California Water Research Technical Memo

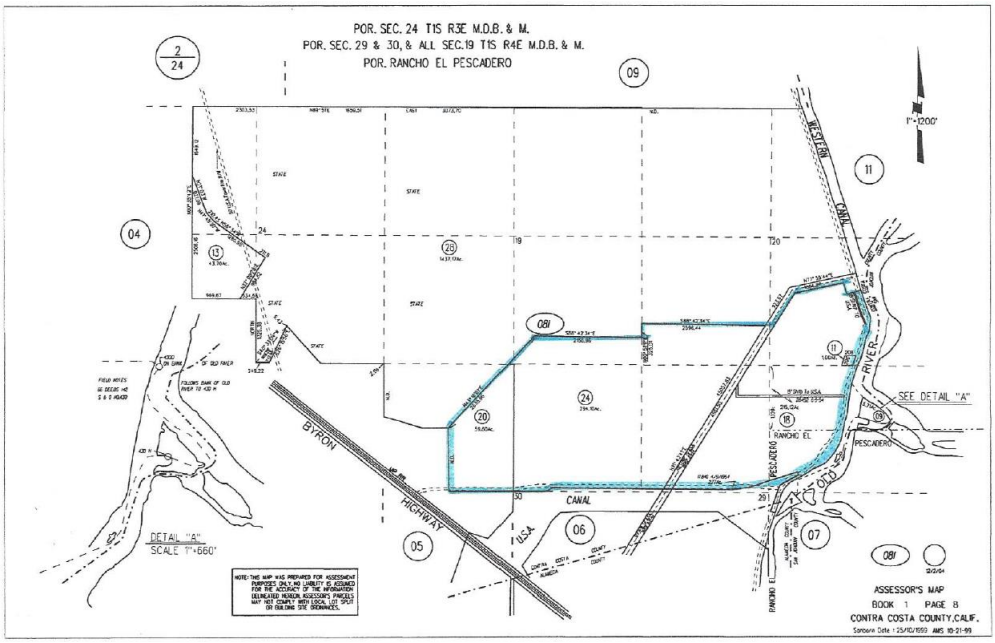
July 2018 Dr. Clyde Thomas Williams

Under-Seepage and Seismic Safety Issues at Clifton Court Forebay

As explained below, under-seepage and seismic events appear to be a potential root cause of failure modes for the Clifton Court Forebay embankments. The issues with under-seepage and other failure modes are long-standing.

I. Seepage issues

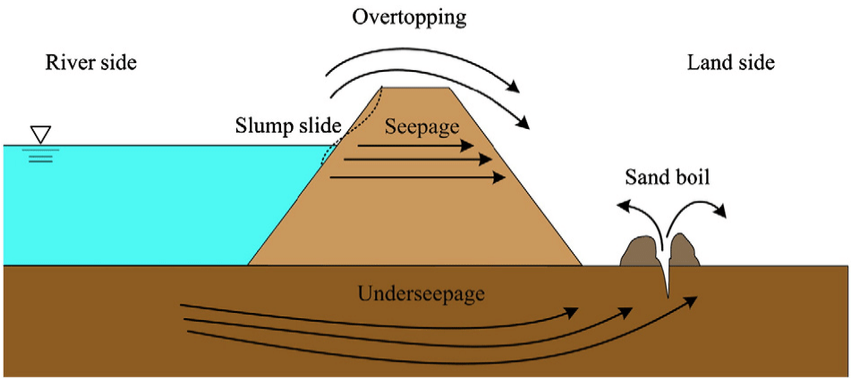
Suzanne Womack, a partner in Clifton Court LLP, has reported ongoing seepage on land next to Clifton Court Forebay to the State Water Resources Control Board in the WaterFix Change Petition Hearing. Ms. Womack testified in the Hearing that seepage started after the Forebay was constructed, and has continued. She stated that seepage severely impaired 25 acres during the drought, and impaired another 15 acres. The area of impairment reportedly expanded in 2017. Ms. Womack states that after talking to her tenant farmer, she believes seepage may be affecting up to 70 acres. Ms. Womack called the Delta Field Division of the Department of Water Resources in 2017 to report the seepage. As described below, the resulting investigation appears to have been cursory and inadequate, given that under-seepage is a failure mode for the Forebay embankment.



1 Assessor's Map showing Clifton Court LLP property Source: Exhibit CCLP-11

A. Background on Seepage and Embankments:

Studies consistently show that seepage related failures of dams comprise about one half of all dam failures. (FEMA, *Evaluation and Monitoring of Seepage and Internal Erosion, Interagency Committee on Dam* Safety, 2015.). Under-seepage is also known to be a cause of levee failure, and is a widely known risk in delta soils.



The Army Corps of Engineers *Draft Integrated Interim Feasibility Study and Draft EIR/EIS for the San Joaquin River Basin, Lower San Joaquin River, CA* explains the problems with under-seepage in Delta soils***:***

> The potential for seepage problems to occur along the existing levees in the project area is created by discontinuous layers of coarse-grained pervious soils (i.e., sands and gravels). These are found at varying depths of up to -100 feet. During high-water events, water from the river can enter the pervious soil layers and then move laterally through these layers under/through the levee. Excessive seepage can erode soil within the levee and lead to a rapid collapse and subsequent breach. Historically, foundation conditions were evaluated assuming homogeneous materials, but the floods of 1986 and 1997 and the resulting levee failures throughout the Central Valley resulted in a revision of the criteria for the evaluation of under-seepage***.*** The risk of levee failure is not due to design deficiency or to lack of O&M of the existing levees, but to a better understanding of the mechanics of under-seepage in the Central Valley***.*** (p. 90, underlining added.)

Due to under-seepage, the Army Corps of Engineers estimated that the "risk and uncertainty" of levee failure could be as high as 50% a year for some of the levees protecting the northern part of Stockton. As part of alluvial and deltaic deposits, channel sand lenses are likely sources of discontinuous layers of pervious ground beneath Clifton Court Forebay and its embankments. Records show that the CCF embankment has similar construction to Delta levees.

B. DWR's Geotechnical Evaluation

Ms. Womack received a letter from Tim Wehling, Chief of the Department of Water Resources' Dams and Canals Section of the Geotechnical and Engineering Services Branch and Erdom Abraham from DWR's Civil Engineering and Surveillance Section, Engineering Branch, Delta

Field Division, Division of Operations and Maintenance, about her complaints of seepage. The letter states in part,

> Based on DWR's recent geologic report (DWR, 2015b), the majority of the reservoir is constructed out of fine grained soils, the majority of which are clay. Clay generally has the lowest hydraulic conductivity of soil-like material (sand, clay, silt, etc.)

The letter concludes that

> Therefore, the seepage from the Forebay through the clay embankment should be very small and well within the capacity of Pump 6.

The report references Bulletin 200, *California State Water Project, Volume III, Storage Facilities* (1974.) Bulletin 200 Volume III records that Clifton Court Forebay and its embankment finished construction in 1969. Sections of Bulletin 200 contradict Wehling's conclusions.

Bulletin 200, Volume III documents that Clifton Court Forebay was constructed on unexcavated delta sediments, with an organic layer of one to over twelve feet:

> Foundation. The dam alignment rests almost entirely on deltaic sediments which consist of nonorganic flood-plain deposits covered by a blanket of organic and peaty soils. The organic blanket ranges in thickness from less than 1 foot to over 12 feet. In general, the organic soils have low shear strengths and low densities. <u>They include soft organic clays, organic silts, and peat in various stages of decomposition</u>. At first it was thought that the organic soil should be removed, but the existing Clifton Court levees, which had been constructed on this soil at steeper side slopes than planned for the Forebay, showed that the organic soil was usable as a foundation. Reinforcing the same existing levees to serve as forebay embankments was ruled out because the strengths of both levee and foundation were indeterminable. (p. 202, underlining added.)

Bulletin 200, Volume III further documents that the Forebay reservoir was enclosed by a high levee, with soil-cement admixture on the reservoir side:

> Description. The dam, which has a maximum height of 30 feet, has two basic compacted zones and is ballasted with uncompacted material (Figure 174). Zone 1 material, which consists of fairly uniform inorganic silty and sandy clays, was placed on the reservoir side of the embankment. <u>The balance of the embankment proper, designated Zone 2, consists of inorganic clays, sands, and silts</u>. Waste materials, such as peats and soft organics, were placed as ballast on the outside of the embankment where needed for stability and were designated Zone 3. Slopes are protected from wave action with soil-cement consisting of nine pounds of cement per cubic foot of soil. (p. 202, underlining added.)

Given this construction design, significant seepage would be expected, and~~.~~ Bulletin 200, Volume III documented that seepage pumps were part of the design for seepage:

> Piping and Drainage Systems

> Four pump structures were installed between the embankment of Clifton Court Forebay and the original levee to drain accumulated surface water and seepage (Figure 180). Each structure consists of a vertical, 72-inch, reinforced-concrete pipe placed on a 1-foot-thick concrete pad; a 24-inch, reinforced-concrete, inlet pipe; a 900-gallon-per-minute centrifugal pump equipped with a 1,200-rpm electric motor; and automatic controls actuated by a metal float. Water is discharged into the Forebay from each pump through an 8-inch steel pipe installed through the embankment. (p. 208.)

The letter also states that

> Reservoir seepage has been observed since at least April, 1979 (DWR, 2006) on the northern side of the reservoir (p. 2.)

The letter from Tim Wehling offered to do the following at the request of the landowner:

- Perform a site visit with the landowner present to the precise locations of the reported seepage.
- Check if the existing two monitoring wells are functional and begin a monitoring program.
- Consider installing additional monitoring wells or piezometers to clarify the relationship between groundwater and the Forebay water.
- Inspect the Forebay embankment frequently, given that it is a relatively homogeneous clay embankment (DWR, 1970b). Between the desiccation cracking, animal burrows, and potential piping, it is entirely possible for a new seep to appear.

However, as discussed below, Ms. Womack had previously reported the seepage and there was no indication of consideration of starting a monitoring program or installing additional monitoring wells or piezometers.

C. Previous Field Inspection

In response to complaints by Ms. Womack, staff from the Delta Field Division of the Department of Water Resources did an inspection of the seepage pump system. Amber Candela-Cooney, Chief of the Delta Field Division stated in a February 14, 2017 letter to Ms. Womack:

> DWR operates several pumps and drainage structures to remove seepage by pumping groundwater back into the Clifton Court Forebay. After analyzing the inspection results, I found that the Delta Field Division pumps are maintaining groundwater levels at appropriate levels within our seepage basins and channels.
>
> Specifically, DWR staff inspected our pump station that is near your property and identified as "seep 6" on the attached map. The inspection found that the seep pump, the seep well, and the standing groundwater within our seep basin is fully operational and operating efficiently. The seep basin is currently at the level it is supposed to be.

Based on the Field Division staff investigation, it does not appear that DWR facilities are a source of seepage on your property.

2 Closeup of Clifton Court Forebay

Source: WaterFix Hearing Exhibit CCLP-32, February 14, 2017 letter from Amber Candela-Cooney, Chief of the Delta Field Division, California Department of Water Resources, to Ms. Womack

3 Satellite Photo of Forebay Embankment / Levee
Source: Google Earth

Showing

Seep 6 **Seepage Field**

Drain

DWR's Delta Field Division did not provide any project design, operating conditions, or other explanations of why "normal water" levels in the seep basin would be inconsistent with under-seepage onto Ms. Womack's property and potential seepage flows, nor was information provided about seepage flow rates and paths to the seepage drain.

The original Forebay design appears to have changed with the installation of additional seepage pumps since the original four pumps documented in Bulletin 200, Volume III. No information is provided as to why the additional pumps were installed, and how much additional seepage they may be pumping and from where. The drainage system appears to be inadequately monitored and recorded for seepage flow rates, pathways, and quantities as well as water level***s*** which are required to adequately assess drainage from the Forebay. (FEMA Guidelines on Evaluation and Monitoring of Seepage and Internal Erosion, 2015.)

Bulletin 200, Volume III reported that the only instrumentation installed in Clifton Court Forebay during construction were settlement gauges and structural monuments. It is unclear whether the need for additional instrumentation to measure seepage such as flow gauges and piezometers was ever assessed.

> Instrumentation
>
> Instrumentation of Clifton Court Forebay was accomplished by using (1) settlement gauges, (2) slope indicators, (3) plastic tubes, and (4) structural monuments […]
>
> Permanent bench marks installed on the control structure have been monitored periodically since July 1969. During the period July 1969 to October 1969, when the structure became operational, settlement of 0.14 of a foot occurred. (p.213-214.)

It also appears that under-seepage onto neighboring lands is not being monitored or investigated. DWR's field personnel appear to be unaware that under-seepage is a potential failure mode for the embankment and needs careful investigation**,** review, and modeling. FEMA's guidelines on Evaluation and Monitoring of Seepage and Internal Erosion (FEMA, 2015) states:

> Increases in the number or sizes of wet areas downstream can indicate poor dam performance. These wet areas should be noted during visual inspections. Wet areas indicate that excess seepage that is not being collected or measured is occurring. They may be indications of active erosion and piping… (p. 8-10)

D. Remedial Actions on Seepage Issues

The Department of Water Resources needs to

(1) Implement an appropriate seepage and soil moisture monitoring system (including satellite images), which meets the standards in FEMA's guidelines on Evaluation and Monitoring of Seepage and Internal Erosion.

(2) Investigate and analyzes under-seepage from Clifton Court Forebay;

(3) Develops seepage model(s) based on current understanding of seepage in the Delta and evaluate risks to the embankment and surrounding lands;

and take appropriate remedial actions.

II. Seismicity and Response Issues at Clifton Court Forebay

As explained below, seismicity events and sources represent a potential failure root cause for the Clifton Court Forebay channels and their embankments and levees. The issues with seismic responses and other failure modes are long-standing. This issue must be investigated and appropriate review, assessment, and remedial actions must be taken, along with those for seepage.

A. Seismic Issues

Bulletin 200, Volume III states:

> No known active faults occur at, or adjacent to, Clifton Court Tract. The area is located approximately 21 miles from the nearest known active fault, the Calaveras fault, and

about 45 miles from the San Andreas fault. Seismic considerations similar to those used on the California Aqueduct intake channel and its related structures were applied to the Forebay. (p. 202.)

Since the Forebay was constructed, significantly more seismic sources and events have been discovered and recorded. The Seismology Technical Memo for the Delta Risk Management Strategy states that the nearest crustal faults are the Greenville Fault (16 miles) and Mt. Diablo South Fault (25 miles.) In addition, the Southern Midland Fault (5 miles), previously thought to be inactive in the Holocene period, is now considered to be active during the last 10,000 years. The Seismology Technical Memo lists the following faults as controlling at Clifton Court Forebay for a 100-year return period:

Table 6a
Controlling Seismic Sources at a Return Period of 100 Years in 2005

Location	PGA	1.0 Sec SA
Clifton Court	Southern Midland Mt. Diablo	Mt. Diablo Hayward-Rodgers Creek
Delta Cross Channel	Southern Midland Northern Midland Zone	Mt. Diablo
Montezuma Slough	Concord-Green Valley	Concord-Green Valley
Sacramento	Northern Midland Zone	Mt. Diablo San Andreas
Sherman Island	Southern Midland	Southern Midland Hayward-Rodgers Creek San Andreas
Stockton	Southern Midland Hayward-Rodgers Creek Calaveras	Hayward-Rodgers Creek San Andreas
Note: Seismic sources are ordered by contribution.		

Because the Southern Midland and Greenville faults are significantly closer to the Forebay than the Calaveras fault, the maximum magnitude seismic motion should be significantly increased over those levels used when the Forebay was designed.

In addition, Bulletin 200, Volume III documents that a peak ground acceleration of only 0.15g was assumed:

> Stability Analysis. The embankment was designed using the Swedish Slip Circle method of analysis employing a seismic force of 0.15g applied in the direction that would produce the lowest factor of safety for the condition being analyzed. (p. 207.)

Estimates of peak ground acceleration in the Delta have increased by a factor of four (x4) since Clifton Court Forebay was designed. Table 5 of the Seismology Technical Memo for the Delta Risk Management Strategy estimated peak ground accelerations of 0.40 ***[4x0.15=0.6]*** for a 1 in 500 year event (10% in 50 years), to 0.66 for a 1 in 2,500 year event (2% in 50 years.) (p. 52, Table 5.)

Table 5
Ground Motions for Return Periods of 100 to 2,500 Years in 2005

Site	PGA (g's)			
	100 years	200 years	500 years	2,500 years
Clifton Court	0.22	0.29	0.40	0.66
Delta Cross Channel	0.15	0.19	0.25	0.37
Montezuma Slough	0.27	0.35	0.47	0.74
Sacramento	0.12	0.15	0.20	0.30
Sherman Island	0.24	0.31	0.41	0.64
Stockton	0.13	0.17	0.22	0.32

For these reasons, embankments for the Clifton Court Forebay appear to not meet the higher current state of practice in seismic safety of dams. Similarly, the earlier Forebay embankment designs do not appear to meet current seismic safety criteria of the Division of Safety of Dams for existing dams, which are reportedly based on 1 in 500 year seismic ground motions. Therefore risks of seismic failure of embankments for the Forebay water supply water supply needs to be re-assessed and upgraded, as well as risks to people**,** improvements including the new proposed Byron Tract Forebay, and property in the vicinity.

The Department of Water Resources needs to:

Review and report current monitoring of seismicity and event sources within a 25-mile radius of the Forebay;

(1) Evaluate seismic risks to the embankment and surrounding lands using a minimum 1 in 500 year seismic ground motions;

(2) Assign seismic ground motions to specific fault planes for that evaluation.

(3) Assess appropriate remedial actions;

(4) Prepare a timeline for implementation***;***

III. Effects of breach and emergency preparedness

The effects of a breach of the Clifton Court Forebay embankment would depend on the water level inside the embankment and the tidal stage when the breach occurred and the seismic severity . Bulletin 200, Volume III records the maximum operating level as 5 feet, and minimum operating level as -2 feet (MSL). If there was a low tide, there could be a greater head difference *of* up to 7 feet, as indicated by the letter from Tim Wehling.

The Department of Water Resources needs to assess the potential impact and inundation path of seismically induced (at 0.40, 0.5, and 0.66 G) or seepage induced breaches of Forebay embankments/levees, and the resulting risks to people and property.

Susan Womack also reports that there is a ranch house and other dwellings on the Clifton Court LLP property. If human lives would be at risk from a breach of Clifton Court Forebay, the Forebay meets the FEMA definition of a High Hazard dam. While an Emergency Action Plan is not currently required under state law, the industry standard is to prepare an Emergency Action Plan for all High Hazard dams. Thus there is an issue with duty of care. And while the Department of Water Resources obtained a release from Clifton Court LLP for damages due to seepage in 1970, such a release would likely not extend to damages from a dam breach due to failure to adequately maintain the forebay embankments.

The Department of Water Resources must prepare an Emergency Action Plan for a potential Clifton Court Forebay breach and share it with Contra Costa County and the appropriate Reclamation Districts.