.
- Member of review board to reduce total dissolved gas content from the spillways on Boundary Dam in the state of Washington and on Cabinet Gorge Dam in Idaho.
- Author of the following papers on hydraulics of spillways and outlet works.

Engineering monographs

"Air-Water Flow in Hydraulic Structures," US Bureau of Reclamation Monograph No. 41, 143 pp., 1980.

"Cavitation in Chutes and Spillways," US Bureau of Reclamation Monograph No. 42, 143 pp., 1990.

Papers

"Hydrodynamic Pressures in Conduits Downstream of Regulating Gates," *IAHR Congress*, Fort Collins, CO 1976.

"Mean Air Concentration of Self-Aerated Flows," ASCE *Journal of the Hydraulics Division*, Technical Note, Vol. 105, No. HY1, pp. 91-96, 1979.

"Predicting Cavitation in Tunnel Spillways," *International Water Power and Dam Construction*, pp. 13-15, Aug. 1982.

"Prevention of Cavitation on Chutes and Spillways," ASCE *Proceedings of the Conference on Frontiers in Hydraulic Engineering*, Cambridge, MA, pp. 432-437, Aug. 1983.

"Tests on Cavitation Inception from Cylindrical Holes in a Boundary," (Co-authored with B. Mefford), ASCE *Hydraulics Division Specialty Conference*, Coeur d'Alene, ID, Aug. 1984.

"Increasing Shongweni Dam Discharge Capacity with a Hydroplus Fusegate System," (Co-authored with E.F.A. Snell and J. Raussiguier), *Proceedings of the USCOLD Annual Meeting*, Phoenix, AZ, 1994.

"Hydraulics and Design of Fusegates," (Co-authored with Treille), ASCE *Journal of Hydraulic Engineering*, Vol. 121, No. 7, 1995.

"Case Study - Dillon Dam Trashrack Damage," (Coauthored with J.H. Weldon), 2002, *ASCE Journal of Hydraulic Engineering*, Vol. 128, No. 2. , pp. 144-150.

"Investigation and Repair of the Outlet Works Tunnel Slab Damage - Seven Oaks Dam, Santa Ana River, California," *Poceedings of the IAHR International Symposium on Hydraulic Structures*, Ciudad Guayana, Venezuela, Oct. 2006 (Co-authored with Burgi, P.H., Cozakas, D.P., Kwan, R., Sawka, M.J., Schlenker, S.J. and Waller, T.N.)

Book

Hydraulic Design of Labyrinth Spillways, ASCE Press, 2002.

Membership

Member of International Association for Hydraulic Research (IAHR),
American Society of Civil Engineers (ASCE), United States Committee on Large Dams (USCOLD
Associate editor for Journal of Hydraulic Engineering ASCE.
Member of Hydraulics Committee of USCOLD and Unsteady Flow in Hydraulic Machinery Work Group of IAHR..
Consulted or taught in Algeria, Australia, China, Egypt, France, Germany, India, Mexico, Pakistan, Romania, Switzerland, Taiwan, and Turkey.

Education:

BSCE with Honor	Georgia Institute of Technology
1953-1958	Atlanta, Georgia
MSCE	California Institute of Technology
1959-1960	Pasadena, California
Dr.-Ing.	Universität Karlsruhe
1962-1964	Karlsruhe, Germany

Experience Record:

1960-1962: Hydraulic Engineer, Division of Research, US Bureau of Reclamation, Denver, CO
1962-1964: Student, Universität Karlsruhe Germany
1964-1970: Hydraulic Engineer, Division of Research, US Bureau of Reclamation, Denver, CO
1970-1972: Head, Hydraulic Research Section, Division of Research, US Bureau of Reclamation, Denver, CO
1972-1974: Senior Research Officer, Ecole Polytechnique Federale de Lausanne, Switzerland.
1974-1987: Technical Specialist, Division of Research, US Bureau of Reclamation
1987-1991: Private Consultant and Faculty Affiliate, Colorado State University
1991-present: President, Henry T. Falvey & Associates, Inc. and Faculty Affiliate, Colorado State University.

Languages:

	Speaking	Reading	Writing
English	Native	Native	Native
German	Excellent	Excellent	Good
French	Fair	Good	Poor

Honors:

- Bureau of Reclamation - Silver Medal for Meritorious Service.
- Nominated for the Denver Federal Executive Board Outstanding Scientist/Engineer Award.
- Denver Federal Center Professional Engineers Group - Engineering Achievement Award.
- American Society of Civil Engineers - Hydraulic Structures Medal.
- American Society of Civil Engineers - Best paper in Division of Irrigation and Drainage, 1993.
- Society for Technical Communication - Distinguished Technical Communication Award for *Air-Water Flow in Hydraulic Structures* (1981) and *Cavitation in Chutes and Spillways* (1991).
- International Television Association - Award of Excellence for Video *Cavitation - A Bursting Bubble*.
- College Awards - Chi Epsilon, Tau Beta Pi, Briarian Society, Distinguished Military Graduate.
- Holder of one patent and applied for another.
- Recognized as one of eleven eminent water resources engineers who have made a great contribution to the profession during their career at the 2004 American Academy of Water Resources Engineers meeting in Anchorage Alaska. Bestowed the Academy's highest honor of "Honorary Diplomate."

John Trojanowski, PE
President: Trojanowski Dam Engineering, Limited
Dam Engineering Consulting Services

Work Experience:

Work Related to Hydraulic Jacking of Spillway Slabs and Failure Modes Related to Stagnation Pressures at Spillway Joints and Cracks

- Replacement of Cold Springs Dam Spillway – Project Manager for the Bureau of Reclamation (Reclamation) in 1996 for the replacement of Cold Springs Dam spillway. The original spillway had numerous open joints and cracks, and it was determined that it could fail during low flow discharges due to hydraulic jacking. As project manager, I was responsible for the design and construction of a low-cost replacement spillway. The original concrete spillway was removed and replaced with a Roller Compacted Concrete (RCC) spillway having enough weight to resist hydraulic jacking for all design flow conditions up to the PMF.
- Emergency Modifications to Hyrum Dam Spillway and Long-Term Modification Planning – In the fall of 2003 I was asked by Reclamation's Dam Safety Office to inspect cracks in the Hyrum Dam spillway stilling basin. The stilling basin had been unwatered for the inspection. Upon arriving at the site, I noticed that foundation soil had been transported through the drainage system and had been deposited in the stilling basin. I determined that this was due to water flowing into open chute joints. I was designated the Project Manager for dam safety studies. In preparation for the 2004 flood season, I directed field staff to seal open joints and cracks in the spillway chute, and lower the reservoir to provide additional storage for spring runoff. After completing hydraulic analyses and performing a risk analysis I determined that the most vulnerable portion of the spillway was the steep section of the chute, where hydraulic jacking could easily fail chute slabs during high flows, resulting in a rapid headcut to the reservoir. I formed a team to design and construct an emergency modification that would be completed before the spring 2005 runoff. I was the Project Manager for long-term studies to replace the spillway. I later supervised these studies as the Manager of the Waterways and Concrete Dams Group at Reclamation.
- Papers, Articles, and Presentations Related to Spillway Failure Modes – As a Reclamation Dam Safety Advisory Team (DSAT) member and a Risk Facilitator I became aware that there was a lack of understanding of spillway failure modes both within Reclamation, and within the dam engineering community in general. As a result, I prepared two papers ("Assessing Failure Potential of Spillways on Soil Foundation," ASDSO Dam Safety Conference in Phoenix, AZ, September 2004; and "Can Your Spillway Survive the Next Flood?" 26th Annual USSD 26th Annual Conference, San Antonio, TX, May 2006). I also wrote an article for Hydro Review ("Evaluating Spillway Condition," Hydro Review, April 1, 2008). I also provided several technical update lectures for Reclamation and USACE staff. This was all to get the word out that spillways could fail in various ways, including from hydraulic jacking. I was also trying to alert engineers to the fact that their spillways may not have been designed to resist some of these failure modes.
- *Uplift and Crack Flow Resulting from High Velocity Discharges Over Open Offset Joints* – Based on my experience as the Project Manager for Hyrum Dam and my ongoing duties as a DSAT member and a Risk Facilitator at the Bureau of Reclamation, I requested funding from the Dam Safety Office to perform model studies that could act as a guide for prediction of potential uplift forming at offset joints and cracks in a spillway chute. I was the Project manager for these studies and peer reviewed the resulting report: Report DSO-07-07, *Uplift and Crack Flow Resulting from High Velocity Discharges Over Open Offset Joints*. This study also resulted in another paper that I coauthored ("Recent Advances in Predicting Uplift and Structural Collapse on Spillways with Open Offset Joints or Cracks," Warren Frizell and John Trojanowski, 2008 USSD Annual Meeting and Conference, Portland, Oregon, on April 28-May 2, 2008.)
- Risk Analysis Facilitation – I was one of two risk analysis facilitators at Reclamation that could perform risk analyses related to spillway failure modes. In this capacity, I facilitated numerous risk analyses related to spillway failure modes, including hydraulic jacking and foundation erosion. I also trained several individuals to be future risk facilitators.
- US Army Corps of Engineers (USACE) Spillway Toolbox (2007-2008) – I was asked to participate in developing a toolbox for the USACE to assess various potential failure modes for spillways. I worked with an international team of experts to develop criteria to be used for assessing the failure potential for all types of spillways in the USACE inventory. The team relied heavily on by knowledge of foundation erosion and hydraulic jacking potential at joints and cracks in spillways.
- Bennett Dam Spillway – In 2011 I was contacted by BC Hydro in British Columbia, Canada to consult with them on Bennett Dam spillway. This request was based on papers and articles I had published related to hydraulic jacking failure modes. BC Hydro was planning a release of 150,000 cfs through there spillway. The spillway had no waterstops at critical joints. I showed them how to estimate the potential for chute slab instability due to hydraulic jacking, and helped them come prepare joint modification details to prevent jacking issues at critical joints in the spillway. With my help, they were also able to determine which joints did not need to be modified.
- Consultation and Peer Review Related to Spillway Failure Modes – While at Reclamation I became the resident expert and go-to person within the Technical Service Center related to spillway failure modes. I assisted on too many projects to list. Many of these projects involved identifying potential failure modes during the Comprehensive Review process.

I assisted Principal engineers from both the Civil Engineering and Geotechnical Engineering Divisions to understand and evaluate potential spillway failure modes related to the dams they were reviewing.

- Hydraulic Structures Workshop – I have participated in providing training related to spillway failure modes for the USACE, both as Reclamation employee and as an independent consultant. As part of the training I put the participants through an exercise to determine the potential hydraulic jacking forces and potential flow into a spillway joint and ask them to determine if the drains have adequate capacity, and if the chute slab can be jacked.
- Bluestone Dam – The USACE Bluestone Dam spillway has components that are vulnerable to hydraulic jacking failure. I was hired as a consultant to help them prepare a detailed risk analysis and to determine ways to modify the spillway to make it safe.

Trojanowski Dam Engineering, 2016

Participation in a Value Engineering Study for Cherry Creek Dam in Colorado for the US Army Corps of Engineers (USACE), as a sub-contractor for AECOM.

Participation as an instructor for the USACE Hydraulic Structures Workshop, as a sub-contractor for AECOM.

Member of the Bluestone Dam Stilling Basin Design Expert Panel as a subconsultant for Stantec. Included review of the hydraulic model studies and foundation drainage and grouting designs.

Previous Work Experience:
U.S. Department of the Interior, Bureau of Reclamation, Denver Colorado from 1978 to 2014 (Retired after 36.5 years)

General Manager/Civil Engineer – Waterways and Concrete Dams Group at the Bureau of Reclamation's Technical Service Center (2010-2014)

Managed 15 to 25 Civil Engineers as the General Manager (GM) for the Waterways and concrete Dams Group. Group work included design of new and modified concrete dams and appurtenant structures such as spillways, outlet works, bridges, powerplants, fish bypass, and other reinforced concrete structures. The group was responsible dam safety aspects of all concrete dams, spillways, and outlet works in the Bureau of Reclamation's (Reclamation) inventory. This included conducting Comprehensive Reviews that included evaluation of structural (static and seismic) and hydrologic/hydraulic risk, making recommendations for engineering studies, conducting Issue Evaluations, Corrective Action Studies, final designs and specifications preparations, and engineering support during construction. This responsibility also extended to dams owned by other Department of the Interior (DOI) Bureaus. As GM I assigned work to Project Managers and design staff related to this work. I also was responsible for policy and quality of the work products. I hired and trained staff as needed to complete the workload. During my tenure as GM I peer reviewed a large percentage of the work prepared by my group, was an active member of Project Management Teams (PMT) for dam safety projects, participated as a Dam Safety Advisory Team (DSAT), and acted as a consultant for other government agencies such as the Corps of Engineers and National Park Service, and for outside organizations such as BC Hydro. My group was also responsible for updating Design Standards, maintaining and updating flood routing and water surface profile software, and standardizing and updating Dam Safety Best Practices used by both the DOI and Corps of Engineers. I also worked with other Technical Service Center (TSC) General Managers and the Dam Safety Office to develop and maintain annual workload planning schedules.

Civil Engineer – Waterways and Concrete Dams Group at the Bureau of Reclamation's Technical Service Center (1978-2010)

General Experience
My time at the Bureau of Reclamation I worked in design groups specializing in concrete dams and waterways for dams. During this period my work experience includes design and analysis related studies, inspections, and construction support, for all civil engineering related aspects of concrete and embankment dams. This included operations studies (such as flood routings and reservoir evacuations), hydraulic analyses, sizing and design of various types of spillways and outlet works, structural analyses and design of various types of dams and waterways (including reinforced concrete structures), concrete dam foundation analyses and design, numerous risk analyses, cost analyses, and various other studies related to dams. I was certified as a risk facilitator for Reclamation and is a member of Reclamation's DSAT. I have authored numerous technical papers, articles for publications, reports, and manuals, and was a team member on a joint project with the UCACE to prepare a spillway failure toolbox. I am also a current member of ASDSO and USSD.

Specific Work Experience

Technical Expert: As a technical expert I have participated in various projects for other organizations where I provided engineering reviews and participated in training as an instructor, participated as a technical representative at hearings, participated in risk analyses, and provided technical reviews. This work included Bennett Dam Spillway reviews for BC Hydro,

Bluestone Dam Risk Analysis for the USACE, participation as an instructor for the USACE's Risk Management Center for their first Hydraulic Structures Workshop and various other projects, reviewed issues related to the Gavins Point Dam Spillway for the USACE, participated in a failure mode analysis for the USACE's John Day Dam, reviewed technical proposals for the design of the San Vicente Dam Raise for the San Diego County Water Authority, reviewed and prepared reports for numerous projects for the government of Taiwan, participated in an emergency dam replacement for Kirby Dam for the US Forest Service, and acted as a technical advisor and hearing officer for the National Park Service for the historic Pawtucket Dam.

Research Projects: As a design engineer was actively involved in the planning of research projects that were both general in nature and specifically tailored to various dam projects. Of note was my work to initiate hydraulic laboratory studies to define hydraulic jacking parameters for evaluating spillway failures under various flow conditions. I expanded this study to include estimates for flow into open cracks and joints in concrete slabs for the purpose of estimating required foundation drainage capacity. I was the peer reviewer of the final report (DSO-07-07) from this study. My participation in this study resulted in me preparing criteria for these specific spillway potential failure modes in the Best Practices handbook, and my participation in preparing a Corps of Engineers toolbox for assessing spillway failure modes.

I participated in the early studies by Reclamation to define cavitation potential in spillway chutes. I worked with Dr. Hank Falve on this study. My responsibilities included computing water surface profiles and cavitation index for various high velocity spillways to determine when the computed index resulted in major, minor, or no damage. These results were used in the publication of Reclamation's Engineering Monograph No. 42. As a result of my participation in this study I became one of the Group's leading experts in cavitation damage prediction and the use of water surface profiles to predict cavitation potential. My subsequent work has resulted in changes in operating procedures for critical spillways in order to reduce or prevent cavitation damage without requiring structural modification.

Comprehensive Reviews: *Senior Engineer* for several including: Stony Gorge, American Falls, Grand Coulee, Hoover, Morrow Point, Crystal, Bartlett, Altus, Parker
Peer Reviewer for several including: Pueblo, Stewart Mountain, Clear Creek, Crystal, Flaming Gorge
Civil Engineer team member for many

Issue Evaluations: *Project Manager* for several including: Parker, Grand Coulee, Morrow Point, Flaming Gorge, Crystal, Minidoka, Hyrum, Gerber, Pueblo, Clear Creek, Navajo
Team Member for many

Risk Analysis: Risk Facilitator for many dams

Final Designs and Corrective Action Alternatives: *Project Manager* for several including: Minidoka (new spillways and post-tensioned tendon stabilizations), Hyrum, Clear Creek, Pueblo, Glen Canyon, San Vicente Dam (TPEC to select the Design organization), Milltown Hill (Proposed New RCC Dam), Kirby Dam Reconstruction
Team Member for several including: Brantley (new concrete dam), Stewart Mountain Dam Modifications, Spring Creek Debris Dam Raise, Cold Springs, Minidoka Powerplant, Theodore Roosevelt (Outlet Works Gate Shaft, Tunnel, and Control Structures)
Engineer preparing designs and analyses on other projects including: Three Gorges Dam in China, Auburn Thin Arch and Concrete Gravity Dams, Stony Gorge Dam, McPhee Dam.

Dam Safety Advisory Team Member: This involves review of all kinds of dam safety studies, modifications, and new designs. Review of associated risk analyses and decision documents. Providing technical support for the Dam Safety Office, Region, and Area Offices within Reclamation and for others within the Department of the Interior.

Education: B.S.C.E. from the University of Colorado in Boulder, Colorado

Registration: Professional Engineer in the State of Colorado

Publications:

Papers:

"Dam Safety Modifications for Clear Creek Dam," Manuscript for ASCE Hydraulics Division, 1993 National Conference on Hydraulic Engineering, July 1993, Author.

"Stabilization of Minidoka Dam Using Epoxy Coated Strand Rock Anchors," ASDSO Dam Safety Conference, Pittsburgh, PA, September 1997, Co-author.

"Risk Reduction Through Monitoring at Pueblo Dam," USCOLD 18th Annual Conference, 1998, Buffalo, NY, August 1998, Co-author.

"Stabilization of Pueblo Dam Using RCC," ASDSO Dam Safety Conference, St. Louis, MO, October 1999, Author.

"Dam Safety Investigations and Modifications for Clear Creek Dam," FEMA National Dam Safety Program Technical Workshop No. 8, Emmitsburg, MD, February 2001, Author.

"Grouted RCC Contraction Joints at Pueblo Dam," ASDSO Dam Safety Conference, Snowbird, UT, September 2001, Co-author.

"Assessing Failure Potential of Spillways on Soil Foundation," ASDSO Dam Safety Conference in Phoenix, AZ, September 2004, Author.

"Stabilizing the Spillway Foundation at Pueblo Dam," ASCE Proceedings of the Biennial Denver Geotechnical Symposium, October 2004, Denver, CO, Co-author.

"Construction Methods for Roller-Compacted Concrete Spillways," ASDSO Dam Safety Conference, Orlando, FL, September 2005, Co-author.

"Can Your Spillway Survive the Next Flood?" 26th Annual USSD 26th Annual Conference, San Antonio, TX, May 2006, Author.

"Recent Advances in Predicting Uplift and Structural Collapse on Spillways with Open Offset Joints or Cracks," Warren Frizell and John Trojanowski, 2008 USSD Annual Meeting and Conference, Portland, Oregon, on April 28-May 2, 2008.

Articles:

"RCC Used to Stabilize Pueblo Dam," USCOLD Newsletter, March 2000, Author.

"Methods of Construction," International Water Power & Dam Construction, February 14, 2006, Co-author.

"Evaluating Spillway Condition," Hydro Review, April 1, 2008, Author.

Manuals:

"Roller-Compacted Concrete, Design and Construction Considerations for Hydraulic Structures," Bureau of Reclamation, Technical Service Center, 2006, Co-author.

Research Reports:

"Testing and Examination of Concrete Cores - Minidoka Dam Idaho," GR-80-8, Concrete and Structural Branch, Division of Research, Engineering and Research Center, Denver, CO, December 1980, Co-author.

"Uplift and Crack Flow Resulting from High Velocity Discharges Over Open Offset Joints," Report DSO-07-07, Dam Safety Technology Development Program, USBR, December 2007, Peer Reviewer.

Irfan A. Alvi, P.E.
President & Chief Engineer

RESUME

Education

B.S. (Honors), 1989, Civil Engineering
University of Maryland

More than 70 credits of post-graduate coursework in engineering, risk analysis, geology, physics, chemistry, biology, and other topics

Professional Registrations

1994, PE, MD, 20775
1999, PE, VA, 033361
2012, PE, DE, 18065
2015, PE, WV, 021527
2016, PE, PA, 084842

Relevant Areas of Specialization

New Dam Design
Dam Rehabilitation Design
Dam Inspection
Materials Testing
Forensic Investigation
Human Factors Investigation
Reservoir Routing Analysis
Open Channel Hydraulics
Seepage and Stability Analysis
Structural Engineering
Geotechnical Engineering
Risk Analysis
Dam Removal Study
Fluvial Geomorphology
Construction Management

Summary of Experience

Mr. Alvi has 28 years of experience in structural, water resources, geotechnical, and transportation engineering for dams and other infrastructure. His uniquely multi-specialist background is ideally suited to projects involving dams. In his role as Chief Engineer, he also regularly teaches mechanics of structures, fluids, soil, and rock to all of the engineers at Alvi Associates, at a conceptual depth beyond that offered in typical university courses and textbooks.

Mr. Alvi has completed many hundreds of projects involving inspection, materials testing, forensic investigation, studies, remedial design, and new design. Many of these projects have involved providing innovative solutions to meet challenging situations, with the result that many of his projects have received design awards during the past decade.

Mr. Alvi is a nationally-recognized expert in dam engineering. He served as technical leader for Alvi Associates' Prettyboy Dam project, which received the *2010 National Rehabilitation Project of the Year Award* from the Association of State Dam Safety Officials (ASDSO), which is among the most prestigious awards attainable in the dam engineering profession. The project also received three other awards in 2011, including an ASCE/MD Outstanding Civil Engineering Achievement Project award, ACEC/MD Engineering Excellence Outstanding Project Award, and ESB Outstanding Engineering Achievement Award.

More generally, Mr. Alvi has completed a diverse range of dam projects involving inspection, materials testing, forensic investigation, hydrologic and hydraulic analysis, reservoir routing and spillway capacity analysis, dam break modeling and inundation mapping, stream geomorphic study and restoration design, fish passage design, seepage and stability analysis, three-dimensional structural analysis, remedial design, design of new concrete and embankment dams, evaluation and design for dam removal, and construction management.

Mr. Alvi is also nationally-recognized as a pioneer and leader in the role of human factors in dam failure and safety. He has served on the ASDSO Dam Failures and Incidents Committee (DFIC) since 2010, leading the committee's work on human factors, making numerous presentations on human factors at ASDSO conferences (including a keynote address) and publishing several peer-reviewed papers. He also recently served as a Technical Advisor and Human Factors Expert for a FEMA project related to dam failures and incidents. In addition, at the request of ASDSO, in 2015 he presented a two-hour webinar (link) on human factors in dam failure and safety, as part of ASDSO's expert series of webinars. Several of his investigations of dam failures and the associated role of human factors are described below.

Examples of Dam Study and Design Projects

Prettyboy Dam in Baltimore, Maryland. For this large high-hazard concrete gravity dam which is a key component in the water supply system for the City of Baltimore, performed review of extensive records related the dam's construction and history (including previous crack monitoring and investigations), abovewater and underwater inspection using an ROV in order to prepare detailed defect mapping, concrete coring and testing, forensic investigation of structural cracking using three-dimensional structural analysis (accounting for creep effects) and an innovative causes/effects matrix model, gatehouse stability analysis considering a wide range of potential failure surfaces, remedial design for a $6 million post-tensioned anchorage system installed underwater in water depths up to more than 100 feet and consisting of 38 anchors drilled up to 70 feet into the dam (the first system of this type in the world), contractor prequalification, and extensive construction-phase services including development and evaluation of a preproduction anchor testing program. This 15-year project received four major design awards, as noted above.

Mill Pond Dam in Cecil County, Maryland. Performed alternatives studies and preliminary design for dam reconstruction to address breach in 1999 of an embankment dam dating to circa 1837. Alternatives included elements such as a new twin-cell box culvert outlet structure with a multi-stepped weir and a fish ladder, reconstruction of the failed embankment, embankment widening to allow a wider roadway, roadway reconstruction, a new sheet pile wall, riprap slope protection, and measures to control seepage, piping, and erosion within the new and re-used portions of the embankment dam.

Embankment Dam at I-695/Charles Street Interchange in Baltimore County, Maryland. Performed hydrologic analysis, hydraulic analysis, and geotechnical studies for design of a new embankment dam, along with dam break and inundation modeling to assess risk to the adjacent interstate highway and perform hazard classification. Included installation of a geomembrane for seepage control.

Seneca Crossing Dam in Montgomery County, Maryland. Complete structural, geotechnical, and hydraulic design for a new concrete gravity dam flanked by embankment dams at each abutment. The concrete gravity dam was selected in order to minimize the dam footprint, and thus reduce the impact to wetlands. Due to adverse subsurface conditions involving highly compressible and permeable materials, an innovative design founding the dam on steel piles was developed and a sheet pile cutoff wall extending 18 feet deep was designed for seepage and uplift control. This design is estimated to have reduced construction costs by at least 40% relative to a conventional concrete dam.

Bishopville Pond Dam in Bishopville, Maryland. To address fish passage needs on a tidal waterway, performed inspection of an existing steel sheet pile dam, tidal hydrologic and hydraulic analysis using TR-20 and HEC-RAS to assess feasibility of dam removal and floodplain impacts (accounting for an existing bridge in the model), and design of a new offline pond isolated via an embankment in order to meet recreational needs of local residents.

Examples of Dam Forensic Investigations

Prettyboy Dam in Baltimore, Maryland. In addition to the design aspects described above, extensive forensic investigation was performed for this high-hazard concrete gravity dam founded on micaceous schist. The dam is 150 feet high and 700 feet long.

By 1978, extensive cracking was observed in the gatehouse and the adjacent main body of the dam, along with substantial water leakage into the gatehouse stairwell. To respond to this concern, continuing until 1994, six investigations of the cracking were performed by five previous consultants, but with inconclusive and/or inconsistent findings.

We then became involved and performed a comprehensive multi-phase dam investigation involving many tasks: exhaustive review and summary of all available records, abovewater inspection, underwater inspection using divers and a remote-operated vehicle (ROV), precise mapping of defects throughout the exterior of the dam as well as inside the gatehouse, crack monitoring during gate testing operations, concrete coring and testing, analyses and evaluations, and preparation of a 300-page study report with recommendations.

We next performed a forensic structural/geotechnical investigation of the gatehouse cracking, eventually discerning that the cracks clustered into eight distinct groups, and likewise discerning three distinct general causes of the cracking, with each cause contributing in varying degrees to each crack group. In other words, we developed a "cause-effect matrix," thus transcending the usual assumption of a simple one-to-one influence of cause to effect. The three identified causes of the cracking were vertical flexure of the dam, differential settlement between the gatehouse and main body of the dam, and deformation from the reactions of the bridge spans adjacent to the gatehouse. Our hypothesized causal matrix was quantitatively validated by analyses of stresses and deformations of the dam, gatehouse, and bedrock, and the resulting predictions were found to fit the observed cracking remarkably well.

The findings of the investigation were presented in a report for the client, a peer-reviewed paper in the ASDSO *Journal of Dam Safety* (link), and a presentation at the ASDSO national conference.

Big Bay Dam in Mississippi. This embankment dam was over 50 feet high and 2000 feet long, and failed in 2004, resulting in damage or destruction of more 100 structures. Performed a comprehensive investigation of the failure, including review of many hundreds of pages of documents, including plans, calculations, construction records, deposition transcripts, engineering reports, etc. Focused on the human factors aspect of the failure, identifying the roles of the engineer, owner, state regulatory agency, maintenance personnel, and inspectors, as well as the complex interaction of human factors and physical factors during the two decades from the design until the failure. Findings of the investigation were presented in a peer-reviewed paper in the ASDSO *Journal of Dam Safety* (link), a dedicated 'soapbox' session at the ASDSO national conference, an ASCE invited speaker presentation, and Mr. Alvi's 2015 webinar for ASDSO.

Sella Zerbino Secondary Dam in Italy. The Sella Zerbino secondary dam was a concrete gravity dam about 46 feet high and 360 feet long. In 1935, a decade after construction, the dam failed catastrophically, resulting in at least 111 fatalities. Starting with the planning of the project four decades prior to the failure, a series of human and physical factors interacted and compounded, until a 1000-year storm was the final physical trigger for the failure. Additional physical factors included lack of a spillway for the secondary dam, instability and erodibility of the foundation rock at the secondary dam, and grossly inadequate discharge capacity for the reservoir, which was exacerbated by clogging of spillways and outlets. The human factors contributing to the failure included hasty design and construction of the secondary dam after a late decision to raise the height of the main dam, inadequate geologic investigation and missed warning signs related to the foundation of the secondary dam, and lack of rainfall data to adequately design spillways and outlets. This investigation involved an extensive literature review, mapped out the role of physical factors, and contributed new insights into the failure by identifying the role of human factors in the failure, using the framework pioneered by Mr. Alvi. Findings of this investigation were presented in a peer-reviewed paper (link) and presented at an ASDSO national conference.

St. Francis Dam in California. This arched concrete gravity dam near Los Angeles was nearly 200 feet high, and failed in 1928, about four year after construction began and a day after fully filling the reservoir for the first time, resulting in a flood which extended more than 50 miles and resulted in at least 400 fatalities, along with millions of dollars of property damage. The failure is considered by many to be the worst US civil engineering disaster of the 20th century. Performed a comprehensive investigation of the failure, including review of more than one hundred pages of documents, including plans, engineering analyses, other investigations, etc. Focused on the human factors aspect of the failure, identifying the roles of the chief engineer, other engineers working under the chief engineer, City of Los Angeles, and local citizens who reported warning signs, as well as the complex interaction of human factors and physical factors during the years preceding the failure. Findings of the investigation were presented in a peer-reviewed paper (link) and a presentation at the ASDSO national conference.

Ka Loko Dam in Hawaii. This embankment dam was 42 feet high and 770 feet long, and failed in 2006, resulting in flood depths of 10 to 30 feet, seven fatalities, extensive property and environmental damage, a criminal sentence for the owner, and a civil settlement of many millions of dollars. Performed a comprehensive investigation of the failure, including extensive literature review of many hundreds of pages of documents, including plans, calculations, engineering reports, other investigations, news reports, etc. Focused on the human factors aspect of the failure, identifying the roles of the owner, Corps of Engineers, a trust which owned a portion of the reservoir, the County and Mayor, state regulatory agency, federal regulatory agencies, maintenance personnel, and inspectors, as well as the complex interaction of human factors and physical factors during the century preceding the failure. Findings of the investigation were presented at an ASDSO national conference, a keynote address at an ASDSO conference (link), and Mr. Alvi's 2015 webinar for ASDSO.

Curriculum Vitae - Stephen James Rigbey

POSITION

Director, Dam Safety, BC Hydro, British Columbia, Canada

President, SJR Consulting Inc., Vancouver, Canada

EDUCATION

B.A.Sc., and M.A.SC., Geological Engineering,

University of Windsor, Canada, 1975, 1980

PROFESSIONAL ASSOCIATIONS

Association of Professional Engineers and Geoscientists of the Province of British Columbia

Professional Engineers of Ontario

Canadian Dam Association (CDA) – member Dam Safety Committee

International Congress on Large Dams (ICOLD) – Canadian representative on the Seismic Committee

SUMMARY OF EXPERIENCE

Stephen joined Acres International (now Hatch) in 1979, where he rose to Principal Geotechnical Engineer and Project Manager. Through Acres, he gained extensive worldwide experience, working in more than 15 countries and following numerous projects through investigations, design, construction of underground complexes, concrete and earthfill dams, and long-term monitoring. Specialties include instrumentation and dam safety, seismicity assessments, and rock mechanics designs.

Stephen then joined BC Hydro in 2008, and is now the Director of Dam Safety, responsible for ensuring safe reservoir retention and passage through and around hydro facilities at 41 sites throughout the province of British Columbia, Canada. He is responsible for monitoring and surveillance, the identification and prioritization of all associated risks, initiating Investigation and Capital projects, and providing technical oversight to these projects, which will total $CAN 1.9B over the current 10-yr Capital Plan. He has a staff of about 35 professionals, technologists and support staff.

Externally from BC Hydro, Stephen has been a member of Advisory Boards for the Lower Churchill Project in Newfoundland and for audits of dam safety programs for utilities in Sweden and Turkey. As a member of the CDA Dam Safety committee, Stephen was heavily involved with the 2013 review and updating of the Dam Safety Guidelines.

Stephen has been recently awarded the prestigious Inge Anderson Award by the Canadian Dam Association in recognition of his “significant contributions to the advancement of knowledge and practices related to dams in Canada”.

- **Operational Safety**: At BC Hydro, Stephen has initiated changes to spillway and reservoir operations in a number of cases as interim risk management measures. He has also initiated overall operational reviews of reservoirs and river systems in view of dam safety considerations. Current work involves the Campbell River System on Vancouver Island, where operations and input hydrographs have been stochastically modelled to better understand the consequences of a single random spillway gate failure to operate on demand. Results have indicated that changes to operational rules will greatly reduce overall downstream flooding risks while only marginally increasing upstream risks. Stephen is also one of the four sponsors responsible for initiating the work behind the recently published book *Operational Safety of Dams and Reservoirs* (Sept 2016, ICE Publishing).
- **Dam Safety Assessments**: Prior to joining BC Hydro, Stephen performed numerous dam safety assessments of various earth and concrete structures within Canada, including detailed foundation condition investigations, coordination of laboratory work, and assessment of rock/concrete shear strengths. A systematic approach to the evaluation of parameters for stability analyses was developed for this work, and is quoted in the Canadian Dam Association Guidelines. Internationally, Stephen has performed Dam Safety Reviews and seismic hazard assessments for high-risk dams in Iran, El Salvador and Panama.
- **Administration and Quality Control** : At BC Hydro, Stephen is responsible for initiating and reviewing all major projects involving water passages and dams. At Acres, he was responsible for the administration and technical coordination of all geotechnical work on hydro projects, including seismicity assessments. Stephen also has significant experience in quality control reviews, and has acted as Lender's Engineer in the review of designs and construction of dams in Panama and India.
- **Dam Investigations and Design** : Stephen has been the Project Manager for the design of a 35-m high, 500-m long embankment dam founded on sands and gravels, including a 65-m deep plastic concrete cutoff wall. He had previously managed an investigations and monitoring program for the original dam, which included an extensive remote automated instrumentation system, development of a detailed Emergency Preparedness and Response Plans, infilling of sinkholes, geophysical surveys, exploratory boreholes through the damaged core of the dam, and sonar surveys of the headpond. A methodology for precise sonar surveying of the sinkholes was developed under Stephen's supervision as part of the work for this project. Stephen has worked in karst environments for projects in both Iran and Indonesia.
- **Rock Mechanics and Geological Engineering** : Stephen has designed layouts and support for underground powerhouses and tunnels under various conditions, including extremely high horizontal in situ stresses and time dependent deformations. Design studies have included the development of specialty laboratory tests to investigate swelling rock pressures. He also has experience in the laboratory and field identification of alkali-aggregate reactions. Stephen spent 2 years on-site in India during the construction of a major underground power facility, and was also Resident Site Engineer during the construction of a 600-m long, 3.5-m dia adit and a 13.5 m dia trial excavation chamber in shales. He was involved onsite at the Karun III project in Iran during the construction of a 200-m concrete arch dam and underground powerhouse complex. He also worked for a number of years on the Niagara Diversion Tunnel project, a10-km long, 14.4-m diameter rock TBM drive, including investigations, design, and the development of the project Geotechnical Baseline Report.

CAREER CHRONOLOGY

SJR Consulting Inc – Vancouver, 2013 to present

- Advisory Board member, Muskrat Fall Hydroelectric Project, Newfoundland (Nalcor) : project involves RCC and embankment dams about 20 to 40 m high, and a unique abutment issue where a currently meta-stable landform must be transformed into a robust reservoir retaining structure.
- Audits of Dam Safety Programs: extensive audit of management and technical processes and procedures against ICOLD Bulletin B154 - Dam Safety Management: Operational Phase of the Dam Life Cycle, for Vattenfall Vattencraft (Sweden) and EnerjiSA (Turkey), resulting in 40 to 50 specific recommendations for consideration in each case.

BC Hydro – Vancouver : Manager (now Director) of Dam Safety, 2008 to present

- Responsible for all aspects of safety involved with water retention and water passage structures at 41 separate hydroelectric sites, developing the appropriate scope and initiating all major studies, investigations and civil projects associated with dam safety, and for providing technical guidance throughout the execution of these projects.
- Reporting directly to the Deputy CEO, and to the Board of Directors on a quarterly basis

Hatch Energy – Vancouver : Principal Geotechnical Engineer & Project Manager, 2006 to 2008

- Comprehensive review of shear strength parameters for the Ruskin Dam, including investigations for basic resistance of the bedrock-concrete contact.
- Forrest Kerr Hydroelectric Project Feasibility Study —Responsible for geotechnical investigations and feasibility level designs for a 190 MW underground powerhouse scheme and 3.4 km tunnel in Northern British Columbia.
- Risk Study for Kemano Tunnel, including investigation of submersible inspection techniques. This partially-lined rock tunnel has a history of rock collapses, and is critical to the supply of power for Alcan's aluminum smelter at Kitimat. Various alternatives to reduce failure risk were compared on a Net Present Value Basis.
- Project Manager for various detailed sonar bathymetry studies for BC Hydro and TransAlta.
- Dam Safety Review Engineer for various large dams, including BC Hydro's extreme consequence category Mica Dam, a 240-m high earthfill structure, and the 120 m high Wood Creek Suncor tailings dams.
- External consultant to BC Hydro for an audit of monitoring and surveillance practices within the Dam Safety Group.

Acres International (later Hatch Energy),* Niagara Falls: Principal Geotechnical Engineer, *2001 to 2005

Responsible for quality control of geotechnical work and mentoring/guidance of geotechnical staff within the hydro division. Continued in previous role as Department Head.

Development of the Geotechnical Baseline Report (GBR) for the Niagara Diversion tunnel project (14.4-m excavated dia., 10 km long). Participated in technical evaluation of the bids and contract negotiations.

Seismic hazard assessments and dam safety reviews for high-risk dams, including regional seismicity reviews, deterministic and probabilistic hazard analyses, selection of design events for:

- Dez dam, Iran
- four dams in El Salvador
- Fortuna dam, Panama.

Due diligence studies and site visits as Lender's Engineer for hydroelectric projects during construction:

- Está project in Panama, a 120-MW scheme involving an earth dam, 6-km canal, 50-m high concrete-face rockfill dam, 4.8-km, 7-m dia tunnel and surface powerhouse
- Vishnuprayag project in India, involving 11-km, 4-m dia tunnel and 400-MW underground powerhouse.

Onsite review of abutment stability safety for a 140-m high, concrete gravity arch dam at the Chamera project, northern India, following a massive downstream landslide.

Project Manager for the design of the 35-m high, 500-m long Shikwamwka Replacement embankment dam, founded on sands and gravels, and incorporating a 65-m deep plastic concrete cutoff wall. Also acted as Project Manager for the monitoring and investigations program involving the original dam.

Numerous dam safety assessments of various earth and concrete structures in Ontario and New Brunswick, including detailed foundation condition investigations, coordination of laboratory work and assessment of rock/concrete shear strengths for the stability analyses. A systematic approach to the evaluation of parameters for stability analyses was developed for this work.

Acres International, Niagara Falls, Geotechnical Department Head - 1996—2001

Responsible for the administration and technical coordination of all geotechnical work on all projects involving geology, soil and rock mechanics, and seismicity. The department had a staff of 12-15 engineers and technologists.

Acting Geotechnical Site Engineer, Karun III hydroelectric project, Iran. Responsibilities included

- supervision of foundation preparation in a faulted area for a 205-m concrete arch dam
- providing advice on major ground movements experienced during excavation of the 26-m span underground powerhouse; review of all instrumentation results
- development of 3D numerical rock mechanics models for the underground complex
- development of 2D seepage models for the arch dam abutment

Project Manager responsible for a study to examine possible causes of, and to develop alternative remedial options for, significant leakage at the Old Mill Station subway tunnel portal, Toronto, Ontario. The study included geotechnical investigations, conditional surveys and a full-scale pump test.

Inspection and interpretation of monitoring data, detailed hydrogeological site assessment, and detailed analysis of groundwater chemistry for the Irving Paper aeration and stabilization basin. The basin containment dike is constructed on a soft marine clay deposit, Saint John, New Brunswick. Preparation of yearly monitoring reports are issued for the New Brunswick Ministry of the Environment.

Project Manager for potential rockfall studies on 48 highway rockcuts in eastern Ontario. Report included recommendations for remediation, cost estimates and benefits.

On-site consultation for remediation of a collapsed 3.5-m dia tunnel in overburden in Bolivia.

Design of remedial works for a 100+ m slope undergoing long-term creep in weathered rock over a water tunnel intake for the Cañon del Pato project in Peru. On-site consultations and construction reviews.

Provided on-site technical advice for the Second Power Reconstruction project, Bosnia and Herzegovina, in the planning for re-instrumentation of the Bocac and Trebinje dams following damage during the war. Developed specifications for international tendering through the World Bank. Instrumentation included precise survey equipment for geodetic monitoring, regional seismicity monitoring and local accelerometer networks, automatic weather stations, and various geotechnical instrumentation systems, including telependula, vibrating wire piezometers, strain gauges, tiltmeters, and ADAS systems.

Vibrating wire piezometer design and installation in boreholes in Welland, Ontario, to measure uplift pressures on tunnel portal structures for the Ministry of Transportation, Ontario. Readings were data logged and alarm software developed for notification via a remote communications link.

Pre-bid and final designs of underground excavations for the Western Beaches combined sewer outfall storage tunnel (3 m dia, 4 km long) in Toronto, Ontario. The project also included excavation of 30-m dia. shafts through rock to tunnel elevation. Ongoing site visits and consultation during construction.

Design of bar anchor and lining support for two 9-m dia. mine shafts in Wyoming for use as storage bins.

Coordination of tender preparation and pre-bid design of underground support, including large bar anchors and shotcrete for the Nam Ngum III project in Laos (involving a 440-MW underground powerhouse scheme and 10 km of 5-m dia. tunnels).

Project Manager for the Welland River shoreline rehabilitation project, involving the stability assessment of natural, concrete wall and other shoreline types along an unused ship canal and the development of remedial recommendations and cost estimates.

Tunnel inspections and stability reviews for two 4- to 6-m dia. power tunnels in northern Ontario. Review of existing bar anchor and shotcrete support and design of remedial measures.

Acres International **Senior Geological Engineer** ***1990—1996***

Design of layout and support for an underground powerhouse and water transfer tunnels for the Alto Cachapoal project, Chile, including excavation design and sequencing, bar anchor and shotcrete support design for both drill and blast and TBM excavation.

Site reconnaissance and project layout review for the Upper Marsyangdi hydroelectric project, Nepal.

Review of alkali-aggregate reactivity (AAR) in the concrete of three locks in the St. Lawrence Seaway system, including the preparation of instrumentation plans for long-term monitoring of concrete growth.

Assessment of rock/concrete shear strengths for the stability analyses of a number of concrete gravity structures in northern Ontario.

Review of conceptual plans for the underground storage of low-level radioactive waste in Ontario. Assisted in the preparation of tenders and contract awards.

Responsible for the long-term automation planning for geotechnical instrumentation at a number of hydroelectric plants in northern Ontario, and the design and installation of remote monitoring systems.

Project Engineer for the Malvern remedial project, involving site preparation for the sorting and storage facilities for 9000 m3 of mildly radioactive contaminated soils. Responsible for detailed final designs, contract preparation, construction supervision and contract closeouts.

Resident Site Engineer during the Stage 3 geotechnical investigations for the Niagara River hydroelectric development. These investigations included the construction of a 600-m long, 3.5-m dia. adit and a 13.5-m dia. trial excavation chamber in the Queenston shale by means of roadheader. The site was affected by high in situ stresses, highly corrosive groundwaters and swelling rock conditions. The program also included various instrumented arrays, measurement of in situ stresses, borehole dilatometer and geophysics testing, and the development of special in situ and laboratory testing for rock swell.

Geotechnical coordination for the definition phase design of the generation facilities for the Niagara River hydroelectric development. These facilities included a proposed 26-m wide powerhouse cavern, transformer gallery, 12.5-m dia. penstock and tailrace tunnels, and associated access tunnels. Design studies included 3D boundary and finite element analyses of the underground complex, and preliminary support design. The work was superseded by the Niagara Diversion Tunnel project.

Coordination of geotechnical and geophysical field investigations for feasibility and final design of a proposed extension to the Owen Falls generating station, Uganda. Responsible for overall review of project seismicity. The project involves a 20-m deep cut in residual soils for a 1-km long power canal and an intake structure on very weak bedrock foundations.

Coordination of investigations for feasibility of siting a health center on an existing landfill in Toronto, Canada. Specific concerns included methane gas control and excavation/redisposal of solid wastes.

Acres International **Geological Engineer** ***1978—1990***

Resident geotechnical representative at the construction site of the 540-MW Chamera hydroelectric generating station in Himachal Pradesh for National Hydro Power Corporation of India. Work included

- supervision of rock excavation, rock support and quality control for 9.5-m dia, 6.5-km long power tunnel, underground powerhouse complex and tailrace tunnel. Installation of 10.5-m long, 52-mm high tensile hollow core bar anchors in crown, and 13-m long, 36-mm dia anchors in walls
- training and transfer of technology to a group of local engineers and geologists
- geotechnical instrumentation.

Planning and supervision of drilling, testing and instrumentation at the Mactaquac generating station, New Brunswick. Investigation of structures and their foundations included determination of concrete characteristics of, and defining the cause of movements within, a concrete gravity intake/spillway and powerhouse. Fieldwork involved a study of concrete cracking and construction joint conditions by borehole photography and ultrasonic methods. Instrumentation installations included tape and borehole extensometers, normal and inverted plumb lines, various deformation and strain gauges, pneumatic piezometers and thermocouples. Concrete tests included direct shear, strength and index properties, thermal properties and both standard and non-standard tests for potential AAR.

Involved in geological investigations for a major project in the Middle East including in situ stress measurements in deep boreholes and core orientation studies.

Development of stereographic projection, statistical analysis and other computer program packages for general use in interpretation of geological field data.

Feasibility site reconnaissance and geologic interpretation of general site conditions for the Sentani hydroelectric project in Irian Jaya, Indonesia. Project involved 4-m dia. tunnels through karstic limestone ridges and 20-m deep channel excavations in weak soils. Evaluation of bids for field explorations.

Detailed dam abutment geologic mapping and assessment for the proposed Granite Canyon hydroelectric development, Yukon.

Development of a computer aided borehole photography interpretation system for use in a foundation investigation program for the spillway at the Limestone generating station, Manitoba.

Prefeasibility site reconnaissance for the Yom-Nan diversion project in Thailand. Responsible for interpretation of general site conditions for determination of project feasibility. Project involved a 25-km long, 8-m dia. tunnel in rock and 48-km of canal excavation in residual soils.

Responsible for geological mapping, core logging, borehole photography and geological interpretation of site conditions for the Upper Salmon hydroelectric development, Newfoundland. Project involved excavations up to 25 m in vertically fissile rock, greater than 5 km of earth-fill dams and dikes up to 25 m high, and overburden excavation for diversion channels. Preparation of data for tenderers and technical specifications for contract purposes. Calculations of rock slope stability and support requirements on site during part of the construction period to review the rock excavations and performance of bar anchors. Responsible for installation of dam instrumentation and supervision of post-impounding monitoring program. Instrumentation included inclinometers, hydrostatic settlement profile gauge, tape extensometer and pneumatic piezometers.

Layout, field supervision and report on an exploratory drilling program related to the stability of a powerhouse rock intake tunnel near Wawa, Ontario.

Responsible for geological mapping, core logging and geological interpretation of site conditions during a major investigation program for a thermal power generating station at Atikokan, Ontario. Project involved dam rehabilitation, construction of rock tunnels, deep excavations in rock and overburden, and heavy structure foundations.

TECHNICAL PAPERS AND MAJOR PRESENTATIONS

Dam Safety Risk – Canadian and BC Hydro Perspectives, ICOLD-INCA Symposium on Dam Safety for the Americas, Mexico City, October 2016

Next Steps in BC Hydro's Risk Informed Decision Making, keynote presentation at ANCOLD Annual Conference, Brisbane, November 2015

BC Hydro Seismic Hazard Model, presentation at Emergency Preparedness and Business Continuity Conference, Vancouver, November 2014

Reframing Risk Informed Decision Making at BC Hydro, Canadian Dam Association Conference, October 2014 and keynote speech, 2013 HG Acres Seminar, Niagara Falls.

Why Every Owner Needs Risk Informed Decision Making, presentation at CEATI Dam Safety Interest Group meeting, Vancouver, October 2013

Assessment of Extreme Flood Hazard, Series of articles for CDA Newsletter, 2011-2013, that led to the 2013 revision of the CDA Guidelines

Assessment of Shear Resistance for Blasted Rock Foundations, Canadian Dam Association Conference, September 2007.

The Design and Construction of the Shikwamkwa Replacement Dam, Canadian Dam Association Conference, September 2007. (Coauthor)

Accounting for Time-Dependent Deformation in the Niagara Diversion Tunnel Design, Proc. 1st Canada-US Rock Mechanics Symposium, Vancouver, May 2007

Concepts of Shear Resistance and Practical Applications. Dam Engineering, Volume XVI, Issue 3, November 2005. (Coauthor)

Monitoring Sinkhole Development by Detailed Sonar Profiling. Proceedings; Association of State Dam Safety Officials Annual Conference, September 2005, and Proceedings; Canadian Dam Association Conference, October 2005. **Best Paper Award**

The Assessment of Sliding Resistance Beneath Concrete Structures. WaterPower XIII, July 2003. (Coauthor)

Grouting of a Karstic Arch Dam Foundation. 55th Canadian Geotechnical Society Conference, Niagara Falls, Ontario, October 2002. (Coauthor)

A Phased Approach to the Rehabilitation of an Aging Northern Dam. HydroVision 2000 Conference, August 2000. (Coauthor)

Exploratory Adit Program for the Niagara River Hydroelectric Development. 12th Annual Canadian Tunneling Conference, Vancouver, BC, October 1994.

Design of Underground Powerhouse Complex, Niagara River Hydroelectric Development. 45th Canadian Geotechnical Conference, Toronto, Ontario, October, 1992.

Placement and Performance of Impervious Fill Blankets on Slopes. 44th Canadian Geotechnical Conference, Calgary, Alberta, 1991. (Coauthor)

Rock Support for a Large Underground Cavern at Chamera. All India Conference on Underground Engineering, Lucknow, India, February, 1989.

Engineering and Construction Options for the Management of Slow/Late Alkali-Aggregate Reactive Concrete. Proceedings, 16th International Congress on Large Dams, San Francisco, 1988. (Coauthor)

Laser Strain Measurement System. Paper presented at Annual Meeting, Association of Engineering Geologists, Hershey, Pennsylvania, 1978.

The Effect of Sodium Chloride on Water Sorption Characteristics of Rock Aggregate. Bulletin, Association of Engineering Geologists, Vol XIII, No. 3, 1976. (Coauthor)

LANGUAGES

English

DAVID K. ROGERS, P.E.,C.E.G.

GEOLOGICAL ENGINEERING SERVICES FOR DAMS AND SPILLWAYS

KEY QUALIFICATIONS:

Mr. Rogers has over 50 years of broad professional experience as a senior project manager and geological engineer for planning and design and rehabilitation of a variety of dams including earth fill, roller compacted concrete (RCC), concrete gravity and arch, and rock fill, as well as rehabilitation of powerhouses and penstocks, tunnels, hydroelectric power plants, penstocks, large diameter pipelines, pumping stations, flood control levees, and other water resource projects with constructed values up to the billion dollar range. This senior project experience includes the management of multidisciplinary teams for the planning, design and construction of spillway rehabilitation. His technical and project management experience includes foundation engineering, design of grout programs, design and implementation of dewatering systems, base line geotechnical reports, groundwater control, soil and rock mechanics, earthquake fault evaluation, seismicity and response spectra, and slope stability analyses.

Mr. Rogers, as a consultant to the U.S. Bureau of Reclamation, served as Deputy Program Manager for the safety evaluation of 20 dams under their jurisdiction. As expert witness and technical advisor to various legal counsels, Mr. Rogers has participated in a wide spectrum of litigation and potential litigation representing the owner against contractor claims. He is skilled in consensus building and negotiations for dam safety and environmental requirements by many years of interface with several governmental agencies including the California Division of Safety of Dams (DSOD), U.S. Bureau of Reclamation (USBR), Federal Energy Regulatory Commission (FERC), U.S. Corps of Engineers (USCOE), State Water Resources Control Board (SWRCB), Regional Water Quality Control Boards (RWQCB), California Department of Fish & Game (DFG), California State Historic Preservation Office (SHPO), U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (USFLS), U.S. Environmental Protection Agency (EPA), Environment Canada and several State level fish and wildlife agencies.

EDUCATION AND PROFESSIONAL REGISTRATION:

Master of Science, Geological Engineering, Mackay School of Mines, University of Nevada, Reno; 1975
Bachelor of Science, Geological Engineering, Mackay School of Mines, University of Nevada, Reno; 1967

Continuing Education: NEPA/CEQA (EIR/EIS) Process, U.C. Davis Extension, 1974; California Construction Law: Federal Publication, Inc., November, 1993; Contractor Claim Resolution, National Law Institute, 1993; Civil Penalties and Criminal Enforcement of Environmental Violations, CLE International, 1993; General Engineering Contracting: Contractor's License Center, Nevada, August, 1994; A-E Contracting: U.S. Army Corp of Engineers, Directorate of CE Training Management, Huntsville, Alabama, December, 1994; DPIC Continuing Education Program: Contract Review and Negotiations, October, 1997, Mechanical Tunneling in Soft Ground/Hard Rock, Society of Mining Engineers, 2003, Pricing and Negotiation, May 2004.

Professional Societies: American Society of Civil Engineers; Society of Military Engineers.

Professional Registrations: Professional Engineer, California, C37113 (1983); Geologist, California 3369; Engineering Geologist, California EG967; California Contractor-A Hazardous (inactive) 790325

SENIOR TECHNICAL ADVISOR/ADVISORY BOARD MEMBER

SACRAMENTO MUNICIPAL UTILITY DISTRICT

Advisory Board Member for the Iowa Hill Pumped Storage Project, a new 400 MW hydroelectric facility planned in the Central California foothills. Provided guidance on geotechnical design criteria and exploratory programs including horizontal/directional borings, baseline groundwater monitoring and a test adit for the underground powerhouse cavern, access and utility tunnels, evaluated slope stability and foundation conditions for a new upper reservoir servicing the existing lower Slab Creek Reservoir. Was instrumental in the re-design of access and service tunnels to minimize construction impacts and cost. Developed new project construction access roads to minimize environmental and community impacts during construction. Assisted the client with public relations and environmental impacts. Performed detailed technical interpretation of LIDAR imagery and identified potential landslide hazards and bedrock structure for detailed analysis of regional stress conditions. Total Construction cost of $800 million. (2008-2016)

Technical review of geotechnical conditions for construction of a combined hydroelectric power plant/fish release structure for the Lower Slab Creek Structure to meet the re-licensing requirements with the U.S. Forest Service. Total Construction costs of $40 million. (2014)

CALIFORNIA DEPARTMENT OF WATER RESOURCES

Twin Tunnel Alternative, Bay Delta Conservation Plan
California Department of Water Resources/URS
Senior Advisory Technical Review of conceptual design 40 miles of twin, 40-foot diameter tunnels, two new forebays, three new river intakes, and 14 vertical shafts for construction. Total Estimated Construction costs of $4 billion. (2009)

SAN FRANCISCO PUBLIC UTILITIES COMMISSION EXPERIENCE

Sunol Regional Manager, Project Management Bureau

Senior Project Manager for the Calaveras Dam Replacement and New Irvington Tunnel Projects, and Senior Project Manager supervising several Project Managers within the Sunol Region including the Alameda Creek Fisheries Enhancement Project, Removal of Unsafe Structures, Calaveras Reservoir Upgrades, San Antonio Backup Pipeline, Alameda Creek Release Valve Upgrades, Alameda Siphon No.4, SVWTP Expansion & New Treated Water Reservoir,, Standby Power, and Pipeline Repair Readiness Improvements. Assisted on technical review and oversight on the Lower Crystal Springs Dam Probable Maximum Flood (PMF) and spillway upgrades. Prepared monthly accrual reports, Sunol Valley Cost Loading Report, Supplemental Budget Requests, Budget Reallocation Requests, Prop. A Level 13 Reports, and Interim Project Status Reports. Prepared and reviewed staffing plans for Calaveras Dam Replacement, New Irvington Tunnel, and Calaveras Reservoir Upgrades and negotiated staffing levels with other SFPUC Bureaus providing support services including Engineering Management Bureau, Water Quality Bureau, Bureau of Environment,, and Construction Management Bureau.. Responsible for review and approval of consultant invoicing and HRC compliance reports. Responsible for review and approval of internal staff charges to projects and monitoring FAMIS reports and P3e through P6 reporting. Presented project overviews to Multi-Agency environmental/permitting representatives. Led and participated in Calaveras and Alameda Creek watershed tours with representatives from DF&G, RWQCB, USCOE, and NOAA/NMFS. Participated in management level discussions related to fisheries and “fish policy” issues of the Calaveras and Alameda Creek. Conducted public presentations to stakeholders, property owners, project opponents, resource agencies, for two controversial project, Calaveras Dam Replacement and New Irvington Tunnel. Mentored and trained younger/less experienced staff on public relations, presentations, tunnel and dam design criteria, and geotechnical issues affecting design. Was responsible for coordinating resources, maintaining budgets and schedules, and public outreach for $856 million of total project costs of the Sunol Region. Estimated construction cost of the Calaveras Dam Replacement was $257 million and the New Irvington Tunnel was $290 million.

DAM PLANNING, DESIGN, AND REHABILITATION EXPERIENCE

Calaveras Dam Replacement Project, California, U.S.A.
San Francisco Public Utility Commission
Senior Project Manager for the conceptual and final design of the Calaveras Dam Replacement Project. Provided oversight and overall project guidance to the consultant design team of URS Corporation and SFPUC civil, electrical and mechanical designers. Inter-faced with the Calaveras Technical Advisory Panel, consisting of Dr. Clarence Allen, Dr. John (Jack) Cassidy, Dr. Ed Idriss, Alan O'Neill, and Eric Kollgaard. Conducted public presentations to land owners, stakeholders, and resource/regulatory agencies including RWQCB, Dept. of Fish & Game, U.S COE, USF&WLS, NOAA/NMFS. Provided guidance to the environmental consultant, EDAW-Turnstone Joint Venture on dam construction technical issues. Responsible for maintaining compliance with approved budgets and schedules. Total project value was $308 million with total construction cost of $257 million. (2005-2007)

Upper San Joaquin River Storage Investigation Study, California, U.S.A
Client: U.S. Bureau of Reclamation
Task Manager for Engineering Services including evaluation of 18 dams of various construction (rock fill, earth fill, concrete arch, concrete gravity, and RCC), alternative designs, conceptual design and cost estimating for selected alternatives to raising Friant Dam to increase storage up to 700,000 AF. Managed a multi-disciplinary team of civil/mechanical/electrical/ hydraulic/geotechnical engineers, cost estimators, and engineering geologists. Engineering tasks are part of a 3-year EIR/EIS program involving stakeholder meetings and issuance of technical memorandum documents. Cooperative coordination with the Department of Water Resources and the U.S. Corps of Engineers is involved. Consensus building and negotiations with regulatory agencies include the California Division of Safety of Dam (DSOD), Federal Energy Regulatory Commission (FERC), U.S. Fish & Wildlife Service, U.S. Forest Service. Estimated constructed project value $1.5 billion. (2001-2004)

FERC Hydroelectric Power Project 184 Rehabilitation, California, U.S.A.
Client: El Dorado Irrigation District
Construction Manager for rehabilitation of the FERC Project 184 dam and hydroelectric power plant facilities, which were flooded or damaged in the January 1997 floods. Project facilities include a 18-foot high diversion dam, fish ladder and screen, and intake structure on the South Fork of the American River, repairs to several flumes along 22.5 miles of open canals, removal and restoration of 2.5 miles of canal, rebuilding the crane and two high head, pelton wheel driven generators, rewinding stators and rotors, replacement of isolation valves and electrical controls. Coordination and scheduling for all engineering, plans, specifications, and bid documents for rehabilitation work. Coordination for all environmental compliance and permitting.. Economic analysis of water and power options with assistance from Complete Energy Systems. FERC is lead agency consensus building and negotiations were conducted with U.S.F.S., U.S. Fish and Wildlife Service (U.S.F.&W.S.), CDF&G and RWQCB participating. Constructed project value $28 million. (1999-2004)

Animas LaPlata Water Supply Project, Colorado
Client: U.S. Bureau of Reclamation/Ute Mountain Indian Tribe
Senior Project Manager and Lead Geological Engineer for a planning appraisal level engineering, design, and cost estimation of a water supply project providing 112,000 acre feet (AF) per year to implement the Colorado Ute Water Rights Settlement Act and serve additional municipal and industrial water needs. Design and cost estimates included the evaluation of six alternative schemes with storage capacities from 90,000 to 135,000 AF earth fill dam at the Ridges Basin Site, enlargement of the existing Lemon Rock Fill Dam, and two other off stream, earth fill dam and storage reservoirs. The selected alternative for feasibility level design and cost estimate is a 120,000 AF reservoir with a 217-foot high, 1,670 long, zoned earth fill dam, a pumping plant building housing five 56 cubic feet per second (cfs) horizontal pumps, and 2-miles of 66-inch diameter pipeline. Estimated constructed project value $526 million. (1999-2003)

L.L. Anderson Rock Fill Dam Spillway Design Modifications, California, U.S.A.
Client: Placer County Water Agency
Program Manager, Technical Reviewer, and Construction Manager for the preliminary design, final design and quality assurance for construction of a new spillway/escape channel after record rainfall in 1996 caused reservoir

overflow to leave the old spillway channel. The design consisted of creating a series of hydraulic jumps to dissipate flow energy, constructing an armored plunge pool with concrete training walls to direct excessive flows to an energy dissipating structure, and other soil bank and erosion control structures. Because of environmental concerns, the construction season was spread over two years. These spillway modifications were negotiated and performed under the jurisdiction of FERC, DSOD, California Department of Fish & Game, U.S. Forest Service, and the U.S. Fish and Wildlife. Constructed project value $20 million. (1997-2000)

Sea Ranch Earth Fill Dam Rehabilitation Design, California, U.S.A.
Client: Sea Ranch Water Company
Senior Project Manager responsible for the investigation and safety evaluation of 2,400 foot long, 70-foot high earth fill dam containing a 300 acre foot water supply reservoir less than a mile from the San Andreas Fault. Drilling, sampling, laboratory testing and installation of piezometers and settlement monuments were completed to evaluate zonation, drainage, seepage and seismic stability of the earthfill dam located less than a mile from the San Andreas Fault. Pseudo-static and 2-D dynamic finite element analysis to evaluate dam embankment deformation during an earthquake. Developed design alternatives, final design plans, cost estimates, and specifications for strengthening of the dam embankment. California Division of Safety of Dams (DSOD) is lead agency. Constructed value of repairs $2 million. (1999-2000)

New Los Padres RCC Dam Design , California, U.S.A.
Client: Monterey Peninsula Water Management District
Program Manager coordinating the activities of a multidisciplinary team of civil, structural, electrical, mechanical, geotechnical engineers, and environmental scientists of the prime consultant, two subconsultants and five subcontractors for the planning and conceptual design and cost estimate for a proposed 282-foot high RCC dam on the Carmel River. Directed the field investigations for potential borrow areas, water pressure testing and grouting, geophysical surveys, and engineering geologic mapping. Primary subconsultants under his direction were responsible for RCC mix design, stability analysis of the RCC fill, constructibility and construction cost estimates, and fault activity studies. Subcontractors included core and rotary drilling, trenching, geophysical surveys, geotechnical laboratory tests, and RCC mix design tests. Provided Total Quality Management (TQM) as principal reviewer of other's technical work and melding the writing style of several authors into a complete yet concise report. The project was completed within budget and on schedule with significant beneficial results for the client. Estimated constructed project value $280 million. (1994-1998)

Finnon Hydraulic Fill Dam Safety Evaluation, California, U.S.A.
Client: El Dorado County Water Agency
Project Manager and lead geological engineer for safety evaluations during a due diligence assessment for the 50-foot high, 830-foot long, hydraulic fill dam. Conducted site reconnaissance, reviewed existing construction and exploratory data, and prepared a work plan to be submitted to the DSOD to evaluate the seismic stability and develop remedial measures to strengthen the liquefiable embankment. (1997)

Weber Dam PMF Design Modifications, California, U.S.A.
Client: El Dorado Irrigation District
Construction Manager for implementing plans, specifications, and other bid documents for flood improvements to Weber Dam. Responsible for Quality Assurance/Quality Control (QA/QC) review and construction implementation and schedule. This work enabled the dam to withstand the Probable Maximum Flood (PMF) and to minimize undermining of the dam foundation during the PMF. The safety modifications as directed and approved by FERC and DSOD consisted of lowering the main arch crest by 1.6 feet and raising the side arches by 2.5 feet. A reinforced concrete erosion control slab was constructed to protect the main arch foundations. Safe access to the dam arches was created by installing a new spillway bridge crossing and handrails on the arches. Constructed project value $5 million. DSOD lead agency. (1996)

Weber Concrete Arch Dam Stability Analysis and Conceptual Design, California, U.S.A.
Client: El Dorado Irrigation District
Program Manager and technical oversight for a program focused on stabilizing the dam's buttresses by improving the foundations and anchoring them into the hill slope. A preliminary cost comparison with other dam stabilization alternatives (RCC infill, rock fill, concrete gravity, existing dam removal) demonstrated the buttress anchoring program would be significantly less costly than other alternatives. Seismicity studies by others for two nearby dams

operated by SMUD (Slab Creek and Brush Creek) showed the peak ground acceleration at Weber Dam could be reduced; thus, significantly reducing stresses in the arch due to seismic loading, and making the buttress anchoring feasible but not without risk. DSOD lead agency. (1990)

Los Verjeles Concrete Arch Dam Safety Evaluations, California, U.S.A.
Client: Thousand Trails Corp.
Project Geological Engineer for a DSOD required safety analyses of the 56-ft high multiple arch dam. Built in 1915, the dam consisted of 12 cylindrical reinforced concrete arches set at 45 degrees to horizontal and supported by buttress walls. The arches had a radius of 10 feet and were 9-inches thick at top and 18 inches thick at the bottom. Responsible for evaluations of faulting and seismicity and assistance in development of ground motion time-histories, performance of static and dynamic 3-D finite-element analyses, and stability evaluations under seismic loads, and spillway design flood (SDF) and over pore loads. DSOD was lead agency. (1987)

Safety Evaluation and Expansion, Sawmill Hill Earth Fill Dam , California, U.S.A.
Client: Pebble Beach Public Utilities Department
Project Geological Engineer conducting field investigations (geologic mapping, borings and slug tests) for earth fill embankment stability analysis and routing studies for 5 miles of 30-inch sewer main. Also evaluated the feasibility of raising the existing earth fill embankment another 10 feet. (1984)

Milliken Concrete Arch Dam Safety Evaluation, California, U.S.A.
Client: City of Napa - Department of Public Works
Project Geological Engineer for DSOD required safety analyses of the 110-ft high single radius concrete arch dam, including tectonics/faulting and seismicity studies and assistance in development of ground motion time-histories, performance of static and dynamic 3-D finite-element analyses, and stability evaluations under seismic (0.6g due to close proximity of active Greensville Fault) loads, and spillway design flood and over pore loads. The studies showed the 1924 built structure meets the present day seismic and flood requirements. DSOD was lead agency. (1983)

Folsom Rock Fill Dam Seismic Safety Analysis, California, U.S.A.
Client: U.S. Bureau of Reclamation
Lead Geological Engineer responsible for the detailed faulting/seismotectonic investigations as part of safety review of the 275-ft high rockfill dam built in 1956. Investigations included air-photo lineament analysis, color IR and LANDSAT imageries, trenching, mapping, and age dating of the Quaternary deposits overlying the Bear Mountains Fault Zone. U.S. Corp of Engineers was lead agency.(1983)

Combie Dam Stabilization Design and Construction Management, California, U.S.A.
Client: Nevada Irrigation District
Senior Project Manager of the five-year periodic post-construction testing and safety evaluation of post-tensioning tie-down system for the 85-ft high concrete arch dam. The 1928 built structure had come under FERC jurisdiction by installation of a small hydroelectric power plant. A prior safety inspection had indicated seismically unsafe condition due to excessive uplift seepage forces. A tie-down system was designed and constructed which consisted of 15 sets of low relaxation steel strand tendons post-tensioned to 270 kip each (350 kip capacity). FERC is lead agency. (1980-1982)

Summit Earth Fill Dam Safety Evaluation, California, U.S.A.
Client: East Bay Municipal Utility District
Project Geological Engineer for the DSOD required safety investigations and analyses of the 61-ft high earth fill dam and 117-af covered reservoir built in 1881. Assisted in geotechnical and earthquake engineering investigations including drilling, sampling, and laboratory testing, faulting and seismicity studies, and development of ground motion time-histories, and 3D finite element dynamic stability analysis of the earth dam and its intake and outlet structures, which are only a few hundred feet from the Hayward fault. The results indicated that the dam and its appurtenant structures meet the safety criteria of DSOD. (1982)

Seismic Safety Evaluation of Existing Dams (SEED) Program, California, Colorado, Arizona, Utah, U.S.A.
Client: U.S. Bureau of Reclamation
As Deputy Program Manager, Mr. Rogers coordinated the research, field and reporting activities of several three-person teams (civil/geotechnical, mechanical, engineering geology) evaluating the seismic safety of 20 dams owned

and operated by the U.S. Bureau of Reclamation. Mr. Rogers provided technical oversight and report QA/QC for the various teams. He also participated as a geological engineer for the safety evaluation of the Stampede Rock Fill Dam and Reservoir and Prosser Creek Rock Fill Dam and Reservoir located in Placer County, California. (1981)

Hume Lake Concrete Arch Dam Safety Evaluation, California, U.S.A.
Client: U.S. Forest Service
Project Geological Engineer for the safety review and analyses of 51-ft high multiple-variable arch dam built in 1908. Responsible for evaluation of the foundation bedrock and concrete properties, faulting and seismicity studies, and assistance in the development of ground motion time-histories, performance of static and dynamic 3-D finite-element analyses, and stability evaluations under seismic loads, and probable maximum flood (PMF) and overpore loads. The dam was found meeting all present day safety criteria. DSOD was lead agency. (1979)

Elgo Earth Fill Dam Design, PS&E, and CQA, Arizona, U.S.A.
Client: San Carlos Indian Tribe
Resident Geological Engineer that oversaw the field investigations and construction quality assurance (CQA) management activities of civil / geotechnical engineers and geologists for design, plans, specifications, and engineering (PS&E). This 180 foot, zoned earth fill dam with a side channel spillway was designed and built for the San Carlos Indian Tribe to provide flood control and recreational revenue to the tribe. The design which incorporated an 80-foot deep, bentonite slurry cutoff wall beneath the clay core with a side channel spillway to pass the PMF received an award for engineering excellence by the American Society of Civil Engineers. (1979)

Soulajule Earthfill Dam Design, PS&E and CQA, California, U.S.A.
Client: Marin Municipal Water District
As Resident Geological Engineer, Mr. Rogers developed and supervised a dam foundation exploration and testing program (core drilling, water pressure tests, test grouting) in Franciscan melange for a 122-foot high, zoned earth fill dam and 100,700 AF reservoir. He conducted fault activity and seismicity studies, regional and local geologic/geomorphic mapping and designed and oversaw the foundation grouting. During construction, Mr. Rogers was the Lead Geological Engineer of record who interfaced with DSOD on design modifications due to field conditions exposed during construction. (1978)

SENIOR PROJECT MANAGEMENT OF MULTI-DISCIPLINARY TEAMS EXPERIENCE

Specialized Engineering Services, Hydroelectric Power, California, U.S.A.

Client: San Francisco Public Utility Commission, Utility Engineering Bureau
Senior Project Manager for providing Indefinite Delivery/Quantity engineering services for design and rehabilitation of various water delivery and hydroelectric power facilities within the jurisdiction of the Hetch Hetchy Water and Power Department. Execution of work was through tasks orders under two consecutive 3-year contracts with maximum funding of $400,000 per period. Managed a multi-disciplinary team of W/MBE subconsultants and in-house staff of civil/structural/electrical/mechanical/geotechnical engineers, architects, environmental scientists, and surveyors. Services included electrical controls, power design, plant capacity studies, life extension and performance testing, electrical-mechanical plans/specifications, cost-benefit analysis, scheduling, environmental permitting, process control monitoring, geotechnical/seismic studies and retrofit, and civil/structural engineering and design for new structures including a third penstock at the Moccasin hydroelectric power plant. Task orders during 1996-2002 included: Task 1-As Needed Administration and MIS support, Task 2-Master Schedule Update, Task 3-Moccasin Penstock Conceptual Design, Task 4-Construction Schedule Review, Task 5-Baden Pump Station Upgrades, Task 6-Generator Inspection, Task 7-Cost Benefit Analysis for Port of San Francisco, Task 8-San Francisco Airport Substation Expansion. Under the second consecutive contract, Mr. Rogers managed: Task 1-Peer Design Review for seismic upgrade of Bay Delta Pipeline No.1 and No. 2 crossing of Hayward Fault, Task 2-Final Design of Moccasin Penstock, Task 3-Survey of Moccasin Penstock, Task 4-Torque calculations for Calaveras Cone valve, Task 5-Underground duct design and HHWP Substation Design, Task 6-Grout observation and control of underwater duct crossing. (1996-2002)

On-Call Engineering Services, Dams and Hydroelectric Power, California, U.S.A.
Client: Sacramento Municipal Utility District
Senior Project Manager for providing Indefinite Delivery/Quantity engineering services for design and rehabilitation of the dams and hydroelectric facilities within the Upper American River Project. Services were provided through three consecutive 3-year contracts with maximum funding of $1,000,000 per period. Managed a multi-disciplinary team of W/MBE subconsultants and in-house staff of civil/structural/electrical/mechanical/geotechnical engineers, environmental scientists, and engineering geologists. A hallmark project was the conceptual design and cost estimate for the $450 million dollar Iowa Hill Pumped Storage Hydroelectric Power Project. An upper reservoir would be built by constructing a ring dike embankment and two power alternatives (750 and 1500 MW) were assessed. Other services included electrical controls, power design, plant capacity studies, electrical-mechanical design and construction supervision, CPM studies, geotechnical/seismic studies and retrofits, civil/structural engineering for new construction. Task orders during the first contract award included: Task 1-Jaybird Generator Rewind, Task 2-Update and provide training on Emergency Preparedness Plan for gas pipelines, Task 3-SCA Gas Turbine Peaker Geotechnical Investigation, Task 4-Engineering Review of Construction Specifications for one mile of natural gas pipeline, Task 5-SCA Peaker Construction Management, Task 6-Camino Tunnel Condition Assessment, Task 7-Canned Shutdown Procedures for Gas Pipeline, Task 8-Construction Management and Inspection of Gas Pipeline Relocation. Under the second consecutive contract, Mr. Rogers managed: Task 1-Update Emergency Preparedness Plan, Task 2-DOT Operator Qualification Training, Task 3-Photovoltaic System Maintenance Program, Task 4-Iowa Hill Pumped Storage Development conceptual design and cost estimate, Task 5-Camino Powerhouse Geotechnical Investigation and defense against contractor claims, Task 6-Gas Pipeline Procedure Manual, Task 7-Facilitate Potential Failure Modes Analysis for Union Valley, Ice House, Loon Lake, and Junction Dams, Task 8-Iowa Hill Pumped Storage Development and Upper American River Project (UARP) Relicensing Engineering Support, Task 9-Iowa Hill Pumped Storage Development Geotechnical Investigation. Under the third consecutive contract, Mr. Rogers managed the following tasks: Task 1-UARP Relicensing Sources of Sediment Study, Task 2-Jaybird Generator Submittal Review, Task 3-Iowa Hill Pumped Storage Development Phase 2 Geotechnical Investigation, Task 3-Iowa Hill Pumped Storage Development Topographic and Boundary Survey, Task 4-Iowa Hill Pumped Storage Development Access Road Survey and Design, Task 5-Iowa Hill Pumped Storage Development Transmission Line survey and design, Task 6-White Rock Development Capacity Analysis, Task 7-Visual Concept and Virtual Imaging of Iowa Hill Project Features. (1998-2004)

The MARK Group, Infrastructure and Environmental Engineers, Inc., California, U.S.A.
Client: Various
Owner and Regional Manager of a 120 person consulting firm with three offices (Walnut Creek, Las Vegas, Santa Ana) providing water resource and environmental engineering services to public utilities, industrial, and hydroelectric clients. Staff consisted of a multidisciplinary team of civil, structural, electrical, mechanical, environmental, and geotechnical engineers, engineering geologist, hydrogeologist, environmental scientists, and environmental planners. Held positions of Chief Financial Officer, Chairman of the Board, and Regional Manager of the Northern and Southern California offices since starting the firm in June 1984. The MARK Group, Inc. was acquired by Harza Engineering Company in February 1999 and Harza Engineering merged with Montgomery Watson in 2002. The MARK Group, Inc. provided water resource services to El Dorado Irrigation District, Nevada Irrigation District, Tri-Dam Agency, Sacramento Municipal Utility District, Monterey Peninsula Water Management Agency, Amador County Water Agency, Placer County Water Agency, U.S. Corps of Engineers-Sacramento and San Francisco Districts, East Bay Municipal Utility District, Contra Costa Water District, Santa Clara County Water District, City and County of San Francisco-Port of San Francisco, Modesto Irrigation District, and Turlock Irrigation District. Some industrial clients for environmental engineering services included Tosco Refinery, USS Posco/U.S. Steel, Chevron, Shell, Dow Chemical, IBM, and Teledyne.

Was responsible for planning and management, marketing and business development, training and mentoring staff, quality control and quality assurance (QA/QC), developing, controlling, and managing scope, schedules, and costs for large projects having consulting fees in excess of $1 million or projects with constructed value more than $100 million. (1984-1997).

The MARK Group, Construction Engineers, Inc., California, U.S.A.
Client: Various
Owner and Responsible Qualifying Officer of a 30 person general engineering construction company operating from the Walnut Creek office of The MARK Group, Inc. providing design-build services for reservoir linings, pond

lining, landfill closures, groundwater pump and treatment systems, underground tank removal and remediation, hazardous waste line removal and cleanup to county and city public works departments, governmental research laboratories, U.S. Army Corps of Engineers, and industrial clients. Staff consisted of a multidisciplinary team of civil engineers, environmental scientists, environmental/mechanical/electrical engineers, carpenters, plumbers, iron workers, masons, laborers, and other trade employees. Was the License Qualifier, by experience and examination of the A-General Engineering Contracting License with Hazardous Materials Removal specialty. Construction services were provided to Lawrence Livermore National Laboratories (design and construction of 20-acre reservoir lining system, capping and closure of nine hazardous waste landfills, installation of a 500 gpm groundwater pumping system, removal and cleanup of mixed waste disposal pipelines, removal of underground solvent tanks and installation of above ground tanks), USS Posco (construction of bridge overpass, removal and closure of wastewater evaporation ponds, closure and construction of 50-acre landfill), City of San Jose (design, build, operate groundwater pump/treatment system), Stockton Scavenger (design, build, operate above ground Vapor Extraction System/groundwater pump/treatment system), Shasta County Public Works Department (installation of geotextile liner and leachate collection system), City of Orland (rehabilitation, cleanup, and installation of double liner system of two brine ponds), J.R. Simplot Company (storm water and wastewater pond rehabilitation), Simpson Paper Company (removal and dewatering of 50,000 tons of sludge), City of Mountain View, Monterey County, and City of Sunnyvale (closure construction of Class III landfills), U.S. Army Corps of Engineers (closure construction of solvent disposal pit, heat enhanced vapor extraction system, bioremediation of fuel impacted soils, removal of ten oil/water separators and replacement of high performance separators) Zeneca Agricultural Products (wastewater pond cleanout and closure construction), Pacific Gas & Electric (closure construction of oil sludge pond, closure construction of cooling tower waste water pond), Tosco Oil Refinery (closure construction of two oily waste ponds), Unocal Refining and Marketing Division (construction and public relations to install large diameter piping for vapor extraction system in downtown of the coast resort town of Avila Beach).

Was responsible for planning and management, marketing and sales, training and mentoring staff, QA/QC, developing bids, construction schedules for constructed project values up to $50 million. (1990-1997)

EMPLOYMENT HISTORY

2010-Present	Geological Engineering, Sole Proprietor
2008-2010	URS Corporation, Senior Project Manager/Consultant
2005-2008	San Francisco Public Utilities Commission, Project Management Bureau, Senior Project Manager
1997-2005	MWH Americas, Inc. Vice President and Senior Project Manager
1990-1997	The MARK Group, Construction Engineers, Inc., Owner and License Qualifier/Manager
1984-1997	The MARK Group, Inc., Owner and Regional Manager
1978-1984	Converse Consultants, Principal Geological Engineer
1977-1978	Woodward Clyde Consultants, Senior Geological Engineer
1974-1977	Converse Consultants, Senior Geological Engineer
1973-1974	Consulting Geological Engineer
1967-1973	Utah Construction & Mining Company, Geological Engineer
1967-1973	U.S. Army Chemical Corps, Chemical Officer

TECHNICAL PAPERS:

Rogers, D.K., Moffitt, C.J., Wade, D.L., Goodman, R.E., Harlan, R.C., and Hall, R., 2000, Camino Penstock Stabilization, El Dorado County, California: USCOLD 2000 Annual Meeting and Lecture, 30 pp.

Wade, D.L., Rogers, D.K., Mattson, J.M., Cassidy, J.J., and Harlan, R.C., 2000, Spillway Modifications at French Meadows Reservoir, Placer County, California: USCOLD 2000 Annual Meeting and Lecture, 35 pp.

Herbert, J.M., and Rogers, D.K., 2000, Right-Abutment Landslide Stabilization Design and Construction, Pine Flat Dam, Kings River Conservation District, Kings County, California: USCOLD 2000 Annual Meeting and Lecture, 22 pp.

Bonham, H.F. and Rogers, D.K., 1983, Geologic Map, Mt. Rose NE Quadrangle: Nev. Bur. Mines and Geol. Map No. 4 Bg, 1:24,000 scale.

Rogers, D.K., Simon, D.B., and Stellar, J. 1979, Active Fault Zones and Regional Seismicity in Western Nevada: in 17th Annual Engineering Geology and Soils Engineering Symposium, April, 1979, Moscow, Idaho, pp. 275□293

Trexler, D.T. and Bell, J.W. (D.K. Rogers contributing mapping), 1979, Geologic Map and Earthquake Hazards Map, Carson City Quadrangle, Nada: Nev. Bur. Mines and Geol. Map, 1:24,000 scale.

Bingler, E.C. (D.K. Rogers contributing mapping), 1977, Geologic Map and Earthquake Hazards Map, New Empire Quadrangle, Nevada: Nev. Bur. Mines and Geol. Map, 1:24,000 scale.

Rogers, D.K., 1975, Project Mapping: in Guidebook to the Quaternary Geology along the western flank of the Truckee Meadows, Washoe County, Nevada, by E.C. Bingler, Nev. Bur. Mines and Geol. Report 22, 14 pp.

Rogers, D.K., 1975, The California Earthquake of June 7, 1975 □ Geology and Isoseismal Map: Earthquake Engineering. Research Institute Newsletter, v. 9, pp. 78□81.

Rogers, D.K., 1975, Environmental Geology of Northern Carson City, Nevada: Univ. Nev. M.S. Thesis, 133 p.

Rogers, D.K., 1975, How Geology Affects Land Use Planning in Northern Carson City, Nevada: Proc. of the 18th Annual Meeting of the Association of Engineering Geologists, Nov. 2□8, p. 42 (abs).

Document Content(s)

Attachment C

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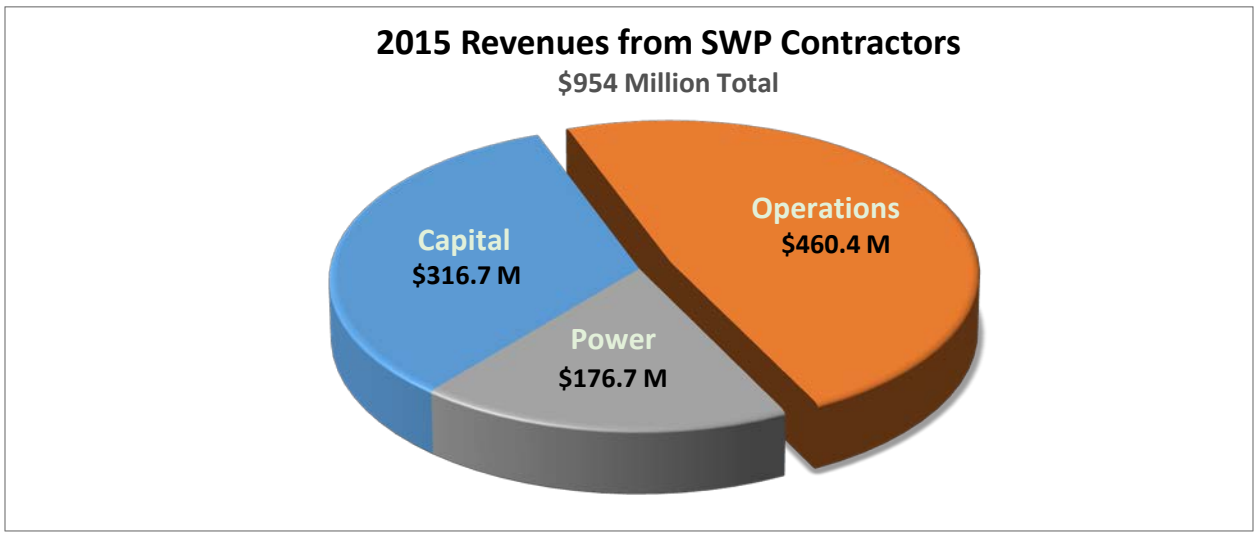
The total State Water Project (SWP) revenues received during 2015 (the most recent year for which final numbers are available) amount to $954 million. These revenues are collected to cover capital, operations, and power purchasing costs of the SWP. The chart below identifies the breakdown of those revenues by the SWP purpose.



The operating costs (the $460.4 million identified above) are broken down by SWP contractor for 2015 on the following pages, as are the costs for the preceding nine years.

Attachment C

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Annual SWP Contractor Operating Charges											
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**10-Year Total**
Feather River Area											
City of Yuba City	141,459	134,599	150,179	167,372	236,442	261,160	284,340	308,697	280,360	398,831	2,363,440
County of Butte	17,682	16,825	437,981	486,041	42,634	69,316	814,517	884,288	803,113	1,142,484	4,714,881
Plumas County FC&WCD	8,679	13,612	35,354	37,421	54,271	63,691	69,809	77,784	73,126	106,724	540,471
North Bay Area											
Napa County FC&WCD	1,144,555	1,096,630	1,396,502	1,526,049	1,909,908	2,360,351	2,921,052	2,434,610	2,804,785	3,386,103	20,980,544
Solano County WA	2,077,519	2,179,426	2,130,042	2,615,432	4,367,562	4,952,156	4,963,128	4,590,321	5,214,627	5,621,226	38,711,439
South Bay Area											
Alameda County FC&WCD, Zone 7	3,665,846	4,351,936	4,815,450	4,658,642	5,112,071	5,685,838	6,082,006	6,764,181	7,146,572	8,326,187	56,608,730
Alameda County Water District	1,821,669	2,155,852	2,385,962	2,206,062	2,567,560	2,824,928	3,006,913	3,315,143	3,443,694	4,146,449	27,874,233
Santa Clara Valley Water District	4,737,705	5,404,329	5,958,274	5,916,998	6,688,647	7,219,757	9,682,453	9,099,225	10,306,304	13,061,743	78,075,436
Central Coastal Area											
San Luis Obispo County FC&WCD	1,114,708	1,177,825	1,616,935	1,520,722	2,025,406	2,129,919	2,182,652	2,496,746	2,275,429	3,072,284	19,612,625
Santa Barbara County FC&WCD	4,292,963	4,226,912	5,990,829	5,316,439	7,358,436	7,807,513	8,594,247	10,268,341	7,160,479	10,481,698	71,497,855
Central Valley Area											
Dudley Ridge Water District	1,308,182	1,329,627	1,479,686	1,513,510	1,738,011	1,971,497	2,060,873	2,272,824	2,108,828	2,534,127	18,317,165
Empire West Side Irrigation District	67,898	68,717	77,026	78,440	102,822	116,863	122,134	134,789	129,697	165,408	1,063,795
Kern County Water Agency	26,123,645	26,924,669	31,465,395	31,377,640	38,623,943	43,897,228	45,950,160	50,030,287	49,558,518	62,155,773	406,107,257
County of Kings	208,643	212,701	240,017	245,957	323,134	364,647	379,502	417,834	405,281	523,848	3,321,565
Oak Flat Water District	110,327	107,006	117,518	126,115	168,025	194,584	199,898	214,810	211,001	281,247	1,730,532
Tulare Lake Basin Water Storage District	2,177,102	2,206,844	2,465,303	2,516,203	3,054,536	3,469,537	3,626,259	4,001,123	3,791,552	4,875,328	32,183,786

Attachment C

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Annual SWP Contractor Operating Charges											
Southern California Area	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**10-Year Total**
Antelope Valley - East Kern Water Agency	6,198,337	6,499,563	7,063,272	7,067,781	7,643,233	8,783,365	9,662,775	10,942,262	11,298,868	12,523,568	87,683,023
Castaic Lake Water Agency	4,630,419	5,721,355	6,693,421	6,132,593	6,619,128	7,308,974	7,960,366	9,083,537	9,259,763	10,143,026	73,552,581
Coachella Valley Water District	13,774,206	13,969,986	14,967,319	14,387,699	16,314,455	18,063,466	18,905,218	19,590,397	23,108,433	22,988,152	176,069,332
Crestline - Lake Arrowhead Water Agency	392,488	409,061	456,739	455,771	504,192	569,573	625,888	680,712	705,110	767,050	5,566,584
Desert Water Agency	4,613,006	4,713,306	5,076,096	4,960,792	5,658,795	6,231,588	6,635,196	7,078,218	7,770,867	8,268,258	61,006,120
Littlerock Creek Irrigation District	108,269	110,835	116,062	117,940	129,325	148,506	165,168	186,009	184,868	206,038	1,473,019
Mojave Water Agency	5,696,286	5,769,981	6,579,660	6,390,662	7,190,846	7,947,974	8,396,575	9,090,426	9,653,749	11,037,747	77,753,906
Palmdale Water District	960,630	988,070	1,069,581	1,069,695	1,149,446	1,351,249	1,472,228	1,664,724	1,680,658	1,832,094	13,238,375
San Bernardino Valley Municipal Water Dist.	8,562,620	9,634,235	10,920,840	10,918,315	11,585,225	12,354,003	13,882,698	15,070,690	15,944,012	17,213,588	126,086,225
San Gabriel Valley Municipal Water District	2,109,112	2,292,299	2,456,442	2,485,034	2,674,405	2,945,222	3,214,067	3,576,880	3,746,502	4,164,372	29,664,336
San Gorgonio Pass Water Agency	1,550,250	1,954,877	2,740,235	2,674,901	3,009,514	3,117,173	3,140,642	3,283,914	3,698,222	3,879,961	29,049,689
Metropolitan Water District of Southern CA	129,648,709	157,483,462	166,307,422	158,520,518	170,505,079	182,488,227	199,696,962	217,689,414	227,997,932	245,183,988	1,855,521,713
Ventura County Watershed Protection District	893,701	1,143,675	1,277,919	1,178,258	1,279,348	1,394,225	1,546,528	1,772,454	1,767,185	1,929,400	14,182,694
Grand Total	228,156,613	262,298,216	286,487,463	276,669,002	308,636,400	336,092,528	366,244,251	397,020,641	412,529,536	460,416,700	3,334,551,350

B132-16 Data SWPAO

These charges reflect actual charges per CY without over/unders for prior years, including actual Variable Charges based on true deliveries. 04.28.17