

The Uneasy Relationship between Folsom Dam and the City of Sacramento

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Analyze | Assess | Manage | Reduce



The Story

- Folsom Dam is located about 20 miles upstream of Sacramento, California.
- Folsom Dam in its current configuration provides robust flood risk reduction for frequent to infrequent hydrologic events. But not rare events.
- Another dam, Auburn Dam, was partially constructed upstream of Folsom Dam, and it would have greatly increased flood storage capacity upstream of Sacramento on the American River. But it was never completed.
- The primary vulnerability for Sacramento's levees is overtopping.
- Pressure from California public and agricultural interests to increase water supply and irrigation is considerable. They want to pass as little water as possible from dams. This pressure is opposed by the need to maintain flood storage capacity.
- An overtopping of the levees in Sacramento by river floods may be expected to result in hundreds to thousands of deaths. Such a flood would be a 1 in a 300 event.
- As a result, Sacramento has had to develop highly detailed flood warning and evacuation plans.



Presentation Overview

- The geography of the dam, the rivers and the city
- Folsom Dam
- Auburn Dam
- Overview of Sacramento's flood protection system
- H&H Hazard Forecasting
- Risk Assessment – with a focus on one Potential Failure Mode (PFM)
- Sacramento's Emergency Plans (Evacuation)



Sacramento Location

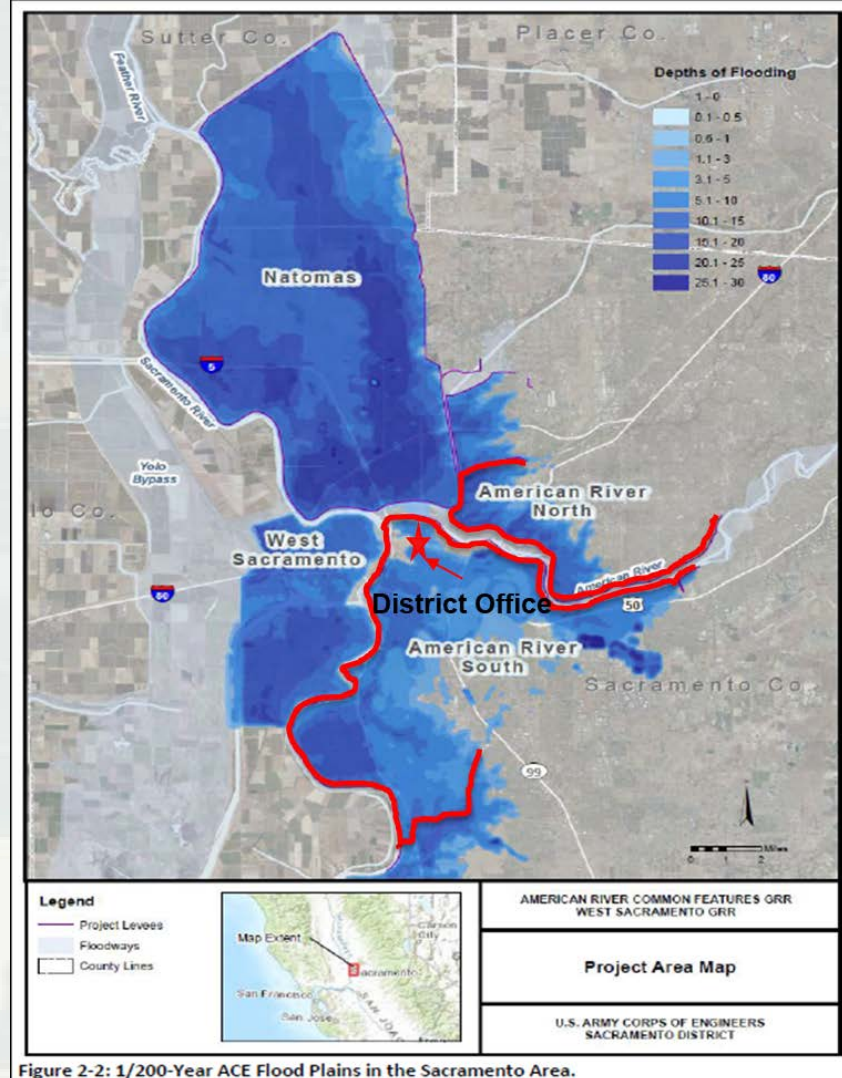
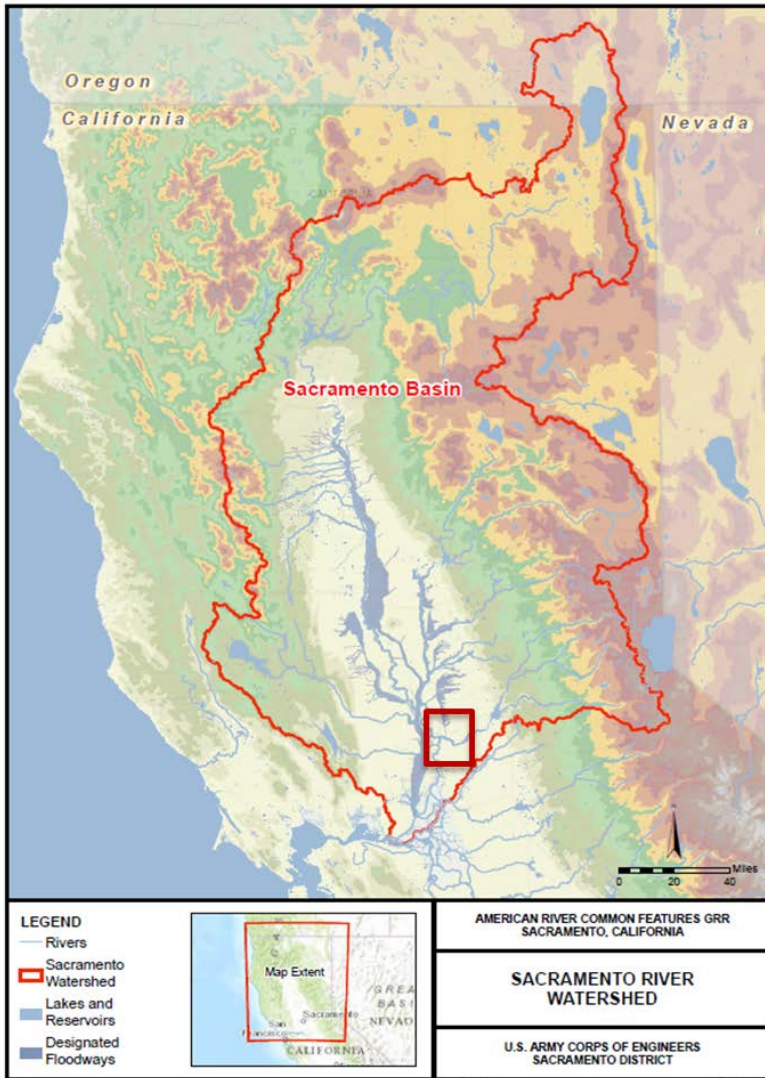
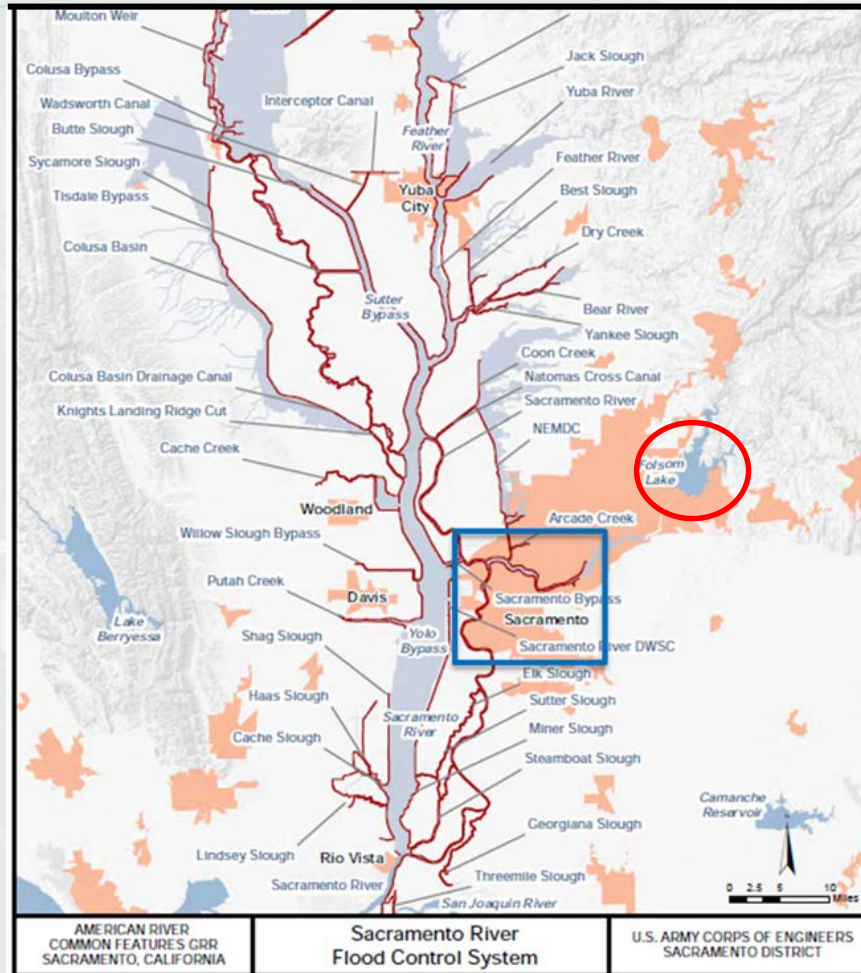
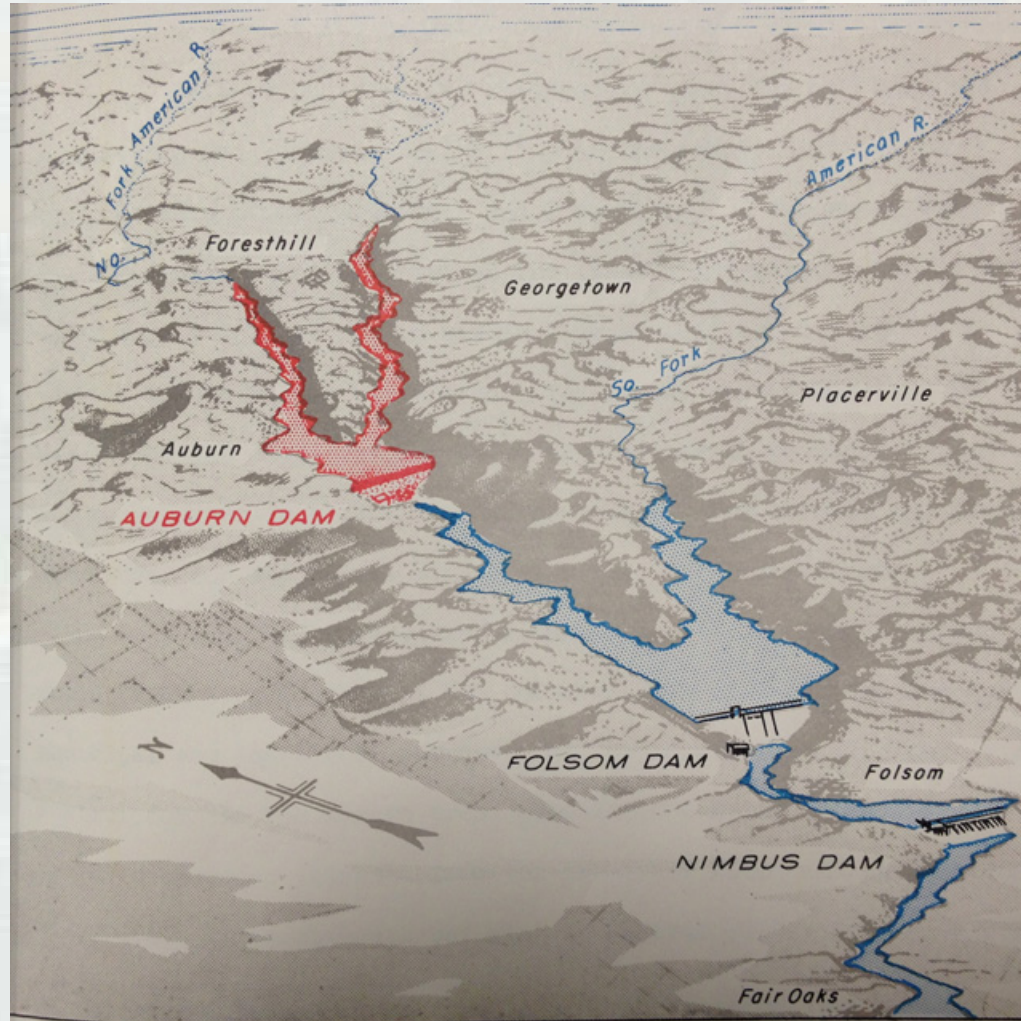


Figure 2-2: 1/200-Year ACE Flood Plains in the Sacramento Area.

Folsom Dam Location Relative to Sacramento Flood Control Features



North Fork American River *Planned* Flood Control Features



Folsom Dam and Auxiliary Spillway



- Completed in 1955 by U.S. Army Corps of Engineers
- New Auxiliary spillway completed in 2017
- On the North Fork of the American River.
- Flood storage capacity of 977,000 acre-feet



Folsom Dam Hydrologic Dilemma

- Folsom Dam was originally designed to reduce flood flows on the American River to a flow rate that could be contained by the downstream levees.
- Construction of Folsom Dam began in 1950, with the design of the dam based on a period of record prior to 1950.
- Folsom Dam was originally designed for an inflow of 340,000 cfs, for what was believed to be the 1/500 ACE, with a release of 115,000 cfs.
- Just after construction of Folsom Dam was completed in 1955, a new record flood was experienced that caused reassessment of the hydrology of Folsom Dam.
- Since the construction of the dam there has been 5 record setting floods (including the storm of 1955).
- The reassessment changed the releases for a 1/500 ACE event to a 1/50 ACE event, when the entire record from 1905 to 2015 is being considered.



Auburn Dam (AKA Auburn-Folsom South Unit)



- Authorized in 1965 by Congress
- Work began in 1967
- On the North Fork of the American River
- Above Folsom Dam.
- Work halted in 1977 following a magnitude 5.7 earthquake in 1975.

- The dam's administrator is the U.S. Bureau of Reclamation
- Designed to provide a new/supplemental water supply for irrigation, municipal & industrial needs
- It would have also provided additional flood storage capacity of more than **2 million acre-feet**

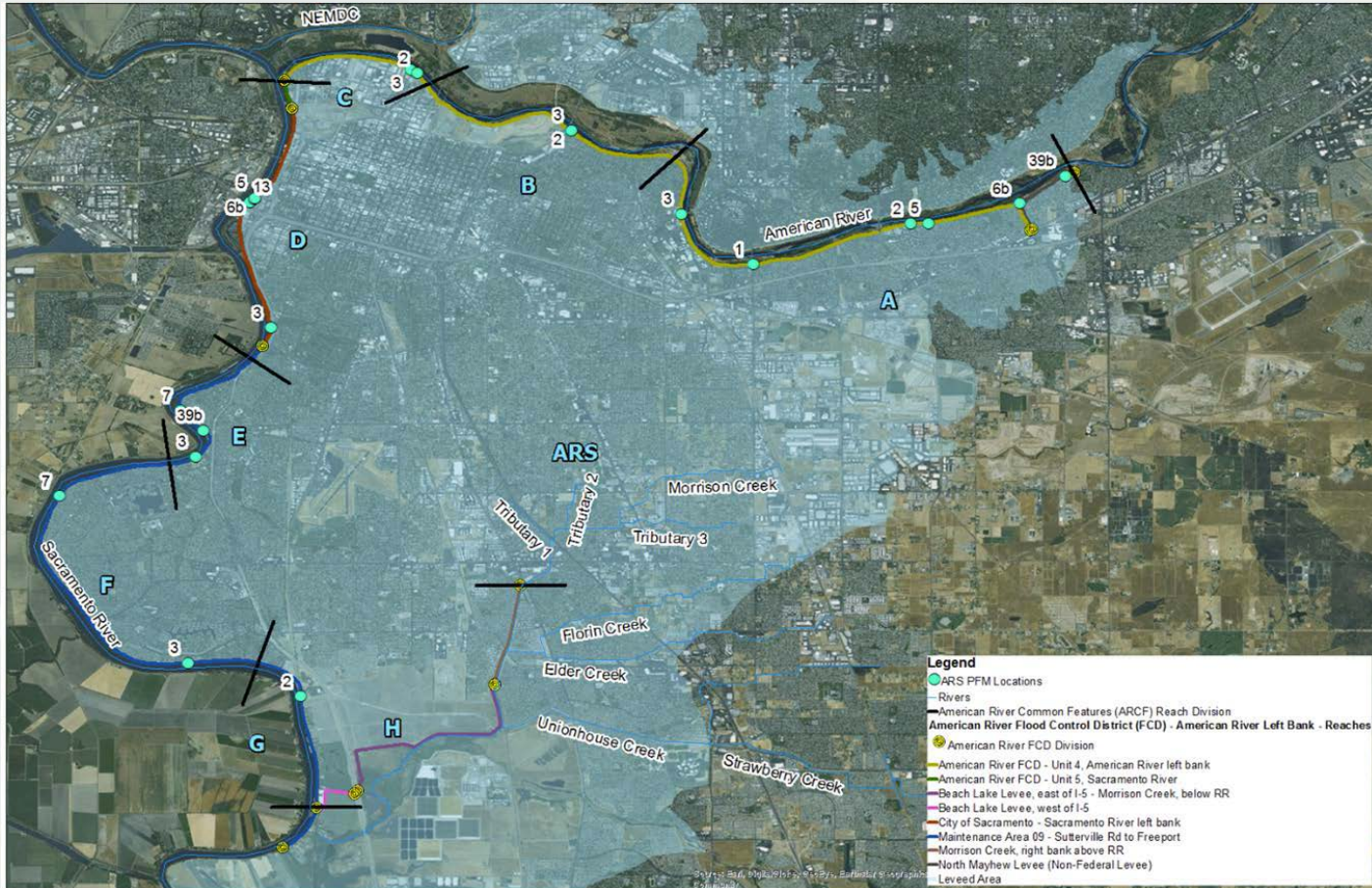


Folsom Dam Modifications

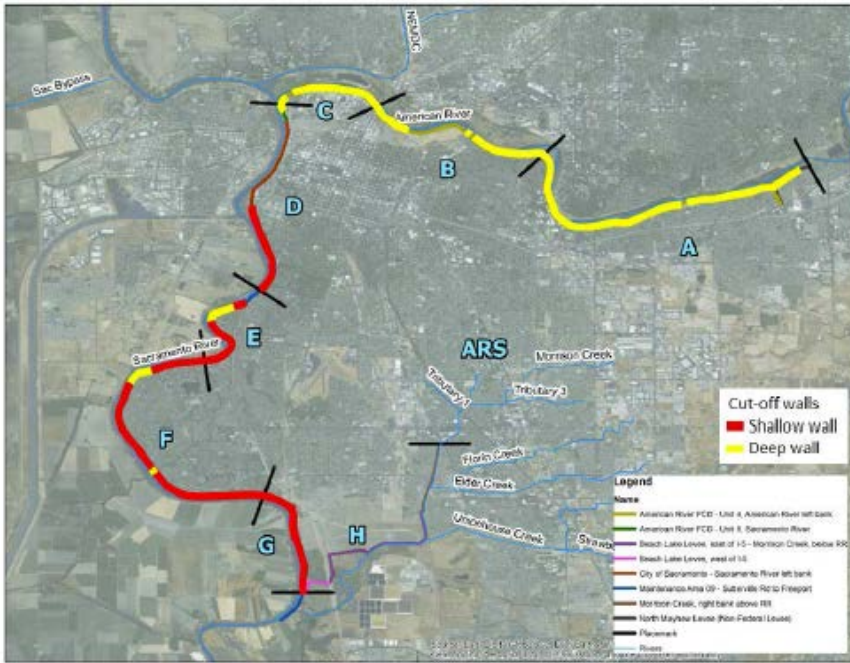
- Hydrologic inadequacy concerns for Folsom Dam lead the U.S. Bureau of Reclamation to embark on a series of significant modifications.
- Although the dam and the Sacramento levee system held without major damages in 1986, the required winter flood control storage capacity was increased 50%, from 400,000 to 600,000 acre feet, to protect against future floods. This was an operational change.
- The dam is also being raised by 7 feet, significantly increasing storage capacity; a less frequent hydrologic event will be required to overtop the dam.
- The concrete monoliths in the spillway section were anchored to resist future, higher hydrostatic loads.
- A new lower auxiliary spillway was designed with outlets at a lower elevation, so lowering of the reservoir could begin earlier in the hydrograph.
- With the new spillway operation the discharge can be higher for more frequent hydrological events but lower for the 100 and 200 year events.



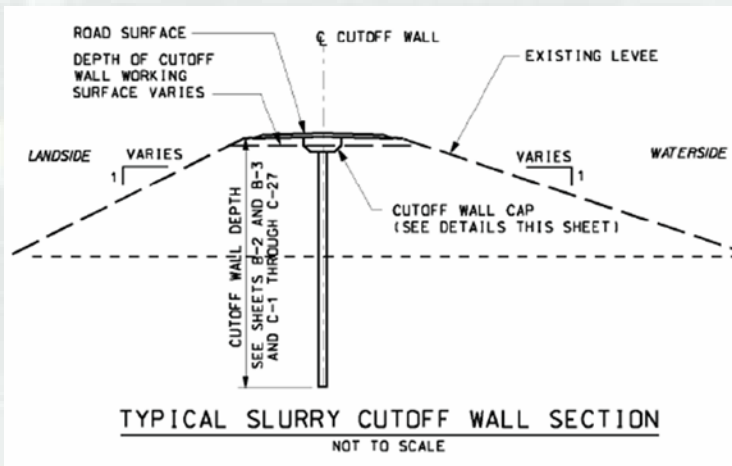
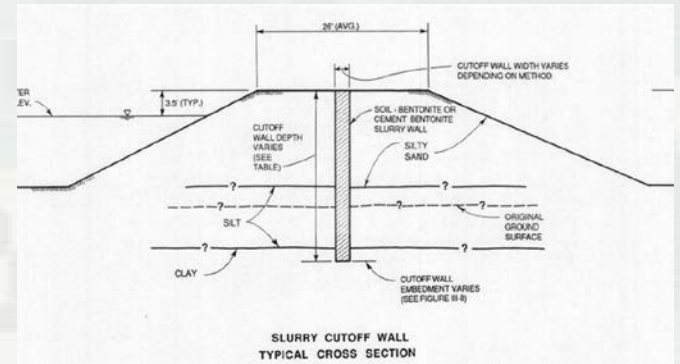
Sacramento Downtown Map



Project Features



Sacramento River Levee



American River Levee

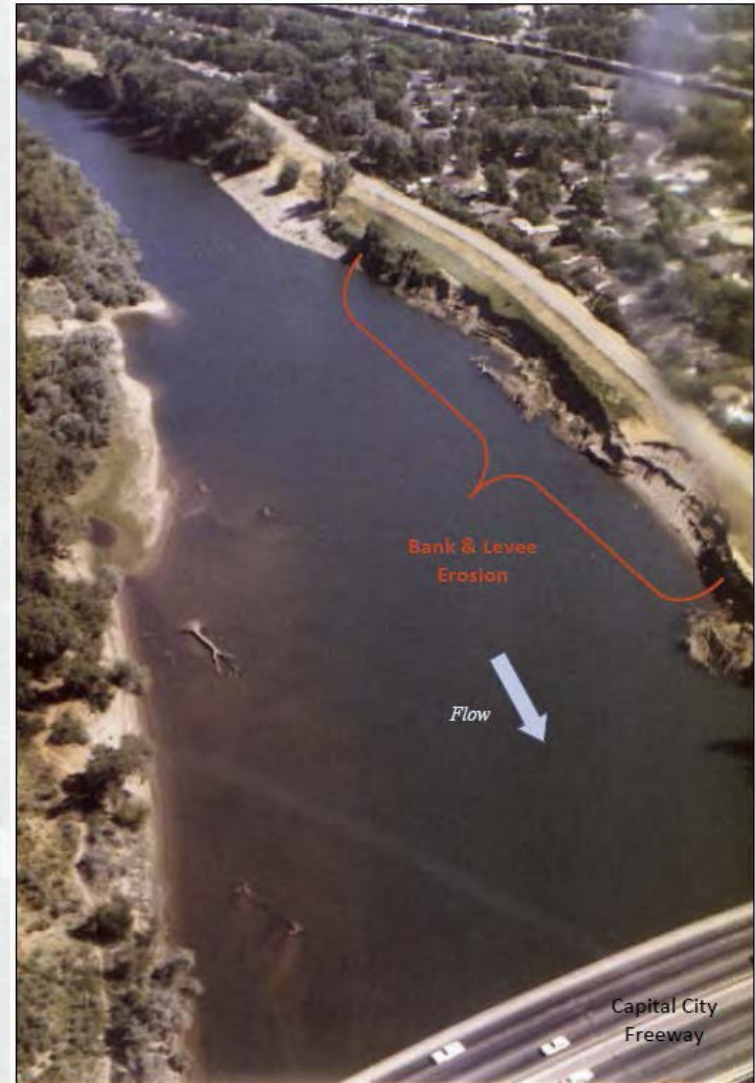


American River Earthen Levee

- Damaged in record February 1986 storm
- 134,000 cfs max. flow
- Heavy erosional damage along about 1500 l.f.



Figure 4-1: 1986 Erosion Distress on the American River South Bank Near I-80



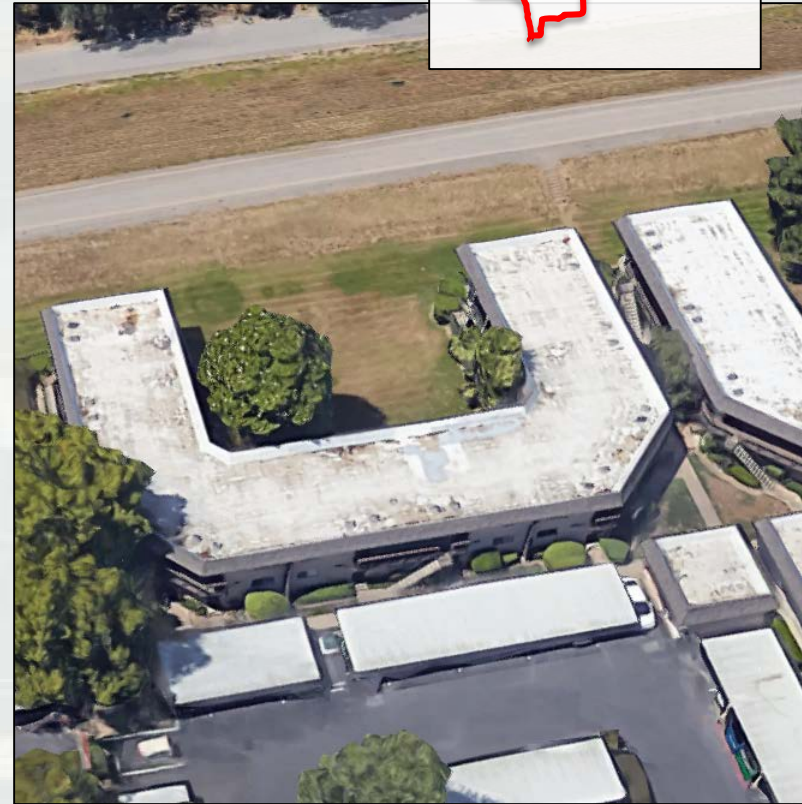
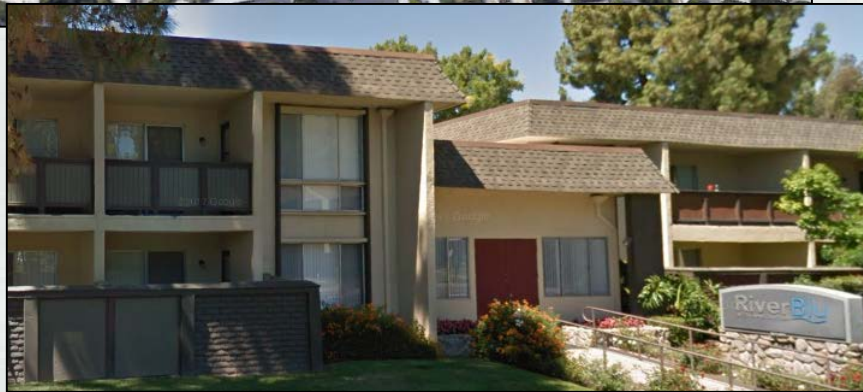
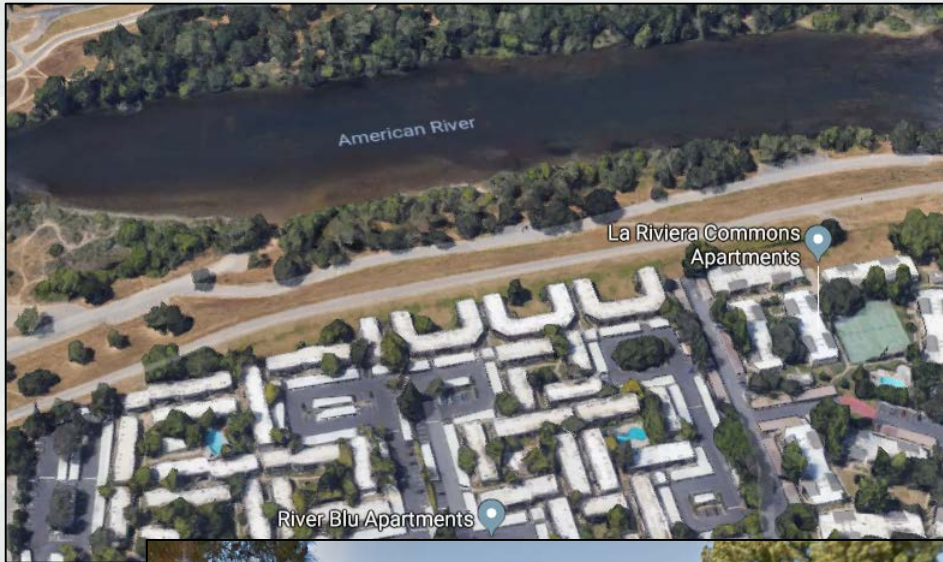
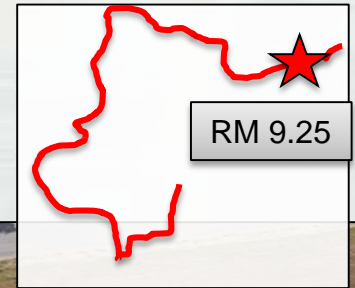
American River Earthen Levee



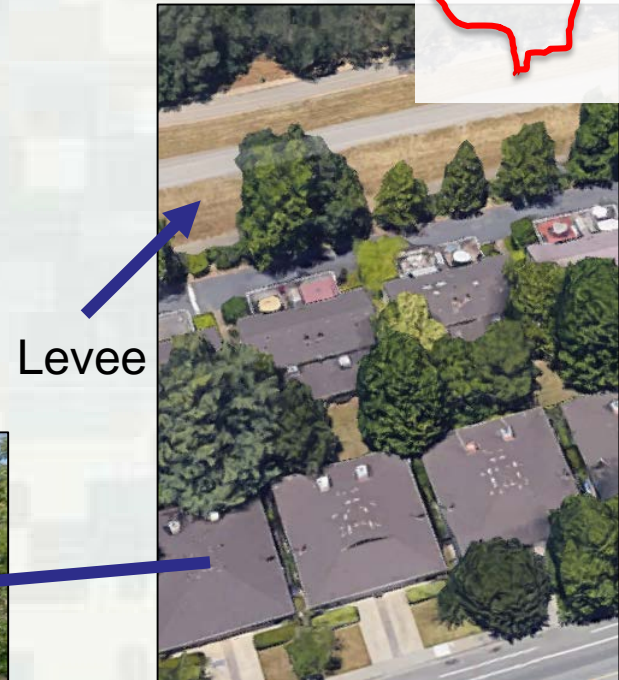
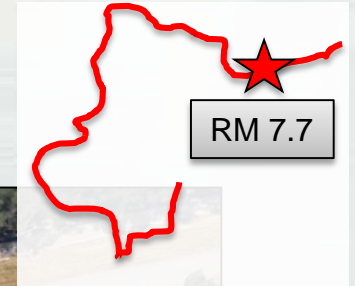
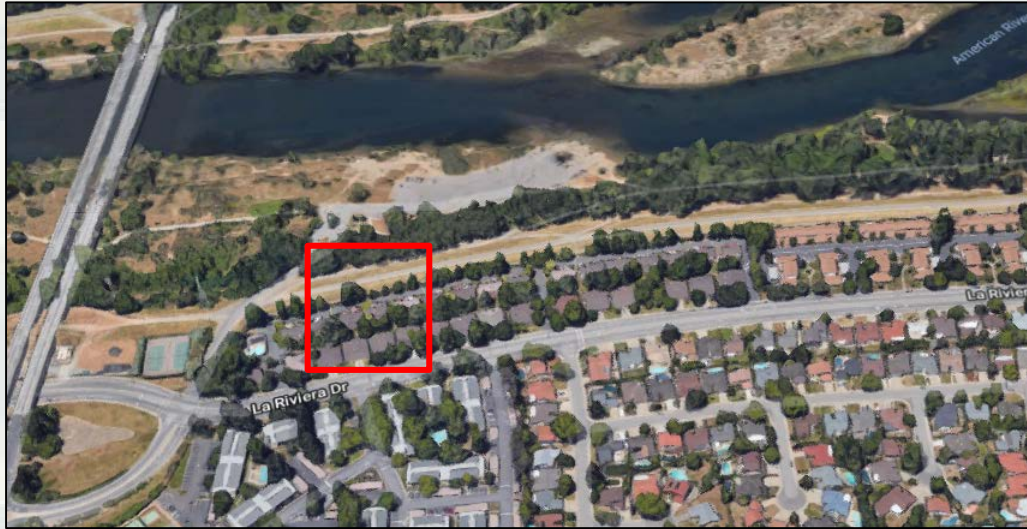
Typical bank protection today in the 1986 erosion zone consists of stone cobbles and plantings



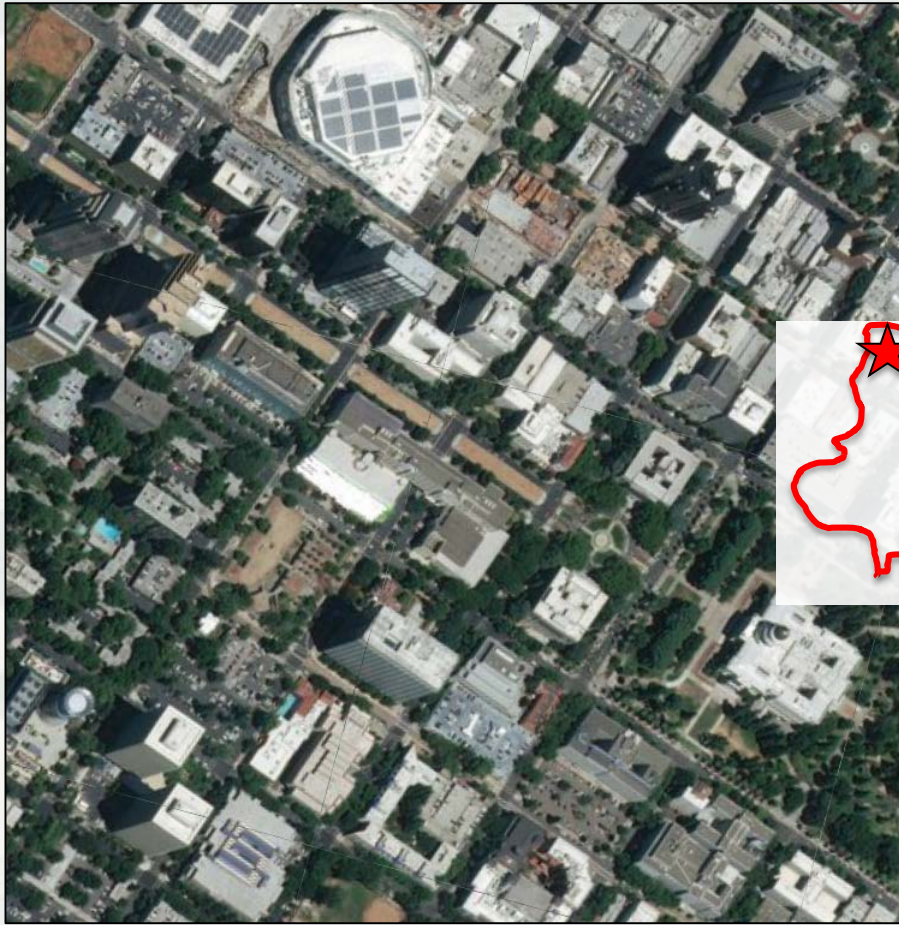
RM 9.25 (American River)



RM 7.7 (American River)



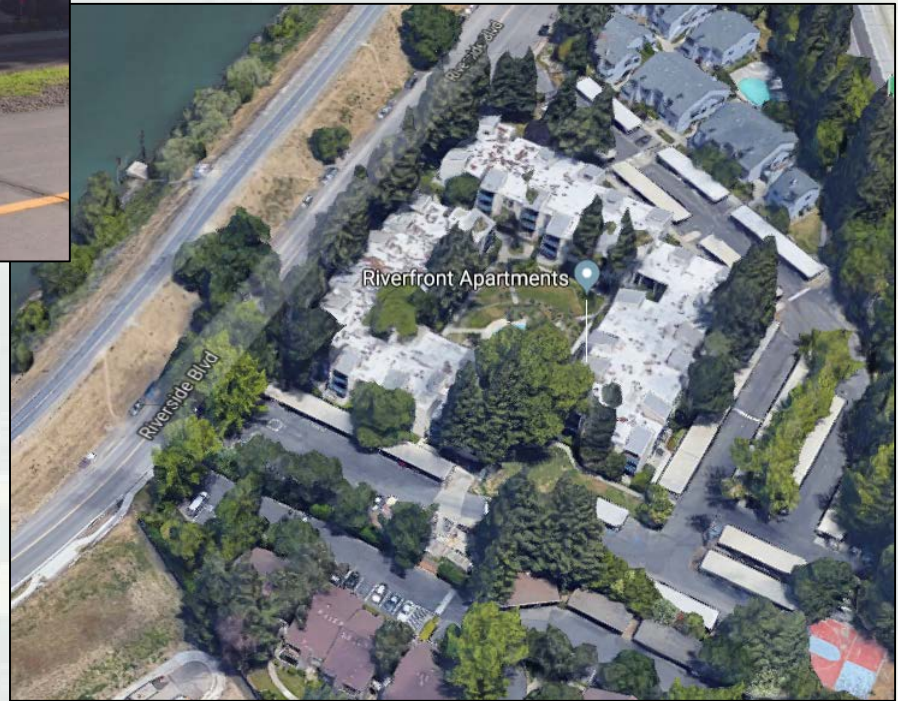
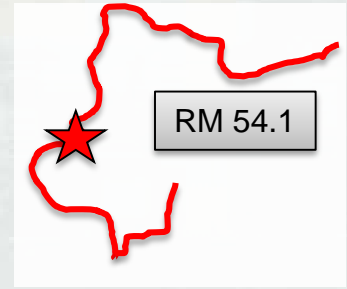
American River (Downtown)



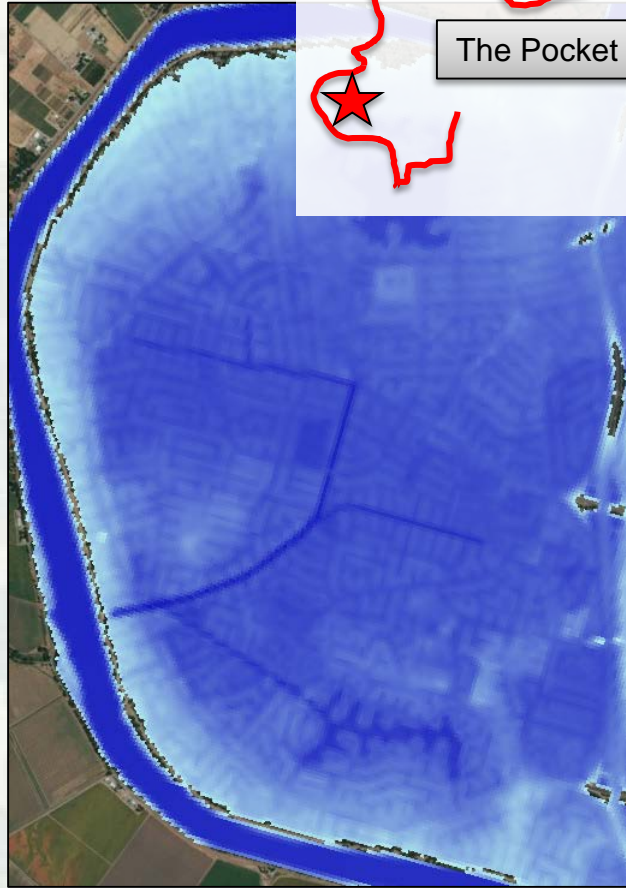
RM 58.4 (Sacramento River)



RM 54.1 (Sacramento River)



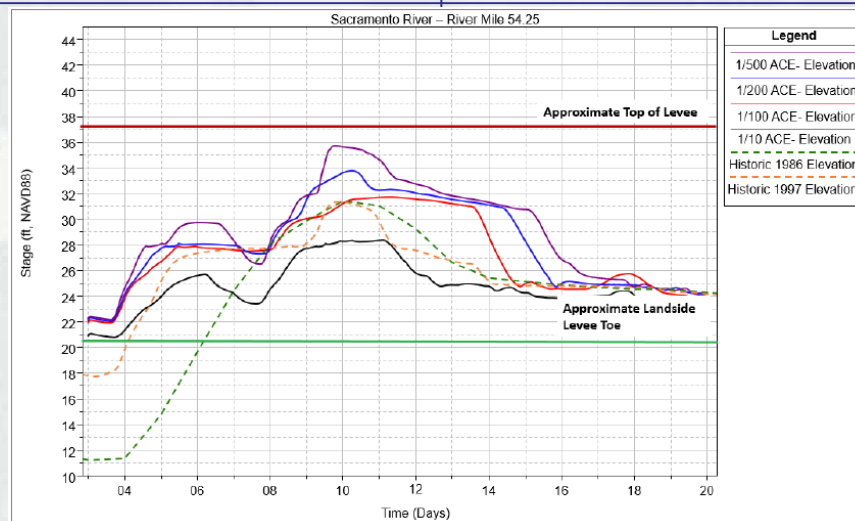
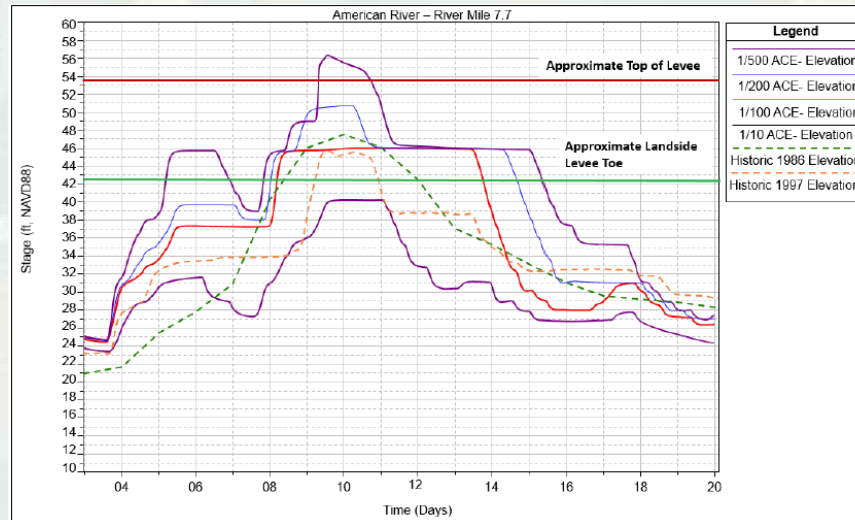
Sacramento River (The Pocket)



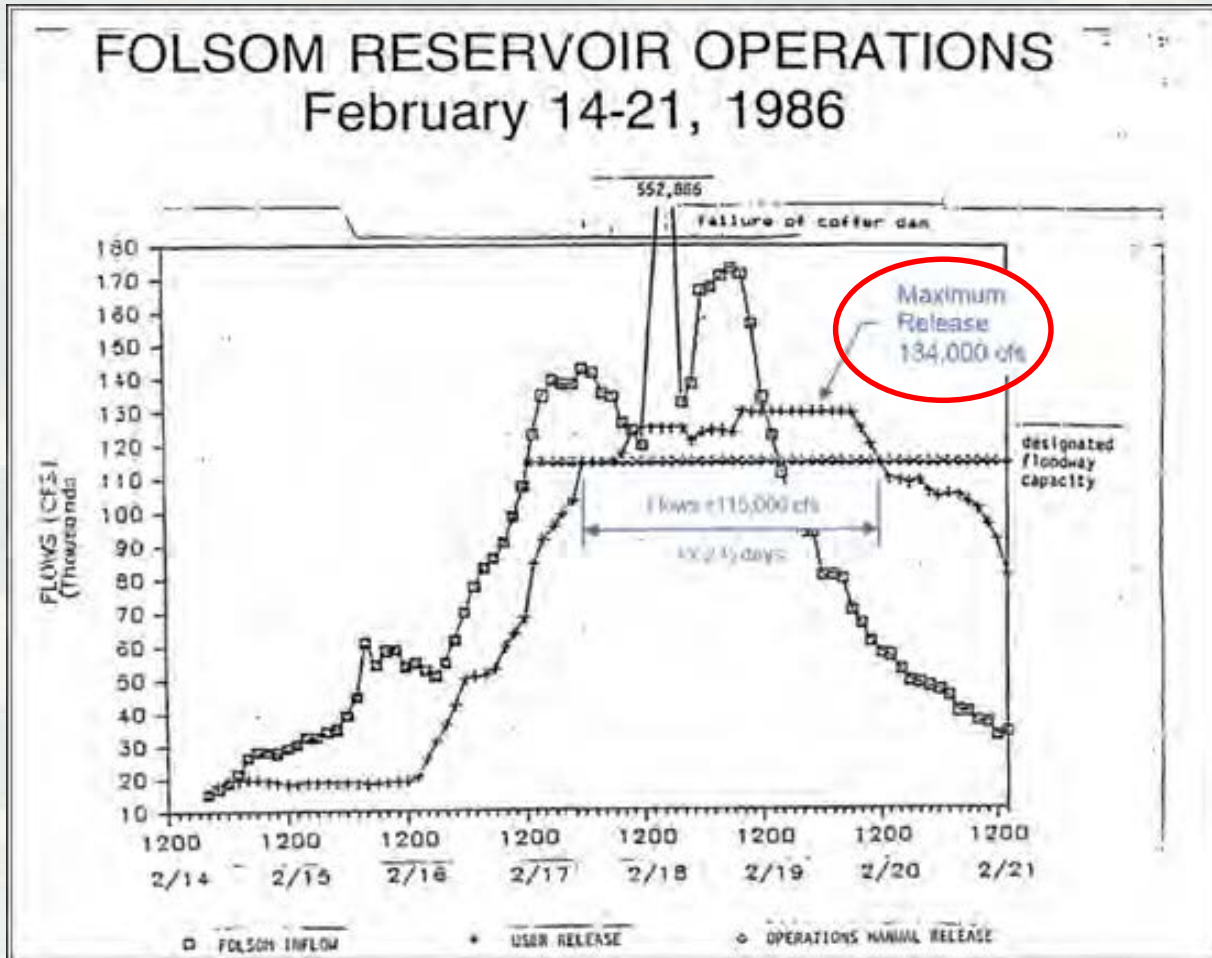
North Beach Lake (Reach H)



Hydrologic Hazard: Hydrographs



Hydrology and Hydraulics

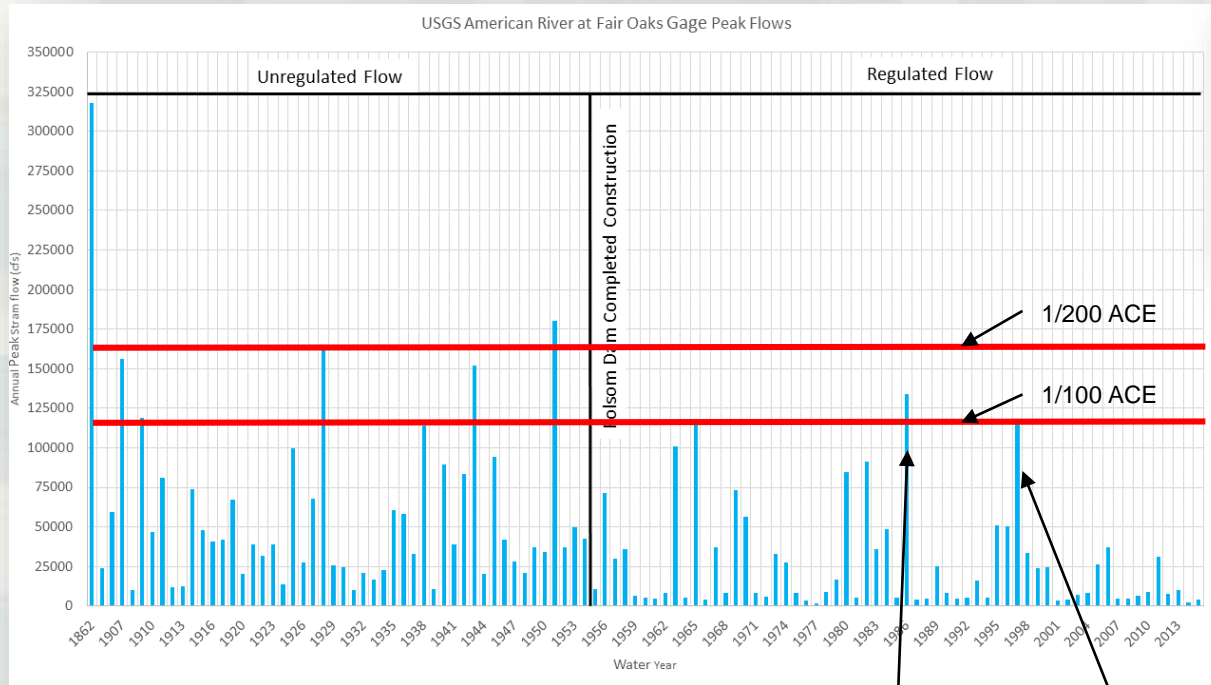


- Feb. 1986 American River Flows
- Max. Inflow to Folsom Dam: 250,000 cfs
- Max. Outflow: 134,000 cfs
- Designated Floodway Capacity: 115,000 cfs
- Sacramento Levees Overtop at: 200,000 cfs (ACE 1/300)

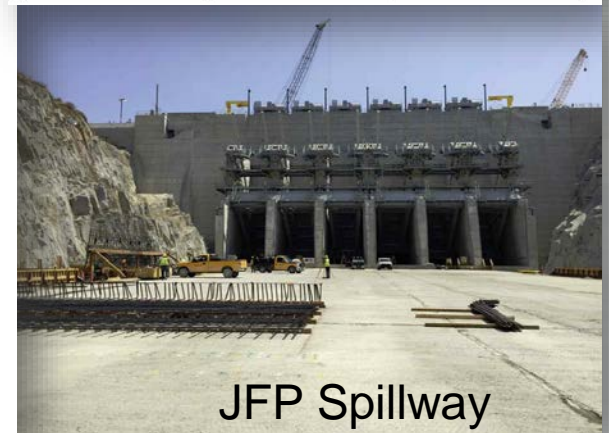


Hydrology and Hydraulics

American River Flows: pre- and post-Folsom Dam



Frequency, Years	Existing Releases, cfs	Future with JFP, cfs
2	25,000	26,000
10	27,000	72,000
25	84,000	115,000
50	115,000	115,000
100	175,000	115,000
200	430,000	160,000
500	530,000	530,000

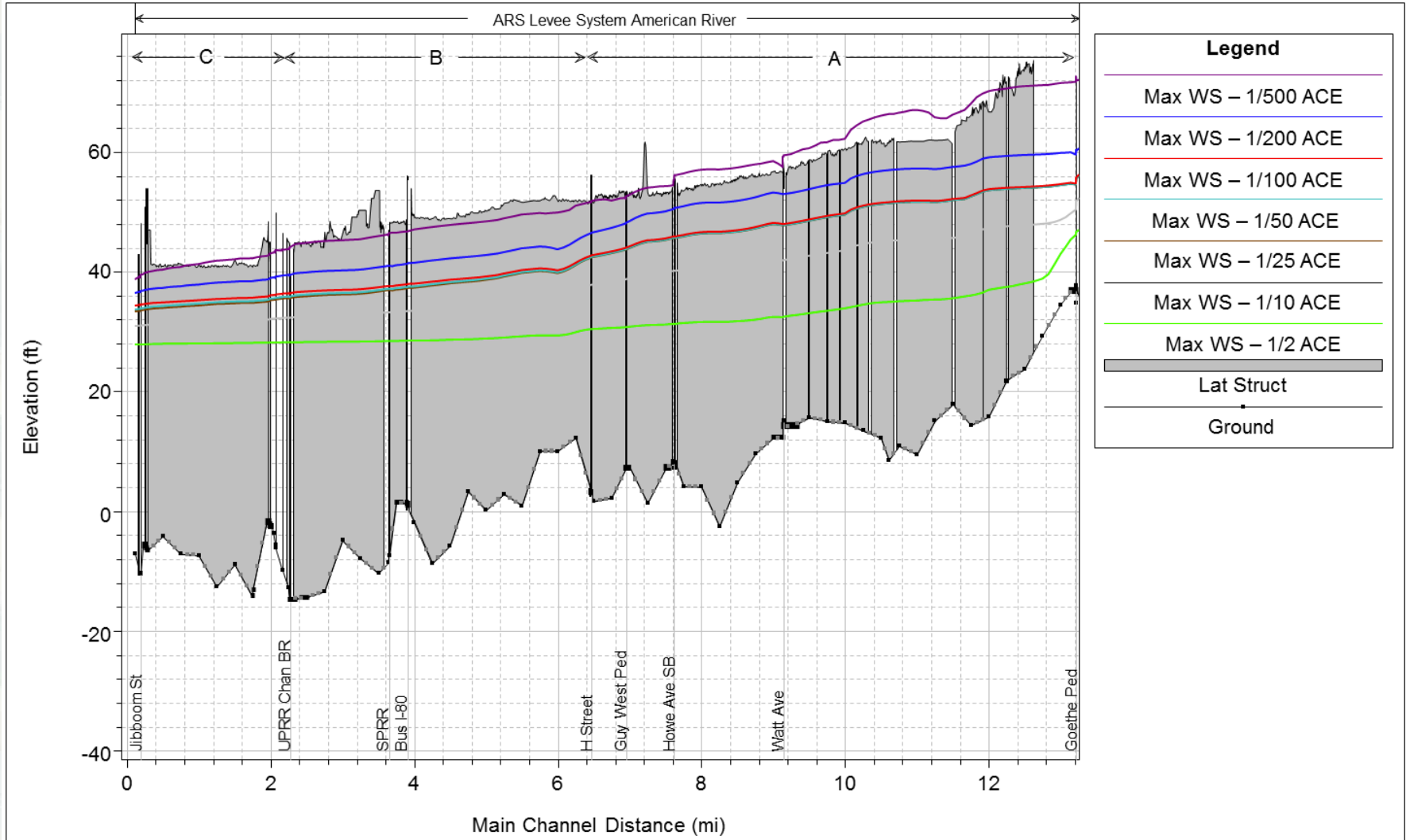


With the new spillway operation the discharge is higher for more frequent events but lower for the 100 and 200 year events.

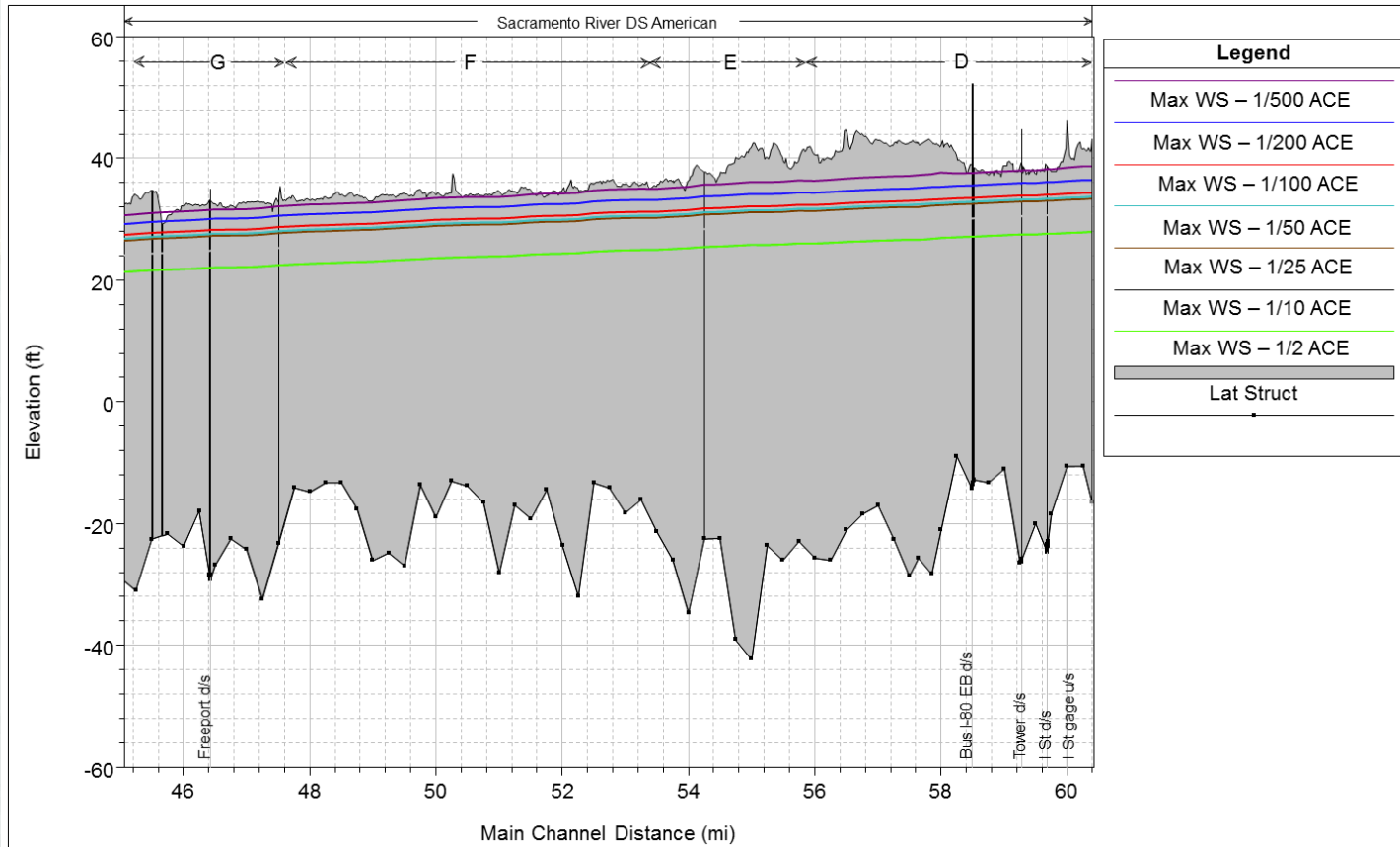
1986 1997



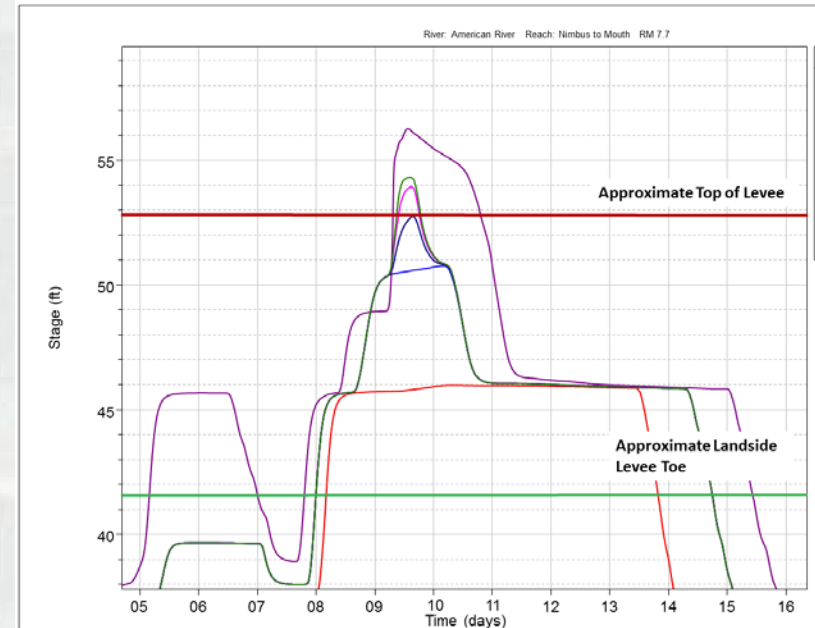
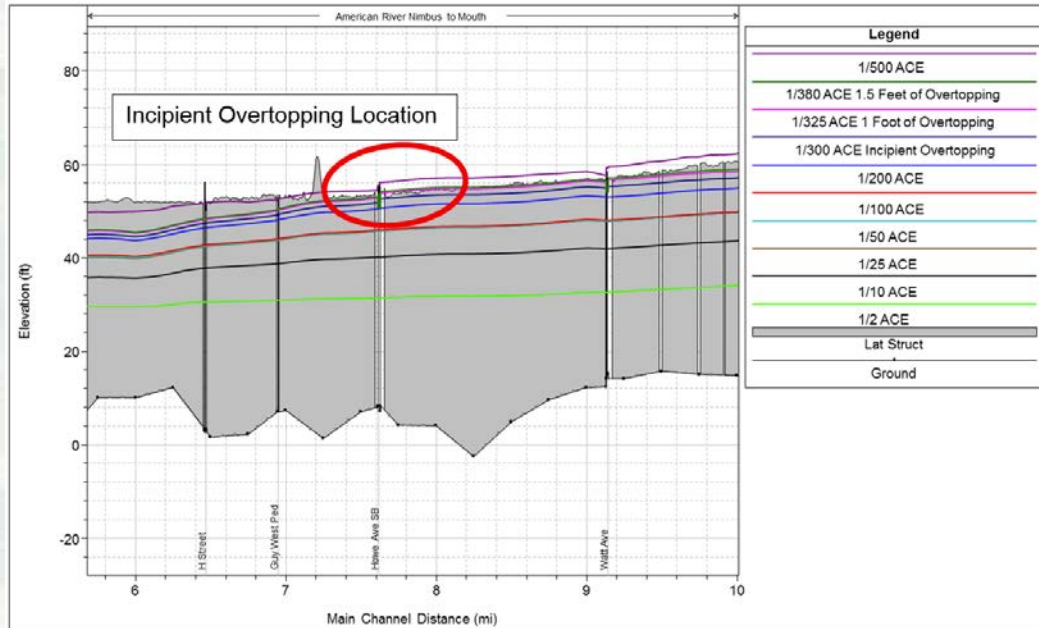
Reach A, B and C Stage Frequency Profiles



Reach D, E, F and G Stage Frequency Profiles



Levee Potential Failure Mode (PFM) 1: Overtopping Levee with Breach



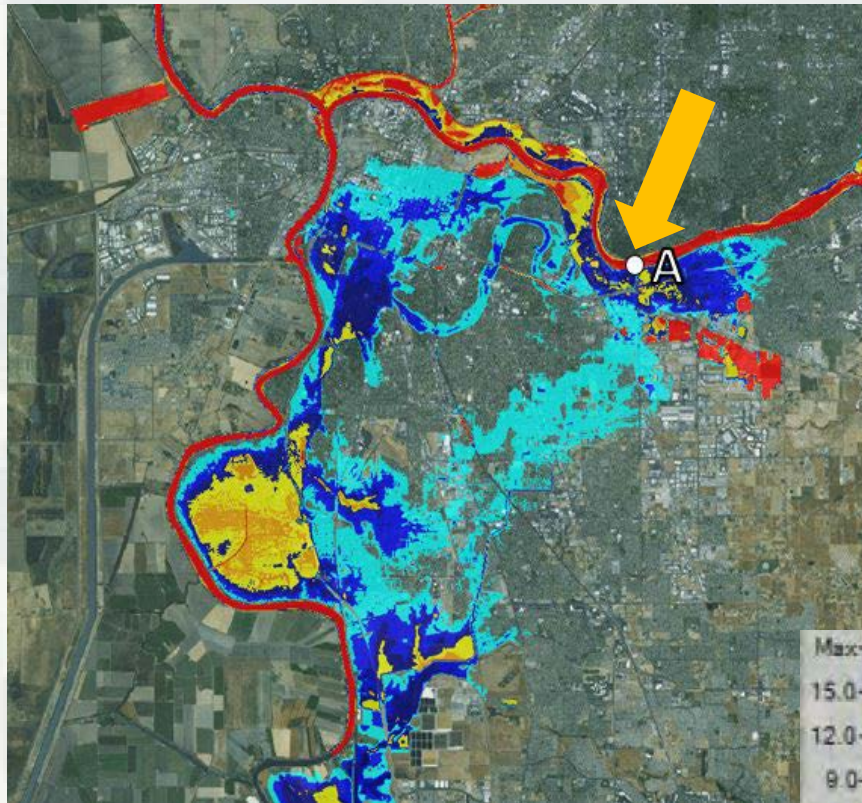
Levee PFM 1: Overtopping Levee with Breach

- ❑ **Annual Probability of Failure: Between 1E-03 and 1E-02**
 - One foot of overtopping of the levee is predicted to occur at a 1/325 ACE.
 - Overtopping is expected to occur over 0.8 miles of levee.
 - The estimated overtopping duration is approximately 9 hours.
 - The levee is composed of clayey sands (SC) and silty sands (SM).
 - These soils are considered erodible to highly erodible.

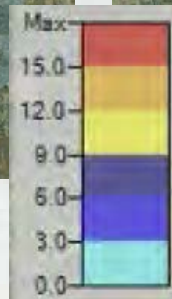
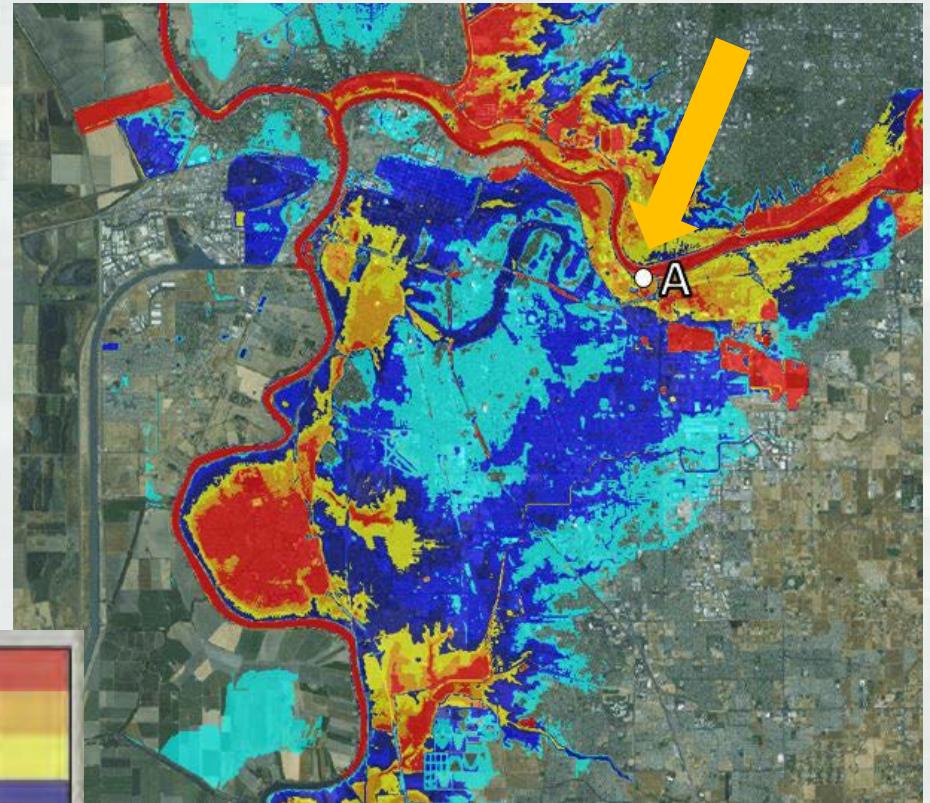


Levee PFM 1: Overtopping Levee with Breach

1/325 ACE



1/500 ACE



Levee PFM 1 Consequences: Overtopping Levee with Breach

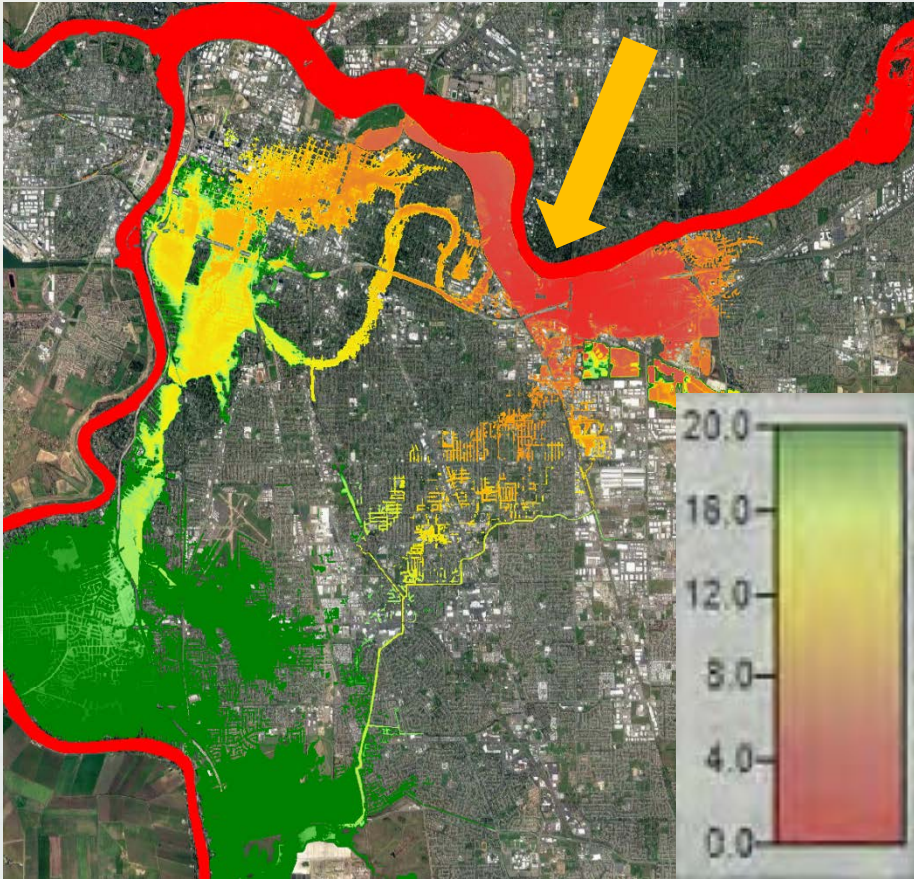
- ❑ **Incremental Life Loss: 300 to 3,000**
 - Breach expected to progress quickly – highly erodible material.
 - Railroad embankment slows down inundation of the protected area
 - Large Population at Risk

- ❑ **Incremental Economic Loss: \$300 Million to \$3 Billion**
 - Based “Location specific” breach modeling
 - Flood damage impacts up to 40,000 structures
 - Flooding would impact densely populated areas

- ❑ **Confidence: High**
 - Structural inventory is based on 2008 parcel data indexed to 2016
 - Development in the area has not changed significantly



Arrival Times for Levee Breach Prior to Overtopping American River mile 7.7

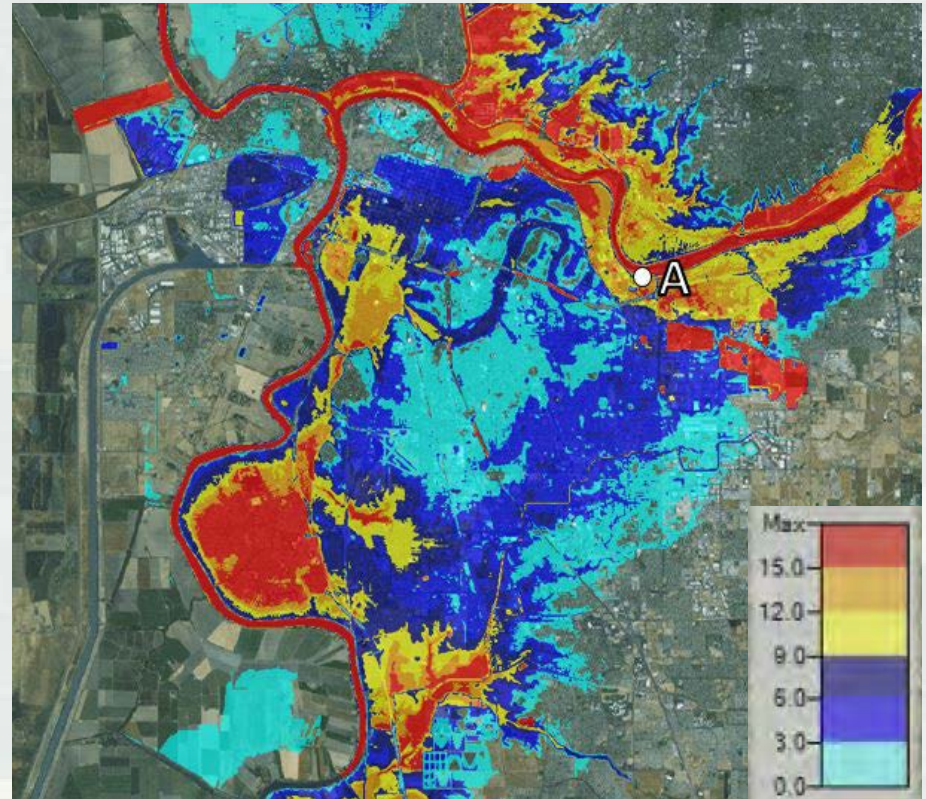
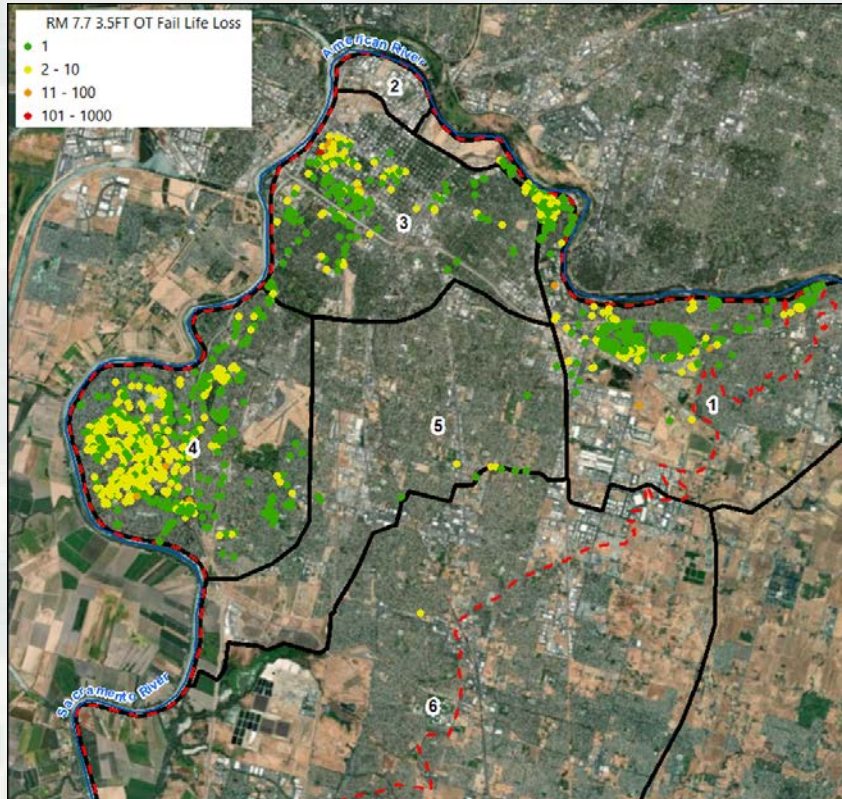


- Arrival times for floodwaters from levee breach to reach a critical depth of 2-feet.
- Evacuating individuals on foot and in cars will begin to lose stability on the roadway.
- During flood events on the American River, arrival times at the breach location in reach A are nearly instant as flood waters quickly move west through the levee district.
- A minimum of 2-feet of flood water arrives downstream at the Pocket within 20 hours.

1/325 ACE Event, Overtopping +1'



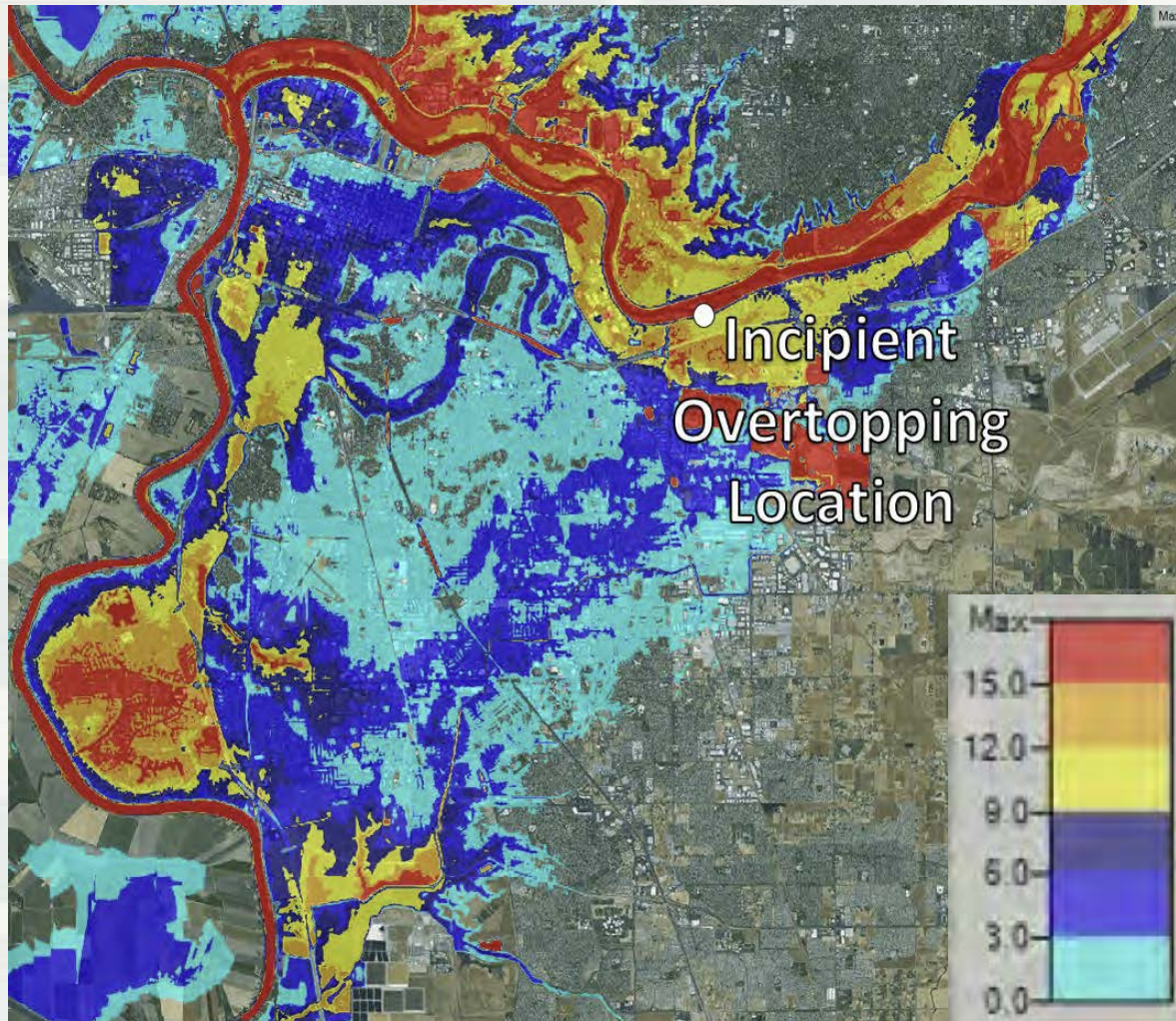
1/500 ACE Levee Overtopping with Breach



- Incipient levee overtopping begins on the American River system around river mile 7.7 during a 1/300 ACE flood event.
- **Max. Inundation Depth for an American River Overtopping event: 28.0 feet.**



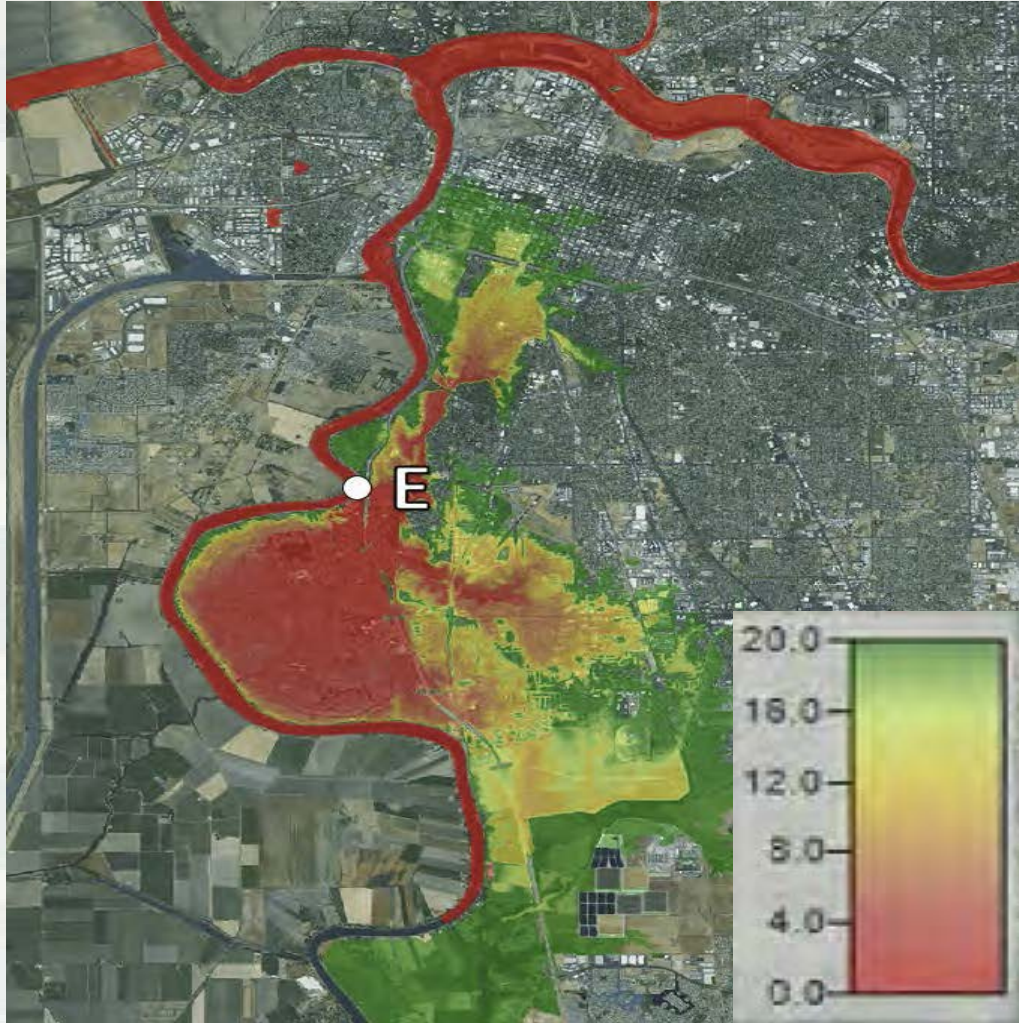
Non-Breach Levee Overtopping



- Incipient levee overtopping begins on the American River system around river mile 7.7 during a 1/300 ACE flood event.
- **Max. Inundation Depth for an American River Overtopping event: 28.0 feet.**



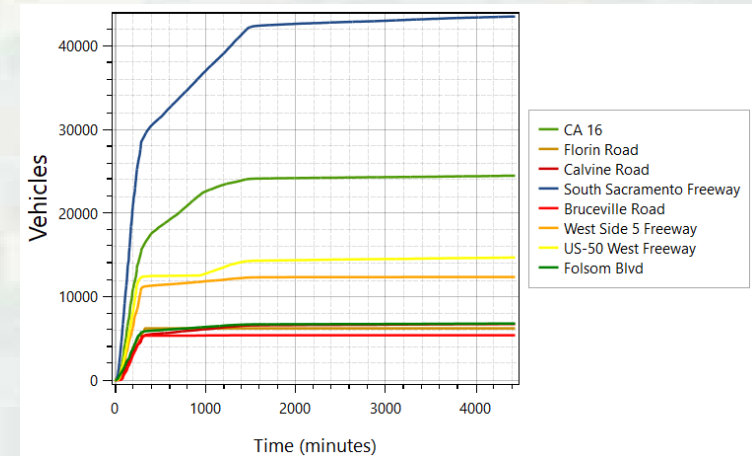
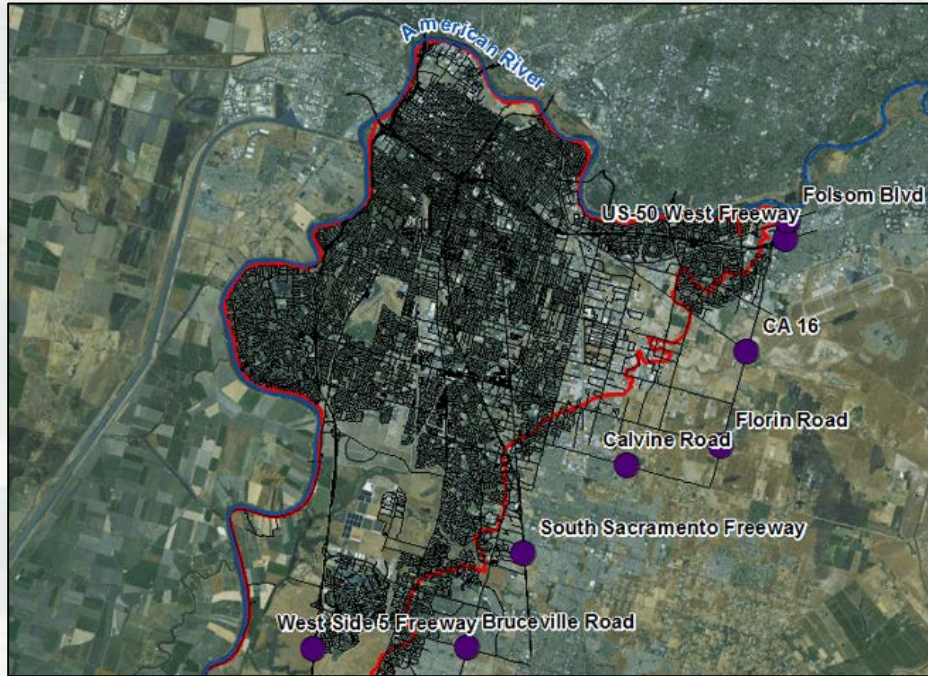
Arrival Times for Levee Breach Prior to Overtopping Sacramento River mile 54.2



- Arrival times for floodwaters from levee breach to reach a critical depth of 2-feet.
- Evacuating individuals on foot and in cars will begin to lose stability on the roadway.
- This figure shows that arrival times from flood-induced breach events on the Sacramento River levee rapidly arrive at the highly populated Pocket in under four hours.
- A minimum of 2-feet of flood water arrives downstream in the Pocket within four hours.



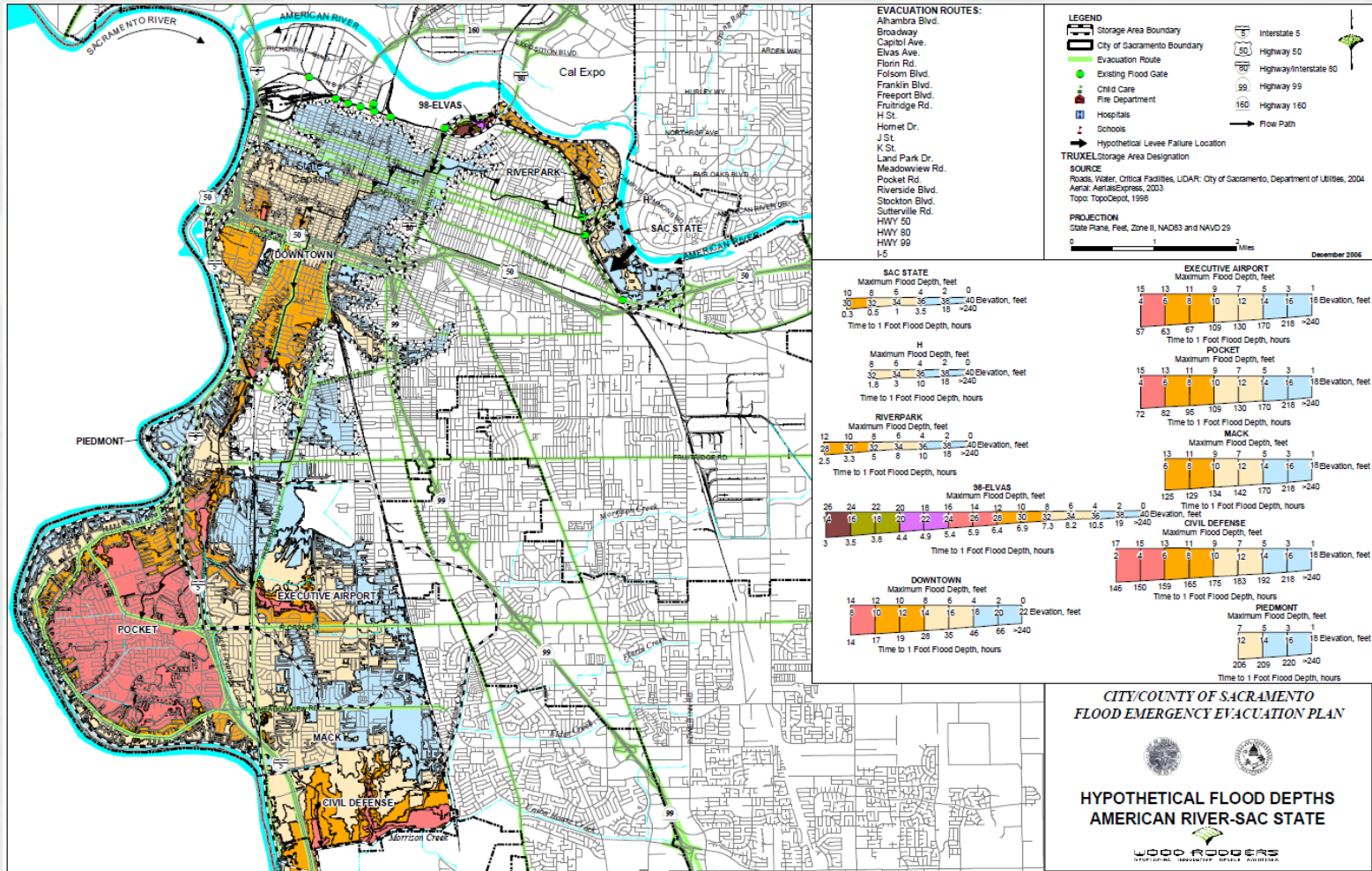
Sacramento Evacuation Destinations: Expected Events



- Top 2 Destinations: 1) South Sacramento Freeway, 2) CA 16
- Expected event destinations assume the population at risk receives ample evacuation notice with destination guidance and therefore the roadways available are more selective (preferred)



Sacramento Evacuation Plan



American River

Folsom Dam Auxiliary Spillway Test Release March 2018

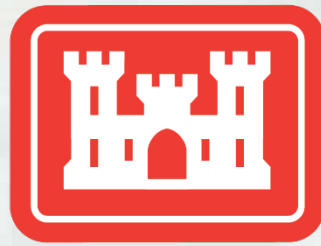
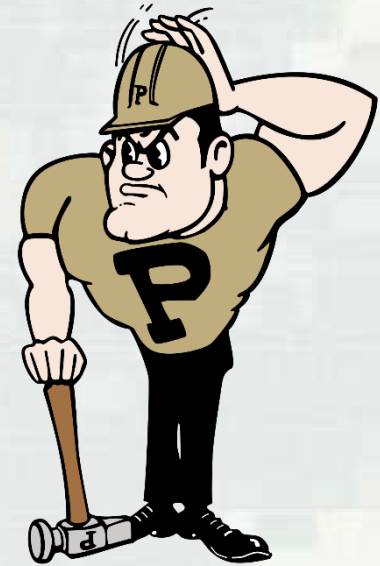


Conclusions

- Folsom Dam provides robust flood risk reduction to downstream areas such as Sacramento for frequent (up to once-in-300+ years) hydrologic events.
- Folsom's new Auxiliary Spillway is one of the modifications that reduces the frequency of potentially damaging releases, but does not eliminate the possibility.
- The cancellation of Auburn Dam greatly reduced flood storage capacity upstream of Sacramento on the American River.
- The primary vulnerability for Sacramento's levees is overtopping.
- A levee overtopping event almost anywhere along Sacramento's levees may be expected to result in thousands of deaths.
- Sacramento has had to develop highly detailed flood warning and evacuation plans.



Thank You, PGS!



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