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Summary of Section 9, Sunny-Day Risk Analysis

Purpose:

Section 9 presents the probability of levee failures in the Delta and Suisun Marsh as a result of causes other than seismic or flood events (referred to as "sunny-day" events).

Methods of Analysis:

To estimate the sunny-day annual frequency of failures, the historical record of summer-time levee failures in the Delta since 1950 is used.

Main Findings:

Assuming 911 miles of Delta levees within the Mean Higher High Water (MHHW) boundary, a sunny-day failure rate of about once every 10 years is estimated for Delta levees. Assuming 75 miles of Suisun Marsh exterior levees within the MHHW boundary, a failure rate of about once every 25 years is estimated for Suisun Marsh levees.

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9.1 ASSUMPTIONS AND DEFINITIONS

Sunny-day failures are levee breaches that are not flood or seismic related. Historical data were used to estimate the rate at which the levee breaches occurred during non-flood and non-seismic conditions. These failures typically occur between the end of the late snowmelt from the Sierras, in late May, and the beginning of the rainy season, in early October. Sunny-day failures are addressed separately from flood-induced failures to differentiate between winter and summer events. Aside from seismic events, factors that can cause levee failures in the Sacramento–San Joaquin River Delta (Delta) in the summer period are different than the factors that can cause winter failures.

Levee failures resulting from flood hazard are discussed in Section 7 of this report. Factors that influence water stage frequencies during winter include the following hydrologic conditions: historical storms, storm surges, snow melt, rainfall and runoff, tides, and their combined effects.

Water stage frequencies associated with the summer, are controlled by tides and remote oceanic storm surges. Therefore, frequencies of failure for the two seasons are different, kept separate, and compared against historical observations for each season.

9.2 HISTORICAL INFORMATION

To estimate the sunny-day annual frequency of failures, the consulting team used the historical record of summer-time levee failures in the Delta since 1950. In this period, eight levee failures were recorded during summers that resulted in island flooding. Data from before 1950 were not used because the information needed, such as water level, crest elevation, and failure mode, is either nonexistent, sparse, or lacks the necessary details to fully document failure conditions. Furthermore, levees constructed before 1950 were much smaller than today's levees.

Table 9-1 summarizes the information collected about sunny-day island flooding. Water levels in the nearby sloughs were obtained from gauge station historical records operated and maintained by the California Data Exchange Center. Levee crest elevations were obtained from the Interferometric Synthetic Aperture Radar data in the Geographic Information System files that the California Department of Water Resources (DWR) provided. Post-failure investigation reports are not available to provide detailed descriptions of the causes of the levee failures. The information provided in the column titled "Conditions at Time of Failure or Assumed Failure Mode" of Table 9-1 is anecdotal and relies on limited available data and communication with DWR personnel and the reclamation districts' engineers.

Figure 9-1 shows the levee crest elevations versus the water stage (North American Vertical Datum of 1988 [NAVD88]) for seven of the eight levee breaches at the time of failure. Figure 9-2 shows the approximate locations of the breaches. A close examination of the data indicates that failures occurred during "unusual" high-tide conditions. An unusual high tide could be caused by offshore storm surges arriving in the Delta, planetary conditions resulting in higher gravitational pull from the concurrent alignment of the sun and the moon, or a combination of the two.

At Simmons-Wheeler in July 2005, the water rose above the crest of the levee at Suisun Marsh and overtopping may have caused the levees to fail. However, other eyewitness reports indicate

also that the levee failure at Simmons-Wheeler may have been caused by rapid drawdown during a period of receding water levels.

Post-failure reports indicate that excavation activities at the landside toes of the levee may have caused the failure of Brannan Andrus Island in June 1972. At MacDonald Island in August 1982, the levee may have been breached as a result of dredging on the waterside toe of the levee. However, that information has not been confirmed in any written report. Generally, these failure events may be the result of a combination of high tide and pre-existing internal levee and foundation weaknesses caused by burrowing animals, internal compounded erosion of the levee and foundation through time, and human interventions such as dredging or excavation at the toe of the levee.

Burrowing animal activities and pre-existing weaknesses in the levees and foundation are the key weak links leading to levee failures. This is the case whether or not the failures occur during a high-tide condition. Most practicing engineers, scientists, and maintenance personnel in the Delta and Suisun Marsh believe that rodents are prolific in the Delta and use levees for burrowing. As a result, they cause undue weaknesses by creating a maze of internal and interconnected galleries of tunnels.

Under-seepage and through-levee seepage are slow processes that tend to work through time by removing fines from levee and foundation material during episodes of high river levels. Cumulative deterioration through the years can lead to foundations ultimately failing by means of uncontrollable internal erosion that leads to slumping and cracking of levees.

Sunny-day levee failures all occurred during higher-than-typical daily high tides. The typical daily high tides over a 24-hour cycle in summer conditions are generally around elevation +5 feet (NAVD88) in the central-west Delta, and about +5.6 feet in Suisun Marsh (DWR 1995b). Water elevations at the times of the summer levee failures, as shown in Figure 9-1, were generally around elevation +6 feet (NAVD88) or higher.

9.3 ESTIMATION OF FREQUENCY OF SUNNY-DAY FAILURES

The frequency of historical sunny-day failures of levees in the Delta and Suisun Marsh was determined from the records of six such failures recorded in the Delta and two sunny-day failures in Suisun Marsh. Assuming 911 miles of Delta levees within the mean higher high water (MHHW) boundary, a failure rate of 1.06×10^{-4} /year/levee-mile or 0.0969 failure/year was estimated using the least square linear fit to the six data points for the Delta shown in Figure 9-3. The standard deviation around the linear trend line is 0.47.

Assuming 75 miles of Suisun Marsh exterior levees within the MHHW boundary, a failure rate of 4.76×10^{-4} /year/levee-mile or 0.036 failure/year was estimated. The data points for the Suisun Marsh are too few to conduct a statistical regression analysis (trend line and standard deviation). The trend for Suisun Marsh is estimated to be an average of two failures over 55 years, and the standard deviation is assumed to be the same as for the Delta, short of any other information.

Because of incomplete information on the exact causes of the sunny-day levee failures at each location, the Delta Risk Management Strategy project team was unable to map out the various conditions leading to sunny-day failures by specific area in the Delta and Suisun Marsh. The project team assumed that the recurrence models of sunny-day failures have uniform

probabilities throughout the Delta and Suisun Marsh, respectively. These two failure rates will be applied to all levees in the two areas within the MHHW boundary, assuming the uniform probabilities shown in the preceding two paragraphs.

Table 9-1 Sunny-Day Failures

Island/Tract	Year	Month	Day	Conditions at Time of Failure or Assumed Failure Mode	Water Level (NAVD88)	Levee Crest (NAVD88)
Webb Tract	1950	Jun	2	High tide, stability	6.1	10.8
Brannan-Andrus Island	1972	Jun	22	Excavation at landside toe	6.2	10.8
Lower Jones Tract	1980	Sep	26	Seepage and rodent activities	6	11
McDonald Island	1982	Aug	23	Seepage from dredging at waterside toe	5.48	11.5
Little Mandeville	1994	Aug	2	High tide, abandoned	6.1	11.5
Upper Jones Tract	2004	Jun	3	High tide, under-seepage, and rodent activity	6.85	11
Simmons-Wheeler (Suisun Marsh)	2005	Jul	20	High tide, breach occurred between two water control structures; beaver activities suspected	7.51	7.3
Sunrise Duck Club (Suisun Marsh)	1999	Jul	NA	High tide and possible beaver activities	NA	5 to 6

NAVD88 = North American Vertical Datum of 1988

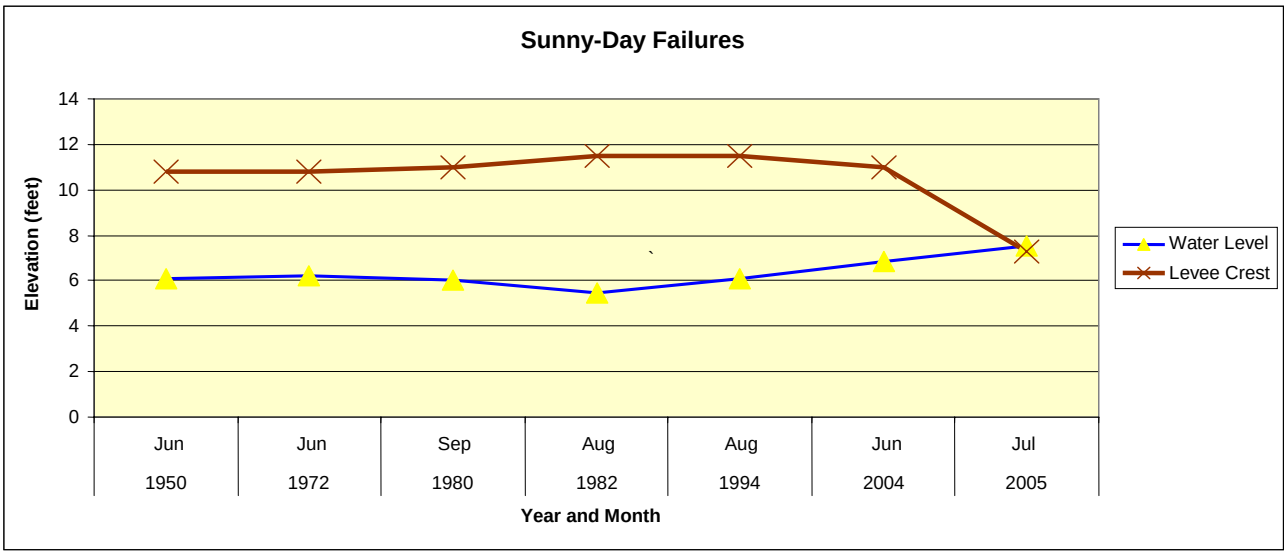

Figure 9-1 Water Stage versus Crest Elevation at Sunny-Day Failure Locations

N
W E
S

SACRAMENTO
West Sacramento
Glide District
Sacramento Pocket Area
Lisbon District
Netherlands
YOLO BYPASS
Sacramento Deep Water Ship Channel
Slough
Elk
Merritt Island
RIVER
Cache Haas '86
Little Holland
Peters Pocket
Liberty Island
Prospect Island
Hastings Tract
Lindsey
Egbert Tract
Ryer Island
Sutter Island
Sutter
Pierson District
Snodgrass Slough
Glanville Tract
McCormack Williamson Tract
DELTA CROSS CHANNEL
Cosumnes River
New Hope Tract
Grand Island
Steamboat
Egbert Tract '04
Beaver Slough
Canal Ranch
Mokelumne
Hog Slough
Brack Tract
Georgiana
Tyler
North Mokelumne
Staten Island
Brannan-Andrus Island
Sycamore Slough
Terminous Tract
Sevenmile Slough
Twitchell Island
Threemile Slough
Bouldin Island
Potato Slough
Little Potato Slough
White Slough
Shin Kee Tract
Rio Blanco Tract
Webb Tract
Venice Island
Empire Tract
King Island
Bishop Tract
Bradford Island
Fishermans Cut
Sherman Island
Grizzly Island
Schafter-Pintail
Simmons-Wheeler Island
Honker Bay Club
Van Sickle Island
Chipps Island
Browns Island
Winter Island
Kimball Island
Donlon Is.
Jersey Island
Franks Tract
Little Franks Tract
Piper Slough
Taylor St.
Bethel Island
Dutch Slough
Mandeville Island
Medford Island
Little Tinsley Island
Stockton Deep Water Ship Channel
JOAQUIN
Rindge Tract
Bear Creek
Shima Tract
Fourteen Mile Slough
Wright-Elmwood Tract
Sargent
Barnhart Tract
Smith Tract
Weber Tract
Rough and Ready Island
Burns Cutoff
Boggs Tract
Columbia Cut
Mound Slough
Hotchkiss Tract
Holland Tract
Connection Slough
Mildred Island
McDonald Island
Latham
Turner Cut
Channel
Lower Roberts Island
Rock Slough
Veale Tract
Bacon Island
Empire Cut
Whiskey Slough
Palm Tract
Fay Island
Lower Jones Tract
Upper Jones Tract
Orwood Tract
Discovery Bay
Indian Slough
Woodward Island
Woodward Canal
North Victoria Canal
Victoria Island
Byron Tract
Victoria Canal
North Canal
Italian Slough
Clifton Court Forebay
Coney Island
Union Island
Middle Roberts Island
Upper Roberts Island
Mossdale
RD 017
Drexler Tract
Trapper Slough
Grant Line Canal
Fabian and Bell Canal
Fabian Tract
Stark Tract
Stewart Tract
Pico-Naglee
Pescadero District
Paradise Junction
Walthall
McMullin Ranch
Kasson District
River Junction
'99 Sunrise Duck Club (location off map)
'86 OT
'04
'05
'06
'83 (twice)
'98
'83
'37
'69
'27
'07
'72
'50
'38
'80
'82
'55
'36
'82 OT
'56
'94
'86 OT
'97

Legend

Year — Levee Failures

Year — Summer Failures

0 2.5 5 10 Miles

URS

DRMS	Locations of Levee Failures	Figure 9-2
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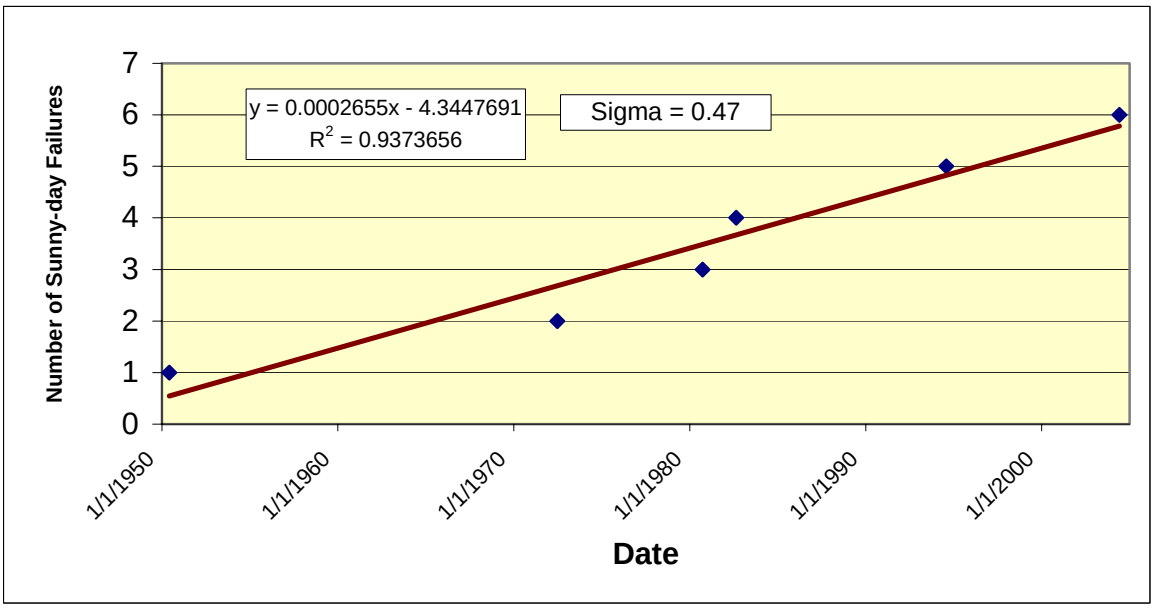

Figure 9-3 Cumulative Number of Sunny-Day Failures and Trend Line for the Delta
(Note: The slope of the trend line in the graph is based on days, not years)