

Smith Canal Gate Operation and Interior Drainage

Prepared for: San Joaquin Area Flood Control Agency

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Introduction

In 2005, as part of the FEMA Flood Map Modernization Program (Map Mod), FEMA began requiring levee owners to submit documentation showing that their levees provided a 100-year level of flood protection. Map Mod was an effort by FEMA to update Flood Insurance Rate Maps (FIRMS) nationwide which was conducted from fiscal year (FY) 2003 to FY 2008. As part of the National Flood Insurance Program (NFIP), FEMA develops FIRMS to identify areas at risk of flooding and to determine flood insurance rates. RD 1614 and RD 828 both determined that levees along Smith Canal would not meet FEMA criteria.

SJAFCA has coordinated with FEMA on the use of a gate structure as a method of providing flood risk-reduction for the Smith Canal area. In 2010, SJAFCA prepared 30% engineering design plans of a proposed structure and submitted a request to FEMA for a Conditional Letter of Map Revision (CLOMR). FEMA reviewed SJAFCA's CLOMR request and, in 2011, concurred that the gate structure would meet FEMA standards for providing at least 100-year flood risk-reduction and would warrant a revision in the FIRM. Recently, FEMA has presented concerns regarding storage of interior drainage behind a closed Smith Canal gate and requested additional data and analysis.

Objective

A conference call was held with FEMA on November 17, 2015 to discuss additional data and analyses needed in their review of the 2010 CLOMR. The following was proposed by PBI on the call, as meeting FEMA's needs:

- Perform a coincident frequency analysis of interior drainage area storms versus Delta stage events to determine the appropriate recurrence of interior drainage storm to superimpose concurrently with a 100-year stage event in the Delta
- Model the interior drainage system with the identified interior drainage storm using an appropriate model to determine the maximum water surface elevation in Smith Canal during the 100-year stage event when the gate is closed

- Perform underseepage, through seepage, and stability calculations for one critical location along the RD 1614 levee, and one critical location along the RD 828 levee at the maximum Smith Canal water surface elevation

The objective of this technical memorandum (TM) is to present the results of the coincident frequency and interior drainage analyses associated with a closed Smith Canal gate, describe the operation of the gate during an interior drainage event, and present the geotechnical calculations associated with impoundment of interior drainage behind the closed gate.

Smith Canal Gate Operation Overview

The normal position for the gate would be open. Tides would continue to flow in and out of the Smith Canal. The purpose of the Smith Canal gate is to create a barrier to block flooding in the event of either an imminent or existing levee breach and during 1% flood events and greater. In these cases, the gate would be closed, preventing flow of water from the Delta into Smith Canal. The Smith Canal gate will close when the Delta stage is forecasted to exceed 8.0 ft NAVD88, which is at a 4-year recurrence interval (*San Joaquin River Delta Base Flood Elevation Refinement*, September 2010). This water surface elevation is 1.4 feet below the 1% maximum water surface elevation of 9.4 ft NAVD88.

For flood control purposes, the gate would be closed only during high Delta stage events forecasted to approach or exceed the design operating water surface elevation between November and April. When a high Delta stage event is anticipated, the gate would be closed at the lowest tide prior to the forecasted high Delta stage. The gate would remain closed until interior drainage pumping causes the water level in Smith Canal to be higher than the Delta, at which point the head differential would force the gate open, equalizing the water surface elevation. Figure 1 and Figure 2 present historical Delta stage data during two high events:

- 1998 – Peak stage of 9.21 ft NAVD88 on February 7, 1998 (approximate 25-year stage)
- 1983 – Peak stages of 9.24 ft NAVD88 on January 27, 1983 (approximate 30-year stage) and 9.29 ft NAVD88 on January 29, 1983 (approximate 50-year stage)

Note that even during both of these events, the tidal influence is observed with two high stages and two low stages each day.

Figure 1. Delta Stage during 1998 High Stage Event

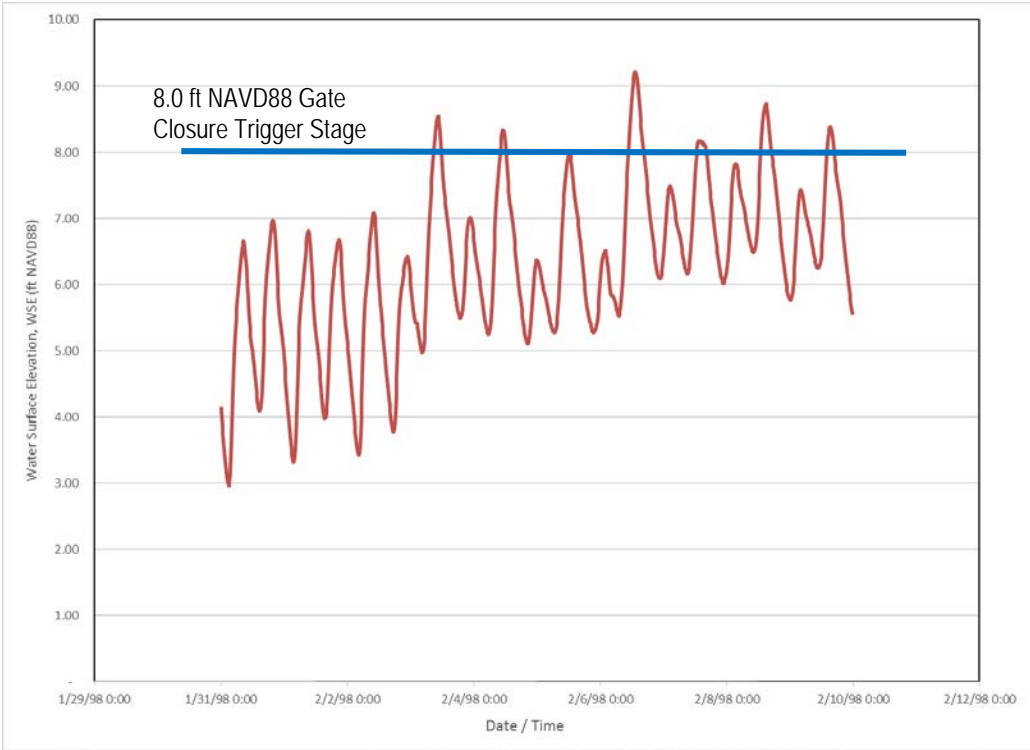
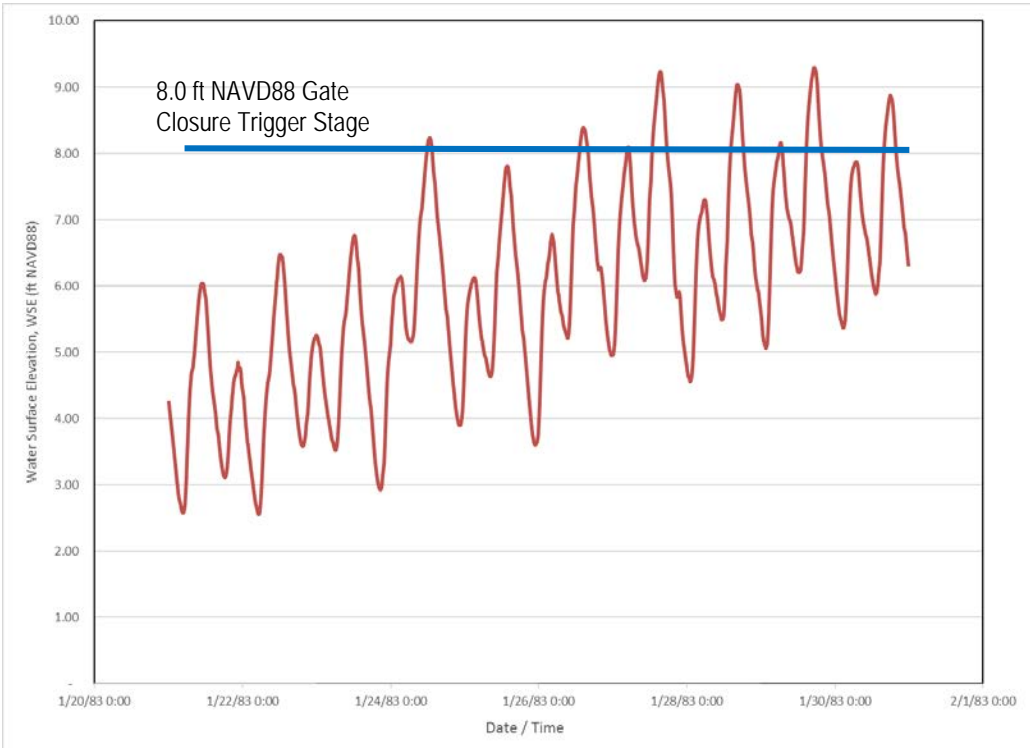


Figure 2. Delta Stage during 1983 High Stage Events



Coincidence of Events

A coincident frequency analysis of interior drainage area storms versus Delta stage events was performed to determine the appropriate recurrence of interior drainage storm to superimpose concurrently with a 100-year stage event in the Delta. The details of this analysis are presented in Attachment 1, *Smith Canal Stage-Storm Coincident Frequency Analysis* (January 2016). A summary of this analysis is presented below.

For the Smith Canal gate, a triggering stage event occurs when the stage is forecast to exceed 8.0 ft NAVD88. So, although the 100-year stage is 9.4 ft NAVD88, the Smith Canal Gate will be closed more frequently. Thus, interior drainage will be confined based on the gate closure triggering stage of 8.0 ft.

USACE provides guidance on determining coincidence of events in *EM 1110-2-1413, Hydrologic Analysis of Interior Areas* (USACE, January 1987). The validity of the assumptions necessary to apply the USACE coincident frequency method is controlled by whether or not the two variables are dependent or independent. Independent variables cannot be analyzed using the USACE method. Three varying factors were used per the USACE method to evaluate the relationship between interior precipitation and Delta stage events:

- Correlation - occurs if a consistent relationship exists between interior and exterior events; analysis to determine the degree of correlation may help determine the likelihood of coincidence or dependence; lack of correlation could suggest independence, but not necessarily determine independence by itself.
- Dependence - occurs if the physical and meteorological processes are related to one another; the degree of dependence is more likely based on inspection of the available record and judgements with regard to the meteorological and physiographic origins of interior and exterior events.
- Coincidence - occurs if a situation exists where the high interior precipitation and exterior stage events coincide; it should be noted that coinciding events can still occur whether or not the two events are determined to be uncorrelated or independent of each other.

The analysis for all three of the above factors showed that the interior rainfall in the Smith Canal basin is independent of the stage in the Delta. Therefore, the USACE coincident frequency method cannot be used. The probability of the two events coinciding can be determined by the Multiplication Rule when the events are known to be independent (*Elementary Statistics*, 2001). The Multiplication Rule determines the coincident probability by finding the product of the probability of each individual event. Using this method, the 100-year recurrence of the Delta stage and local Smith Canal rainfall is the product of the Delta stage (4-year recurrence at a stage of 8.0 ft) and local rainfall (25-year, 24-hour storm). Therefore, a 25-year 24-hour storm event is an appropriate recurrence interval to be superimposed with a triggering stage event in the Delta to represent a 100-year coincident storm and stage frequency. Recall that a triggering stage event occurs when the stage is forecast to exceed 8.0 ft NAVD88. So although the 100-year stage is 9.4 ft NAVD88, the Smith Canal Gate will be closed more frequently. Thus, interior

drainage will be confined based on the gate closure triggering stage of 8.0 ft. The 25-year, 24-hour storm will serve as the design storm used in an interior drainage model for the Smith Canal basin to assess the stage rise in Smith Canal behind the closed gate.

Interior Drainage Model Development

A HEC-HMS model was developed to estimate rainfall runoff hydrographs for the Smith Canal drainage area. The details of this analysis are presented in Attachment 1, *Smith Canal Gate Structure Interior Drainage Analysis* (January 2016). A summary of this analysis is presented below.

Design Storm

Design storms were developed for input into HEC-HMS according to procedures and precipitation depth-duration-frequency data included in the San Joaquin County Hydrology Manual. A 25-year return period, 24-hour duration storm event was created for estimation of interior drainage flows draining into Smith Canal. Table 1 presents the rainfall data that was coded into HEC-HMS as a 25-year, 24-hour Frequency storm.

Table 1. 25-year Depth-Duration-Frequency for San Joaquin County

	25-Year Rainfall Duration							
	15 minute	30 minute	1 hour	2 hour	3 hour	6 hour	12 hour	24 hour
25-Year Rainfall Depth (in)	0.45	0.59	0.78	1.03	1.21	1.60	2.11	2.78

Interior Drainage Pump Stations

The Smith Canal subbasins are drained by through-levee culverts and stormwater pump stations. Nine of the 13 subbasins within the Smith Canal watershed are drained by interior drainage pump stations. The remaining flap-gated gravity culverts are typically submerged during high tide events and do not allow conveyance of stormwater into Smith Canal. Table 2 presents the Smith Canal interior drainage subbasins and their associated total pump station capacity. These pump stations were added to the HEC-HMS model.

Table 2. Smith Canal Interior Drainage Pump Station Capacities

Subbasin	Subbasin Area (acres)	Total Pump Station Capacity (cfs)
Buena Vista North	121.6	12.3
Lake Drive	4.2	6.0
Franklin Ave	425.2	34.0
Plymouth Road	90.4	31.9
Gardena	54.7	12.5
Moreing	35.9	12.3
Yosemite Lake	1,935.9	240.8
Buena Vista South	477.5	69.3

Subbasin	Subbasin Area (acres)	Total Pump Station Capacity (cfs)
Ryde Ave	167.1	37.4
Kingsley Ave	18.0	gravity culverts only
Pinetree Drive	7.8	gravity culverts only
Occidental	5.6	gravity culverts only
Louis	21.3	gravity culverts only
TOTAL	3,365	456.5

HEC-HMS Model Verification

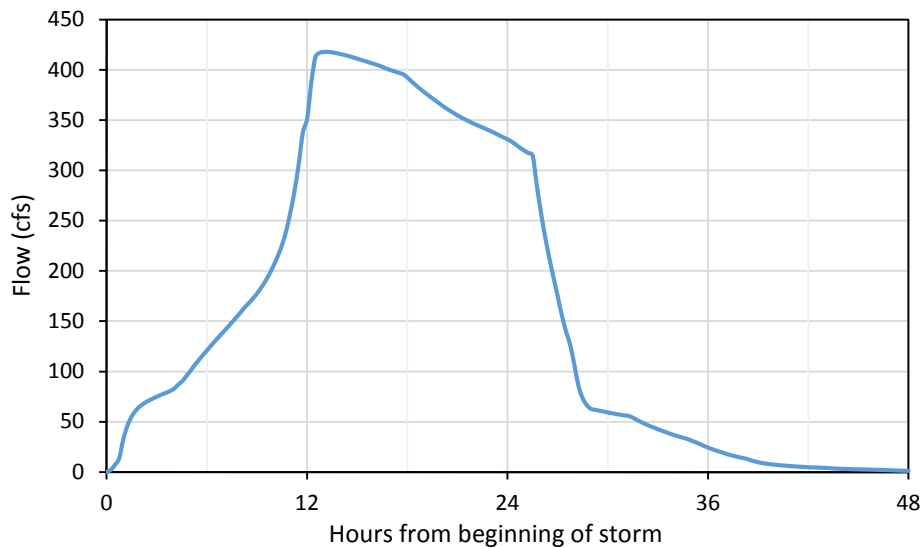
The HEC-HMS model was run using rainfall from an observed storm event and the model output was compared to observed pump station records. The observed storm event occurred on December 11-12, 2014 where 2.16 inches of rainfall fell over a 24-hour period. For the observed December 2014 storm event, model results were verified by comparing the modeled runoff volume within the largest subbasin, Yosemite Lake (nearly 60% of the total basin area) with observed runoff volumes that were determined based on stormwater pump records associated the same storm.

The modelled results estimate 296.3 ac-ft of runoff being generated within the Yosemite Lake subbasin as a result of the December 11-12, 2014 storm event. From pump records, it was estimated that this pump station discharged 300.8 ac-ft from the Yosemite Lake subbasin into Smith Canal in response to this same storm. This represents a 1.5% difference from the modeled estimate. Therefore, the model verification indicates that the HEC-HMS model reasonably represents the hydrologic response of the watershed.

HEC-HMS Model Results

Following model verification, the HEC-HMS model was run with the 25-year, 24-hour precipitation model. Figure 3 presents the resulting inflow hydrograph from all pump stations discharging into Smith Canal for the 25-year, 24-hour storm. The total volume discharge into Smith Canal from this storm is 631 ac-ft. The hydrograph in Figure 3 assumes that all interior drainage is pumped at the maximum pump station capacity into Smith Canal with no attenuation from street storage.

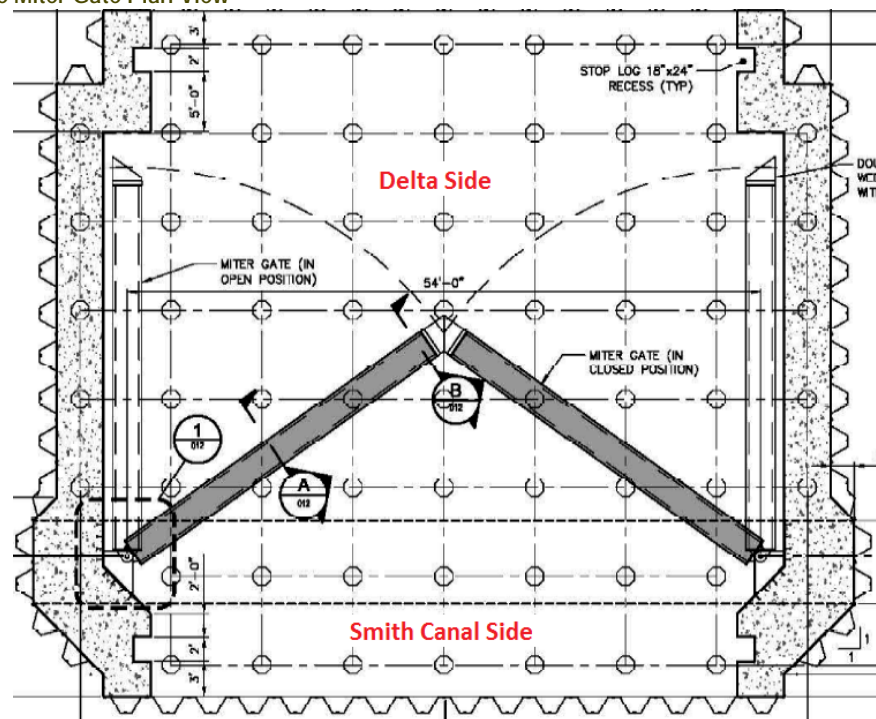
Figure 3. 25-Year, 24-Hour Storm Hydrograph from All Smith Canal Interior Drainage Pump Stations



Smith Canal Gate Operation Impact on Interior Drainage

The Smith Canal gate will be a miter gate (double door type, see Figure 4) that is typically used for locks. The gate will close when the Delta stage is forecasted to exceed 8.0 ft NAVD88. A miter gate of this size can be closed in approximately 5 minutes. The gate will remain closed until the Delta stage recedes to match the water surface elevation in Smith Canal. The only exception to this operation is when the Smith Canal WSE is greater than the Delta stage; at this point, the gate will open to release water from Smith Canal into the Delta. Note that the miter gate’s design does not allow it to stay closed when the WSE is higher in Smith Canal than in the Delta. The “reverse” head on the miter gate will cause it to open.

Figure 4. Example Miter Gate Plan View



Smith Canal WSE Determination

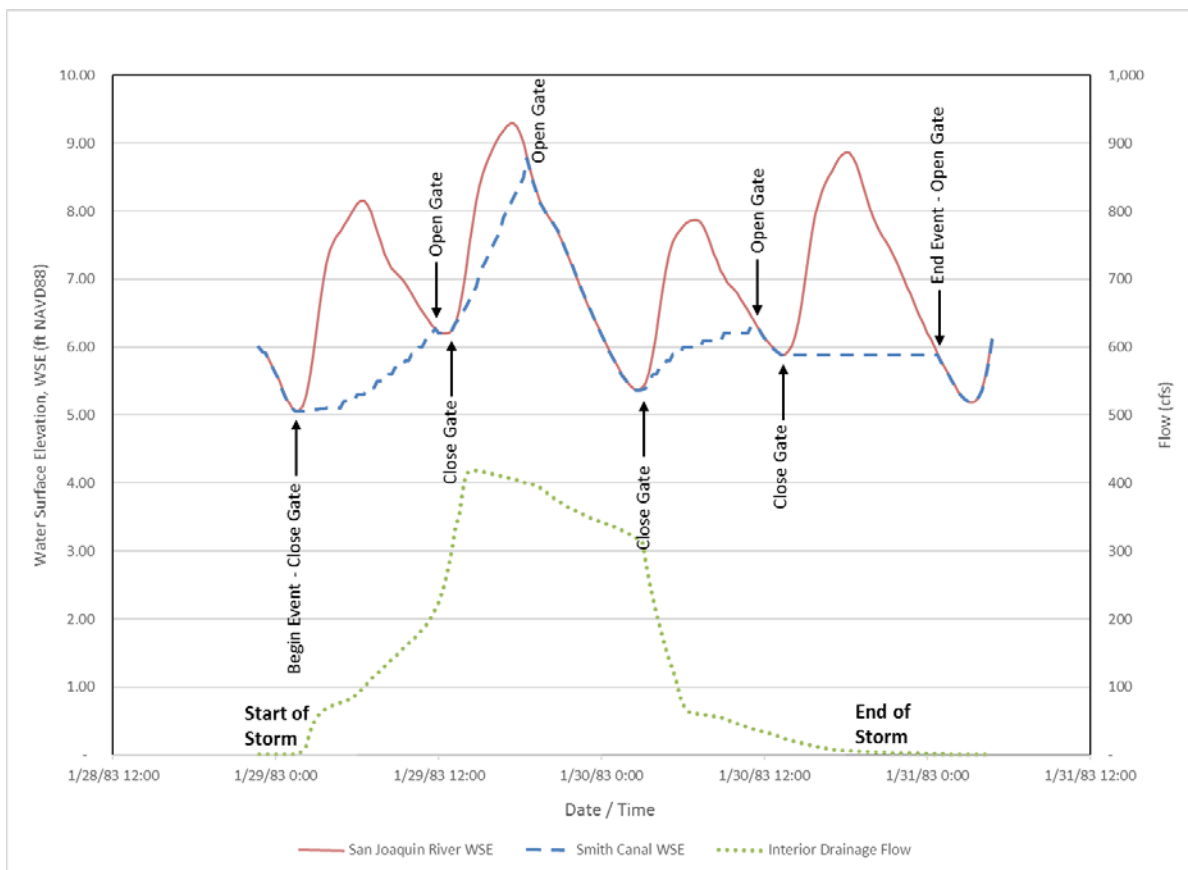
To determine the water surface elevation in Smith Canal when the gate is closed during the 25-year, 24-hour storm event, a spreadsheet model was developed. This model evaluates the Delta stage, Smith Canal WSE, and interior drainage pumped into Smith Canal per Figure 3 on 15 minute intervals. The gate is modeled to close on the lowest low tide that is 48-60 hours before the peak forecasted Delta stage (the forecast period of the DWR Venice Island gage). The gate is modeled to open when Delta stage recedes following its peak or when the Smith Canal WSE elevation exceeds the Delta stage.

Figure 4 presents operation of the Smith Canal gate with a 25-year, 24-hour storm superimposed on the 50-year historical Delta stage from January 29, 1983. The gate closure and storm start are synchronized to present the worst case condition. The discussion below presents a description of the Smith Canal gate operation during the gate closure event shown in Figure 4:

- Begin Event (1/29/83, 01:30) - gate is closed at the lowest tide (5.06 ft) prior to the peak Delta stage within the forecast period; the 25-year, 24-hour storm is also started at this time; while the gate is closed, 89 ac-ft of interior drainage is accumulated behind the gate
- Gate Opens (1/29/83, 12:00) – gate is opened when the rising Smith Canal WSE meets the Delta falling stage (6.25 ft); while the gate is open, 37 ac-ft of interior drainage is released from behind the gate

- Gate Closes (1/29/83, 13:00) – gate is reclosed when the Delta stage begins to rise (6.14 ft); gate stays closed during peak Delta stage of 9.29 ft; while the gate is closed, 184 ac-ft of interior drainage is accumulated behind the gate
- Gate Opens (1/29/83, 18:30) – gate is opened when the rising Smith Canal WSE meets the falling Delta stage (8.78 ft); while the gate is open, 476 ac-ft of interior drainage is released from behind the gate
- Gate Closes (1/30/83, 03:00) – gate closes in preparation for predicted Delta stage of 8.86 ft on 1/30/83 at 18:15; while the gate is closed, 72 ac-ft of interior drainage is accumulated behind the gate
- Gate Opens (1/30/83, 11:30) – gate is opened when the rising Smith Canal WSE meets the falling Delta stage (6.30 ft); while the gate is open, 33 ac-ft of interior drainage is released from behind the gate
- Gate Closes (1/30/83, 13:15) – gate is reclosed when the Delta stage begins to rise (5.88 ft); gate stays closed during peak Delta stage of 8.86 ft; while the gate is closed, 7 ac-ft of interior drainage is accumulated behind the gate
- End Event (1/31/83, 00:45) – gate is opened following peak Delta stage once the Delta stage equals the Smith Canal WSE

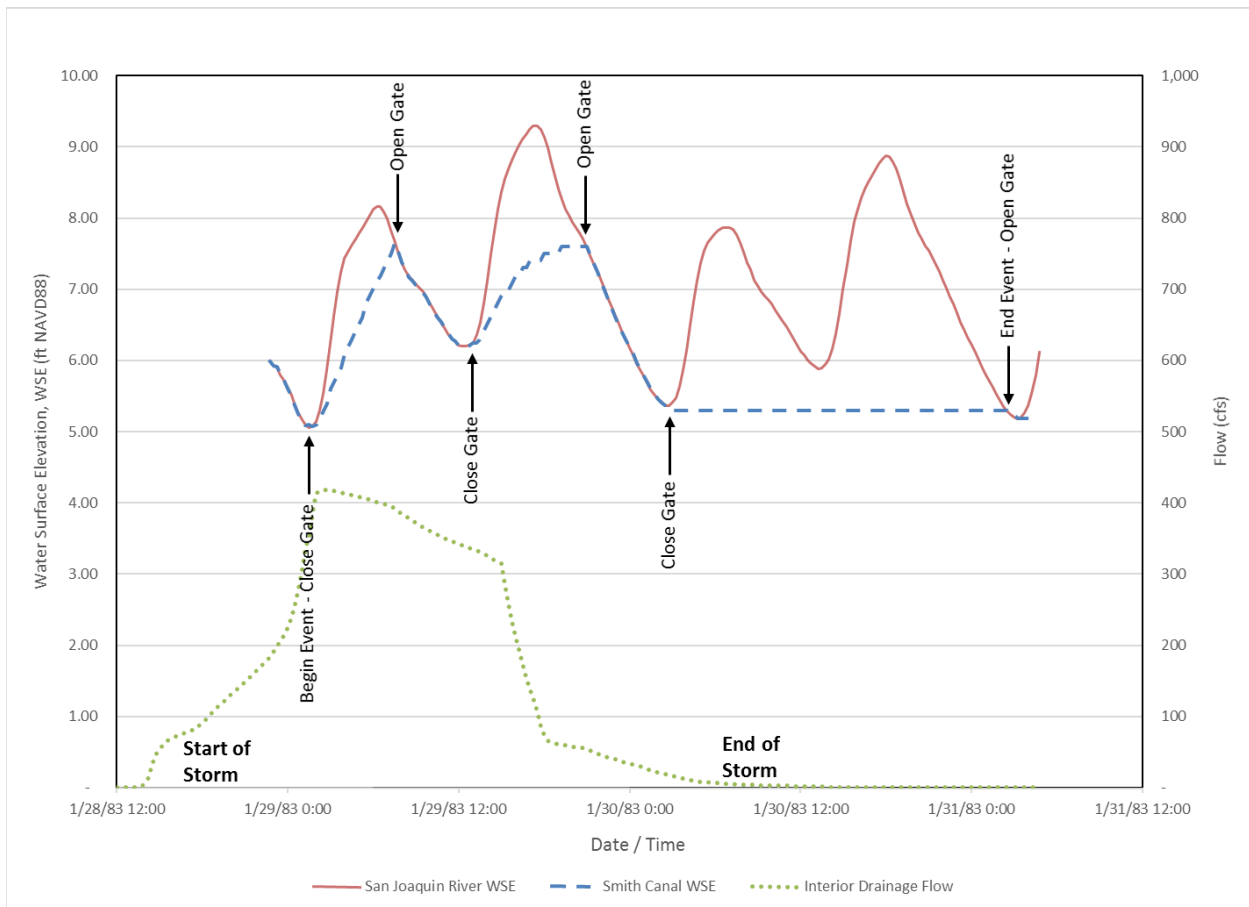
Figure 5. Smith Canal WSE during Gate Operation (Gate Closed at Start of Storm)



Impact of Storm Timing

As stated above, the combined event shown in Figure 4 is a worst case combination of the 25-year, 24-hour storm superimposed on the closed Smith Canal gate during the 1983 peak tide event, which was approximately a 50-year event. The maximum WSE in Smith Canal during this event was 8.78 ft. However, if the storm had started only 12 hours earlier, or later, the maximum Smith Canal WSE would be reduced by more than 1 ft. Figure 5 presents the operation of the Smith Canal gate with the storm started 12 hours before the gate is closed; the maximum Smith Canal WSE would have been 7.7 ft. Similarly, if the storm started 12 hours after the gate is closed, the maximum Smith Canal WSE would have been 7.6 ft.

Figure 6. Smith Canal WSE during Gate Operation (Storm Initiated 12 hours before Gate Closure Due to 8.0 ft Stage Trigger)



A storm timing sensitivity analysis was completed for all of the occasions that the Smith Canal gate would have been closed during the historical 1998 and 1983 peak Delta stages. Table 3 presents the range of Smith Canal water surface elevations that would have occurred when superimposed with the 25-year, 24-hour storm (assuming varying storm start time relative to the initial gate closure).

Table 3. Sensitivity Analysis of Interior Storm Start Time and Maximum Smith Canal WSEs for Historical 1983 and 1998 Peak Delta Stage Events

Year	Dates	Smith Canal WSE (ft NAVD88)		
		Average Peak	Maximum Peak	Minimum Peak
1983	1/23 to 1/24	6.3	7.9	4.6
	1/29 to 2/1	7.6	8.8*	6.1
1998	2/2 to 2/4	7.0	7.8	6.0
	2/6 to 2/11	7.7	8.7	6.2

* This is the case that was presented in Figure 4.

Maximum Smith Canal WSE

Based on the information presented in Table 3, the maximum Smith Canal WSE that will be used in the geotechnical evaluation of the Smith Canal embankments is 8.8 ft NAVD88. However, it should be noted that this represents another dimension to the multiplication rule of probability. By reporting the most critical storm start time, the probability of the overall event is likely much less than 1%, introducing a significant measure of conservatism in the analysis.

Geotechnical Analysis

Seepage Calculations

Stability Calculations

Conclusions

Based on the evaluations presented above, the following conclusions are made relative to interior drainage stored behind a closed Smith Canal gate:

- The appropriate interior drainage storm recurrence associated with closure of the Smith Canal gate is the 25-year recurrence
- The peak Smith Canal WSE behind the closed gate ranges between 4.6 ft and 8.8 ft NAVD88, depending upon the timing of the storm relative to required gate closure
- At a Smith Canal WSE of 8.8 ft, the steady-state seepage analysis exit gradient is less than 0.5 for the Smith Canal embankments

- At a Smith Canal WSE of 8.8 ft, the steady-state slope stability analysis safety factor is greater than 1.4 for the Smith Canal embankments