3. Assessment of Flood Hazards in the Region: Deficiencies, Risks, and Challenges

3.1. Flood Control System Deficiencies

3.1.1. *Channel Capacity*

Many factors contribute to a channels ability to safely convey design flood flows. Channels can have lower than designed flow capacity because of insufficient levee height or obstructions. Insufficient levee height can reduce the effective cross sectional flow area. Similarly, obstructions such as bridges, sediment deposits, pilings, docks, marinas, and increased channel roughness from vegetation can also reduce the effective cross-sectional flow area and increase water levels, leading to levee overtopping or foundational failures.

Vegetation can decrease channel capacity, and vegetative debris can collect at bridges and other in-channel structures, restricting and redirecting flow, and can lead to levee erosion and/or overtopping. Deposits of sediment carried by floodwaters can reduce the cross-sectional areas of flood channels, leading to decreased conveyance capacity.

Channel conveyance capacity can also be reduced by a number of other factors, such as encroachments in the channel, bank erosion, revetments, and bank caving. Localized levee settlement or original deficiencies in the levee design can also contribute to a channels inability to meet design flows. Consequently, it is often difficult to identify the specific causes of channel conveyance problems, and determining whether or not they are channel-related or levee-related often requires additional site-specific investigation. Another difficult challenge is the fact that the conveyance capacity of the system is dynamic, and therefore needs to be reevaluated at regular intervals. In addition, the complexities associated with analyzing channel capacity via hydraulic models make it a very time consuming process that involves data gathering, calibration, simulation, model refinements, and estimation of uncertainty.

Detailed evaluations regarding the ability of SPFC facilities within the Regions to convey design flows are currently underway by DWR. This work is currently in-progress and was not available for inclusion in this Working Draft version of the MUSR RFMP.

Project specific modeling is also conducted by DWR's Flood Maintenance Program to assess channel conveyance capacity data in the Sacramento River watershed and to determine where in-channel maintenance work is needed. DWR is responsible for maintaining channel flow capacity for Sacramento River Flood Control Project channels, and for performing channel-specific maintenance activities identified in the USACE O&M manuals, including channel clearing, to maintain design flow capacity. Project-specific models are used by the flood maintenance program to systematically prioritize channel vegetation management and sediment management activities by determining whether a channel capacity inadequacy is driven by sedimentation,

channel vegetation, subsidence, flow constrictions caused by bridge crossings, or other factors. Where available, project-specific hydraulic modeling results from projects conducted by other agencies are used as the source of channel conveyance capacity data.

The basis for evaluating channel conveyance capacity in the Sacramento River watershed was refined several times after the Flood Control Act of 1917. Design flows were later amended by the Flood Control Act of 1928, Senate Document Number 23, the 1953 Memorandum of Understanding between USACE and the Reclamation Board (USACE and Board, 1953), and the 1957 design profiles for the Sacramento River (USACE, 1957). The profiles and associated design capacities were developed based on USACE analysis of the 1937, 1951, and 1955 floods on the Sacramento River at the request of the Board. For channels not delineated in the 1957, design profiles above, design capacities were determined based on as-constructed capacities specified in appendices to O&M manuals provided by USACE.

SPFC channel conveyance capacity has been estimated based on the ability of a channel to pass original design flood flows. Design flood flows (or design channel capacities) from different official sources have been sometimes inconsistent. These discrepancies have complicated the evaluation of channel conveyance capacities throughout the Sacramento River watershed. For example, design channel capacities reported in USACE O&M manuals sometimes do not agree with channel capacities associated with design profiles. This is because USACE created some O&M manuals before the design profiles were adopted. DWR operates and maintains SPFC facilities based on design capacities calculated from the design profiles when available, rather than on design capacities included in the USACE O&M manuals (USACE, 1969).

Approximately half of the 1,016 miles of SPFC channels are potentially unable to convey design flows, and approximately one-quarter of channel design capacities reported in O&M manuals do not agree with flows specified in the original 1957design profiles (DWR, Flood Control System Status Report).

Table 3-1 and Figure 3-4 shows a summary of the channel capacity results identified in the FCSSR. The existing capacities were estimated through system-wide modeling performed via the CVFED program using the best data available at the time (DWR, FCSSR). The following criteria was used to determine whether estimated current capacities of the SPFC channels were sufficient to safely convey identified design capacities in the O&M manuals or design capacities calculated from design profiles:

- If the estimate of current capacity was greater than both the design capacity reported in the O&M manual and the design capacity based on the design profile, channel status was reported as “no obvious inadequacy.”
- If the estimate of current channel capacity was less than the design capacity reported in the O&M manual, or the design capacity based on the design profile (or both), the channel status was reported as “potential inadequacy; additional evaluation required.”
- If the estimate of current channel capacity for a reach depends on backwater flow assumptions, channel status was reported as "backwater controlled; additional evaluation required."

Please note that although Cherokee Canal, the Yolo Bypass, and their respective tributaries are technically outside of the MUSR Regional boundary, they were included in the following table for the sake of system context, and due to the inter-connectivity that they have with the Butte Basin and Colusa Drain. More specific descriptions regarding capacity and other channel deficiencies are included in the Urban Areas and System-wide Improvements Chapters of this RFMP

Table 3-1. Summary of FCSSR Channel Design Capacities for the MUSR Region

River Reach[1]	River Miles[2]		Design Flows from Senate Doc. No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawing (cfs) (basis of State operation)	Diff. Between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Red Bluff to Chico Landing										
Sacramento River										
Deer Creek to Chico Landing	No data	No data	260,000 cfs	Not specified	Not specified	N/A	No data	No data	Estimated flow at Chico Landing is 260,000 cfs (Senate Document No. 23)	None
Tributaries to Sacramento River										
Elder Creek	6	0	Not specified	17,000	17,000	No	9,000 – 17,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program Modeling by DWR Northern Region Office	None
Deer Creek	7.4	0	Not specified	21,000	21,000	No	7,000 – 21,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program Modeling by DWR Northern Region Office	None
Chico Landing to Colusa Weir										
Sacramento River										
Chico Landing to head of east levee	175	166	160,000	160,000	160,000	No	195,000	No obvious inadequacy	*Determination of Channel Capacity of the Sacramento River* (USGS, 1976) and EIR for Butte Basin Overflow Area, (Reclamation Board, 1986)	None
East levee head (Parrott Grant Line) to Princeton-Afton Road	166	153	160,000	160,000	160,000	No	159,000	Potential inadequacy; additional evaluation required	Ayers modeling for USACE and Princeton Pump Plant	None

River Reach[1]	River Miles[2]		Design Flows from Senate Doc. No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawing (cfs) (basis of State operation)	Diff. Between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Princeton-Afton Road to Moulton Weir	153	148.25	160,000	160,000	160,000	No	110,000 – 184,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis – 184,000 cfs. DWR Channel Evaluation Program – 110,000 cfs.	150,000 cfs design capacity authorized with Butte Basin Bypass if it was constructed.
Moulton Weir to Colusa Weir	148.25	138	145,000	110,000	135,000	Yes	126,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
Tributaries to Sacramento River										
Mud Creek and Big Chico Creek										
Mud Creek – end of levees to Sycamore Creek	8.22	6.82	Not specified	5,500	No data	N/A	No data	No data	N/A	None
Mud Creek – Sycamore Creek to SPRR	6.82	4.32	15,000	15,000	15,000	No	No data	No data	N/A	None
Mud Creek – SPRR to Big Chico Creek	4.32	0.00	13,000	13,000	13,000 – 15,000	No	No data	No data	N/A	None
Tributaries to Mud Creek										
Sycamore Bypass	12.4	11.0	8,500	8,500	8,500	No	>8,500	No obvious inadequacy	DWR Channel Evaluation Program Modeling by Flood Maintenance Office	None
Sycamore Creek										
Sycamore Bypass to North Sycamore Creek	11.0	9.4	10,000	10,000	10,000	No	>10,000	No obvious inadequacy	DWR Channel Evaluation Program Modeling by Flood Maintenance Office	Significant scouring of the channel bed has occurred since project was completed and appears to be migrating upstream into the bypass channel.

River Reach[1]	River Miles[2]		Design Flows from Senate Doc. No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawing (cfs) (basis of State operation)	Diff. Between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
North Sycamore Creek to Sheep Hollow	9.4	8.6	10,000	10,000	10,000	No	>8,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program Modeling by Flood Maintenance Office	Recently completed sediment removal at Cohasset Bridge restored localized restriction but much conveyance in the reach remains below design capacity.
Sheep Hollow to Mud Creek	8.6	6.8	11,000	11,000	11,000	No	5,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program Sycamore Creek Sediment Removal Project	None
Lindo Channel	10.3	2.75	Not specified	6,000	6,000	No	<4,000-6,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program Modeling by DWR Northern Region Office	Capacity inadequacies are dispersed throughout. There is a major constriction just downstream from the Lindo Channel Control Structure and at Big Chico Creek, where capacity is limited to less than 4,000 cfs.
Big Chico Creek – Mud Creek to Sacramento River	2.75	0	15,000	15,000	15,000	No	No data	No data	N/A	None
Distributaries from Sacramento River										
Overflow to Butte Basin	175	166	100,000 cfs	100,000 cfs from Senate Document No. 23		N/A	150,000	No obvious inadequacy	*Determination of Channel Capacity of the Sacramento River* (USGS, 1976) and EIR for Butte Basin Overflow Area (Reclamation Board, 1986)	None

River Reach[1]	River Miles[2]		Design Flows from Senate Doc. No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawing (cfs) (basis of State operation)	Diff. Between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Moulton Weir [3]	158.5	158.5	15,000	25,000	25,000	No	34,000	No obvious inadequacy	*Two-Dimensional Hydraulic Modeling of Riparian Habitat Restoration from Colusa to Princeton* (Nature Conservancy, 2007)	None
Colusa Weir [3]	146.2	146.2	80,000	70,000	70,000	No	75,300	No obvious inadequacy	*Two-Dimensional Hydraulic Modeling of Riparian Habitat Restoration from Colusa to Princeton* (Nature Conservancy, 2007)	None
Colusa Weir to Fremont Weir										
Sacramento River										
Colusa Weir to Colusa Bridge	138.0	135.0	65,000	48,000	65,000	Yes	50,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Colusa Bridge to Butte Slough	135.0	130.0	47,000	48,000	65,000	Yes	50,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Butte Slough to Hwy 20 Road	130.0	126.0	47,000	48,000	66,000	Yes	67,000	No obvious inadequacy	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Hwy 20 to Tisdale Weir	126.0	119.5	72,000	48,000	66,000	Yes	47,000	Potential inadequacy; additional evaluation required	Estimate from adjacent project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Tisdale Weir to Wilkins Slough	119.5	118	33,500	30,000	30,000	No	29,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None

River Reach[1]	River Miles[2]		Design Flows from Senate Doc. No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawing (cfs) (basis of State operation)	Diff. Between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Wilkins Slough to Knights Landing	118.0	90.0	33,500	30,000	30,000	No	29,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Knights Landing to Fremont Weir	90.0	85.0	33,500	30,000	30,000	No	29,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Tributaries to Sacramento River										
Butte Slough Outfall	138.2	138.2	7,000	3,500	1,000	N/A	Not applicable	Not applicable	N/A	This facility is subject to backwater control.
Knights Landing Outfall	90.2	90.2	Not specified	Not applicable	Not applicable	N/A	Not applicable	Not applicable	N/A	This facility is designed to protect the Colusa Basin from backwater from the Sacramento River – thus, capacity is not relevant.
Distributaries from Sacramento River										
Tisdale Weir and Bypass	119.2	119.2	38,500	38,000	38,000	No	15,000 – 32,000	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program 2006 sediment removal project	Backwater from Sutter Bypass limits the capacity of the weir and bypass during large floods. See Note 4.
Fremont Weir [3]	85.2	82.2	343,000	343,000	343,000	No	No data	Not applicable		Weir flow needs to be analyzed. See Note 4.
Sutter Bypass										
Butte Slough to Wadsworth Canal	93.2	83.0	178,000	178,000	150,000	Yes	111,000 – 150,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis – 111,000 cfs. DWR Channel Evaluation Program – 150,000 cfs.	DWR Channel Evaluation Program started at 1957 profile elevation, running profile irrespective of upstream levee profile.

River Reach[1]	River Miles[2]		Design Flows from Senate Doc. No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawing (cfs) (basis of State operation)	Diff. Between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Wadsworth Canal to Tisdale Bypass	83.0	77.8	178,000	178,000	155,000	Yes	125,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis	None
Tisdale Bypass to Feather River	77.8	67.0	216,500	216,500	180,000	Yes	142,000 – 180,000	Potential inadequacy; additional evaluation required	Project-specific modeling from MBK for Natomas 408 Impact Analysis – 142,000 cfs. DWR Channel Evaluation Program - 180,000 cfs.	In 1997, flood reverse flow occurred for a few hours due to backwater from the Sutter Bypass.
Feather River to Verona	67.0	59.0	416,500	416,500	380,000	Yes	400,000	No obvious inadequacy	Project-specific modeling from MBK for Natomas 408 Impact Analysis	Model separates flow at the training levee and splits the flow in the channel.
Tributaries to Sutter Bypass										
Butte Creek										
Little Chico Creek Diversion Channel to Midway	15.32	8.2	12,000 (see comments)	27,000	27,000	No	27,000 to 44,222	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) - 44,222 cfs. *Butte Creek Watershed Floodplain Management Plan* (Butte Creek Watershed Conservancy, 2005) - 22,000 cfs.	Design flows from Senate Document 23 apply to reach SPRR to US Highway 99. Little Chico Diversion channel not specified in Senate Document 23. *SPFC Existing Channel Capacity Assessment TM* indicates uncertain estimated capacity.

River Reach[1]	River Miles[2]		Design Flows from Senate Doc. No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawing (cfs) (basis of State operation)	Diff. Between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Midway to 1.6 miles downstream from Aguas Frias Road	8.2	0	Not specified	22,000	22,000	No	22,000 – 44,222	No obvious inadequacy	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) - 44,222 cfs. *Butte Creek Watershed Floodplain Management Plan* (Butte Creek Watershed Conservancy, 2005) - 22,000 cfs.	*SPFC Existing Channel Capacity Assessment TM* indicates uncertain estimated capacity.
Cherokee Canal										
Dry Creek to Gold Run Creek at Nelson Road	21.72		Not specified	8,100	8,100	No	No data	No data	N/A	None
Gold Run Creek at Nelson Road to Cottonwood Creek at Western Canal	20.22			8,500	8,500	No	3,600 – 4,500	Potential inadequacy; additional evaluation required	DWR Channel Evaluation Program	4,050 cfs from Cottonwood Creek to Old Nelson-Shippee Road; 3,600 cfs from Old Nelson Shippee Road to Old SNNR; and 4,500 cfs from Old SNRR Road to Nelson Road.
Cottonwood Creek at Western Canal to RD 833 canal entrance at Afton Road	15.82			11,500	12,500	Yes	No data	No data	N/A	None
RD 833 canal entrance at Afton Road to Lower Butte Basin about 1 mile downstream from Colusa-Gridley Road	7.92			12,500	12,500	No	No data	No data	N/A	None

River Reach[1]	River Miles[2]		Design Flows from Senate Doc. No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawing (cfs) (basis of State operation)	Diff. Between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Yolo Bypass (outside MUSR Boundary)										
Fremont Weir to Knights Landing Ridge Cut	57.2	54.2	343,000	343,000	343,000	No	290,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
Knights Landing Ridge Cut to Cache Creek	54.2	51.8	362,000	362,000	362,000	No	276,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
Cache Creek to Sacramento Bypass	51.8	45.3	377,000	377,000	377,000	No	201,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
Sacramento Bypass to Putah Creek	45.3	39.5	480,000	480,000	480,000	No	334,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
Putah Creek to RM 29	39.5	29.0	490,000	490,000	490,000	No	322,000	Potential inadequacy; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	None
RM 29 to Miner Slough	29.0	18.5	500,000	490,000	500,000	Yes	No data	No data	N/A	The Comprehensive Study UNET model does not provide reliable results in this reach. Additional model development will be required.
Miner Slough to Sacramento River	18.5	14.1	500,000	490,000	500,000	Yes	N/A	Backwater controlled; additional evaluation required	MBK modeling for Natomas 408 Impact Analysis	Backwater control – flows vary accordingly.
Tributaries to Yolo Bypass										
Knights Landing Ridge Cut	2.6	0	16,000	20,000	20,000	No	16,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009)	None
Colusa Basin Drainage Canal	36.5	0.00	Not specified	20,000	20000	No	No data	No data	N/A	None

River Reach[1]	River Miles[2]		Design Flows from Senate Doc. No. 23	Design Capacity from O&M Manual (cfs)	Design Flow from 1957 Revised Profile Drawing (cfs) (basis of State operation)	Diff. Between 1957 Profile Flow and O&M Capacity (yes/no)	Estimated Current Channel Conveyance Capacity (cfs)	Channel Capacity Status	Data Source for Estimated Current Capacity	Comments
	From	To								
Cache Creek	12.9	4.50	20,000	30,000	30,000	No	27,000 – >30,000	Potential inadequacy; additional evaluation required	*SPFC Existing Channel Capacity Assessment TM* (CVFED, 2009) – 27,000 cfs DWR Channel Evaluation Program – >30,000 cfs.	Recent DWR analysis indicates additional study required due to subsidence of the levees and channel.
Cache Creek Weir and Settling Basin	4.5	0	20,000	30,000	30,000	No	0 – 30,000	Not applicable	DWR Channel Evaluation Program	Recent modeling shows weir submerged in high flows.
Tributaries to Cache Creek										
Middle Creek										
Upstream of Clover Creek Diversion	1.0	0	Not specified	12,500	Not applicable	N/A	No data	No data	N/A	None
Clover Creek Diversion to Clover Creek	2.25	1.0	Not specified	21,500	Not applicable	N/A	No data	No data	N/A	None
Clover Creek to Scott Creek	3.13	2.25	Not specified	19,000	Not applicable	N/A	No data	No data	N/A	None
Scott Creek to Clear Lake	4.18	3.13	Not specified	27,000	Not applicable	N/A	No data	No data	N/A	None
Tributaries to Middle Creek										
Scott Creek	1.38	0	Not specified	11,000	Not applicable	N/A	No data	No data	N/A	None
Clover Creek	0.5	0	Not specified	500	Not applicable	N/A	No data	No data	N/A	None
Clover Creek Diversion	1.04	0.35	Not specified	8,000	Not applicable	N/A	No data	No data	N/A	None
Tributaries to Clover Creek Diversion										
Alley Creek to Clover Creek Diversion Facilities	1.2	1.0	Not specified	8,500	Not applicable	N/A	No data	No data	N/A	None
Clover Creek	0.2	0	Not specified	5,000	Not applicable	N/A	No data	No data	N/A	None
Alley Creek	1.53	1.2	Not specified	2,800	Not applicable	N/A	No data	No data	N/A	None

Figure 3-1. Upper Sacramento River Region Channel Capacities and Flood Forecast Network

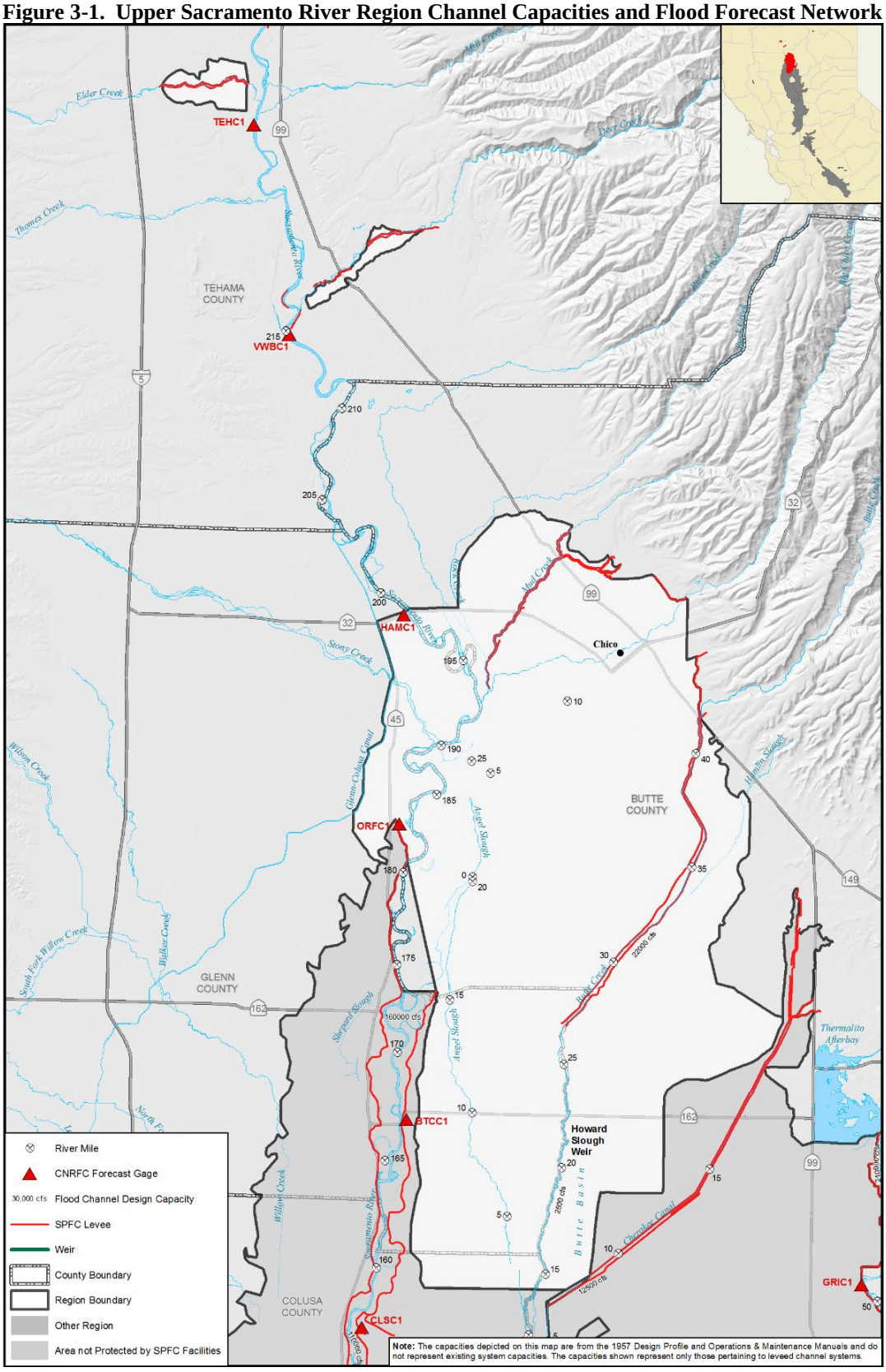


Figure 3-2. Mid Sacramento River Region Channel Capacities and Flood Forecast Network

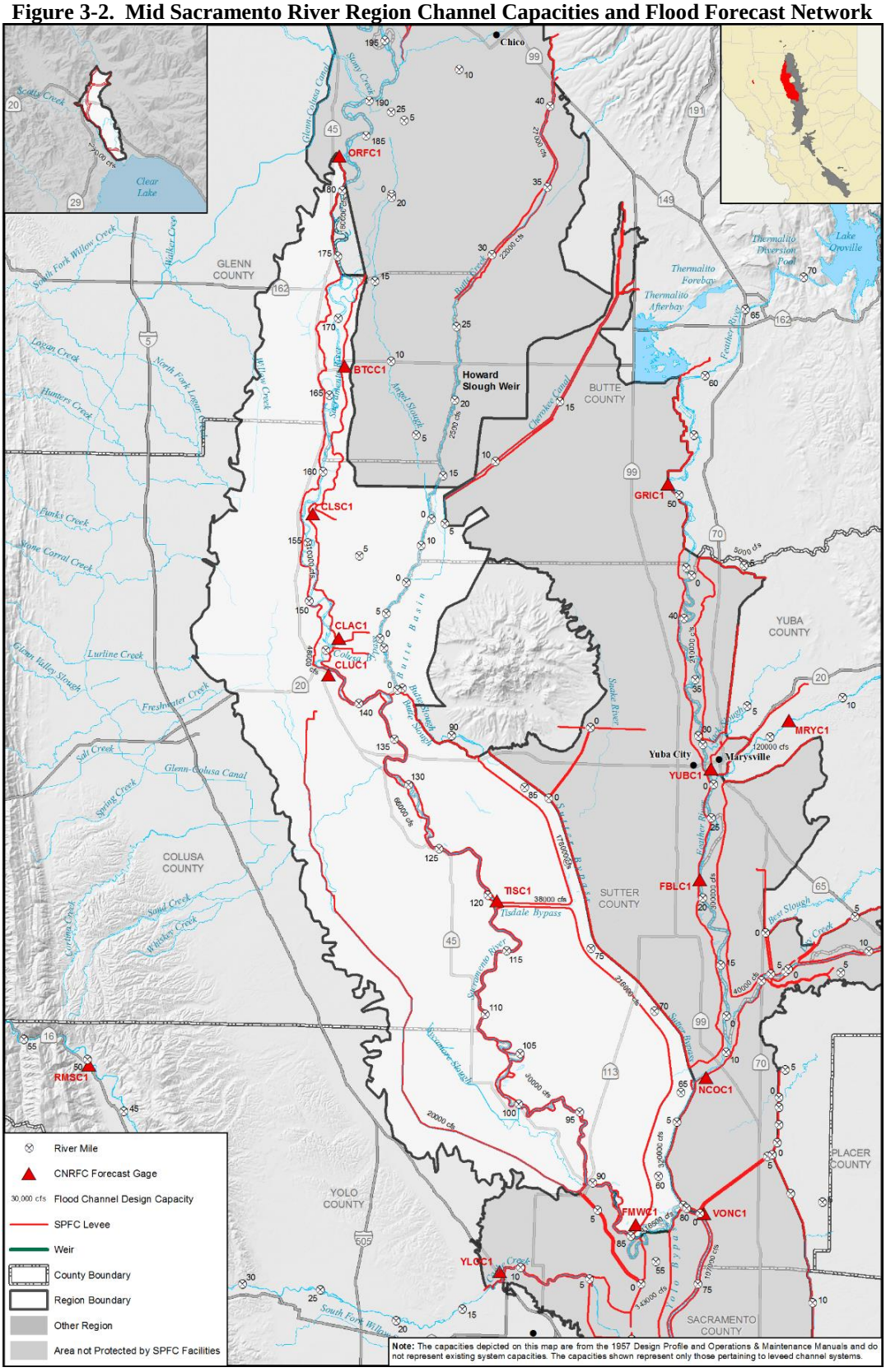
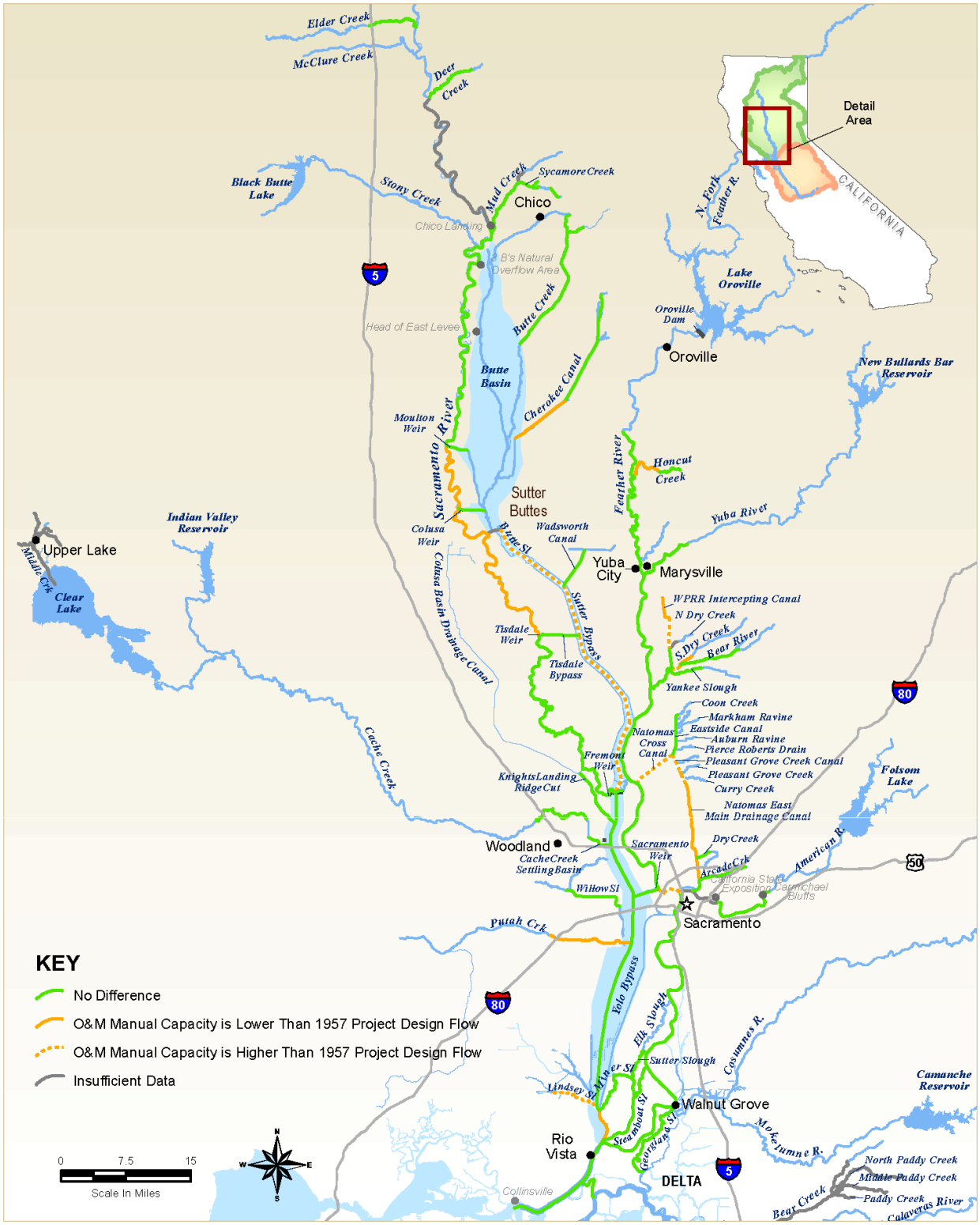
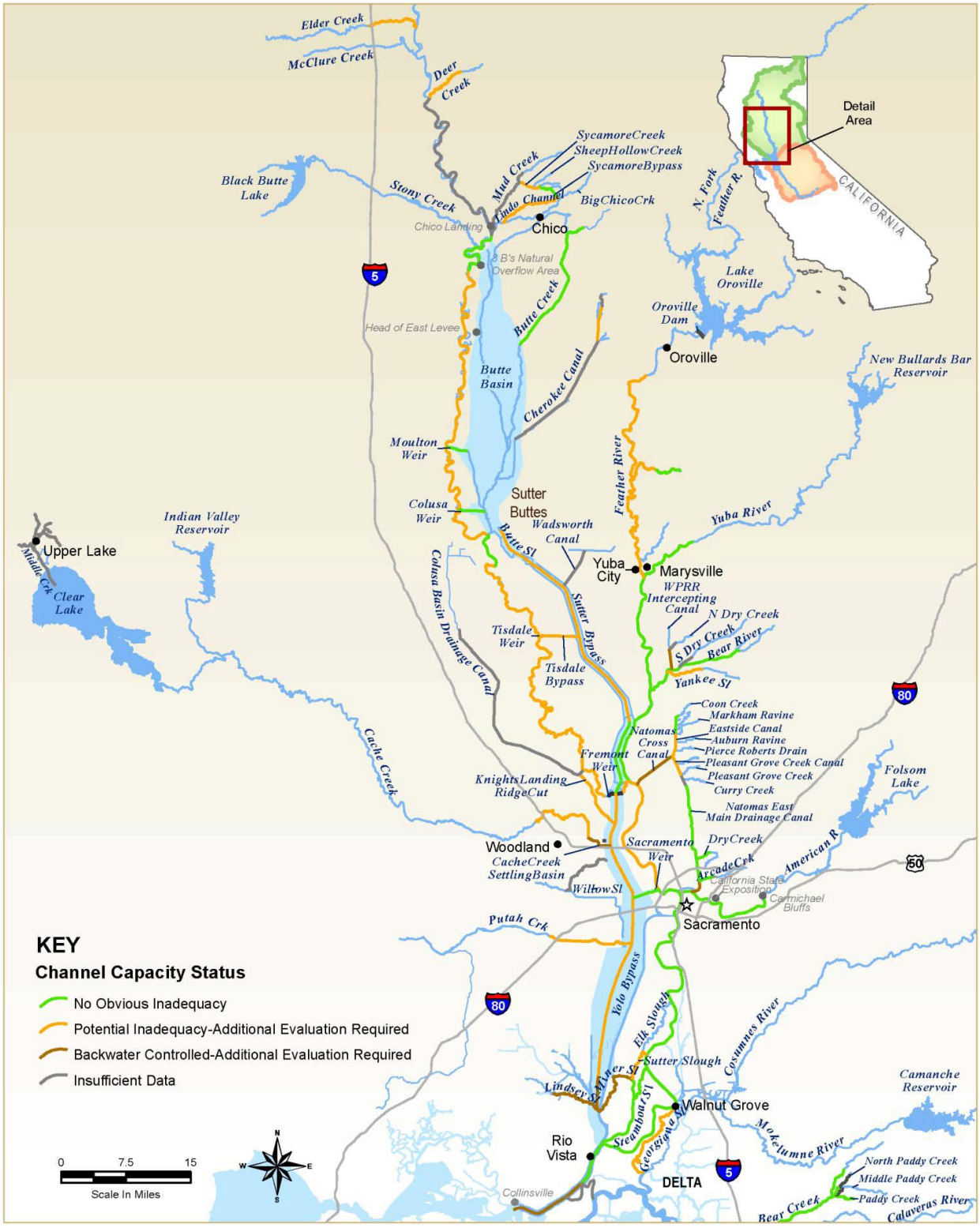


Figure 3-3. Differences between O&M Manual Design Capacities and Design Profile Flows



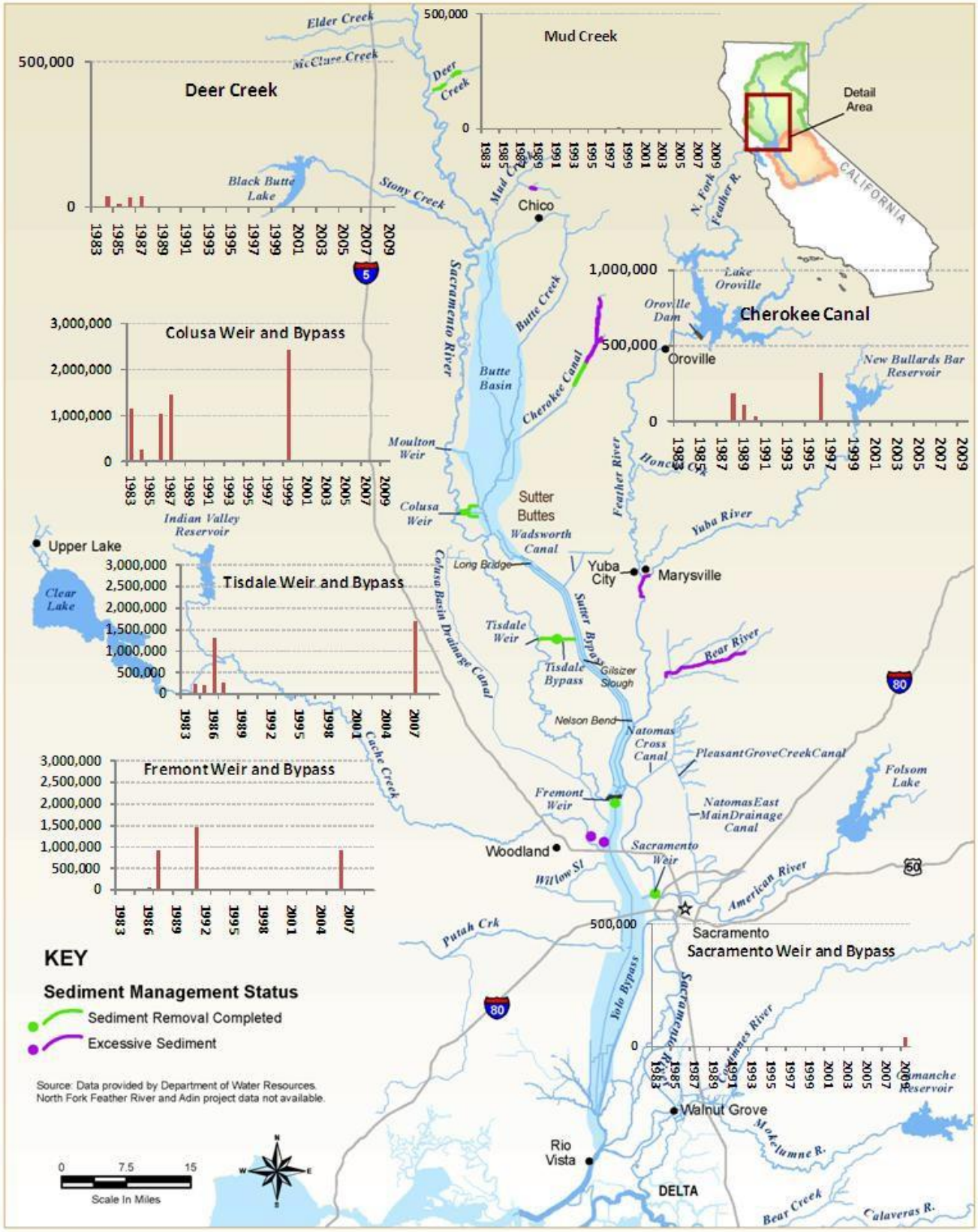
Source: DWR, FCSSR

Figure 3-4. Channel Capacity Status



Source: DWR FCSSR

Figure 3-5. Past Channel Sediment Removal Projects



Source: DWR FCSSR

3.1.2. *Levees*

This section presents information related to the overall condition of levees within the MUSR Regions. A 'cut sheet' which characterizes the deficiencies and remedial measures for each levee segment in the MUSR Region has been prepared and is included in Appendix B. More detailed, site specific information related to various LMA levee deficiencies is presented in Chapter 9 of this RFMP.

The information in this section was acquired from the following sources:

- Locally provided information and studies
- DWR and USACE Levee Inspection Results
- DWR Flood System Repair Project Information
- DWR NULE and ULE Information
- DWR Flood Control System Status Report

For the MUSR Region, 19 out of the 21 USACE levee systems are currently inactive in the Rehabilitation Inspection Program (RIP), and thus ineligible for PL84-99 post disaster recovery funding. Table 3-2 shows a summary of the RIP levee inspection status as of 2013 and Table 3-3 shows a summary of the fall 2013 DWR inspections.

Table 3-2. Summary of USACE Levee Inspection Status for LMAs in the MUSR Region

Levee System	Location	Maintaining Agency	Inspection Type	System Rating	RIP Status	Major Issues
Chico Creek-Mud Creek - Unit 1	Chico	Butte County Public Works	Periodic	Unacceptable	Inactive	Encroachments/ Animal Control
Chico Creek-Mud Creek - Units 2 north and 3	Chico	Butte County Public Works	Periodic	Unacceptable	Inactive	Animal Control/ Encroachments
Chico Creek-Mud Creek - Unit 3 east, Sycamore	Chico	Butte County Public Works	Periodic	Unacceptable	Inactive	Encroachments/ Animal Control
Chico Creek-Mud Creek - Units 2 south and 4	Chico	Butte County Public Works	Periodic	Unacceptable	Inactive	Encroachments/ Animal Control
Chico Creek-Mud Creek - Unit 4 east, Sycamore left	Chico	Butte County Public Works	Periodic	Unacceptable	Inactive	Encroachments/ Animal Control
Chico Creek-Mud Creek - Unit 5, diversion levee	Chico	Butte County Public Works	Periodic	Inspection to be scheduled	Inactive	Erosion/ Bank Caving/ Animal Control

Levee System	Location	Maintaining Agency	Inspection Type	System Rating	RIP Status	Major Issues
Elder Creek left bank, Unit 4 east	Gerber	Tehama County FCWCD	Periodic	Unacceptable	Inactive	Encroachments/ Erosion/ Bank Caving
Elder Creek left bank, Unit 4 - Gerber levee	Gerber	Tehama County FCWCD	Periodic	Unacceptable	Inactive	Encroachments/ Erosion/ Bank Caving
Elder Creek right bank, Unit 5	Gerber	Tehama County FCWCD	Periodic	Unacceptable	Inactive	Encroachments/ Erosion/ Bank Caving
Deer Creek left and right banks (Unit 1 and Unit 2)	Vina	Tehama County FCWCD	Periodic	Minimally Acceptable	Active	-
Sacramento River - East Bank	Rural / Glenn & Colusa Counties	LD3, DWR (ST 3)	Periodic	Unacceptable	Inactive	Encroachments, animal control, erosion, slope stability, sod cover, depressions/rutting, cracking
Sacramento River West Bank	Colusa, Yolo	LD1, LD2, Maintenance Area 1 & 12, Sac River West Side LD, RD 108, RD 787	Periodic	Unacceptable	Inactive	Encroachments, Animal Control, Seepage, Slope Stability, Erosion/Bank Caving, Cracking
RD 70/RD 1660 and Tisdale Bypass – Sutter Basin North	Meridian	RD 70, RD 1660, DWR (ST 9)	Periodic	Unacceptable	Inactive	Encroachments, Erosion/Bank Caving
RD 1500 and Tisdale Bypass - Sutter Basin South	Robbins	RD1500, DWR (ST 9)	Routine	Unacceptable	Inactive	Encroachments, Erosion, Animal Control
Middle Creek - U1 Left Bank	Clear Lake	Lake County WPD, DWR (MA 17)	Routine	Unacceptable	Inactive	Encroachments
Middle Creek - U1 North	Clear Lake	Lake County WPD	Routine	Unacceptable	Inactive	Encroachments
Middle Creek - U1 U5	Clear Lake	Lake County WPD	Routine	Unacceptable	Inactive	Encroachments
Middle Creek - U2 U3	Clear Lake	Lake County WPD	Routine	Unacceptable	Inactive	Encroachments

Levee System	Location	Maintaining Agency	Inspection Type	System Rating	RIP Status	Major Issues
Middle Creek - U2 North	Clear Lake	Lake County WPD	Routine	Minimally Acceptable	Active	Encroachments, unwanted vegetation
Butte Creek - Right Bank	Rural / Butte & Glenn County	DWR (MA 5)	Periodic	Unacceptable	Inactive	Encroachments, animal control, erosion
Butte Creek - Left Bank	Rural / Butte & Glenn County	DWR (MA 5)	Periodic	Unacceptable	Inactive	Encroachments, animal control, erosion

Table 3-3. Summary of Fall 2013 DWR Levee Inspection Results (Number of M/U Miles)

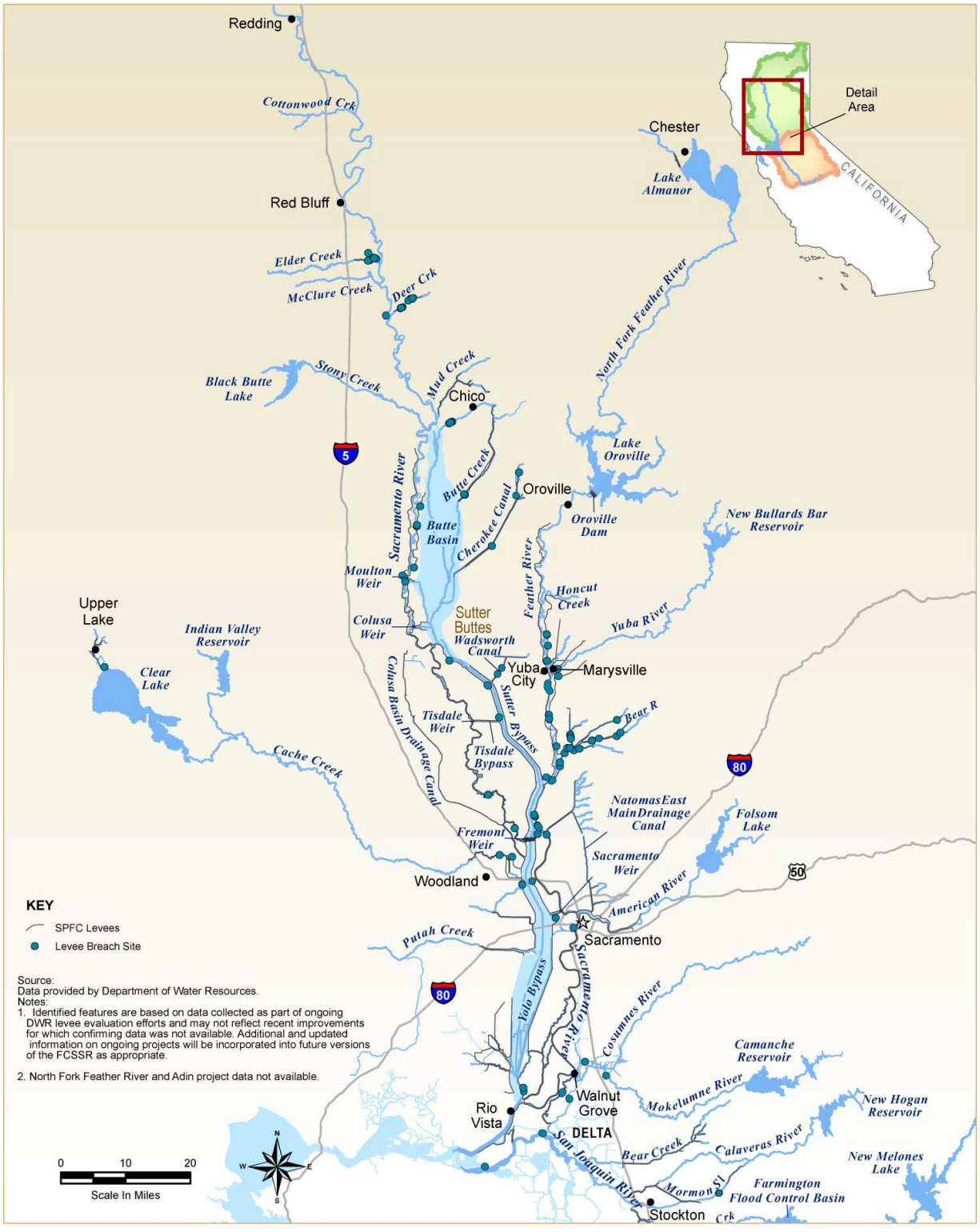
LMA Name	Total Miles of Levee	2013 DWR Overall Rating	Vegetation	Thin / Trim Trees	Encroachments	Animal Control	Slope Stability	Erosion/Bank Caving	Cracking	Crown Surface / Depressions / Rutting	Under-seepage Relief Wells	Repair Gates	Flood Preparedness & Training	Emergency Supplies and Equipment	USACE Erosion
Levee District 1, Glenn - LD0001G	12.45	A	0.06	0.11	0.04	0.15	0.01								
Levee District 2	4.89	A				0.32									0.01
Levee District 3	12.24	U	0.01	0.19	0.21	1.94	0.07								0.03
Reclamation Districts No. 70, Meridian Farms	23.57	A			0.06		0.03	0.01							0.83
Reclamation District 108	20.87	A					0.01		0.05						0.01
Reclamation District No. 787, Fair Ranch	4.4	A											0.04		0.13
Reclamation District No. 1500, Sutter Basin	54.35	M*		0.01 / 0.01	0.13	0.14 / 0.01					0.42 / 0.01				0.1
Reclamation District 1600, Tisdale	14.73	U	25.6	0.03			0.03	0.78 / .02		3.28					0.05

LMA Name	Total Miles of Levee	2013 DWR Overall Rating	Vegetation	Thin / Trim Trees	Encroachments	Animal Control	Slope Stability	Erosion/Bank Caving	Cracking	Crown Surface / Depressions / Rutting	Under-seepage Relief Wells	Repair Gates	Flood Preparedness & Training	Emergency Supplies and Equipment	USACE Erosion
Butte County Public work, NA 3	24.71	A	0.08		0.05	0.01	0.01								0.05
Lake Count Watershed Protection District, NA 9	10.47	A	0.22	0.34	0.01		0.05								
Lake Count Watershed Protection District, NA 9, Middle Creek RB, Unit 2 North	0.58	A	0.22	0.34	0.01		0.05								
Sacramento River West Side Levee District, NA 16	50.21	A	0.01		0.02	0.01									0.26
Tehama County Flood Control & Water Conservation District, NA19	13.64	M*	1.4		0.08	0.07	0.33	0.04							0.16

LMA Name	Total Miles of Levee	2013 DWR Overall Rating	Vegetation	Thin / Trim Trees	Encroachments	Animal Control	Slope Stability	Erosion/Bank Caving	Cracking	Crown Surface / Depressions / Rutting	Under-seepage Relief Wells	Repair Gates	Flood Preparedness & Training	Emergency Supplies and Equipment	USACE Erosion
Yolo County Service Area 6, NA 22	5.97	U	10.88 / 0.34	0.04	0.28	0.06		0.01						0.06	0.39
DWR Sutter Maintenance Yard, Maintenance Area 1	17.12	A	0.04			0.01									0.66
DWR Sutter Maintenance Yard, Maintenance Area 5	33.32	A	0.02		0.08	0.01	0.04					0.01			
DWR Sutter Maintenance Yard, Maintenance Area 12	11.31	A				0.02	0.01								0.01
DWR Sutter Maintenance Yard, Maintenance Area 17	3.9	U	3.13 U	3.12 U											

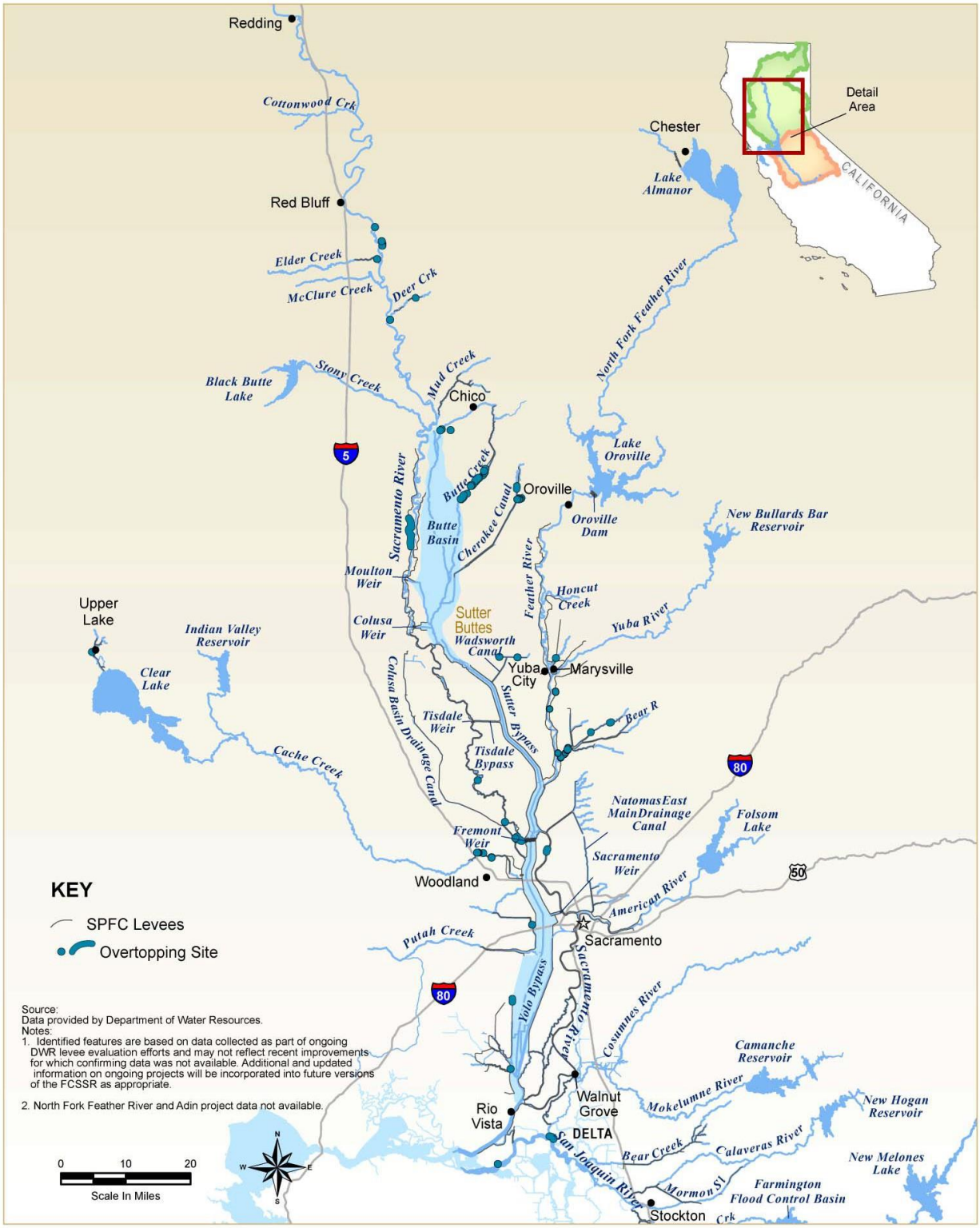
LMA Name	Total Miles of Levee	2013 DWR Overall Rating	Vegetation	Thin / Trim Trees	Encroachments	Animal Control	Slope Stability	Erosion/Bank Caving	Cracking	Crown Surface / Depressions / Rutting	Under-seepage Relief Wells	Repair Gates	Flood Preparedness & Training	Emergency Supplies and Equipment	USACE Erosion
DWR Sutter Maintenance Yard, Maintenance Area 17, Middle Creek LB, Unit 1 South	3.51	U	3.13 U	3.12 U											

Figure 3-6. Historical Levee Breaches



Source: DWR FCSSR

Figure 3-7. Historical Levee Overtopping



Source: DWR FCSSR

Figure 3-8. Upper Sacramento River Region Overall Levee Conditions

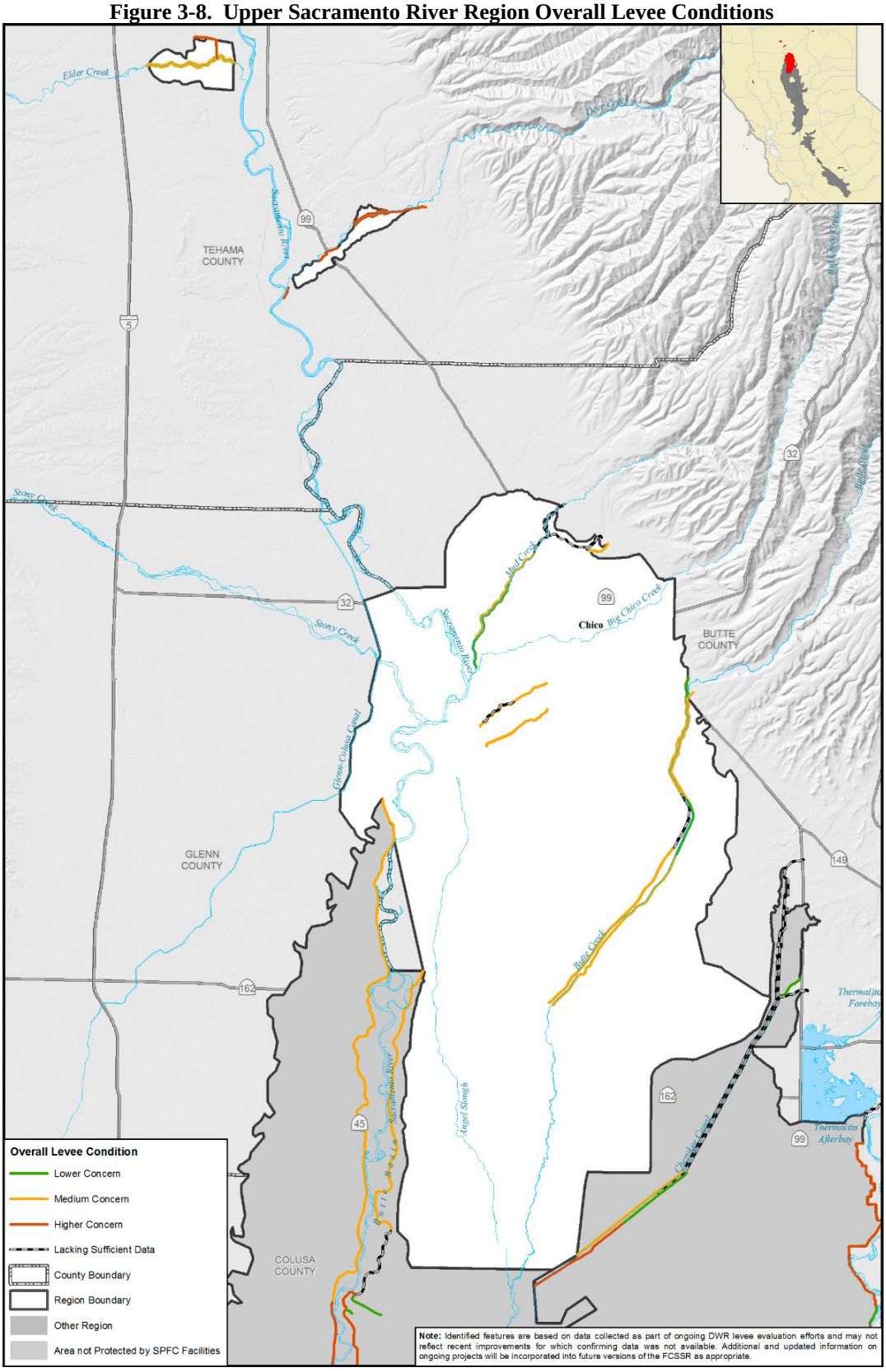


Figure 3-9. Mid Sacramento River Overall Levee Conditions

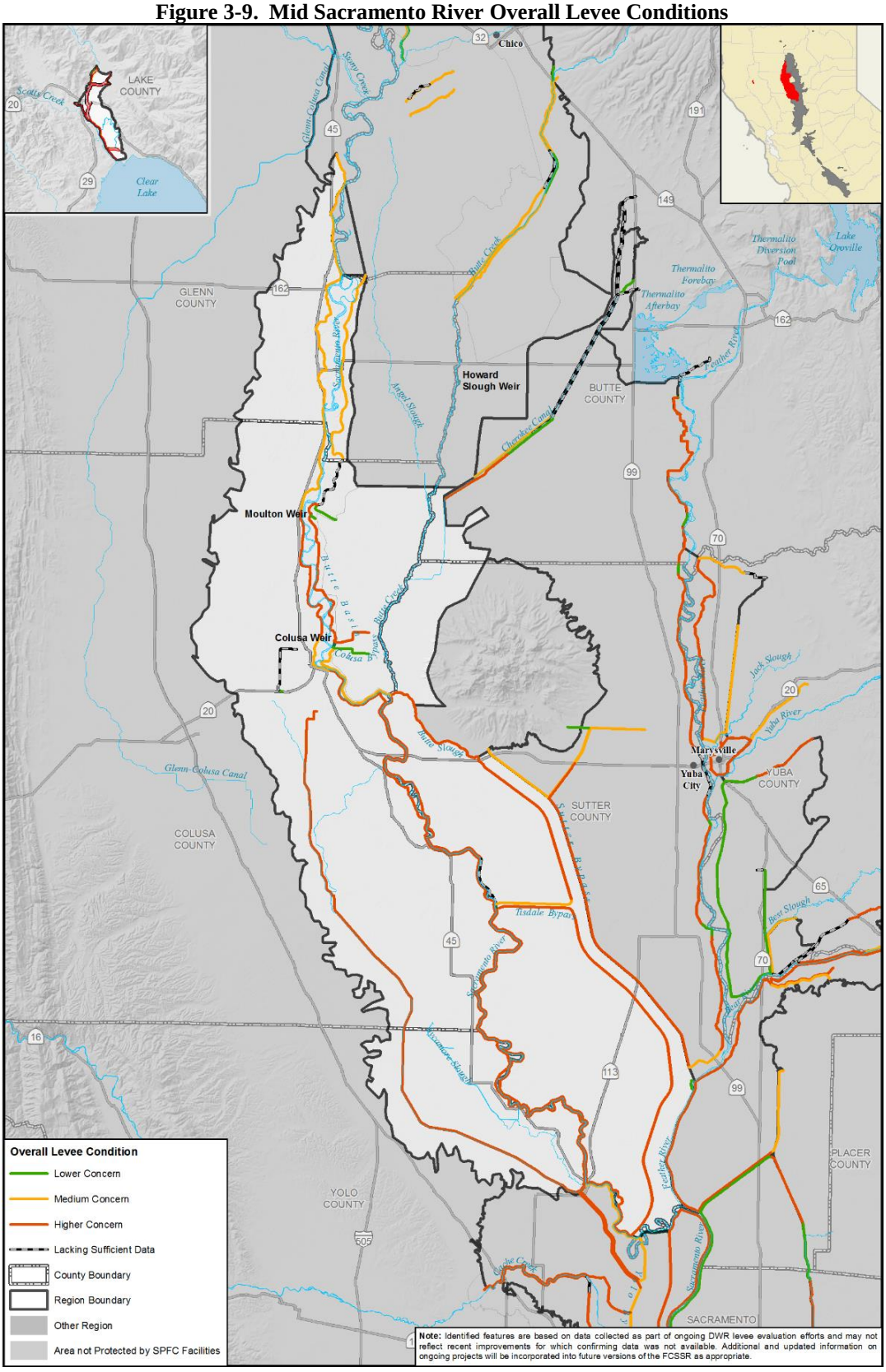


Figure 3-10. Upper Sacramento River Region Seepage Past Performance Problems

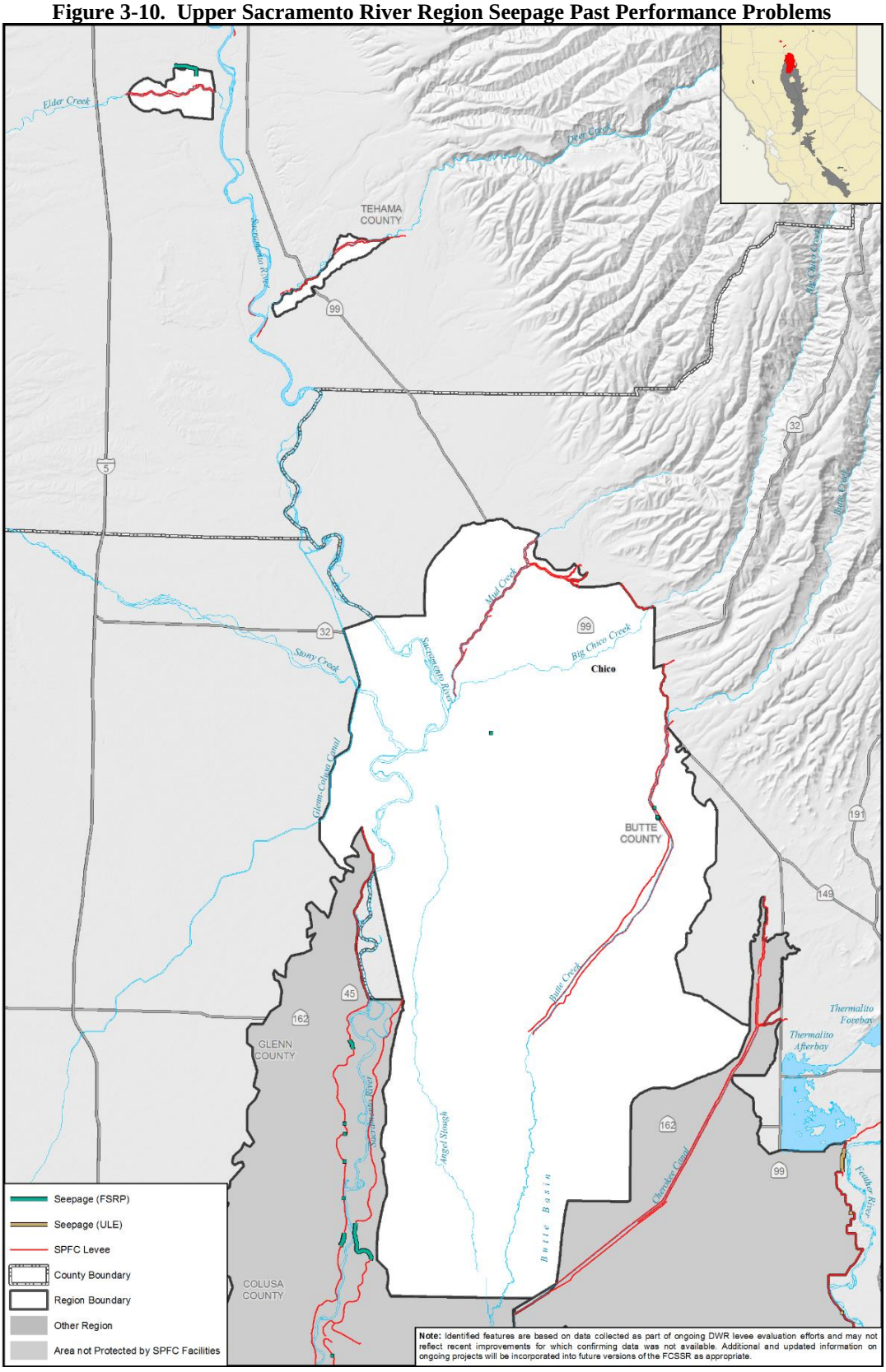


Figure 3-11. Mid Sacramento River Region Seepage Past Performance Problems

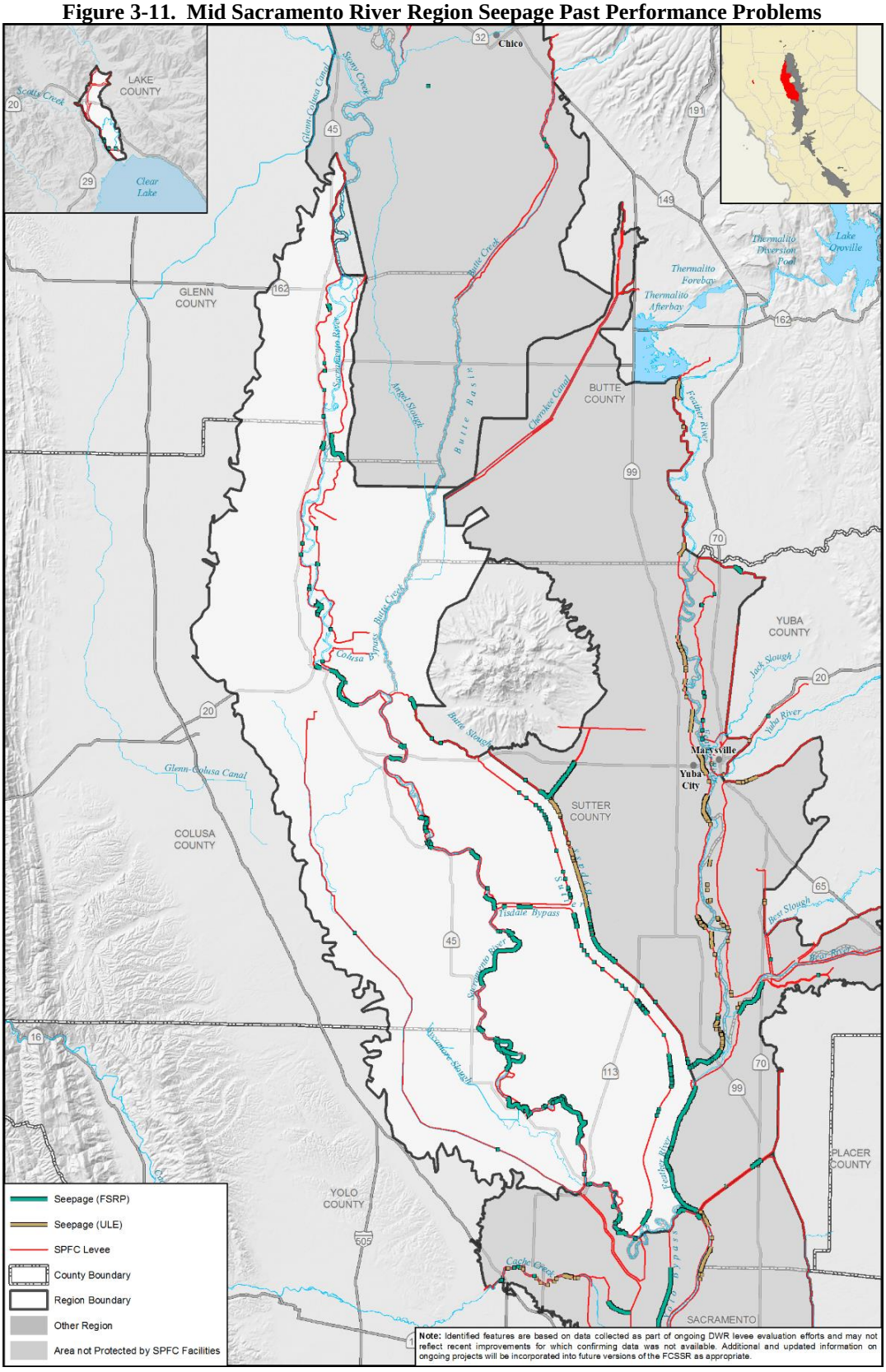


Figure 3-12. Upper Sacramento River Region Slope Stability Past Performance Problems

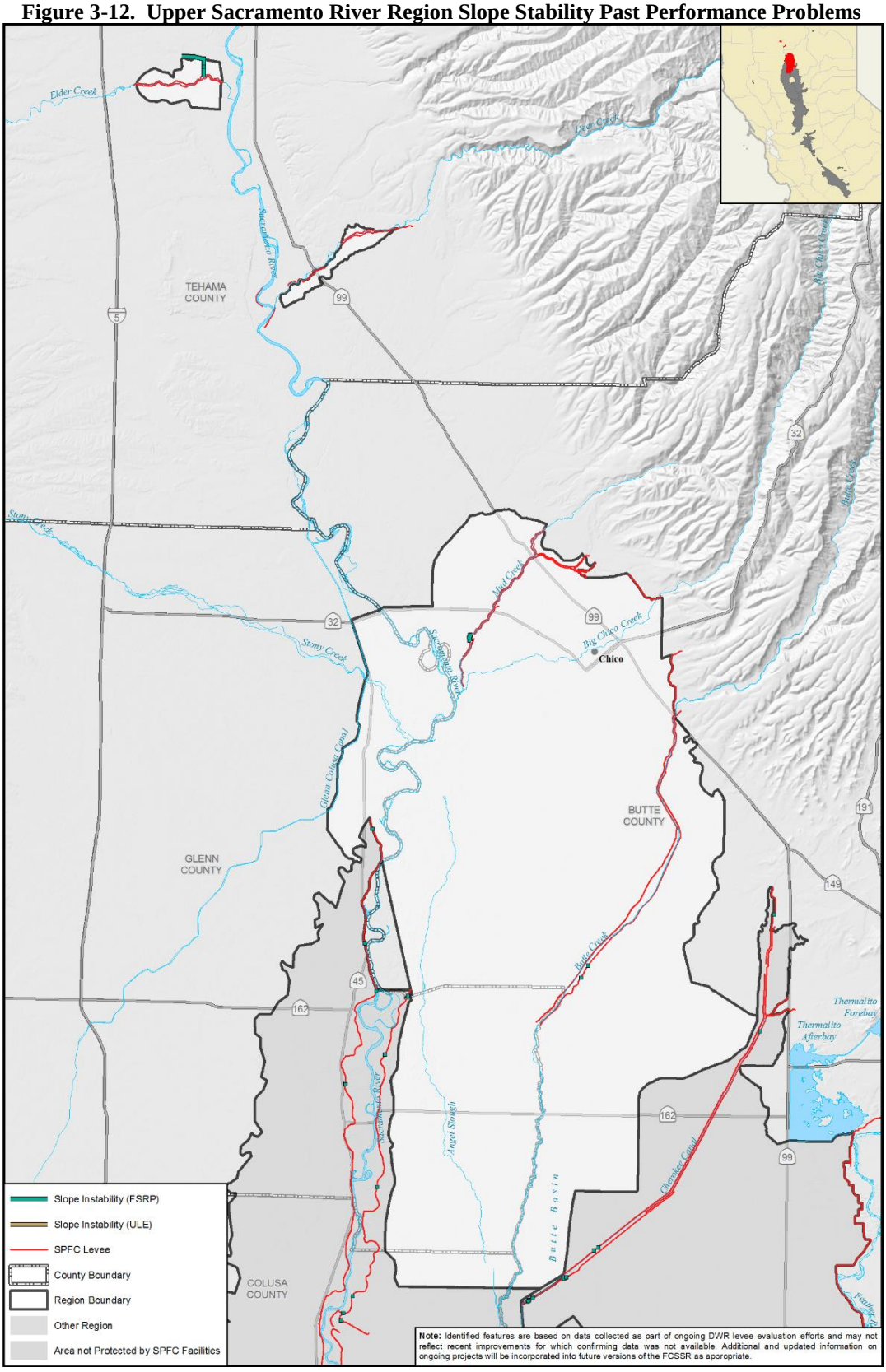


Figure 3-13. Mid Sacramento River Region Slope Stability Past Performance Problems

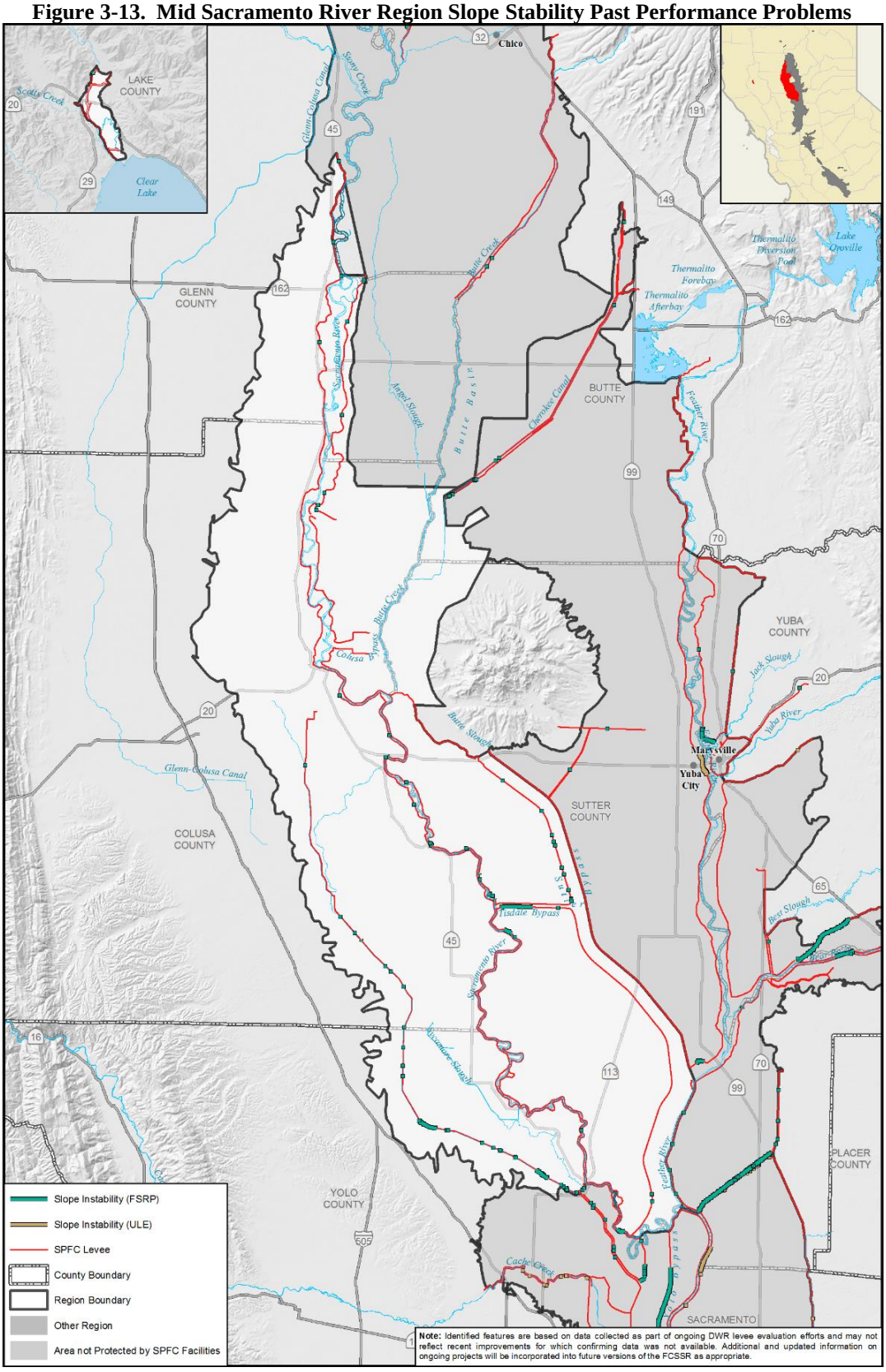


Figure 3-14. Upper Sacramento River Region Erosion Past Performance Problems

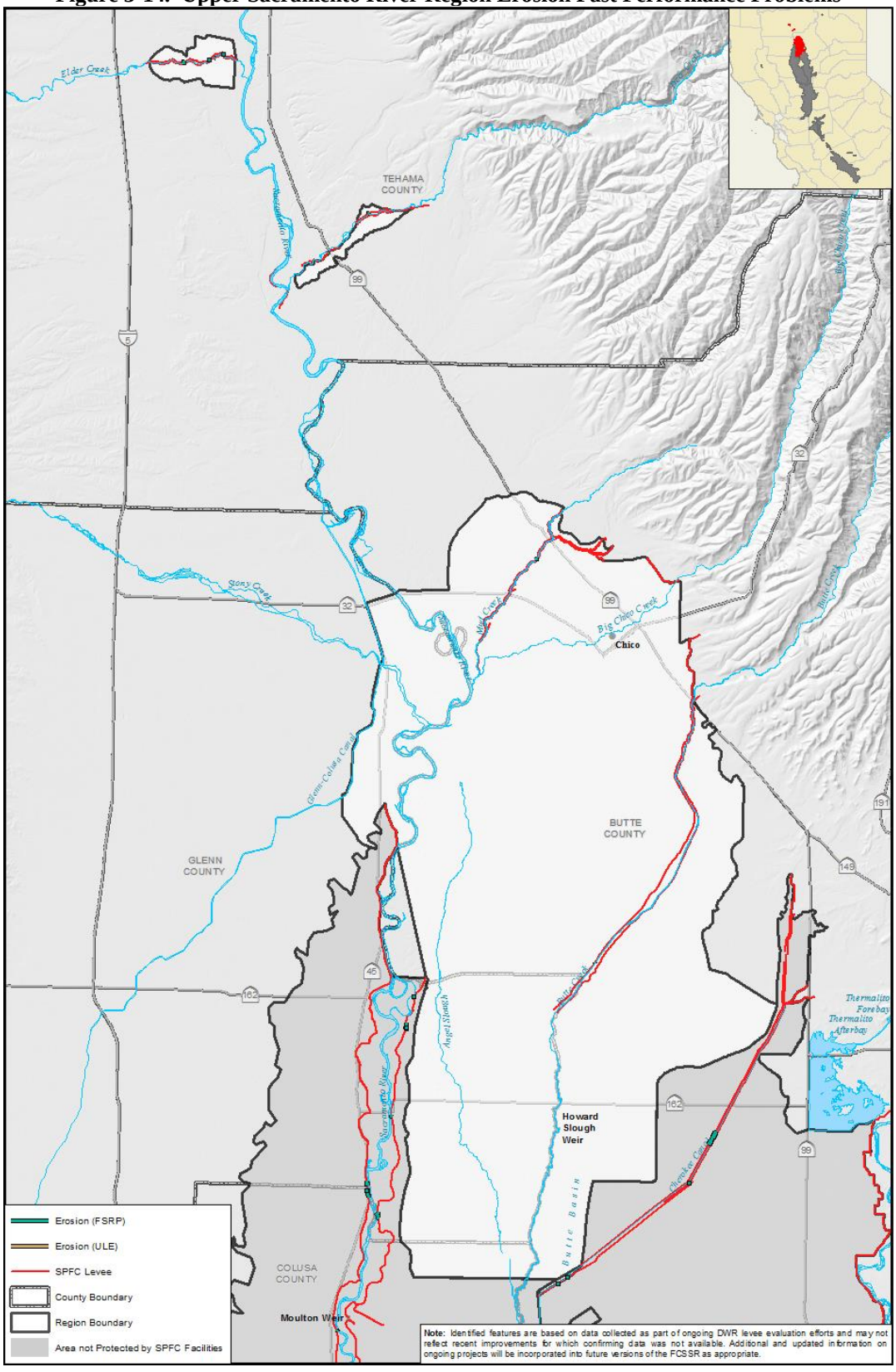
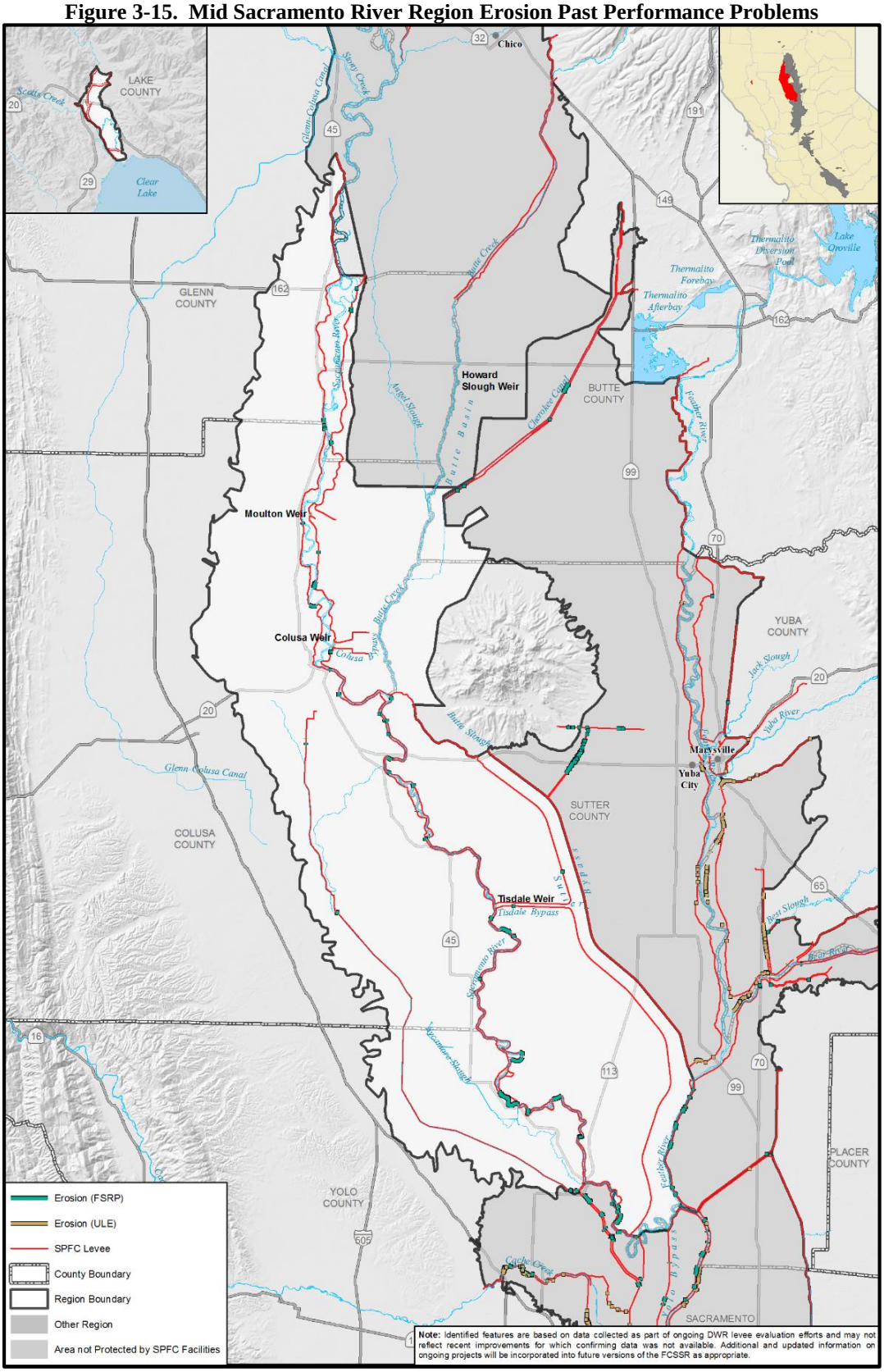


Figure 3-15. Mid Sacramento River Region Erosion Past Performance Problems



3.1.3. *Weirs*

As described in Chapter 2, floodwaters in the Sacramento River are reduced by diversion into flood bypasses via weirs and channels located in historic lowland overflow areas. These diversions are controlled principally by overflow weir structures and quasi-natural overflow areas, as described in the following section and shown in Figure 3-16.

Butte Basin Overflow Areas: M&T, 3B's, Goose Lake

The M&T, 3 B's and Goose Lake overflow areas and relief structures serve to divert a substantial portion of flood flows over the east bank of the Sacramento River into Butte Basin. DWR maintains all three of these flood relief structures (DWR, 2010). The existence and operation of these overflow areas is critical to downstream flood management as they relieve pressure off of the Sacramento River main channel levees. These overflow areas were not engineered to current USACE or DWR construction or performance standards, and are subject to erosion, which requires regular post-flood maintenance. For example, the 3-B's overflow structure is an unprotected weir comprised dominantly of silt-sized soil, which experiences scour and allows Sacramento River flows to bypass into the Butte Basin at lower stages than designed. The M&T and Goose Lake relief structures have required installation of localized rip-rap and concrete to help prevent scour and maintain structural integrity.

Moulton, Colusa, and Tisdale Weirs

There are three primary flood relief weirs in the Regions, all of which consist of fixed elevation, lowered sections in the levee profile that serve to spill floodwaters when discharge in the Sacramento River is sufficient to flow over the crest of these weirs. These three hydraulic flood relief weirs, in order from upstream to downstream, are the Moulton Weir and Colusa Weirs that drain into the Butte Basin, the Tisdale Weir that drains into the Sutter Bypass, The Fremont Weir, which is the upstream extent of the Yolo Bypass is located just outside the Regional boundaries).

Functioning properly and without obstructions or debris, the weirs limit the discharge and stress to levees in the main stem Sacramento River downstream of each respective weir. The flow dispersed into the Butte Basin and Sutter Bypass also serve to attenuate the flood hydrograph to downstream areas. These weirs function by gravity, spill when discharge of the river is sufficient to exceed crest height, and there are no gates or operable controls. Each of the weirs are concrete, have concrete stilling basins immediately downstream to dissipate energy, have channel stabilization features (rip-rap and/or erosion control blankets) further downstream of the stilling basin, and have training levees that define weir flow down the respective bypass, or relief channels (DWR, 2010).

A common operational and maintenance challenge is the removal of sediment deposits at the weir structures or in the channels downstream of the weirs. Sediment (gravel, sand and silt) deposition in the channel can have a significant negative impact on the hydraulic capacity of the channel and/or the weirs themselves (DWR, 2010a). Recognized as a specific and critical problem, a project in the Tisdale Bypass channel was conducted in 2007 to remove sediment, and this work was completed as a component of DWR's Early Implementation Program (DWR, 2007). Similar to sediment deposition is the potential for deposition of debris along the face of

the weirs, which also has a negative impact on hydraulic capacity. Sediment and debris removal will continue to be ongoing maintenance issues.

Because they are a large source of flow into the Butte and Sutter Basins during floods, these weirs essentially serve as the "headwaters" during flood prone winter seasons. Because up-migrating salmon and steelhead in the basins may be queued toward this flow, fish passage and fish stranding is a concern. Currently, Fremont Weir has a small fish ladder at the center of the weir that operates during flood or overtopping flows (DWR, 2010a). The other weirs do not allow passage of fish during higher flows. Additionally, the fixed elevation nature of these structures do not allow for variation in flow depth/discharge during variable flow rates in the Sacramento River.

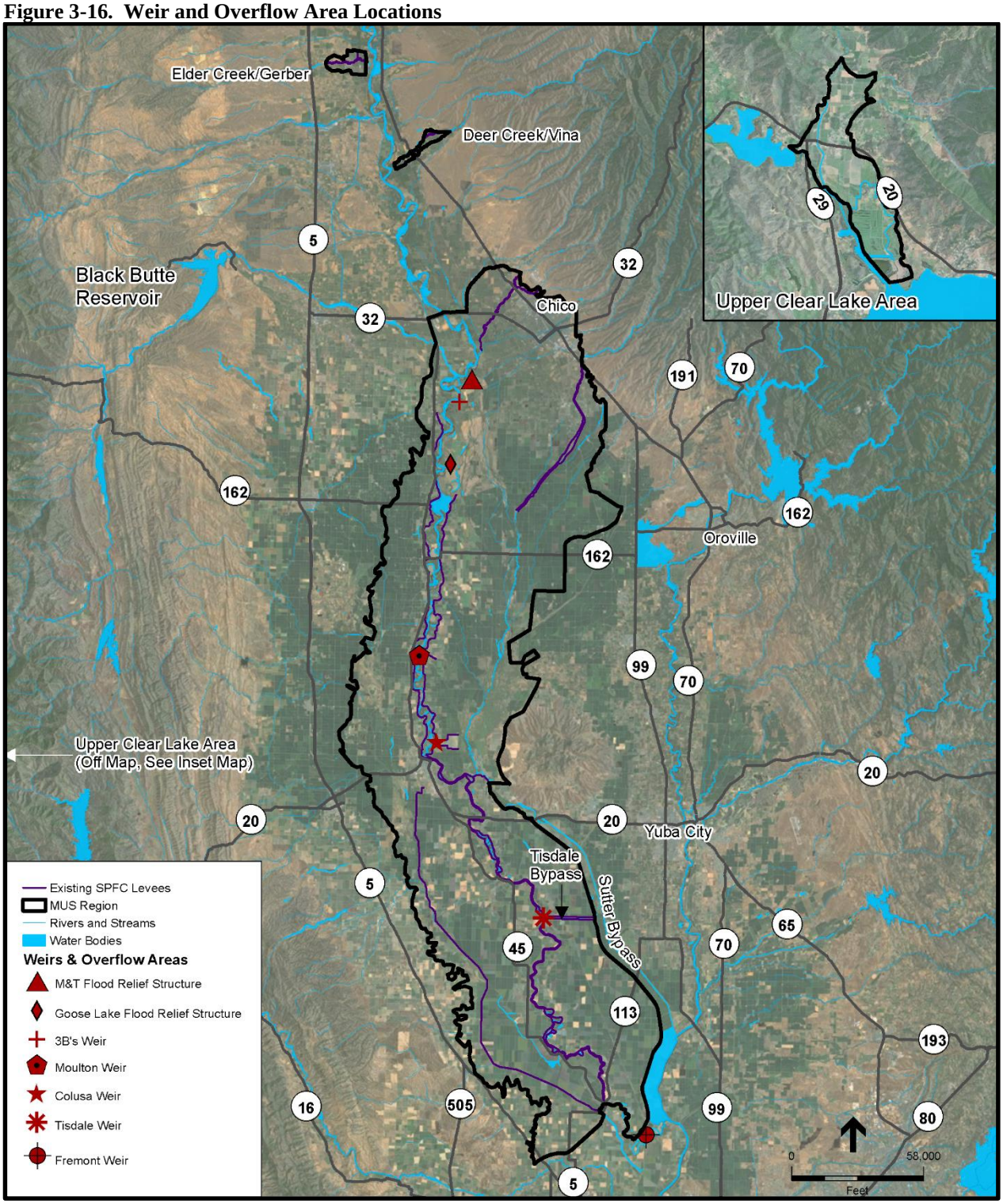
3.1.4. *Reservoirs*

There are two reservoirs with flood management capacities that discharge into the plan region, Shasta Lake and Dam of the Sacramento River near Redding, and Black Butte Reservoir and Dam on Stony Creek. Shasta Lake, the 1949 federally-built and operated facility by the United States Bureau of Reclamation (USBR) is substantially larger than the also federally built and operated (USACE) Black Butte facility. Shasta Lake provides significant water supply benefits, but also is a critical component of the SPFC. Despite not being part of the State Plan of Flood Control (SPFC), the operation of the facility is coordinated with State operations to best manage discharges and reduce flood risk and meet other regulatory demands (DWR, 2010b).

The primary concern amongst local stakeholders regarding reservoirs is the lack thereof, and the current (2013/14) extreme drought conditions have spotlighted the need for the creation of new reservoirs to bolster California's existing water supply. While the primary benefit of these facilities would be water supply reliability, the development of new reservoirs would also include secondary benefits to flood control.

An increase to the storage capacity of Shasta Lake is currently proposed by the USBR and is currently in the Feasibility Analysis stage of project development. A draft feasibility report was released in February 2012, which recommended an 18.5 foot increase to the dam as the feasibility analysis shows this to have the greatest net economic benefits. The USBR released the project Environmental Impact Statement (EIS) in July 2013 (USBR, 2013). The 14% (634,000 acre-feet) increase in storage capacity has primary objectives of anadromous fish survival and water supply reliability, with reduced flood damage being a secondary objective. The construction cost is estimated at $1.07 billion (USBR, 2013).

Figure 3-16. Weir and Overflow Area Locations



3.2. Risks Associated with Identified Flood Control System Deficiencies

The different types of flooding most prevalent within the Regions include stormwater, slow rise, and flash flooding and flooding associated with structure failure. Floods within the MUSR Region originate principally from heavy rainfall, with most events occurring in December and January as a result of multiple storms and saturated soil conditions. However, heavy flows also occur in October and November or during the late winter or early spring months with rainfall occurring on top of snow (DWR, 2013).

Risk can be defined as the possibility of loss, injury, or other adverse condition. Risk can be evaluated numerous ways, but with respect to flooding potential, risk is generally understood as the combination of the relative probability that an event will occur and the consequences of the event occurring, which includes the value of assets involved and how vulnerable the impacts are to other facets of the region (FEMA, 2006).

3.2.1. *Floodplain Delineation: Currently Mapped FEMA and DWR Floodplains*

Knowing where potential floodwaters may physically extend on the landscape serves a vital role in planning for and assessing flood risk. This delineation of where flood water will occur is commonly referred to as a "floodplain". The extents of floodplains are determined using mathematical hydraulic computer models, which use topographical and hydrologic inputs. Over time, these hydraulic models have become more sophisticated and provide users with more options to best simulate actual conditions. However, the accuracy of these models is inherently limited due to the dynamic physical properties of natural channels and limited accuracy of input data. Hydrologic inflows are traditionally based on exceedance probability, or the number of years a flow will be met or exceeded, based on historical knowledge and data. Flood frequencies typically used are the 100-year, 200-year, and 500-year based exceedance probabilities.

Floodplains have been delineated by multiple agencies for the Sacramento River and associated tributary channels. These different agency floodplain delineations have unique purposes to illustrate a specific risk. These agencies that have floodplain delineation include the Federal Emergency Management Agency (FEMA), State Central Valley Flood Protection Board, and Department of Water Resources.

The more commonly known floodplain delineation is those provided by FEMA. FEMA manages the National Flood Insurance Program (NFIP), which is a federal program that communities can participate in as an insurance mechanism that requires a premium to be paid for financial protection against flood losses. FEMA has jurisdiction to regulate lands and activities within the FEMA floodplains and labels these flood plains as 'flood zones'. Flood zones are geographic areas that FEMA has defined according to varying levels of flood risk and type of flooding. These zones are depicted on published Flood Insurance Rate Maps (FIRMs) or Flood Hazard Boundary Maps (FHBMs). Flood zones designated as "special hazard" flood zones are those with 100-year recurrence intervals. Some areas have rather recent and more accurate

floodplain delineations than other areas, depending on the age and methodology of analysis (FEMA).

Figure 3-17. Overview of 100-year and 200-year Floodplains

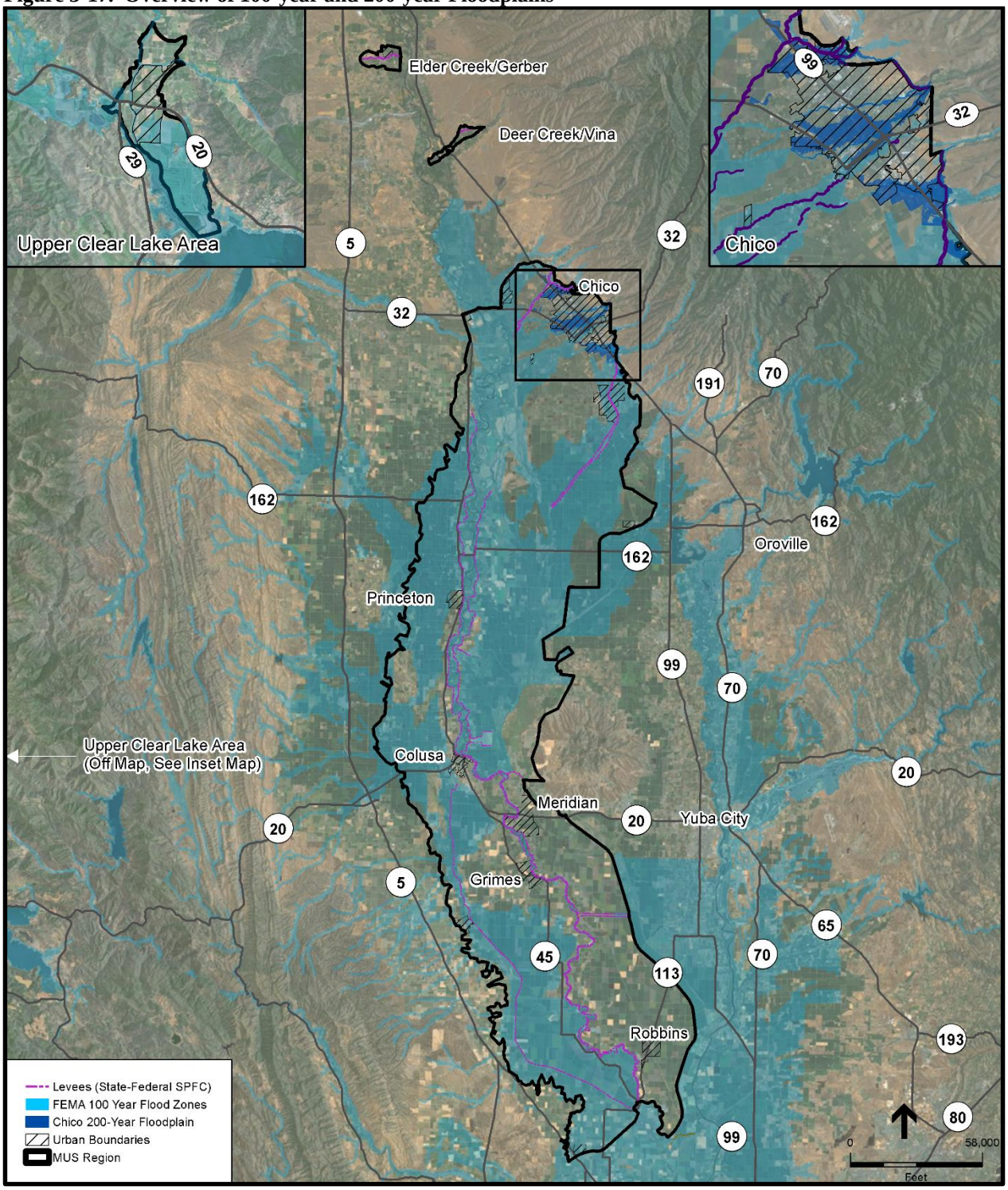


Figure 3-18. Upper Sacramento River Region Special Flood Hazard Areas

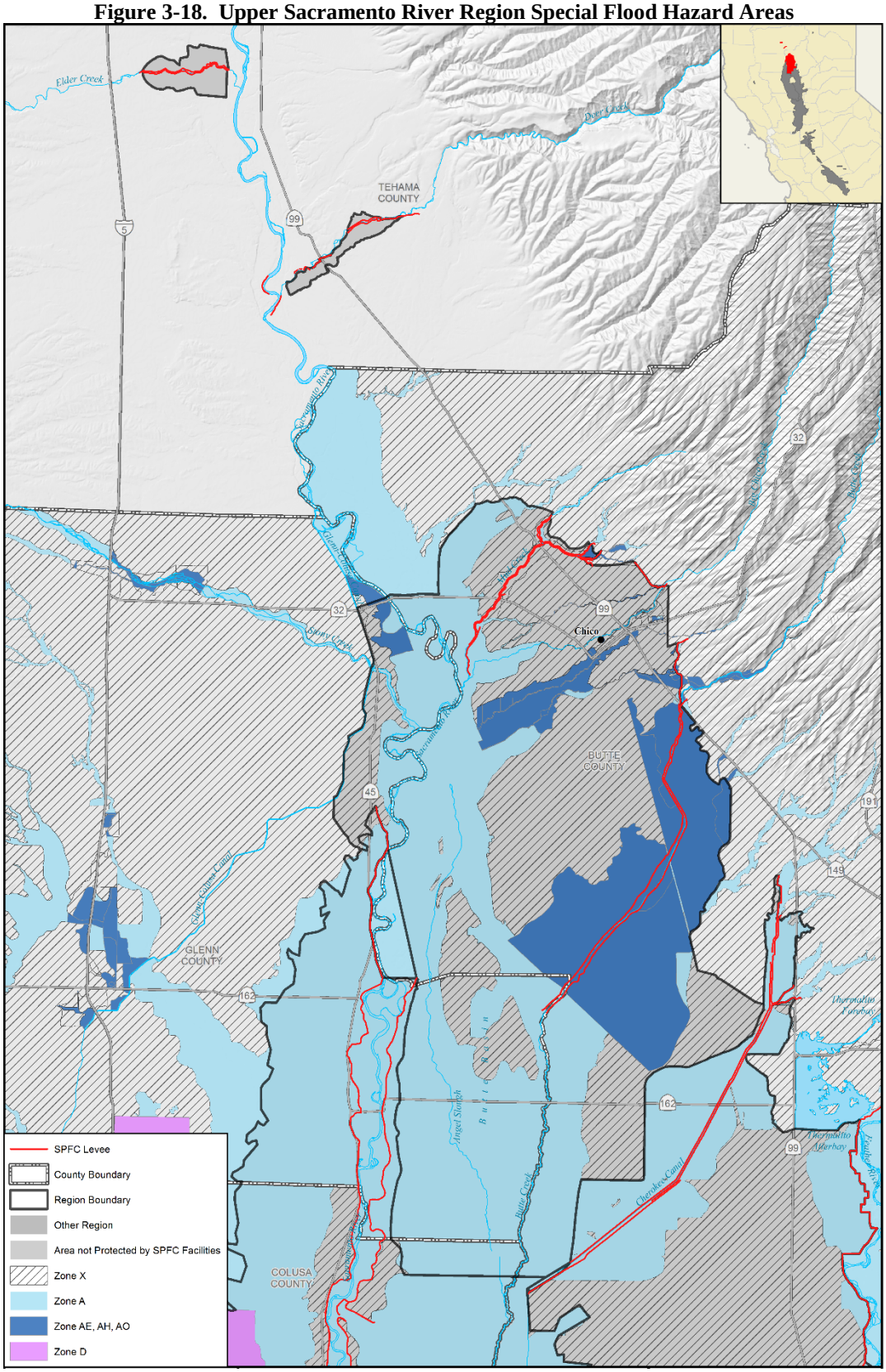
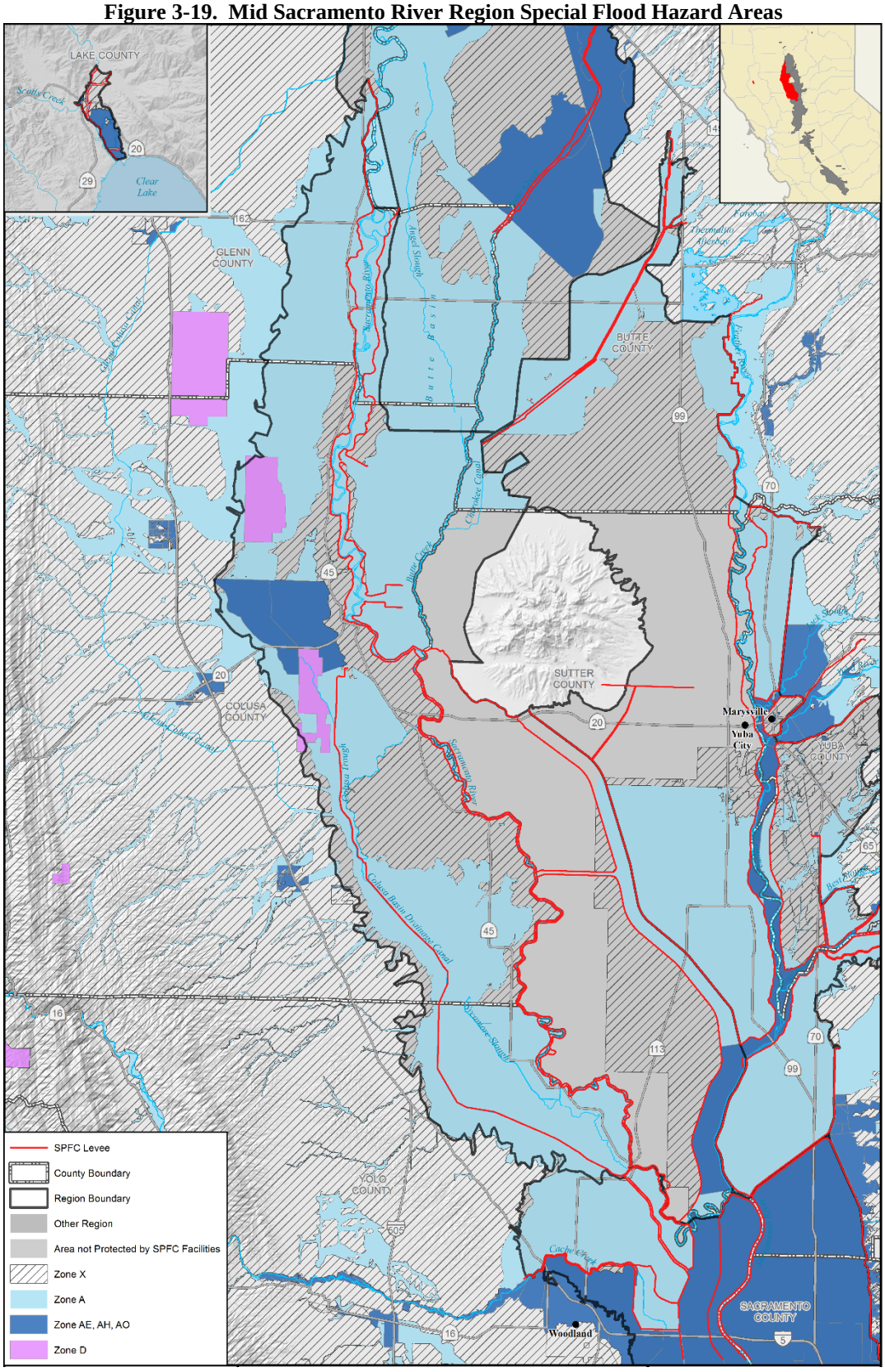


Figure 3-19. Mid Sacramento River Region Special Flood Hazard Areas



The Central Valley Flood Protection Board manages designated floodways within the central valley, including the Sacramento River and tributary channels within the reach. These designated floodways are not part of the SPFC as they do not contain assurances to, or participation from the federal government. These designations began in 1968 to control encroachments and preserve flow capacity of floodways based on CWC Section 8609 (DWR, 2010).

The California Department of Water Resources (DWR) have delineated floodplains in an effort to help inform landowners, decision makers and facilitate land use planning. DWR prepared Levee Flood Protection Zone (LFPZ) Maps, which represent floodplain areas protected by Central Valley State-Federal Project Levees, and identify the areas where flood levels would be more than three feet deep if a project levee were to fail. These maps were developed based on the best available information as required by Assembly Bill 156.

As part of SB 5, DWR prepared Central Valley Floodplain Evaluation and Delineation (CVFED) Maps and represent 100- and 200-year floodplains for urban and urbanizing areas within the Sacramento-San Joaquin Valley watersheds. These maps were developed in 2013 and distributed to the City of Chico, which is the only urbanized area in the region for which these delineations apply. These delineations serve to improve the quality and accuracy of flood hazard data and mapping available to urbanized areas within the SPFC.

3.2.2. *Population and Assets at Risk*

Broadly stated, the levees that were originally constructed to protect largely agricultural areas are inadequate to protect developing areas. Although the regional flood management system has prevented millions of dollars in flood damages since its construction, a better understanding of the risk assessment and engineering standards has made it clear that some of the regional levee segments face an unacceptably high chance of failure. This, combined with growth in the Regions has increased the estimated level of flood risk. While the chance and frequency of flooding has decreased since construction of the Regions' levees and multipurpose reservoirs, the damages that would occur if a levee were to fail in one of these areas are much greater, resulting in a net long- term increase in cumulative damages if no further action is taken to improve the flood management system.

The Mid and Upper Sacramento River Regions land use is predominantly agricultural and rural. However, several communities along with a substantial number of rural dwellings are at risk of flooding due to either their proximity to waterways, or due to their relatively low lying elevation. Within the boundary of the Regions, the City of Chico and surrounding area is both the most dense and highest populated area subject to flooding. Many small communities and rural areas are also heavily impacted. Table 3-4 below presents population and asset values for the counties in the Regions. These values are from DWR's 2013 *Flood Future Report* and illustrate the rural nature and potential flood risk of the Regions.

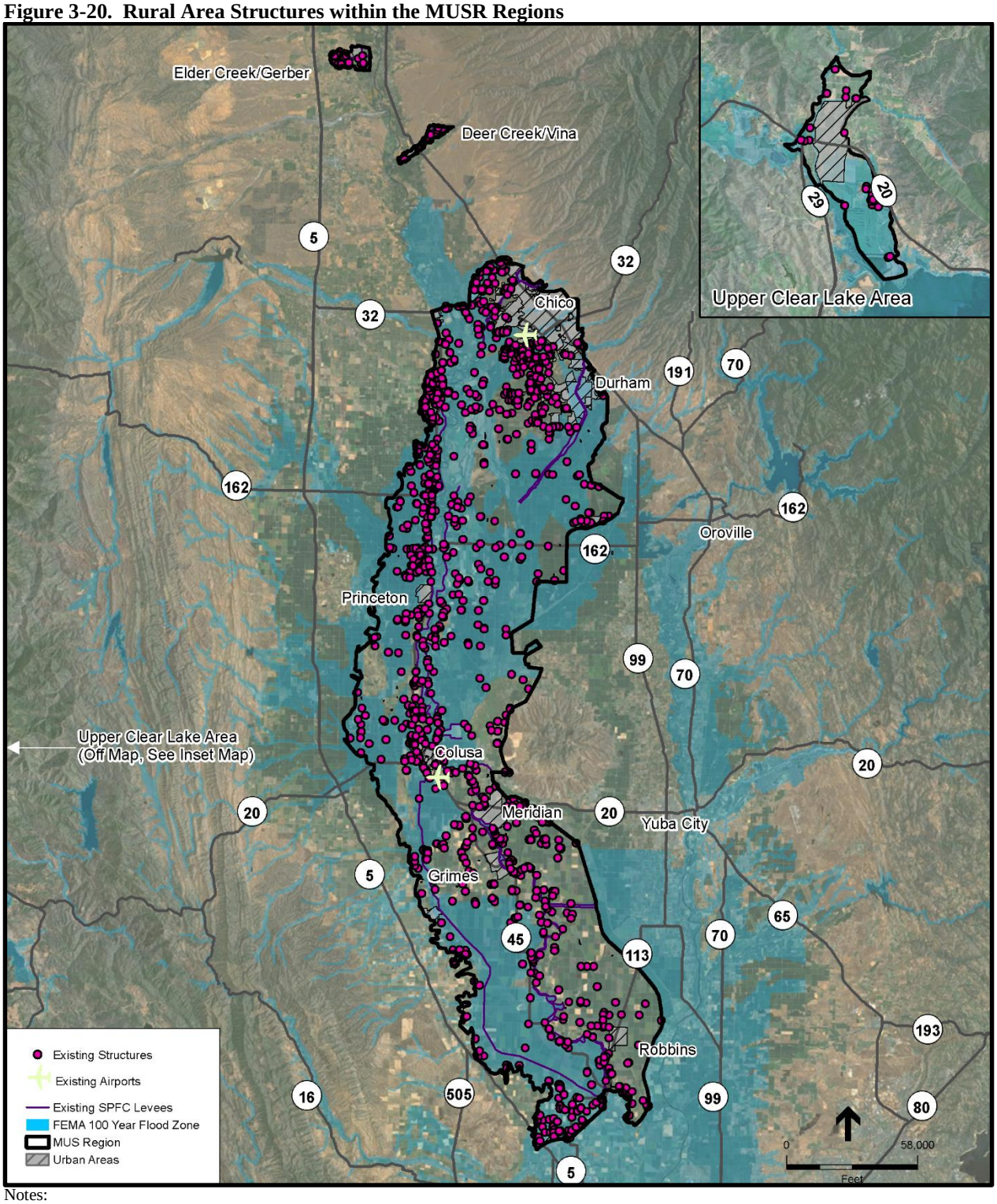
Table 3-4. Population and Asset Summary

County	County Wide[1]					Within 100-year Floodplain								
								Structures and Contents			Crop			
	Population	Area (AC)	Structure and Contents Valuation[2]	Crop Area (AC)	Crop Valuation[2]	Area (AC)	% Total	#	Valuation[2]	% Total	Area (AC)	% Total	Valuation[2]	% Total
Butte	220,000	1,100,000	$16,800	223,900	$340.7	198,800	18%	5,300	$1,100.0	7%	119,000	53%	$146.9	43%
Glenn	28,100	849,100	$1,700	244,700	$324.9	123,300	15%	1,800	$246.0	14%	80,900	33%	$86.5	27%
Tehama	63,500	1,900,000	$4,100	112,400	$166.9	86,800	5%	3,800	$625.0	15%	24,300	22%	$62.3	37%
Colusa	21,400	740,400	$1,300	293,200	$335.6	175,300	24%	2,300	$334.0	26%	12,100	4%	$78.1	23%
Sutter	94,700	389,300	$7,300	282,500	$394.2	195,000	50%	2,100	$405.7	6%	164,300	58%	$218.8	56%
Lake	64,700	850,800	$5,600	28,500	$84.1	69,700	8%	6,400	$919.3	16%	7,200	25%	$22.0	26%
Yolo	201,300	653,500	$15,500	348,000	$631.8	240	0%	19,500	$5,800.0	37%	180,500	52%	$330.7	52%

Notes:
1. The values in this table are from DWR's 2013 Flood Future Report, which is based on the entire county, not the MUSR RFPM Planning Area
2. Valuations are in millions of dollars. Valuations are based on DWR's Flood Future Report, which used county assessor parcel records to identify structures and valuations based on reconstruction and subsequent depreciation. Content value was estimated implicitly as a function of structure value (DWR, 2013).

Assets can generally be defined as those fixed facilities that have an assessed or known monetary value. There may also be assets that have an intrinsic or sentimental value, however, these are difficult to quantify. As discussed previously, agricultural land use dominates most of the Sacramento Valley within the MUSR Regions. These lands contain a variety of different types of structures that range from storage garages to rural homes to high dollar agricultural processing facilities. The density of these structures also varies throughout the Regions, where some areas consist of smaller (10- or 20-acre) farmsteads with homes, and other areas consist of large tracts of land used primarily for larger industrial agricultural operations. Figure 3-20 helps illustrate the relative spatial density of structure assets within the region.

Figure 3-20. Rural Area Structures within the MUSR Regions



Notes:
Existing structure locations were determined from aerial imagery provided by ESRI.
Existing structures are not shown in Urban Areas. Urban Areas include all areas that contain a relative high density of structures.

3.2.3. *Critical Infrastructure*

Transportation plays an essential role in the economy and the overall functioning of society. Providing mobility enables individuals to participate in the labor force and facilitates the movement of goods and services. During times of catastrophic events, such as flooding, having a reliable and robust transportation network is critical to prompt emergency response.

The Mid and Upper Sacramento River Region has several major transportation roadways and bridges threatened by flooding that connect communities within the Regions and connect the Regions to outside areas. Table 3-5 identifies the most critical flood prone routes which play a vital role to the interconnectivity of the Regions.

Table 3-5. Major Regional Roadways threatened by Flooding

Roadway Name	Connectivity	Flood Threat Sources
I-5	Major north-south route.	Western Foothill Streams
Hwy 99	Major north-south route. Alternate route to I-5.	Elder Creek, Deer Creek, and Rock Creek/Keefer Slough
Hwy 36	Major East-West route into Sierra Nevada Foothills	Battle Creek
San Benito Ave	Only one of two exits for Gerber.	Elder Creek
South Ave	Connects Corning and I-5 to 99. Alternate Route to I-5 and is primary route for heavy traffic	Sacramento River
Hwy 32	River crossing near Hamilton City; Connects Chico to I-5	Sacramento River
Ord Ferry Road	River crossing near Ord Bend	Sacramento River; Routinely floods from overflows into the Butte Sink
Hwy 162	River crossing near Butte City	Sacramento River; Routinely floods from overflows into the Butte Sink
River Road (Colusa)	River crossing near Colusa; Connects Colusa to lower Butte Sink	Sacramento River
Hwy 20 (Colusa - Sutter)	Major east-west route.	Sacramento River, Colusa Drain, and Sutter Bypass
Hwy 45	Major north-south route.	Sacramento River
Hwy 113	Major north-south route.	Sacramento River and Sutter Bypass
Hwy 20 (Lake County)	Major Regional east-west roadway.	Middle Creek
Nice-Lucerne Cutoff Rd.	Major east-west roadway; Alternate route to Hwy 20.	Middle Creek

Utilities are the various external services that are provided to a community, building or facility to provide a certain level of functionality. Utilities can be segregated between ‘wet’ and ‘dry’, with wet utilities being water supply and wastewater or sanitary sewer facilities, and dry utilities being gas distribution and transmission, electrical distribution and transmission, and phone and cable communication lines. Utilities that cross river or channel crossings are of a more critical concern due to the potential for exposure or disruption from channel scour. In addition, there are

major distribution gas and petroleum facilities, major communication facilities, and other utilities that play a vital role in the inter-connectivity of the State.

Other critical facilities include hospitals, schools, communication facilities, and other emergency service facilities such as fire and police stations. These facilities are typically given special consideration as they provide for the safety and health of citizens during a time of emergency. The following figure provides an overview of critical facilities known to exist within flood prone areas of the Region. These critical utilities and facilities are further discussed in Chapter 5 of this RFMP.

3.2.4. *Water Quality*

There are several important connections between flood management and water quality. Most importantly, floods are capable of mobilizing large sediment loads and any included contaminants, carrying them downstream, and then sorting and re-depositing them. Also, when levees fail, the inundation of homes, farms, businesses, and industries often results in the release and dispersion of known toxic chemicals or oils and fuels from a flooded chemical storage facility, which can have far reaching health and economic effects. For example, when levee overtopping occurred on Middle Creek in 1995, it inundated a local junkyard and distributed many oils and toxins into the environment. Also, due to the rural agricultural setting of the Region, there are numerous fertilizer, herbicide and pesticide processing and storage facilities at risk.

These types of water quality concerns will continue to affect flood management programs by requiring that contaminants and toxics be addressed in the planning, design, construction, and maintenance phases of flood management projects, most likely intensifying in the future.

Figure 3-21. Upper Sacramento River Region Emergency Response Facilities

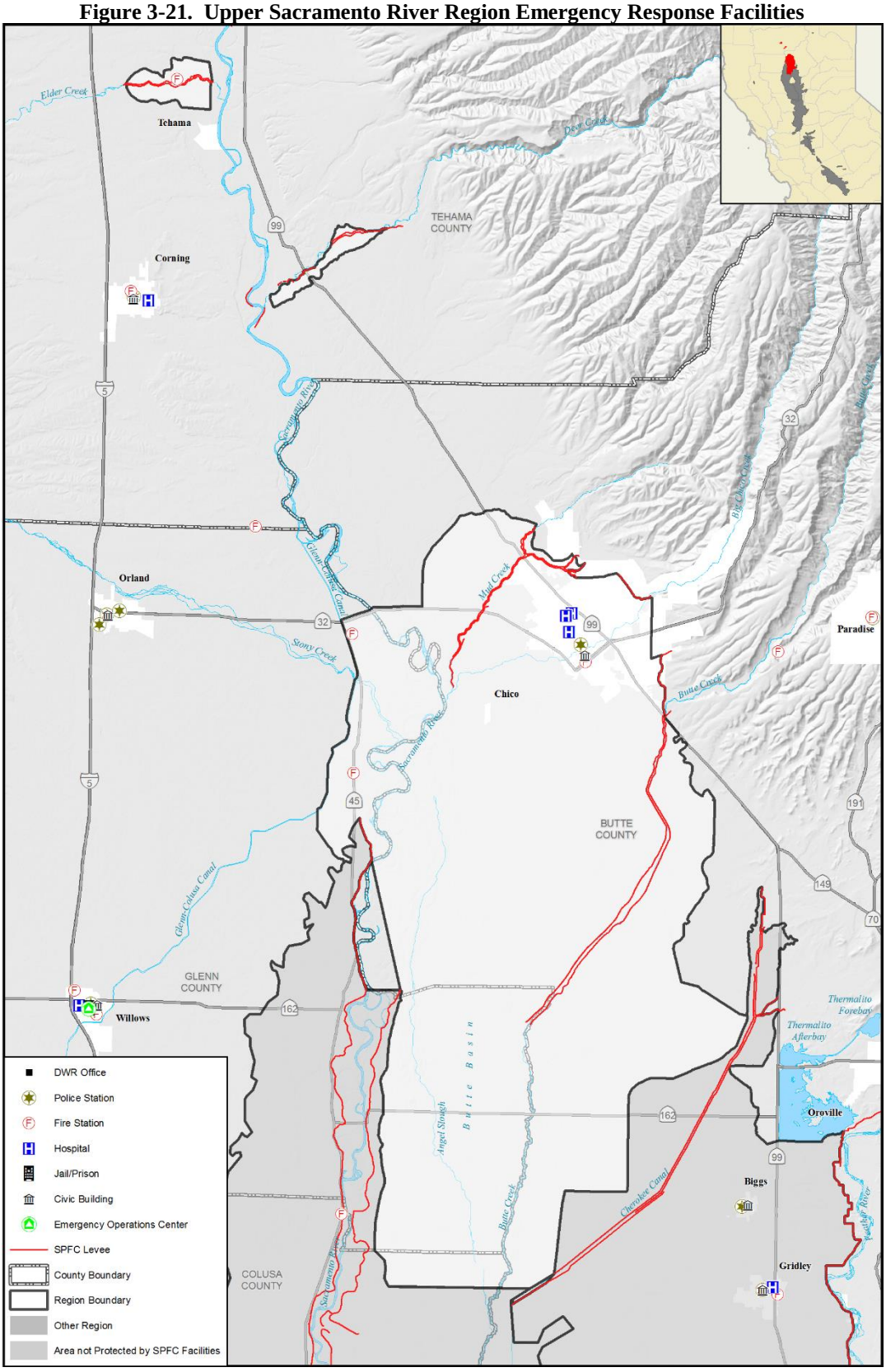
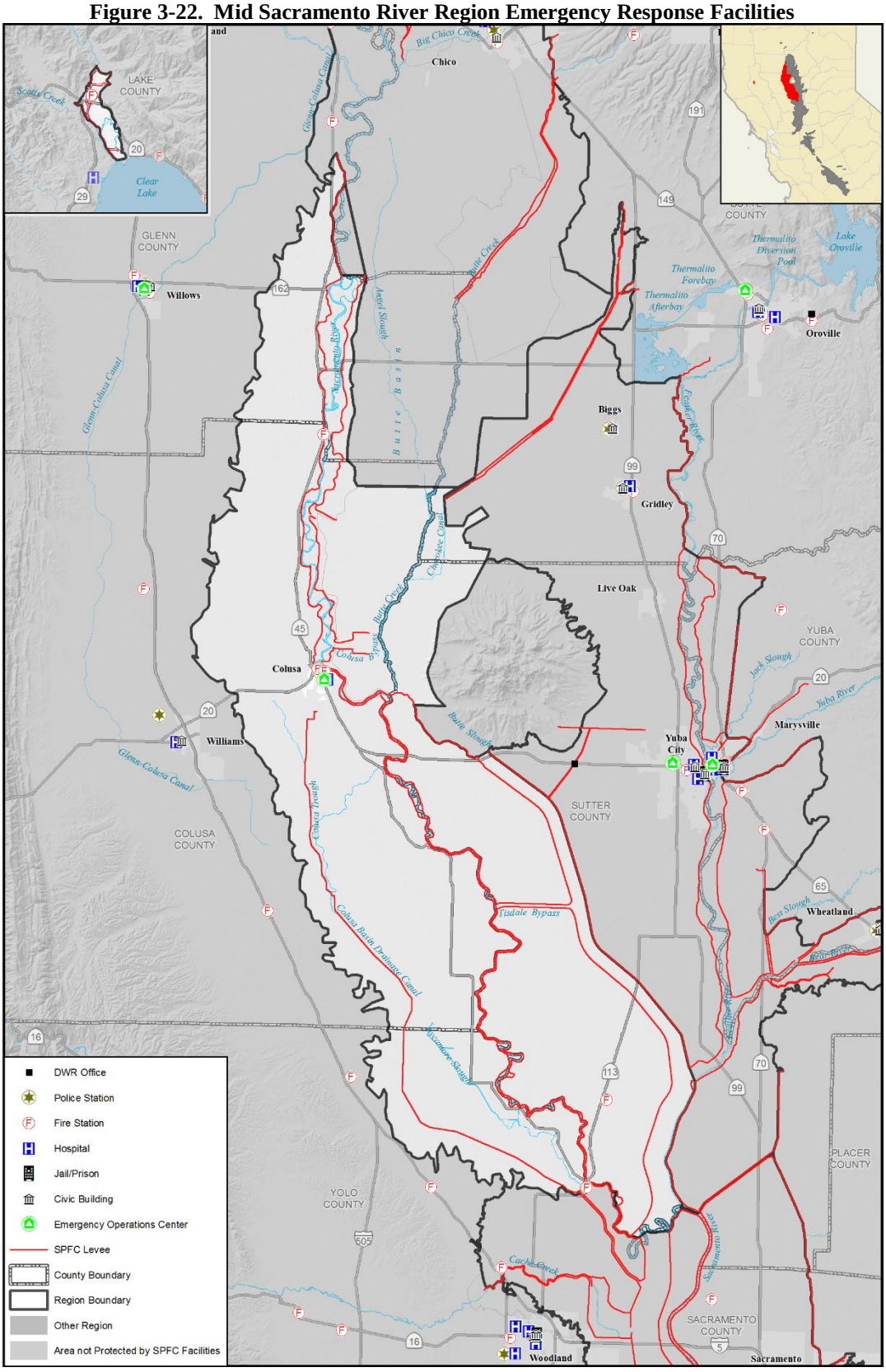


Figure 3-22. Mid Sacramento River Region Emergency Response Facilities



3.3. Flood Management Challenges

3.3.1. *Project Implementation*

To address the deficiencies and reduce the risks discussed, flood system improvement projects within the Regions will need to be undertaken. However the development and ultimate implementation of flood system improvement projects is a difficult process. Developing a project and guiding it to construction involves a substantial commitment on behalf of the project sponsor. The project development process includes feasibility and preliminary studies; securing funding; performing detailed technical studies, completing biological surveys, and environmental permitting; obtaining other flood and land use permits; performing public outreach; administering contracts; final design development; and ultimately construction of the project. For the most part, local levee maintaining agencies were established and structured to provide basic operation and maintenance (O&M) activities and they are simply not adequately funded or staffed to implement large flood control capital improvement projects. The same is true for the towns, cities, and counties which now feel compelled to become involved in upgrading and providing flood control infrastructure due to regulatory pressures from State and federal agencies to improve flood protection.

The project development and implementation process typically takes several years to accomplish, with both recent and current projects providing some insight into the various challenges and obstacles that can cause significant delay or potential project termination. Some of the more typical project development components that have proved difficult include securing a robust funding source; the cost and time required to complete technical environmental studies and, in particular the review and resolution and granting of environmental permits;; and the cost variability and duration of acquiring property access.

For small communities and rural areas, acquiring a secure funding source that is sufficient to fund all project components is universally rare, oftentimes despite a substantial level of support for a project. The Hamilton City "J-Levee" is a particularly good example of a widely accepted and supported project being delayed because of a lack of funding. That project has been authorized for nearly 10 years (USACE, 2004), and had been awaiting a federal funding appropriation since being approved in 2007. In March 2014 the project received its first federal appropriation of $8.6 million for the first phase. Significant addition funding will be needed to complete the project. As illustration of the challenges of current projects, Table 3-6, which includes a summary of existing and currently-contemplated large-scale flood projects in the regions, also demonstrates timelines and challenges faced by these projects, even with all of these projects generally well-supported.

In addition to funding challenges, the lengthy and costly, project by project environmental review and permitting process is problematic. Flood improvement projects inherently involve aquatic and riparian areas and, in California, these areas typically include a relatively-higher concentration of sensitive species, some that are listed as threatened or endangered by the state and/or federal governments. Consequently, projects with relatively small footprints and/or low construction cost may still require substantial environmental review and permitting as compared

to larger projects. Staff reductions at regulatory agencies further complicate and add delays to the situation as those individuals must still comply with established laws and regulations despite inappropriate workloads.

Table 3-6. Summary of Select Major Projects within the MUSR Regions

Project	Description	Year Issue Emerged	Project Initiated	Status/ Duration					
				Funding Status	Technical Solution Developed	Environmental Permitting	Regulatory Compliance (CEQA/NEPA)	CVFPB and/or Section 408[1] Approval	Project Approval (Congress)
Lower Deer Creek Levee Improvements and Habitat Restoration (five phases)	Floodway Improvement, Ecological Habitat Restoration, and Levee Improvements (including Levee Setbacks)	1980s or earlier	2011	DWR considered direct funding Phase 1 and a portion of Phase 2 by the Flood Corridor Program in 2013, awaiting competitive selection.	Feasibility Study Completed, 2011	Not Started	Not Started	Not Started	Not Started
Hamilton City J-Levee	Levee setback	No Specific Year- ongoing flooding history	2000	Federal FY14 funding approved	Engineering and Design Completed, 2009	None. Categorically exempted or impacts avoided	Done, 2004	No Section 408 required. CVFPB permit not required.	Authorized in WRDA 2007
Kopta Slough	Flood Damage Reduction and Habitat Restoration Project	1980s	USACE initiated, 1998 DWR continuing feasibility study, 2007	Planning currently funded by DWR. Need construction funds	In Process, Draft feasibility study completed in 2014	In Progress	NOP likely out in Spring 2014	In Progress. Working with USACE and CVFPB Staff	Likely will not require Congressional approval
Riparian Sanctuary Restoration and Pumping Plant/Fish Screen Facility Protection Project	Rock removal, bank stabilization (rock placement) and habitat restoration	2001	2002	Need	Completed, 2012	Applications Done 2013 (preparing to submit)	Done, 2013	Preparing to submit	N/A. Can be approved at the Corps District level

1. Rivers and Harbors Act of 1899, Title 33 United States Code, Section 408

3.3.2. *Habitat Mitigation Requirements*

Habitat mitigation is required to mitigate the impacts of a development or infrastructure construction or repair/replacement project. Habitat mitigation is comprises enhancement protection or restoration/rehabilitation of habitat in specific ways, for the betterment benefit of the impacted species. These actions may include planting of vegetation, grading and contouring of the land surface and/or adjusting the hydrologic regime of the area through irrigation or management of drainage. This may at times involve the conversion of agricultural lands back to habitat or placement of a conservation easement on all or a portion of lands. While mitigation can occur on-site, these mitigation areas are often located away from the project's site of impact, and the land use changes associated with the habitat mitigation have an influence on the properties adjacent to the mitigation site. The time and cost requirements associated with the project by project mitigation process are a challenge for many local agencies whom are already struggling with other fiscal and staffing constraints.

3.3.3. *Evolving and Conflicting Levee Standards*

The methods used by USACE and DWR to estimate flood risk have become more conservative. Since 1995, USACE has been developing and implementing its risk and uncertainty methods, as well as upgrading its structural design criteria, with the net result that many existing facilities, which were previously rated as substantially adequate to meet project design criteria, have subsequently been downgraded. For example, the Natomas levee system, thought to provide 200-year to 400-year protection when upgraded in 1998, was downgraded to a 30-year rating ten years later.

In addition, standards for the design, construction, and management of levees have evolved over time, often in response to structural failures during floods. SPFC levees have been constructed through the individual and combined efforts of local, State, and federal agencies. The facilities were constructed with materials at hand over many decades, to meet evolving design standards and construction techniques. As a result, these facilities provide varying levels of protection, depending on when and how they were constructed and upgraded (DWR, 2012).

The flood risk evaluation and designation process has been very dynamic, with frequently changing standards for all aspects of levee system management being developed. This liquid regulatory dynamic poses unique challenges for responsible agencies who work to upgrade their levees to keep pace with these standards. A brief summary of some of the recent changes in State and federal levee standards is provided below.

USACE Standards:
In 2005, Hurricane Katrina caused widespread flooding and devastation along the Gulf Coast, most notably the flooding of much of New Orleans. As a result, USACE launched a multi-pronged effort to improve levee management nationwide, including the creation of a national levee database, risk notification procedures, and more stringent enforcement of its levee

standards. Among the key changes in the USACE approach to national levee standards was the promulgation of levee vegetation management standards, which have had the effect of requiring the removal of most woody vegetation from levee slopes and adjacent ground. From the State perspective, the removal of woody vegetation does not rank high in terms of levee safety risks. Accordingly, the CVFPP recommends a life cycle approach to vegetation management, in which woody vegetation is monitored and managed to assure that it does not pose localized threats to levee integrity. It should be noted that not all resources agencies are in agreement with the CVFPP life cycle approach to vegetation management, or the USACE levee vegetation policy. USACE recently issues new interim guidance postponing the need for levee maintainers to comply with USACE levee vegetation policy.

USACE has also stepped up enforcement of other standards for various aspects of levee integrity, including encroachments, penetrations, erosion protection, patrol roads, and structural cross sections. Levees that are deemed noncompliant with current USACE standards risk being classified as inactive in the federal Rehabilitation and Inspection Program (RIP), which would make the levees ineligible for PL 84-99 rehabilitation assistance in the event of damage or failure during a flood. In addition, in many cases FEMA has based its National Flood Insurance Rate Maps (FIRM) hazard classification upon USACE determinations or certifications of levee integrity and channel capacity. When USACE downgrades levee structural ratings within its evolving standards, re-mapping by FEMA is a likely outcome.

State Urban Levee Standards:

Prior to 2008, the State primarily relied on USACE levee design, construction, operation, and management standards. Its historic role in the region included cost sharing in the construction of Project levees, providing Lands, Easements, Real Estate, Relocations (LERRDs), borrow materials, and disposal sites, and certifying that that the State, through the CVFPB, would take responsibility for Operation, Maintenance, Repair, and Rehabilitation (OMRR).

With the enactment of the 2007 California Flood Legislation however, the State's role in establishing levee standards was expanded. DWR led the development of the new levee standards for urban areas called the Urban Levee Design Criteria (ULDC, May 2012), which describes the levee and floodwall design criteria that flood control facilities protecting urban levees must now meet.

The ULDC provides engineering criteria and guidance for the design, evaluation, operation and maintenance of levees and floodwalls that provide an urban level of flood protection, as well as determining design water surface elevations along leveed and unleveed streams. Other topics are presented to provide reasonable assurance that once a levee or floodwall is found to provide an urban level of flood protection, it will continue to do so. The ULDC is very comprehensive and more stringent than current practice for levee design and accreditation

Rural Levee Repair Guidelines:

Most of the levees in the MUSR Regions were constructed to a geometry standard with the intent to pass design flows with adequate freeboard, and although they were improved and incorporated into the Sacramento River Flood Control Project, most do not meet current levee engineering performance standards because of inadequate cross sections, geotechnical weaknesses, erosion,

encroachments, penetrations, or other concerns. It is unlikely that the combined resources of regional LMAs and the communities they protect can fund improvements to achieve a FEMA 100-year level of flood protection or better, even if State and federal funds are leveraged to the extent feasible. Nevertheless, it is important to improve flood protection for rural-agricultural areas, in accordance with the priorities set by the communities in the region.

In preparing and adopting the CVFPP, both DWR and CVFPB made strong commitments to work with LMAs in the Central Valley to develop local and regional flood management plans for repairs and improvements to rural-agricultural levee systems, including the development of rural-agricultural levee repair criteria.

The purpose of developing a set of common, consistent rural-agricultural levee repair criteria is to achieve the most cost effective reductions in flood risk feasible for these areas. This will likely require a strategy of making numerous repairs and improvements to multiple sites with known deficiencies. Available funds can be stretched further if repair criteria are less stringent than those required for urban areas or small communities.

Consistent with the State commitments, the Rural Levee Repair Criteria (RLRC) are currently under development by DWR, in coordination with the CVFPB, for levee repairs in the Central Valley's rural-agricultural areas. DWR has formed a work group of interested stakeholders to help develop criteria to be used to guide repair of documented rural levee performance problems. In addition to DWR staff, work group members will include representatives of the local maintaining agencies, CVFPB Board member(s) and staff, USACE representatives, and other interested parties.

3.3.4. *Levee Decertification and Floodplain Re-mapping*

When FEMA's National Flood Insurance Program (NFIP) was first established in 1968, areas protected by USACE levees were presumed to meet 100-year criteria. As a result, most of the floodplains in the MUSR Regions protected by the levees of the State Plan of Flood Control were mapped with 100-year ratings on FEMA's Flood Insurance Rate Maps (FIRMs). In 2005, FEMA issued Procedure Memorandum 34 (PM 34), which fundamentally reversed the historic presumption regarding USACE levee systems by requiring the agencies responsible for levees to demonstrate and document the integrity of their levee systems.

Recognizing that in many cases responsible agencies would need to conduct extensive field work, hydraulic and hydrologic studies, and geotechnical and engineering analyses in order to demonstrate that their levees met FEMA's certification criteria, FEMA issued PM 43 in 2007. PM 43 permits FEMA to issue preliminary and effective FIRMS with Provisionally Accredited Levees (PALs) if the responsible agencies believe that their systems meet 100-year criteria, but cannot provide adequate supporting documentation. The PAL designation provides the responsible agencies 24 months to gather and provide the necessary documentation.

FEMA embarked upon a map modernization process in the mid 2000's which resulted in updated FEMA maps (known as DFIRMs) being issued to most cities and counties within the MUSR

area. A summary of the FEMA Remapping efforts for the counties within the MUSR Regions is show in Table 3-7

Table 3-7. Summary of FEMA DFIRM Re-Mapping Status

County	FEMA DFIRM Re-Mapping Status	Notes Regarding FEMA DFIRM Status	Current FIRM Effective Date
Tehama	Complete	-	09/29/11
Glenn	Complete	-	08/05/10
Butte	Complete	An accreditation package for select urban reaches of the Sycamore-Mud Creek levee system was submitted by the City of Chico/Butte County in January of 2011 and approved by FEMA in May of 2011. The City and County are currently working on an accreditation package for select non-urban reaches of the Sycamore-Mud Creek levee system.	01/06/11
Lake	In-Progress	Revision of the countywide DFIRM to address expired PALs, address a vertical datum shift, correct existing floodway/channel errors and correct an incorrect profile for Adobe Creek. Revised prelims will update mapping for Adobe and Highland Creeks while remainder of County is on hold.	09/30/05
Colusa	In-Progress	FEMA has initiated a project for public outreach and planning activities to support a planned future Colusa County, CA countywide DFIRM project. This project will include levee assessment and issuance of PAL agreements and a Discovery meeting.	05/15/03
Sutter	On-Hold	A countywide DFIRM project that will incorporate several existing data studies as well as utilize flood hazard data from the effective Sutter County and contiguous county DFIRMs.	12/02/08
Yolo	Complete	FEMA incorporated the Cache Creek South Levee Floodplain study into a revised Flood Insurance Study (FIS) Report, Flood Insurance Rate Map (FIRM), and Digital FIRM (DFIRM) database. The revised Physical Map Revision (PMR) is effective as of May 16, 2012. The final FIS Report and map products for this project can be obtained from the Product Catalog on the Federal Emergency Management Agency's (FEMA's) Map Service Center web site.	05/16/12

FEMA's remapping will result in much of the MUSR Regions being placed within FEMA's 100-year floodplain. As a result, development in these areas will be more expensive, difficult to insure, and subject to flood-proofing or elevation requirements.

In July 2012, the U. S. Congress passed the Biggert-Waters Flood Insurance Reform Act of 2012 (BW-12), which calls on the FEMA and other agencies to make a number of changes to the way the NFIP is administered. Some of these changes already have occurred and others will be implemented over time. Key provisions of the legislation will require the NFIP to raise rates to reflect true flood risk, make the program more financially stable, and change how FIRM updates

impact policyholders. Over time, the changes will mean the premium rate increases. Further challenges associated with NFIP rate increases are described later in this plan.

In addition to FEMA floodplain mapping, the State of California put in place new floodplain regulatory requirement for the Central Valley. The 2007 California Flood Legislation mandated that new development within urban and urbanizing areas have an urban (200-Year) level of flood protection. The 2007 California Flood Legislation defines an "urban area" as a developed area in which there are 10,000 residents or more, and an "urbanizing area" as a developed area or an area outside a developed area that is planned or anticipated to have 10,000 residents or more within the next 10 years.

3.3.5. *PL84-99 Eligibility*

Public Law 84-99 (PL84-99) provides for federal rehabilitation assistance for levees following a flood emergency. For a levee system to be eligible for PL 84-99 rehabilitation assistance, the levee system must have "active status" in the USACE's Rehabilitation and Inspection Program (RIP). Levee systems are inspected through the USACE RIP. Systems that receive unacceptable ratings through either routine or periodic inspections are placed on inactive status in the RIP, which affects the amount and type of federal funding assistance for which a non-federal sponsor may be eligible following a flood event.

A system status of inactive in the RIP results in a loss of PL 84-99 rehabilitation assistance following a flood event. It does not necessarily result in a loss of FEMA NFIP certification or accreditation nor does it result in a loss of federal assistance for emergency flood fighting. A system status of active in the RIP does not guarantee rehabilitation assistance will be provided, only that it is eligible. Rural LMAs may have difficulty meeting the benefit cost ratio requirements in order to receive the rehabilitation assistance.

Flood control works that are eligible for USACE's RIP program, either Active or Inactive, are ineligible for assistance from FEMA for emergency repairs and permanent restoration. Although, FEMA may provide assistance for the placement and removal of flood fighting measures (e.g., sandbags, buttresses) on flood control works that are eligible for USACE's RIP program if such activity is necessary to eliminate an immediate threat to life, public health and safety, or improved property.

Loss of eligibility in the PL 84-99 RIP would mean that the LMAs and the State of California would have to fully fund rehabilitation following a high water event. Neither the State nor the rural LMAs have sufficient budgets to fund the increased rehabilitation costs.

The State now requires a local partnership agreement for many new projects including those funded under Propositions 1E and 84. Clauses in this agreement, also referred to as a "local O&M agreement", include a requirement for the LMA "to continue to participate in and comply with the policies and procedures of the USACE Rehabilitation and Inspection Program" as well as Section 208.10.

System-Wide Improvement Frameworks (SWIFs) provide one avenue to maintain eligibility in the RIP and thus receive rehabilitation assistance while addressing long-term maintenance or repair deficiencies. Several LMAs in the Regions wish to pursue SWIFs but questions remain as to how their development and implementation will be funded. LMAs that have indicated their willingness to pursue SWIFs in order to regain PL84-99 eligibility include:

- Sacramento River West Bank Levee System comprising of RD 787, RD 108, LD 1, LD 2, Sacramento River West Side Levee District, and DWR.
- Sutter Basin South Levee System comprising of RD 1500 and DWR
- Sutter Basin North Levee System comprising of RD 70, RD 1660 and DWR
- Elder Creek North and South Levee Systems comprising of Tehama County FCWCD

Development of SWIFs as part of the regional planning process is ineligible under the current guidelines, however, DWR may wish to reconsider the fact that this loss of PL84-99 eligibility may have cost implications for the State. Also, the development and implementation of SWIFs can help optimize system performance, resiliency and robustness, which are key aspects of the 2012 CVFPP and the SSIA.

Figure 3-23. Sacramento River West Bank Levee System SWIF Area

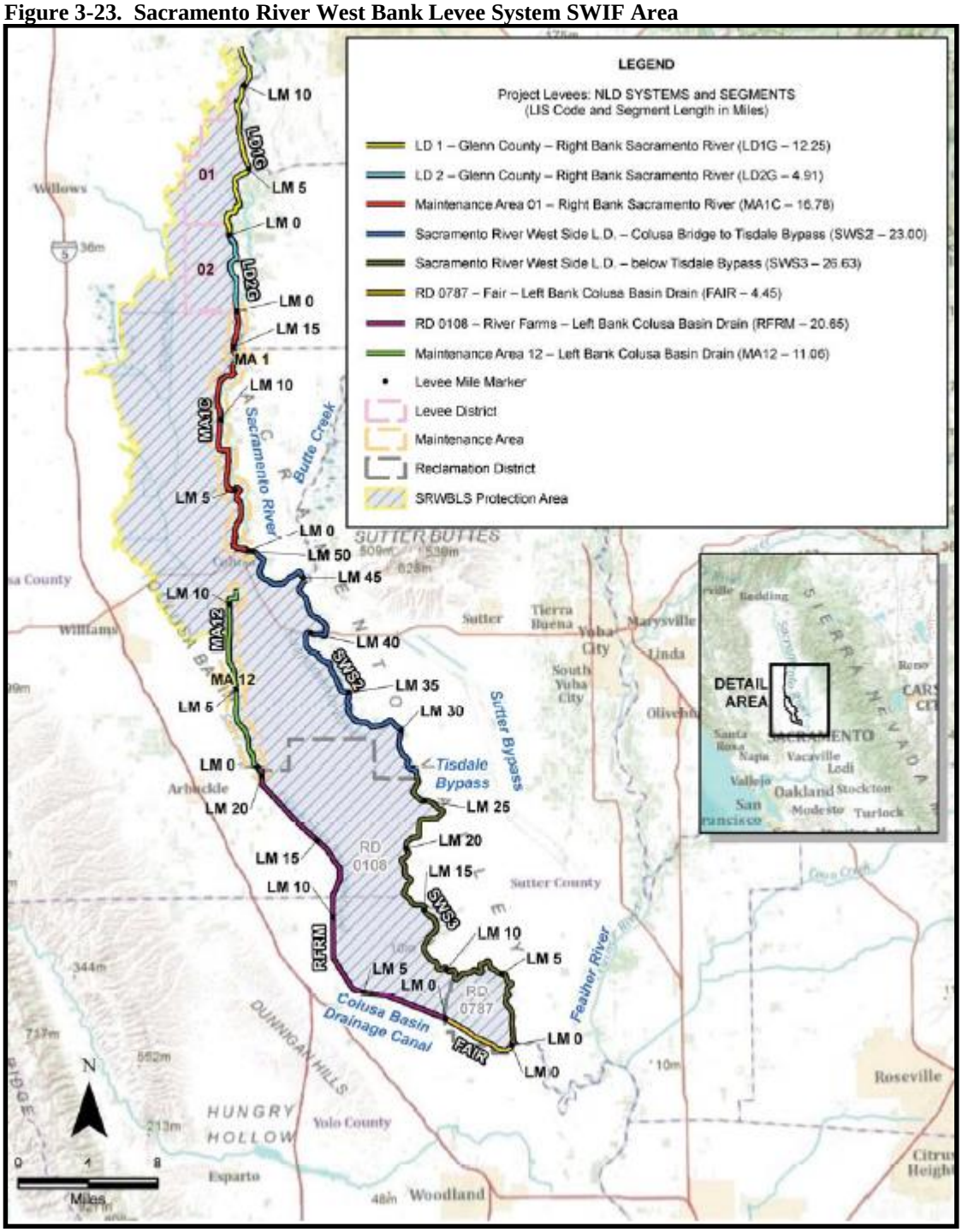


Figure 3-24. Sutter Basin South Levee System SWIF Area

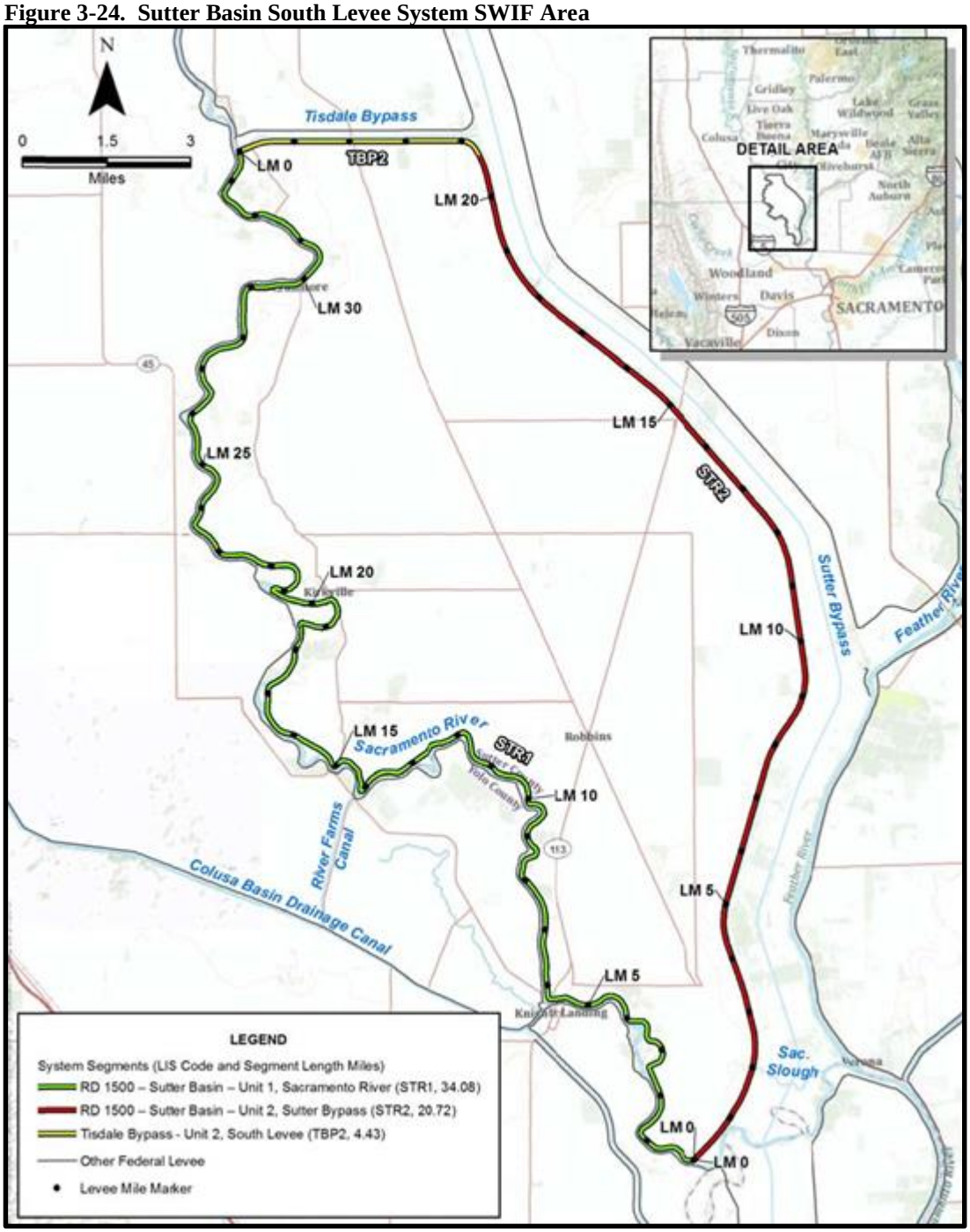
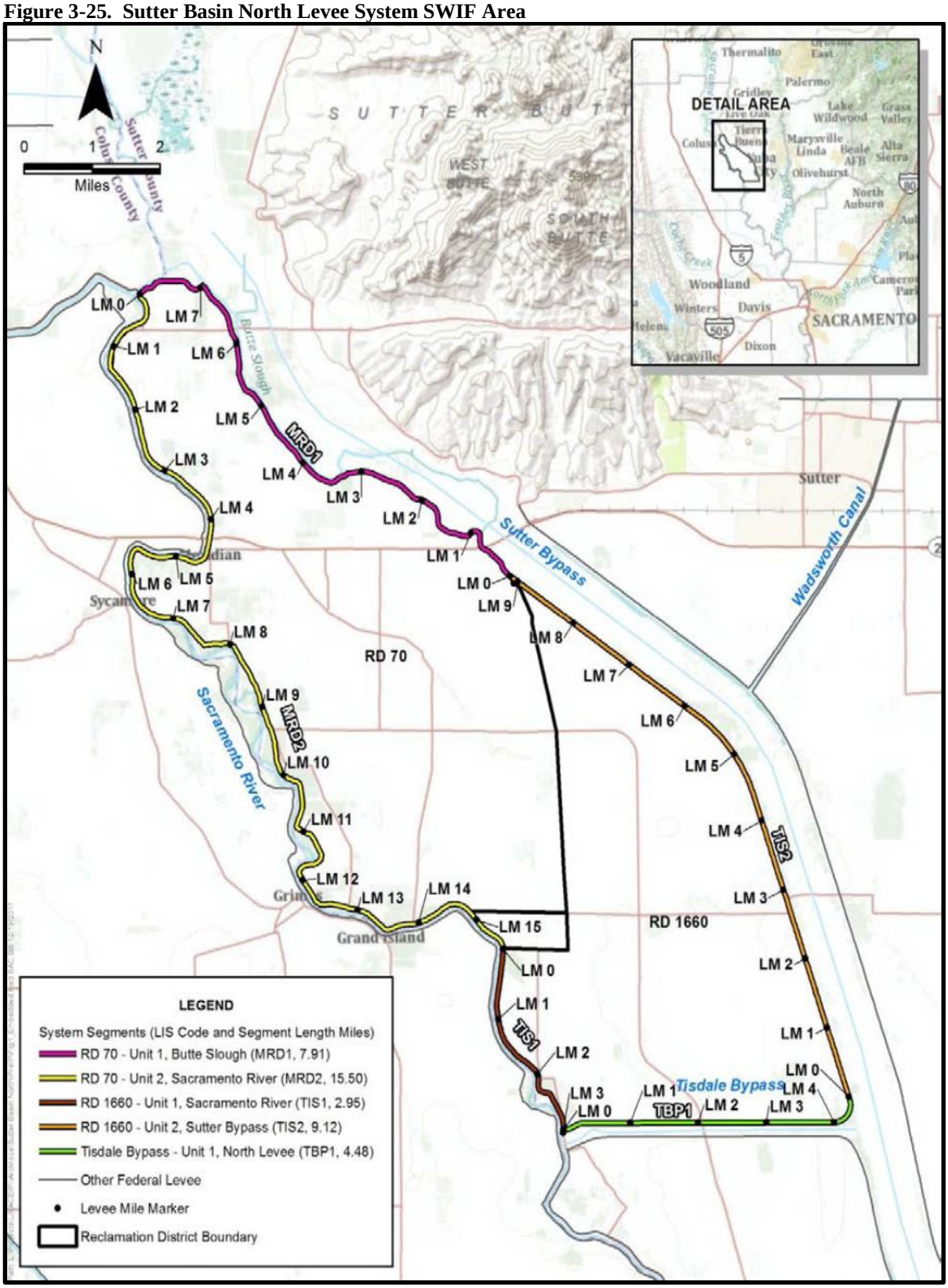


Figure 3-25. Sutter Basin North Levee System SWIF Area



3.3.6. *Compliance with Federal Flood Management Policies and Standards*

The levees comprising the Sacramento River Flood Control Project (SRFCP) are referred to as "Federal Project" levees as they are part of a congressionally authorized project. While the State of California is the non-federal sponsor of the SRFCP, the project remains subject to federal regulations as agreed to in cost-share agreements; Operation, Maintenance, Repair, Replacement, or Rehabilitation (OMRR&R) agreements; or other binding documents.

The primary benefits of being part of the federal program (i.e., a congressionally authorized project) are the cost-sharing of planning studies and construction of projects, and non-cost-shared rehabilitation assistance during and after declared emergency events. Participation in a planning and potential construction of a Federal project can be difficult for rural LMAs as the cost of levee upgrades are expensive and the benefits (i.e., damages) often do not outweigh the high costs.

As a result, obtaining "Federal Interest" is difficult and subsequent funding recommendation from the Office of Management and Budget is even more difficult as it typically requires a benefit to cost ratio of greater than 3.0. Cost-shared assistance during and after declared emergencies is available to both project and non-project levees if the LMA has requested and received eligibility in the PL 84-99 Rehabilitation and Inspection Program (RIP). The RIP also requires a minimum 1.0 benefit to cost ratio, but because repairs are generally smaller as compared to major levee system upgrade projects, history indicates that this requirement can be met.

Secondary benefits have in the past included the Corps' certification of projects to support local communities in obtaining FEMA accreditation for the 100 year event. However, based on review of new guidelines (EC 1110-2-6067) published by the Corps it is unlikely that this benefit will be realized as was in the past.

In accordance with commitments made in applicable cost-sharing agreements, the non-federal sponsor's primary responsibility following construction of the project is Operation and Maintenance (O&M) of the project under 33 CFR 208.10 through compliance with the O&M Manual provided by the USACE at the time of project completion. The USACE can adapt and/or revise existing regulations, create new regulations, or modify O&M Manuals as tools, technology, and science improve over time. Generally, the guiding document remains the O&M Manual, although recent updates of regulations by the USACE will likely require a modification to O&M manuals and thus O&M practices.

. In some cases, it is no longer realistic (financially cost advantageous) for the LMAs to maintain the levees to current USACE standards. For example, some federal levees provide a relatively low degree of protection and the cost of diverting limited financial resources to maintain them to current USACE standards, such as those for pipe inspections, may not provide the same level of benefit when compared to using those resources to directly repair the levee deficiencies or to reserve the money for flood fighting. .

Removal of projects from the federal program would almost certainly require a congressional act. USACE has authority to conduct deauthorization studies, which are submitted to Congress, but funding and processing of these studies would be uncertain. USACE deauthorizations are uncommon. Independent from the USACE deauthorization project, non-federal sponsors, or others, could pursue their own congressional legislation to remove the project from the federal program.

If a project levee was deauthorized and removed from the RIP, it could be eligible for assistance for both flood fighting and rehabilitation through the Federal Emergency Management Agency (FEMA) or National Resources Conservation Service (NRCS) programs if Congress indicated so. Flood control works that are eligible for USACE's RIP program, either Active or Inactive, are ineligible for assistance from FEMA for emergency repairs and permanent repairs.

If a project were no longer in the federal program, permitting requirements under 33 USC 408 would be eliminated except in cases where an alteration could have an effect on an adjacent, or neighboring, Federal project. Permitting under other federal and State authorities would likely be required.

In summary, continued participation in the federal program, and adherence to federal polices and standards provides benefits for planning and implementation of major repair and/or improvement projects as well as benefits during and following emergency events. However, deauthorization, or removal from the federal program through other means, may provide its own benefits. A weighing of advantages and disadvantages should take place to determine if deauthorization should be pursued and if so how and where (i.e., large or small systems, rural or urban systems, etc.).

As part of this RFMP, stakeholders have identified the need for a feasibility level analysis to identify levees that while providing critical flood protection, may benefit from being removed from the federal program, while remaining in the State Plan of Flood Control. In this study, consideration should be given to the ability of LMAs and the State to meet standards that would provide emergency and rehabilitation assistance, the ability to fund levee improvement projects without federal cost-share dollars, and liability for damages in the event of failures. Further consideration should be given for evaluating where levees may not be necessary and could altogether be removed from the federal program.

3.3.7. *Water Surface Profile Deficiencies*

As flood flows are conveyed downstream, water elevations rise to accommodate the increased flows, and the water either spreads out over adjoining flood plains or rises against confining levees. The relationship between stage and flow at any given location (typically at a gaging location) is called a rating curve.

The relationship between stage and flow can be extended along the length of a stream channel to provide a water surface profile, and can be computed or measured for storms of various

magnitudes. The water surface profile depends on many factors, including the magnitude and duration of the flood wave, channel roughness, shape, and capacity.

Detailed mathematical modeling is typically undertaken for feasibility-level studies, to subsequent design and construction. Over the past several decades the Sacramento Valley flood management system has been modeled with increasing levels of accuracy and sophistication. A complete system hydrologic analysis was completed as part of the Sacramento-San Joaquin Comprehensive Study (2002). DWR has recently worked closely with USACE to update and refine the hydrologic and hydraulic modeling system for the Sacramento Valley under two inter-related programs.

The Central Valley Hydrology Study (CVHS) is providing updated unregulated flow-frequency curves for streams throughout the valley at key locations, simulating the effects of reservoir regulation on those streamflows, and evaluating the effects of climate change on the system in the future.

The Central Valley Floodplain Evaluation and Delineation Program (CVFED) is providing updated mathematical models for evaluating flood risks and alternatives for reducing those risks, improved topographic mapping and floodplain delineation, and improved flood risk information for use by local, State, and federal agencies involved in land use planning and flood risk evaluation.

3.3.8. *Accommodating Climate Change*

While the exact conditions of future climate remain to be seen, there is considerable certainty about past conditions. Analysis of paleoclimatic data (such as tree-ring reconstructions of streamflow and precipitation) indicates a history of naturally and widely varying hydrologic conditions in California and the western United States, including a pattern of recurring and extended droughts (DWR 2008). This natural variability is inherent in the climate of the west; however, there are several trends that are more recent, which may be linked to a changing climate, and are potential cause for concern.

The average early spring snowpack in the Sierra Nevada decreased by about 10 percent during the last century, a loss of 1.5 million acre-feet of snowpack storage (California Natural Resources Agency, 2009). During the same period, sea level rose seven inches along California's coast. California's temperature has risen 10 F, mostly at night and during the winter, with higher elevations experiencing the highest increase (DWR, 2008). A disturbing pattern has also emerged in flood patterns; peak natural flows have increased on many of the State's rivers during the last 50 years (DWR, 2008). At the other extreme, many Southern California cities have experienced their lowest recorded annual precipitation twice within the past decade. In addition, during the formation of this report, 2013 ended up as the driest year in California recorded history (DWR, 2014). Increased seasonal temperatures and altered runoff patterns would also affect both agriculture and the health of the region's ecosystems and habitats.

The quantity of mountain snowpack is critical for water supply and environmental needs, but so is the timing of snowmelt runoff into rivers and streams. Rising snowlines caused by climate change will allow more high-elevation watersheds to contribute to peak storm runoff. High frequency flood events (e.g., 10-year floods) in particular are likely to increase with a changing climate. Along with reductions in the amount of the snowpack and accelerated snowmelt, scientists project greater storm intensity, resulting in more direct runoff and flooding. Changes in watershed vegetation and soil moisture conditions will likewise change runoff and recharge patterns. As streamflows and velocities change, erosion patterns will also change, altering channel shapes and depths, possibly increasing sedimentation behind dams, and affecting habitat and water quality. With potential increases in the frequency and intensity of wildland fires due to climate change, there is a potential for more floods following fire, which increase sediment loads and water quality impacts (DWR, 2008).

California has invested in, and now depends upon, a system that relied on historical hydrology as a guide to the future for water supply and flood protection. However, with the uncertainty in climate change, the hydrology of the past is no longer a reliable guide to the future. For the purposes of federal flood insurance, the Federal Emergency Management Agency (FEMA) has traditionally used the 100-year flood event, which refers to the level of flood flows that has a one-percent chance of being exceeded in any single year. As California's hydrology changes, what is currently considered a 100-year flood may strike more often, leaving many communities at greater risk. Moreover, as peak flows and precipitation change over time, climate change calls into question the validity of key assumptions typically used in flood-related statistical hydrologic analyses, such as the "100-year flood" (DWR, 2010). This climate uncertainty requires flexibility in flood management planning.

The State has acknowledged the importance of climate change, as demonstrated by the passage of Assembly Bill (AB) 32 – the California Global Warming Solutions Act, which states, "Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California." Additionally, as stipulated by CWC Section 9614, the Central Valley Flood Protection Plan among other items, shall include a description of the probable impacts of projected climate change, projected land-use patterns, and other potential flood management challenges on the ability of the system to provide adequate levels of flood protection.

In summary, the uncertainty in climate change may have a profound impact on our hydrologic patterns, and those hydrologic patterns may stress the existing flood management system in ways which were never previously expected. As California's climate changes, floodplain risk assessments and development constraints will likely be adjusted accordingly. For example, the 100-year and 200- year (1% and 0.5% annual chance) flood events, calculated based on historical flood events may become larger for the Sacramento River, with long-term effects on National Flood Insurance Program map ratings, flood insurance costs, floodplain development, and the economic viability of the region. In addition, if the moderating effects of snowpack on runoff decrease, there will be a need for more water supply storage, putting greater pressure on the multipurpose reservoirs protecting the region.

3.3.9. *Funding*

Major capital improvement and routine maintenance of the flood management system are primarily dependent on public funding generated by local, State, and federal sources. Flood risk management programs must compete with numerous other pressing funding needs such as education, transportation, health, and welfare. Major infusions of funding for flood risk management have historically followed major floods, when public attention is focused on the catastrophic damages they cause. For example, Propositions 1E and 84, with a combined bond funding capability of $4.9 billion, were approved by California voters a little more than a year after Hurricane Katrina flooded and destroyed much of New Orleans, killing over 1,200 people. However, flood risk reduction programs and infrastructure need steady, long-term funding to achieve and sustain the requisite level of protection. Governments at all levels struggling with heavy debt burdens, recession-damped revenue projections, and rising construction costs all add uncertainty for fully funding the flood risk management programs and projects described in this report.

Current trends suggest that future federal funding for flood risk reduction projects will be diminishing over time, as the federal government struggles to achieve a balanced budget while facing enormous pressure from nationwide entitlement programs, infrastructure needs, and defense needs. Therefore it will be important to assess the feasibility of developing of multi-benefit flood management projects that incorporate water supply, ecosystem restoration/conservation, and recreation components could open up alternative funding sources.

State bond funds, which are authorized until June 20, 2016, will need to be supplemented by subsequent bond measures or other sources to maintain current levels of State leadership in Central Valley flood risk reduction.

3.3.10. *Land Use Challenges*

Land ownership underlying the flood management facilities in the Regions is a patchwork of private and public parcels. A variety of easements cover many private parcels and these easements have been established for a variety of different and often site-specific purposes. The types and terms of these easements relate to, for example, levee operation and maintenance, periodic flooding, conservation of agricultural land, and habitat restoration. This patchwork of land ownership and easements both constrains and complicates the potential for providing flood or environmental improvements over areas greater than individual parcels.

Impacts of modifications to facilities and environmental restoration on adjacent properties must also be carefully considered and mitigated, where feasible. For example, where wildlife habitat is proposed in proximity to existing agricultural lands, the impacts of plowing, spraying, and harvesting of agricultural lands on nearby wildlife habitat and, conversely, the impacts of protected species on agricultural lands, must both be carefully addressed to successfully implement flood risk reduction projects with environmental enhancement components. A major goal of the RFMP will be to help identify the methods that provide mutual benefits to agriculture and ecosystem functions.

Flood protection structures can be adversely impacted by land use decisions ("land-use activities") that do not fully consider how the activity is integrated into a region's flood protection requirements and systems. These adverse impacts can be minor, requiring recurring, unbudgeted maintenance effort; significant, creating a need for major levee repair projects; or even catastrophic, causing failure of the levee during a high-water event, leading to a major flood event. In addition, un-integrated land-use activities can be cited by flood protection authorities as reason for decertification of a flood protection structure and/or removal of flood protection systems from aid programs such as PL84-99. To ensure LMAs have an opportunity to review and comment on land-use activities which could impact their systems, improved communication and interaction between LMAs and land-use authorities is needed. Creation of "Flood Structure Protection Areas" directly adjacent to levees and other flood control structures would provide LMAs an opportunity for input on land-use decisions occurring in the vicinity of their facilities. These areas would be identified in county and city floodplain management ordinances and/or general plans as zones in which input is required from LMAs before land-use decisions are finalized.