OROVILLE DAM INCIDENT - 2017

LESSONS TO BE LEARNT

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CONTENTS

This document summarises the webinar by Brian Benson and David Menéndez Arán who discuss lessons to be learnt from the 2017 Oroville dam incident in California. These are relevant to engineers of all disciplines.

Brian and David work for Damwatch, specialising in dam engineering and safety.

They describe the Oroville dam incident – what happened and why, and the lessons to be learnt from this incident for all engineers.

1: INTRODUCTION

Oroville Dam, the tallest dam (235 metres) in the United States, was completed in 1968. Its main functions are to supply water, generate hydroelectricity, and provide flood control.

Between 7-14 February 2017 there was a major incident when the dam spillway chute failed. An evacuation order was given for 188,000 downstream residents on 12 February 2017 and was lifted two days later.

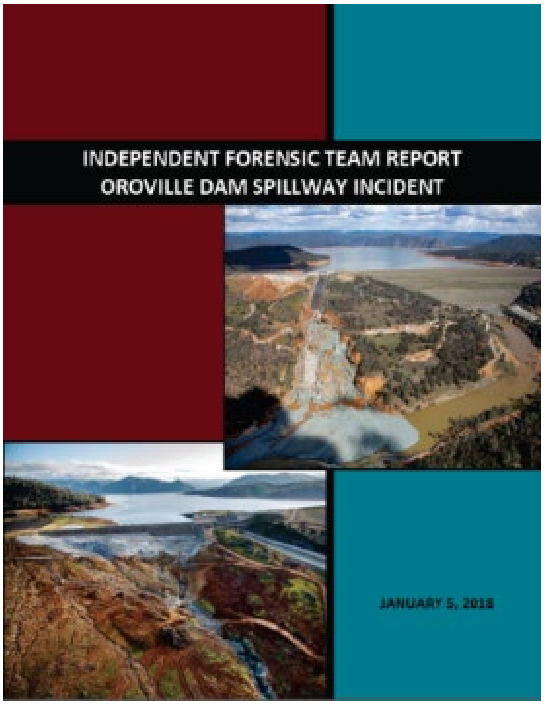
‘The Oroville Dam spillway incident was caused by a long-term systemic failure of the California Department of Water Resources (DWR), regulatory, and general industry practices to recognize and address inherent spillway design and construction weaknesses, poor bedrock quality, and deteriorated service spillway chute conditions.’
(INDEPENDENT FORENSIC TEAM REPORT OROVILLE DAM SPILLWAY INCIDENT, 2018)

This webinar highlights issues that contributed to this incident especially the human, organisational and industry factors.

ACKNOWLEDGEMENT

Please note:

- Source material for this webinar is from the ***INDEPENDENT FORENSIC TEAM REPORT OROVILLE DAM SPILLWAY INCIDENT*** (January 5, 2018). This includes the Executive Summary and Appendix J which have in-depth insights about human and organisational factors contributing to the incident. Please refer to this document for detailed information on the incident.
- Images are from the **California Department of Water Resources** website.



2: WHAT HAPPENED

On 7 February 2017 the Oroville Dam spillway chute failed due to flow-induced uplift and extensive erosion occurring in the underlying foundation. Dam personnel decided to close the service spillway gates to control erosion, which increased reservoir levels and meant the emergency spillway was operated. Soon after, erosion occurred downstream which led to the evacuation order.

This incident was caused by a combination of many factors, including the initial design.

INITIAL DESIGN OF SPILLWAY

As part of the design of Oroville Dam, geologists identified and accurately mapped heavily weathered rock zones along the spillway chute foundation. However, the lead dam engineer was relatively inexperienced, and did not adequately consider this information in their design of the spillway chute**.**

SERVICE SPILLWAY FAILURE

The first significant discharge on the service spillway since 2011 occurred in January and February 2017 (~1,300 m^3/s at the time of failure). This flow was well below the maximum design capacity of the service spillway.

At 10:00am on 7 February the California Department of Water Resource (DWR) personnel who were monitoring the dam noticed a disturbance in the spillway flow.

After closing the gates, they identified that a section of the chute slabs was missing, and erosion of the dam's foundation had started.

The Independent Forensic Team (IFT) determined that failure was likely caused by stagnation-driven uplift pressures as high-velocity water was injected into the drainage system through open cracks and joints. The chute was susceptible to this failure mode due to extensive cracking along the entire chute formed in line with the drainage system.

After the spillway gates were closed, the condition of the spillway was assessed. Note the missing and broken chute slabs and the erosion progressing behind the left sidewall.

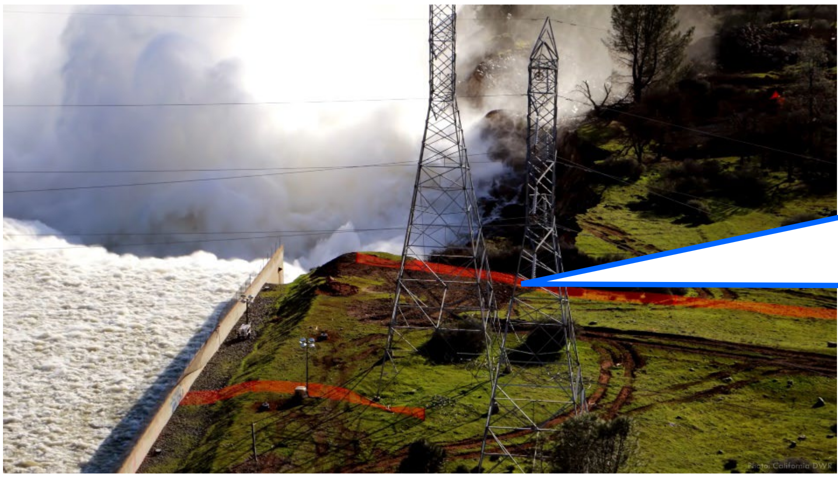
In the following days (February 8-10), the DWR tested the damaged service spillway as they expected they would need to use it due to high expected inflows. Erosion progressed during testing and compromised a significant section of the chute. Two additional potential operational issues were identified.

1. Debris was accumulating on the river channel, raising tailwater levels and threatening to flood the powerhouse.
2. Chute erosion could affect the transmission line crossing over the spillway.

These were both serious issues for the emergency leaders, as either could threaten the powerhouse, which would take it out of operation for several months.

Inspection of the problem area when spillway gates were closed. Note relatively thin slab and erosion of the weathered foundation rock.

Alternative flow channel formed by erosion after failure of the spillway chute. Note the debris in the river channel, which was responsible for raising tailwater levels.



The erosion came close to the transmission towers but did not undermine the structures.

As rain continued and the reservoir continued to rise, the emergency leaders had to decide between two options, they could either:

1. Open the service spillway gates and lower the reservoir, potentially compromising the powerhouse and allowing the chute to continue to be undermined; or
2. Keep the gates to the service spillway closed and let the reservoir level rise causing the emergency spillway, which had never operated, to spill.

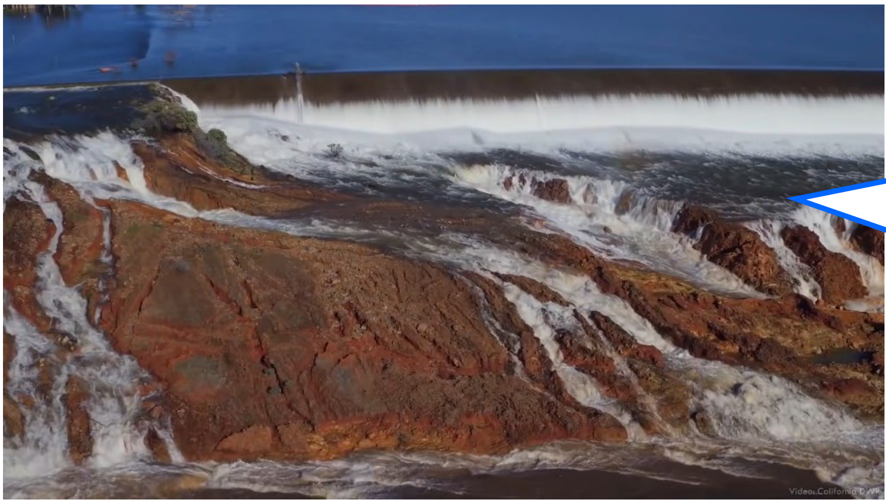
The emergency spillway consisted of a concrete weir that discharged on to the natural hillside. The hillside was not lined in concrete, as the design engineers thought the ground was sound and no significant erosion would occur if the emergency spillway ever operated. However, considering the significant erosion observed on the service spillway, DWR civil engineers recommended the emergency leaders should **NOT** use the emergency spillway.

Despite this advice, the emergency leaders decided to close the service spillway gates and allow overtopping of the emergency spillway. Greater erosion than expected was noted on hillside soon after. Headcutting progressed rapidly towards the concrete weir. Left unchecked, this could have led to the emergency spillway being breached.

EMERGENCY EVACUATION ORDER

The service spillway gates were opened to quickly lower the reservoir level. As a result, at 3:44pm on 12 February, all 188,000 downstream residents were ordered to evacuate.

Emergency spillway in operation.



Erosion progresses as flow concentrates in channels forming downstream of the concrete weir.

The service spillway continued operating until the flood passed and reservoir levels lowered. The erosion did not progress upstream towards the gate structure and the evacuation order was lifted two days later.

3: MISTAKES MADE

The mistakes which led to the dam incident were primarily caused by human error over a period of time.

INITIAL DESIGN

The design engineers did not take the real site conditions into consideration in the design and construction stages. Additionally, they did not meet the best practices of the time (the 1960s).

ONGOING MONITORING

Vulnerabilities of the service and emergency spillways were not recognised in inspections and evaluations by the owners of the dam, DWR. These vulnerabilities were 'normalised' over decades by DWR and not questioned further. They did not expect erosion to be significant even in the case of a situation like the one that took place.

Efforts by the DWR to address defects, like several chute slab repair projects, were undertaken. However, they were ill-conceived and ineffective due to a lack of understanding, by the regulators and industry professionals involved, of the underlying causes.

HUMAN BEHAVIOURS

There was ongoing overconfidence and complacency of DWR regarding infrastructure integrity. They believed the design and construction was the 'best of the best'. This meant that less attention was given to appurtenant structures such as the spillways, compared to the dam and powerhouse.

DWR had not dealt with major incidents before and had a reactive approach to Civil Infrastructure Management. This was driven mainly by cost control pressures, exemplified by:

- An emphasis on operations (water delivery and power production) over dam safety.
- A reliance on regulators, consultants, and regulatory processes around dam safety, but not considering that the scale of a safety review for a dam the size of Oroville would need to be much greater.
- Not adequately managing information. For example, safety reviews and previous project consultations were not easily accessible.
- Having limited capability around dam engineering and dam safety, with insufficient technical expertise in dam engineering and safety
- A lack of emergency scenario training for personnel. While this was an issue at Oroville Dam, it is a common problem Emergency scenario training is often focused solely on scenarios that could result in a breach of the dam, and the release of the entire reservoir, overlooking partial failure scenarios.

4: LESSONS TO BE LEARNT

The Independent Forensic Team who reviewed the Oroville Dam incident were high calibre and put their focus on organisational and human factors that led to the incident. Below are the lessons we can learn from the review.

PERFORMANCE CHANGES

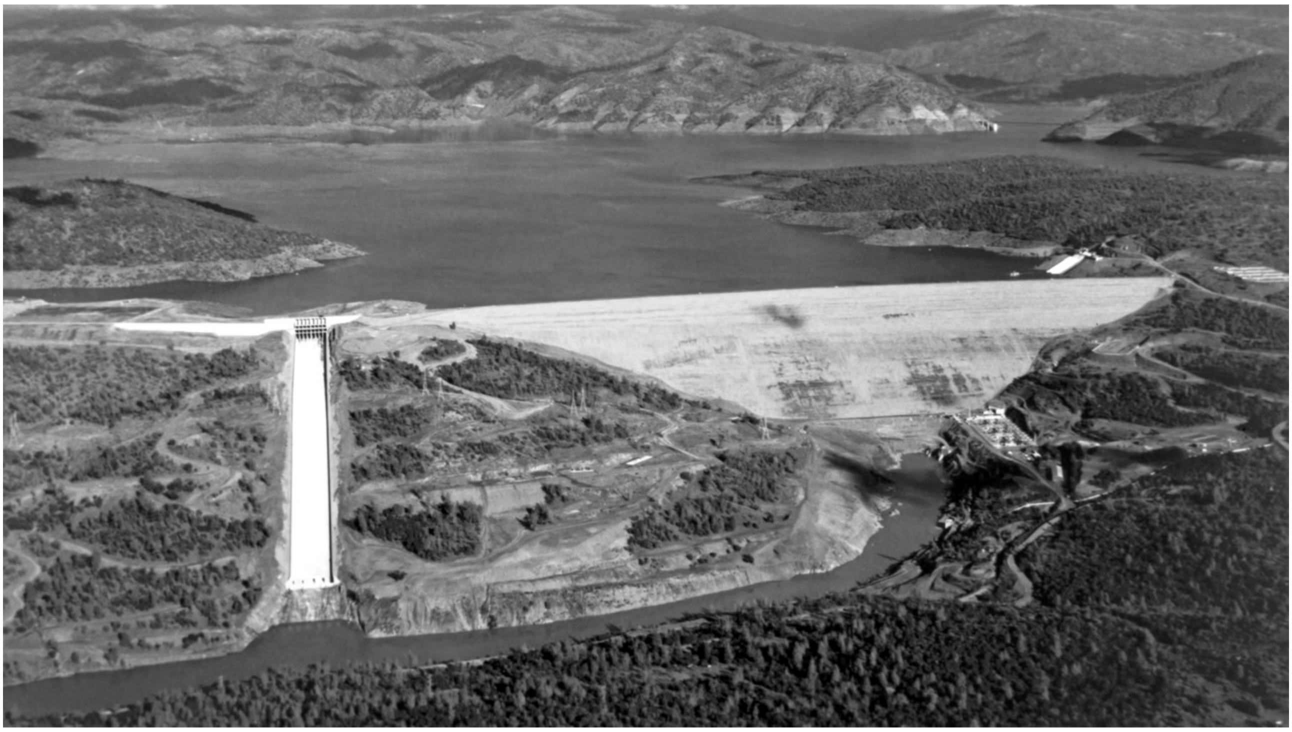
The golden rule 'past performance is the best predictor of future performance' can only be applied if there haven't been any changes which could degrade the performance of a structure. However, change is always occurring. The challenge for the profession is to identify what the changes are, and what the implications are over the long term. However, the effects of change can be hard to comprehend.

There is also a human tendency to normalise behaviours and conditions if nothing bad happens. This often means we can be 'waiting for disaster to strike.'

HUMANS AND ORGANISATIONS

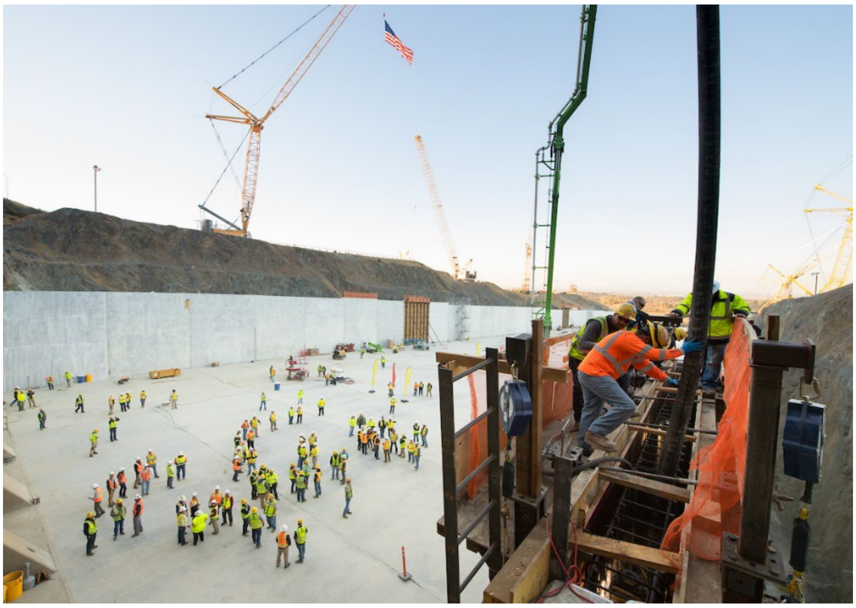
There is also a very strong tendency for organisations to favour dealing with their current concerns over long-term requirements until, inevitably, it's too late. For example, when operational issues are prioritised over safety concerns.

Human and organisational lessons tend to repeat over time. For example, there are no *new* lessons to be learned from Oroville, even the spillway technical details were not new. However, it needed fresh eyes and minds to consider engineering issues, so not to repeat the cycle of bias.



IMPLICATIONS FOR PRACTICE

Emergency spillways are not designed to be tested, rather to operate infrequently and suffer damage if used.



In a way, the incident at Oroville could be seen as successful as:

- The dam didn't fail; and
- The damage was repaired.

But there are clear implications for our professional practice.

The dam industry is trying to update its thinking, in part because of Oroville.