California Department of Water Resources

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Hydrodynamic Modeling Report

June 2017

Prepared by

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Acronyms/Abbreviations

1D	one-dimensional
2D	two-dimensional
3D	three-dimensional
ac-ft	acre-foot
ADCP	Acoustic Doppler Current Profiler
ADF	area-duration-frequency
Ag crossing	agricultural crossing
BDCP	Bay Delta Conservation Plan
BKS	Barker Slough
BOR	Bureau of Reclamation
Bypass	Yolo Bypass
CCSB	Cache Creek Settling Basin
CCY	Cache Creek at Yolo
CDEC	California Data Exchange Center
CFR	Code of Federal Regulations
Cfs	cubic feet per second
CHMTT	core hydraulic modeling technical team
CIMIS	California Irrigation Management Information System
CVFED	Central Valley Floodplain Evaluation and Delineation
CVP	Central Valley Project
DEM	Digital Elevation Model
DES	DWR Division of Environmental Service
DOP	Doppler
DPS	Distinct Population Segment
DWR	California Department of Water Resources
EIS/EIR	Environmental Impact Statement and Environmental Impact Report
ESA	Endangered Species Act

ESRI	Environmental Systems Research Institute
FEA	Feather River
FEMA	Federal Emergency Management Agency
FIRM	flood insurance rate map
FLT	binary raster format
Fps	feet per second
FreSm	small channel at Fremont Weir alternative
FreMed	medium channel at Fremont Weir alternative
FreLg	large channel at Fremont Weir alternative
GIS	Geographic Information System
GPS	Global Positioning System
HMAT	hydraulic modeling advisory team
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center – River Analysis System
HWM	high water mark
I-80	Interstate 80
in/hr	inches/hour
KLOG	Knights Landing Outfall Gates
KLRC	Knights Landing Ridge Cut
LDW	Last Day Wet
LFRCMP	Lower Feather River Corridor Management Plan
LiDAR	light detection and ranging
LSHB	Lindsey Slough Hastings Bridge
Management Strategy	Yolo Bypass Management Strategy
MWD7	Metropolitan Water District Gauge 7
NAD83	North American Datum 1983
NAVD88	North American Vertical Datum 1988
NCC	Natomas Cross Canal

NCRO	North Central Regional Office
NEMDC	Natomas East Main Drainage Canal
NFIP	National Flood Insurance Program
NGVD29	National Geodetic Vertical Datum 1929
NMFS	National Marine Fisheries Service
NMFS Operation BO	National Marine Fisheries Service Operation Biological opinion
NVCS	National Vegetation Classification System
RCS	Ridge Cut Slough
RD	Reclamation District
RM	River Mile
RMSE	root-mean-square-error
RPA	Reasonable and Prudent Alternative
RTK	Real Time Kinematic
SacW	Sacramento Weir option alternative
SCWA	Solano County Water Agency
SFHA	special flood hazard area
SMS	Surface-Water Modeling System
SUT	Sutter Bypass
SWP	State Water Project
SWRCB	State Water Resources Control Board
UCS	Upper Cache Slough
USACE	US Army Corps of Engineers
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WLK	Wilkins Slough
WSE	water surface elevation
WY	water year

1.0 Introduction

1.1 Purpose

The purpose of this document is to provide an overview of the hydrodynamic modeling of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project's Environmental Impact Statement and Environmental Impact Report (EIS/EIR) for Reasonable and Prudent Alternative (RPA) Actions I.6.1 and I.7. RPA I.6.1 and I.7 require creating floodplain habitat and fish passage in the Bypass. The Model was developed primarily for two reasons: 1) to evaluate the ability of project alternatives to create floodplain habitat and improve fish passage within the Yolo Bypass; and 2) to evaluate the relative differences between the alternatives' impacts and benefits on the environment (including flood safety, land use, and other environmental considerations), for EIS/EIR analysis purposes and to inform the selection of a preferred alternative. This report covers model development, calibration, validation, and analysis conducted and presents results based on the hydrodynamic modeling performed on potential alternatives within the Lower Sacramento River Region and Yolo Bypass (Bypass) System. The model will inform evaluations of the impacts and benefits of selected alternatives that have been identified by the Department of Water Resources (DWR) and Bureau of Reclamation (BOR), herein referred to as the Lead Agencies.

1.2 Scope

The scope of this hydrodynamic modeling effort was to identify and use appropriate tools to prepare inputs to other models and analyses in order to compare various impacts and benefits of a wide range of alternatives to existing conditions (no action alternative) for the EIS/EIR. Some environmental resources could be affected by changes in the inundation pattern in the Bypass, and the model will help characterize those potential impacts (including, but not limited to potential impacts to fisheries, socioeconomics, agricultural resources, methylmercury, cultural, and terrestrial resources). The intent of this modeling is to learn about how location, size, and timing of operations of gated inundation channels affect these resources. Using this modeling, the impact analyses will help identify refinements that could be made to the project alternatives in order to avoid and/or minimize impacts or identify which alternatives would be screened out from further consideration in the EIS/EIR. Key follow-on models that depend on the results of the hydrodynamic model are the Agricultural Economic Impact Analysis and Fish Benefits Simulation Model Analysis. Both of these models required unique hydrodynamic modeling data as inputs. The following requirements and outputs of the hydrodynamic model were scoped out with the help of the teams leading the Agricultural Economic Impact Analysis and the Fish Benefits Simulation Model Analysis:

Fish Benefits Simulation Model Analysis

- Daily results of existing conditions and imposed project conditions from 1997-2012 to overlap a period for which fisheries presence data is available from the Knights Landing Rotary Screw Trap.

- Daily flow, velocity, and depth of the Sacramento River from upstream of the Knight Landing Rotary Screw Trap and downstream of the confluence of Sacramento River and the Yolo Bypass.

- Daily flow, velocity, and depths within the Yolo Bypass and or proposed floodplain inundation location.

Agricultural Economic Impact Analysis

- Geographic Information System (GIS) layers of fields within the project area that will indicate the last day the field was wet under existing conditions and with imposed project conditions.

To meet the demands of the EIS/EIR analyses a 1D/2D hydrodynamic model was created using TUFLOW Classic. Comments received on suggested improvements to previous Bypass modeling efforts were incorporated into the new model as appropriate. The TUFLOW Classic model was used to perform hydrodynamic simulations of a sixteen year period from 1997-2012, with a daily time step, for five different project end dates. The simulation outputs were parsed and presented in different formats so they could easily be inserted into the Agricultural Economic Impact Analysis and the Fish Benefits Simulation Model. The standalone hydrodynamic simulation results are not intended to determine impacts to agricultural yields or benefits received to the targeted species. However, the hydrodynamic simulation results have been summarized in this report.

1.3 Background

Significant modifications have been made to the historic floodplain of California‘s Central Valley for water supply and flood damage reduction purposes. The resulting losses of rearing habitat, migration corridors, and food web production for fish have significantly hindered native fish species that rely on floodplain habitat during part or all of their life history. Although the primary function of the Bypass is to receive peak flood flows of Sacramento River Basin water up to 343,000 cubic feet per second (cfs) (DWR 2012b) from Fremont Weir, the Bypass has also been identified by several State and federal entities as a potential site for habitat restoration to ease pressure on and increase benefits to threatened and endangered fish species. The Bypass still retains many characteristics of the historic floodplain habitat that are favorable to various fish species. The Bypass received at least 3,000 cfs and 6,000 cfs for 7 days in approximately 80 percent and 60 percent of years, respectively, between the water years of 1940 and 2011, based on the United States Geological Survey (USGS) Woodland gauge data. Fremont Weir overtopped in approximately 70 percent of years between 1935 and 2012 (DWR 2012b), joining flows from western tributaries.

On June 4, 2009, the National Marine Fisheries Service (NMFS) issued its Biological Opinion and Conference Opinion on the Long-term Operation of the Central Valley Project (CVP) and State Water Project (SWP) (NMFS Operation BO). The NMFS Operation BO concluded that, if left unchanged, CVP and SWP operations were likely to jeopardize the continued existence of four federally-listed anadromous fish species: Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and Southern Distinct Population Segment (DPS) North American green sturgeon. The NMFS Operation BO sets forth RPA actions that would allow continuing SWP and CVP operations to remain in compliance with the federal Endangered Species Act (ESA).

- RPA Action I.6.1: Restoration of Floodplain Rearing Habitat, through the increase of seasonal inundation within the lower Sacramento River basin. The goal of RPA Action I.6.1 is to restore floodplain rearing habitat for juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and California Central Valley steelhead in the Bypass by providing floodplain connectivity that will provide physical habitat conditions that will in turn support juvenile growth and mobility, water quality, and the forage necessary to support juvenile development. The planning and environmental compliance process will consider a reasonable range of alternatives as well as potential operations for implementing this RPA action; and

- RPA Action I.7: Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon, through the modification of Fremont Weir and other structures of the Bypass. The overall goal of RPA Action I.7 is to reduce migratory delays and loss of adult and juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and Southern DPS of green sturgeon at Fremont Weir and other structures in the Bypass. RPA Action I.7 calls for the provision of a reliable means of fish passage through the Bypass. Reducing stranding by means of improved passage would provide ancillary benefits to fish utilizing the floodplain. Under current conditions, in addition to being unable to reach spawning grounds, fish stranded on the Bypass are vulnerable to illegal harvesting by poachers.

2.0 Project Setting

A description of the project setting is provided in the EIR/EIS.

3.0 EIS/EIR Alternatives

3.1 Introduction to Alternatives

The Lead Agencies used the Federal Principles and Guidelines for Water and Land Related Resources Implementation Studies to evaluate and screen a large number of potential alternatives. Information regarding the alternative screening process will be contained within the final EIS/EIR. Alternative criteria and rating scales were developed with coordination and input from various technical teams. The evaluation criteria are:

- Effectiveness: How well an alternative plan would alleviate problems and achieve objectives.
  1. Increase inundation- Inundation area, duration, and timing corresponding to fish presence and percent of fish entrained onto floodplain.
  2. Fish passage- Effective adult fish passage and safe and timely juvenile fish passage.
- Completeness: Whether the alternative plan would account for all investments or other actions necessary to realize the planned effects.
  1. Improvements to all four focus fish species.
- Acceptability: The viability of a comprehensive plan with respect to acceptance by federal, State, and local entities and compliant with existing laws.
  1. Agricultural impacts- Frequency of inundation during agricultural production periods.
  2. Waterfowl impacts- Inundation of recreational areas, available foraging habitat, and food production.
  3. Education impacts- Inundation of areas used for educational outreach.
  4. Biological impacts- Impacts from construction operation.
  5. Compatibility with other related efforts.
- Efficiency: How well an alternative plan would deliver economic benefits relative to project costs.
  1. Relative benefits and costs.

The Lead Agencies decided to first focus on alternatives that could be implemented to provide seasonal floodplain habitat as required per RPA I.6.1 since these alternatives may have a larger footprint and potential impact when compared to the fish passage alternatives for RPA I.7. In addition, the seasonal floodplain habitat structure for RPA I.6.1 may also serve as the primary fish passage location for compliance with RPA I.7. Therefore, the alternatives described in this report only refer to seasonal floodplain habitat alternatives. Fish passage alternatives and elements for compliance with RPA I.7 will be added to the seasonal floodplain habitat alternatives once additional information regarding gate design and fish behavior becomes available.

After a list of preliminary alternatives was screened against the listed evaluation criteria, a smaller subset of alternatives was carried forward for hydrodynamic analysis and is described in greater detail below. Additional alternatives that may arise and that pass screening may need to be modeled at a later time.

3.2 Description of Alternatives

The alternatives consist of different configurations of gates and channels with lower elevations representing “notches” to either Fremont Weir or Sacramento Weir to provide a greater number of juvenile salmonids access to seasonal floodplain habitat in the Bypass. Currently Sacramento River run juvenile salmonids first have access to the Bypass once Sacramento River stage at Fremont Weir is approximately above 32.8 feet North American Vertical Datum 1988 (NAVD88). Sacramento River run juvenile salmonids can also entire the Bypass from Sacramento Weir, which brings flows into the Bypass less frequently than Fremont Weir and typically after Fremont Weir has overtopped (DWR 2012b). By lowering a section of Fremont Weir or Sacramento Weir to allow up to 6,000 cfs to enter the Bypass prior to receiving flows for flood relief purposes, juvenile salmonids will have the opportunity to enter the Bypass earlier and potentially more frequently, thus allowing them to grow at a faster rate than staying in the Sacramento River mainstem where they are subject to predation (Sommer, et al. 2001). The design flow rate was capped at 6,000 cfs through the gated alternatives because this discharge was suggested as a practical limit to balance biological benefits within the overall Sacramento River system (BDCP 2009).

Figure 3-1 illustrates nine potential alignments of alternatives near the Fremont Weir. Only four of these alternatives were selected to be modeled after a screening process. During the screening process it was learned that the alignments on the west side of Fremont Weir and east of the Yolo Bypass would not be cost effective since those alignments go through areas with higher ground elevations resulting in higher construction costs. Based on the assumption that alternatives would behave similarly in capturing water from the Sacramento River and inundation patterns further down the Bypass would be comparable as the modeled flows would not change significantly between alternatives of similar sizes, it was decided that the hydrodynamic performance of alternatives 2a, 2b, 2d, 2e, and 2g could be represented by three alternatives modeled on the east side of Fremont Weir, within the Bypass. The three alternatives to be modeled near the Fremont Weir area are:

Fremont Weir Small – 14.0 feet NAVD88, 20 feet wide bottom width, 3 to 1 horizontal to vertical side slopes

Fremont Weir Medium – 17.5 feet NAVD88, 225 feet wide bottom width, 3 to 1 horizontal to vertical side slopes

Fremont Weir Large – 14.0 feet NAVD88, 225 feet wide bottom width, 3 to 1 horizontal to vertical side slopes

3.2.1 No Action Alternative

For the No Action Alternative, water would behave as it has historically with natural overtopping events at Fremont Weir when the stage in Sacramento River allows. The inundation patterns within the Bypass would remain unchanged and behave as they have historically.

3.2.2 Alternative 2a-Fremont Weir East Small Gated Notch

For Alternatives 2a, (FreSm), water would be diverted from the Sacramento River through a gated notch in Fremont Weir located near the east end of the weir. The configuration consists of a 20-foot bottom width, with 3:1 (horizontal to vertical) side slopes, and an invert elevation of 14.0 feet NAVD88. This alternative has a significantly smaller cross-sectional area than the other alternatives described below and thus would require a higher river stage to allow 6,000 cfs to entire the Bypass than the other alternatives considered. This alternative was designed to have a narrow configuration to lessen or possible eliminate the need for gate operations to limit flows to 6,000 cfs.

3.2.3 Alternative 2b, -Fremont Weir East Medium Gated Notch

For Alternative 2b, 2e, and 2g (FreMed), water would be diverted from the Sacramento River through a gated notch in Fremont Weir located near the east end of the weir. The configuration consists of a 225-foot bottom width, with 3:1 side slopes, and an invert elevation of 17.5 feet NAVD88. Due to the wider configuration of this channel, limiting flows to 6,000 cfs, as the Sacramento River stage rises, would be achieved by opening and closing a series of gates.

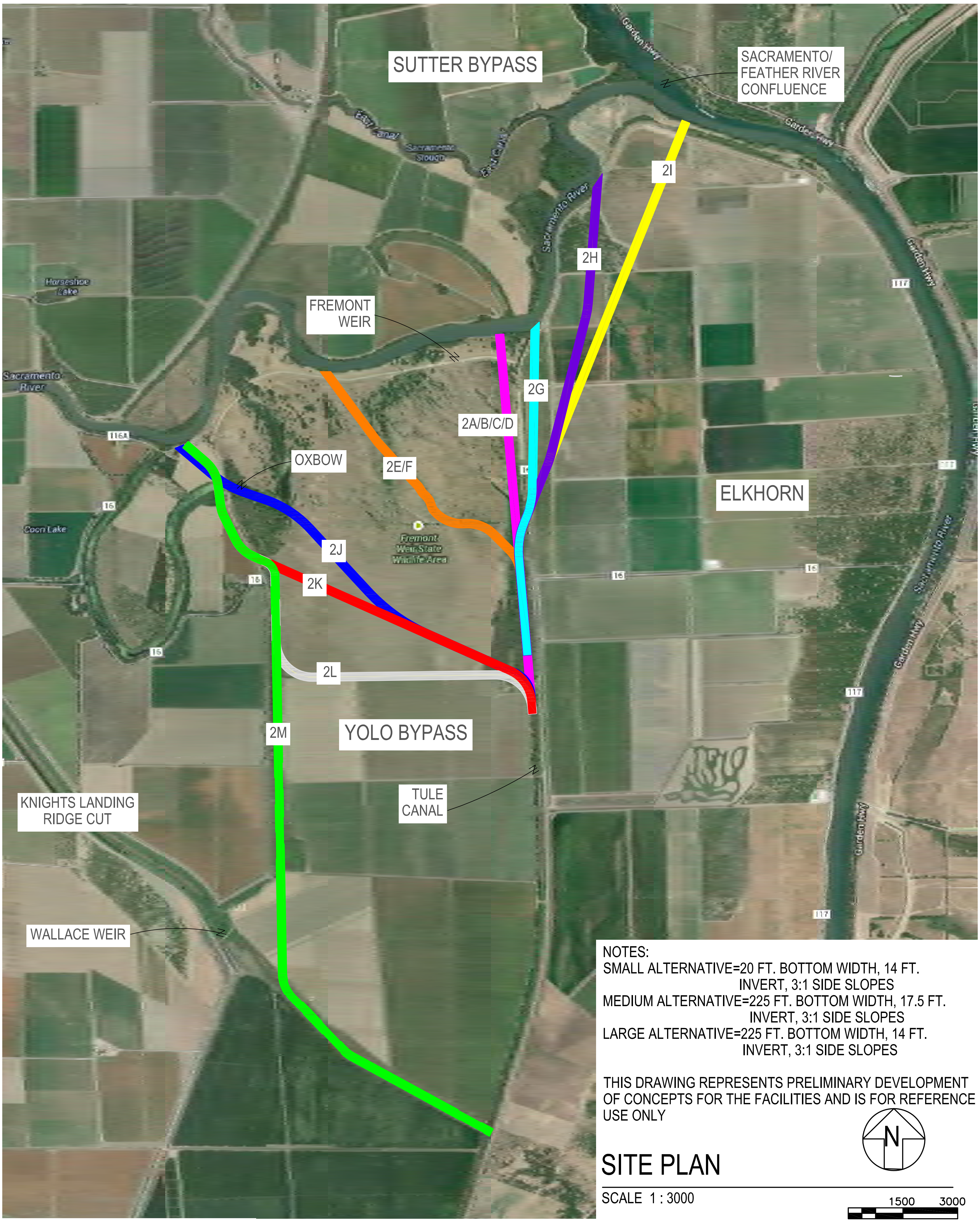
3.2.4 Alternative 2d-Fremont Weir East Large Gated Notch

For Alternative 2d (FreLg), water would be diverted from the Sacramento River through a gated notch in Fremont Weir located near the east end of the weir. The configuration consists of a 225-foot bottom width, with 3:1 side slopes, and an invert elevation of 14.0 feet NAVD88. Due to the wider and deeper configuration of this channel, limiting flows to 6,000 cfs, as the Sacramento River stage rises, would be achieved by opening and closing a series of gates.

3.2.5 Alternative 5b-Sacramento Weir Gated Notch

For Alternative 5b (SacW), water would be diverted from the Sacramento River through a gated notch in Sacramento Weir. The configuration consists of a 225-foot bottom width, with

3:1 side slopes, and an invert elevation of 7.0 feet NAVD88. Due to the wider and deeper configuration of this channel, limiting flows to 6,000 cfs, as the Sacramento River stage rises, would be achieved by opening and closing a series of gates.



NOTES:
SMALL ALTERNATIVE=20 FT. BOTTOM WIDTH, 14 FT. INVERT, 3:1 SIDE SLOPES
MEDIUM ALTERNATIVE=225 FT. BOTTOM WIDTH, 17.5 FT. INVERT, 3:1 SIDE SLOPES
LARGE ALTERNATIVE=225 FT. BOTTOM WIDTH, 14 FT. INVERT, 3:1 SIDE SLOPES

THIS DRAWING REPRESENTS PRELIMINARY DEVELOPMENT OF CONCEPTS FOR THE FACILITIES AND IS FOR REFERENCE USE ONLY

SITE PLAN

SCALE 1 : 3000

1500 3000

LEGEND

- 2A - SMALL ALTERNATIVE, GATED STRUCTURE ON EAST SIDE OF FREMONT WEIR. CHANNEL AND FOOTPRINT WITHIN YOLO BYPASS.
- 2B - MEDIUM ALTERNATIVE, GATED STRUCTURE ON EAST SIDE OF FREMONT WEIR. CHANNEL AND FOOTPRINT WITHIN YOLO BYPASS.
- 2C - SAME AS 2B WITH SUPPLEMENTAL FLOWS FROM RED BLUFF DIVERISON DAM.
- 2D - LARGE ALTERNATIVE, GATED STRUCTURE ON EAST SIDE OF FREMONT WEIR. CHANNEL AND FOOTPRINT WITHIN YOLO BYPASS.
- 2E - MEDIUM ALTERNATIVE, GATED STRUCTURE NEAR CENTER OF FREMONT WEIR. CHANNEL AND FOOTPRINT LOCATED ON AN OUTSIDE BEND OF THE RIVER, MAY BE ABLE TO CAPTURE MORE FISH AND BRING THEM INTO YOLO BYPASS.
- 2F - LARGE ALTERNATIVE, GATED STRUCTURE NEAR CENTER OF FREMONT WEIR. CHANNEL AND FOOTPRINT LOCATED ON AN OUTSIDE BEND OF THE RIVER, MAY BE ABLE TO CAPTURE MORE FISH AND BRING THEM INTO YOLO BYPASS.
- 2G - MEDIUM ALTERNATIVE, GATED STRUCTURE EAST OF FREMONT WEIR CONNECTING TO TULE CANAL WITH NEW SEGMENT OF LEVEE PARALLEL TO CHANNEL & REMOVAL OF EXISTING LEVEE SEGMENT.
- 2H - MEDIUM ALTERNATIVE, GATED STRUCTURE EAST OF FREMONT WEIR CONNECTING TO TULE CANAL WITH NEW SEGMENT OF LEVEE PARALLEL TO CHANNEL & REMOVAL OF EXISTING LEVEE SEGMENT.
- 2I - MEDIUM ALTERNATIVE, GATED STRUCTURE EAST OF FREMONT WEIR CONNECTING TO TULE CANAL WITH NEW SEGMENT OF LEVEE PARALLEL TO CHANNEL & REMOVAL OF EXISTING LEVEE.
- 2J - MEDIUM ALTERNATIVE, GATED STRUCTURE WEST OF FREMONT WEIR CONNECTING TO TULE CANAL WITH NEW SEGMENT OF LEVEE PARALLEL TO CHANNEL & REMOVAL OF EXISTING LEVEE SEGMENT.
- 2K - MEDIUM ALTERNATIVE, GATED STRUCTURE WEST OF FREMONT WEIR CONNECTING TO TULE CANAL WITH NEW SEGMENT OF LEVEE PARALLEL TO CHANNEL & REMOVAL OF EXISTING LEVEE SEGMENT.
- 2L - MEDIUM ALTERNATIVE, GATED STRUCTURE WEST OF FREMONT WEIR CONNECTING TO TULE CANAL WITH NEW SEGMENT OF LEVEE PARALLEL TO CHANNEL & REMOVAL OF EXISTING LEVEE SEGMENT.
- 2M - MEDIUM ALTERNATIVE, GATED STRUCTURE WEST OF FREMONT WEIR CONNECTING TO TULE CANAL WITH NEW SEGMENT OF LEVEE PARALLEL TO CHANNEL & REMOVAL OF EXISTING LEVEE SEGMENT.

DRAWN BY: JU
CHECKED BY:
SHEET:

BAR IS ONE INCH ON ORIGINAL DRAWINGS; ADJUST SCALE FOR REDUCED PLOTS
0 1"
DATE: 02.17.2015

FIGURE 3-1

PRELIMINARY ALTERNATIVE ALIGNMENTS
FREMONT WEIR INUNDATION CHANNEL
CONCEPTUAL LAYOUTS

CALIFORNIA DEPARTMENT OF WATER RESOURCES
YOLO BYPASS SALMONID HABITAT RESTORATION & FISH PASSAGE
3500 INDUSTRIAL BLVD, WEST SACRAMENTO, CA

DEPARTMENT OF WATER RESOURCES STATE OF CALIFORNIA

REVISION NO.	DATE	DESCRIPTION

4.0 Hydrodynamic Model Development

4.1 Hydrodynamic Modeling Software Selection

A core hydrodynamic modeling technical team (CHMTT), comprised of representatives from the Lead Agencies and their hydrodynamic modeling team, worked with the fisheries and engineering technical teams to develop ranking methodology for a scoring matrix to select a two-dimensional (2D) hydrodynamic modeling software program. The scoring matrix provides a qualitative evaluation of several modeling software considered for the Bypass modeling and allows for the evaluation and comparison of model software features and considerations. Following the evaluation, the 2D model software programs were ranked by CHMTT. The scoring was subjective and is based upon CHMTT's experiences with the modeling software or based on information from the software vendor's website. The key features and considerations reflected in the ranking process were grouped into the following three categories: Key Model Software Capabilities, Other Considerations, and Optional Model Software Capabilities.

A hydraulic modeling advisory team (HMAT) assembled by the Lead Agencies, including subject matter experts from various agencies, reviewed the ranking methodology, scoring matrix, and the ranking results of the top four ranked 2D modeling software. A blank modeling software scoring matrix was provided to the HMAT members so they could fill-in scores based on their own experiences with the modeling software. The HMAT members were also requested to answer a questionnaire on what modeling software attributes they deemed most important and least important. The model attributes included: performance, cost, public domain, breadth of user base, and model longevity. Based on the information from the scoring matrix and in the supplemental questionnaires, the HMAT members viewed model performance as the most important attribute of a modeling software. The cost and breadth of user base of a modeling software were viewed to be important as well. This information was then provided to the CHMTT for consideration.

TUFLOW was ranked high along with MIKE 21, SRH, and RiverFLO. TUFLOW was chosen due to its high performance, relative low cost, a growing agency user base, GIS interface, and quick run times. TUFLOW, developed by BMT-WBM, was chosen as it scored high in the HMAT rankings and meets the stringent requirements for the project.

4.1.1 TUFLOW Yolo Bypass Model

The approach selected was to use a single hydrodynamic model to provide data to evaluate benefits and impacts both within the Bypass and for the larger region. The model includes simulation of existing and proposed alternatives during 16 water years, from the months of October through May, and occasionally to June for water years with May or June Fremont Weir overtopping occurrences. TUFLOW is able to meet the challenges of large computational domains and long simulation times by using a combination of 1D channels and multiple grids of varying resolution and an efficient finite-difference solver. Other aspects of TUFLOW include:

- Solves the full 2D shallow water equations
- Numerically stable even with wetting and drying
- GIS inputs and outputs
- Powerful scenario management options
- Computes flows using weir equations automatically when appropriate
- Support for hydraulic structures including operational controls
- License includes technical support

TUFLOW uses an alternating direction implicit finite difference solution scheme to solve the full 2D free surface shallow water flow equations. More information on the solution scheme is available on the TUFLOW website (www.tuflow.com).

The ability of TUFLOW to simulate a combination of 1D and 2D domains allows for coarser cells in the floodplains while maintaining high resolution in channels and was necessary to keep runtimes reasonable. Internally TUFLOW creates boundary conditions at the 1D nodes and 2D cells along the boundary of the domains. The 1D channel is assigned a flow boundary condition and the 2D cells are assigned specified WSE boundary conditions. All flows entering the boundary 2D cells are fed to the associated 1D nodes. The 1D domain incorporates these flows in its calculations. The computed WSEs at the 1D nodes are interpolated back to the 2D cells. This mass conserving approach to connect domains is robust, stable, and accurate (Syme, 1990, 1991).

As part of the computations, TUFLOW analyzes elevations and WSEs of the 2D cells to determine areas experiencing upstream controlled flow such as would exist at roadway or berm features. The broad-crested weir equation (Equation 1) is used to compute flowrates at these locations. In the equation q represents unit flowrate ($ft^3/s/ft$), g represents gravity (32.2 ft/s^2), and H represents the energy head upstream relative to the weir crest (Syme 2001). Weirs become submerged once the downstream H exceeds 0.75 to 0.85 of the upstream H (depending upon the characteristics of the embankment). After the weir becomes submerged the flows are calculated using the shallow water equations.

$$q = \frac{2}{3} H \sqrt{\frac{2}{3} g H} \qquad (1)$$

Additional TUFLOW model parameter values specific to this application are listed in Table 4-1.

Table 4-1. Additional TUFLOW model parameter values

Parameter		Value
Time Step	100-ft grid	6 s
	200-ft grid	12 s
	400-ft grid	12 s
	1D channels	1.5 s
Wet/dry depths	Cell	0.006562 ft
	Cell side	0.003281 ft
Viscosity formulation	Combination Smagorinsky/Constant (see TUFLOW manual)	
	Smagorinsky coefficient	0.6
	Constant viscosity coefficient	0.55

4.2 Model Domain

The model domain (see Figure 4-1) extends along the Sacramento River from River Mile (RM) 118 just south of the Tisdale Bypass near Wilkins Slough to RM 12 near Rio Vista and includes the entire Yolo Bypass. River miles are based on the CVFED HEC-RAS model (described later) and are presumably USACE stationing. The domain extends 7 miles to the north along the Feather River and into the Sutter Bypass. The Feather-Sutter boundary was located far enough to the north of the flow split between the Yolo Bypass at Fremont Weir and the Sacramento River at Verona to minimize model boundary effects at the flow split (and the proposed gated channel at Fremont Weir). The domain includes the Sacramento Weir at RM 63 and extends 22 miles to the east along the American River to just below Nimbus Dam. The domain also includes various North Delta sloughs (i.e., Elk, Sutter, Miner, Steamboat, Haas, Cache, Lindsey, and Barker) and a boundary connection with the Delta Cross Channel and Georgiana Slough at RM 27.

The model domain is comprised of a combination of one-dimensional (1D) channels and 2D grids, which assist in overall computational efficiency (see Figure 4-1). The 1D channels describe the flow of water in the major sloughs, creeks, and rivers bordering or bisecting the flood control bypasses and are represented with a series of cross sections (see Section 4.3.3). The 2D grids describe the flow of water within the flood control bypasses when channel capacity is exceeded, flood control weirs are activated, and restricted height levees are overtopped. A 2D grid was also prepared for the section of the Sacramento River between Knights Landing and Verona to accurately describe the complex hydrodynamics that occur during flood conditions as Sacramento River, Sutter Bypass, and Feather River flows converge and are split between the Yolo Bypass at Fremont Weir and the Sacramento River at Verona.

The TUFLOW model includes three separate 2D grids. Multiple grids were used to vary the cell size spatially to balance required resolution and reduced runtimes. Each grid has elevations at each cell centroid, edge mid-point, and cell corner giving nine elevation values per cell. The grid elevations are assigned within the TUFLOW model based upon a Digital Elevation Model (DEM) and modifications to enforce berm and gully features (see Section 4.3.4).

The cell sizes for the grids are 400 feet-, 200 feet-, and 100 feet-square, which provide elevation values every 200 feet, 100 feet, and 50 feet, respectively. The 200 foot grid covers the majority of the 2D domain. The 100 foot grid represents the section of the Sacramento River between Knights Landing and Verona. The 400 foot grid represents Liberty Island.

4.3 Geometric Data

Elevation data for the 1D channels and 2D grids were prepared from multiple sources (see Table 4-2 and Figure 4-2). The cross section geometry for the 1D channels were derived from a combination of bathymetric and field surveys. The land surface elevations for the 2D grids were derived largely from light detection and ranging (LiDAR) data. The only exception is that elevations for the 100 foot grid for the Sacramento River between Knights Landing and Verona were prepared with LiDAR for the overbanks and cross section interpolation for the channel due to the absence of detailed multibeam data upstream of Verona.

4.3.1 LiDAR

LiDAR data for the Delta and Sacramento valley was collected by DWR (2012) in 2007 and 2008, respectively, and subsequently processed to create hydro-enforced[1] DEMs at a 3.125 foot horizontal resolution on 5000 foot tiles. For the purposes of this project, the DEM tiles were mosaiced and resampled to a 25 foot DEM to create a manageable DEM to read into TUFLOW. The elevation of each raster cell was an average of the 64 (8 in each direction) overlapping cells in the 3.125 foot DEM. The DEM was subsequently updated with bathymetric data (see Section 4.3.2) for Liberty Island to replace the hydro-enforced water surface and for Prospect Island to fill a data void in the LiDAR.

4.3.2 Bathymetry

Bathymetric data was collated from multiple sources and includes a combination of field surveys, single-beam surveys, and multibeam surveys. Multibeam surveys were performed along the Sacramento River between Verona and Clarksburg (DWR 2008a) and between Clarksburg and Walnut Grove (DWR 2010) and were used to describe the below-water portion of 1D cross sections (see Section 4.3.3).

Single-beam surveys augmented with field surveys were performed along multiple channels and were used to describe the below-water portion of 1D cross sections. Liberty Island and adjoining sloughs were surveyed in 2009 by cbec (2011) as part of a modeling study in the Cache Slough Complex. Prospect Island was surveyed in 2011 by WWR (2011) in support of the Prospect Island Tidal Restoration Project. The Tule Canal/Toe Drain north of Lisbon Weir, to include Swanston Ranch check dam (in its degraded condition) was surveyed in 2010 by cbec (2012) as part of a modeling study in the Yolo Bypass. The Tule Canal north of Knights Landing Ridge Cut (KLRC), to include Tule Pond, was surveyed in 2013 by DWR (2013) in

[1] Hydrologic-enforcement (hydro-enforced) of DEMs include modified elevations of artificial impediments (such as road fills or railroad grades) to simulate how man-made drainage structures such as culverts or bridges allow continuous downslope flow.

support of this study. KLRC, Wallace Weir, the three agricultural crossings north of KLRC on the Tule Canal, Swanston Ranch check dam, and Lisbon Weir were surveyed in 2013 by cbec (2014). Putah Creek was surveyed in 2013 by WWR (2013) in support of the Lower Putah Creek Restoration Project. Sacramento Slough and Willow Slough were surveyed by cbec in 2013 as part of this study (see Appendix A). All other channels relied on data collected in 2010 by DWR (2011a).

Table 4-2. Summary of elevation data sources

Coverage Area within Model Domain	Data Source	Year Collected	Method	Stated Accuracy/Resolution	Horizontal Datum	Vertical Datum	Geoid
Complete coverage for entire study	**DWR/CVFED LiDAR (DWR 2012a)**	2008	LiDAR	Hydro enforced HDEM (3.125ftgrid resolution)	Feet, UTM 10N, NAD83.	FeetNAVD88	GEOID 03 South Potterfield draft 09 North
Sacramento River (Verona to Clarksburg)	**DWR/CVFED Multibeam Bathymetry (DWR 2008)**	2008	Multibeam	1 m horizontal and ±0.5 ft vertical at 95%; data filtered to 1 m posting on average	Feet, CA State Plane Zone 2, NAD83.	FeetNAVD88	Not stated
Sacramento River (Clarksburg to Walnut Grove)	**DWR/CVFED Multibeam Bathymetry (DWR 2010)**	2010	Multibeam	3 ft horizontal and ±0.5 ft vertical at 95%; data filtered to 3 ft posting on average	Feet, UTM 10N, NAD83.	Feet NAVD88	GEOID03
Feather R, Sacramento R, Natomas Cross Canal, KLRC, Elk Slough, Steamboat Sl, Miner Sl, Sutter Sl, Georgiana Sl, Lindsey Sl, Cache Sl, Hass Sl, American R, Sacramento Deep Water Ship Channel	**CVFED Single-beam Bathymetry (DWR 2010)**	2010	Single-beam	6 ft horizontal and ± 0.5 ft vertical at 95% for depths < 15 ft; 12 ft horizontal and ± 1 ft vertical at 95% for depths > 15 ft; transects spaced 900 ft to 1800 ft apart	Feet. UTM 10N. NAD83.	Feet NAVD88	NROS-2
Fremont Weir, Tule Pond, Tule Canal north of KLRC	**DWR Bathymetry (DWR 2013)**	2013	Single-beam/RTK	Not stated	Feet, CA State Plane Zone 2, NAD83.	Feet NAVD88	GEOID09

Coverage Area within Model Domain	Data Source	Year Collected	Method	Stated Accuracy/Resolution	Horizontal Datum	Vertical Datum	Geoid
Lower Putah Creek within Yolo Bypass Wildlife Area	**WWR Bathymetry (WWR 2013)**	2013	Single-beam	±3ft horizontal, ±0.5ft vertical	Feet, CA State Plane Zone 2, NAD83.	Feet NAVD88	GEOID09
Tule Canal, Toe Drain	**cbec Single-beam Bathymetry (cbec 2012)**	2010	Single-beam	±3ft horizontal, ± 0.5ft vertical	Feet, CA State Plane Zone 2, NAD83.	Feet NAVD88	GEOID09
Knights Landing Ridge Cut	**cbec Bathymetry (cbec 2014)**	2013	Single-beam	±3ft horizontal, ± 0.5ft vertical	Feet, CA State Plane Zone 2, NAD83.	Feet NAVD88	GEOID12a
Sacramento Slough, Willow Slough	**cbec Bathymetry (see Appendix A)**	2013	Single-beam	±3ft horizontal, ± 0.5ft vertical	Feet, CA State Plane Zone 2, NAD83.	Feet NAVD88	GEOID12a
Liberty island, Little Holland Tract, Toe Drain, Stair Step, Cache Slough, Shag Slough, Prospect Slough, Liberty Cut	**cbec Single-beam Bathymetry (cbec 2011)**	2009	Mixed-RTK, Single-beam, Total Station	USACE Class 1 hydrographic survey[1]; transects spaced 300 ft to 1,000 ft apart	Feet, CA State Plane Zone 2, NAD83.	Feet NAVD88	GEOID03
Prospect Island	**WWR Bathymetry (WWR 2011)**	2011	Mixed-RTK, Single-beam, Total Station	Not stated	Feet, CA State Plane Zone 2, NAD83.	Feet NAVD88	GEOID09
[1] USACE Class 1 Hydrographic survey: 6 ft horizontal and ± 0.2 ft (± 0.4 ft) vertical at 63% (at 95%) for depths < 15 ft 6 ft horizontal and ± 0.5 ft (± 1 ft) vertical at 63% (at 95%) for depths > 15 ft							

4.3.3 1D Cross Sections

Cross-sections outside of the Yolo Bypass were trimmed versions of cross-sections obtained from a draft Central Valley Floodplain Evaluation and Delineation (CVFED) HEC-RAS model (CVFED 2013). The cross-sections within the Yolo Bypass were developed for this project based upon elevation and bathymetric data identified in Section 4.3.Both sets of cross sections were prepared from the data described in Section 4.3.1 and Section 4.3.2.

4.3.3.1 CVFED HEC-RAS Derived Cross Sections

The CVFED HEC-RAS model's reaches and cross-sections were converted into TUFLOW channels and cross-sections using a combination of TUFLOW utilities, ArcGIS geo-processing scripts, and manual editing. The cross-sections were trimmed to restrict flows to the area between the levees. The geometry conversion included cross-section geometry, channel alignments, and Manning roughness coefficients. Hydraulic structures such as bridges and piers were not converted and are not represented in the model. In general, most bridges decks are out of the flow field and localized losses from these structures were not significant to capture in a large scale study. Adjustments to Manning roughness coefficients or other modeling parameters during model calibration helped to compensate for losses not captured at structures when looking at far field effects.

Some modifications were made to individual cross-sections to improve numerical stability. Significant differences in cross-section geometry between neighboring cross-sections can be a source of numerical instability unless represented by a hydraulic structure. Large changes in channel inverts can also introduce instabilities particularly during the early (warm-up) portion of the model. To reduce numerical instabilities, especially where neighboring cross-section invert elevations differed significantly, narrow pilot channels were added. The pilot channels were kept narrow to prevent excessive changes to the channel area. The change in channel area for most of the modified cross-sections was less than 3 percent at bank-full conditions.

4.3.3.2 Non-CVFED HEC-RAS Cross-Sections

Non-CVFED HEC-RAS model cross-sections were generally derived from a combination of bathymetric data below the water line and LiDAR data in the overbanks. Cross-sections extracted from the elevation data extended to the crowns of bounding restricted height-features (e.g., KLRC and Putah Creek), or in the case of Tule Canal/Toe Drain, from the east levee crown to the western edge of the riparian zone along the right overbank. Due to riparian or vegetation returns not completely filtered from the LiDAR data, the cross-sections were extended through the riparian zone to the landward edge of the riparian zone to open ground or a visible berm. The purpose of keeping the riparian zone within the 1D channels was to allow flows into the 2D domain at the appropriate water surface elevation (WSE) which is controlled by the 2D cell elevations along the 1D/2D interface.

The locations of extracted cross-sections were carefully chosen along the channels to avoid aquatic vegetation returns in the single-beam bathymetry data. Aquatic vegetation was observed to be especially problematic in the Tule Canal north of KLRC where the water is slow-moving in the summer time and creates ideal growing conditions for aquatic vegetation.

4.3.3.3 Additional Nodal Storage

Within a 1D/2D model, 2D cells within a 1D domain are removed from the 2D domain and 2D cells that intersect the edge of the 1D domain are treated as boundary condition cells as discussed in Section 4.1.1. Storage in the boundary conditions cells are removed from the 2D domain and partially captured in the 1D cross sections for the portion of the 2D cells overlapping the 1D domain. As such, the total storage for the system may be underrepresented in a combined 1D/2D model particularly when using coarse 2D cells and narrow 1D channels as storage for the portion of 2D boundary cells not overlapping the 1D domain is ignored.

In addition, some locations along 1D/2D boundaries within the Yolo Bypass were susceptible to numerical instabilities and created WSE oscillations at high flowrates largely due to the difference in time steps between the 1D and 2D domains. The TUFLOW manual states that adding additional storage to 1D nodes is an acceptable approach to stabilize 1D nodes but may attenuate the model results. Nodal storage was explored using two methods to enhance model stability at 1D/2D interfaces, either specifying a percent increase in nodal volume over the entire flow depth of the cross section or by modifying the cross section geometry at specific elevations. By specifying a percent increase through a storage multiplier, flow attenuation was observed, which led to a preference to apply the latter approach. For example, the cross section geometry of 1D-channels in the Yolo Bypass was modified at specific locations along the 1D/2D interface for elevations above the elevation of the 2D floodplain to limit the influence of nodal storage to higher Yolo Bypass discharges.

Widening cross-sections to provide additional storage helped to minimize instabilities at 1D/2D boundaries. Points were added to the end of the cross-sections. The first point added to the cross-section was assigned an elevation one foot higher than the highest endpoint elevation so new storage would be limited to floodplain flows. The last point added to the cross-section was assigned an elevation 15 ft higher than the first point so the maximum additional storage would only be realized in very large floods. The cross-sections that were widened are shown in Figure 4-3.

In addition to widening cross-sections, some 1D nodes were assigned storage multipliers as shown in Figure 4-4. Nodes were assigned additional storage because they encountered instabilities due to transitions between 1D/2D domains, proximity to hydraulic structures, or were connected to narrow channels perpendicular to floodplain flows (e.g., Putah Creek).

Adding additional storage has the potential to attenuate flood hydrographs. This was minimized by limiting storage multipliers to select locations and limiting the majority of added storage after reaching flood stage. A cross-section with an original width of 300 ft is widened to 600 ft gradually increasing the storage after the floodplain was activated. The calibration models verify that the storage changes do not significantly attenuate flood hydrographs.

4.3.4 Adjustments to Geometry

The Yolo Bypass includes many features, such as roads, field berms, ditches, drains, and culverts, that impact how water moves through the Bypass. A complete accounting for all such features is beyond the scope of this analysis but significant features were included that influence wetting and drying of the floodplain. To represent these features in TUFLOW, the crown and thalweg profiles of berms (road and field berms) and gullies (ditches and drains) were restamped into the sampled DEM to overcome data loss and surface smoothing when resampling to a coarser resolution (e.g., 200 foot grid).

The berm features were originally delineated in GIS using an automated method that was adapted for this project. The delineation approach was based upon the hydrology GIS tools for delineating streams after inverting the DEM elevations to make berm features appear like channel features. The delineation process included an automated cleanup step that removed minor berms. The automated method correctly identified significant berms, but did not always capture complete berms, often leaving gaps in the berms. Figure 4-5 shows the automated delineation results for a section of the Bypass around Interstate 80 (I-80).

During the 2010 low-flow and 2011 flood-recession calibrations, the wetting and draining of Yolo Bypass were evaluated by modifying the berm density, adding drainage features, and analyzing the elevations along the 1D/2D interface. Relative to the 200-foot grid cell size, capturing all of the interior field berms (e.g., rice checks internal to field units) proved to significantly affect field-by-field drainage by ponding shallow water for too long. As such, the field berms were limited to those berms and road features along the field perimeters.

It was further determined that primary drainage features external to the fields were needed to drain the individual fields to allow ponded water to enter/exit the Tule Canal/Toe Drain and/or westside canals. In lieu of detailed cross-section information describing the numerous drainage features and hydraulic structures (e.g., culverts, flap gates, pumps), primary irrigation supply and drainage features within the Yolo Bypass were digitized (see Figure 4-6), whereby elevations were assigned from the native 3.125 foot hydro-enforced DEM. Due to grid cell size constraints, the digitized drainage features were 200-foot-wide rectangular channels with channel inverts often derived from ponded water elevations within the LiDAR. To offset the overly wide drainage features and lack of flow impediments along their length, layered flow constrictions were implemented in TUFLOW at the drainage feature connections along the Tule Canal/Toe Drain, where hydraulic structures exist, to partially restrict conveyance into and off of the Yolo Bypass. In addition, small drainage ditches connecting the field interiors to the primary drainage features, often via small culverts, were created by adding 600-foot-long drainages that cut a 200-foot-wide swath across the field perimeter features (see Figure 4-6).

The final drainage feature that was evaluated was the 1D/2D interface (TUFLOW HX boundary) between the Tule Canal/Toe Drain and Yolo Bypass. The HX boundary was digitized along the landward edge of the riparian zone in open ground (typically north of I-80) or on top of a visible berm (typically south of I-80). Due to the potential of an agricultural berm being obscured within the riparian corridor north of I-80, the HX boundary elevations along the Tule Canal were tested by raising the HX elevations a maximum of two feet between the drainage feature connections. The tests revealed that there were insignificant changes in the water surface profiles along the Tule Canal/Toe Drain, thus there was no need to refine the HX boundary.

4.3.5 Horizontal and Vertical Datum

All of the model data is referenced to the horizontal North American Datum 1983 (NAD83) Universal Transverse Mercator (UTM) Zone 10. The input and output elevations are referenced to NAVD88.

Some small pockets of supplemental bathymetric and topographic data collected over the years for various projects were incorporated into the CVFED LiDAR data for the hydrodynamic modeling efforts. Based on a conference call with the CVFED LiDAR contractors, it was agreed that as long the data to be stitched into the CVFED LiDAR data set was in vertical datum NAVD88, it could be inserted directly into the LiDAR set without any GEOID conversions.

4.4 Hydrological Data

Long term daily average hydrologic data was prepared for water years 1997 through 2012 to serve as upstream boundary conditions for the TUFLOW model while the downstream boundary was 15-minute tidally driven stage. Data collection and estimation efforts relied on:

- Readily available flow or stage data at the stream gauges along the waterways to be modeled. The gauge information was compiled from a variety of sources such as USGS, California DWR, BOR, County of Sacramento, and Solano County Water Agency (SCWA).
- Where data was not available, flows were estimated using computer/spreadsheet models, estimation techniques, or information in previous studies.

Table 4-3 provides a list of boundary conditions and summarizes data sources used to obtain flow and stage data. Figure 4-1 shows the extents of the hydrodynamic model domain and boundary locations that informed the model.

Table 4-3. Summary of model boundary condition data

Boundary Location	Data Source	Data type[2]
Upstream Boundaries		
Sacramento River inflow below Wilkins Slough near Grimes	USGS 11390500	Gauged flow
Knights Landing Outfall Gates inflow	DWR A02945	Gauged flow
Feather River and Sutter Bypass inflows	This study[1]	Estimated flow based on data from USGS 11390500, USGS 1142500, A02930, A02945, Arcade Creek/EMC02 gauges
Natomas Cross Canal inflow	This study[1]	Estimated flow based on data from Arcade Creek/EMC02 gauge
Sacramento Weir inflow	USGS 11426000	Gauged flow
Westside Tributaries		
Knights Landing Ridge Cut inflow	DWR A02930 and this study[1]	Gauged flow and estimated flow based on data from A02976, A02945 and A02930 gauges
Cache Creek Settling Basin inflow	This study[1]	Estimated flow based on data from USGS 11452500 gauge
Willow Slough Bypass inflow	Yolo Bypass Management Strategy	Estimated flow
Putah Creek inflow	Yolo Bypass Management Strategy	Estimated flow based on BOR reservoir operations data
American River		
American River inflow	USGS 11446500	Gauged flow
Steelhead Creek (formerly called Natomas East Main Drainage Canal) inflow	This study[1]	Estimated flow from City of Sacramento's Arcade Creek/EMC02 gauge
Delta Sloughs		
Delta Cross Channel and Georgiana Slough outflow	DWR's Dayflow program	Gauged flow and estimated flow
Haas Slough, Cache Slough, Barker Slough, and Calhoun Cut	This study[1]	Estimated flow based on data from DWR's UCS and BKS and SCWA's DOP and LSHB gauges
North Bay Aqueduct	DWR's Dayflow program	Gauged flow and estimated flow

Boundary Location	Data Source	Data type[2]
	Downstream Boundary	
Rio Vista downstream stage	DWR B91212	Gauged stage[3]

Notes:
[1] Estimated as a part of the current study and largely relying on verification of local gauge records and extrapolation for the period of analysis
[2] Time series data for daily flows (in cfs) and stages (in feet, NAVD88) were compiled in HEC-DSS, converted to an hourly time step to maintain daily average conditions in TUFLOW, and exported to CSV.
[3] Rio Vista stage is in feet, USED prior to October 1, 2005; and feet, NAVD88 thereafter.

4.4.1 Modeling Period of Record

The Fremont Weir overtopping events were initially gauged in 1968, which is also after the majority of the major reservoirs in the Sacramento River watershed were in operation, providing 44 years of comparable hydrology data through 2012 (CALFED 2001). In order to reduce model runtimes to a reasonable level (not excessively long) and to be consistent with the period when fisheries data is available for the fish benefits model, it was decided to model the 16 year period from water year 1997 through water year 2012. This period has a similar breakdown of water year types based upon a water-year classification system that provides a means to assess the amount of water originating in a hydrologic basin.

The Sacramento Valley 40-30-30 Index was developed by the State Water Resources Control Board (SWRCB) for the Sacramento hydrologic basin as part of SWRCB's Bay-Delta regulatory activities. The classification system defines:

- one "wet" year classification
- two "normal" classifications (above and below normal)
- and two "dry" classifications (dry and critical)

Using the classification standard recognized by SWRCB, a comparison of classifications for the 44years versus the 16years was performed and the results are shown in Figure 4-7.

As seen in Figure 4-7, the 16 years of data selected resemble a similar classification as the 44 years of historical data since Fremont Weir overtopping has been measured, suggesting that using the 16 years of data provides an appropriate surrogate for the longer term record. Also, using the most recent 16 years of hydrology data would reflect recently built structures and recent operations of the system as well as relatively recent climate trends.

For consistency with the fish benefits model and for efficiency, using the most recent 16 years of data across multiple analysis processes was preferred.

4.4.2 Boundary Locations

The following sections describe in greater detail the source data for the boundary locations summarized in Table 4-3. Source data based on direct use of published gauge data are described in brevity whereas source data based on estimation techniques applied in this analysis are described at length.

4.4.3 Sacramento River Near Grimes

Daily inflows along the Sacramento River below Wilkins Slough near Grimes were obtained from USGS stream gauge 11390500. This location is also just downstream of the Tisdale Bypass which diverts nearly half of the flood waters from the Sacramento River into the Sutter Bypass.

4.4.4 Knights Landing Outfall Gates

Daily inflows from Colusa Basin Drain to the Sacramento River via Knights Landing Outfall Gates (KLOG) were obtained from DWR's Water Data Library gauge A02945.

4.4.5 Feather River and Sutter Bypass

Due to the absence of flow gauges along the Feather River (FEA) and Sutter Bypass (SUT) in the vicinity of their confluence (see Figure 4-8), daily flows were estimated using the following mass balance relationship at their confluence (Method #1) based on gauge data downstream of their confluence (see Area #1 in Figure 4-8):

$$(FEA + SUT)_1 = (VON + FRE) - (WLK + KLOG + NCC)$$

where:

- $(FEA + SUT)_1$ are the summed daily flow at the Feather River and Sutter Bypass confluence for Area #1 (see Figure 4-8)
- VON are the daily flows for the Sacramento River at Verona obtained from USGS gauge 11425500
- FRE are the daily flows for Fremont Weir Spill into Yolo Bypass obtained from DWR's Water Data Library gauge A02930 until September 2003 and from DWR's California Data Exchange Center gauge FRE from October 2003 to September 2012.
- WLK are the daily inflows for the Sacramento River below Wilkins obtained from USGS gauge 11390500 and translated to Verona using a time delay of one day. The time delay was based on a typical flow velocity of 2.5 feet per second (fps) as derived from the CVFED HEC-RAS model.
- KLOG are the daily inflows from Colusa Basin Drain to the Sacramento River via Knights Landing Outfall Gates obtained from DWR's Water Data Library gauge A02945.
- NCC are the daily flows for Natomas Cross Canal as estimated from Steelhead Creek (formerly known as Natomas East Main Drainage Canal [NEMDC]) flows, which are discussed in Section 0 in more detail.

The estimated daily flows for the Feather River (FEA) and Sutter Bypass (SUT) using Method #1 were validated using the following mass balance relationship (Method #2) based on gauge data upstream of their confluence (see Area #2 in Figure 4-9):

$$(FEA + SUT)_2 = (GRL + MRY + BRW) + (BSL + TIS)$$

where:

- $(FEA + SUT)_2$ are the summed daily flow at the Feather River and Sutter Bypass confluence from Area #2 (see Figure 4-9)
- GRL are the daily flows for the Feather River at Gridley obtained from DWR's Water Data Library gauge A05165. The flows were translated using a time delay of 1 day based on a typical flow velocity of 3.0 fps derived from the Lower Feather River Corridor Management Plan (cbec 2013).
- MRY are the daily flows for the Yuba River near Marysville obtained from USGS gauge 11421000. The flows were translated using a time delay of 0.5 days based on a typical flow velocity of 3.5 fps derived from the Lower Feather River Corridor Management Plan (cbec 2013).
- BRW are the daily flows for the Bear River near Wheatland obtained from USGS gauge 11424000. The flows were translated using a time delay of 0.5 days based on a typical flow velocity of 2.5 fps derived from the Lower Feather River Corridor Management Plan (cbec 2013).
- BSL are the daily flows for Butte Slough near Meridian on the Sutter Bypass obtained from DWR's Water Data Library gauge A02972. The flows were translated using a time delay of 1 day based on a typical flow velocity of 2.0 fps derived from the Lower Feather River Corridor Management Plan (cbec 2013).
- TIS are the daily Tisdale Weir spills into the Sutter Bypass near Grimes obtained from DWR's Water Data Library gauge A02960. The flows were translated using a time delay of 0.5 days based on a typical flow velocity of 2.0 fps derived from the Lower Feather River Corridor Management Plan (cbec 2013).

Daily flows from Wadsworth Canal to Sutter Bypass were not accounted for during the flow validation as flow data was not available. Figure 4-9 presents the time series comparison of estimated daily flows at the Feather River and Sutter Bypass confluence using the mass balance methods described above. Figure 4-10 shows a scatter plot of the estimated flows shown on Figure 4-9. Given the potential uncertainty in gauged flows (i.e., rating curve error and hysteresis, lack of gauged inflows for Wadsworth Canal, and inflow estimation for Natomas Cross Canal) and simplified routing (i.e., translation) for purposes of these calculations, it is shown that Method #1 reasonably predicts the inflow at the Feather/Sutter model boundary as validated by Method #2. Method #1 inflows will be used in the TUFLOW model because it directly uses measured flows at Fremont Weir and Verona. However, the flow split between the Feather River and Sutter Bypass will be based on Method #2.

4.4.6 Steelhead Creek

Steelhead Creek was formerly known as the Natomas East Main Drainage Canal (NEMDC). Two stream gauges (see Figure4-11), one along Steelhead Creek and one at the confluence of Arcade and Steelhead creeks, were used to generate daily flows along Steelhead Creek to the Sacramento River. While the City of Sacramento operates these stream gauges, the long-term data is maintained by the County of Sacramento. The gauge along Steelhead Creek (NEMDC [C04]) is located just upstream of the West El Camino Avenue bridge and is the most downstream gauge with stage data and measured flows from the entire watershed. However, the stage data appears unreliable due to no observed stage variation even during known storm events. Therefore, the gauge at the confluence of Steelhead and Arcade creeks (Arcade Creek/EMD C02), located approximately 0.6 miles upstream of NEMDC (C04), was used for developing daily flows for Steelhead Creek. This gauge had two sensors that recorded stage: sensor 1691 located on the Arcade Creek side of the levee crossing and sensor1692 located on the Steelhead Creek side of the levee crossing.

DWR's Division of Environmental Service (DES) has evaluated and computed Steelhead Creek daily flows for a water quality investigation study (DWR 2008b) from July 2001 to December 2006. The study found that the real time stage data for the Arcade Creek gauge correlated very closely with the Steelhead Creek gauge at the West El Camino Avenue Bridge leading to the development of an equation that relates the two stage datasets. The study also developed a stage-discharge rating curve that can be used to convert computed stage data at Steelhead Creek gauge to flows.

The rating curve developed in the water quality investigation study was limited to a stage of 25.5 feet, which corresponds to a flow of 6,024 cfs. cbec extended the rating curve to include flows for higher stages based on the historic peak flows developed by US Army Corps of Engineers (USACE) for the American River Watershed Common Features Project for Natomas Basin (USACE 2010). The estimated peak flows and 5-day volumes for four events during the time period of interest are summarized in Table 4-4. Peak flows for the New Years 1997, February 1998 and New Years 2006 storm events were used to extend the rating curve using stage data estimated based on Arcade Creek stage as discussed before. Other events were excluded due to the lack of stage data. Figure 4-12 shows the updated rating curve for Steelhead Creek. Table 4-5 summarizes the data used to develop daily time series flows for Steelhead Creek.

The Arcade Creek stage data from both the sensors was not reported for the following periods:

- February 1997
- August- September 1997
- January - May 2001
- August - September 2008
- mid August - September 2012

The flows for the periods above were set to an observed minimum flow of 23.8 cfs. This is a valid assumption during low flow periods of August to September 1997, August to September 2008 and mid-August to September 2012. For the remaining periods, flows generated from rainfall events are likely underestimated using this simplistic assumption but they were also set to 23.8 cfs for this analysis.

The flows along Steelhead Creek will likely be influenced by backwater from high flows in the Sacramento River. The potential impact of backwater effects in estimating daily flows was not refined as part of this analysis.

Table 4-4. Peak flows and 5-day volumes for Natomas Cross Canal to Steelhead Creek for historic floods

Tributary	Area (ac)		Feb 1986	Jan 1995	NY 1997	Jan 1997	Feb 1998	NY 2006	Avg
Steelhead Creek (NEMDC)	188.32	5-day vol (ac-ft)	58,300	45,700	27,500	41,600	37,500	27,600	---
		Peak flow (cfs)	14,060	17,840	8,470	11,300	11,050	10,860	---
Natomas Cross Canal (NCC)	288.22	5-day vol (ac-ft)	89,800	72,900	42,500	54,300	49,500	35,000	---
		Peak flow (cfs)	30,700	43,000	16,100	23,200	20,800	21,300	---
Ratio	1.53		1.54	1.60	1.55	1.31	1.32	1.27	**1.43**

Table 4-5. Data used for generating daily flows along Steelhead Creek

Time Period	Data Available	Source
October 1996 – December 2000	Recorded stage (ft, NGVD 29) for the sensor 1691[1,2]	Sacramento County Department of Water Resources
January 2001 – December 2006	Computed daily flows along the Steelhead Creek[2,3]	DWR's Municipal Water Quality Investigations Section
January 2007 – September 2012	Recorded stage (ft, NGVD 29) for the sensor 1692	Sacramento County Department of Water Resources

Notes:
[1] Stage data at sensor 1691 was found to be unreliable for the time period. Therefore, stage data at sensor 1692 was used instead.
[2] The recorded stage was first converted to stage at NEMDC (C04) using published correlation and then converted to flows using the updated rating curve.
[3] Computed flow data for stages exceeding 25.5 ft was replaced using the updated rating curve (this study).

4.4.7 Natomas Cross Canal

As detailed in Section 4.4.6, the American River Watershed Common Features Project for Natomas Basin (USACE 2010) provides peak flows and 5-day volumes during historic floods. Ratios of 5-day volumes for Natomas Cross Canal to Steelhead Creek were computed and summarized in Table 4-4. Using an average scaling factor of 1.43, the NCC daily flows were derived as follows:

NCC = 1.43 x NEMDC

4.4.8 Westside Tributaries

The Yolo Bypass receives its primary inflows from four major tributaries separate from the Fremont Weir and the Sacramento Weir:

- Knights Landing Ridge Cut
- Cache Creek Settling Basin
- Willow Slough Bypass
- Putah Creek

As part of the Yolo Bypass Management Strategy (Management Strategy) prepared by Jones & Stokes (2001), measured and estimated hydrology for the flood control weirs and Westside tributaries was compiled for water years 1968 through 1998. cbec extended this data set through water year 2012 using measured data and refinements to the Management Strategy flow estimation techniques (this study). Refinements to the estimated flows for the Westside tributaries (see Figure 4-13) are discussed in the following sections.

4.4.8.1 Knights Landing Ridge Cut

Gauged flow data for Ridge Cut Slough at Knights Landing (RCS) is available starting December 7, 2006 from DWR's Water Data Library for gauge A02930. This data was used to develop daily flows through water year 2012. However, due to lack of gauged data for prior years, those flows had to be estimated. One option for estimating KLRC flows was to use the current equation described in the Management Strategy. Per the Management Strategy, daily KLRC inflow to the Yolo Bypass was estimated by subtracting outflows from Colusa Basin Drain to the Sacramento River via the KLOG as measured by gauge A02945, from gauged flow for Colusa Basin Drain at Highway 20 (CDR) per gauge A02976 that was scaled up to account for the entire watershed area. This daily calculation is only performed if the rainfall rates at Colusa exceed 0.3 inches per day; otherwise the estimated KLRC inflow value falls to zero (Jones & Stokes 2001). The rainfall data used was obtained from the California Irrigation Management Information System (CIMIS) Colusa station. The calculation procedure is represented using the following logic.

If: rainfall rates at Colusa CIMIS station > 0.3 inches per day,
Then: Estimated KLRC daily inflow = $(130.4/107.7)^* \, CDR_{obs} - KLOG_{obs}$
Else: Estimated KLRC daily inflow = 0

The second option involved the development of a new regression equation based on correlation between gauged flows at Colusa Basin Drain near Highway 20 (A02976) and estimated daily flows just upstream of the Colusa Drain split to Ridge Cut Slough computed as sum of gauged flows at KLOG (A02945) and RCS (A02930), referred herein as (RCS + KLOG). The flows along Colusa Drain during non-wet season are influenced by the Davis Weir and agricultural water uses (typically April 1 to mid-October). Therefore, only the wet season flows (November 1 to March 31) were used for the analysis. A time delay of 1 day between Highway 20 and KLRC was incorporated into the CDR flows for comparison to the RCS + KLOG flows. The time delay was based on a typical flow velocity of 2.5 fps as derived from the CVFED RAS model.

Figure 4-14 shows the scatter plot of estimated daily flow at the Colusa Basin outlet $(\text{RCS + KLOG})_{pred}$ to the flow at Highway 20 (CDR). This figure indicates a strong correlation for the lower flows with a weaker correlation for higher flows due to greater hysteresis. The RCS gauge manager revealed that the rating curve for the RCS gauge was based on measured flows within the channel of up to 1,600 cfs and extrapolated for higher flows that flow over the banks onto the floodplain. Two power curves were fitted to the data, one representing flows less than 3,400 cfs at CDR and one for flows greater than 3,400 cfs. The transition between the two curves corresponds to RCS channel capacity of 1,600 cfs. The equations are provided on Figure 4-14. Daily inflows to KLRC prior to December 2006 were computed as follows:

$$\text{KLRC} = (\text{RCS} + \text{KLOG})_{pred} - \text{KLOG}_{obs}$$

Figures 4-15,4-16, and 4-17 compare the KLRC inflows estimated for water years 2010, 2011, and 2012 using the Management Strategy (option 1) and the new regression equation (option 2). The new equation provides a better estimate of the low flows entering the Yolo Bypass from the Colusa Basin via KLRC during the wet season that would otherwise default to zero inflow per the Management Strategy in the absence of rainfall. As such, the new regression equation will be used to estimate KLRC inflows to the Yolo Bypass prior to December 2006 and RCS observed flows will be used post December 2006.

4.4.8.2 Cache Creek Settling Basin

As described in the Management Strategy, inflows to the Yolo Bypass from Cache Creek are gauged by the USGS near Interstate 5 at long-term gauging station Cache Creek at Yolo (USGS ID 11452500 [CDEC ID: CCY]). While the Management Strategy notes that no significant tributaries or diversions exist downstream of this gauge, the timing and magnitude of inflows to the Yolo Bypass are likely affected by storage in the Cache Creek Settling Basin (CCSB) located adjacent to the western edge of the Yolo Bypass.

Therefore, the flows measured at CCY were transformed with basic routing to account for storage and attenuation in the CCSB. The storage routing was performed in this study using a HEC-HMS (HMS) model developed to represent CCSB and its outlet works consisting of an overflow weir and low flow outlet. The storage-volume curve and overflow weir geometry were based on the CVFED HEC-RAS model. cbec surveyed the upstream sill elevation for the low flow outlet works while the downstream invert elevation was based on Cache Creek Settling Basin Final General Design Memorandum (USACE 1987).

The tailwater of the low flow outlet will be influenced by an incised channel downstream of the outlet works. The incised channel has a scour pool followed by a shallow earthen sill at elevation 18.3 feet NAVD88 that could create a tailwater pool for the low flow outlet. In the absence of floodplain inundation in the Yolo Bypass exceeding this elevation, the tailwater pool affects outflow from the CCSB low flow outlet works. Tailwater stage for the low flow outlet was therefore assumed to be the higher of the sill elevation or the stage at Yolo Bypass Woodland as determined from measured flow and a rating curve at USGS gauge 11453000.

Limited validation of the modeled outflows was conducted by comparison to observed inflow into the CCSB using USGS gauge 11452600 and observed total outflow from the CCSB using USGS gauge 11452901 (which was installed in February 2009). Figures 4-18, 4-19 and 4-20 show a comparison of the gauged inflows, gauged outflows, and the modeled outflows for rainfall events in 2009, 2010, and 2011, respectively. These figures demonstrate that the HMS model of the CCSB does reasonably attenuate inflows through the CCSB. Peak inflows during larger rainfall-runoff events are reduced as they pass through the CCSB and smaller rainfall-runoff events are stored and slowly released into the Yolo Bypass.

4.4.8.3 Willow Slough Bypass

The equations from the Management Strategy were used to estimate Willow Slough Bypass daily inflows. As described in the Management Strategy (Jones & Stokes 2001), Willow Slough has not been gauged during the historical record. Instead, historical hydrology was estimated by correlating Willow Slough flow with gauged runoff in the Interdam Reach (between Lake Berryessa and Lake Solano) of Putah Creek adjusted for drainage area. The daily flows were computed through water year 2012.

4.4.8.4 Putah Creek

The equations from the Management Strategy were used to estimate Putah Creek daily inflows. The Management Strategy estimated inflows to the Yolo Bypass from Putah Creek are based on release and spill at Monticello Dam and Putah Diversion Dam. During times of no active rainfall-runoff (Condition 1), or if Monticello Dam is spilling (Condition 3), inflow to the Yolo Bypass equals Putah Diversion Dam releases minus 30 cfs for seepage and evapotranspiration losses. When there is active rainfall-runoff (Condition 2), defined as Interdam Runoff in excess of 100 cfs, then inflow to the Yolo Bypass equals two times the Putah Diversion Dam releases minus 30 cfs to account for losses. The Management Strategy provides a more detailed discussion of these assumptions.

Interdam Runoff is defined as the difference between (a) Berryessa release plus spill and (b) Putah Diversion Dam release after diversion to the Putah South Canal. The daily flows were computed through the water year 2012.

It is noted that the low flow gauges managed by SCWA were reviewed, but not used. The gauges are typically used to monitor summer irrigation flows and to check that Putah Creek Accord flow requirements are being met. Flows are not rated higher than 100 cfs and the gauges are typically removed from the creek in the winter time.

4.4.9 American River

Daily inflows to the American River below Nimbus Dam were obtained from USGS gauge 11446500.

4.4.10 Delta Cross Channel and Georgiana Slough

DWR's Dayflow program provides the most accurate daily estimates for cross-Delta flows out of the Sacramento River through Delta Cross Channel and Georgina Slough. Dayflow data was developed using measured flow at USGS gauges installed in December 2002 and January 2003, along the Delta Cross Channel and Georgiana Slough and empirical relationships for non-recorded periods and prior years.

4.4.11 Delta Sloughs and North Bay Aqueduct

Delta sloughs boundaries consist of inflows at Haas Slough and Upper Cache Slough on the Cache Slough system and Campbell Lake and Calhoun Cut at Highway 113 on the Lindsey and Barker Slough (BKS) system (see Figure 4-21).

The net daily flows for Haas Slough, Upper Cache Slough, Campbell Lake, and Calhoun Cut were estimated using mass balance of observed flow data on Upper Cache Slough at DWR gauge UCS, Lindsey Slough at Hastings Bridge at SCWA gauge Lindsey Slough Hastings Bridge (LSHB), Barker Slough Doppler Station at SCWA gauge Doppler (DOP), and Barker Slough Pumping Plant at DWR gauge BKS. Observed flow was tidally filtered using a Godin (1972) filter prior to mass balance computations. UCS net daily flow was split equally between Upper Cache Slough below Ulatis Channel and Hass Slough. Campbell Lake net daily flow was computed as the difference in net daily flow between DOP and BKS. Calhoun Cut net daily flow was computed as the difference in net daily flows computed for LSHB and DOP.

The gauge data for LSHB and DOP was available from February 2, 2007 and July 11, 2006, respectively, and was obtained from SCWA. The LSHB data was subject to an update in the velocity rating on April 22, 2011. Data prior to this revision exhibited a strong negative flow that indicated that Calhoun Cut was abstracting water from the system. Hence, only the data following the update was used for estimation purposes. The gauge data for UCS was available from June 21, 2008 and was obtained from DWR's North Central Regional Office (NCRO). The gauged data for BKS was available from October 1, 2007 and was obtained from CDEC.

Sinusoidal curves were used to replicate the general pattern of the tidally filtered flows as shown in Figure 4-22. The daily flow data generated using the fitted sinusoidal curves was used for time periods prior to gauge installation and to fill in missing data. The estimated daily flows are shown in Figure 4-23.

4.4.12 Rio Vista Tides

Sacramento River at Rio Vista serves as the downstream model boundary. Daily mean stage and 15-minute stage data for the Sacramento River at Rio Vista were obtained from DWR gauge B91212. The stage datum is in NAVD88 starting October 1, 2005. Prior to October 1, 2005, the stage data is in USED datum; however, a gauge height correction (NAVD88 = USED - 0.6 feet) was not applied. Sensitivity analysis was performed and demonstrated that the uncorrected gauge height had an insignificant affect on the model results (i.e., last day wet (LDW) and wetted area) within the Yolo Bypass (see Section 6.2).

4.5 Hydraulic Structures

The TUFLOW model contains several hydraulic structures within the Yolo Bypass including the Fremont and Sacramento Weirs, Swanston Ranch check dam, three agricultural crossings along the Tule Canal, and some crossings with culverts along Willow Slough Bypass as shown on Figure 4-24. For the road and railroad bridges, the bathymetry at the bridge, including the channel and embankment, was included. The piers and bridge decks were not included due the relatively small hydraulic effects anticipated from these structures. The majority of the bridges do not become submerged even in the largest events modeled. Based upon the bridge definitions in the HEC-RAS model, the bridge along Country Road 22 which passes over the Tule Canal (bridge #22C0053, just north of the I-5 Bridge) is submerged during large flood events. When the bridge is submerged, the roadway is overtopped which conveys the majority of the flow. Upstream of this bridge is a railroad bridge that becomes submerged in the 1997 water year but not in other years. This has little impact on the results because County Road 22 is the controlling hydraulic feature for the area.

The model has also been calibrated to higher Sacramento River discharges in the absence of including bridge structures in the model along the Sacramento River. Bridges were omitted from the Sacramento River portion because they were not expected to have a significant impact on the results within the Yolo Bypass. However, the presence of bridges was partially accounted for by the addition of local energy losses during calibration. Because the model is being used for comparative purposes, the omission of the details describing the bridge structures will not significantly affect the model outcomes.

4.5.1 Fremont Weir

The Fremont Weir was included explicitly in the model. The crest elevations assigned along the alignment of the weir were derived from the highest LiDAR elevations within a 20-foot radius of the weir alignment. In this way, if the dirt road to the immediate north of and paralleling the weir was higher than the weir, then the dirt road at discrete locations would control overtopping conditions versus the crest elevations of the weir. TUFLOW automatically checks for the presence of weir flow and computes flows based upon the weir equation as appropriate as discussed in Section 4.1.1.

4.5.2 Sacramento Weir

The Sacramento Weir is comprised of 48 gates that are manually opened during large flood events allowing flows from the Sacramento and American Rivers into the Bypass. The Sacramento District of the USACE defined guidelines regarding how the gates should be operated during flood events (USACE 1955). The pertinent guidelines are included in Appendix B. The gates are opened after the I Street gauge (approximately 1000 feet upstream from the I Street Bridge) reaches a stage of 30.04 feet NAVD88. The number of gates opened varies but enough should be opened to maintain a water surface elevation of less than 31.54 feet NAVD88 at the I Street gauge. The gates may be closed after the stage drops below 27.54 feet NAVD88 at the Sacramento Weir. The guidelines state that the gates should be closed within as short as period as practicable. Because the Sacramento Weir is operated manually, the DWR has to decide when to open the gates, how many to open, and when to close the gates. These decisions may be influenced by river stage forecasts, time of day, and other factors. TUFLOW cannot replicate this decision making process. Rules were defined for opening and closing the gates that are implemented consistently for all of the model runs (described below).

Within the TUFLOW model, the Sacramento Weir discharge is determined by a rating curve provided by the DWR based upon the upstream stage and number of open gates (see Appendix B). When the water surface elevation at the I Street gauge exceeds 30.04 feet NAVD88 12 gates (one-quarter of them) are opened. This continues until all of the gates are open. All of the gates are closed simultaneously when the water surface elevation at the Sacramento Weir drops below 27.54 feet NAVD88.

4.5.3 Lisbon Weir

Lisbon Weir is an irrigation supply feature on the Toe Drain just south of Putah Creek that creates a backwater pool to meet irrigation demands within the Yolo Bypass Wildlife Area. The structure consists of a rock weir with a crest elevation ranging from 5.0 to 6.5 feet NAVD88 and three steel flapgates to the immediate west of the rock weir. The 4- by 3-foot flap gates trap water behind the weir to an elevation of 4.5 feet, which corresponds to the top of the flap gate structure, whereby excess water drains back out overtop the flap gates on the ebb tide. After major flood events, the rock weir is rebuilt by reclaiming rock with an excavator from the pool downstream of the weir. However, every 4 to 5 years the rock weir is built back up with new rock. The weir and tide gate geometry was determined by field survey (cbec 2014).

4.5.4 Swanston Ranch Check Dam

The Swanston Ranch check dam is a temporary agricultural crossing that impounds water in the Toe Drain for water supply diversions (see Figure 4-24). It consists of three culverts, one (1) six foot open culvert and two (2) four foot culverts with boards at the intakes, and earth fill.

The earth fill is removed prior to the wet season. The check dam was modeled in its degraded condition based on elevations acquired during a single-beam bathymetric survey (cbec 2012).

4.5.5 Agricultural Crossings

Three agricultural crossings exist on the Tule Canal north of the KLRC (see Figure 4-24). The northern crossing at the downstream end of Tule Pond is an earthen berm that serves to impound water as supply to Reclamation District (RD) 1600 within the Elkhorn Basin on the east side of the levee. The middle crossing is about 0.5 miles downstream, consists of an earthen berm and a single 32-inch culvert, and is well travelled. The southern crossing is another 0.6 miles south, consists of an earthen berm and three 24-inch culverts, provides a right of way, and is primarily used by operations on the Sacramento River Ranch east of the levee. The culvert sizes and inverts were determined by field survey (cbec 2014).

4.5.6 Weir Culverts along Willow Slough

Within the Yolo Bypass, Willow Slough is a dual purpose drainage and irrigation supply feature. There are a series of eight 48-inch and one 30-inch culverts that provide primary access across the slough on the west side of the Yolo Bypass (see Figure 4-24). There is also a water control feature along the slough midway into the Yolo Bypass with one 48-inch and one 30-inch culverts. The culvert sizes and inverts were determined by multiple field surveys (cbec 2014; this study).

4.6 Surface Roughness

Manning roughness coefficients were prepared for the Sacramento River Valley based on detailed medium scale vegetation mapping digitized at a scale of 1:2000 (see Figure 4-25 and Table 4-6. Medium scale vegetation mapping roughness reclassification was prepared by California State University, Chico, as part of riparian mapping projects for the Central Valley (DWR 2011b) and Sacramento–San Joaquin River Delta (CDFG 2007) using the National Vegetation Classification System (NVCS). The Manning roughness coefficients are presented in Table 4-6. Medium scale vegetation mapping roughness reclassifications are regionally calibrated values derived from the Lower Feather River Corridor Management Plan (MBK 2011) and the Yolo Bypass (USACE 2007). Both sources use RMA-2 models calibrated to the 1997 flood event, which were originally developed by relating the NVCS categories to vegetation type characteristics, and using aerial imagery and engineering judgment.

Medium scale vegetation mapping roughness reclassifications were initially assigned to the 2D grids and non-CVFED cross-sections. For CVFED cross-sections, the Manning roughness coefficients were derived from the values assigned in the CVFED RAS model. Manning's n-values for the CVFED cross-sections were changed to improve calibration during the 1997 high flow calibration. In the Feather River, Manning's n-values were increased with a 1.2 multiplier. In the Sacramento River between Verona and Courtland, Manning's n-values were decreased with a 0.85 multiplier.

Table 4-6. Medium scale vegetation mapping roughness reclassification for 2D grids

Map Unit	National Vegetation Classification System	LFRCMP (MBK, cbec)/ Yolo Bypass (USACE)	Manning Roughness Coefficients	
			Previous Studies	Calibrated Values
AGR	Agriculture	Agricultural fields	0.030	0.031
BGS	Barren	Gravel bar/sand bar	0.035	0.036
CAI	Mediterranean California naturalized annual and perennial grassland	Perennial grassland	0.030	0.036
CFG	California annual forbgrass vegetation	Perennial grassland	0.030	0.031
CSS	Central and south coastal California seral scrub	Upland scrub	0.055	0.057
CXC	Californian xeric chaparral	Upland scrub	0.055	0.057
DIV	Western North American Freshwater Marsh	Reeds, tules, bulrushes, cattails	0.050	0.052
ECW	Californian evergreen coniferous forest and woodland	Dense riparian forest	0.080	0.082
FAV	Western North American Freshwater Aquatic Vegetation	Open water	0.030	0.031
FEM	Arid West freshwater emergent marsh	Reeds, tules, bulrushes, cattails	0.050	0.056
FOR	Temperate Flooded and Swamp Forest	Open riparian forest	0.050	0.052
IMF	Introduced North American Mediterranean woodland and forest	Dense or Open riparian forest	0.080, 0.050	0.082
MAC	Introduced North American Mediterranean woodland and forest and Southwestern North American Riparian, Flooded and Swamp Forest/Scrubland	Open riparian forest	0.050	0.052
NRW	Naturalized warm-temperate riparian and wetland	High herbaceous marsh	0.055	0.055
RES[1]	Barren	Perennial grassland	0.030	0.031
RIS	Southwestern North American introduced riparian scrub	Himalayan blackberry scrub	0.045	0.046
RWF	Riparian Evergreen and Deciduous Woodland	Dense riparian forest	0.080	0.082
RWS	Southwestern North America riparian wash/scrub	Upland scrub	0.055	0.056
SSB	Southwestern North American salt basin and high marsh	Reeds, tules, bulrushes, cattails	0.050	0.051

Map Unit	National Vegetation Classification System	LFRCMP (MBK, cbec)/ Yolo Bypass (USACE)	Manning Roughness Coefficients	
			Previous Studies	Calibrated Values
TBM	Temperate Pacific tidal salt and brackish meadow	Reeds, tules, bulrushes, cattails	0.050	0.051
UNK[2]	NA	Dense riparian forest	0.080	0.082
URB	Urban	Rural / Developed	0.030	0.031
VPB	Californian mixed annual/perennial freshwater vernal pool/swale/plain bottomland	Perennial grassland	0.030	0.031
VRF	Vancouverian riparian deciduous forest	Dense riparian forest	0.080	0.082
WAT	Riverine	Open water	0.030	0.034
WCM	Western Cordilleran montane-boreal summer-saturated meadow	Reeds, tules, bulrushes, cattails	0.050	0.051
WDT	Western dogwood thicket	Dense willow scrub	0.065	0.066
WTM	Californian warm temperate marsh/seep	Perennial grassland	0.030	0.031
WVO	Californian broadleaf forest and woodland	Dense riparian forest	0.080	0.082

Notes:
[1] Vegetation characteristics were not available. Review of aerial images indicated that the vegetation was grasslands.
[2] No NVCS description was provided for map unit UNK. Review of aerial image showed dense tree growth indicating dense riparian forest.

4.7 Assumptions/Limitations

This modeling effort is based upon several assumptions, including:

- The 1997-2012 timeframe provides reasonable boundary conditions for comparison purposes. Potential long term hydrology changes due to climate changes or other diversions were not considered.
- The preliminary gate/channel designs are similar enough to eventual proposed designs to provide an appropriate and effective relative comparison of the alternatives.
- The 1D modeling assumptions and limitations, especially uniform flow in the channel direction, are satisfactory for areas modeled using 1D domains.

- Areas represented by 2D domains are adequately represented using depth-averaged assumptions that do not capture 3D velocity gradients and associated losses.

For all of the alternatives, the discharges through the gates were capped at 6,000 cfs before Fremont Weir overtopping to be consistent with prior BDCP efforts (BDCP 2009). The FreSm alternative was modeled with gates that opened and closed to maintain 6,000 cfs but the preferred design would include gates that are fully open or closed. Changes to these or other gate design and operation parameters may modify the project benefits and impacts.

The long time frame simulated and the inclusion of several alternatives constrained the model to use large cell sizes. The model solution is adequate for the defined goals of the analysis which are to provide water levels and velocities and to compare inundation areas, but may not be appropriate for all purposes. The model resolution within the 2D domains is too coarse to evaluate flows around and through small features.

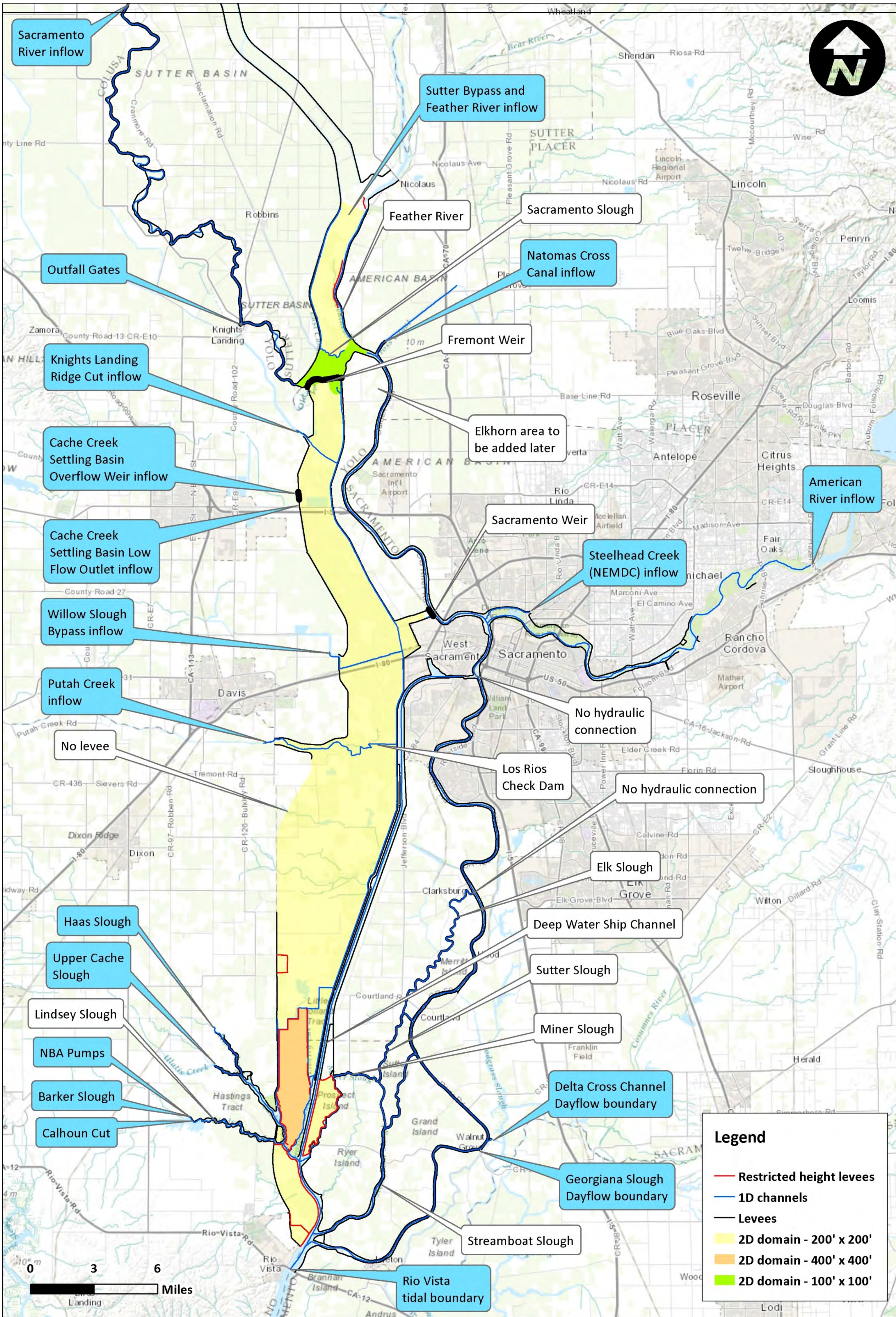
Bridge piers and decks are not included in the model so local flow patterns and energy losses may not be accurately represented in these areas. The Manning roughness coefficient changes to improve model calibration help compensate for losses not captured at structures when looking at far-field effects.

While attempts were made to capture major drainage features within the basin, modeling all drainage features was not practical. Minor drainage features such as ditches, culverts, and field drain check structures are unmapped and numerous. In addition field drain structures may change from year to year.

The model uses the most up-to-date and available topography and bathymetry but some improvements could be made. LiDAR has the ability to capture bare earth elevations in the presence of vegetation within most of the domain. However, LiDAR is unable to penetrate thick vegetation such as in the riparian zones along the Toe Drain/Tule Canal resulting in erroneous elevation data. The effects along the Toe Drain/Tule Canal were minimized by keeping these areas within the 1D domain. Had these areas been represented in 2D the vegetation returns in riparian areas may have prevented flow conveyance from the channels to the floodplain. Because flows between the 1D and 2D domains are controlled by the 2D elevations, inaccurately high elevations do not prevent floodplain inundation. Sensitivity analyses concluded that a minor berm within the riparian zone did not have a significant effect on the model results (see Section 5.4.2).

Model inflows for the Westside tributaries represent the best available information. Model inflows for KLRC and Cache Creek were developed based on regression techniques developed as part of this study. These are a significant improvement over the Management Strategy approaches as KLRC and Cache Creek, relative to Willow Slough Bypass and Putah Creek, provide the most inflow to Bypass. Model inflows for Willow Slough Bypass and Putah Creek were extended through water year (WY) 2012 based on Management Strategy approaches.

Willow Slough is ungauged and a better approach for estimating Putah Creek inflows was not discovered.

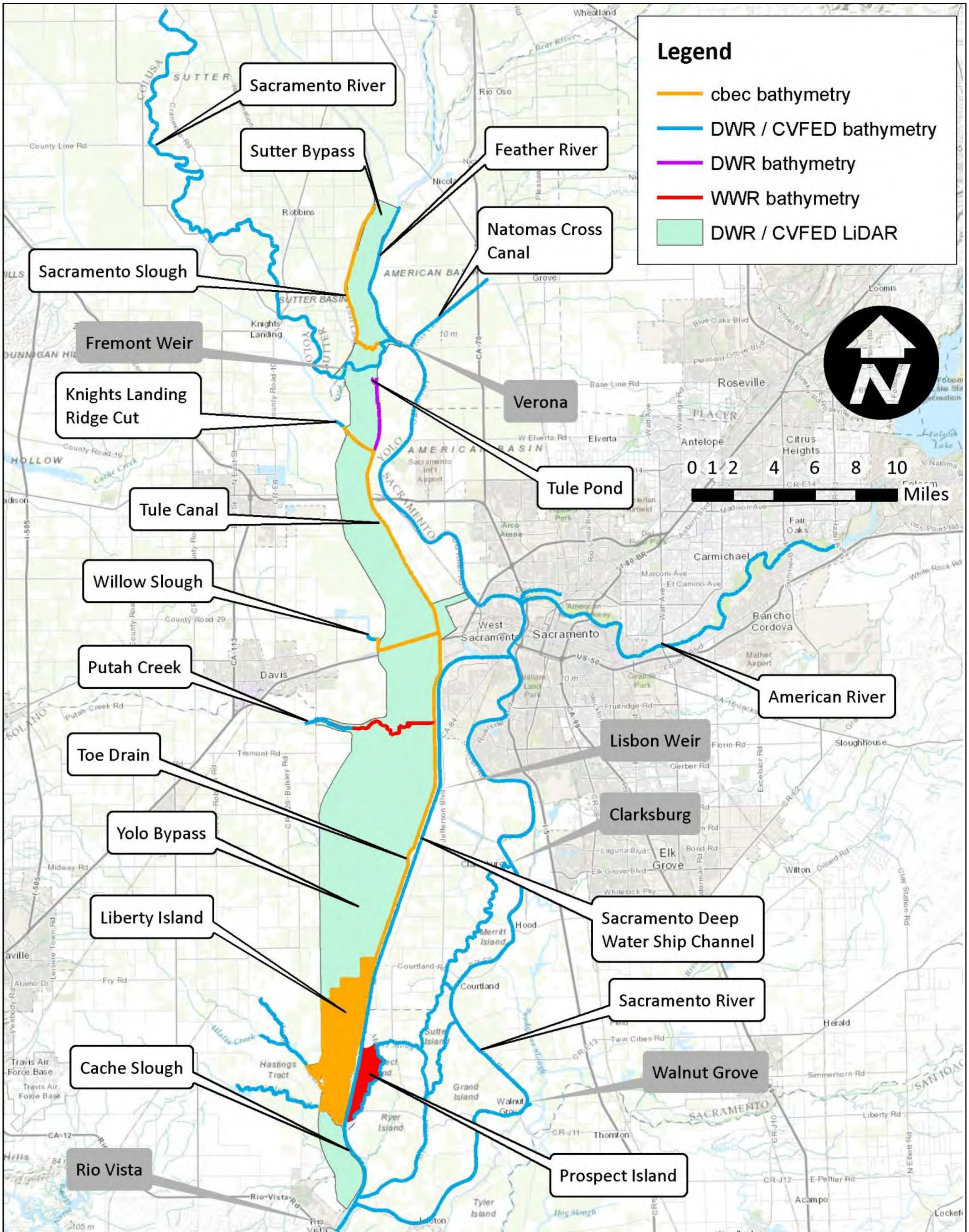


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Model Domain and Boundary Locations

Prepared for DWR | Created By: SP | **Figure 4-1**

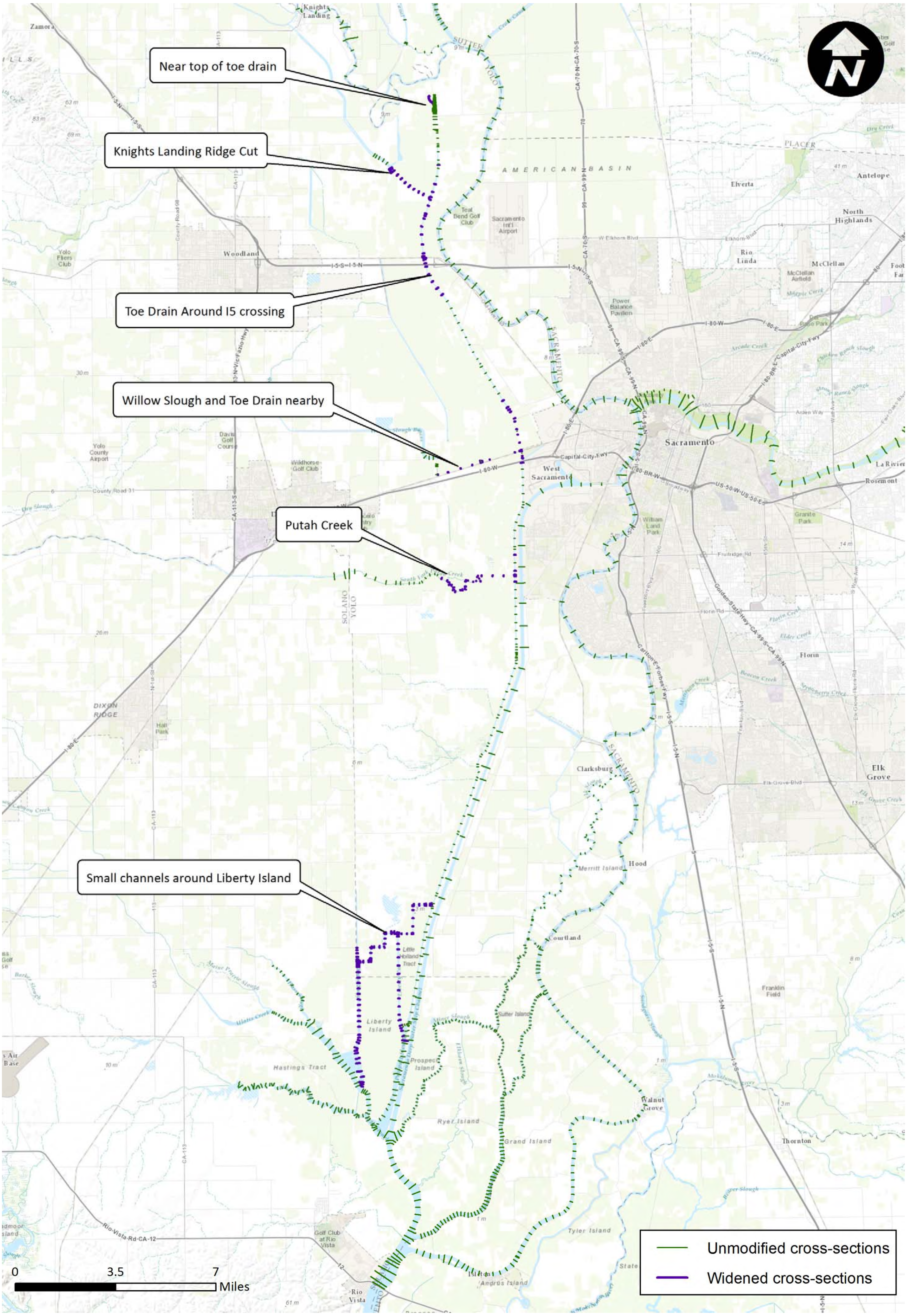


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Geometric Data Sources

Prepared for DWR	Created By: BT	**Figure 4-2**

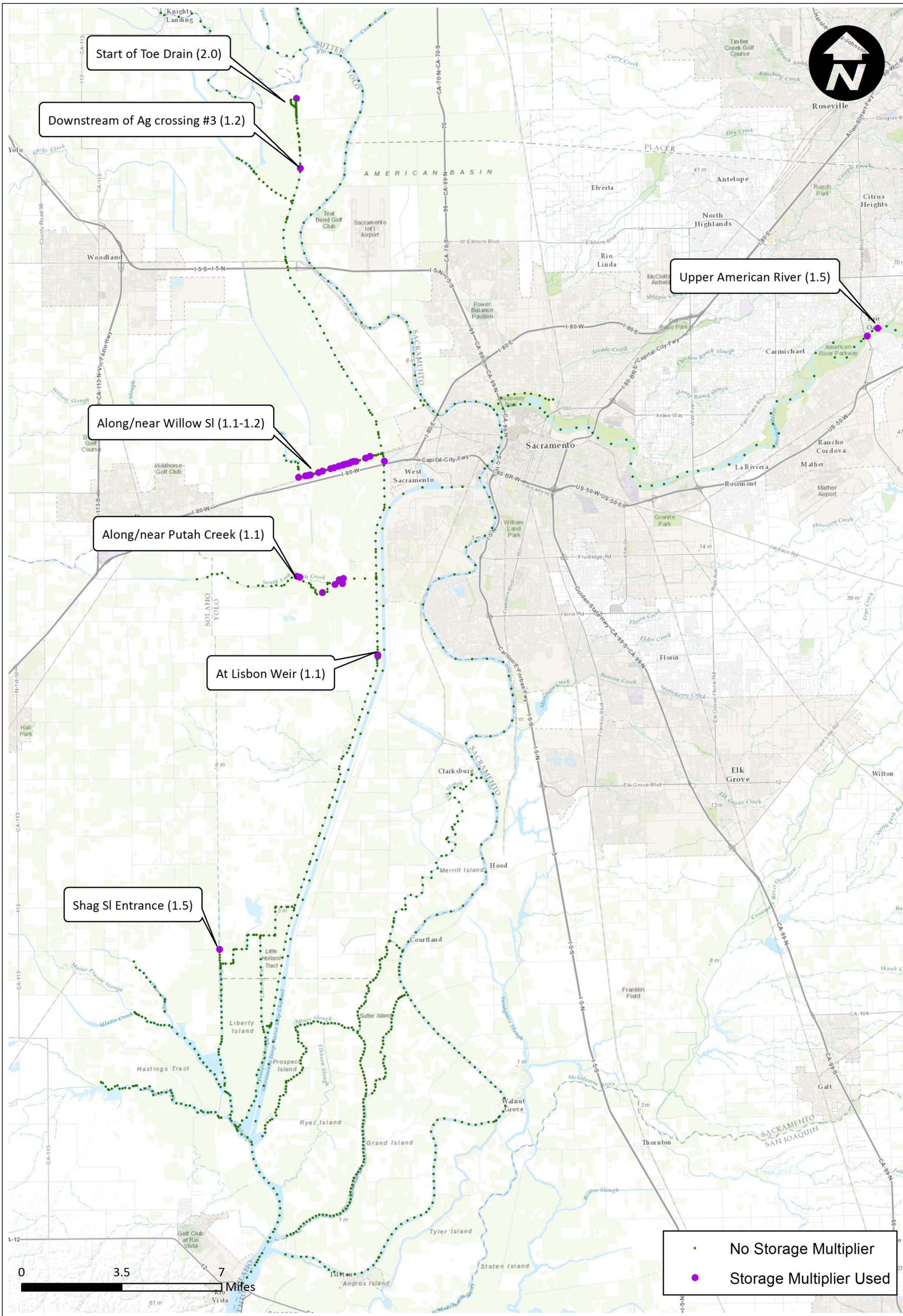


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Widened Cross-sections

Prepared for DWR	Created By: RDJ	**Figure 4-3**



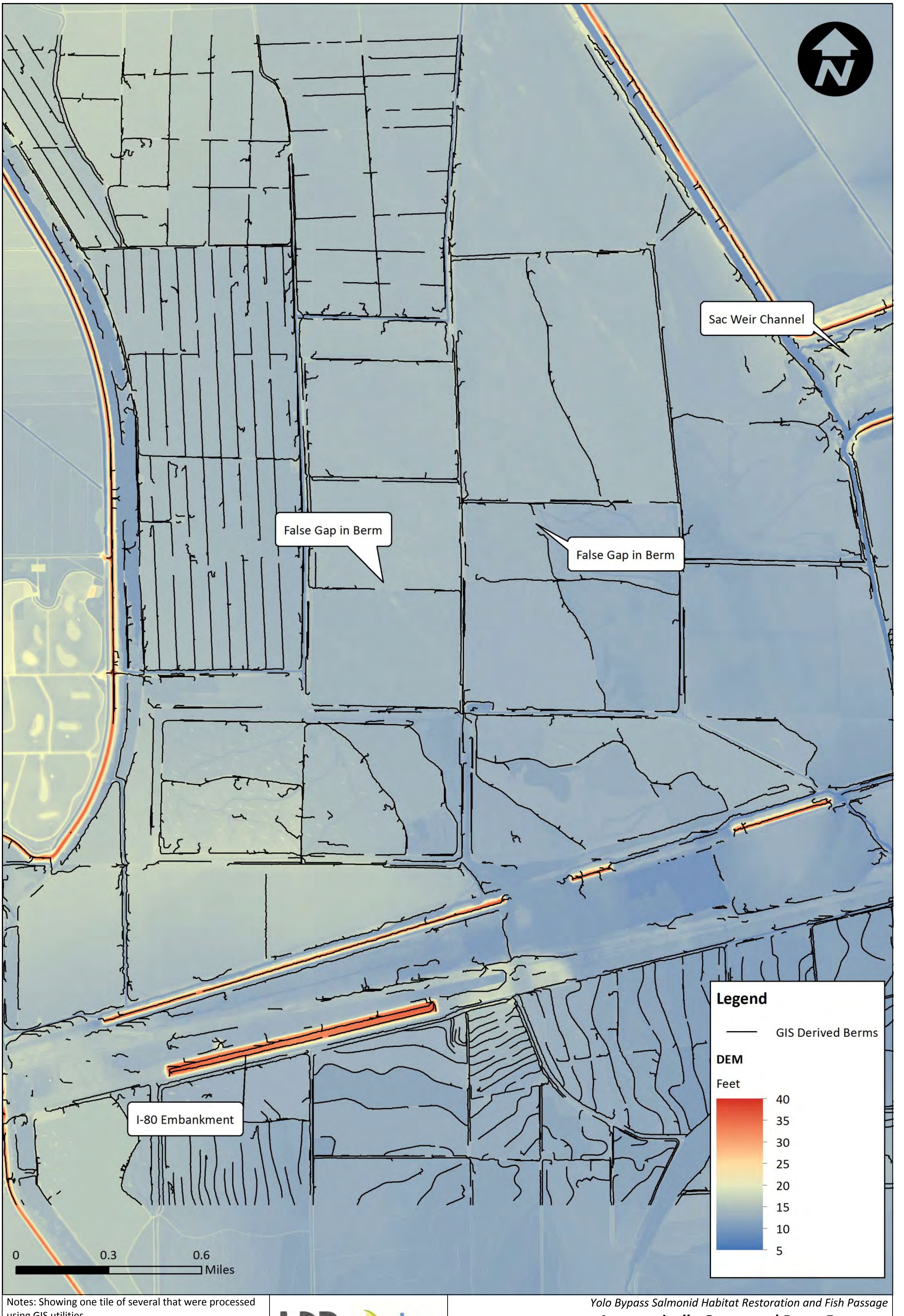
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Storage Multipliers at 1D Nodes

Prepared for DWR | Created By: RDJ

Figure 4-4



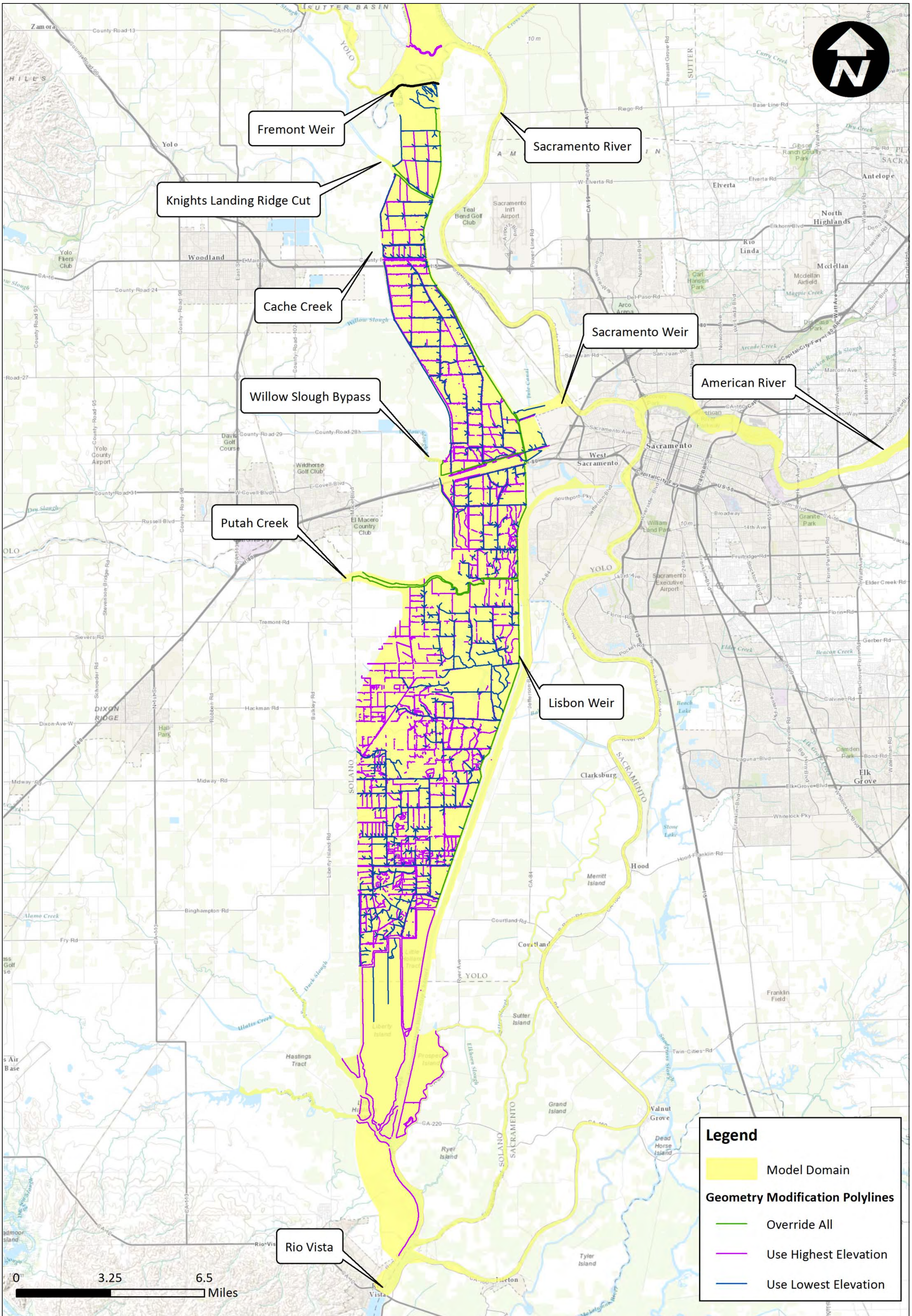
Notes: Showing one tile of several that were processed using GIS utilities

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Automatically Generated Berm Features

Prepared for DWR | Created By: RDJ

Figure 4-5

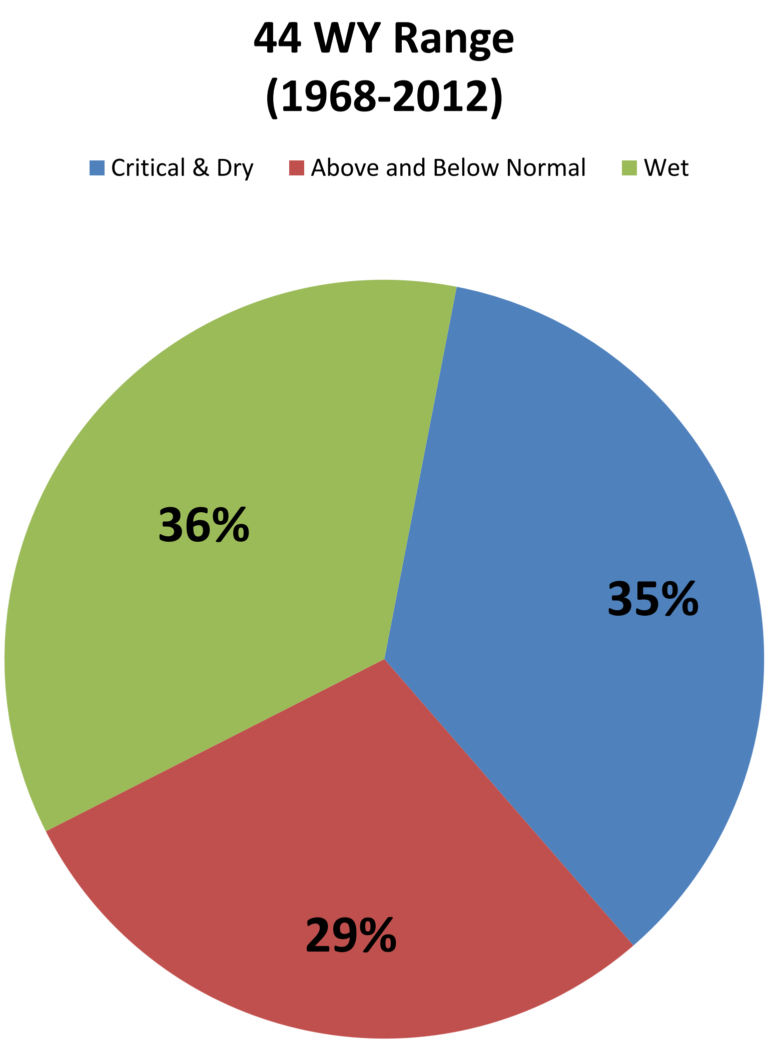


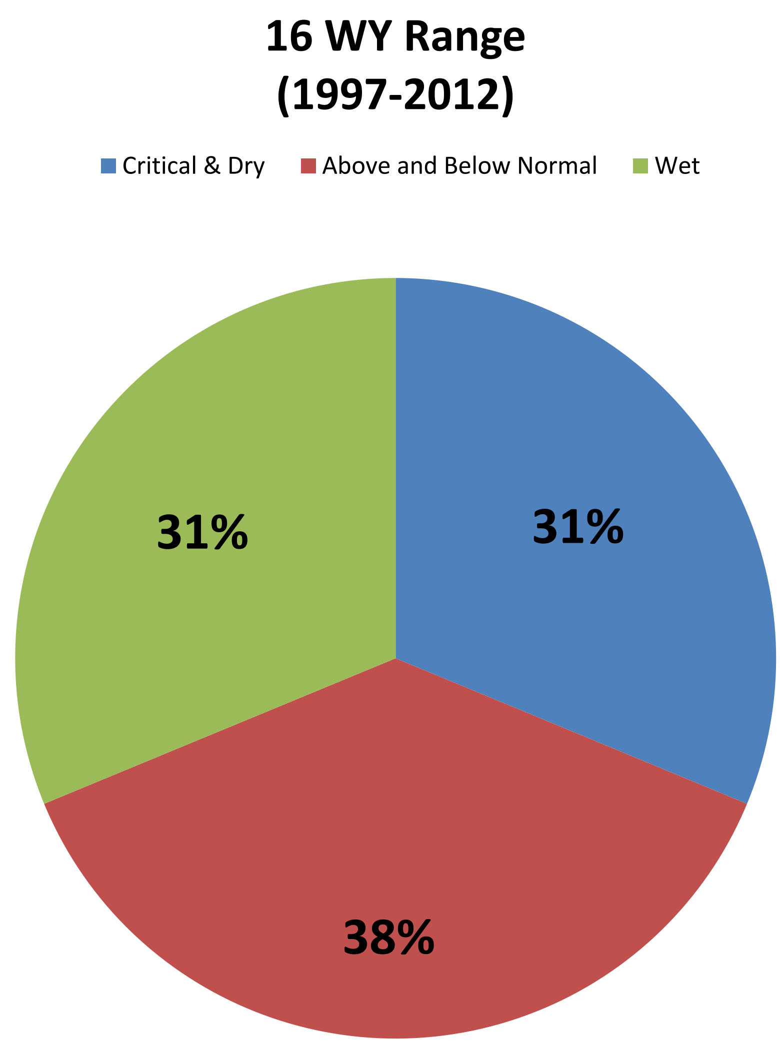
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Primary Geometry Modification Polylines

Prepared for DWR | Created By: RDJ | **Figure 4-6**



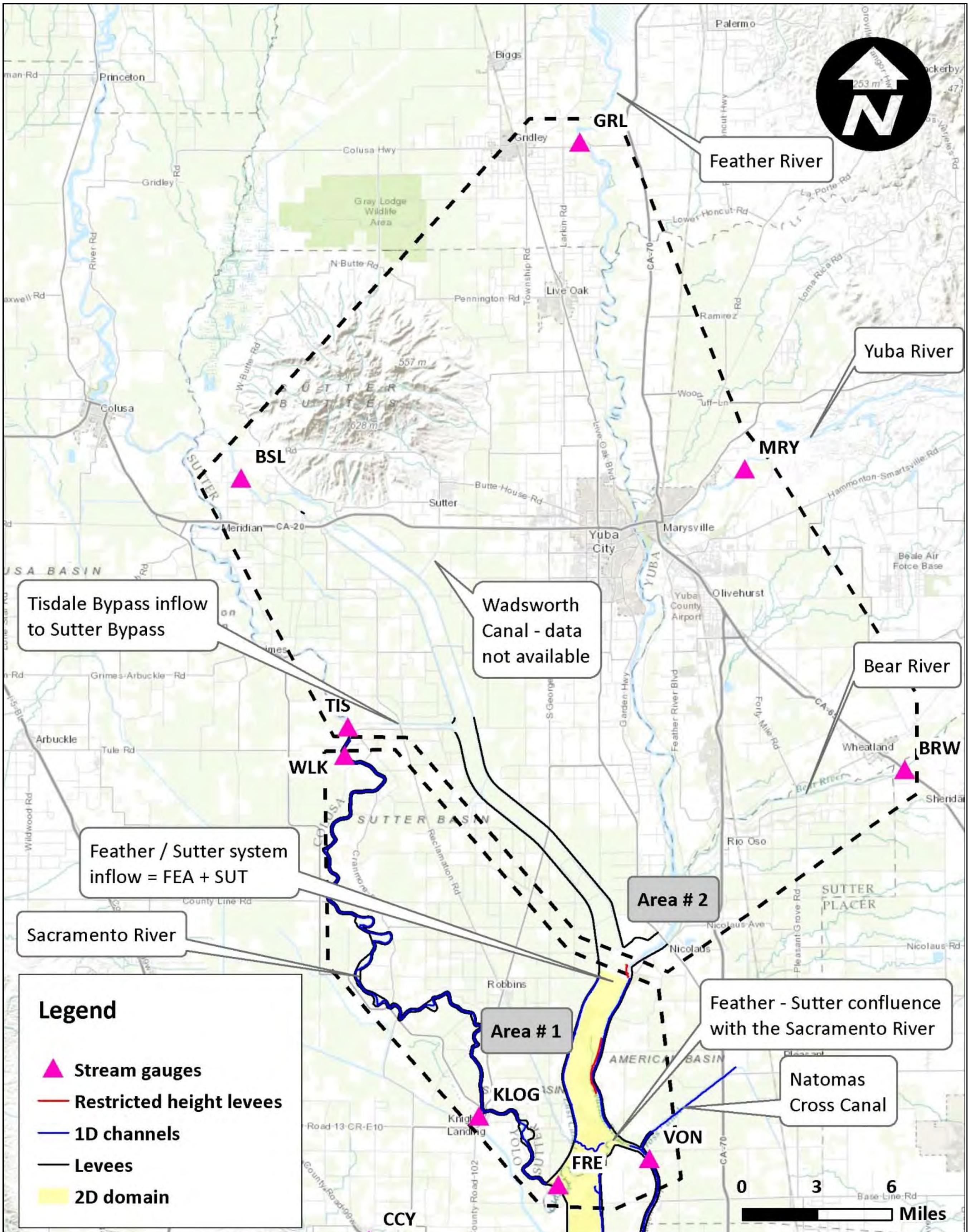


Notes:

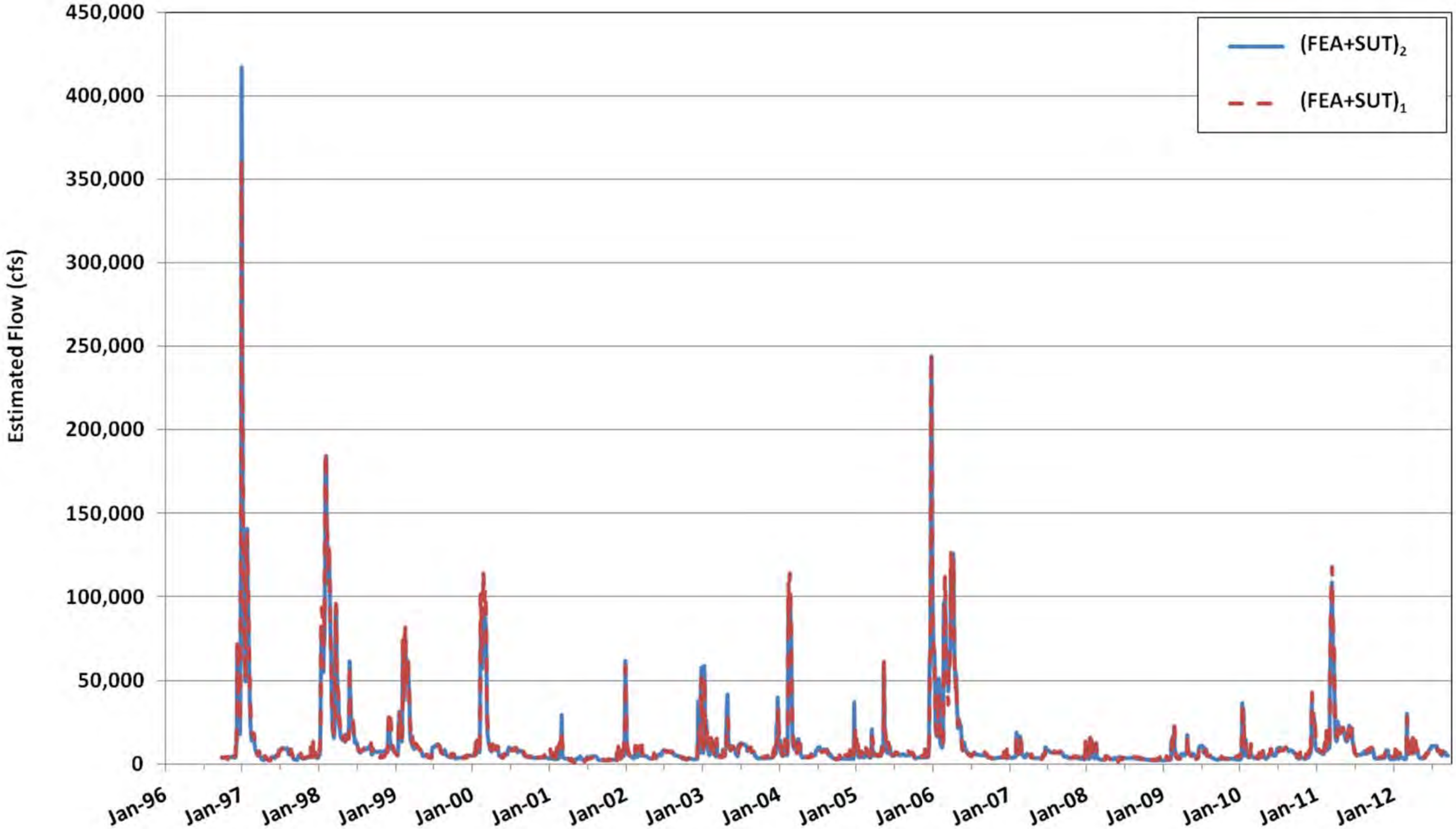
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Water Year Selection

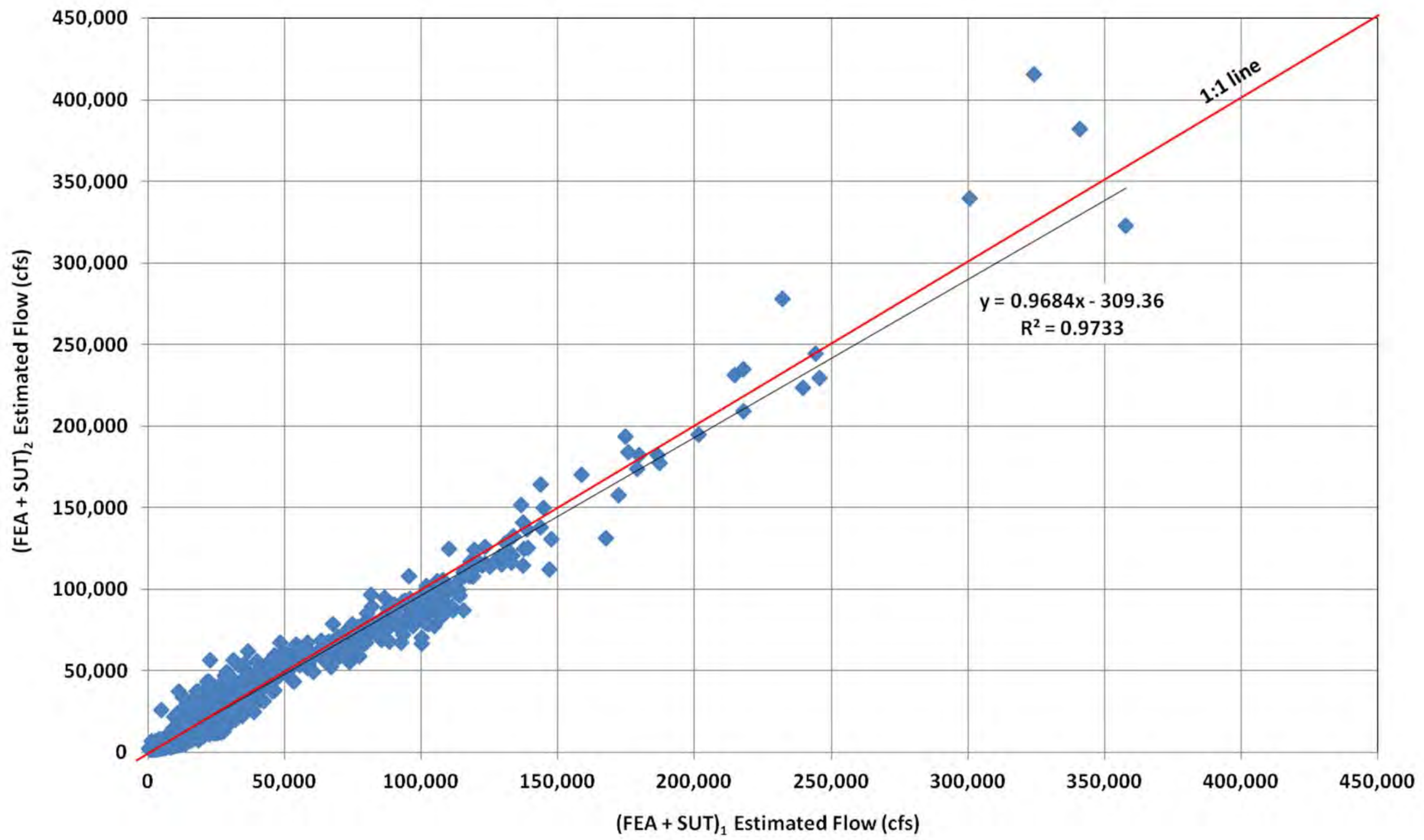
Prepared for DWR	Created By: SJB	**Figure 4-7**



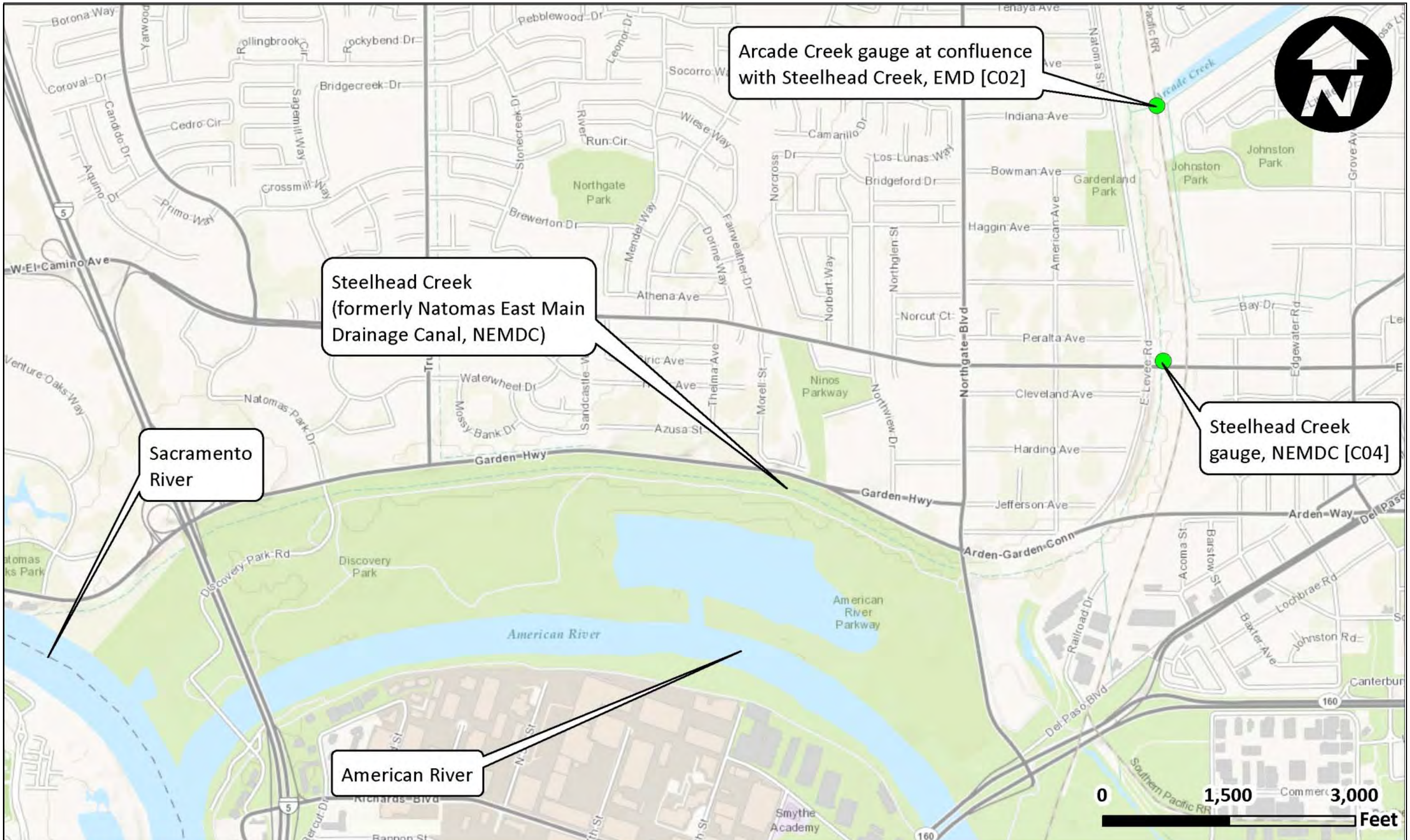
Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage*		
		Feather – Sutter Gauges for Flow Split		
		Prepared for DWR	Created By: SP	**Figure 4-8**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Feather – Sutter Flow Time Series**		
		Prepared for DWR	Created By: SP	**Figure 4-9**



Notes:	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Feather – Sutter flow Scatter Plot**		
		Prepared for DWR	Created By: SP	**Figure 4-10**

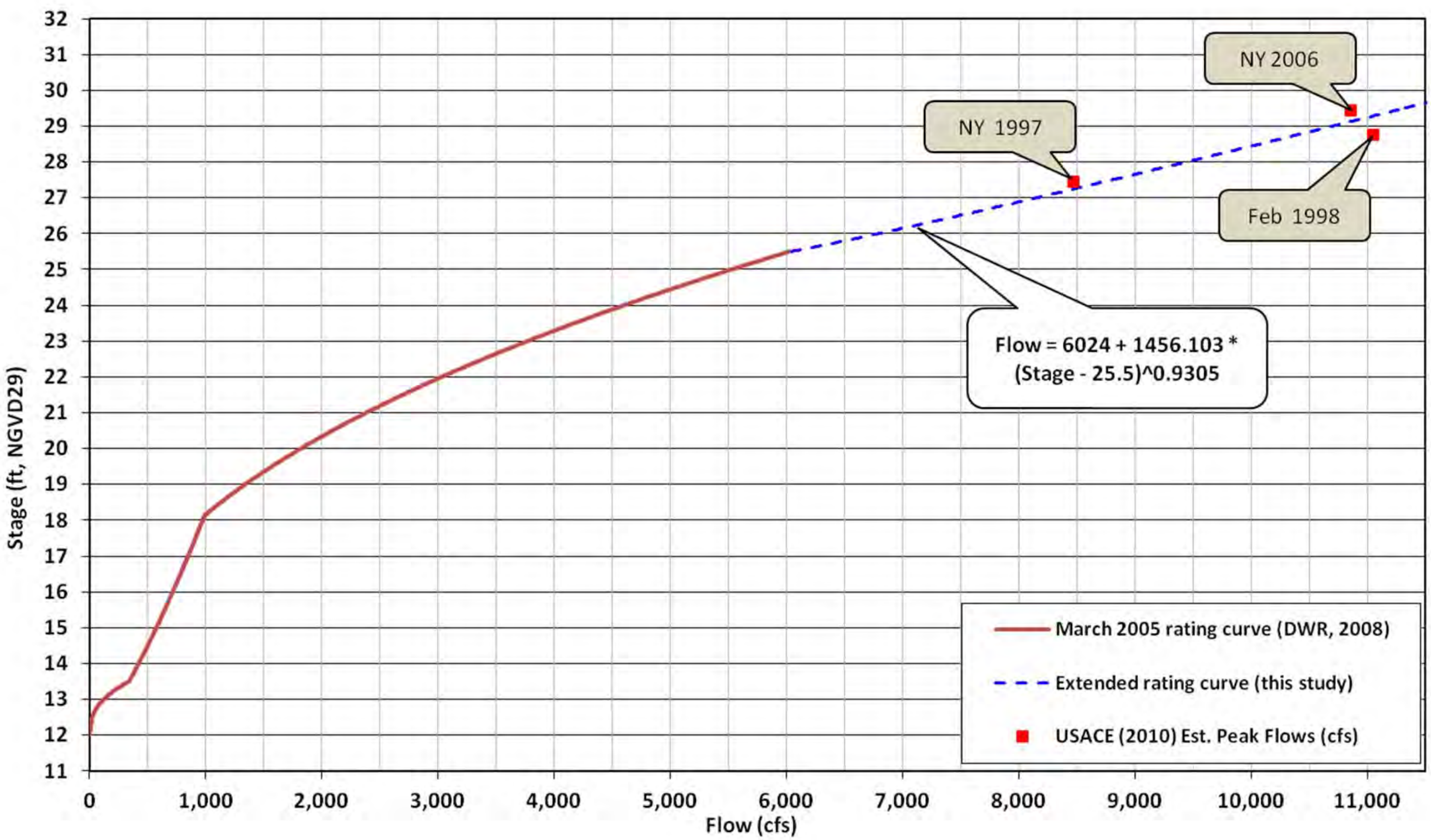


Notes:

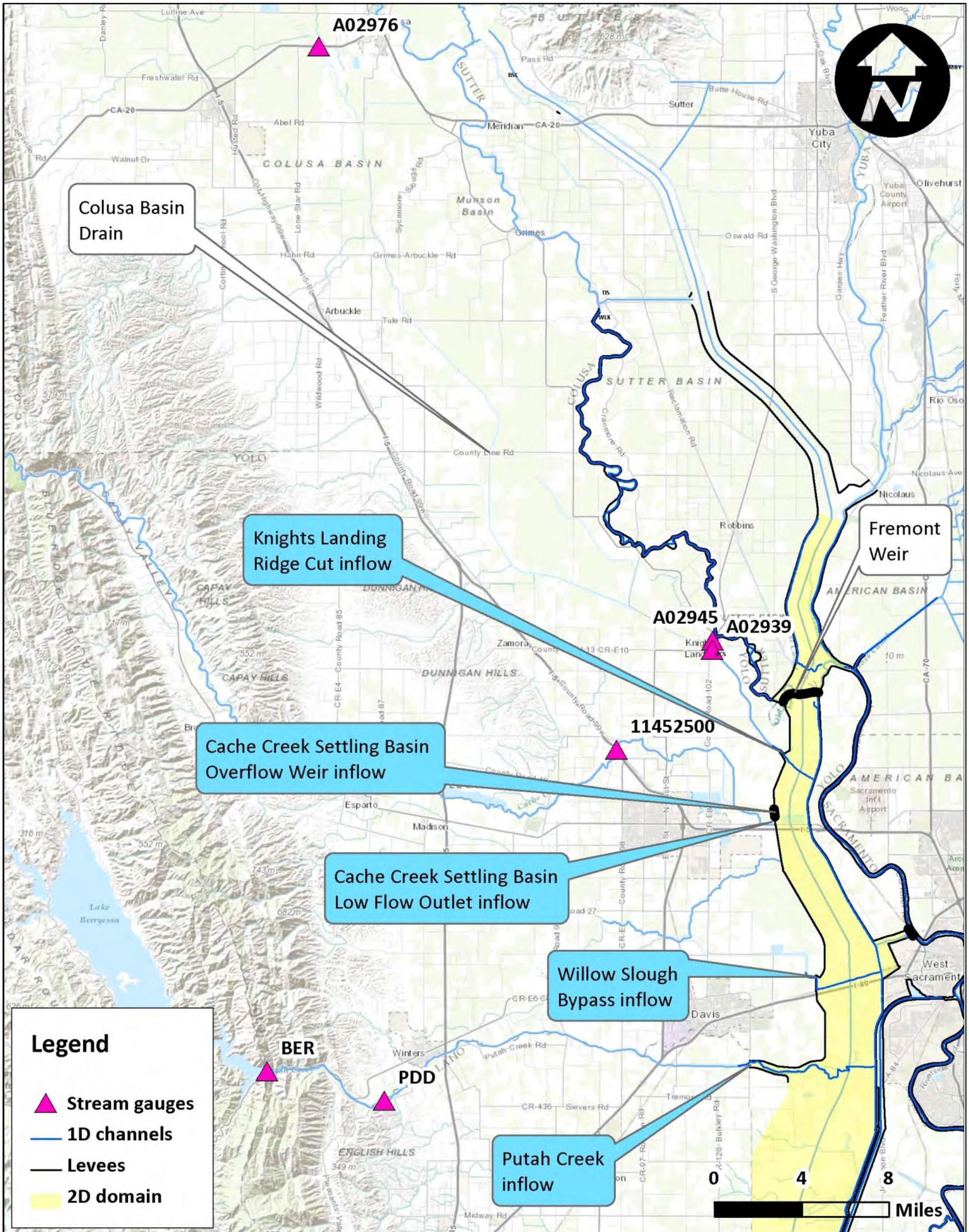
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Steelhead Creek and Arcade Creek Gauges

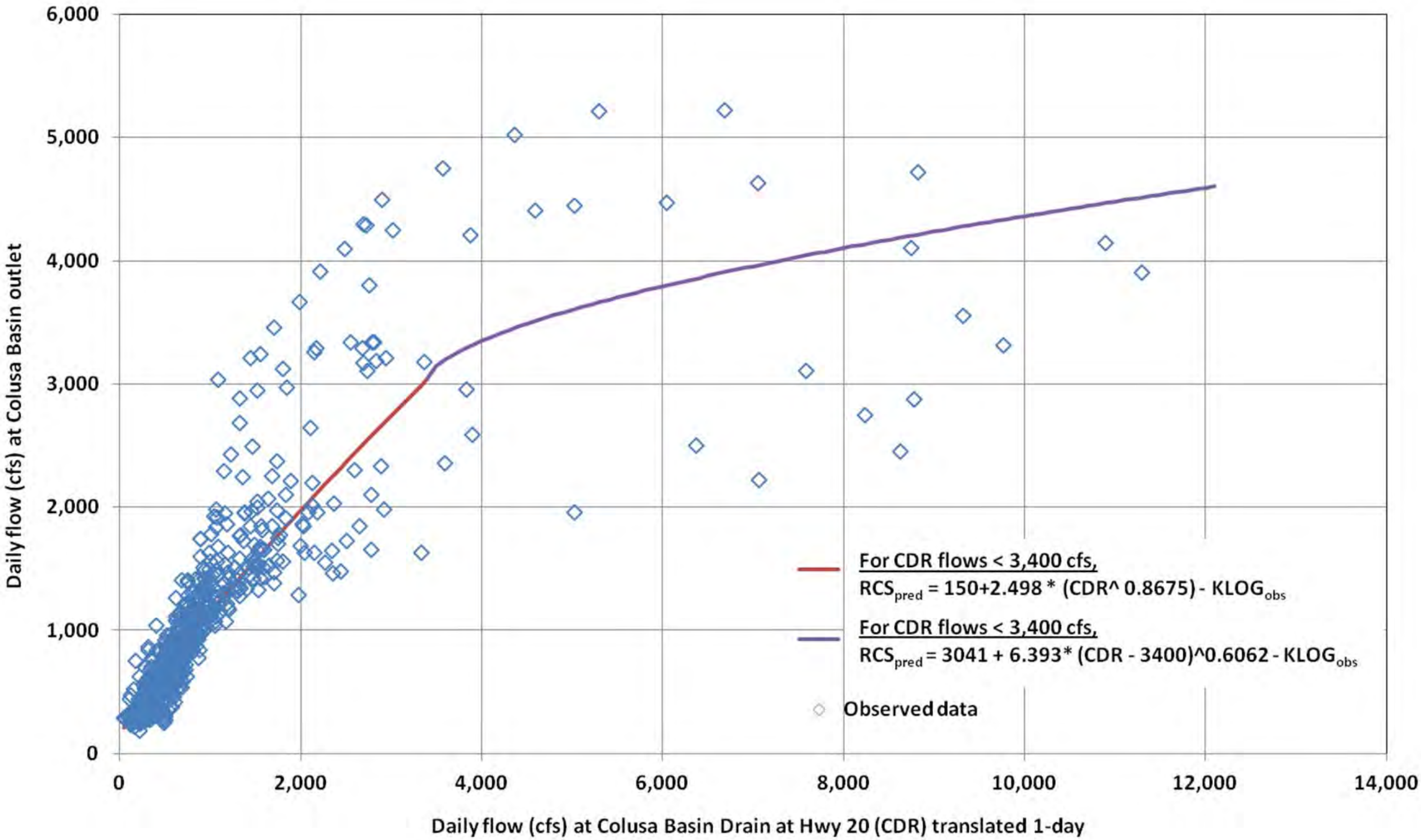
Prepared for DWR	Created By: SP	**Figure 4-11**



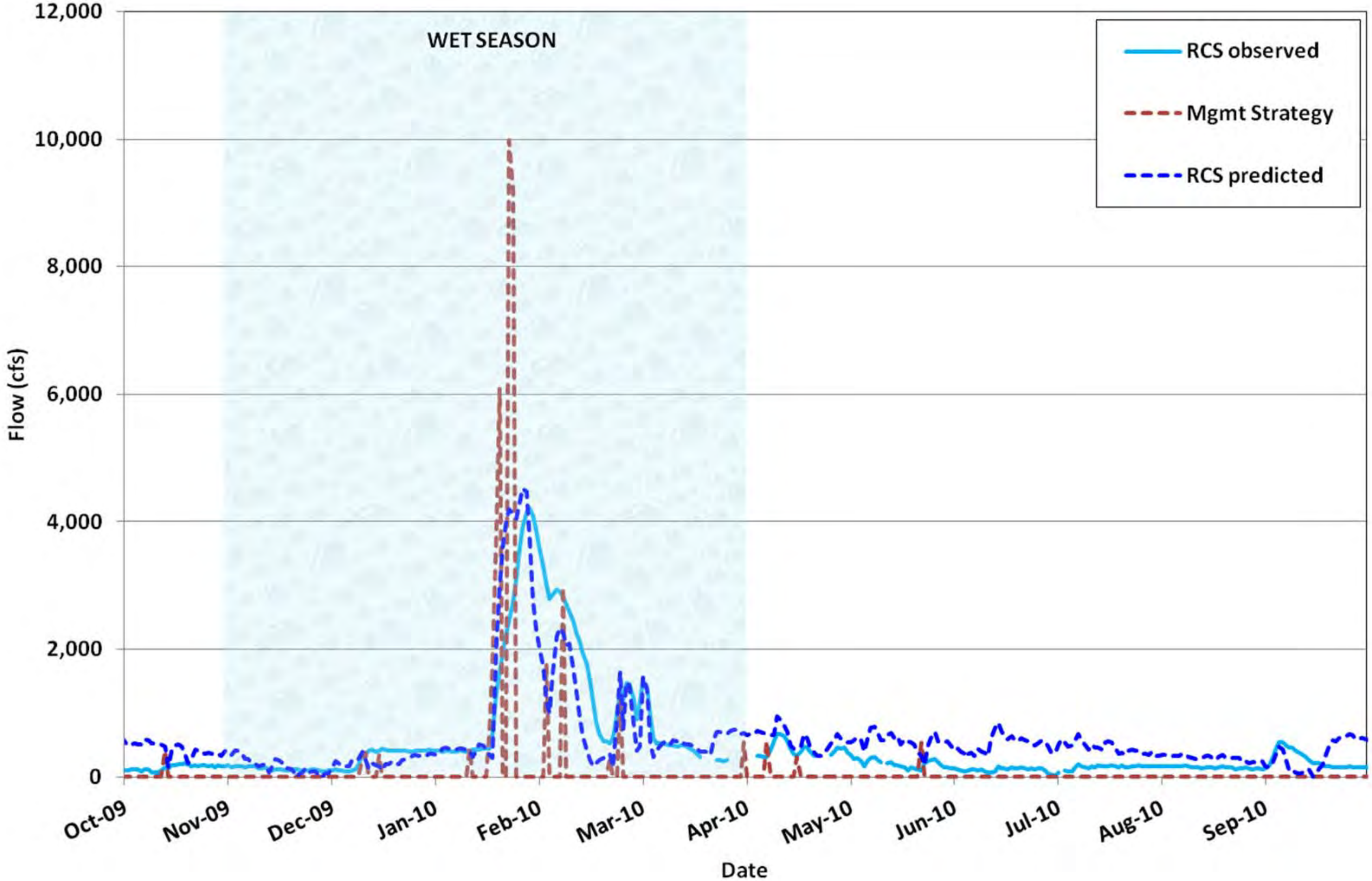
Notes:	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Steelhead Creek Updated Rating Curve**
		Prepared for DWR · Created By: SP · **Figure 4-12**



Notes:	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Westside Tributaries and Gauges**		
		Prepared for DWR	Created By: SP	**Figure 4-13**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage*		
		Knights Landing Ridge Cut Inflow		
		Prepared for DWR	Created By: SP	**Figure 4-14**

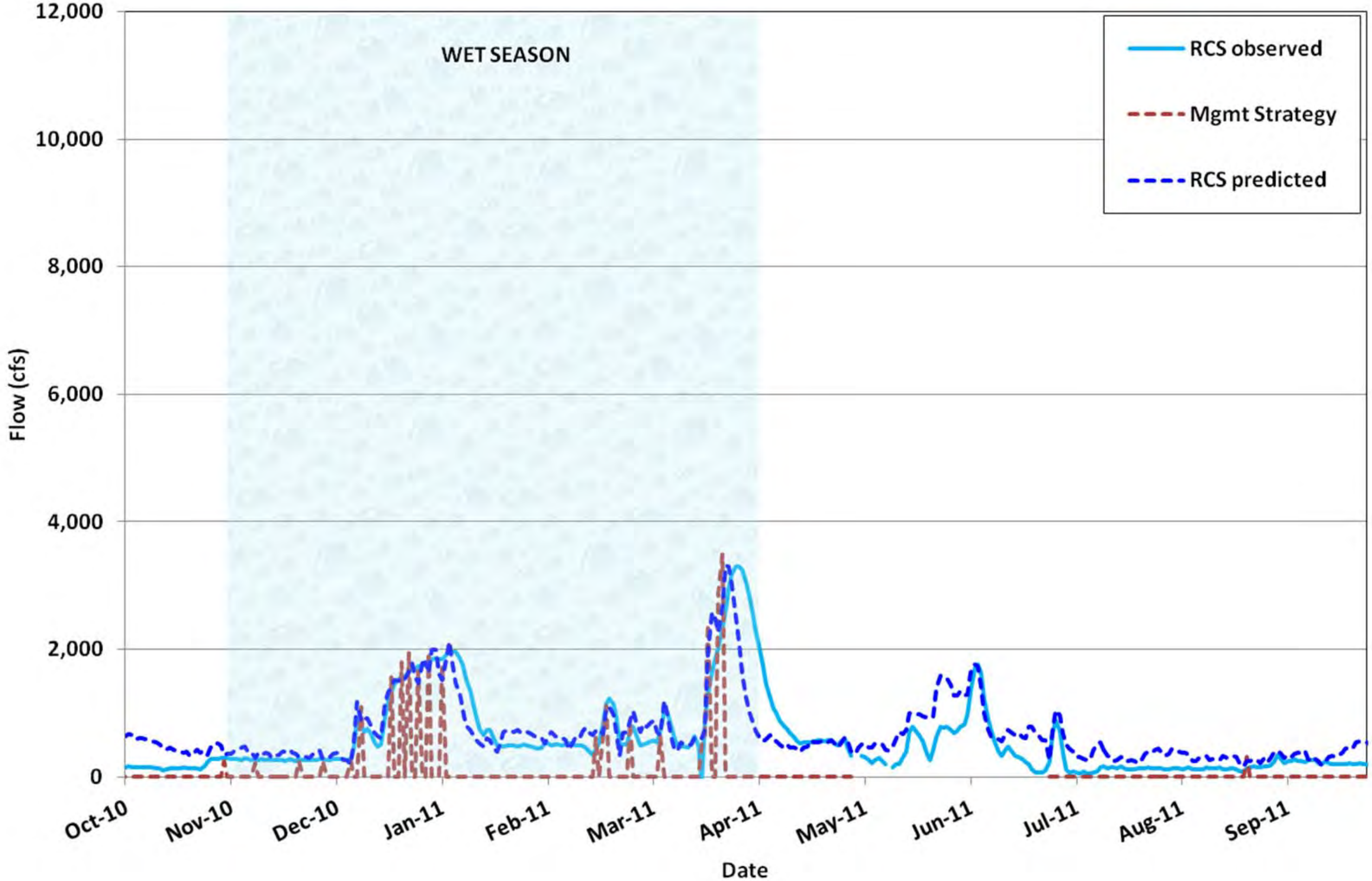


Notes:

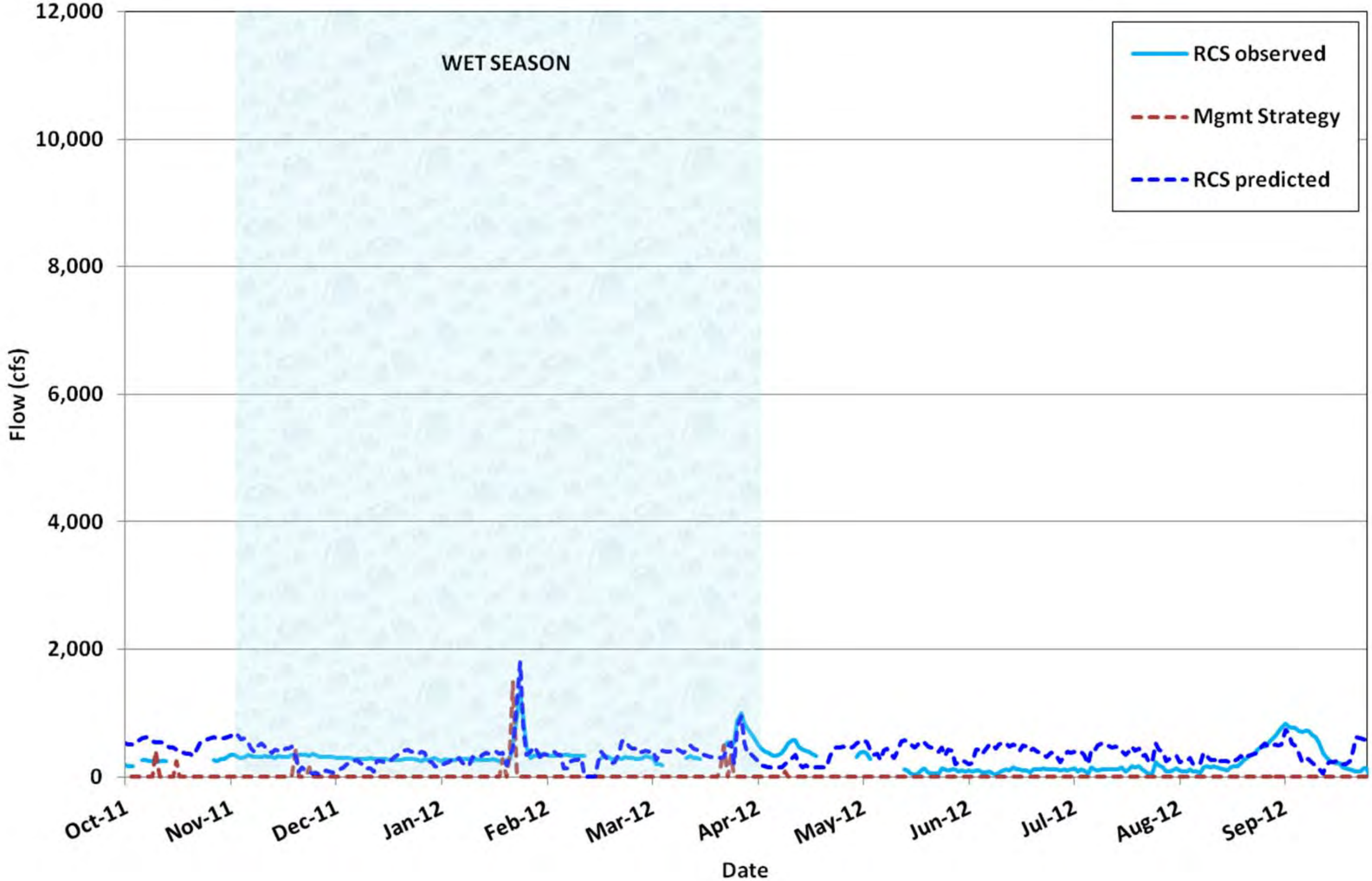
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

KLRC Inflow Validation – WY 2010

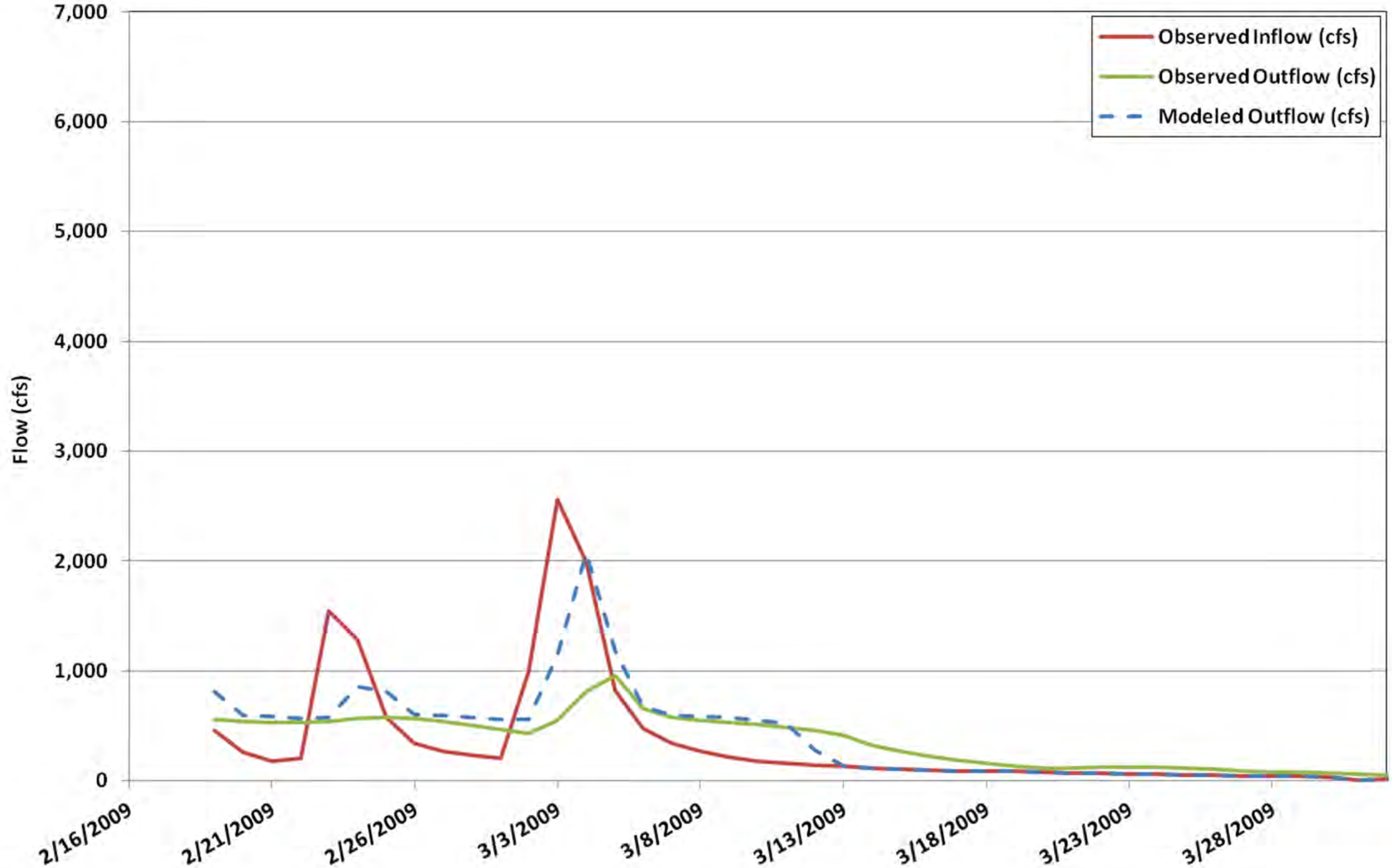
Prepared for DWR	Created By: SP	**Figure 4-15**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **KLRC Inflow Validation – WY2011**		
		Prepared for DWR	Created By: SP	**Figure 4-16**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **KLRC Inflow Validation – WY 2012**		
		Prepared for DWR	Created By: SP	**Figure 4-17**

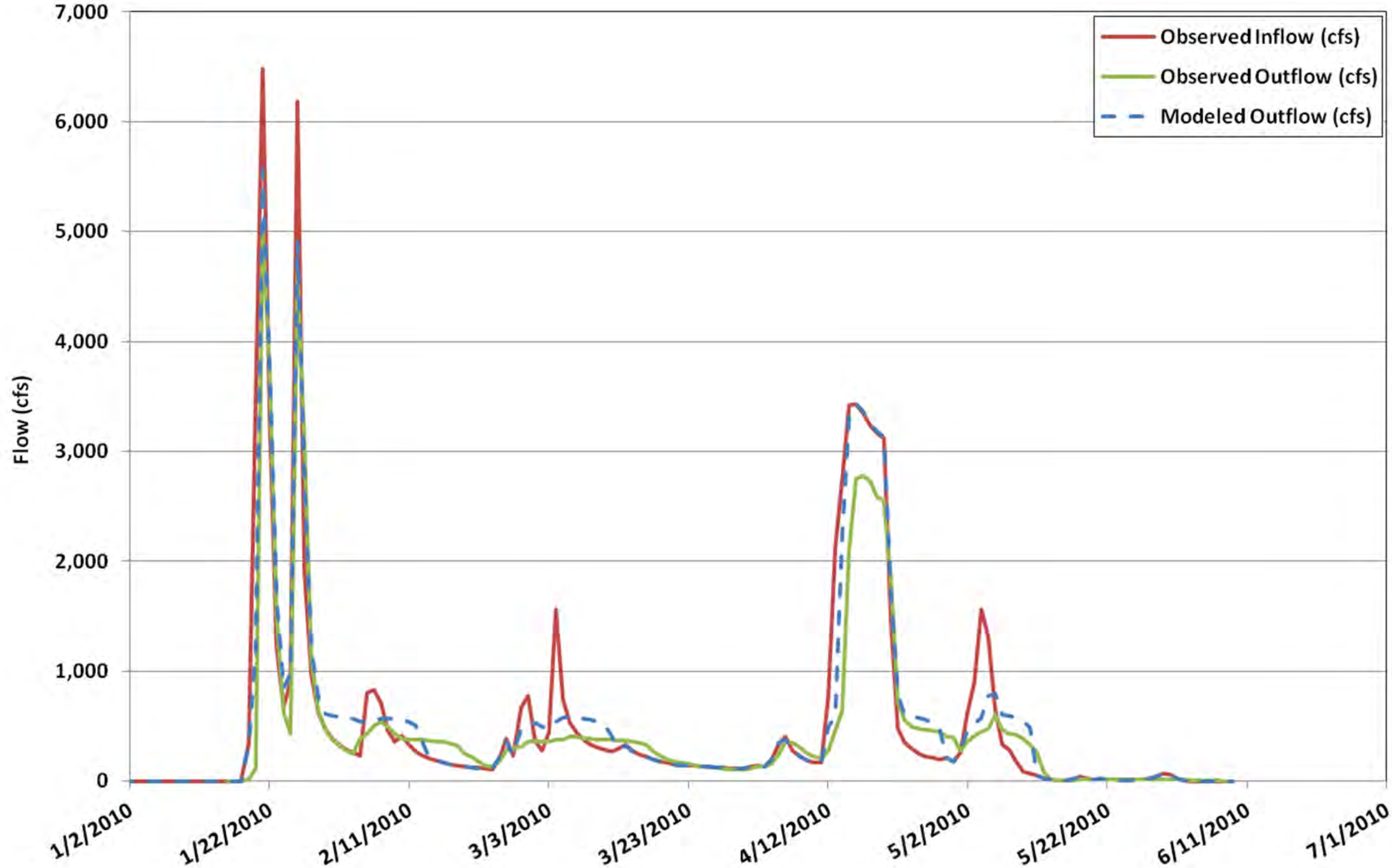


Notes:

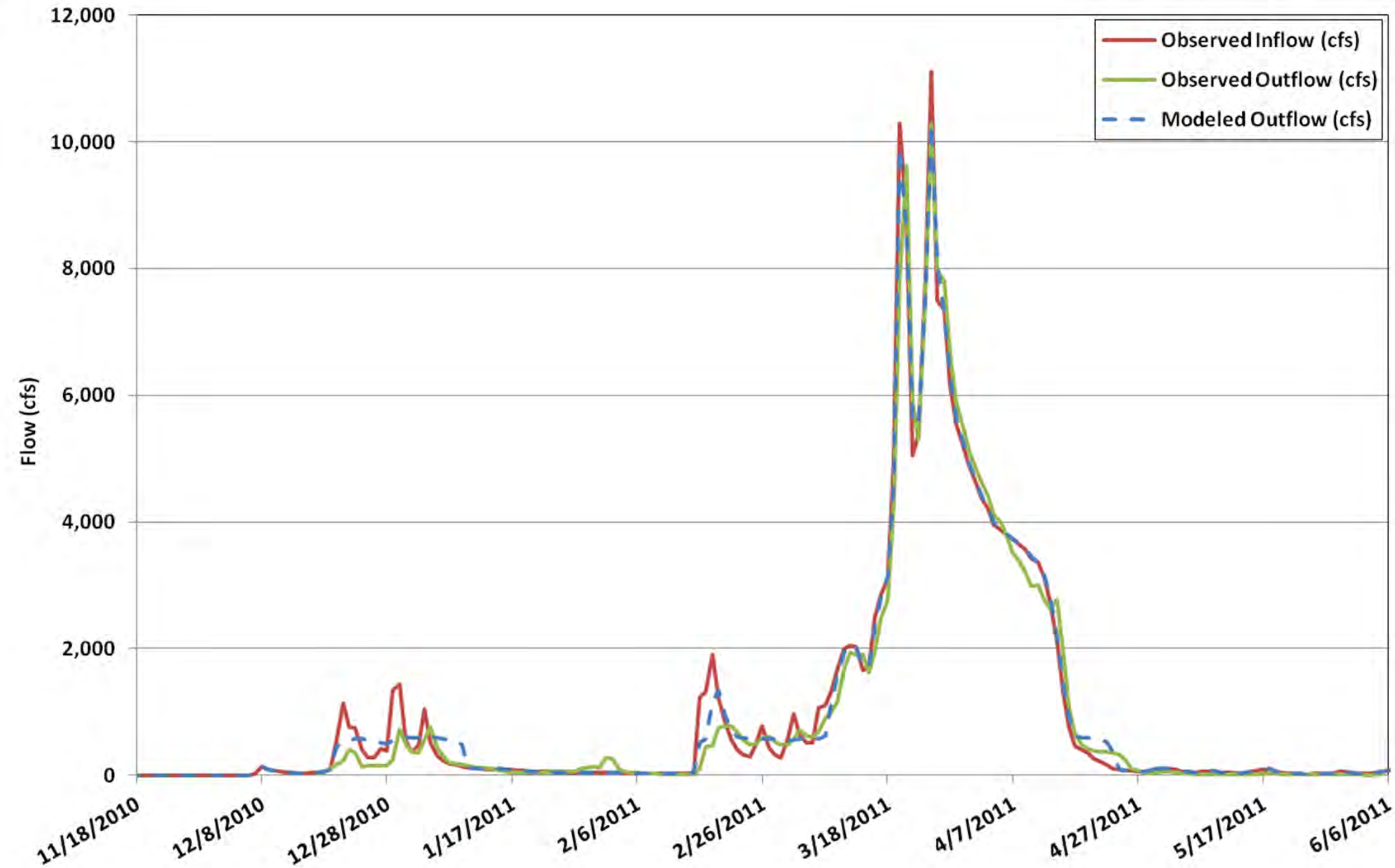
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Cache Creek Settling Basin Outflows – 2009 Rainfall Events

Prepared for DWR	Created By: SP	**Figure 4-18**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Cache Creek Settling Basin Outflows – 2010 Rainfall Events**		
		Prepared for DWR	Created By: SP	**Figure 4-19**

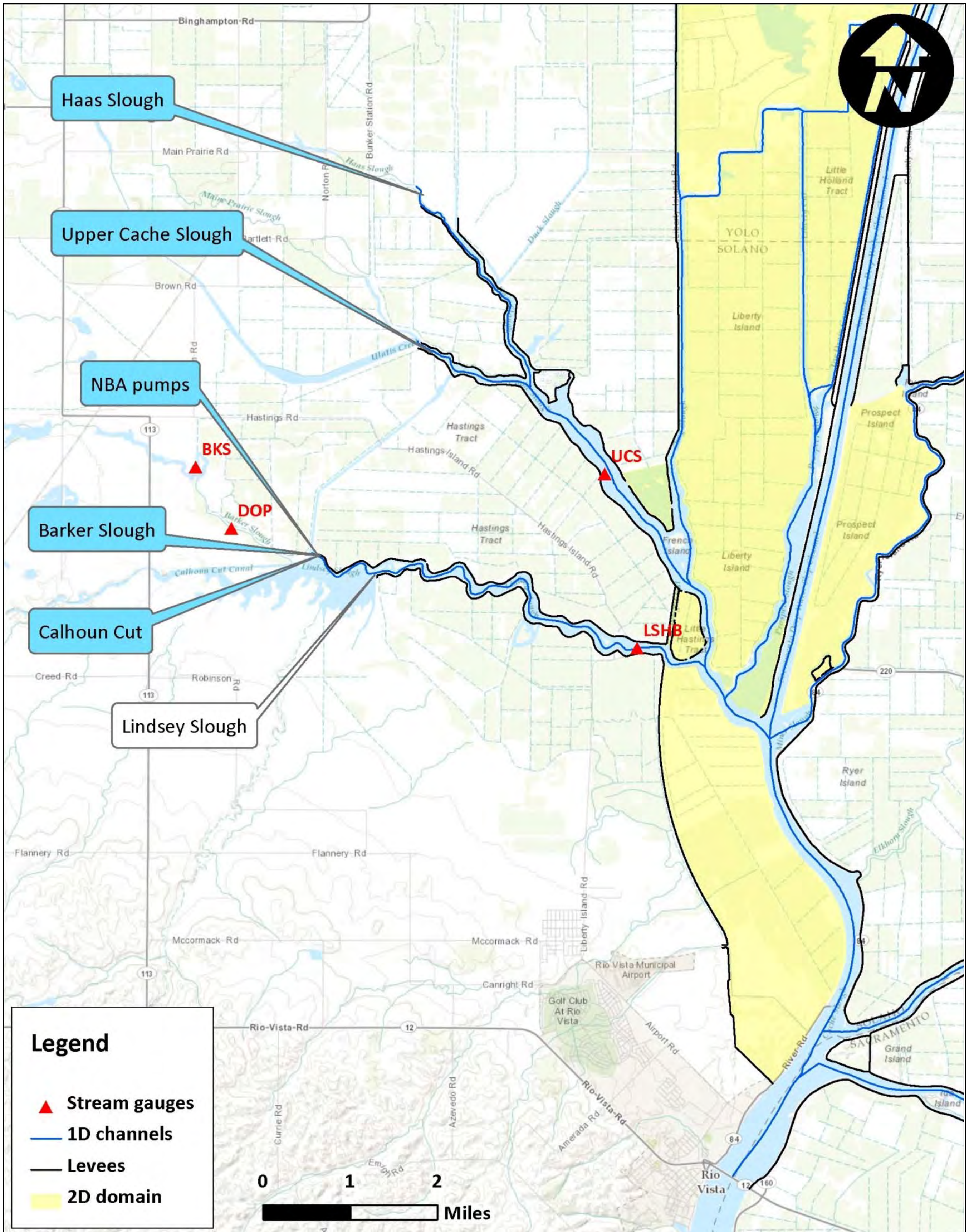


Notes:

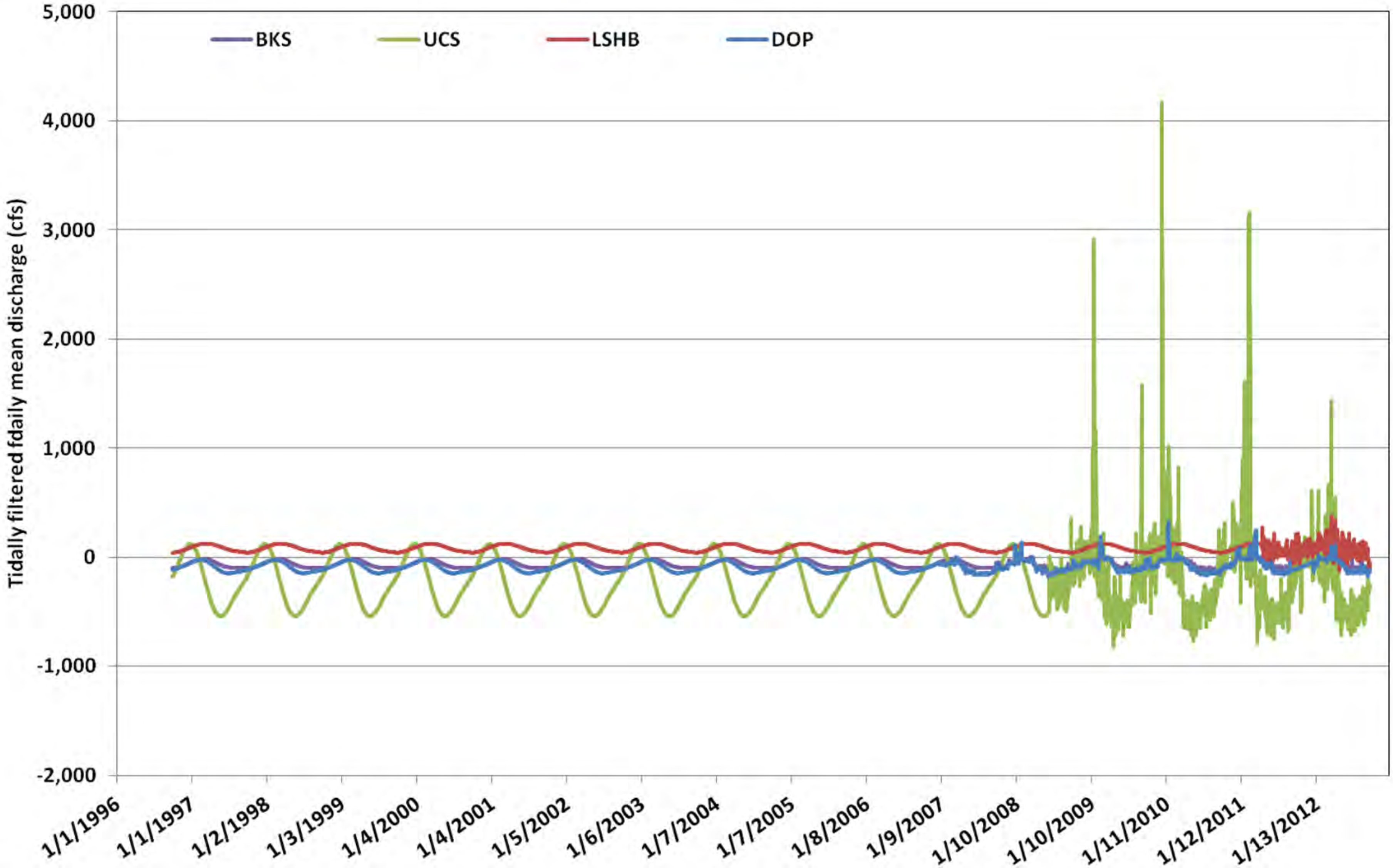
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Cache Creek Settling Basin Outflows – 2011 Rainfall Events

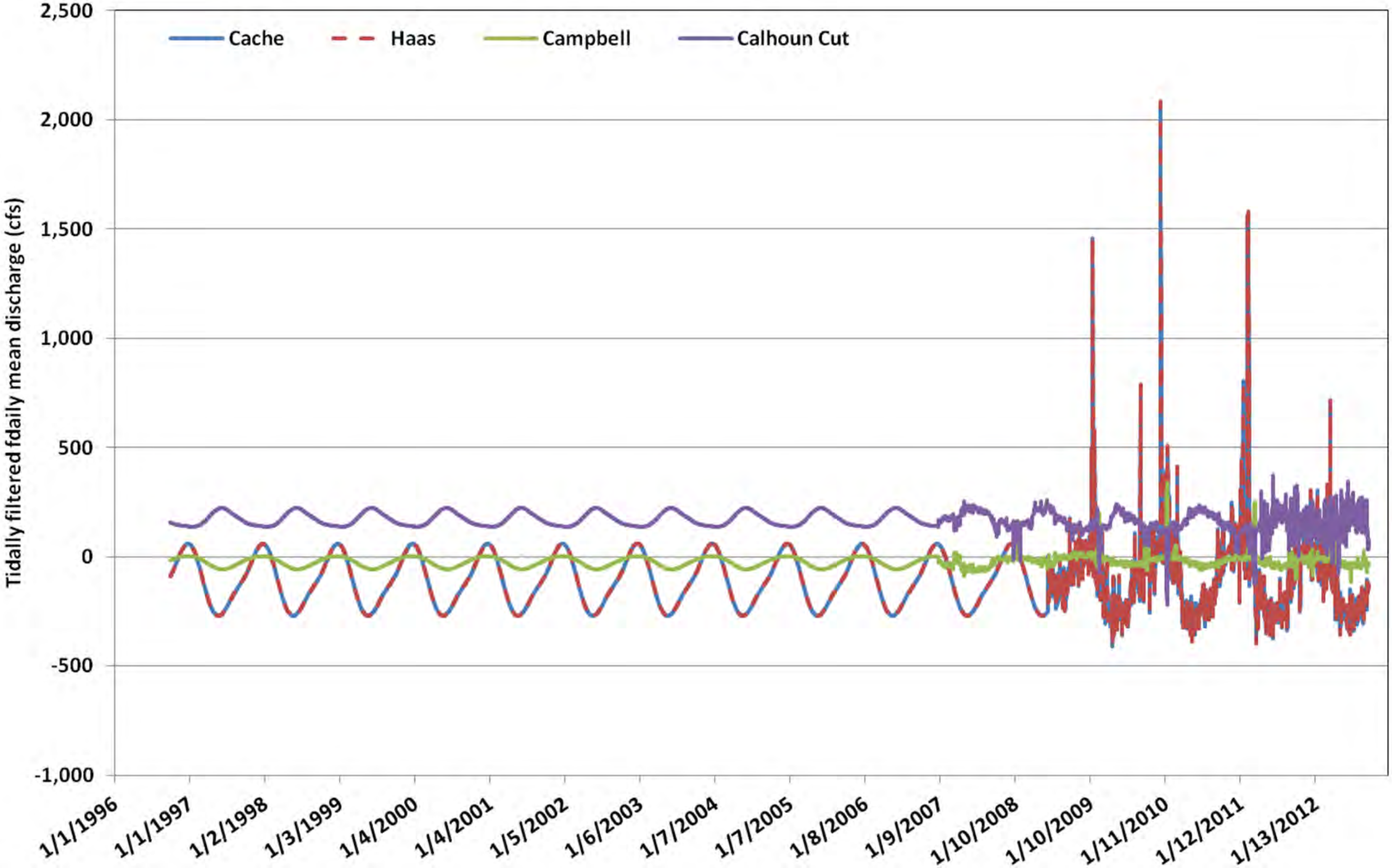
Prepared for DWR | Created By: SP | **Figure 4-20**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Delta Sloughs Inflows and Gauges**		
		Prepared for DWR	Created By: SP	**Figure 4-21**



Notes:	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Sinusoidal Curve Fitting for Delta Slough Gauges**		
		Prepared for DWR	Created By: SP	**Figure 4-22**

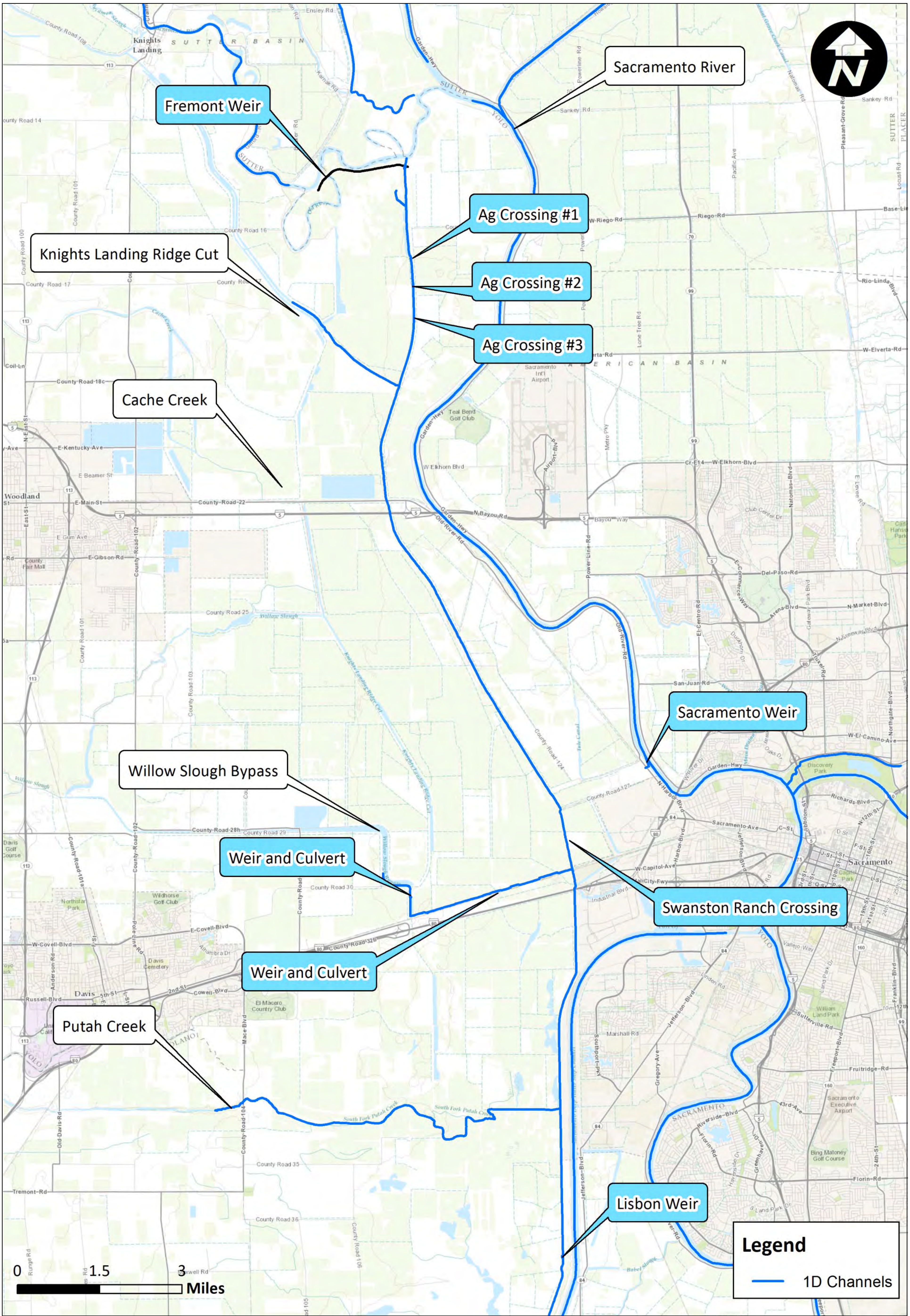


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Estimated Delta Slough Daily Flows

Prepared for DWR	Created By: SP	**Figure 4-23**

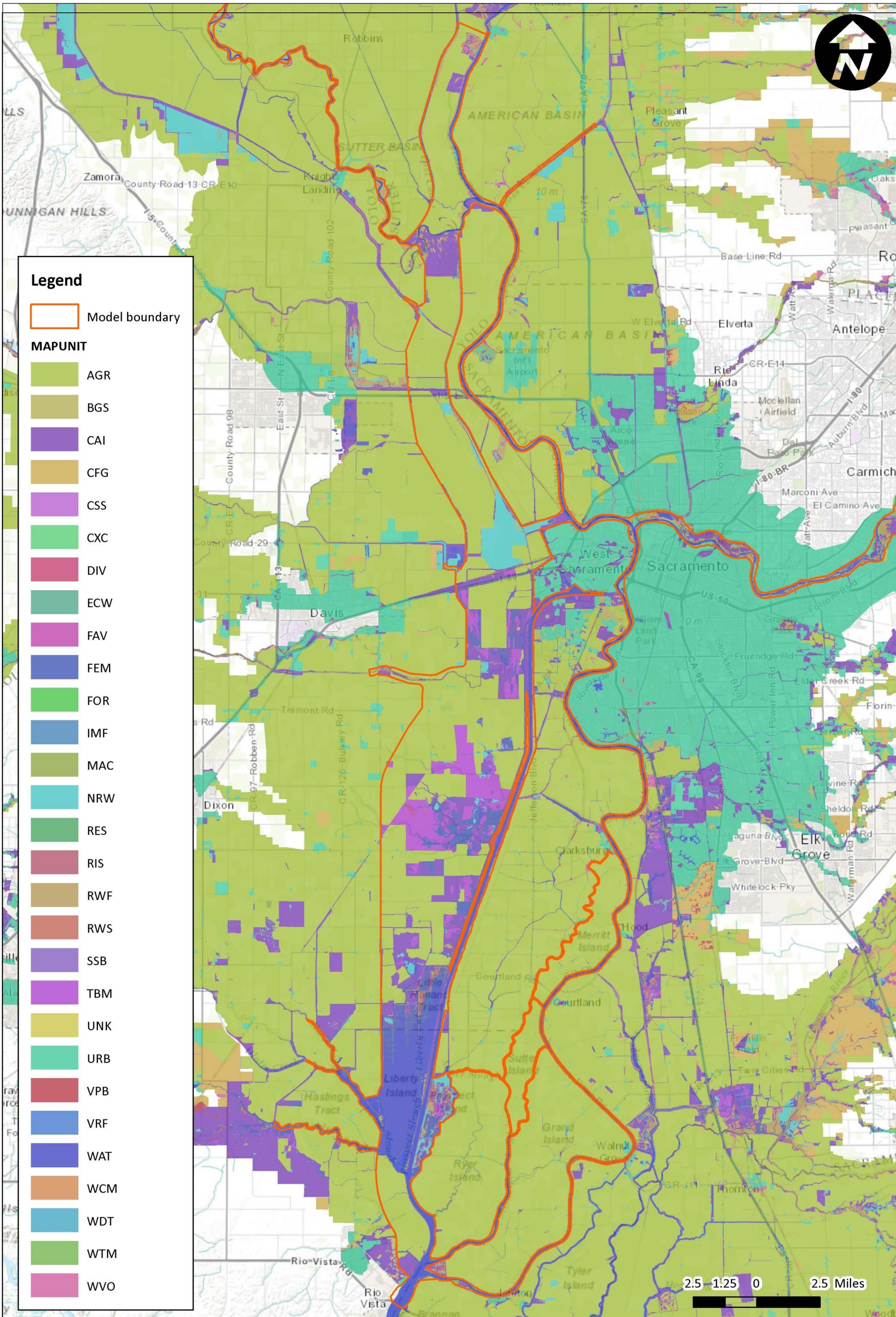


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Hydraulic Structures within the Yolo Bypass

Prepared for DWR | Created By: RDJ | **Figure 4-24**



Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Central Valley Medium Scale Riparian Mapping

Prepared for DWR	Created By: SP	**Figure 4-25**

5.0 Model Calibration

5.1 Overview of Model Calibration

TUFLOW model calibration was performed for three hydrologic conditions in the Bypass to cover the range of flow conditions modeled during the 16 water years. To support model calibration, model data was prepared to include a combination of boundary conditions, measured and gauged flows and stages, surveyed high water marks (HWMs), and gate/weir operations for the following three conditions:

- **1997 Flood** – high flow calibration of the TUFLOW model to HWMs in the Bypass, gauge data (i.e., stage and flow) in the Bypass and the Sacramento River, and the Fremont Weir flow split using gauge data and boundary conditions from the CVFED HEC-RAS model.

- **Low Flow** – calibration to flow within the Tule Canal/Toe Drain channel capacity. Flows and water surface elevations (WSEs) along the Tule Canal/Toe Drain were measured by cbec during February 2010.

- **Flood Recession** – calibration to Yolo Bypass shallow flooding during recession of the March/April 2011 Fremont Weir overtopping event. In addition to readily available gauge data, a series of aerial photographs, HWMs, and limited flow measurements were collected or acquired by cbec.

Calibration of the model was largely focused on river conditions when Fremont Weir spills during system-wide flooding (i.e., January 1997 flood) and localized inundation within the Yolo Bypass (i.e., February 2010 low flow, March/April 2011 flood recession). For conditions when Fremont Weir was not spilling, between elevations 14 to 33 feet NAVD88 when the proposed gated notch could be activated, calibration was not performed. However, the long-term time series plots in Section 6 (i.e., Figures 6-1 to 6-6) provide validation for how the existing conditions model is performing in the Sacramento River when Fremont Weir is not overtopping.

The 2D portion of the model and the 1D channels within the Yolo Bypass (i.e., four Westside tributaries and Tule Canal / Toe Drain) were given initial Manning's n assignments based on medium scale vegetation mapping provided in Table 4-5 in the Report (see tables) as derived from previous studies. The Westside tributaries initial Manning's n assignments never changed as the Westside tributaries were not individually calibrated. The Tule Canal / Toe Drain was individually calibrated and the reach roughness multipliers from the initial values specified in Table 4-5 are provided in Table 5-4 of the Report (see tables). Calibration of the 2D portion of the model by vegetation type occurred by applying global adjustments to the initial Manning's n assignments as provided in Table 4-5 to arrive at the calibrated values. For the 1D-channels outside the Yolo Bypass, in addition to adding energy losses, modifications were made to the CVFED RAS model derived cross section Manning's n values.

The 1997 flood calibration used the full model whereas the other two calibration periods used truncated model domains specific to each calibration period.. The truncated models were used to calibrate specific portions of the Yolo Bypass without having to run the full model. In this way, the team had tighter control over the boundary conditions and the benefit of reduced run times in arriving at solutions quickly. The truncated calibrations focused on refinements to the Tule Canal / Toe Drain channel capacity and relevant hydraulic structures, 1D/2D interface, reinforcement of features in the DEM affecting inundation (i.e., berms and gullies), model stability and coupling across the 1D/2D interface, and modifications to Manning's n assignments. The modifications made to the truncated models were then evaluated in the full model for the 1997 flood calibration, and if further modifications were made to the full model, they were passed back to the truncated models and re-evaluated until the model calibration was satisfactory among all three calibration models. The satisfactory calibration was then verified by the long-term time series plots provided in Section 6.

5.2 High Flow – 1997 Calibration Period

5.2.1 Model Setup

The 1997 event (December 29, 1996 through January 4, 1997) delivered the largest observed discharges into the Bypass over the 16 year period of interest. The observed WSE at the gauge for the Sacramento River on the west side of the Fremont Weir peaked on January 2, 1997 with a stage of 41.4 feet NAVD88. The peak observed flow over the Fremont Weir was 318,000 cfs. For these reasons, the 1997 event was used to calibrate the model for higher flows, with particular attention given to hydrograph timing, peak flows and WSE.

The hydrodynamic model was calibrated to HWMs in the Yolo Bypass, gauge data (i.e., stage and flow) in the Bypass and the Sacramento River, and the Fremont Weir flow split using sub-daily (i.e., 15-minute and hourly) boundary conditions that were generated following the same methods described in Section 4.4. Figure 5-1 shows the boundary conditions, gauges with recorded stage and flow, and surveyed HWMs compiled for the 1997 calibration event. The observed stage and flow data and HWMs were acquired from the CVFED HEC-RAS model. Table 5-1 summarizes the boundary conditions and recorded stage and flow locations that were used for calibration. The Delta Cross Channel gates remained closed during the flood event and diverted no flows out of the Sacramento River.

It should be noted that the gauged Fremont Weir spills for the 1997 flood event consist of a reconstructed hydrograph developed from flow measurements taken downstream of the Fremont Weir during the 1997 flood event (USACE 2007). Based on the measurements taken, DWR discovered that the rating curve was over predicting flows at higher stages and believed that to be caused by sediment buildup causing backwater conditions.

The TUFLOW model was calibrated with:

- Extensive HWMs in the Yolo Bypass and Sacramento River
- Observed stage and flow at multiple gauge locations
- The flow split between Fremont Weir and the Sacramento River

Table 5-1. Boundary conditions and gauge data information for the 1997 calibration event

Boundary Location	Data Source	Stage Gauges	Data Source
Sacramento River			
Sacramento River inflow below Wilkins Slough near Grimes (WLK)	USGS 11390500	Sacramento River at Knights Landing (KNL)	DWR's Water Data Library (A02200)
Knights Landing Outfall Gates (KLOG)	DWR's Water Data Library (A02945)	Sacramento River at Fremont Weir (FRE), West end	DWR's Water Data Library (A02170)
Feather River and Sutter Bypass (FEA+SUT)	Estimated using methods developed in this study[1,2]	Fremont Weir Spill	DWR's Water Data Library A02930
Natomas Cross Canal (NCC)	Estimated using methods developed in this study[1,3]	Sacramento River at Fremont Weir, East end	DWR's Water Data Library (A02160)
		Sacramento River at Verona (VON)	USGS 11425500
American River (AFO)	USGS 11446500	Sacramento River above Sacramento Weir (SBP)	DWR's Water Data Library (A02108)
Steelhead Creek	Estimated using methods developed in this study[1,4]	Sacramento Weir Spill	DWR operations data
Delta Cross Channel(DLC)	Closed during the flood event, no flow	Sacramento River at I Street Bridge (IST)	DWR's Water Data Library (A02100)
Georgiana Slough (GSS)	Estimated using methods developed in this study[1,5]	Sacramento River near Freeport Bridge (FPT)	USGS 11447650
		Sacramento River at Walnut Grove (SDC)	DWR's Water Data Library (B91650)

Boundary Location	Data Source	Stage Gauges	Data Source
Yolo Bypass			
Knights Landing Ridge Cut (KLRC)	Estimated using methods developed in this study[1]	Yolo Bypass near Woodland (YBY)	USGS 11453000
Cache Creek Settling Basin	Estimated using methods developed in this study[1]	Yolo Bypass at Lisbon (LIS)	DWR's Water Data Library (B91560)
Putah Creek	Estimated using methods developed in this study[1]		
Willow Slough Bypass	Estimated using methods developed in this study[1]		
Downstream Boundary			
Sacramento River at Rio Vista (RVB)	DWR's Water Data Library (B91212)[6]		
Notes: [1] Developed following the methods outlined in Section 4.4 [2] Estimated using a mass balance relationship: (FEA + SUT) = (VON + FRE) - (WLK + KLOG + NCC); flows split was based on ratio of (GRL+MRY+BRW) and (BSL+TIS) [3] Estimated as 1.43 x Steelhead Creek flow [4] Estimated using the computed stage along the Steelhead Creek near the West El Camino Avenue bridge and stage-discharge curve previously developed by DWR (2008) and extended by cbec as a part of this study [5] Daily flows provided by DWR's Dayflow program converted to hourly flows [6] The stage data is in USED datum and the gauge height correction (NAVD88 = USED - 0.6 ft) has not been applied			

5.2.1 Results Summary

Modeled maximum WSEs were compared at 43 HWMs within the Bypass and 21 in the Sutter Bypass and along the Feather River. Additionally, gauge records at 11 stream gauges (8 outside the Bypass, 3 within) were compared to model results. Reasonable changes within engineering judgment were made in the model, mainly modifications to the Manning roughness coefficients and adding energy losses to calibrate the model to these data. The model was considered calibrated when modeled peak WSE demonstrated good agreement with the majority of HWMs and gauge stage records and predicted hydrographs at flow gauge locations compared favorably with discharge records.

Additional energy losses were used to improve calibration in areas where 1D losses due to turbulence may have been underestimated such as the confluence of a river or where increasing the Manning roughness coefficients impaired the low flow calibration as shown in Figure 5-2. Energy losses are applied as a function of the velocity head so they have a very small impact at low flows.

A comparison of the peak computed WSEs to collected HWMs is shown in Figure 5-33. The computed WSE within the Yolo Bypass are typically high (average error 0.2 feet) and those in the Sutter Bypass are typically low (average error -0.2 feet). The root-mean-square error (RMSE) for the Sutter Bypass is 1.1 feet. The RMSE for the higher priority HWMs within the Yolo Bypass is 0.8 feet. The RMSE for all of the HWMs is 0.9 feet.

The flow split between the Fremont Weir and Verona are of particular concern for modeling of the Yolo Bypass. Figure 5-4 shows a comparison of the computed and observed relationship between flows into the Bypass and flows down the Sacramento River, indicating that the model is reasonably predicting the flow split.

Outside of the Bypass, calibrated model results were compared at 8 gauges (3 gauges included discharge). Comparison plots are shown in Figure 5-5 through Figure 5-18. Generally, the shape of the predicted stage hydrographs match reasonably well to observed stages. In several instances, although the general shape and magnitude of the predicted WSEs compare well to the gauge records, the full magnitude of peaks and dips observed at gauges are not reproduced in the model. Potential inaccuracies in the assumed Sacramento Weir gate operations and/or boundary conditions may hamper the ability of the model to capture peak stages. At discharge gauges, flow hydrographs from the model reproduce the shape and magnitude of hydrographs well. The WSEs in the Sacramento River at Walnut Grove Stage shown in Figure 5-15 are consistently high but the tidal signal timing matches well.

5.3 Low Flow– February 2010 Calibration Period

5.3.1 Model Setup

The TUFLOW model was calibrated to the capacity of Tule Canal/Toe Drain during low flows in February 2010. Flows and WSEs along the Tule Canal/Toe Drain were measured by cbec (2010) on February 19, 2010 at 19 locations from the northerly extent of the Tule Canal (south of Tule Pond) to just downstream of Lisbon Weir near the DWR Lisbon Weir gauge. Flow in the channel was measured with an Acoustic Doppler Current Profiler (ADCP). WSEs were collected using Real Time Kinematic (RTK) Global Positioning System (GPS) survey equipment and referenced to NAVD88. Figure 5-19 shows the locations of flow and stage measurements. Table 5-2 provides a summary of the flow and stage measurements. The benefit of obtaining these measurements in February 2010 was that the flows in the Tule Canal/Toe Drain were at a point where in most places they were just passing onto the floodplain, or just below the top of bank, thus providing a relatively reasonable estimate of the flow capacity of the Tule Canal/Toe Drain.

For the low flow calibration of the Tule Canal/Toe Drain, the TUFLOW model was truncated to the 1D channel between Tule Pond and Little Holland Tract. The 2D domain was also truncated to these general extents. The flows in Tule Canal/Toe Drain were based on measured flows, as shown in Table 5-2, with incremental flows added or subtracted from the channel. There were minimal spills over the Fremont Weir (less than 3,000 cfs) and no spills over

Sacramento Weir during this low flow event. Flows from the Westside tributaries are included within the measured flows, so inflows from these tributaries are accounted for in the incremental flows. The tidal boundary at Little Holland Tract was based on recorded elevations collected by cbec (unpublished) in support of the Lower Yolo Restoration Project at Metropolitan Water District Gauge 7 (MWD7).

Table 5-2. Summary of flow and stage measurements taken in the Toe Drain/Tule Canal

Location	Elevation (ft NAVD88)	Measured Flow (cfs)[1]
ADCP1	17.08	---
ADCP2	17.26	151
ADCP3	16.86	920
ADCP4	16.37	1072
ADCP5	16.10	1344
ADCP6	15.71	1281
ADCP7	15.60	1443
ADCP8	15.15	1408
ADCP9	14.90	1539
ADCP10	14.46	1541
ADCP11	13.56	1644
ADCP12	11.52	2154
ADCP13	11.12	2307
ADCP14	11.00	2278
ADCP15	10.59	2526
ADCP16	10.28	2622
ADCP17	10.30	2692
ADCP18	9.79	2609
ADCP19	8.58	2805

Notes:
[1] Flow measurements recorded in the Toe Drain/Tule Canal were validated with flow measurements observed at Lisbon Weir. Flow measurements taken by cbec near Lisbon Weir were within 3.0% of those at Lisbon Weir.

5.3.2 Results Summary

Low flow calibration of the Tule Canal/Toe Drain north of Lisbon Weir was achieved by adjusting the hydraulic roughness coefficients (see Table 5-4 for 1D channel multipliers on the 1D channel base values provided by Table 4-6) and implementing energy losses to account for woody debris, hydraulic structures (e.g., piers), and flow transitions (e.g., scour holes downstream of hydraulic structures). These adjustments were made to minimize the RMSE between the measured and modeled values in the water surface profile. At this flow condition, there was minimal flow interaction between the 1D channel and 2D grid, as flows were largely contained to the channel. As shown by Figure 5-20, the RMSE for the WSEs was within 0.3 feet, with the largest errors occurring in the vicinity of hydraulic constrictions (i.e., upstream of KLRC confluence, at Swanston Ranch check dam, and upstream of Lisbon Weir).

5.4 Flood Recession– March/April 2011 Calibration Period

5.4.1 Model Setup

The TUFLOW model was calibrated for shallow flooding on the Bypass during the receding limb of the March/April 2011 Fremont Weir overtopping event. The flows as measured at Yolo Bypass near Woodland per USGS gauge 11423000 show that the overtopping event peaked around March 27 and receded thereafter. The TUFLOW model 1D channel and 2D floodplain was truncated between Fremont Weir in the north and Little Holland Tract in the south. Figure 5-21 shows the model extents, boundary conditions, gauges with recorded stage and flow, and surveyed WSEs compiled for the 2011 calibration event. Table 5-3 summarizes the boundary conditions and recorded stage and flow locations that were used for calibration. Sub daily boundary condition data was largely based on gauged data and estimated where gauged data was not available following the methods outlined in Section 4.4. The Sacramento Weir gates remained closed during the flood event and diverted no flows out of the Sacramento River into Yolo Bypass.

In addition to readily available gauge data, a series of aerial photographs, WSEs, and limited flow measurements were collected or acquired by cbec (unpublished). The aerial photographs were collected on April 9, 2011 around 4 pm (see Figure 5-22) and on April 12, 2011 around 1:45 pm (see Figure 5-23), and were subsequently georeferenced using flight crosses. WSEs along the Tule Canal/Toe Drain were collected on the same days as the aerial photographs using RTK GPS survey equipment. The WSE data collected on April 9, 2011 extended from Fremont Weir to Lisbon Weir. The WSE data collected on April 12, 2011 extended from Tule Pond to Yolo Flyway Farms.

In addition to the WSEs, an ADCP was used to measure flow in the Tule Canal just downstream of the USGS Yolo Bypass at Woodland gauge from the County Road 22 bridge over the Tule Canal. This location includes flows from Fremont Weir, KLRC, Cache Creek Settling Basin, and floodplain drainage north of County Road 22. The measured discharges on April 9, 2011 at 12:30 pm and on April 12, 2011 at 2:25 pm were 7,290 cfs and 4,250 cfs respectively, while the flows reported at the Yolo Bypass at Woodland gauge were 5,750 cfs and 3,460 cfs. Potential discrepancies between USGS published and measured values could be due to an older USGS rating curve or local conditions at the time of the measurements (e.g., presence of aquatic vegetation or debris loading on the railroad track trestle bents).

The TUFLOW model was generally calibrated with:

- Measured WSEs in the Tule Canal/Toe Drain
- Limited measured flows at County Road 22
- Georeferenced aerial photographs showing floodplain inundation

Table 5-3. Boundary conditions and gauge data information for the 2011 calibration event

Boundary Location	Data Source	Gauge Data	Data Source
Yolo Bypass			
Fremont Weir spill into Yolo Bypass	CDEC (FRE)		
Knights Landing Ridge Cut	DWR's Water Data Library (A02939)		
Cache Creek Settling Basin	USGS 11452800 and USGS 11452900	Yolo Bypass near Woodland (YBY)	USGS 11453000
Putah Creek	Estimated using methods developed in this study[1]		
Willow Slough Bypass	Estimated using methods developed in this study[1]	Yolo Bypass at Lisbon (LIS)	DWR's Water Data Library (B91560)
Downstream Boundary			
Little Holland Tract	Westland Water District gauge (WWD6)[2]		
Notes: [1] *Long-term Boundary Conditions Development* technical memorandum (cbec 2014) [2] See cbec (2011)			

5.4.2 Results Summary

During the 2011 flood recession calibration, the wetting and draining of Yolo Bypass was evaluated by modifying the berm density, adding drainage features, and analyzing the elevations along the 1D/2D interface for the Tule Canal/Toe Drain, as previously described in Section 4.3.4. It was determined that adding berms and drainage features to the 2D grid was necessary, but modifying the elevations along the 1D/2D interface was not necessary. Energy losses were also implemented at specific locations to account for woody debris, hydraulic structures, and flow transitions, same as the 2010 low flow calibration.

Infiltration losses were also added to the 2D grid to accommodate 1) sub grid scale field drainage not captured by the drainage features described in Section 4.3.4 and 2) to remove isolated ponding so as not to affect the LDW calculations. The infiltration or loss rate was set to 0.05 inches/hour (in/hr), which corresponds to a typical value for the saturated hydraulic conductivity of the limiting layer for the silty clay to clay soils underlying the Bypass. At this loss rate, 1 foot of ponded water would take approximately 10 days to be infiltrated. It should be noted that infiltrated water is lost from the model and does not reenter the Tule Canal/Toe Drain.

In addition to these changes, the Fremont Weir inflows to the Yolo Bypass were modified specific to this model calibration. Because the Fremont Weir inflows are derived from a rating curve established for a 1.8-mile-long weir, the estimated inflows are sensitive to small changes in stage. After reviewing the April 9, 2011 aerial photograph (see Figure 5-22), it was determined that there was a relatively small amount of flow through the fish ladder as well as very shallow overtopping over a 100-ft segment of the weir immediately to the east of the fish ladder. However, the published inflow would suggest that there was approximately 5000 to 10000 cfs over the weir, which is incorrect based on the aerial photograph. As such, the Fremont Weir inflows were manually modified given uncertainty in the Fremont Weir gauge data so the modeled flows at County Road 22 would reasonably match the measured flows on April 9 and 12, 2011 (see Section 5.4.1). This was also done to provide the best fit with the measured water surface profiles and inundation extents while keeping Manning roughness coefficients within reasonable limits. In doing so, the Westside tributary flows were left unchanged. The final inflows are a slight modification to the Fremont Weir inflows (see Figure 5-24). However, it should be noted that the long-term simulation for water year 2011 used the full model whereby inflow over Fremont Weir was computed by the model per the long-term hydrologic boundary conditions.

The adjustments described above were made to minimize the RMSE between the measured and modeled values in the water surface profiles as well as minimize the difference in flooded extents between observed and modeled. Figure 5-25 and Figure 5-26 show the modeled water surface profile and wetted extents, respectively, compared to observations made on April 9, 2011. The RMSE for the WSEs was within 0.3 feet, with the largest increases in the profile occurring north of County Road 22. The modeled wetted extents north of I-80 were 3.6 percent (or a net 400 acres) higher than observed, with the largest deviations occurring north of County Road 22. The increases in stage and wetted extents north of County Road 22 are closely linked to the modeled flows being 1,110 cfs higher than measured on April 9, 2011.

Figure 5-27 shows the water surface profile on April 12th. Figure 5-28 and Figure 5-29 show the wetted extents north and south of I-80, respectively, on April 12, 2011. The RMSE for the WSEs was within 0.5 feet, but generally under predicting the measured profile. The modeled wetted extents for the entire model domain were 10 percent (or a net 2800 acres) lower than observed, with the largest deviations occurring along Conaway Ranch and south of Lisbon Weir. The decreases in stage and wetted extents could be linked to the modeled flows being 775 cfs lower than measured on April 12, 2011 and a simplified drainage network that is perhaps too efficient at draining the Yolo Bypass.

Given the uncertainties in the modeled inflows over Fremont Weir and contributions from major drainage features not represented by the Westside tributaries (such as the City of Davis and RD 2068), along with simplified representation of field berms and drainage features, the 2010 low flow and 2011 flood recession calibration results are presumed to be satisfactory and to provide a relatively reasonable description of the inundation patterns within the Yolo Bypass during frequent events.

Table 5-4 shows the resultant Tule Canal/Toe Drain subreach multipliers that were applied to the composite Manning roughness coefficients assigned from the medium scale vegetation mapping.

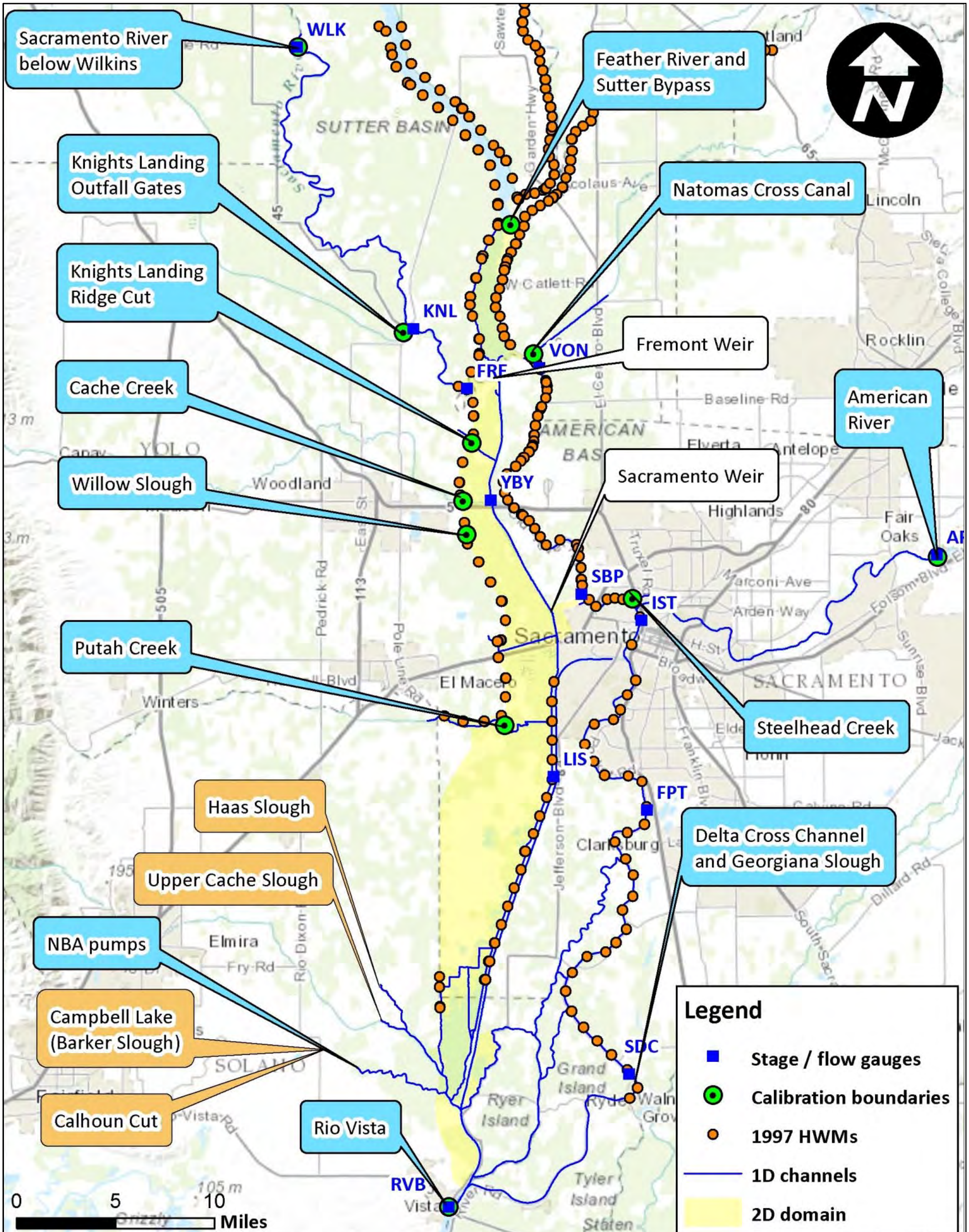
Table 5-4. Tule Canal/Toe Drain 1D low flow roughness multipliers

Subreach Stationing (feet)	Manning Roughness Coefficients Multiplier	Subreach Stationing (feet)	Manning Roughness Coefficients Multiplier
2500 - 69227	1.5	84226 - 91726	0.95
70606 - 75726	1.25	93226 - 98226	1.1875
77226 - 80726	1.1	99726 - 108470	1.25
81226 - 82726	1.045	108727 - 157227	0.95

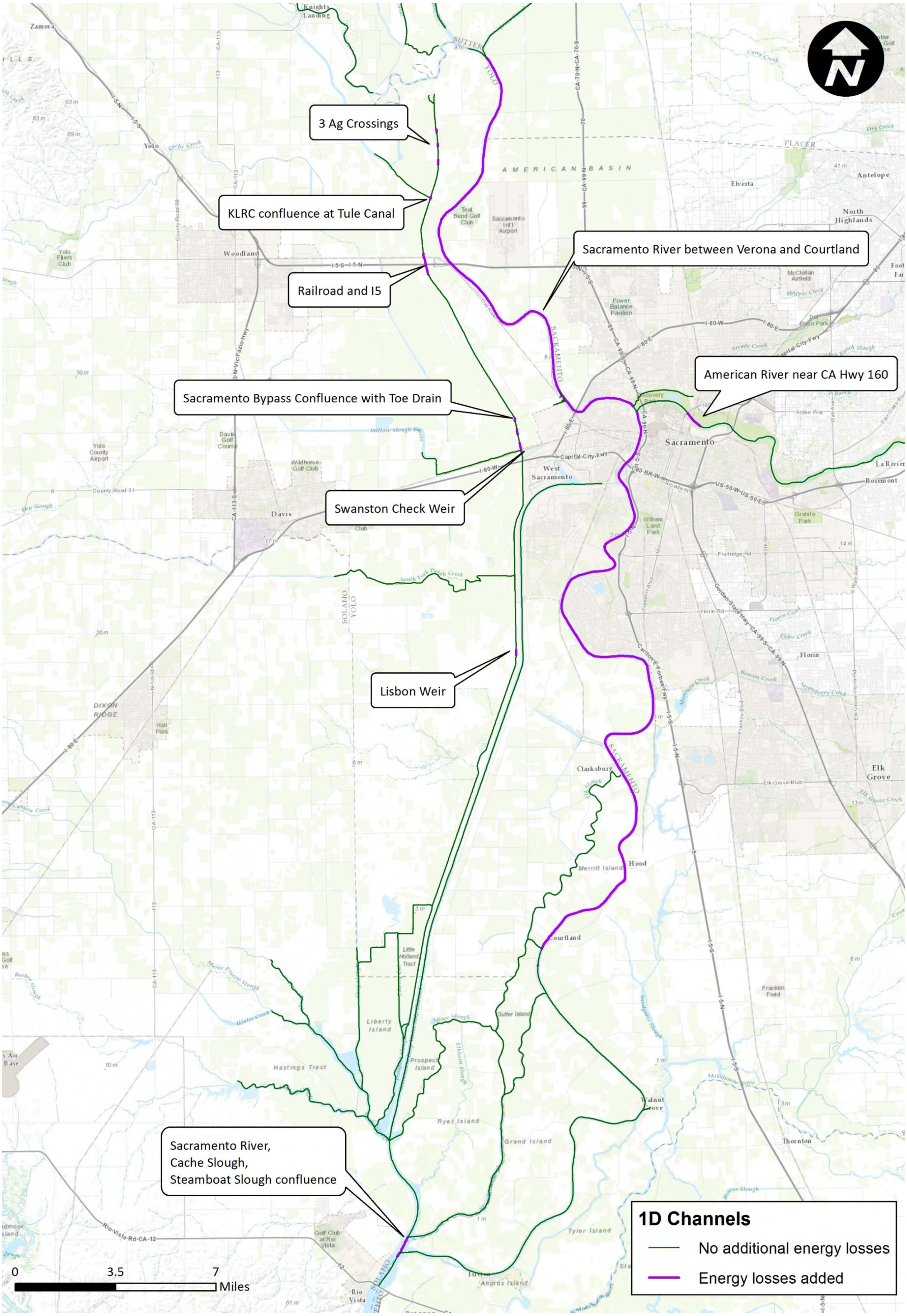
5.5 Results Summary

Three calibration events were used to optimize model parameters and demonstrate that the model performs as expected. Both low flow and high flow scenarios were conducted to ensure the model handles the range of expected flow rates. The RMSE for the WSEs for the low and high flow calibration events were 0.3 ft and 0.9 ft, respectively, providing good fit between observed and modeled results. The 2011 flood recession calibration included aerial photos which provided the ability to compare modeled and observed inundations extents. The RMSE for the WSEs for April 12, 2011 were within 0.5 ft and the area of inundation was within 10% as shown in the aerial photographs. The results of the three calibration events provide assurance that the model represents well the flooding and draining processes in the bypass. The 2010 and 2011 calibrations also provide verification that the flow estimation techniques for the Westside tributaries (see Section 4.4.8) are reasonably accurate given the low RMSE for the WSEs despite the uncertainty in the inflows from major drainage features.

We recognize that the USGS has a comprehensive network of gauges recording stage and flow in the slough system south of the Stair Step and Courtland that can be used to calibrate the flow splits within the Cache Slough Complex. Model calibration was not performed in great detail within the Cache Slough Complex during the 2010 and 2011 calibrations as those calibrations were focused on the Yolo Bypass north of Liberty Island. However, the long-term stage verification at Liberty Island (see Figure 6-6) and downstream boundary sensitivity (see Figure 6-7 and Figure 6-8) demonstrate that the model reasonably predicts WSEs south of the Stair Step and that small deviations in stage do not affect the model results within the area of interest (i.e., Yolo Bypass bounded by Fremont Weir and the Stair Step).



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **1997 Flood Calibration Data**		
		Prepared for DWR	Created By: SP	**Figure 5-1**



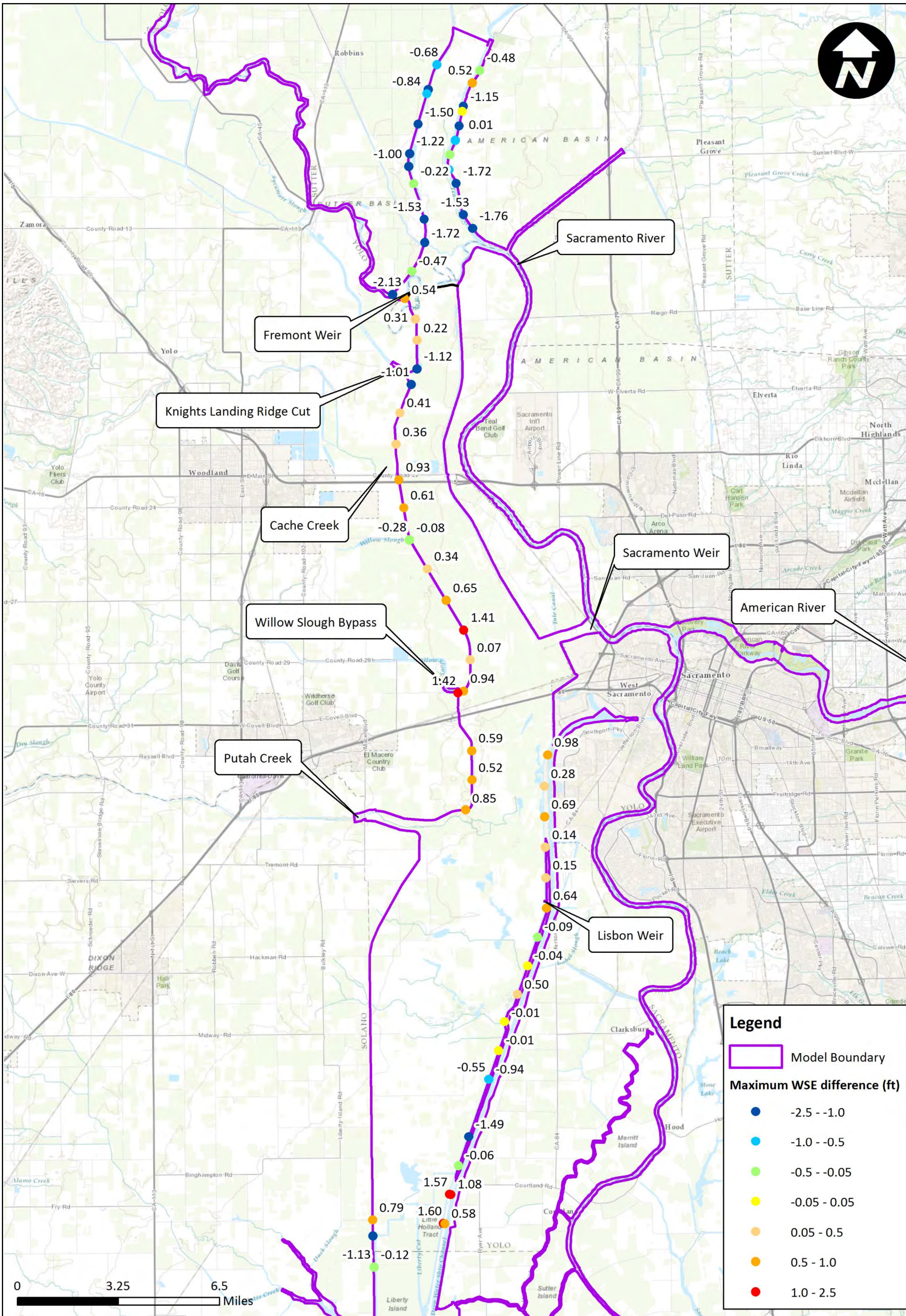
Notes:

HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

1D Channels with Additional Energy Losses

Prepared for DWR | Created By: RDJ | **Figure 5-2**

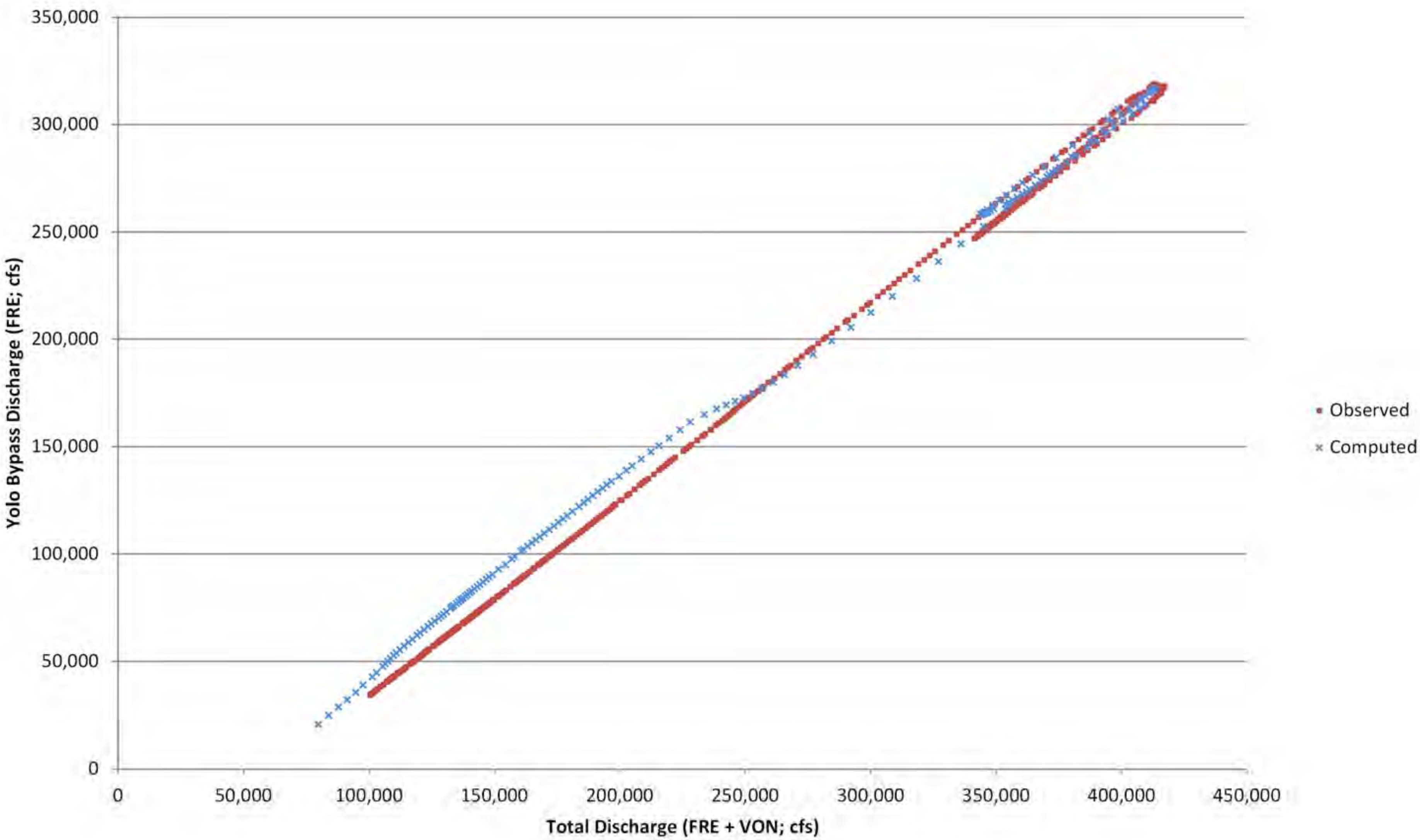


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

1997 Calibration Comparison to High Water Marks

Prepared for DWR | Created By: RDJ | **Figure 5-3**



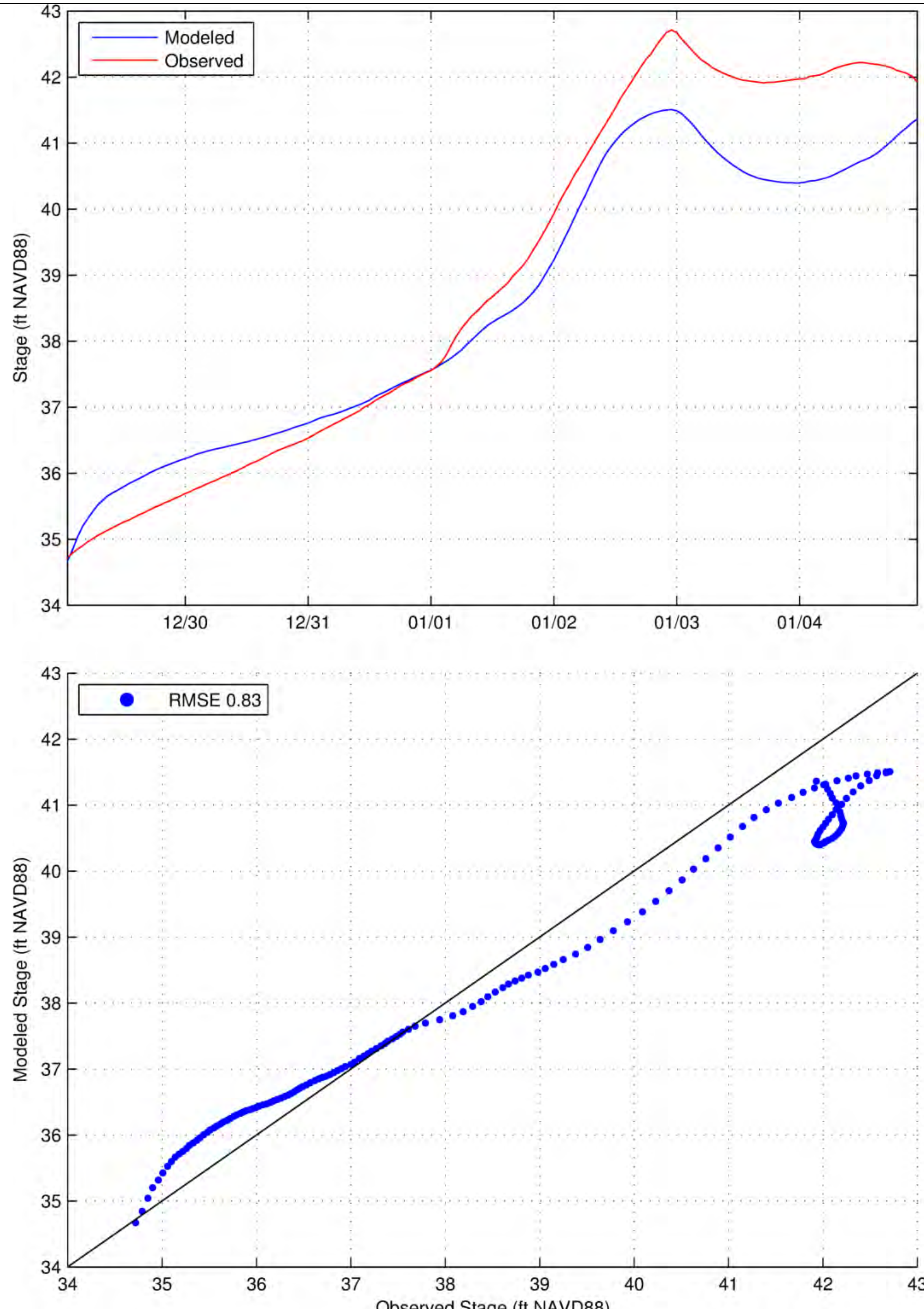
Notes: Comparison of Yolo Bypass discharge vs total discharge for computed and observed data.

HDR cbec eco engineering

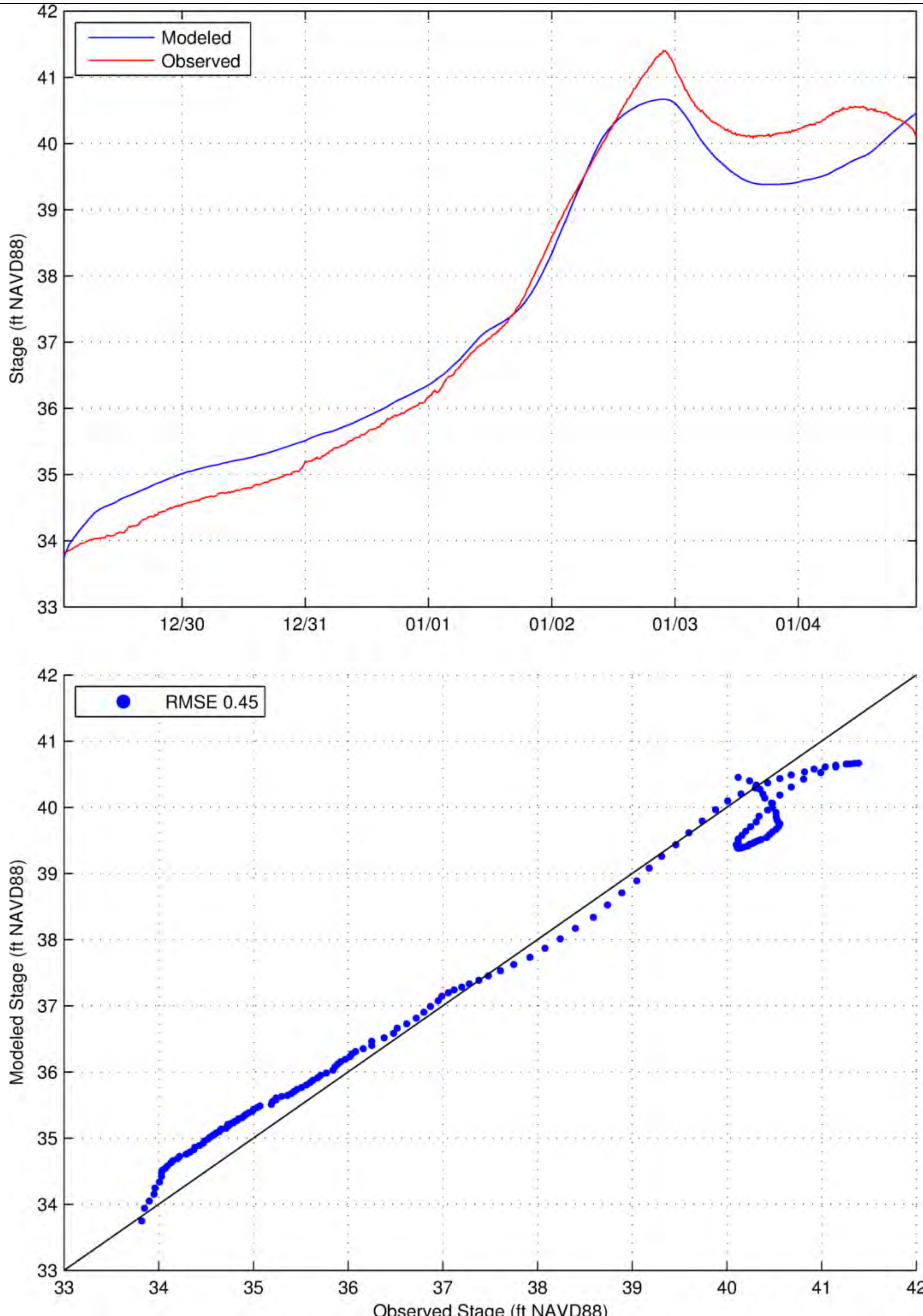
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

1997 Calibration Sacramento River Flow Split

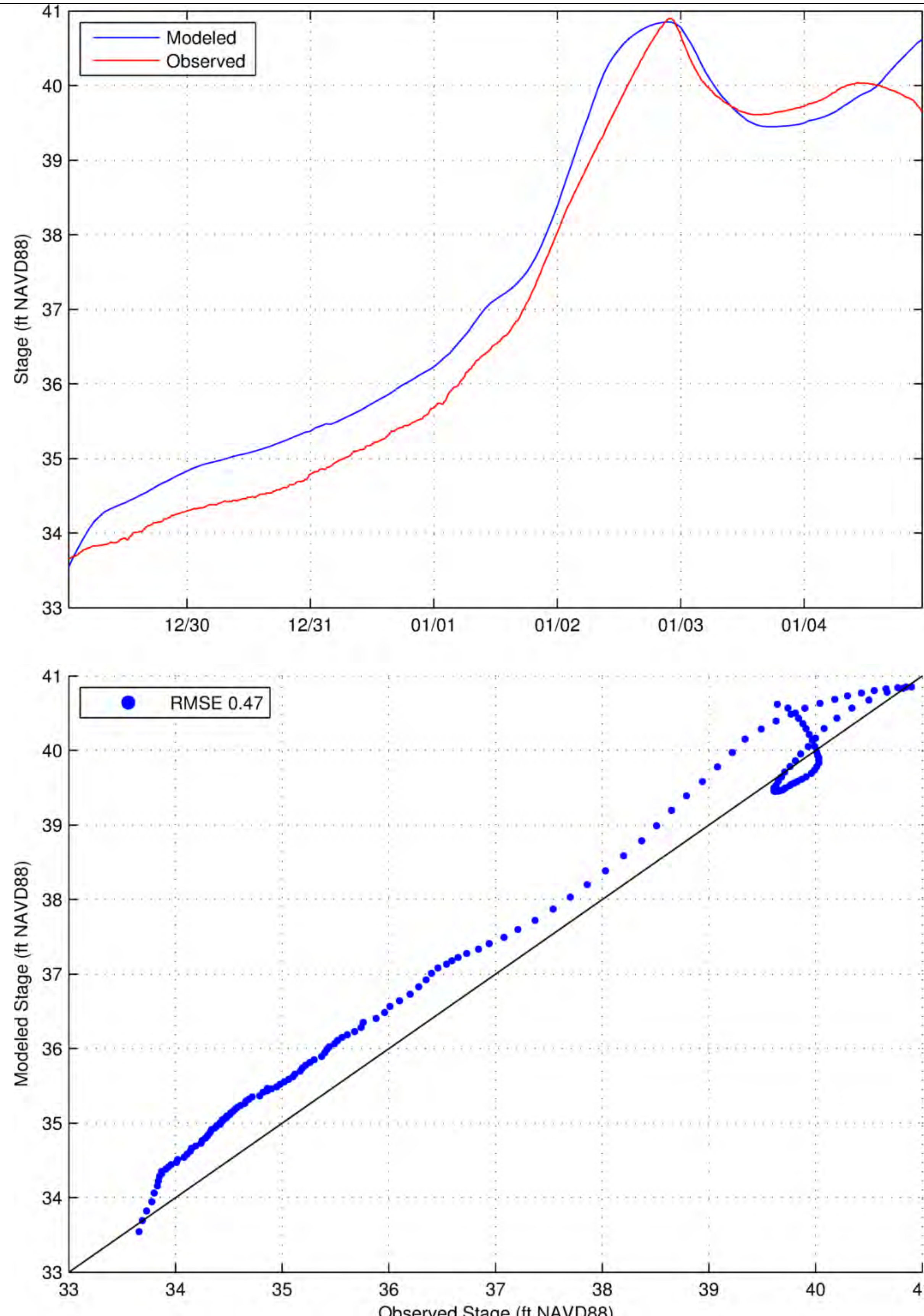
Prepared for DWR	Created By: RDJ	**Figure 5-4**



Notes:	HDR cbec	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **1997 Calibration Sac at Knights L Stage**		
		Prepared for DWR	Created By: RDJ	**Figure 5-5**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage*		
		1997 Calibration Fremont Weir West Stage		
		Prepared for DWR	Created By: RDJ	**Figure 5-6**

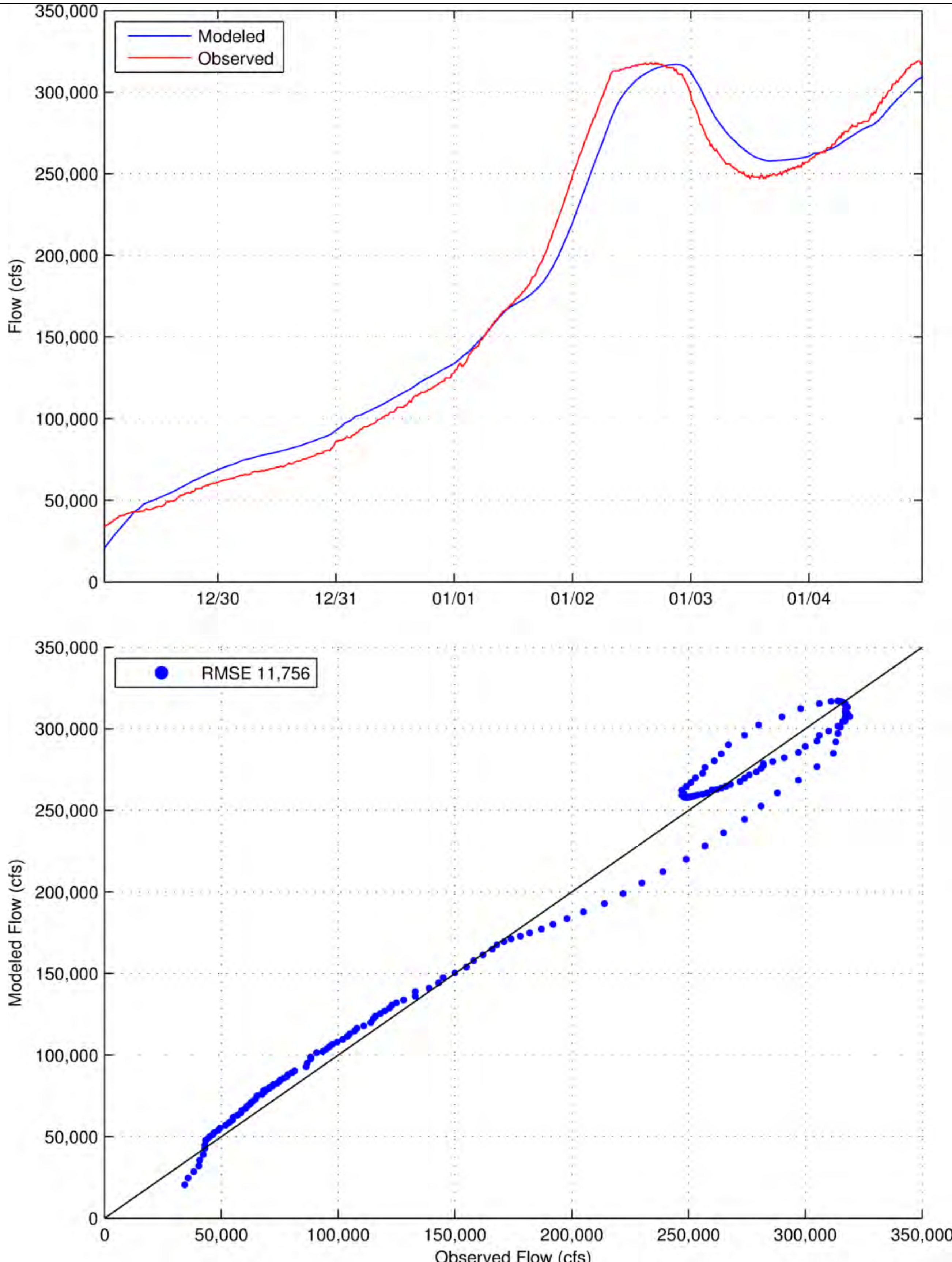


Notes:

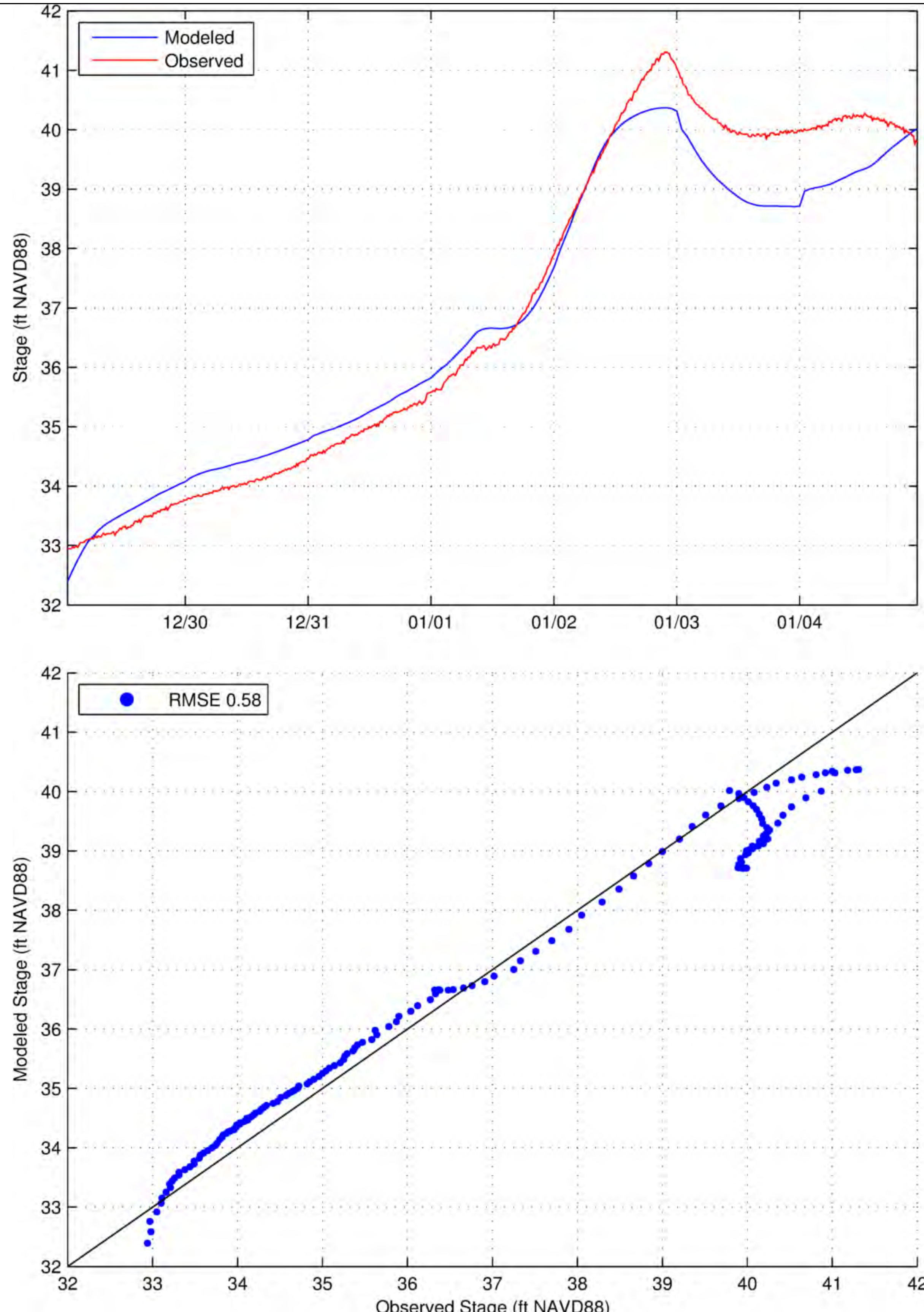
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

1997 Calibration Fremont Weir East Stage

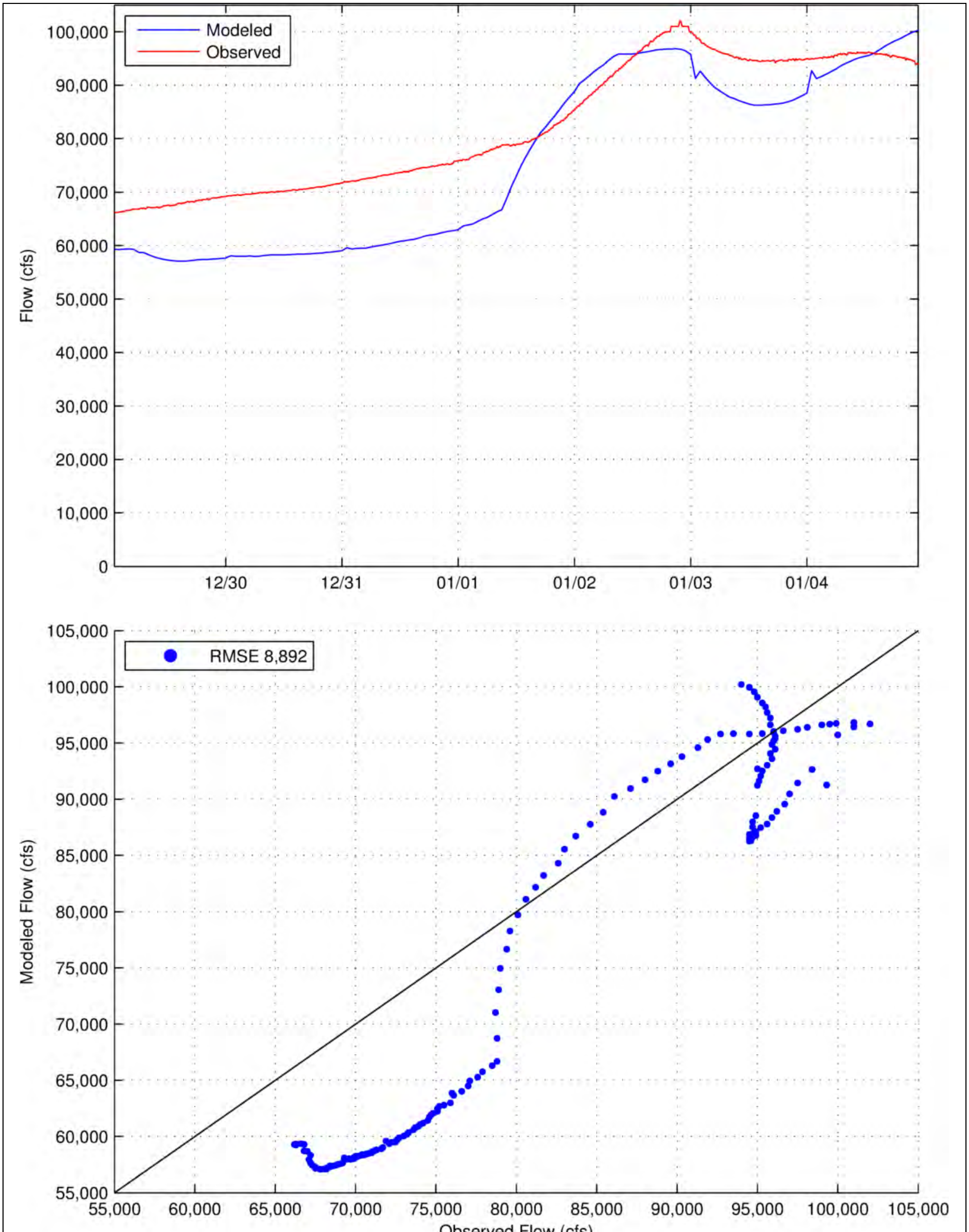
Prepared for DWR	Created By: RDJ	**Figure 5-7**



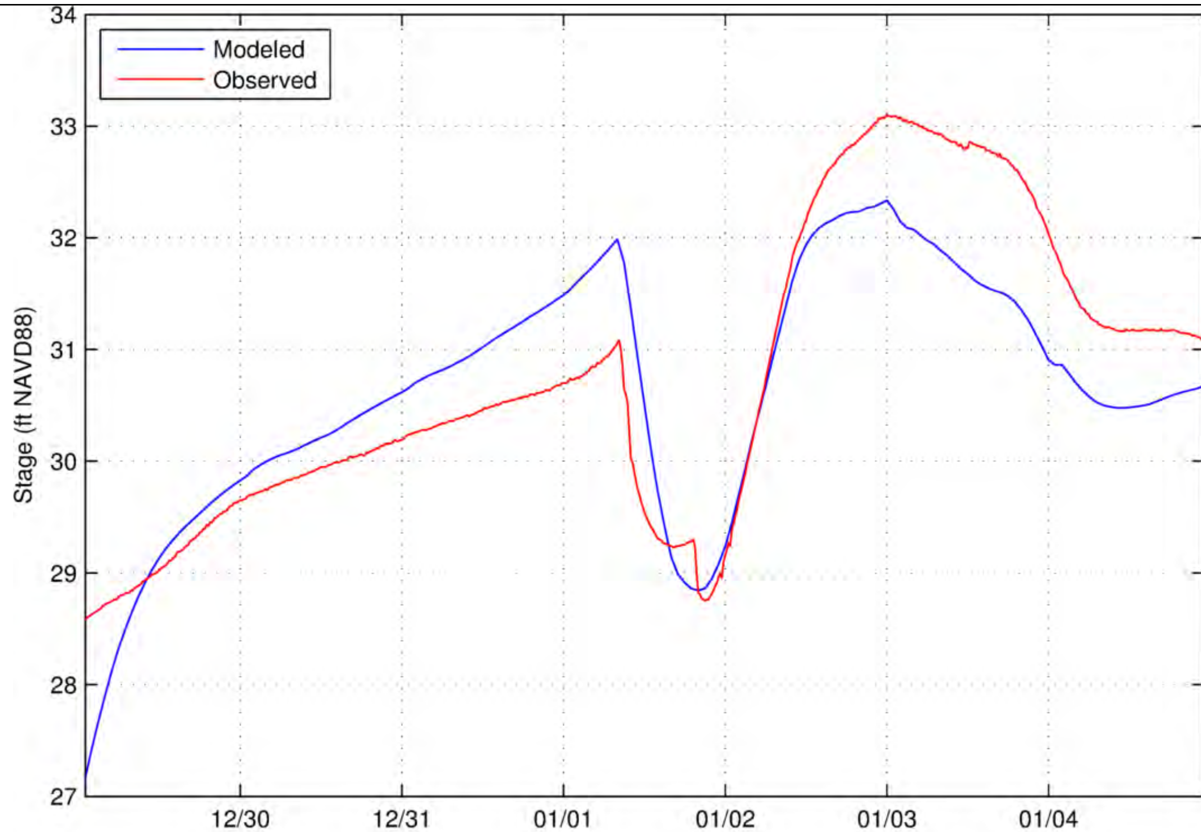
Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **1997 Calibration Fremont Weir Flow**		
		Prepared for DWR	Created By: RDJ	**Figure 5-8**

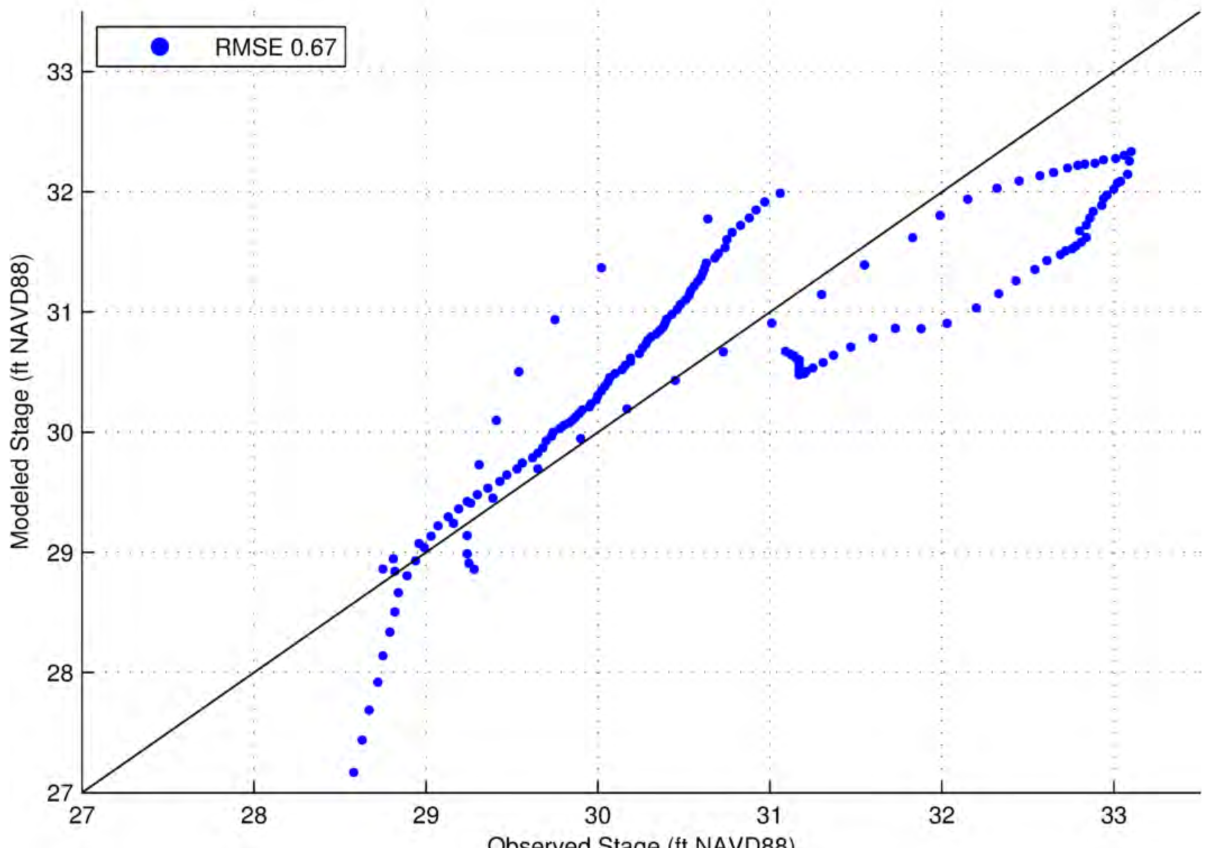


Notes:	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **1997 Calibration Verona Stage**		
		Prepared for DWR	Created By: RDJ	**Figure 5-9**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **1997 Calibration Verona Flow**		
		Prepared for DWR	Created By: RDJ	**Figure 5-10**



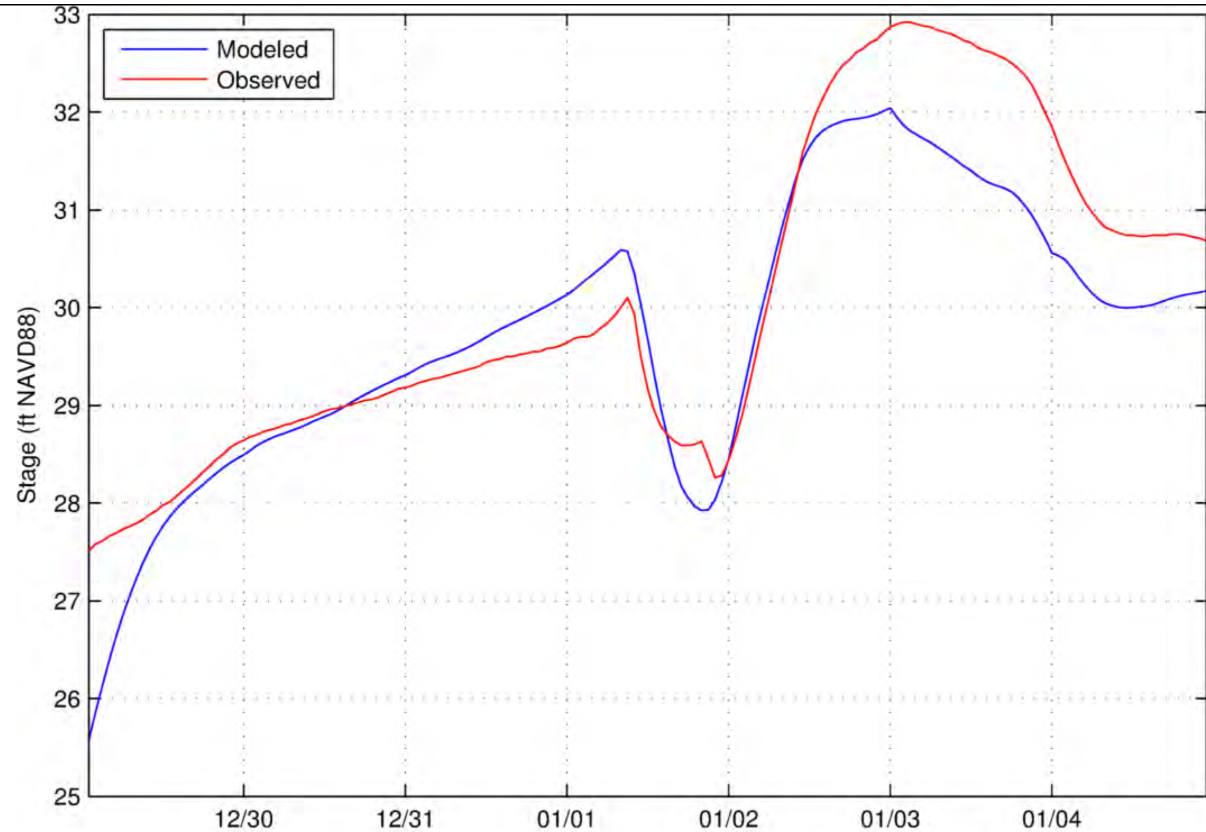


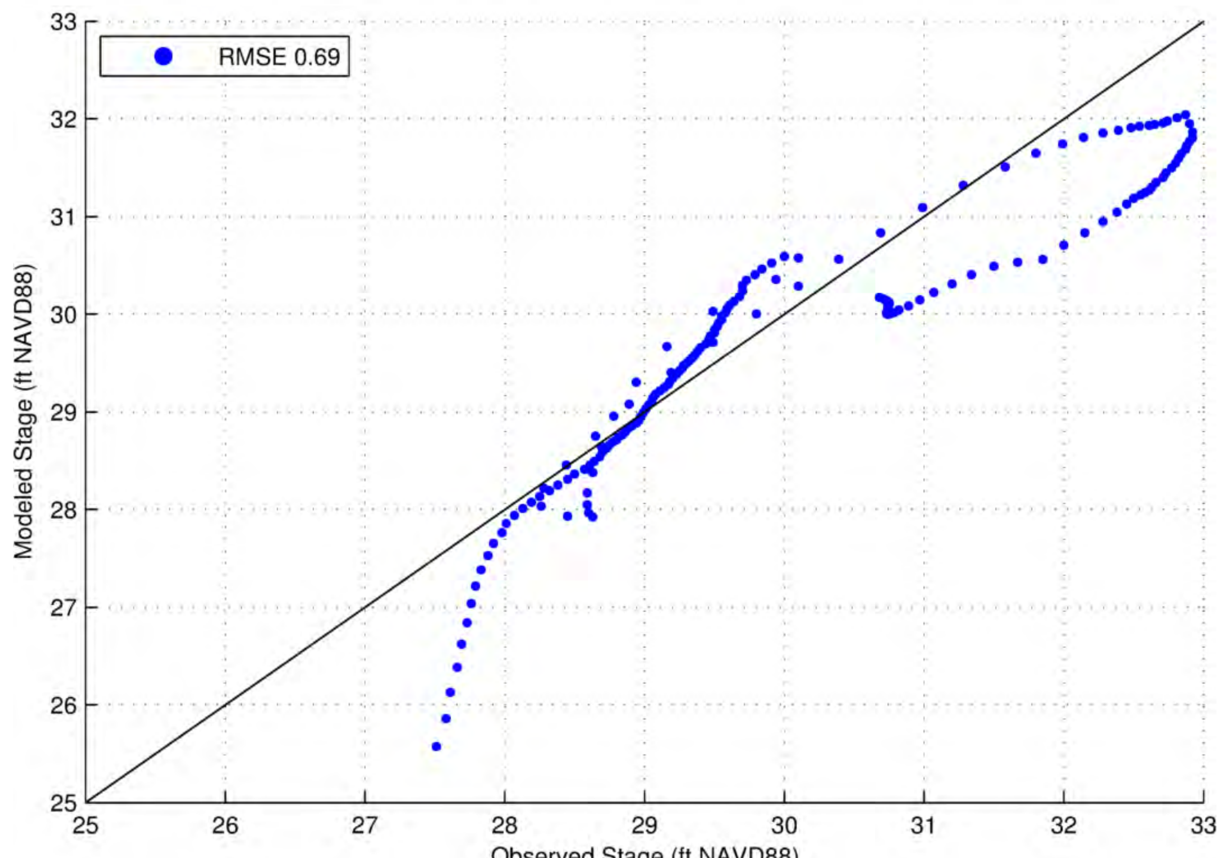
Notes: Upstream of Weir

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

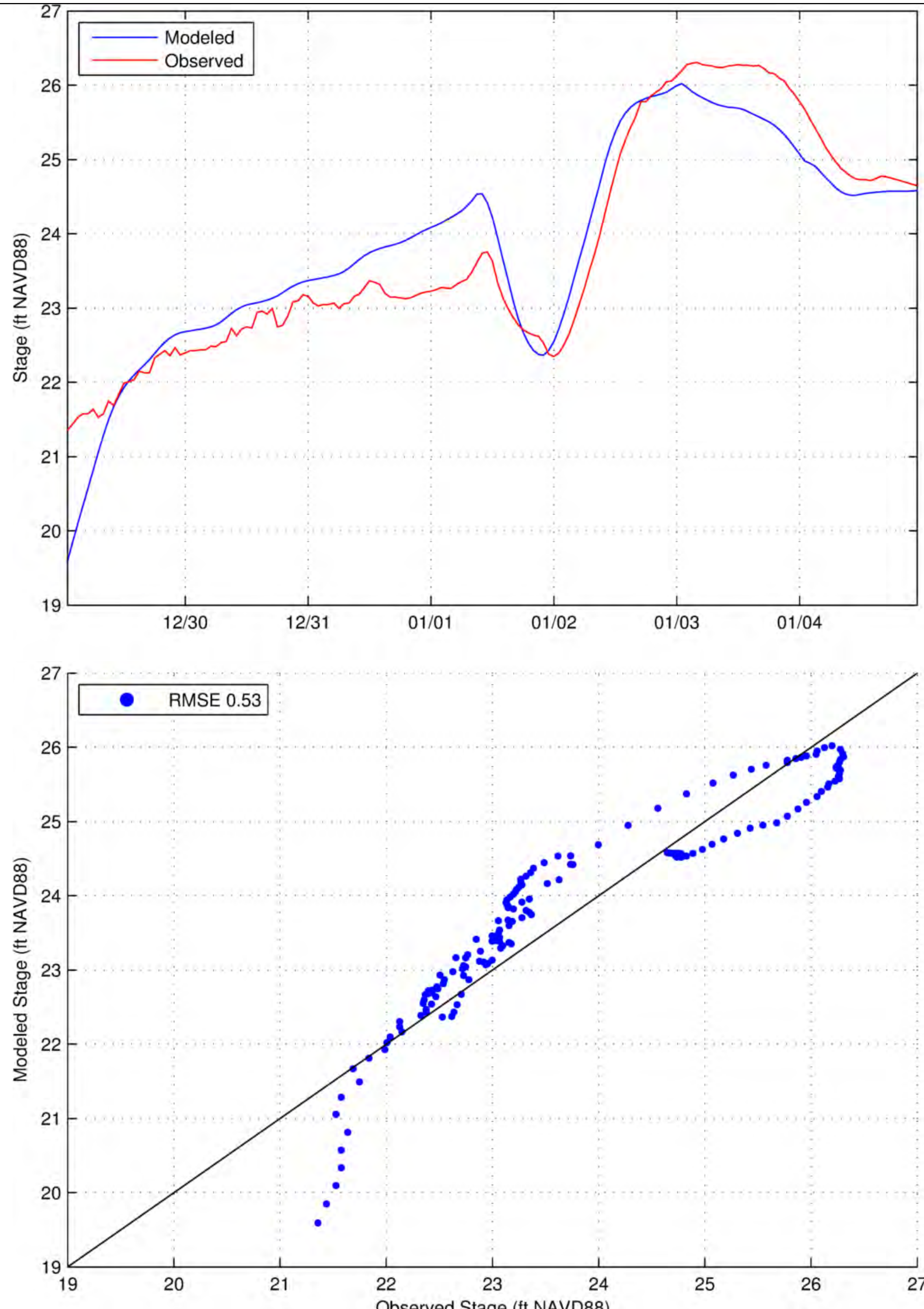
1997 Calibration Sacramento Weir Stage

Prepared for DWR | Created By: RDJ | **Figure 5-11**

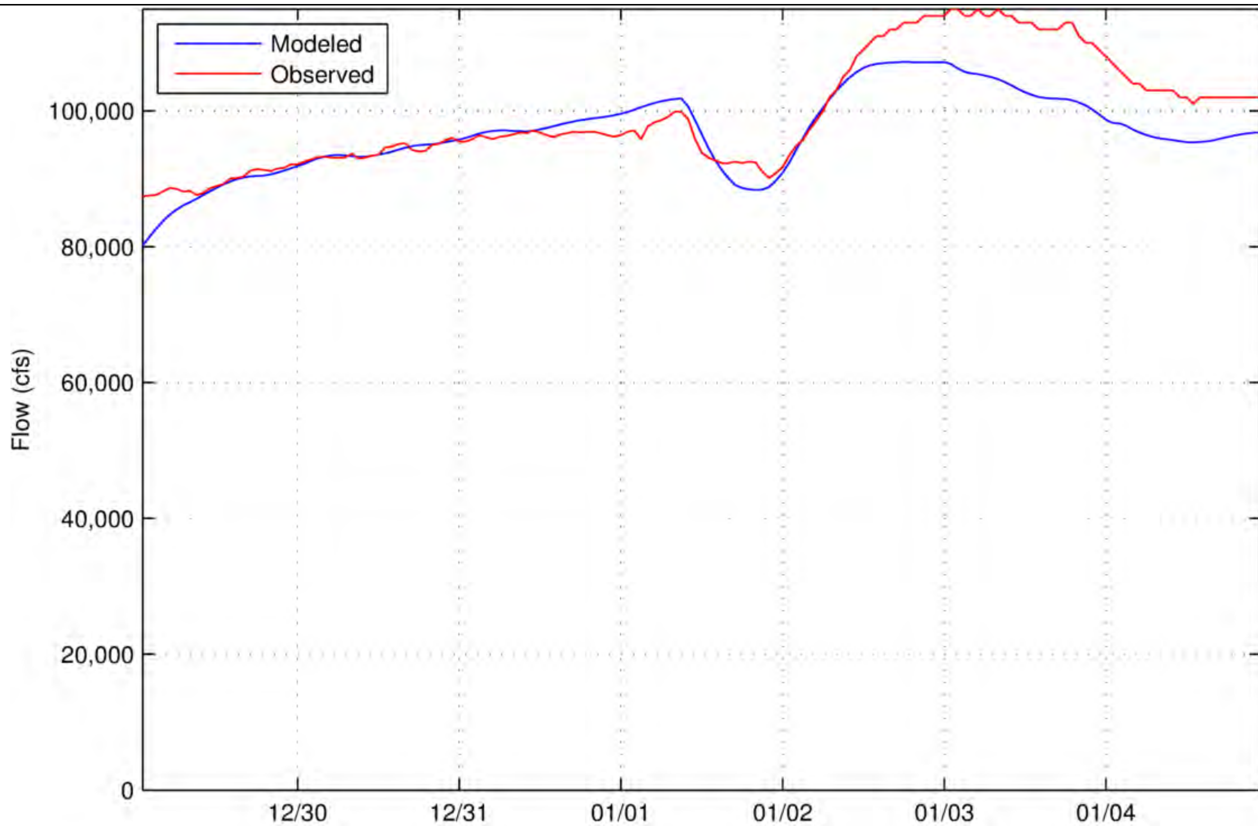


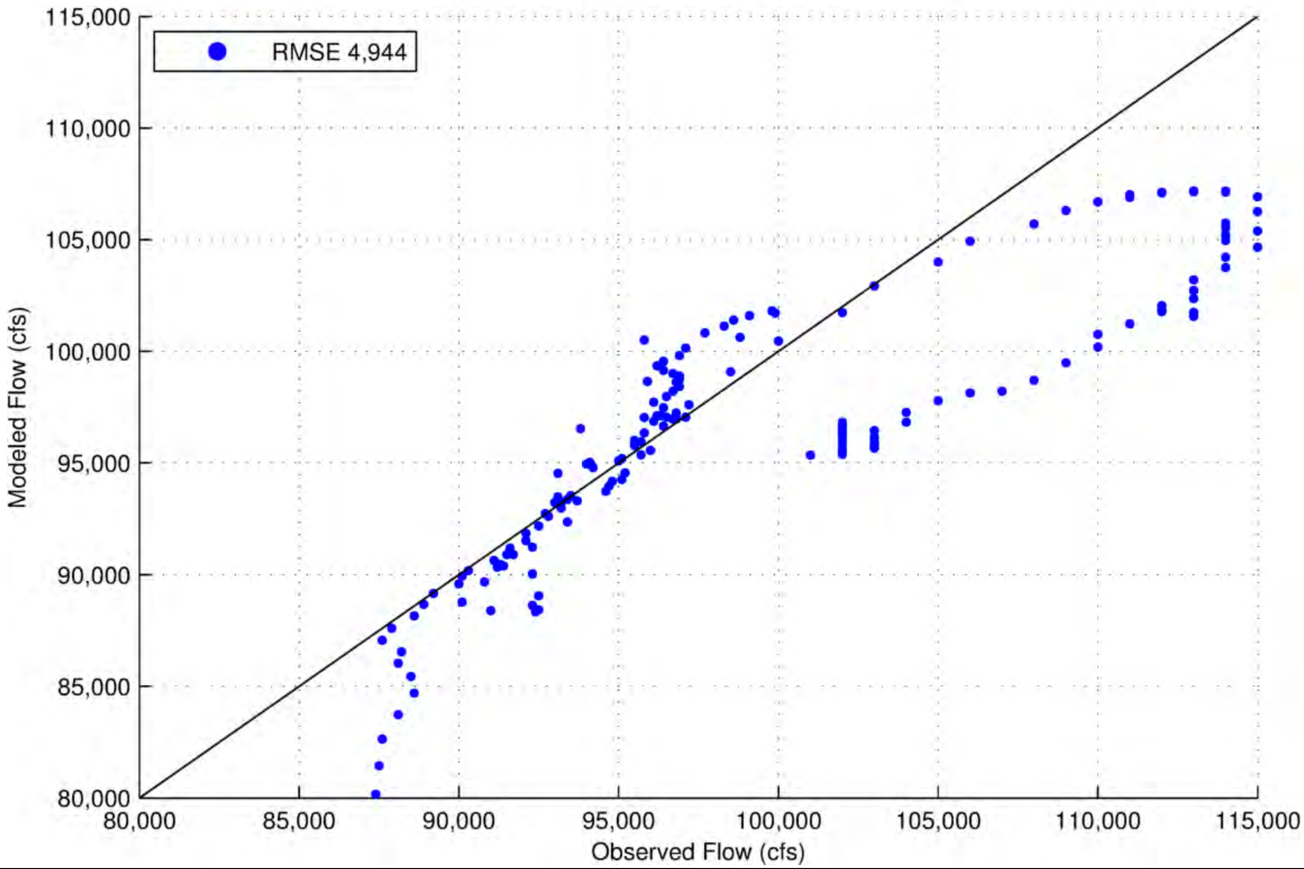


Notes:	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **1997 Calibration Sac U/S Ist Stage**		
		Prepared for DWR	Created By: RDJ	**Figure 5-12**

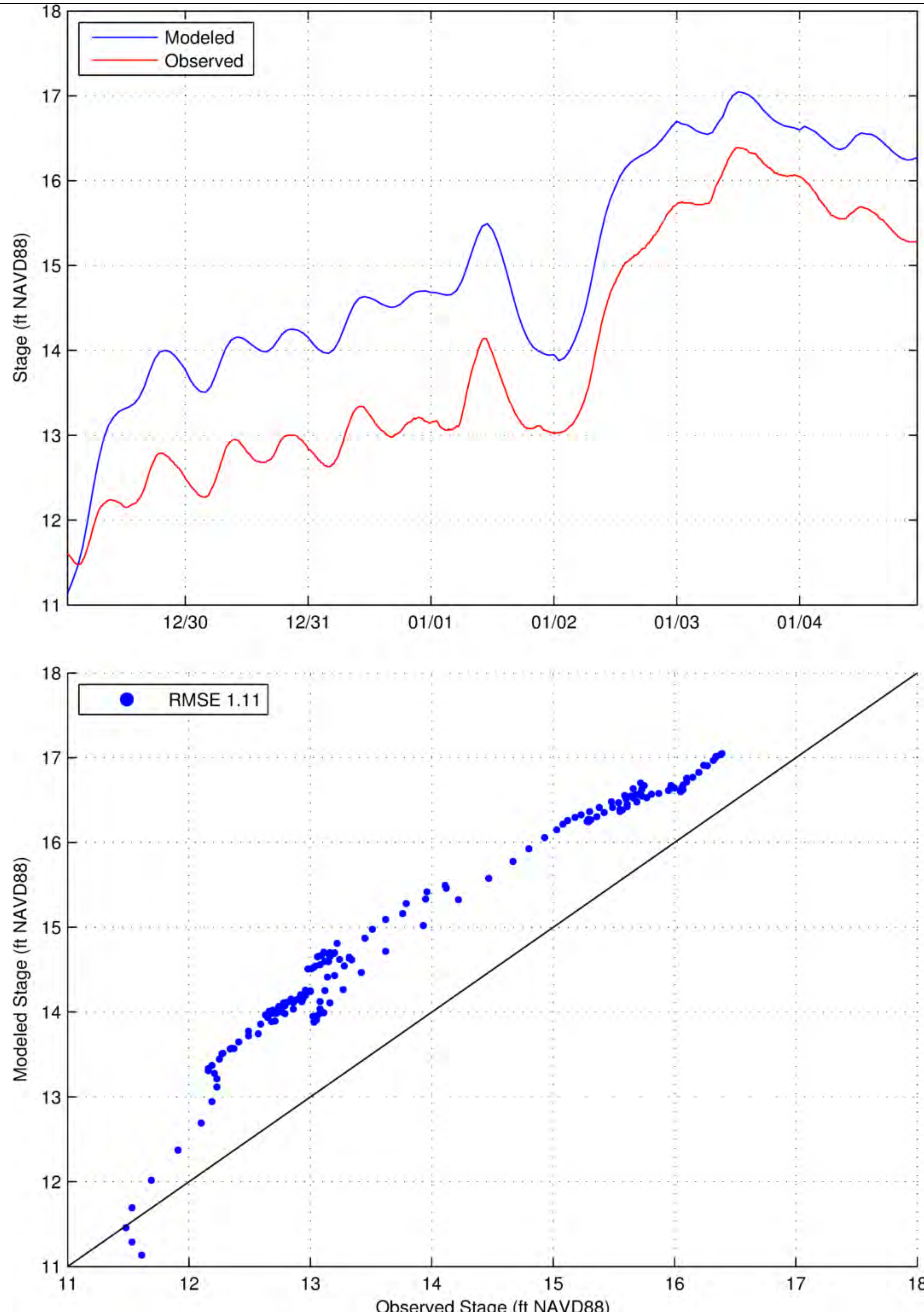


Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage*		
		1997 Calibration Sac at Freeport Stage		
		Prepared for DWR	Created By: RDJ	**Figure 5-13**

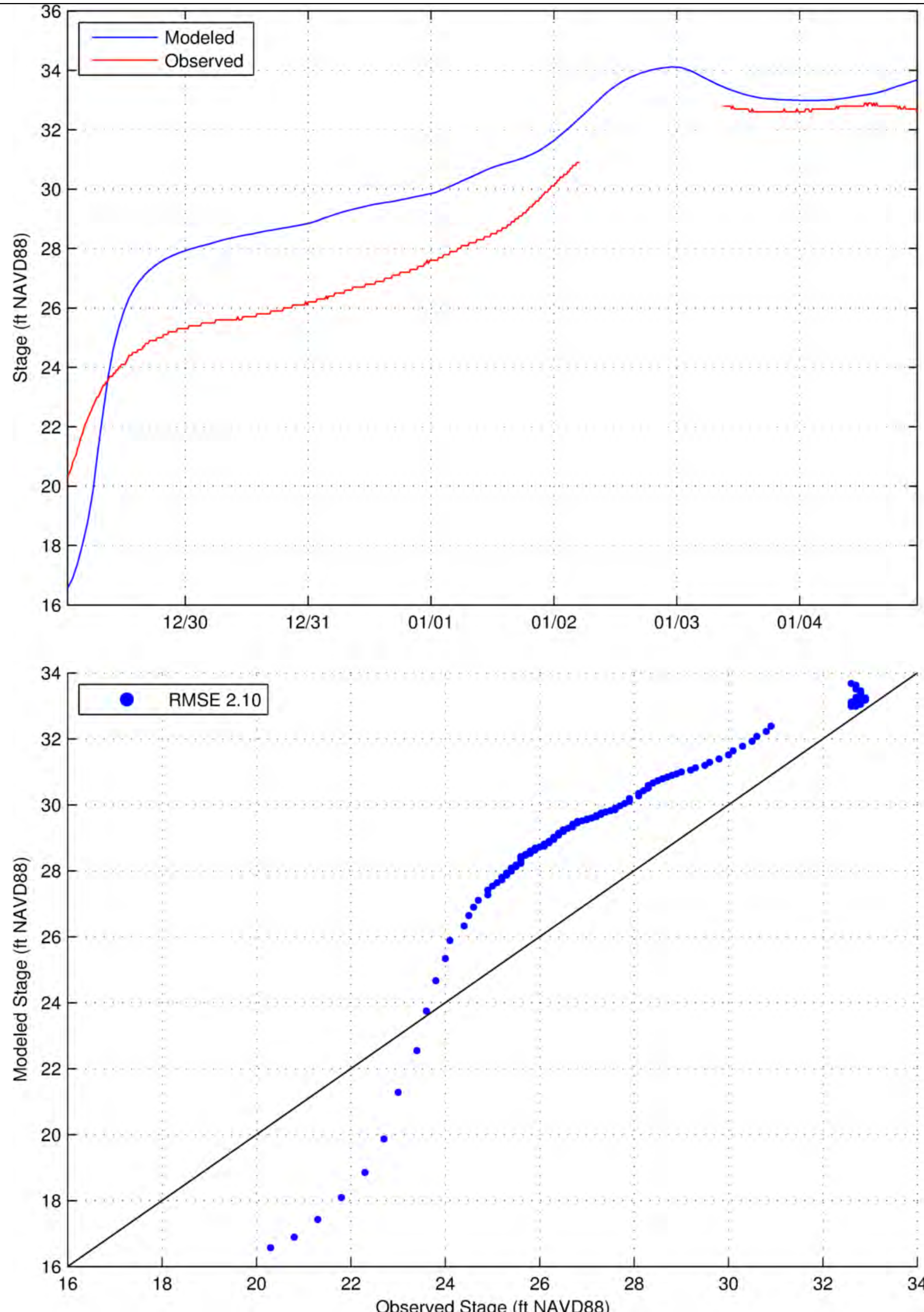




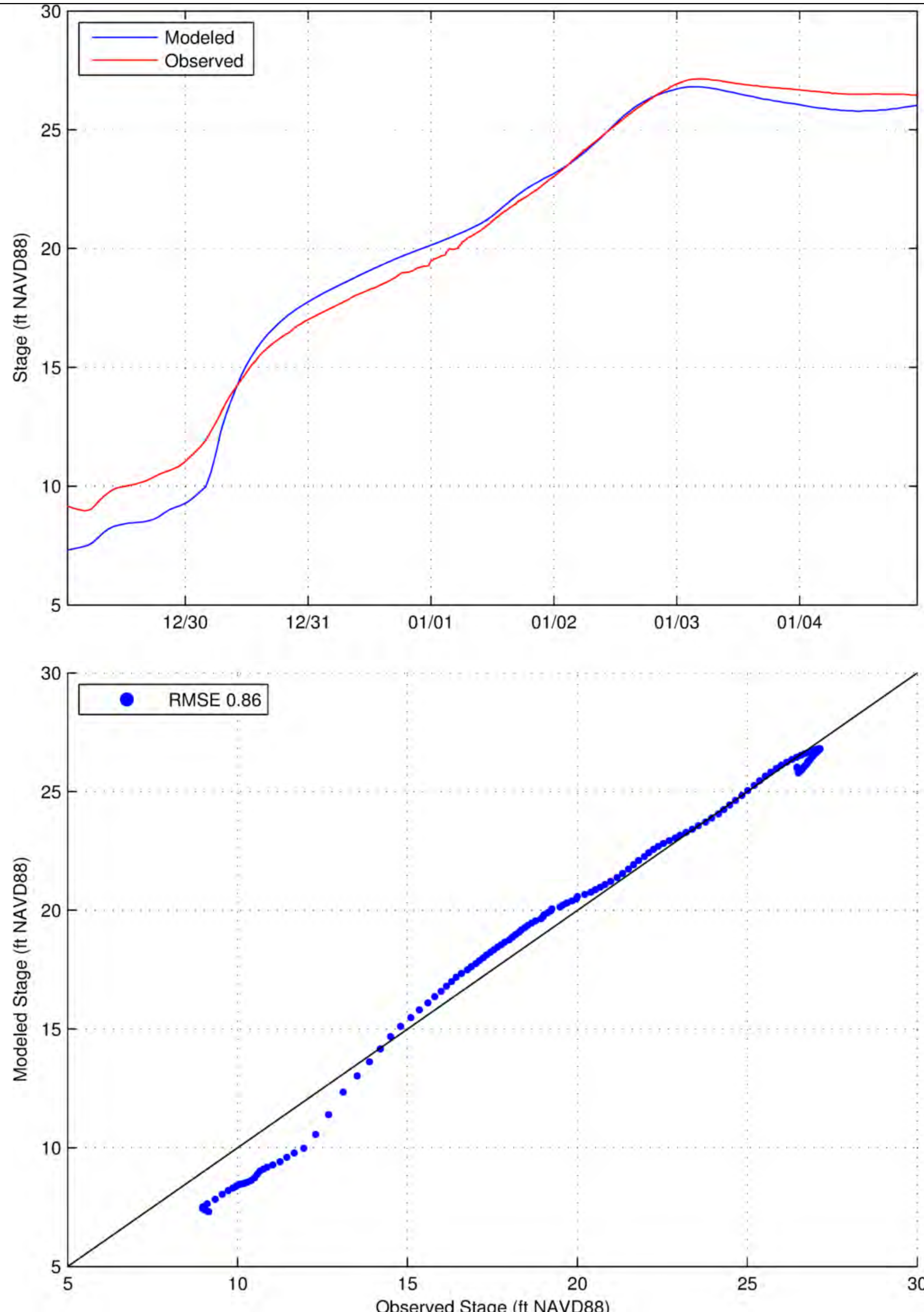
Notes:	HDR cbec	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **1997 Calibration Sac at Freeport Flow**		
		Prepared for DWR	Created By: RDJ	**Figure 5-14**



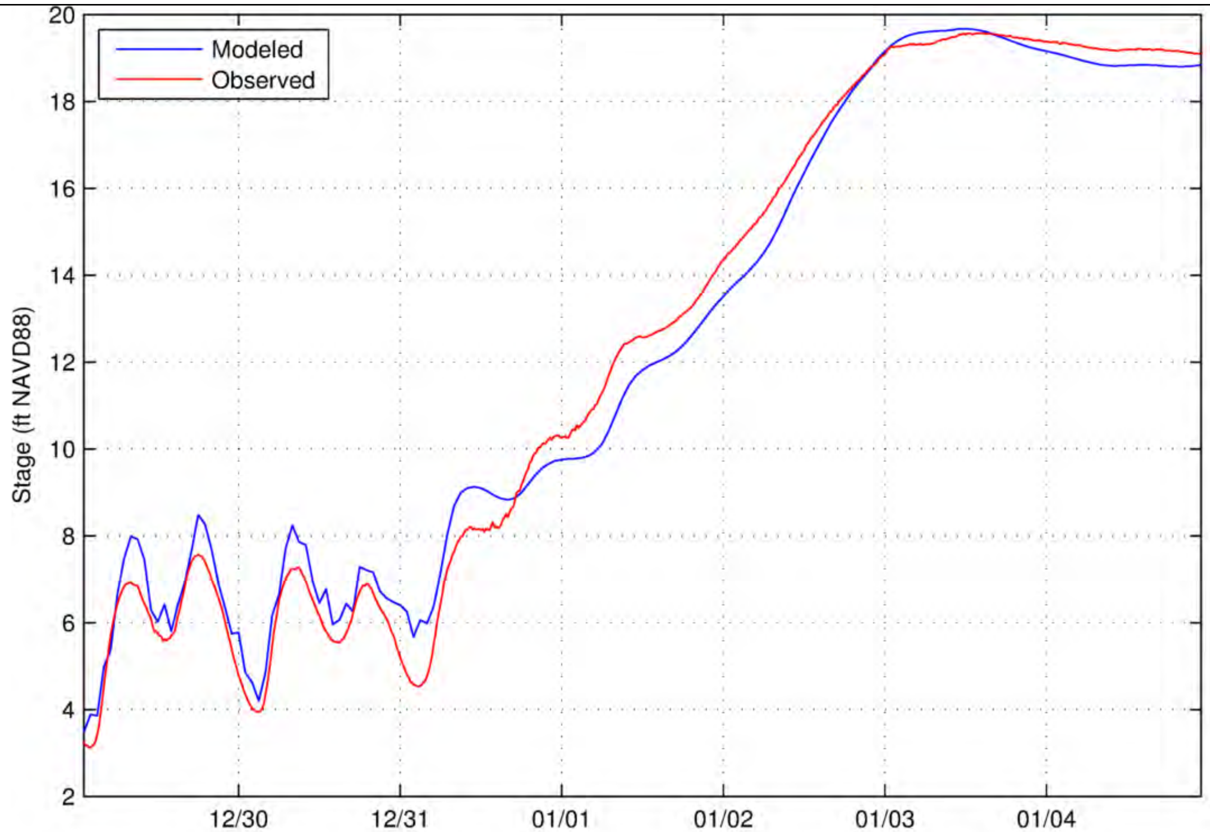
Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage*		
		1997 Calibration Sac at Walnut Grove Stage		
		Prepared for DWR	Created By: RDJ	**Figure 5-15**

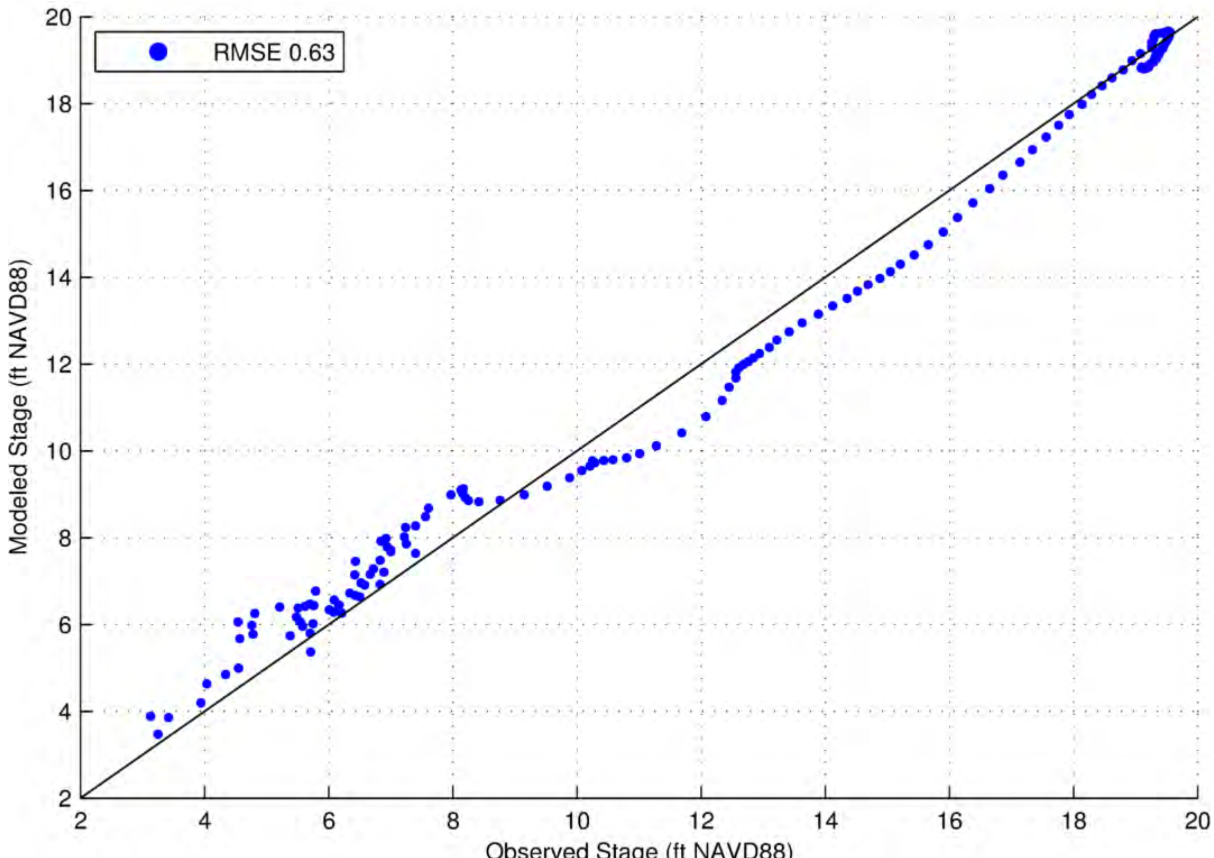


Notes:	HDR cbec	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **1997 Calibration Near Woodland Stage**		
		Prepared for DWR	Created By: RDJ	**Figure 5-16**

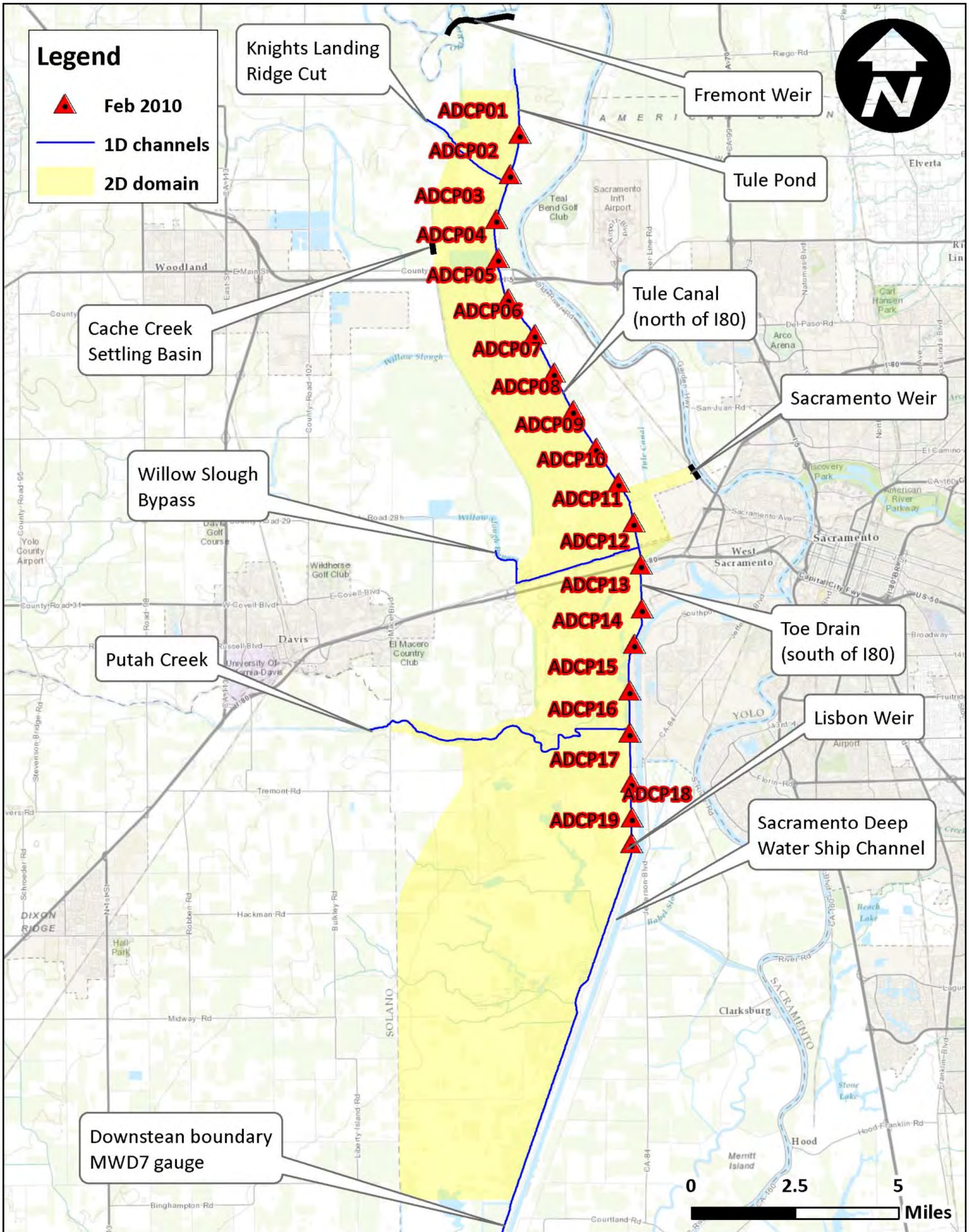


Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **1997 Calibration Lisbon Weir Stage**		
		Prepared for DWR	Created By: RDJ	**Figure 5-17**





Notes: Upstream of Weir		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage*	
		1997 Calibration Liberty Island Stage	
	Prepared for DWR	Created By: RDJ	**Figure 5-18**

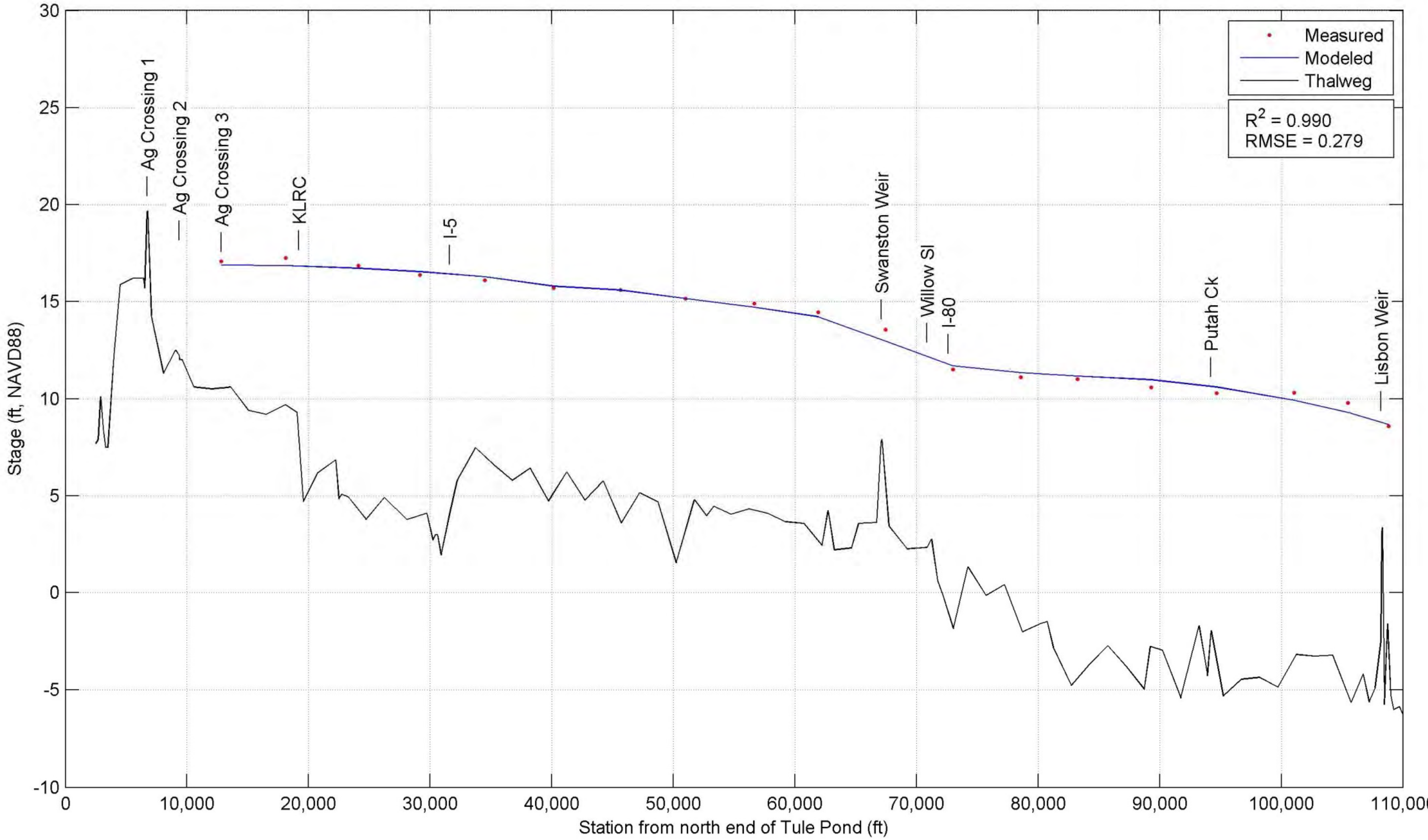


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

2010 Low Flow Calibration Data

Prepared for DWR	Created By: SP	**Figure 5-19**

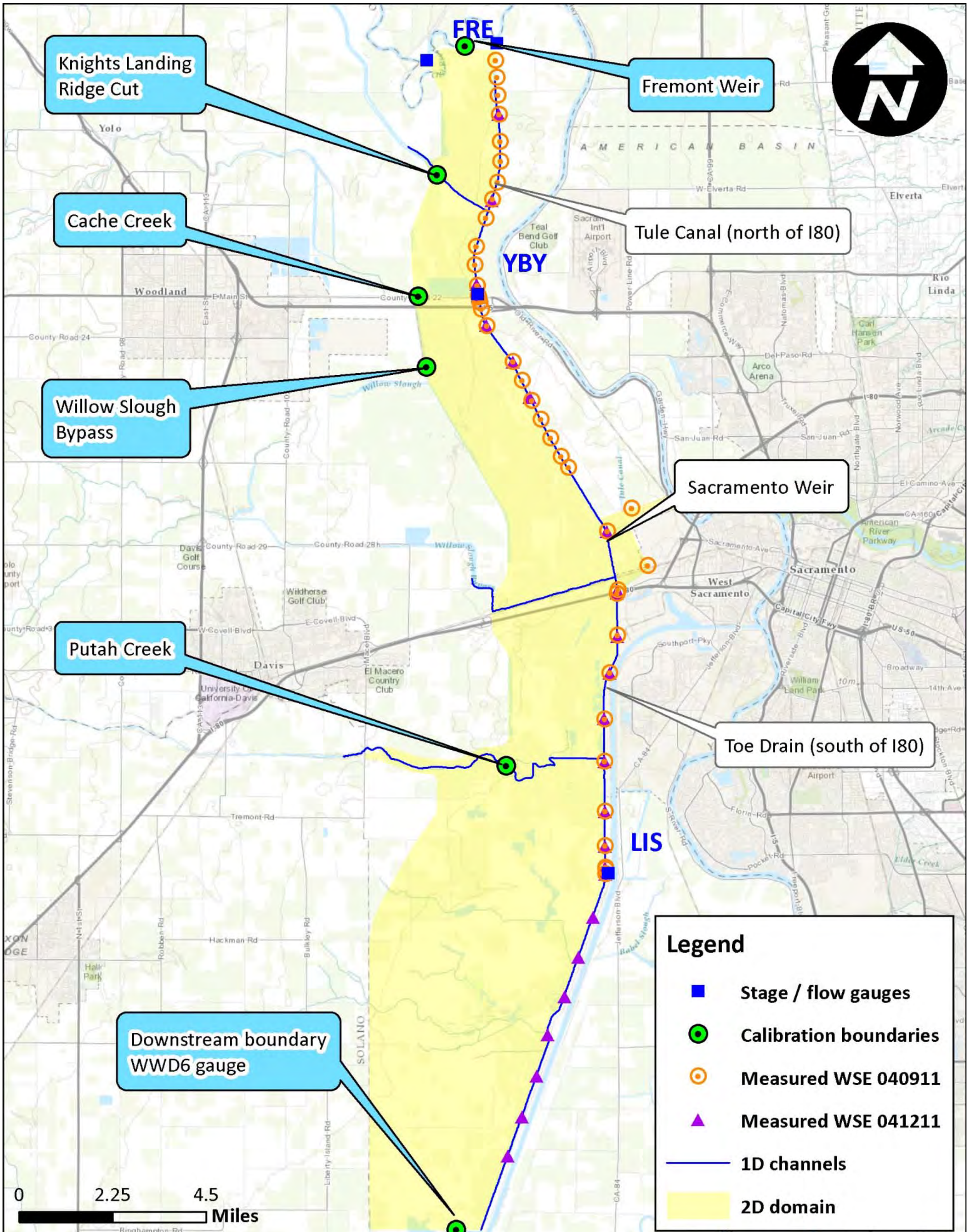


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

2010 Low Flow Calibration-Comparison of WSEs

Prepared for DWR	Created By: SJB	**Figure 5-20**

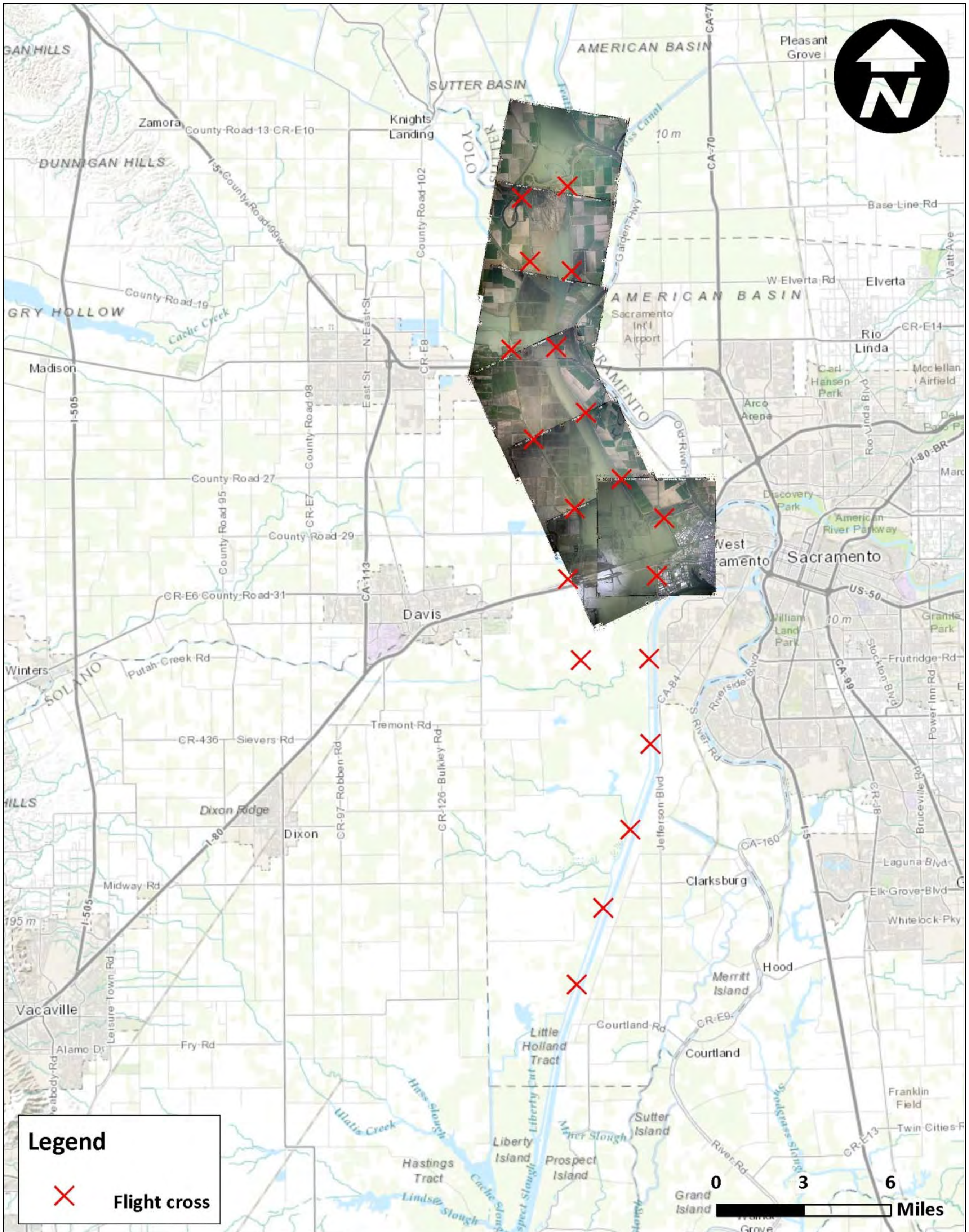


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

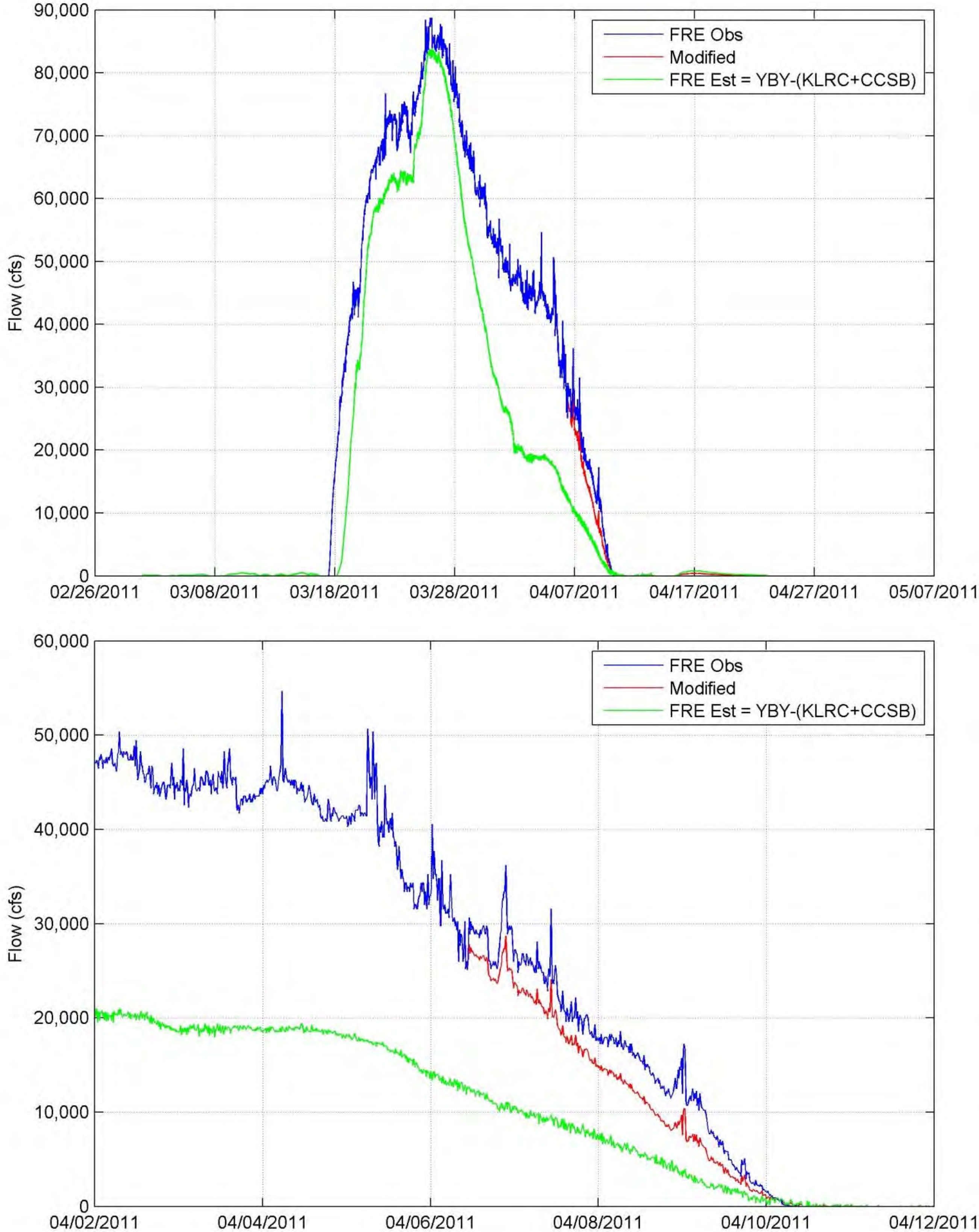
2011 Flood Calibration Data

Prepared for DWR | Created By: SP | **Figure 5-21**



Notes:	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Aerial Photos of Yolo Bypass-April 9, 2011**		
		Prepared for DWR	Created By: SP	**Figure 5-22**

Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage*		
		Aerial Photos of Yolo Bypass-April 12, 2011		
		Prepared for DWR	Created By: SP	**Figure 5-23**

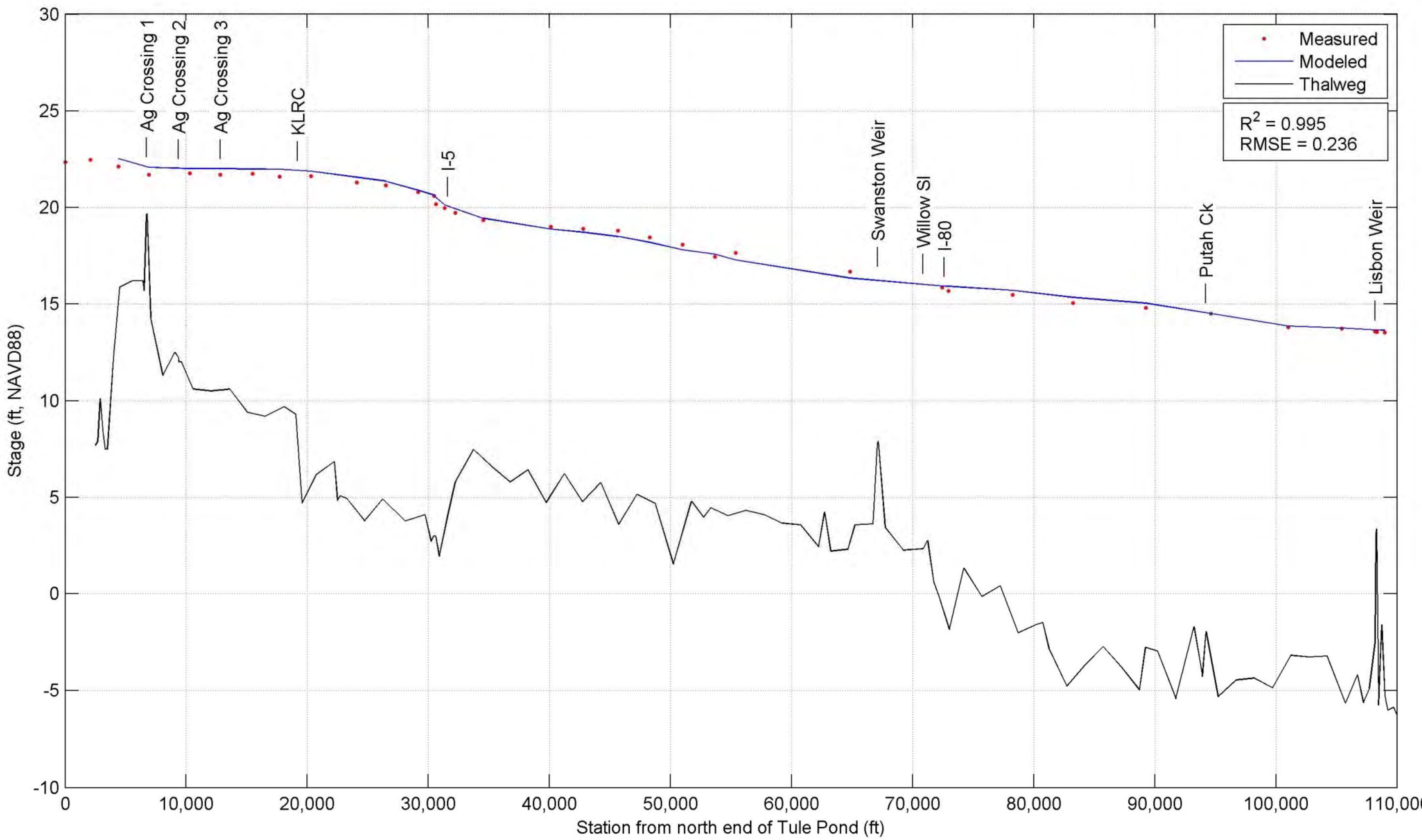


Notes:

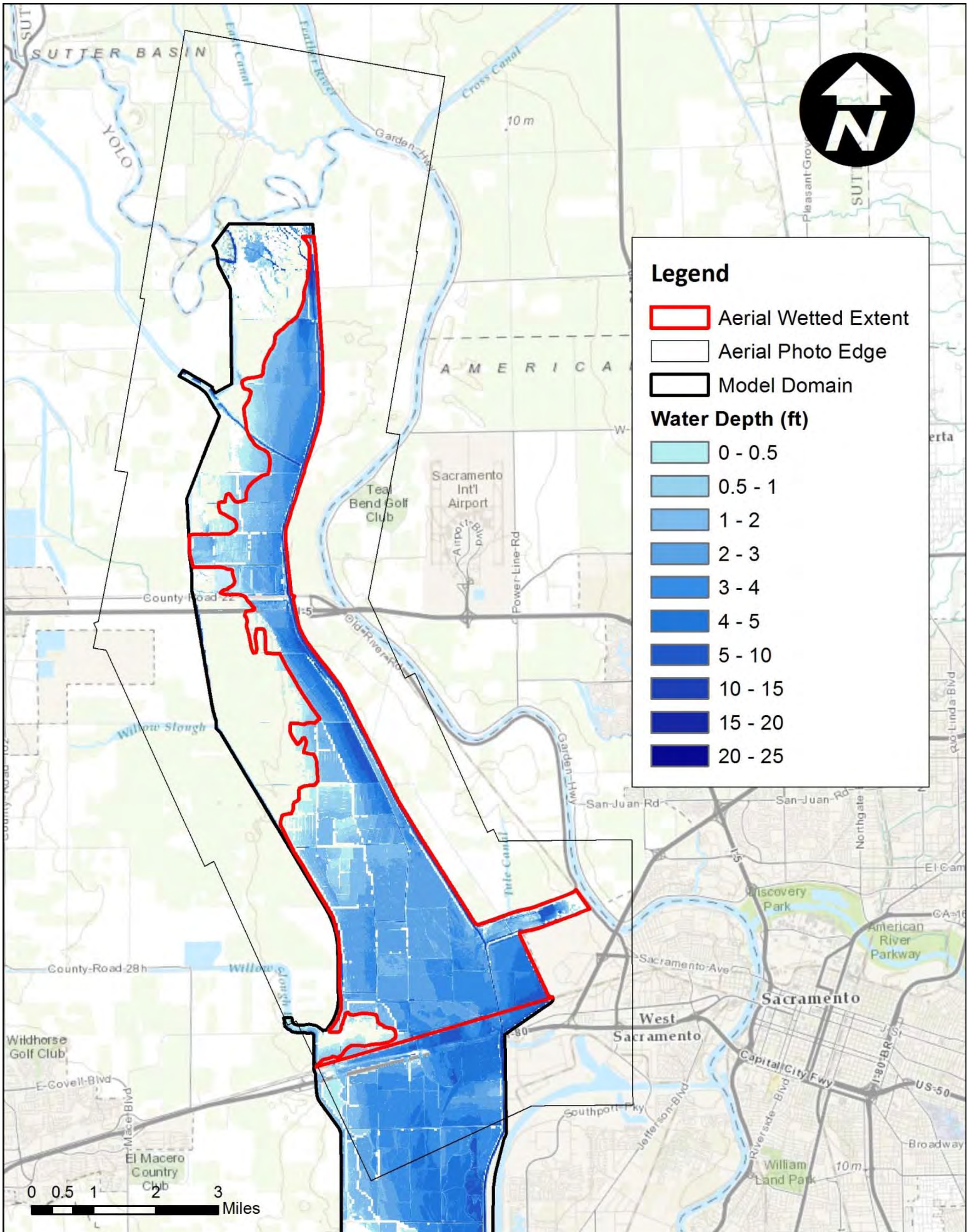
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

2011 Flood Calib-Mods to Fremont Inflows

Prepared for DWR | Created By: CMB | **Figure 5-24**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage*		
		2011 Flood Calib-Comparison of April 9 - WSEs		
		Prepared for DWR	Created By: SJB	**Figure 5-25**

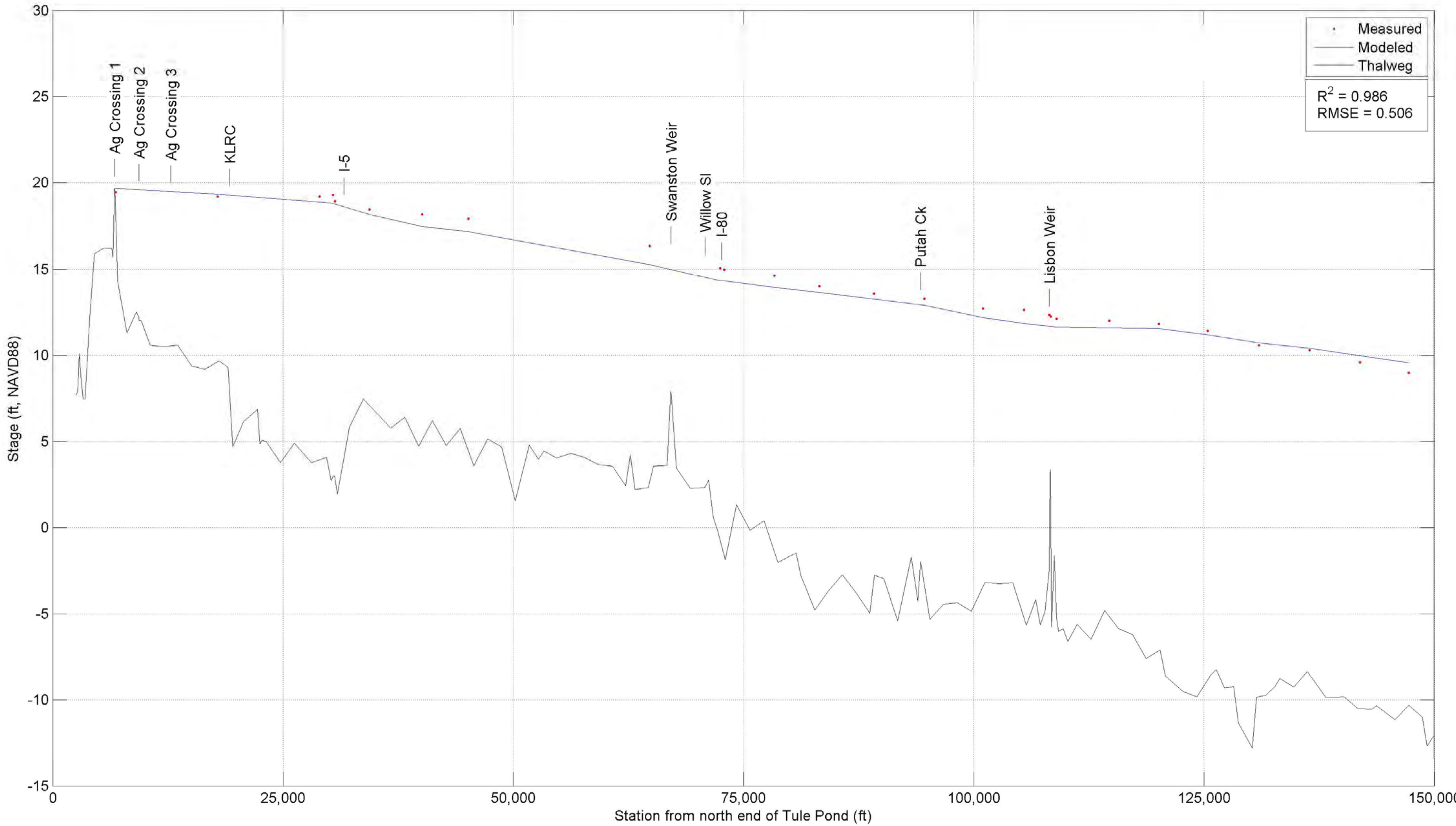


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

2011 Flood Calibration – April 9, 2011

Prepared for DWR	Created By: CMB	**Figure 5-26**

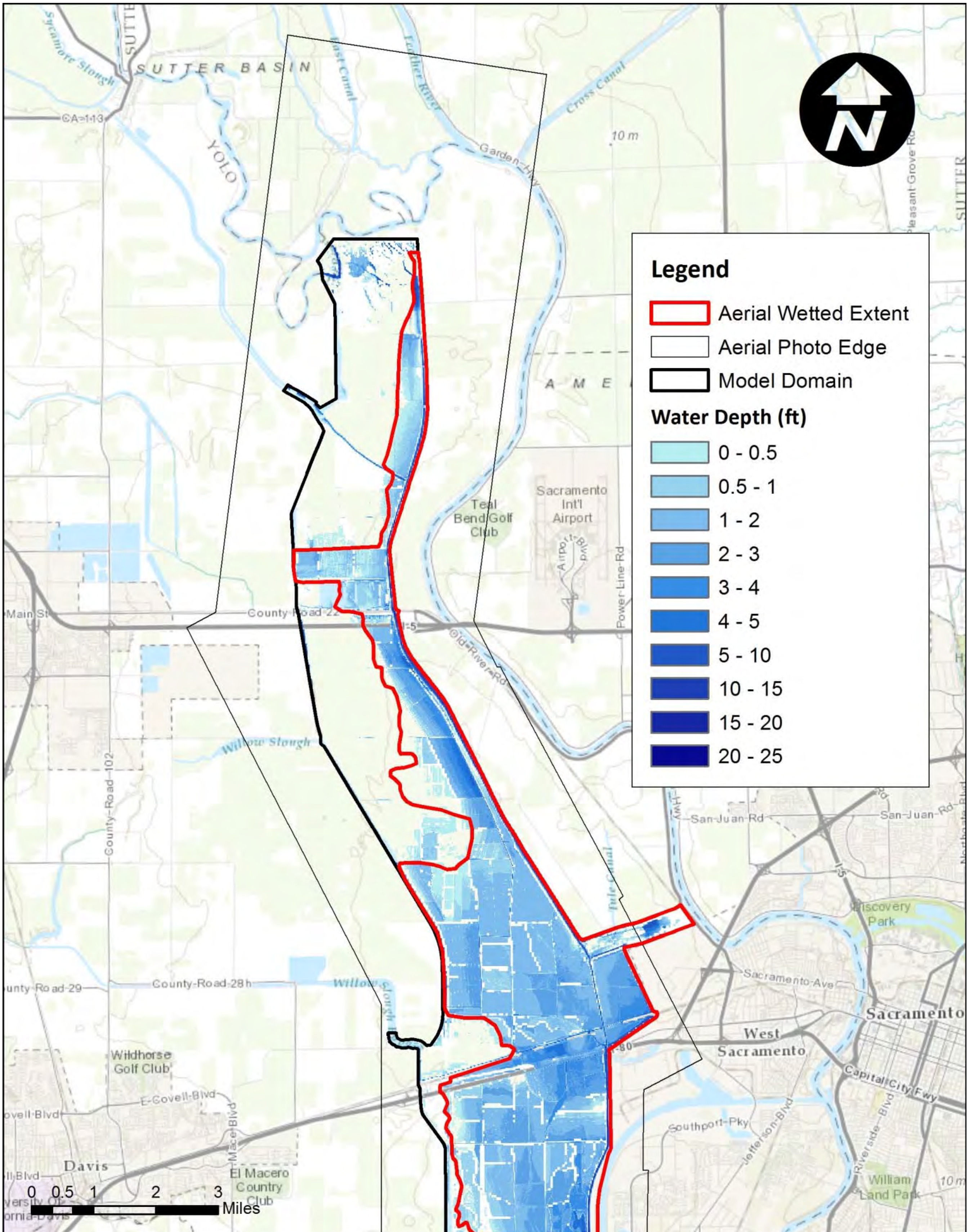


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

2011 Flood Calibration- Comparison of April 12- WSEs

Prepared for DWR	Created By: SJB	**Figure 5-27**

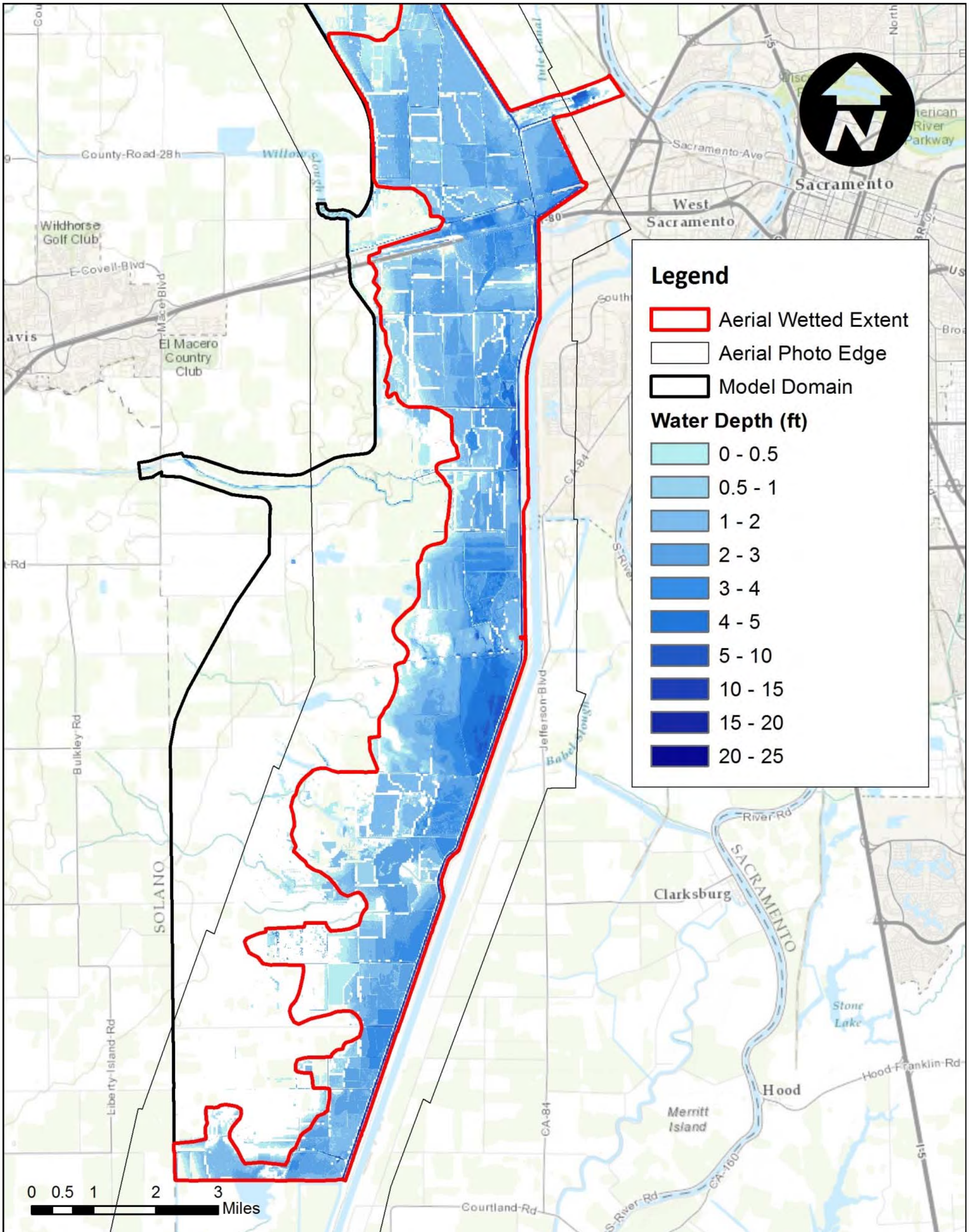


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

2011 Flood Calibration – April 12, 2011

Prepared for DWR	Created By: CMB	**Figure 5-28**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **2011 Flood Calibration – April 12, 2011**		
	HDR cbec eco engineering	Prepared for DWR	Created By: CMB	**Figure 5-29**

6.0 Existing Conditions Analysis

6.1 Overview of Results

The existing conditions model was run for the 16-year period from water year 1997 through water year 2012. All model runs start on October 2. Most runs end on May 31, but the wetter years were extended at least through June 31 to capture late season inundations and/or provide results for extended fish habitat periods (1997, 1998, 1999, 2000, 2003, 2005, 2006, and 2011).

The results for the existing conditions model include daily WSEs, depths, and velocities for the entire model domain extracted from the Model at the 24th hour of each day. Discharge values through time were output at 1D channels and across predefined polylines within the 2D domain. Spatial time-varying results are in the mesh/dataset format used by the Surface-Water Modeling System (SMS) and in Environmental Systems Research Institute (ESRI) binary raster format (FLT).

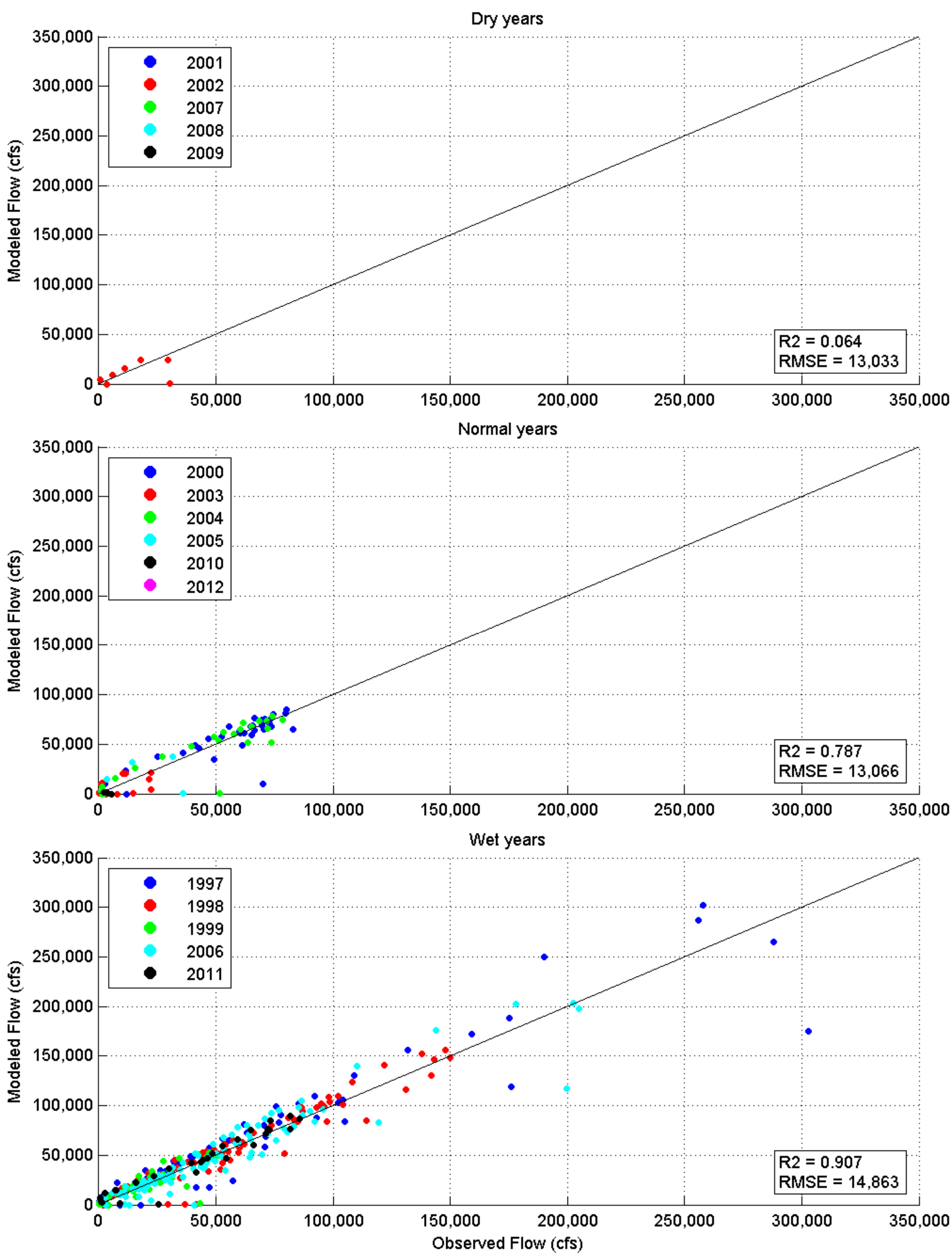
6.2 Comparisons to Observed Data

To verify that the model and underlying assumptions could reasonably simulate existing conditions over the long term, a suite of modeled versus observed scatter plots were prepared. Figure 6-1 shows that the flow over Fremont Weir has a RMSE of 13,000 to 15,000 cfs over the full range of conditions, which compares favorably with the RMSE from the 1997 calibration. Figure 6-2 shows that the Sacramento River stage in front of Fremont Weir has a RMSE of 0.9 to 1.3 feet, which is more than twice as large as the RMSE for the 1997 calibration. Figure 6-3 shows that the Sacramento River flow at Verona has a RMSE of 1,300 to 3,200 cfs over the full range of conditions, which is better than the RMSE 8900 cfs for the week-long 1997 calibration. Figure 6-4 shows that the stage at Yolo Bypass at Woodland has a RMSE of 2.4 to 3.0 feet, which is similar to that observed during the 1997 calibration. The most significant errors occur below an elevation of 17 feet, which is lower than the February 2010 calibration conditions. Flows are largely confined to the Tule Canal below elevation 17 feet and are below the adjacent floodplain, but modeled stages are sometimes more than 5 feet higher than recorded by the USGS. This discrepancy is not considered to impact the results of this study in the larger scale because the larger errors occur when the flows are largely confined to the Tule Canal and such times are not of interest for the current analysis.

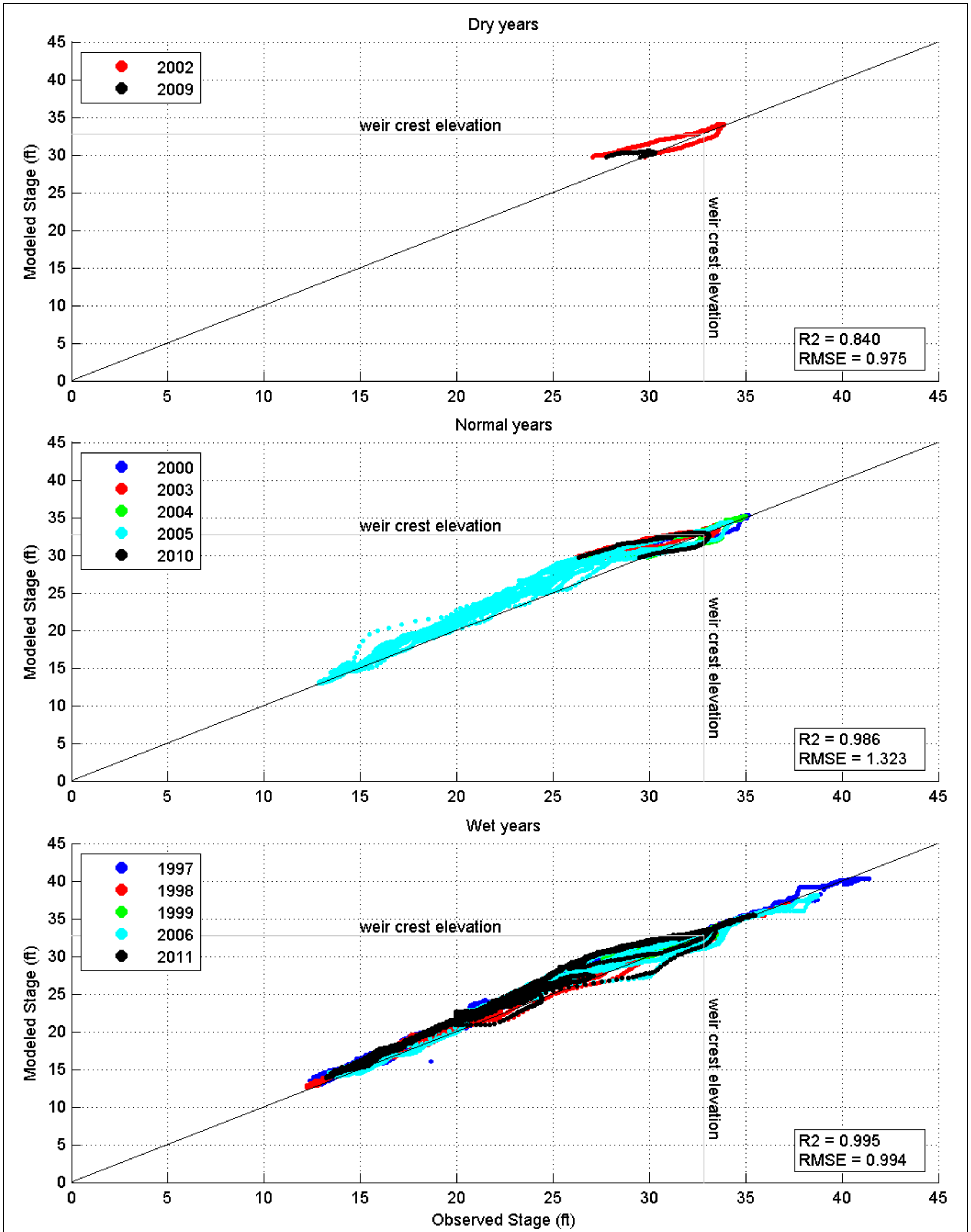
In preparing these figures, it was discovered that the datum conversion from USED to NAVD88 was inadvertently not applied for water years 2005 and prior. This resulted in the tidal boundary at Rio Vista being 0.6 feet too high. This error presents itself in Figure 6-5 and Figure 6-6, hence the reason for computing RMSE twice. Figure 6-5 shows that for water years 2005 and prior, the stage at Lisbon Weir has a RMSE of 0.9 to 1.0 feet, whereas later years have a RMSE of 0.7 to 0.8 feet. Figure 6-6 shows that for water years 2005 and prior, the stage at Liberty Island has a RMSE of 0.7 to 1.0 feet, whereas later years have a RMSE of 0.3 to 0.5 feet.

To understand if this datum correction error has an influence on the inundation results in the Yolo Bypass, Figure 6-7 and Figure 6-8 were prepared to test the sensitivity of wetted acres and LDW, respectively, during water year 2002 with a datum correction applied at Rio Vista. Water year 2002 was classified as a dry year and experienced a small spill event over Fremont Weir. Figure 6-7 shows that there is an insignificant difference in wetted area through time. This is corroborated by Figure 6-8 which shows that a dozen fields between Lisbon Weir and the Stair Step are drier one day sooner with the corrected (or lowered) stage boundary at Rio Vista. As such, inundation and drainage within the Bypass are not significantly affected by the datum error.

Given that model impact outcomes in the Bypass are insensitive to the relatively small datum error, the Lead Agencies with the guidance from the modelers determined not to re-run the model, and to use the original results. Based on the original model results, Figure 6-9 shows the wetted acres time series for existing conditions by water year and water year type. These time series will serve as the basis for making relative comparisons amongst the alternatives.



Notes:	HDR cbec	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Existing Fremont Weir Flow Comparison**		
		Prepared for DWR	Created By: SJB	**Figure 6-1**

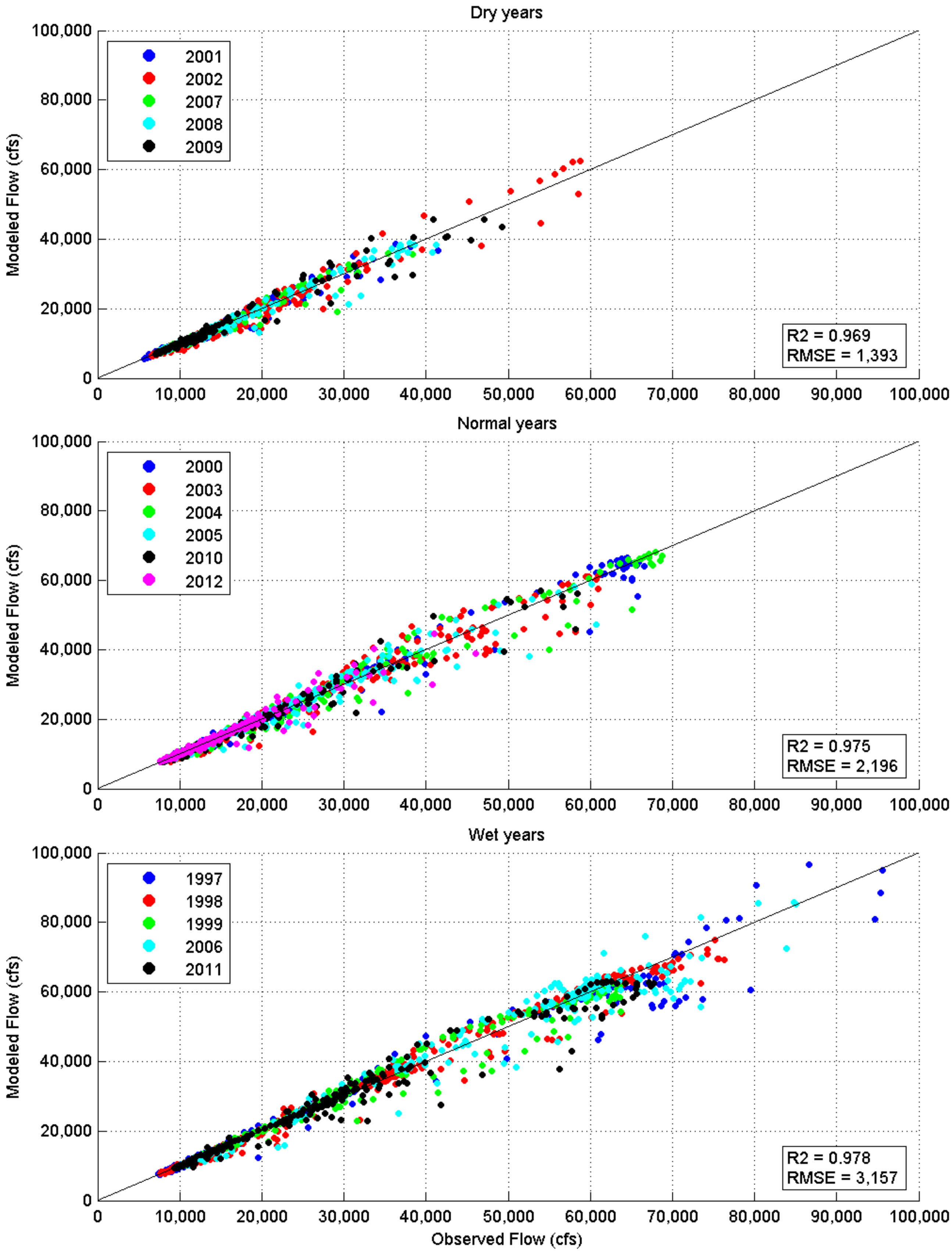


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Existing Fremont Weir Stage Comparison

Prepared for DWR | Created By: SJB | **Figure 6-2**

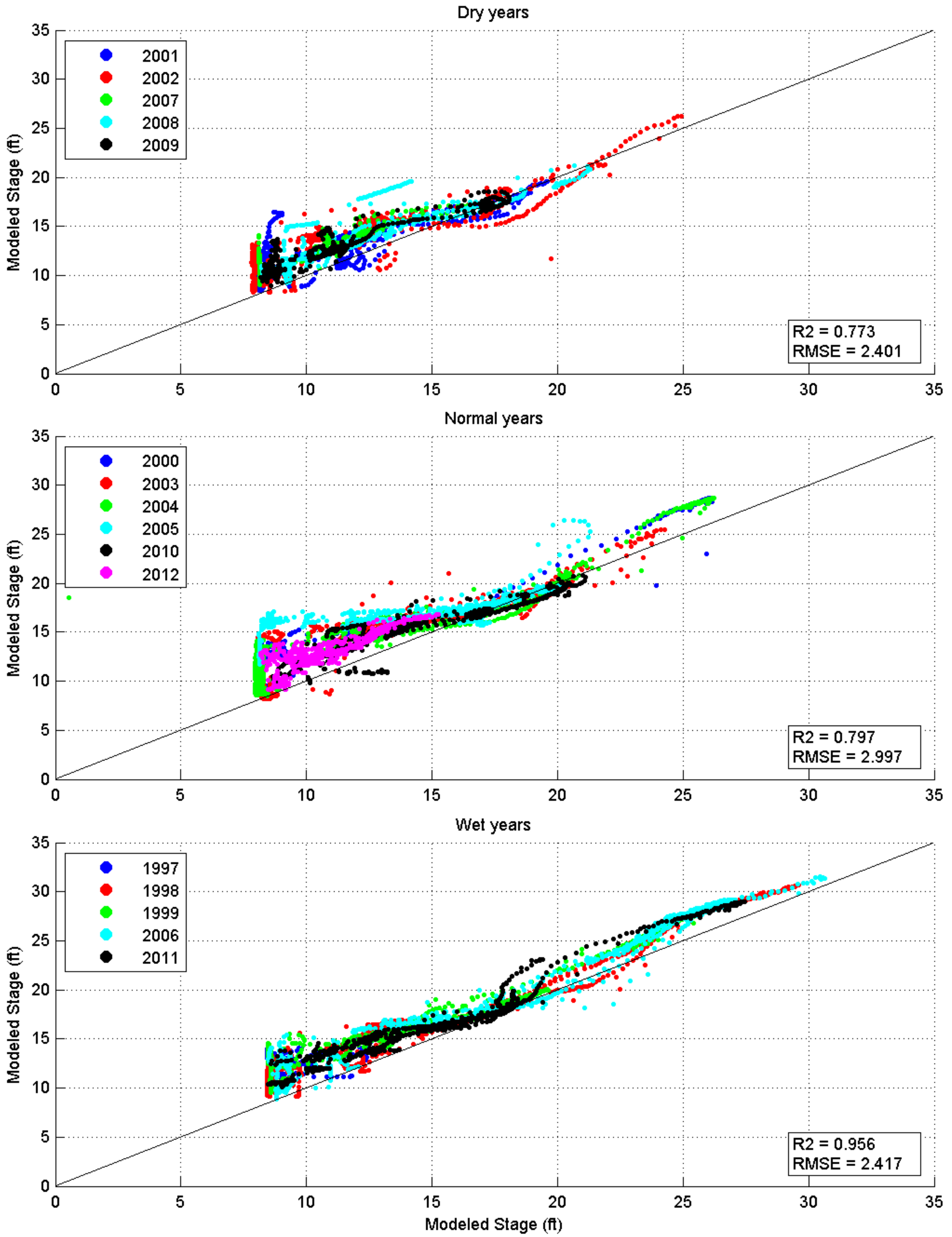


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Existing Sac R at Verona Flow Comparison

Prepared for DWR | Created By: SJB | **Figure 6-3**

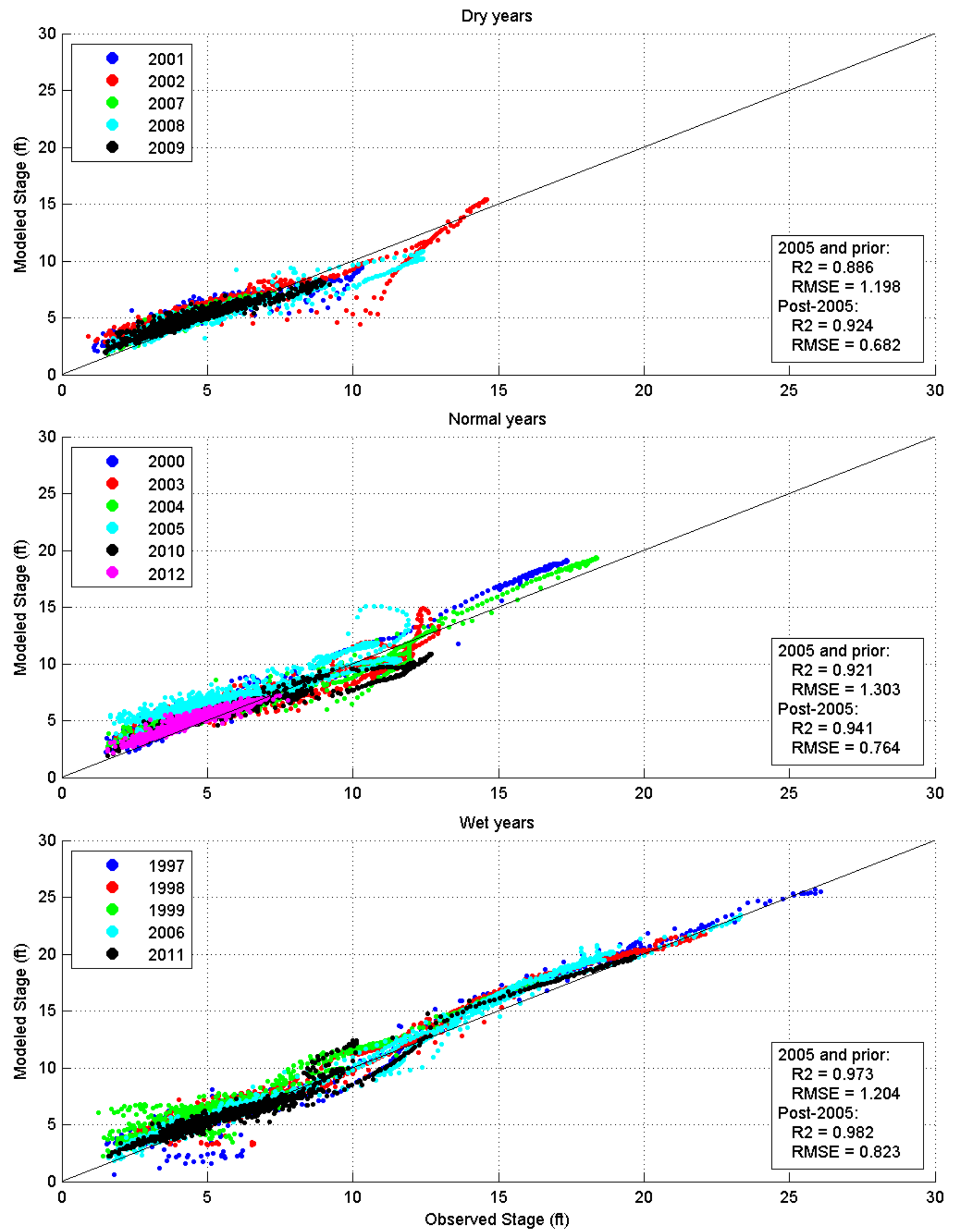


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Existing YB at Woodland Stage Comparison

Prepared for DWR | Created By: SJB | **Figure 6-4**

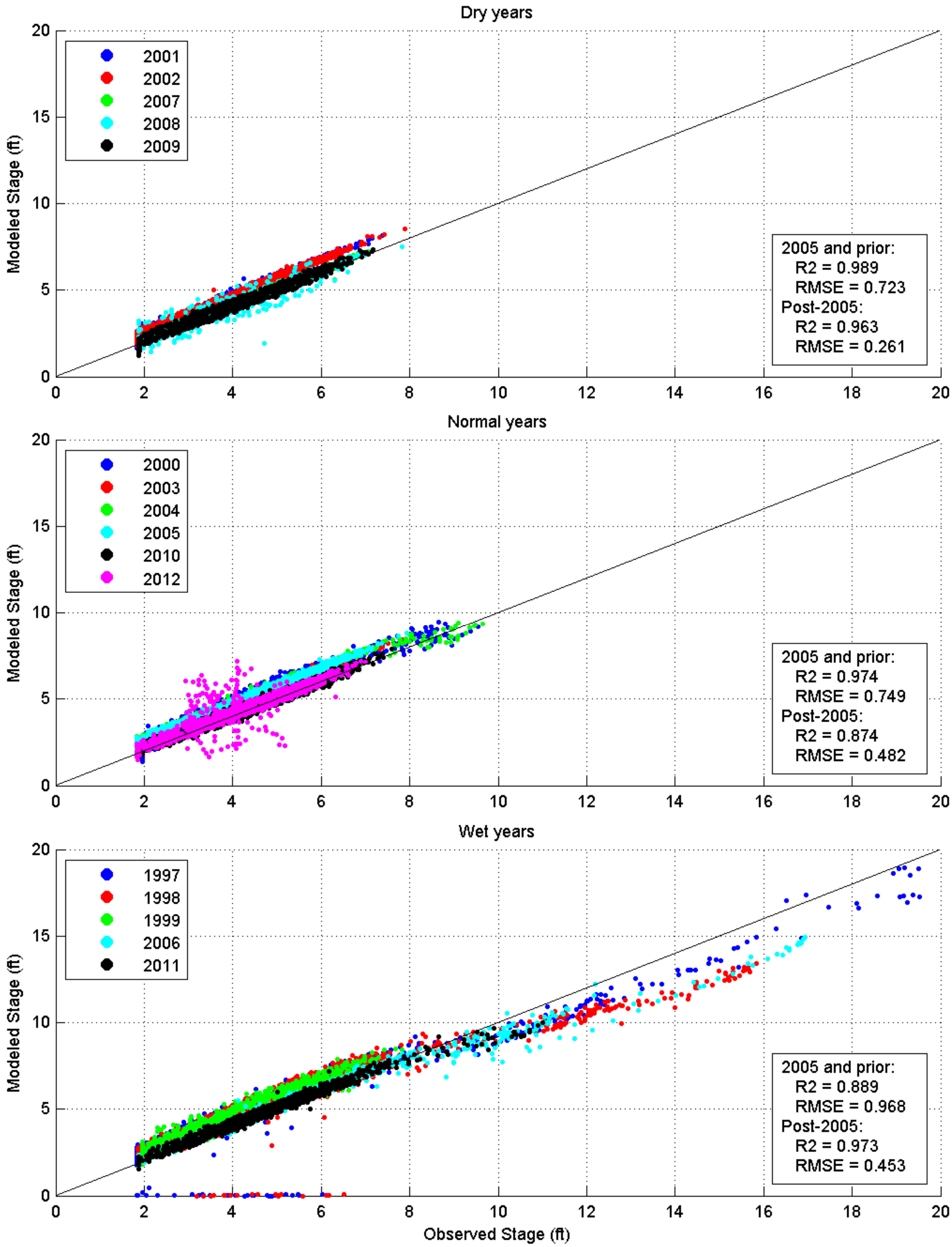


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Existing Lisbon Weir Stage Comparison

Prepared for DWR | Created By: SJB | **Figure 6-5**



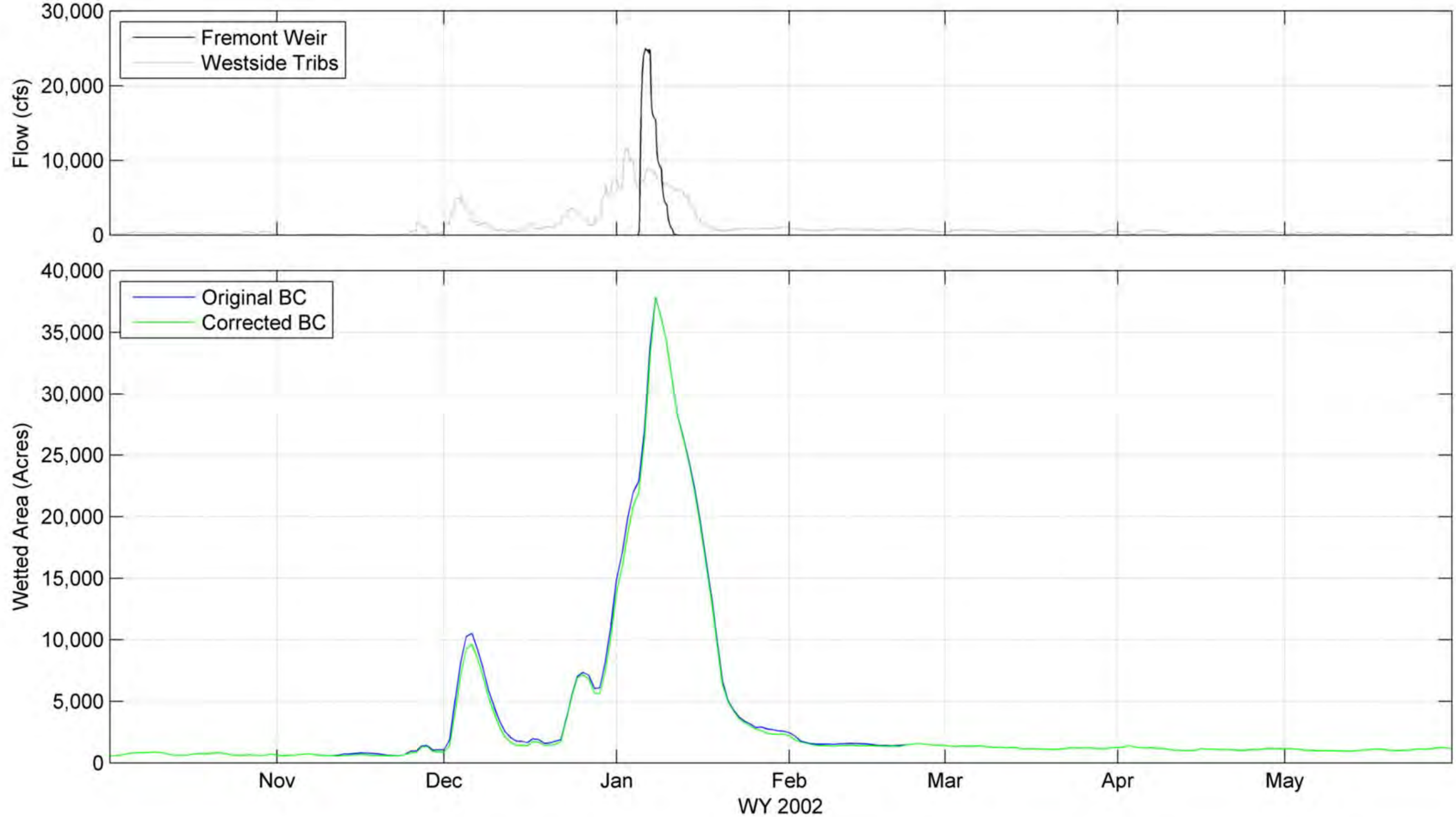
Notes:

HDR cbec eco engineering

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Existing YB at Liberty Is Stage Comparison

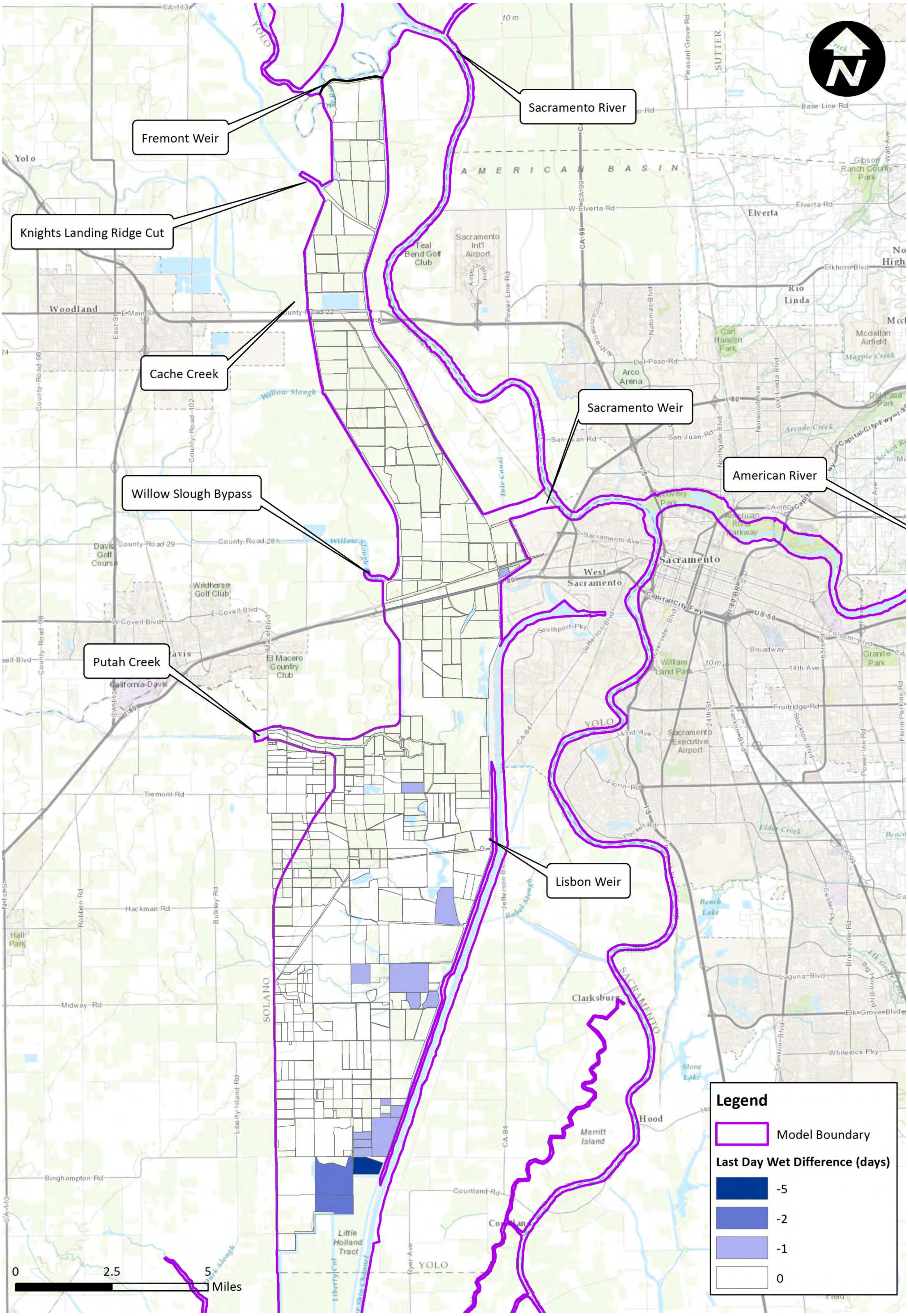
Prepared for DWR | Created By: SJB | **Figure 6-6**



Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Downstream BC Sensitivity – Wet Area 2002

Prepared for DWR	Created By: RDJ	**Figure 6-7**

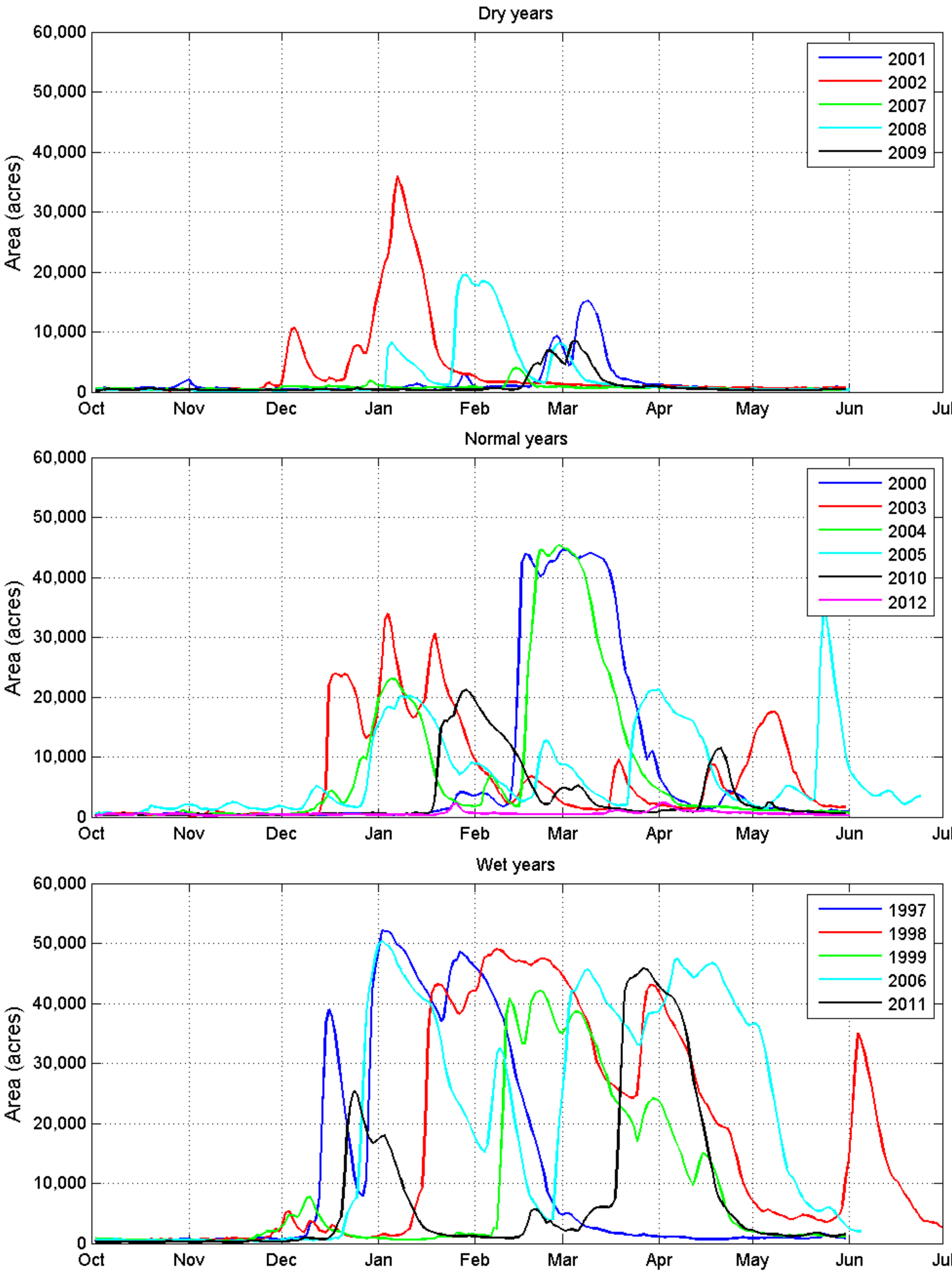


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Exg Downstream BC Sensitivity – LDW 2002

Prepared for DWR | Created By: RDJ | **Figure 6-8**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage*
		Existing Wetted Acres by WY Type
		Prepared for DWR · Created By: SJB · **Figure 6-9**

7.0 Alternatives Analysis

Each of the project alternatives was modeled for the 16 year period including simulations to model different project end dates when all of the gates are closed. The different gate closure dates that were modeled were February 15, March 1, March 15, April 1, and April 30. Each of the simulations for the April 30 gate closure date covered the period from October 2 to May 31. Simulations for the other gate closure dates used the April 30 solution as a "hotstart," that is, starting just before the gate closure date and ending 30 days afterwards. Once the gates have been closed for at least 30 days the alternative results and existing conditions results are nearly equivalent. Output data in the same formats as generated for the existing condition runs were generated for the alternatives.

7.1 Model Implementation

The channel profiles and preliminary gate configurations for the Fremont Weir and Sacramento Weir Gated Channel Alternatives were initially screened in HEC-RAS (see Appendix C) to 1) understand the backwater effects on the gates from Yolo Bypass inundation given that proposed upstream inverts at the river are below the baseline water levels in the Tule Canal; and 2) optimize the notched gate openings ability to divert 6,000 cfs from the Sacramento River to the Bypass during non weir overtopping periods with the objective to maximize fish entrainment while minimizing head losses across the gate. Gate optimization was performed in HEC-RAS because such a function was not yet available in TUFLOW and gate logic was a relatively new feature in TUFLOW.

For the HEC-RAS analysis, the Tule Canal was assumed to have baseline flow contributions of 500 cfs, 350 cfs, 50 cfs, and 300 cfs from KLRC, Cache Creek Settling Basin, Willow Slough, and Putah Creek, respectively, for existing conditions and all four alternatives. Rule operations in the HEC-RAS unsteady flow editor were used to optimize gate operations for the gated channel alternatives to maximize gate flows up to 6,000 cfs based on the Sacramento River WSEs and gate characteristics.

Following gate optimization in HEC-RAS, the Fremont Weir and Sacramento Weir Gated Channel Alternatives were implemented in TUFLOW. The Fremont Weir alternatives were modeled by adding a 1D channel connecting the Sacramento River through Tule Pond to the northern end of Tule Canal. The 1D channel included the proposed gate configurations at Fremont Weir (see Section 7.1.1), which vary in size, number, and gate closure operations by alternative. The Sacramento Weir alternative includes modifications to the 2D grid to represent the proposed channel within the Sacramento Bypass. A 1D channel at the Sacramento River connects the river to the Sacramento Bypass, which includes the proposed gate configuration at Sacramento Weir (see Section 7.1.2). For each alternative, the Sacramento River stage-dependent rule curves were implemented in the TUFLOW for all but one of the multiple bays representing each gate configuration. The remaining bays for each alternative used gate logic in

TUFLOW to regulate flows in the proposed channels downstream of the gates so channel flows would not exceed 6,000 cfs.

7.1.1 Fremont Weir Gated Channel Alternatives Setup (1D channels, gates, Ag crossings)

For the Fremont Weir Gated Channel Alternatives, each alternative included a proposed channel excavated at the east end of Fremont Weir and parallel to the flood levee, connecting the Sacramento River with the Tule Canal (see Figure 7-1). The channel dimensions of the three Fremont Weir alternatives are provided in Table 7-1. For the reach of the proposed channels between the Sacramento River and Fremont Weir, a length of approximately 800 feet, the channel was graded from Fremont Weir to the Sacramento River at a slope of 0.0025 with a bottom width of 225 feet and 3:1 side slopes. This was done to reduce head losses within the channel upstream of the gate and minimize the change in the WSE between the river and the weir.

Table 7-1. Fremont Weir alternatives channel dimensions

Channel Size	Invert at Fremont Weir(ft, NAVD88)	Bottom Width (ft)	Slope	Side Slopes
Small	14.0	20	0.00016	3:1
Medium	17.5	225	0.00035	3:1
Large	14.0	225	0.00016	3:1

Downstream of the gated channel, there are three agricultural crossings (Ag crossings) on the Tule Canal between Tule Pond and the confluence with KLRC (see Section 4.5). Ag Crossing #1 is an earthen berm 1.7 miles south of Fremont Weir at the bottom of Tule Pond that impounds irrigation water for RD 1600 so it can be conveyed through the levee to the Elkhorn Basin. This berm can become degraded during Fremont Weir overtopping events. Ag Crossing#2 is 0.5 miles further south and is an earthen berm with one 32-inch culvert. Ag Crossing #3 is 0.6 miles further south and is an earthen berm with three 24-inch culverts.

The Small and Large channels tie into the Tule Canal just downstream of Ag Crossing #2. The Medium channel ties into the Tule Canal just upstream of Ag Crossing #2. As a result, all three channel alternatives require the partial removal and modification of the earthen berm forming Ag Crossing #1, but only the Small and Large channels require the additional modification to Ag Crossing #2. For the purposes of this analysis, and as demonstrated by the backwater effects on the future gate location at the river during low flows due to the limited capacity of the Tule Canal downstream of KLRC and the agricultural crossings upstream of KLRC (see Appendix C), it was assumed that all three agricultural crossings were replaced with railcar bridges as part of the alternatives to maximize the frequency of inundation from the Sacramento River. The railcar bridges were assumed to be 90 feet long, 3 feet in vertical depth, and situated on 2-foot-wide abutments with wing walls. Under gate operations, all future agricultural crossings were assumed to be fully open.

A series of radial gates (final gate types and design will be determined later) at the channel connection with the Sacramento River was used to maximize the flow into the Yolo Bypass for non-overtopping flow events up to 6,000 cfs. In general, gate widths were limited to 30 feet in width with 3 feet pillars between them. Some of the gates were limited in height to prevent them from extending above the existing weir crest (32.8 feet NAVD88) during an overtopping event. Combinations of gate heights were used to optimize gate openings to achieve the 6.000 cfs discharge cap. After Fremont Weir overtops, the gates remain in their last configuration within the model (either fully open, partially open, or closed). If additional analysis indicates that this modeling assumption increases flood impacts, it is assumed that gate operations will be changed or design modifications will be made to mitigate impacts. For the Small channel, the bottom width of the channel was widened to accommodate three gates to minimize the head loss across the gate structure. The resulting gate configurations are shown in Table 7-2 and Figure 7-2, Figure 7-3, and Figure 7-4 for the Small, Medium, and Large channels, respectively.

Table 7-2. Fremont Weir gate configurations

Channel Size	Invert at River (ft, 88)	Bottom Width at Gate (ft)	Gate Invert (ft)	Gate Height (ft)	Gate Width (ft)	Number of Gates
Small	14	115	14	8, 14	30	3
Medium	17.5	225	17.5	6, 12	30	6
Large	14	225	14	7.5, 10	30	6

7.1.2 Sacramento Weir Gated Channel Alternative Setup (1D channels, gates)

The Sacramento Weir Gated Channel Alternative was assumed to be constructed just north of the southern Sacramento Bypass levee, connecting the Sacramento River with the Tule Canal (see Figure 7-5). The proposed channel has an invert elevation of 7 feet NAVD88 with a 225-foot bottom width and 3:1 side slopes.

WSEs in the Sacramento Bypass are controlled by the low flow conveyance capacity within Tule Canal and an agricultural crossing 2,300 feet downstream of the Sacramento Bypass as operated by Swanston Ranch. The minimum WSE in Tule Canal at the confluence with the Sacramento Bypass during baseline flows (i.e., 850 cfs as contributed by KLRC and Cache Creek) was 10.65 feet NAVD88. At stages below 11 feet NAVD88, flow through the Sacramento Bypass gated channel is limited due to backwater from Tule Canal.

A series of six new radial or sluice gates (final gate types and design will be determined later) at the Sacramento Weir were used to regulate flows into the Sacramento Bypass up to 6,000 cfs. It was assumed that the new gates were installed directly below the existing bays of the Sacramento Weir on the southern end of the weir (see Figure 7-6). The new gate dimensions are provided in Table 7-3, and generally consist of 30-foot-wide gates with inverts at 7 feet NAVD88 and 12 foot pillars between them. The pillars are wider than the Fremont Weir alternatives because the 30 foot new gates are situated directly beneath individual bays of the

Sacramento Weir which are generally 40 feet wide. Gate operations were optimized to maximize discharges into the Sacramento Bypass up to 6,000 cfs for river stages in front of the Sacramento Weir up to elevations corresponding to the I Street WSE trigger of 30.04 feet NAVD88. After the I Street elevation trigger is met, the Sacramento Weir is opened and the new gates will remain open to their last configuration within the model. If additional analysis indicates that this modeling assumption increases flood impacts, it is assumed that gate operations will change or design modification will be made to mitigate flood impacts. Gates 1 and 2 were limited in height to prevent the top of the gate from extending above the existing weir sill (24 feet NAVD88) during a flood event when the Sacramento Weir is open and the two gates are partially open to convey up to 6,000 cfs. The resulting gate configuration is shown in Table 7-3 and depicted in Figure 7-6.

Table 7-3. Sacramento Weir gate configuration

Gate #	Gate Invert (NAVD88 ft)	Gate Height (ft)	Gate Width (ft)
Gate 1	7	7	30
Gate 2	7	11	30
Gate 3 to Gate 6	7	14	30

7.2 Alternatives Results and Analysis of Results

7.2.1 Yolo Bypass Inundation

Modeled inundation area of the Yolo Bypass, relative to existing conditions, has been determined to include the Tule Canal/Toe Drain, as defined north to south between Fremont Weir and the north bank of the Stair Step, and east to west between the project levees. Figures 7-7 through Figure 7-11 show wetted acres and gate flows for all alternatives for WY 2003 for the five gate closure dates. A complete set of graphics for all water years and all gate closure dates can be found in Appendix D. These figures clearly show the increased frequency and duration of inundation and generally demonstrate that the increases in inundation acreage are greatest with the large channel at Fremont (FreLg), followed by medium channel at Fremont (FreMed), small channel at Fremont (FreSm), and Sacramento Weir option (SacW).

To augment these figures, a series of animation snapshots (see Figures 7-12 through Figure 7-15 and Appendix E) were prepared that spatially depict the potential differences in wetted area for each alternative for the April 30 gate closure relative to existing conditions. These figures also show wetted-area times-series comparisons for all gate closure dates within a specific water year for each gate closure date.

To understand and quantify the increased inundation provided by each alternative, expected annual inundation was computed directly from the wetted-area time-series following the recently published methods by Matella & Jagt (2013). To streamline the analysis, the wetted-area time-series outputs for the 16 water years were used directly in the analysis. The wetted-area time-series were imported into HEC-EFM and statistical queries were generated for the period of November 1 to May 30 to populate area-duration-frequency (ADF) curves for durations of 2, 3, 7, 14, 21, 28, and 60 days. The wetted-area time-series considers all wet areas within the previously defined Yolo Bypass extents, and were not further screened for suitable depths or velocities for a specific fish species nor refined for shorter periods of time corresponding to specific fish life history needs; otherwise this may have been stated as expected annual habitat, but this determination is outside the scope of this modeling effort.

The ADF curves were then used in two ways. First, the curves were used to identify inundation acreages at flow frequencies of 1 in 3 years (33 percent exceedance), 1 in 2 years (50 percent exceedance), and 2 in 3 years (67 percent exceedance). Table 7-4, Table 7-5, and Table 7-6 presents the inundation acreages for 33 percent, 50 percent, and 67 percent exceedances, respectively. These tables generally demonstrate that: 1) longer duration events (i.e., > 4 weeks) are inundated longer in 1 out of 3 years; 2) medium duration events (i.e., 2 to 4 weeks) are inundated longer in 1 out of 2 years; and 3) shorter duration events (i.e., < 3 weeks) are inundated longer in 2 out of 3 years. The FreLg alternative provides the greatest inundation increase ranging from 7,700 acres in 2 out of 3 years to 8,800 acres in 1 out of 2 years. The other Fremont Weir alternatives are not too far behind in terms of acres inundated, but the Sacramento Weir alternative typically provides half of the inundation increase as the Fremont Weir alternatives.

Second, the area under the ADF curves were integrated to compute expected annual inundation based on the 16 years of model outputs. Table 7-7 and Figure 7-16 show similar trends amongst the alternatives. Expected annual inundation relative to existing conditions predicted to be 3,650±550 acres for FreLg, 3,350±500 acres for FreMed, 2,800±350 acres for FreSm, and 1,400±350 acres for SacW.

It is noted that the ADF curves and expected annual inundation results are based on an annual maxima approach per Matella & Jagt (2013) for a relatively short 16-year period. Given that there can be multiple discrete inundation events in the Bypass, a partial duration series approach could be considered.

Table 7-4. Inundated area in 33% of years between November 1 and May 30

Duration (days)	Inundated Area (acres)					Inundation Increase (acres)			
	Existing	FreLg	FreMed	FreSm	SacW	FreLg	FreMed	FreSm	SacW
2	47,806	47,832	47,852	47,824	48,112	26	46	18	307
3	47,690	47,718	47,735	47,705	48,001	28	46	16	312
7	46,461	46,501	46,513	46,484	46,817	41	52	23	356
14	45,085	45,154	45,165	45,148	45,458	68	80	63	373
21	36,267	36,378	36,375	36,432	37,068	111	108	165	801
28	30,330	32,630	32,505	32,481	32,024	2,300	2,176	2,152	1,695
60	2,152	14,650	13,137	10,526	5,432	12,498	10,985	8,374	3,281

Table 7-5. Inundated area in 50% of years between November 1 and May 30

Duration (days)	Inundated Area (acres)					Inundation Increase (acres)			
	Existing	FreLg	FreMed	FreSm	SacW	FreLg	FreMed	FreSm	SacW
2	36,180	36,588	36,571	36,622	37,256	408	391	442	1,076
3	34,140	36,214	36,271	36,169	36,769	2,074	2,131	2,029	2,629
7	27,068	31,430	31,433	31,472	30,246	4,362	4,365	4,404	3,178
14	19,704	26,771	26,507	26,082	22,102	7,067	6,803	6,378	2,398
21	15,823	24,695	24,551	23,135	18,949	8,872	8,728	7,312	3,126
28	15,823	24,695	24,032	22,775	18,733	8,872	8,209	6,952	2,910
60	1,667	5,683	4,953	4,081	2,293	4,016	3,286	2,414	626

Table 7-6. Inundated area in 67% of years between November 1 and May 30

Duration (days)	Inundated Area (acres)					Inundation Increase (acres)			
	Existing	FreLg	FreMed	FreSm	SacW	FreLg	FreMed	FreSm	SacW
2	24,850	30,818	30,842	30,919	29,675	5,968	5,992	6,069	4,824
3	24,320	30,026	30,040	30,131	28,797	5,706	5,720	5,811	4,477
7	19,982	26,854	26,572	25,812	23,797	6,872	6,590	5,830	3,815
14	16,391	23,456	22,820	21,592	19,129	7,065	6,429	5,201	2,738
21	9,976	17,670	16,919	15,530	10,545	7,694	6,943	5,554	569
28	6,231	9,709	9,556	9,222	6,690	3,478	3,324	2,991	459
60	1,402	2,189	1,717	1,684	1,469	787	315	282	67

Table 7-7. Expected annual inundation

Duration (days)	Expected Annual Inundation (acres)					Expected Annual Increase (acres)			
	Existing	FreLg	FreMed	FreSm	SacW	FreLg	FreMed	FreSm	SacW
2	34,534	38,413	38,204	37,614	36,318	3,879	3,670	3,080	1,784
3	34,063	37,903	37,699	37,079	35,745	3,840	3,636	3,016	1,682
7	30,787	34,965	34,695	34,019	32,363	4,178	3,908	3,232	1,576
14	27,803	31,495	31,172	30,605	28,912	3,692	3,369	2,802	1,109
21	23,499	26,605	26,313	25,758	24,319	3,106	2,814	2,259	820
28	19,255	21,990	21,729	21,440	20,385	2,735	2,475	2,186	1,131
60	7,029	11,152	10,531	9,955	8,693	4,122	3,502	2,926	1,663

7.3 Post-processed Data

The TUFLOW model results will inform other analyses including agriculture economic impacts, fisheries benefits model, and CALSIM modeling. The model results required post-processing to prepare the output data into the appropriate format for each type of analysis.

7.3.1 Last Day Wet Determination

The most extensive post-processing involved the determination of the last day wet (LDW) for individual field units within the Bypass. Yolo County performed landowner outreach to gather additional information to use in the Yolo Bypass Agricultural Impact Analysis for this project. During those discussions with landowners it was learned that that farmers are likely to begin planting their fields when at least 70 percent of their fields were dry (or conversely, the last day when more than 30% of the area is wet). Based on this information and discussions with the lead modeler of the Yolo Bypass Agricultural Impact Analysis, it was agreed upon to use this assumption as the ratio for last day wet (LDW) calculations. The field units were provided by the Agriculture Economics team which will be utilizing the LDW to inform their analysis regarding the potential impacts the proposed channels may have on agriculture within the Bypass.

It should be noted that the LDW data is produced by post-processing the Model results and the ratio used for determining LDW can be changed without altering the Model. The LDW is determined by analyzing the raster solutions for each day of the simulation (specific water year, alternative, and gate closure date) by subtracting the 25-foot base DEM from the TUFLOW water surface elevation outputs to create 25-foot depth rasters. LDW results for water year 2001 for each configuration are shown in Figures 7-17 through Figure 7-21. Additional LDW results are included in Appendix F. The number of output raster cells that are dry for each field unit are counted and compared with the number of raster cells within the field unit. The last day in the simulation where less than 70 percent of the raster cells are dry is assigned to the LDW attribute.

7.3.2 Post-processing for Fisheries Team

Minor post-processing was required to fulfill the fisheries benefits models hydrodynamic data input needs. The fisheries team requested depth and velocity magnitude raster datasets covering the Bypass in ESRI ASCII format and daily average discharge values for the Fremont Weir (including channel flows), the Sacramento at Verona, and the Sacramento River at Freeport. The raster results from TUFLOW were converted from ESRI binary float format to ESRI ASCII format. The discharge values from the 1D and 2D time-series output were averaged on a daily basis and provided in csv format as requested.

7.3.3 Rating Curve Derivation for CALSIM Modeling

The CALSIM modeling group requested flow versus flow rating curves at the Fremont Weir. Because flows from the Sutter Bypass, the Feather River, and the Sacramento River intermix, the rating curves are based upon comparing flows at Verona with the sum of the flows over the Fremont Weir and through the proposed gate channels. A rating curve was developed for existing conditions based upon the TUFLOW model results and matches well to rating curves previously used in the CALSIM model confirming the approach used.

The rating curves were developed as scatterplots containing a point for each output value where the Fremont Weir overtopped or the gate channels were open and active. The resulting rating curves are shown in Figure 7-22. The lower discharge portion of the rating curves are shown in Figure 7-23.

7.4 Preliminary Flood Impact Analysis

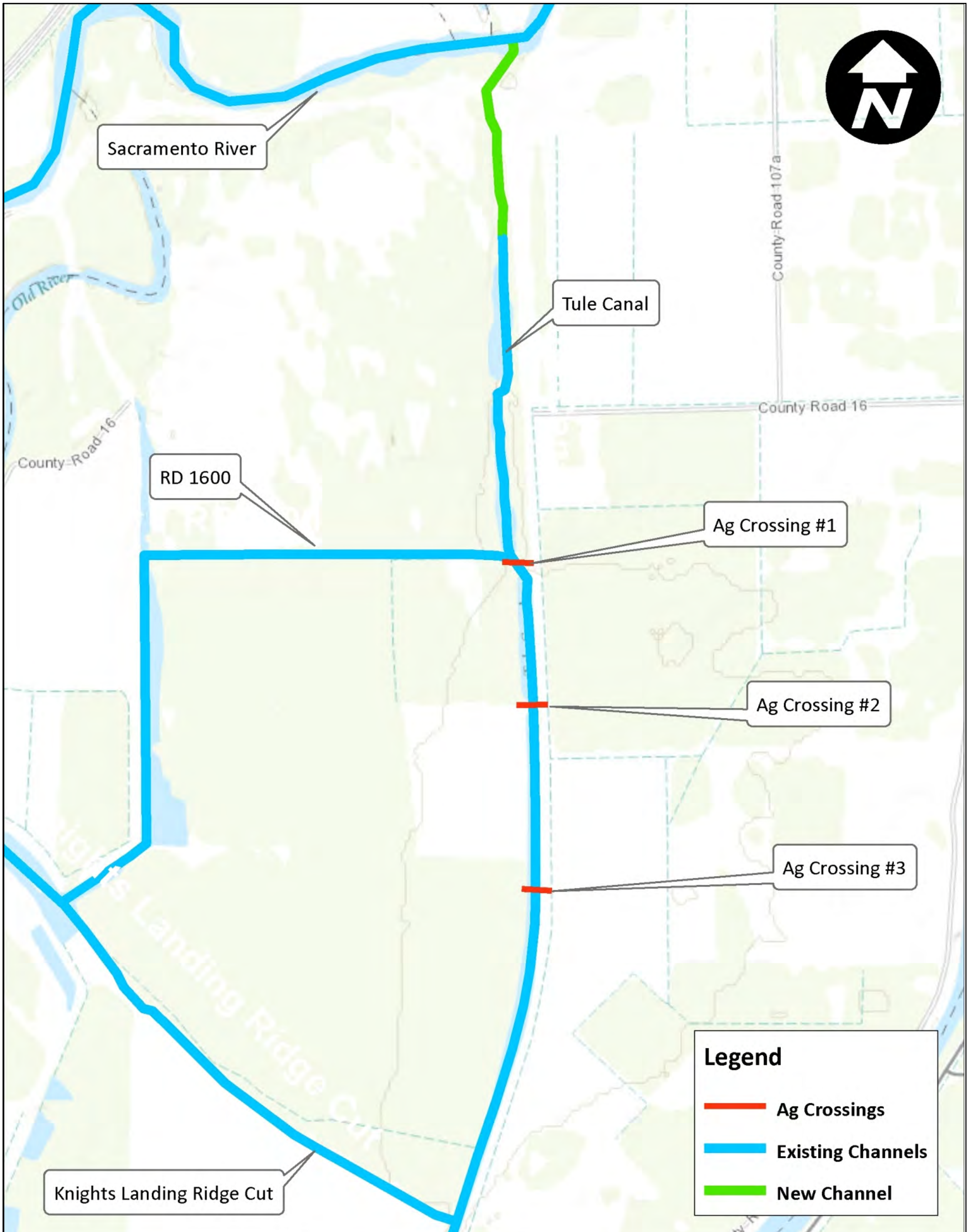
While a complete analysis of flood impacts for permitting purposes is beyond the scope of this report, the results for the water years with the largest floods were compared to predict potential flood impacts. The peak WSE for the existing conditions and the large channel alternative configurations for the 1997, 1998, and 2006 water years were compared to evaluate the potential project impacts on flooding. The analysis is based upon the previously analyzed configuration and operations. The gates were regulated to prevent more than 6,000 cfs through the channel until the Fremont Weir overtops. Once Fremont Weir overtops, the gate openings are held steady (not changed from opened or closed position) until the overtopping has ceased or the project end date (gates closed) has been reached.

Differences in maximum WSEs for the existing conditions and large channel configuration are shown in Figures 7-24 through Figure 7-26.Because the large channel configuration allows higher discharges into the Yolo Bypass than under existing conditions, the maximum WSEs are higher within the Bypass for this alternative. However, this decreases the discharge down the Sacramento River past Verona and lowers the maximum WSEs compared to existing conditions.

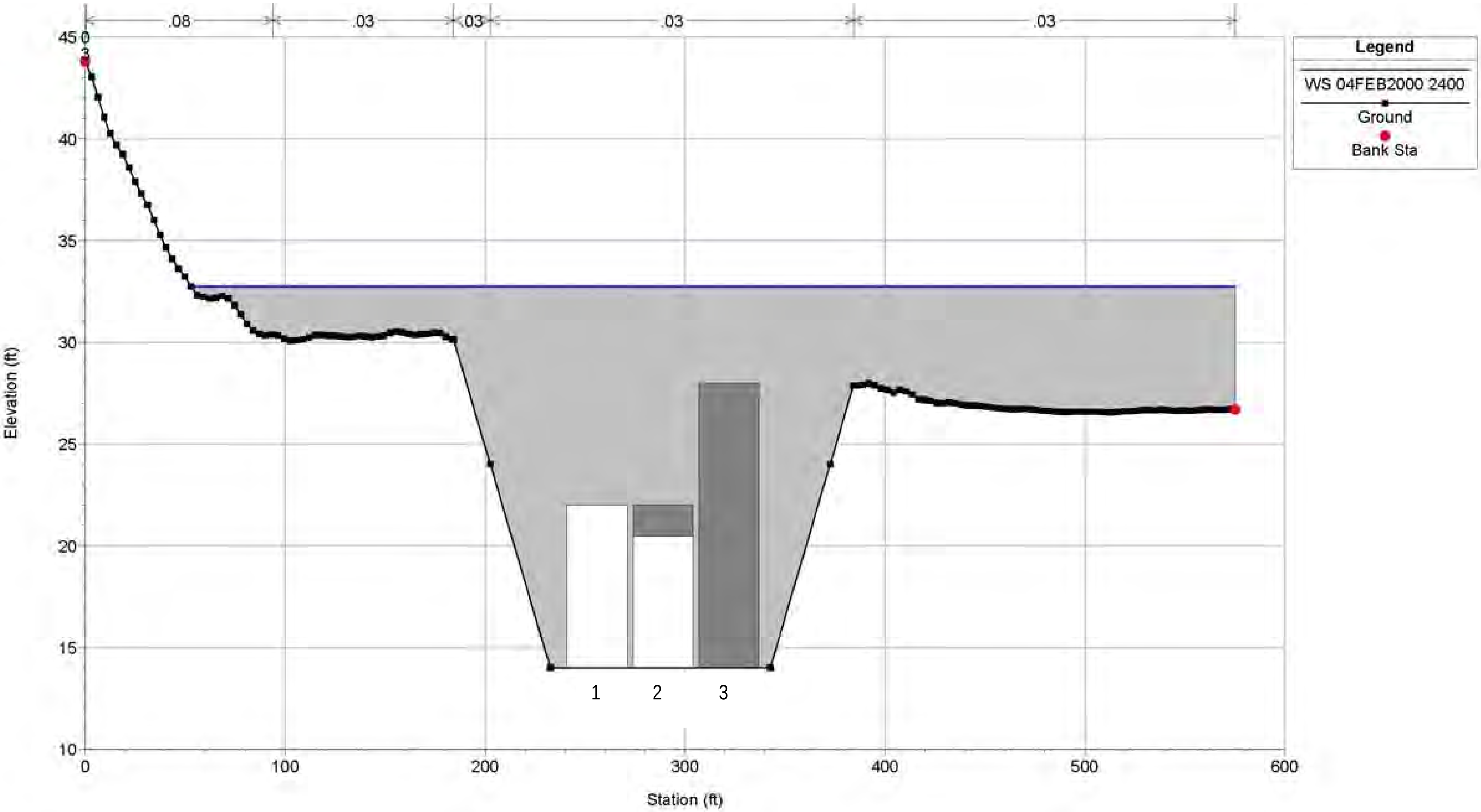
The increases in maximum WSEs within the Yolo Bypass are small for the large channel alternative. Near the proposed channels there are local increases and decreases in WSE because of the geometry changes in these areas. The increase in maximum WSE for most of the Bypass is less than 0.02 feet for all three water years analyzed. The largest flood occurred in 1997 and some portions of the Bypass experienced increases in maximum WSE between 0.02 and 0.05 feet.

Because the Sacramento River downstream of Verona is more constricted than the Bypass, the diversion of additional flows has a larger effect upon the maximum WSEs than was experienced within the Bypass. The decreases in maximum WSE extend upstream of the Yolo Bypass but the effect diminishes moving upstream.

This analysis suggests that the project impacts to flooding will be minor based upon preliminary channel/gate designs and operations. Design changes to the project configuration or operations may alter flood impacts. Further analysis will be required after designs and operations have been finalized and to meet Federal Emergency Management Agency (FEMA) and other agency requirements. The required analysis to meet FEMA floodplain regulations is summarized in Appendix G.



Notes:	HDR cbec	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Fremont Weir Alternatives Location Map**		
		Prepared for DWR	Created By: CRC	**Figure 7-1**

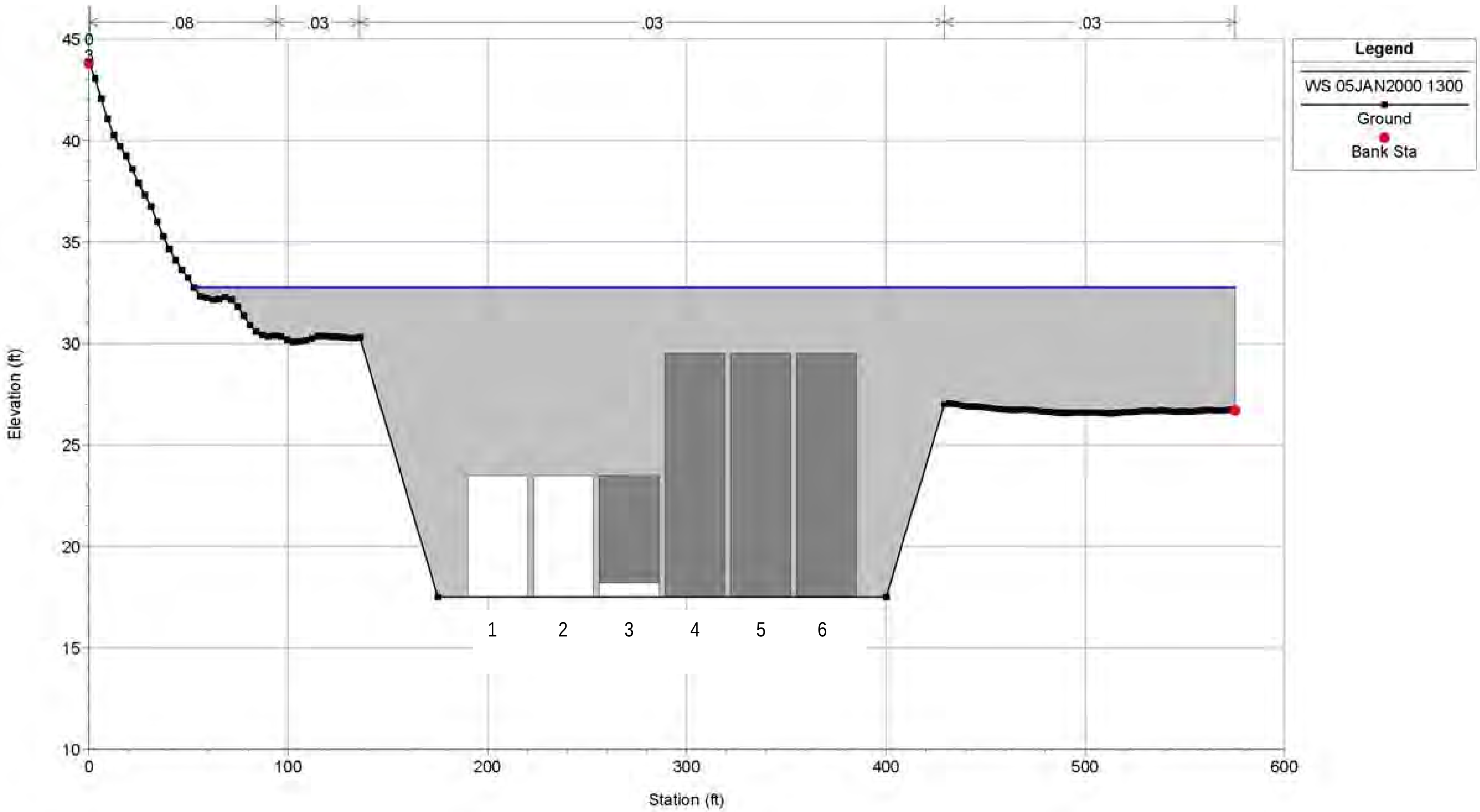


Notes: Gate closure shown represents 6000 cfs at maximum Sacramento River Stage before Fremont Weir begins to overtop for gates operated individually. (white = gate opening, grey = partial gate closure)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Fremont Weir Small Gate Configuration

Prepared for DWR	Created By: CRC	**Figure 7-2**

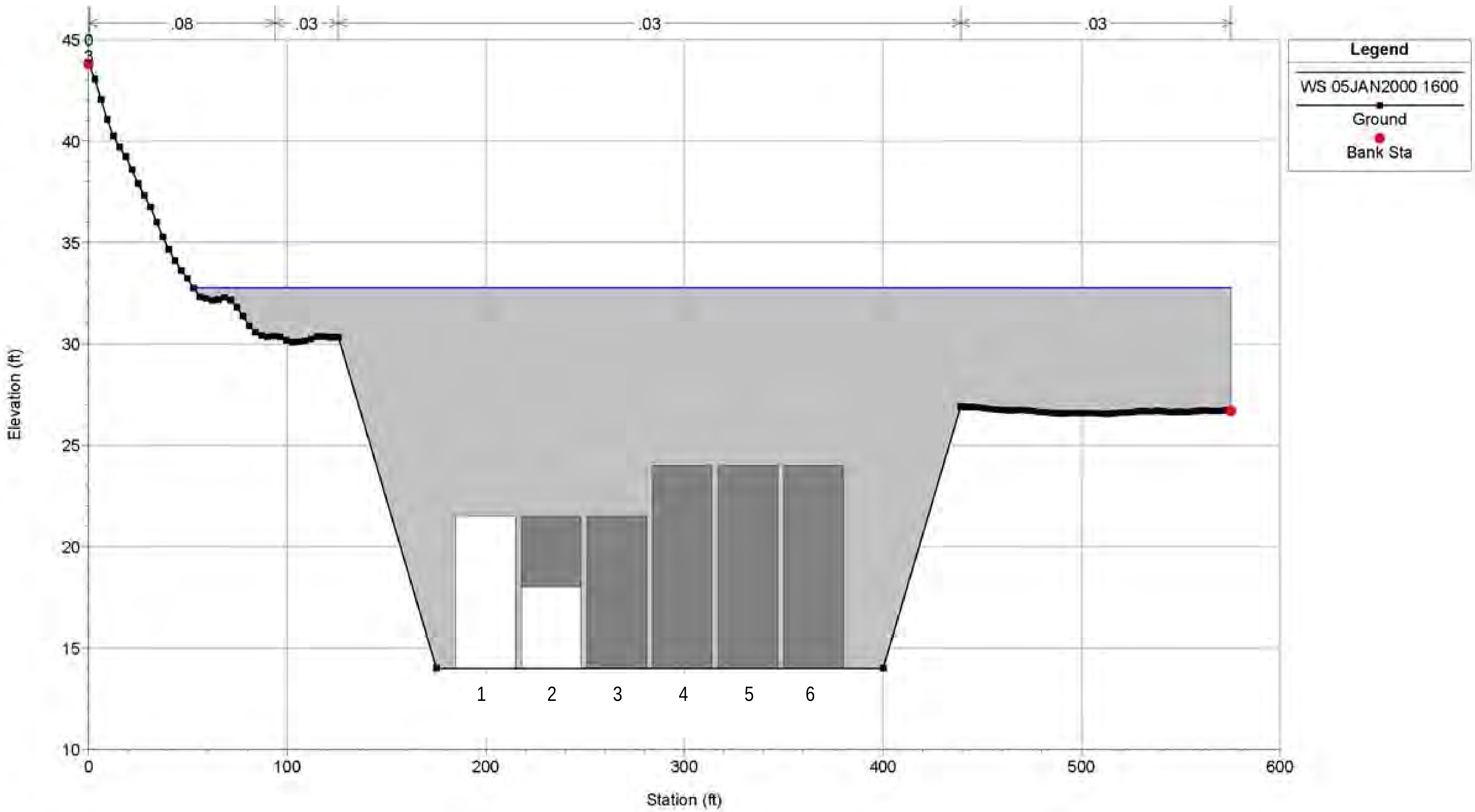


Notes: Gate closure shown represents 6000 cfs at maximum Sacramento River Stage before Fremont Weir begins to overtop for gates operated individually. (white = gate opening, grey = partial gate closure)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Fremont Weir Medium Gate Configuration

Prepared for DWR	Created By: CRC	**Figure 7-3**



Notes: Gate closure shown represents 6000 cfs at maximum Sacramento River Stage before Fremont Weir begins to overtop for gates operated individually. (white = gate opening, grey = partial gate closure)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Fremont Weir Large Gate Configuration

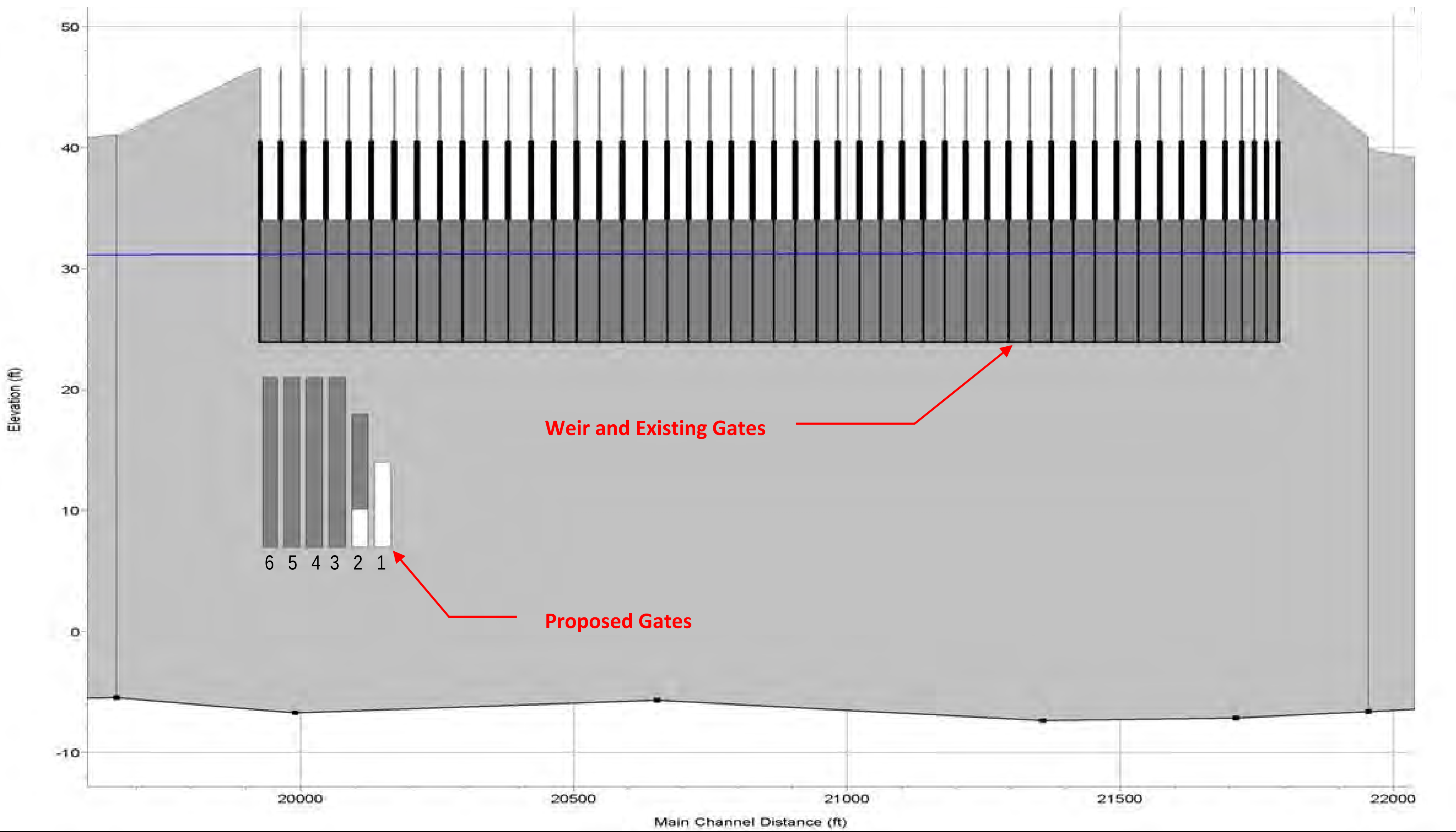
Prepared for DWR | Created By: CRC | **Figure 7-4**

Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Sacramento Weir Alternative Location Map

Prepared for DWR | Created By: CRC | **Figure 7-5**

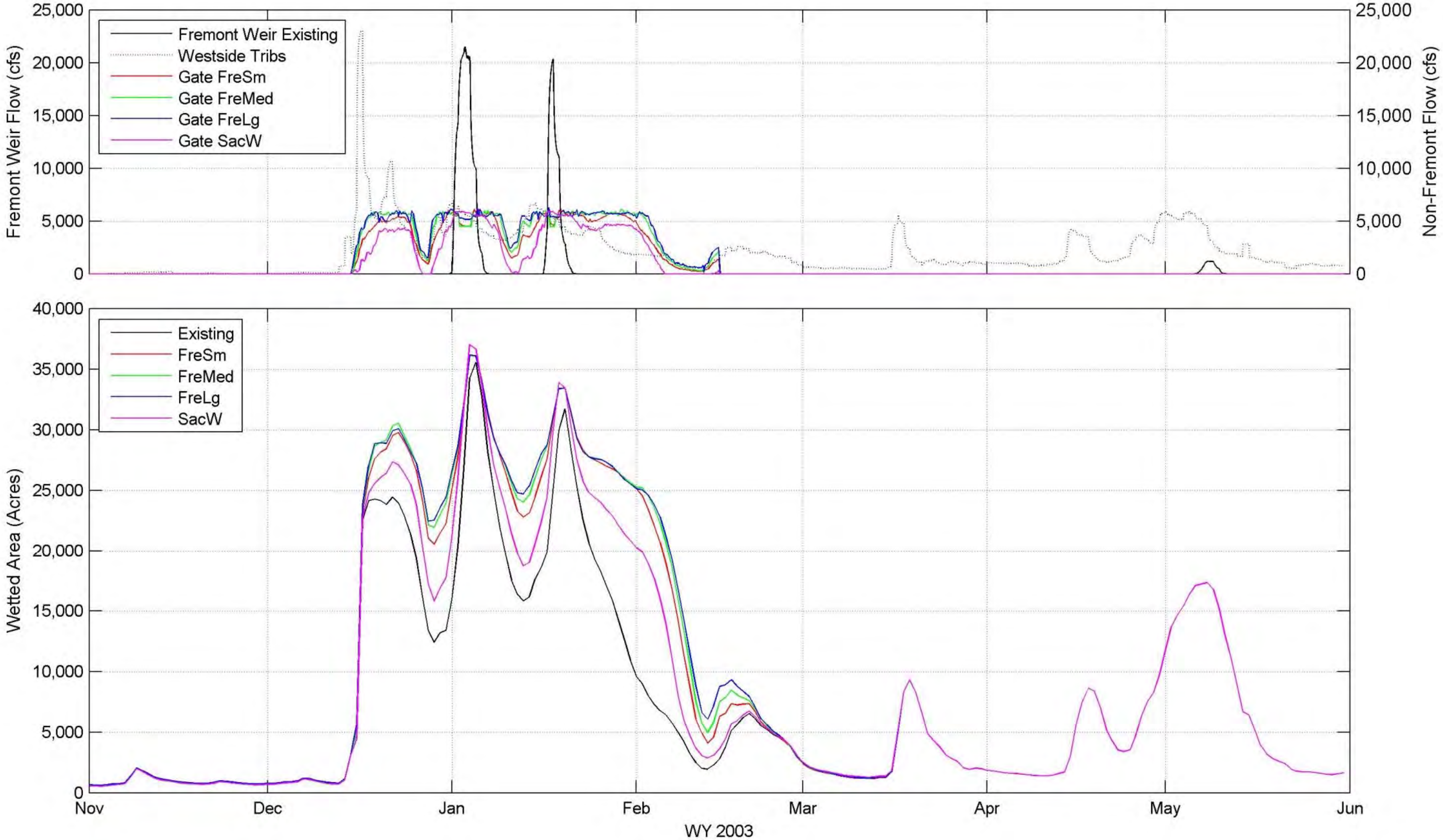


Notes: Gates 1 and 2 were limited in height to prevent the top of the gate from extending above the existing weir sill during a flood event when the Sacramento Weir is open and the two gates are partially open to convey up to 6,000 cfs. (white = gate opening, grey = partial gate closure)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Sacramento Weir Alternative Proposed Gates

Prepared for DWR | Created By: CRC | **Figure 7-6**

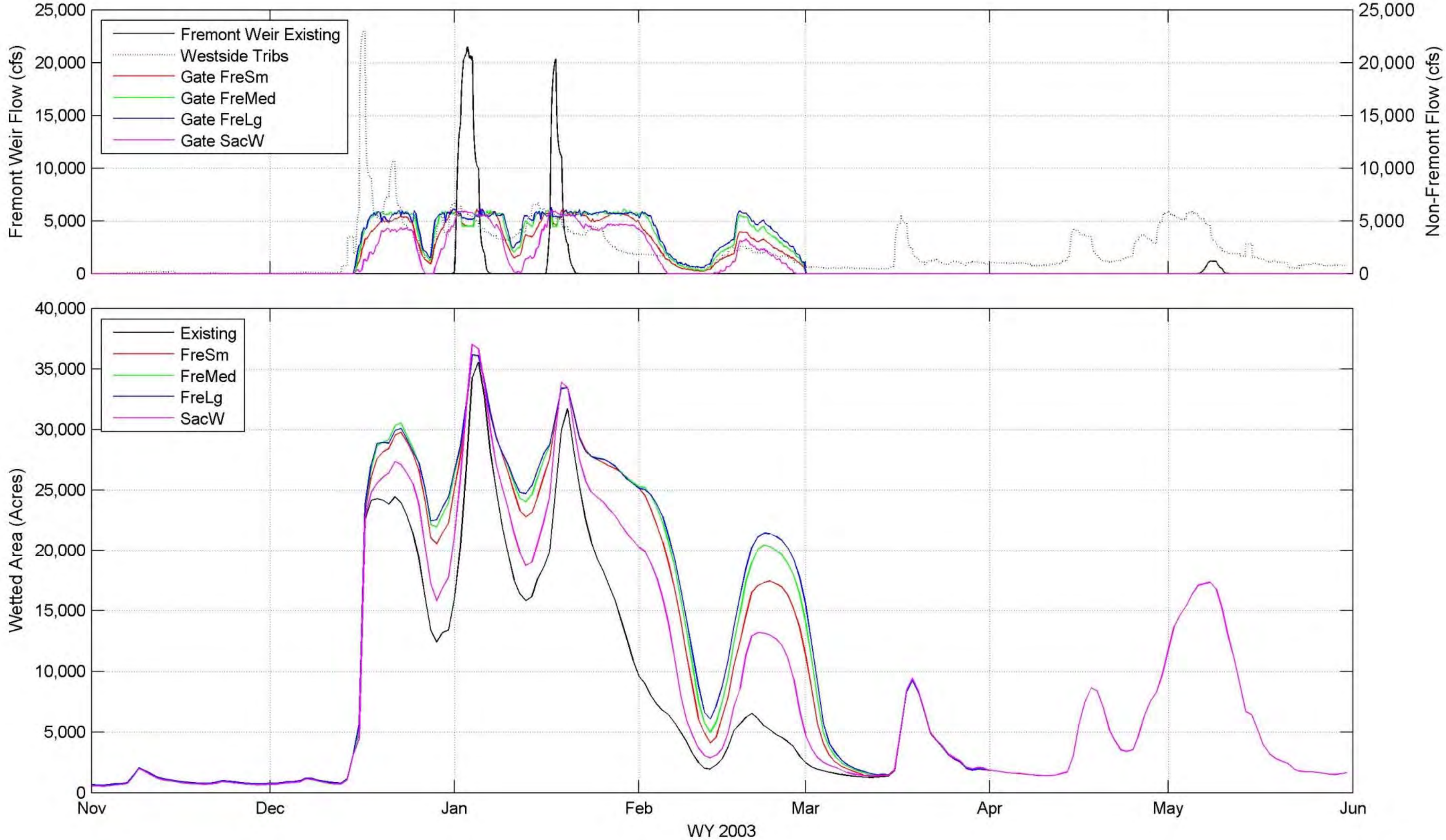


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Acres for Alternatives-WY 2003 Feb. 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure 7-7**

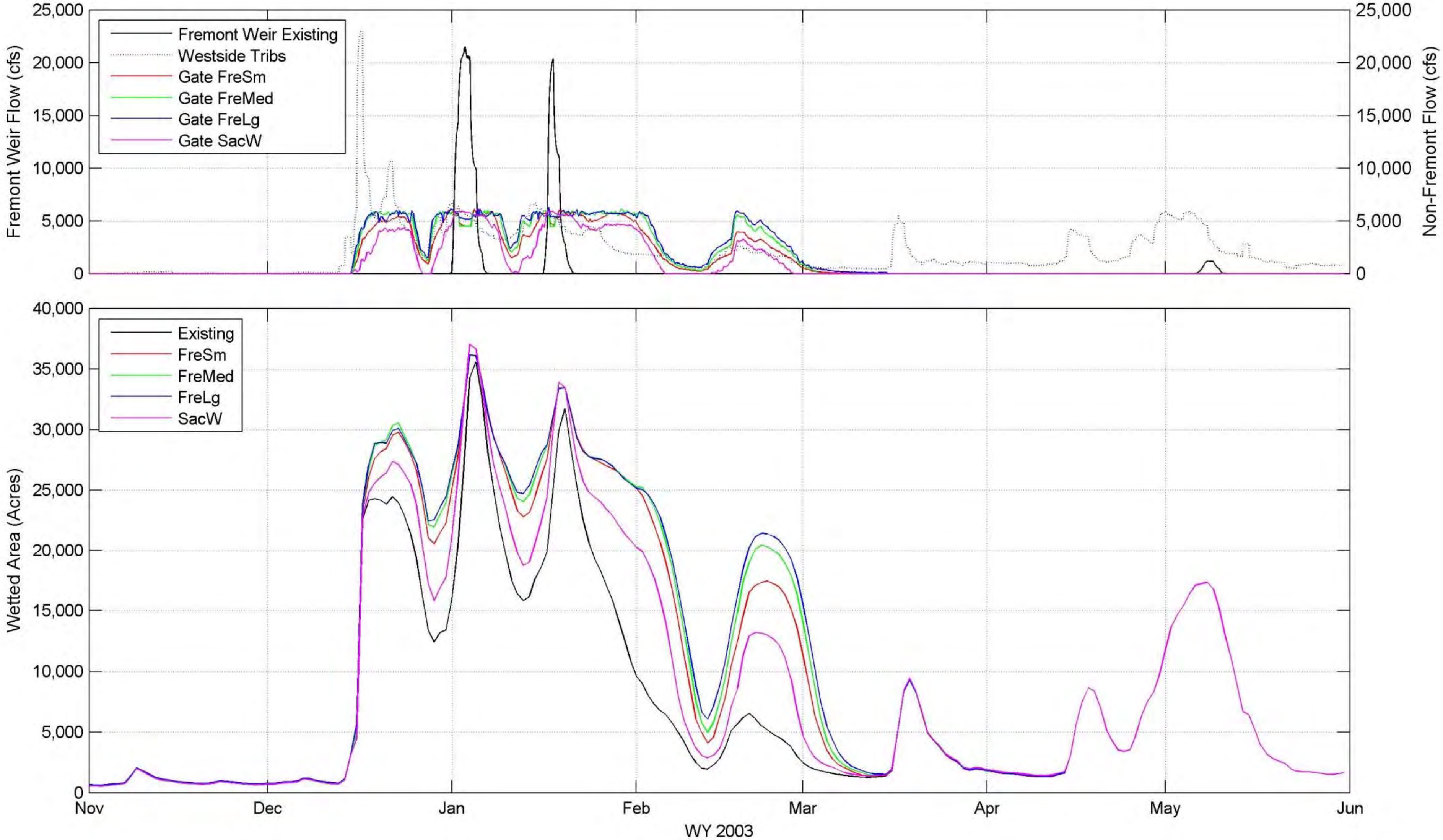


Notes:

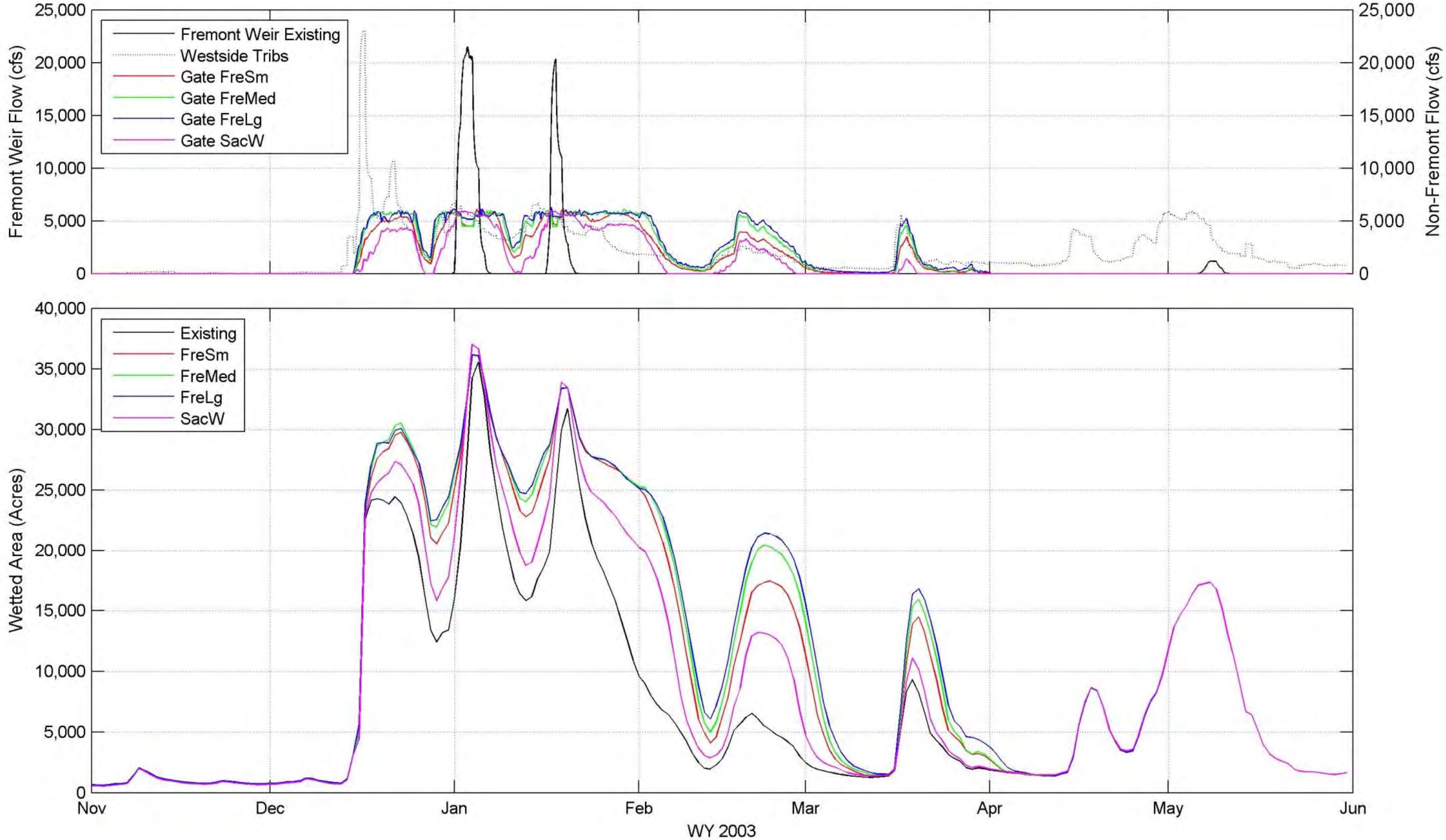
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Acres for Alternatives-WY 2003 Mar. 1 Gate Closure

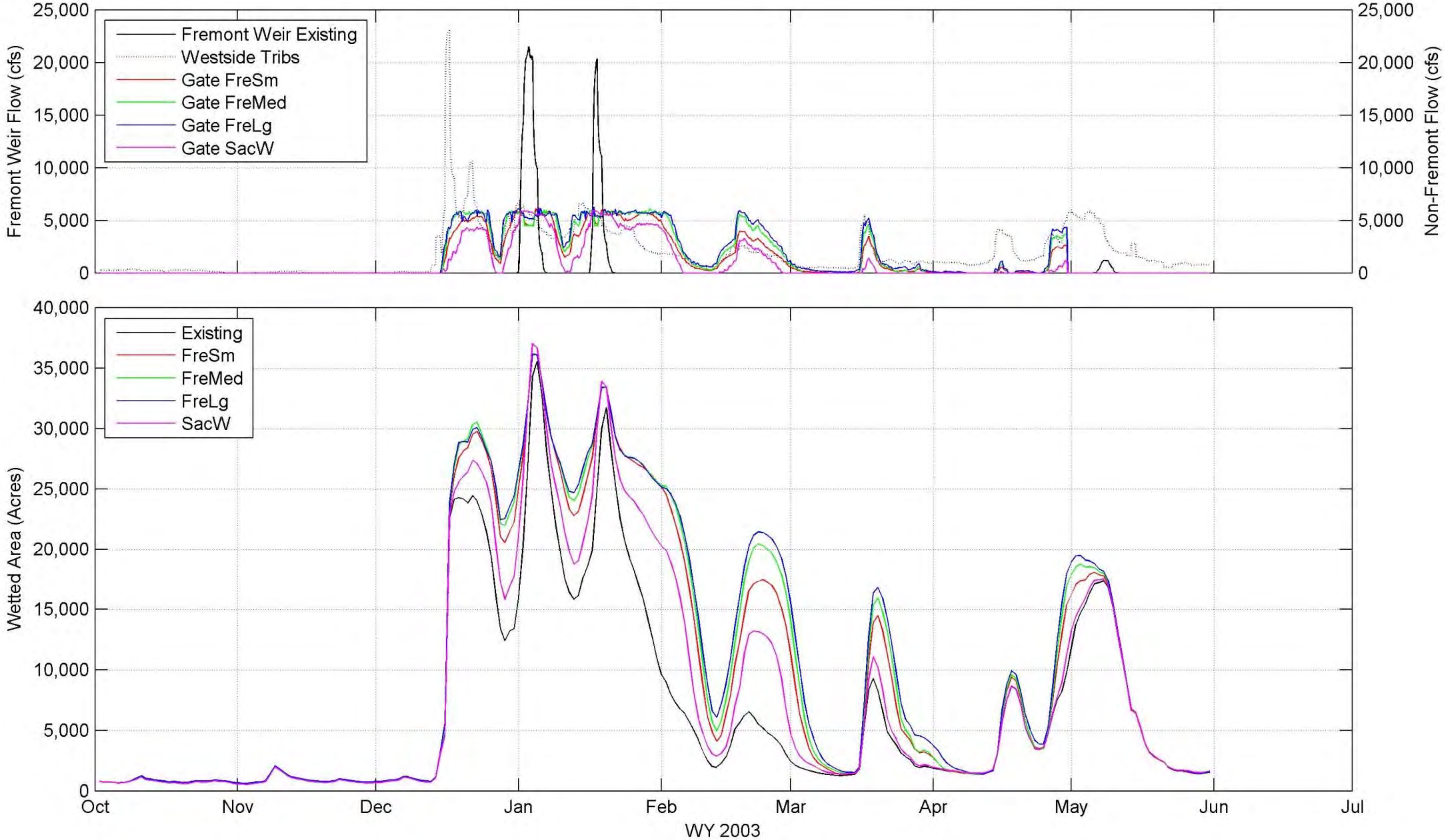
Prepared for DWR	Created By: SJB	**Figure 7-8**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Wetted Acres for Alternatives-WY 2003 Mar. 15 Gate Closure**		
		Prepared for DWR	Created By: SJB	**Figure 7-9**



Notes:	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Wetted Acres for Alternatives-WY 2003 Apr. 1 Gate Closure**		
		Prepared for DWR	Created By: SJB	**Figure 7-10**

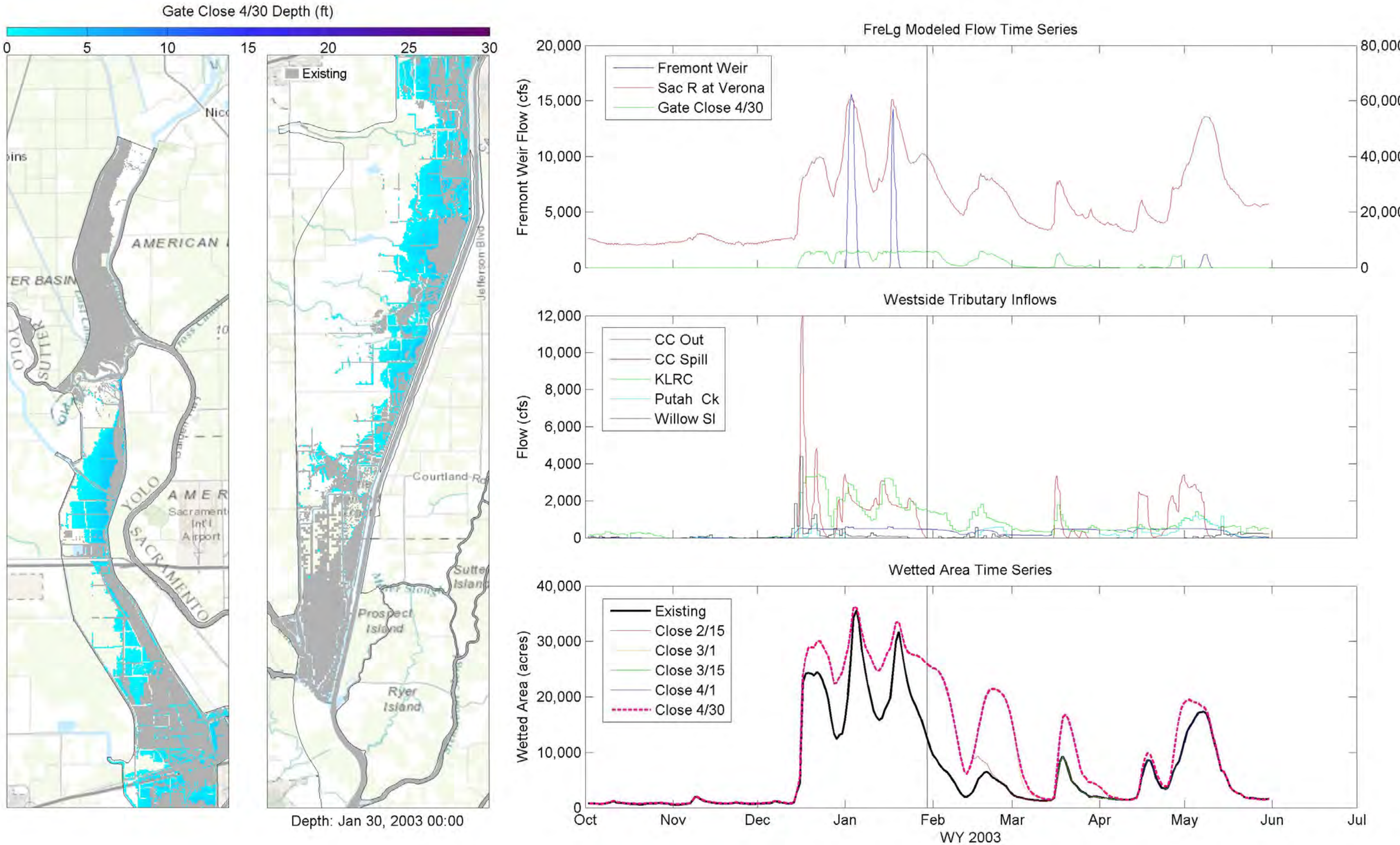


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Acres for Alternatives-WY 2003 Apr. 30 Gate Closure

Prepared for DWR | Created By: SJB | **Figure 7-11**

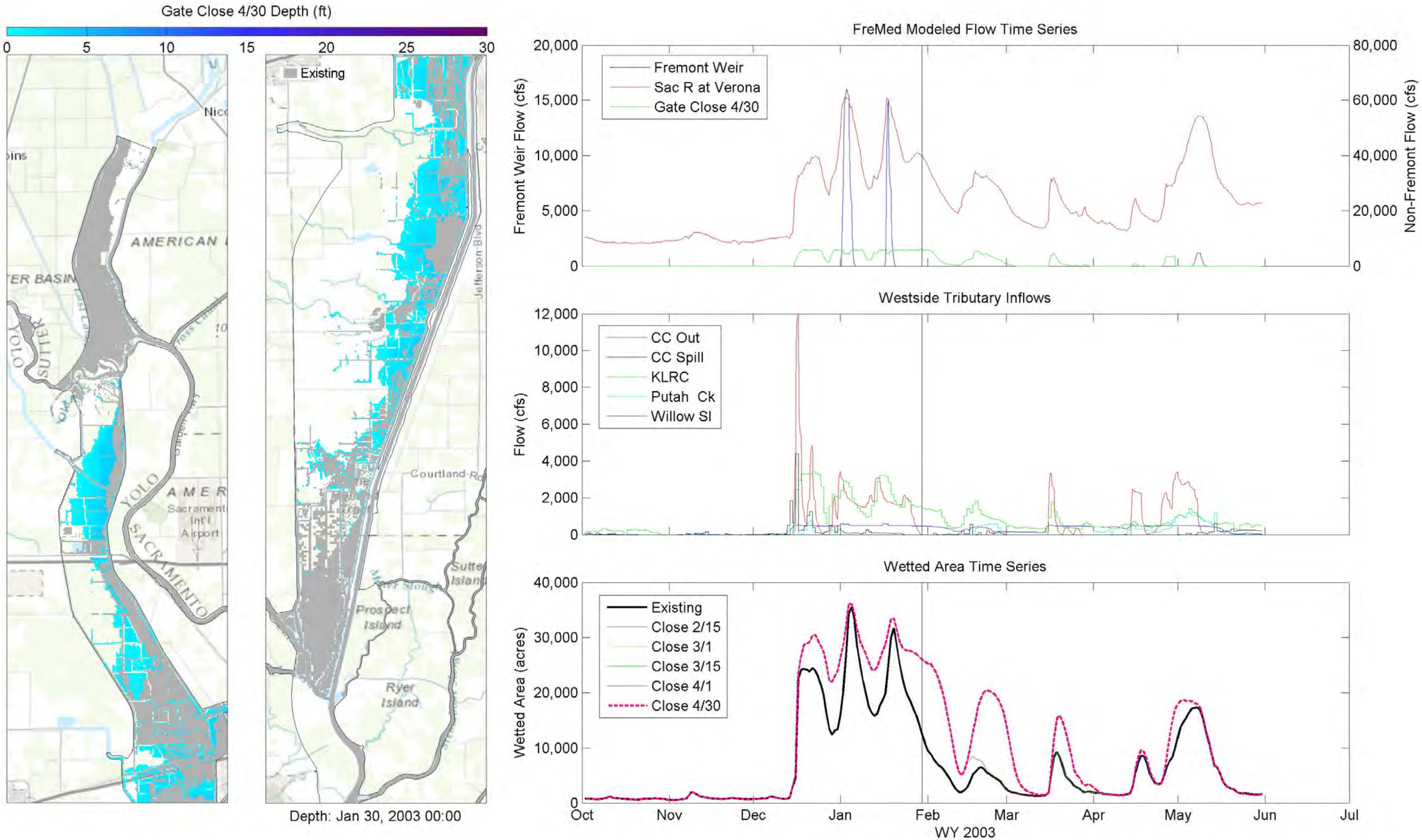


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Acres for All Gate Closures for FreLg – WY2003

Prepared for DWR	Created By: SJB	**Figure 7-12**

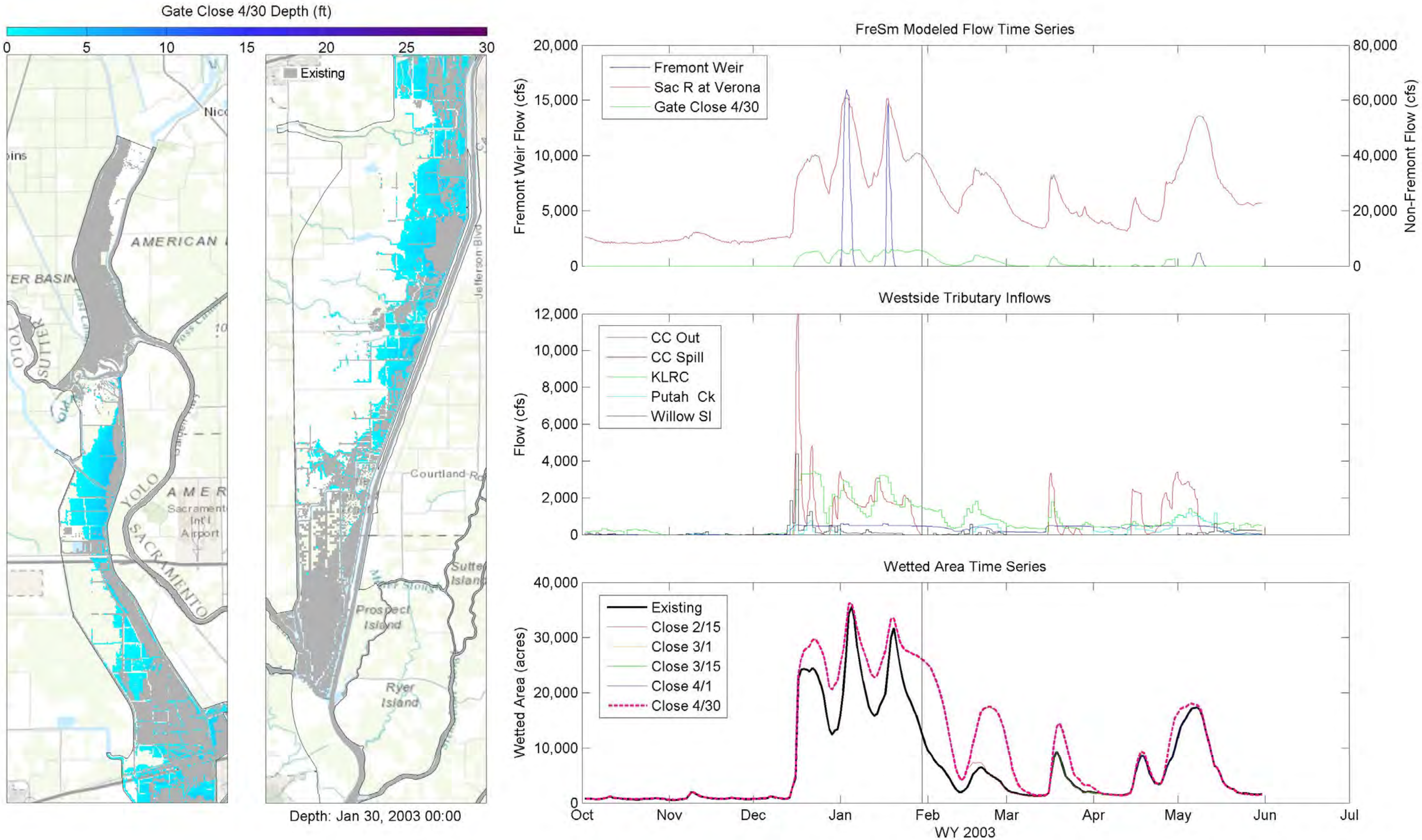


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Acres for All Gate Closures for FreMed – WY2003

Prepared for DWR | Created By: SJB | **Figure 7-13**

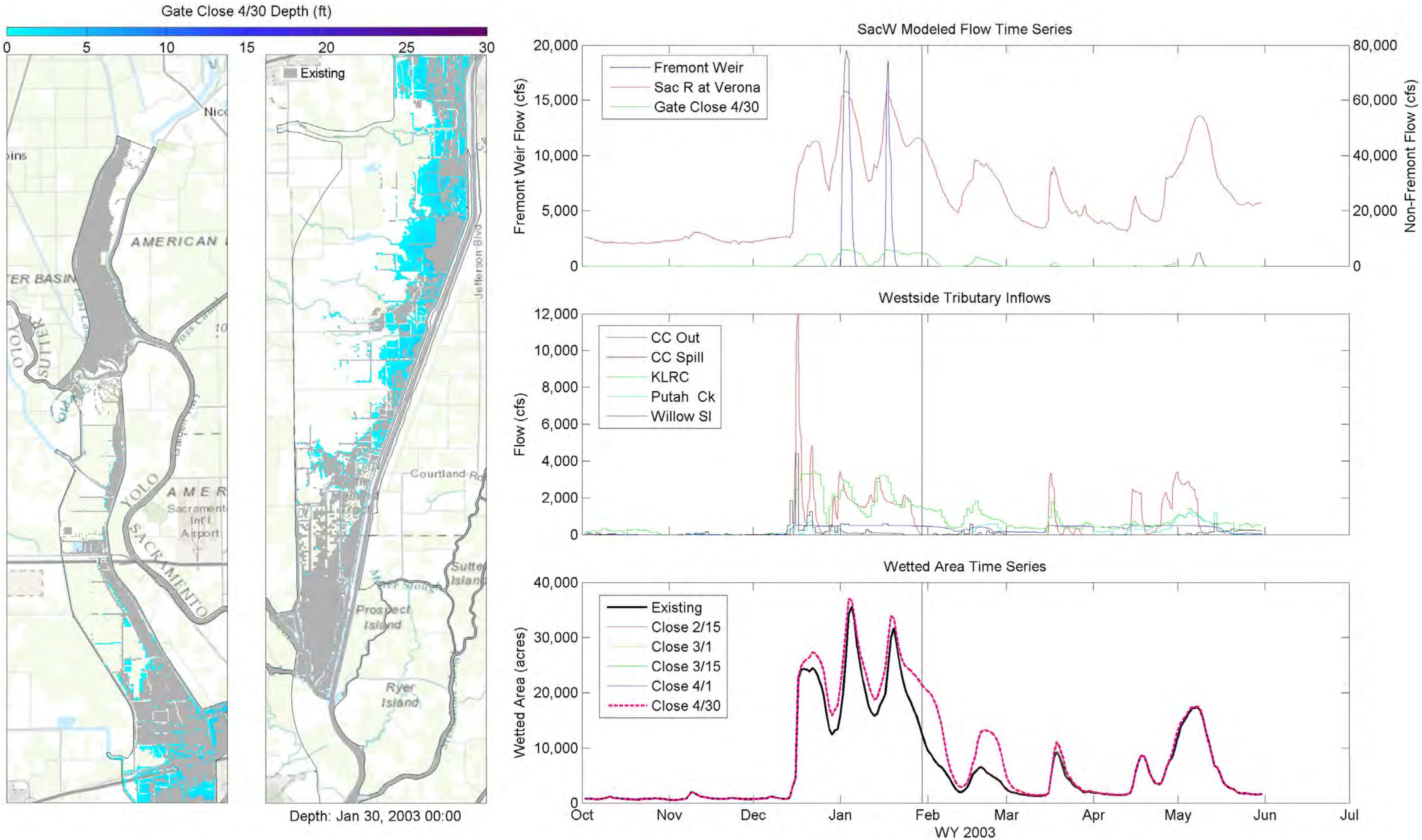


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Acres for All Gate Closures for FreSm – WY2003

Prepared for DWR	Created By: SJB	**Figure 7-14**

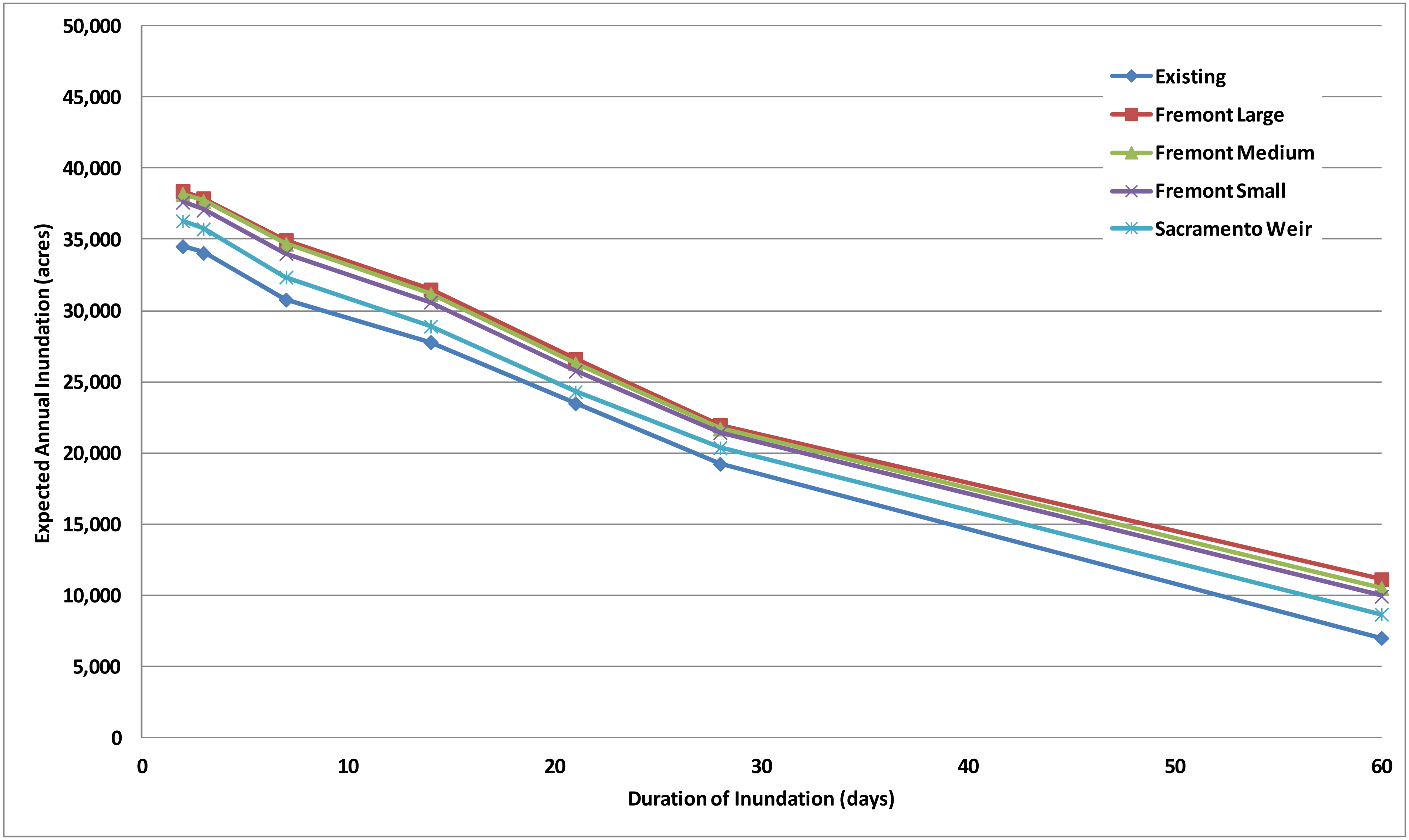


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

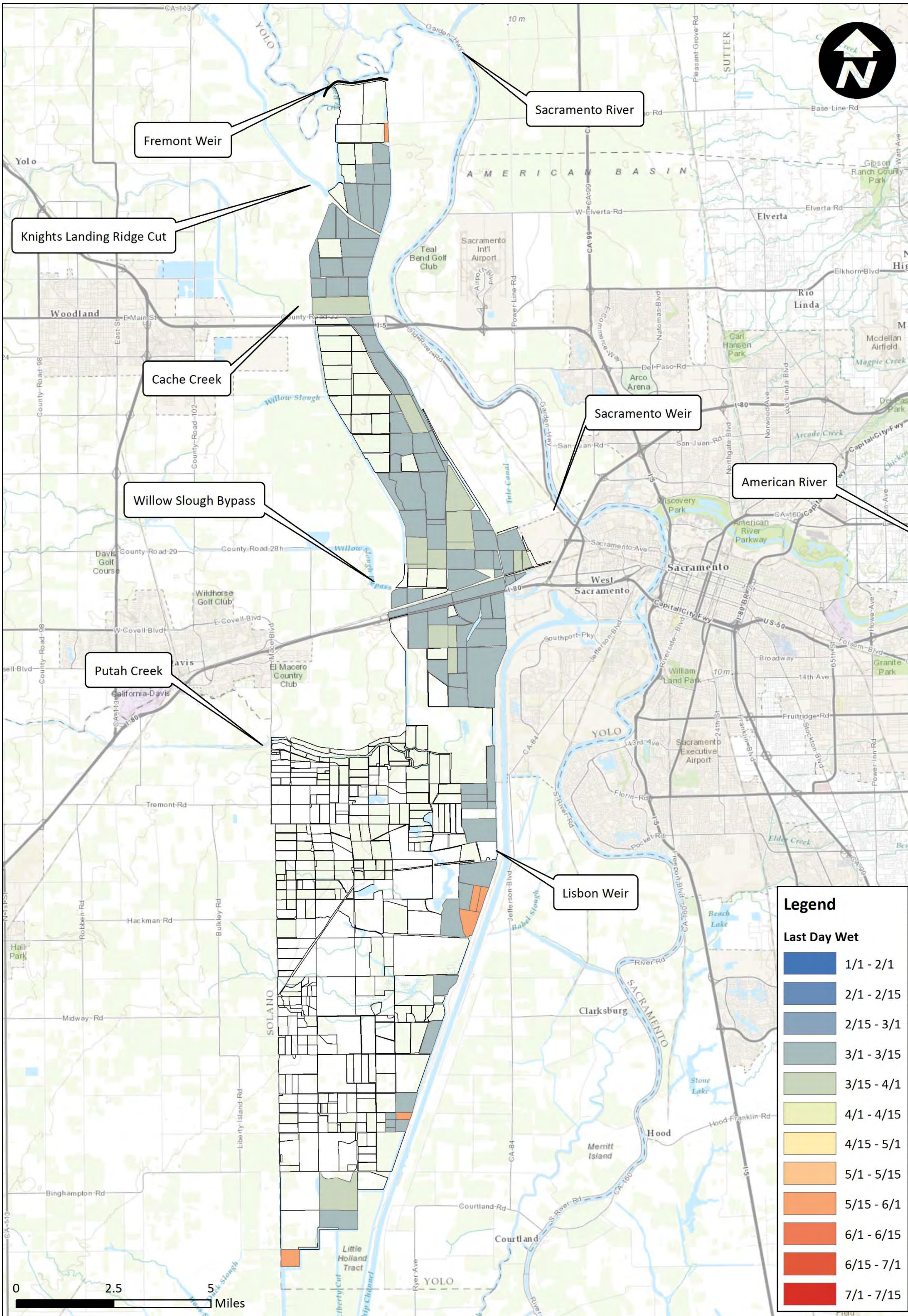
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Acres for All Gate Closures for SacW – WY2003

Prepared for DWR	Created By: SJB	**Figure 7-15**



Notes:	HDR cbec	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Expected Annual Inundation for FreLg 4/30 Closure**		
		Prepared for DWR	Created By: CRC	**Figure 7-16**



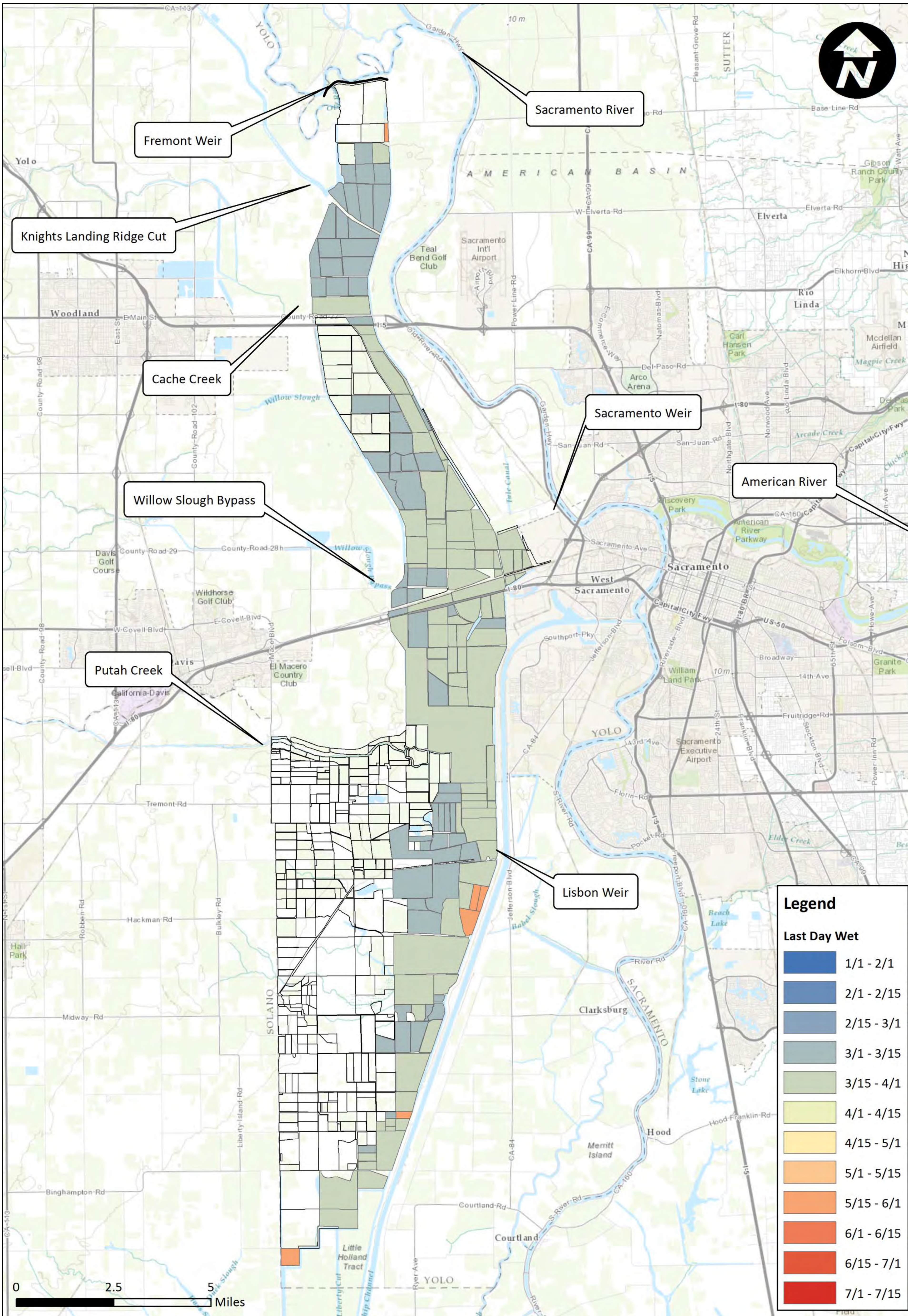
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions WY 2001

Prepared for DWR | Created By: RDJ

Figure 7-17



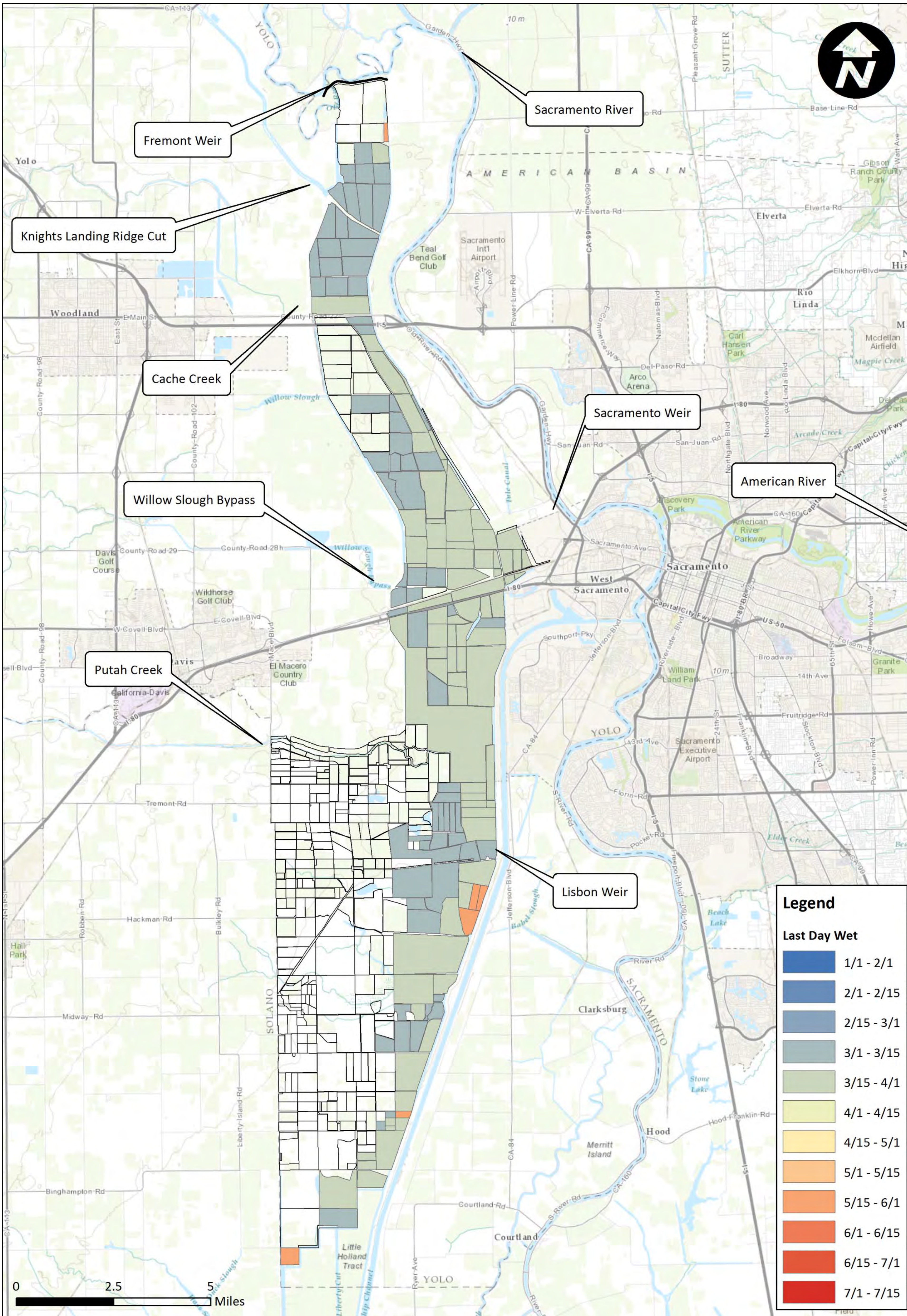
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet FreLg Channel 4/30 Closure WY 2001

Prepared for DWR | Created By: RDJ

Figure 7-18



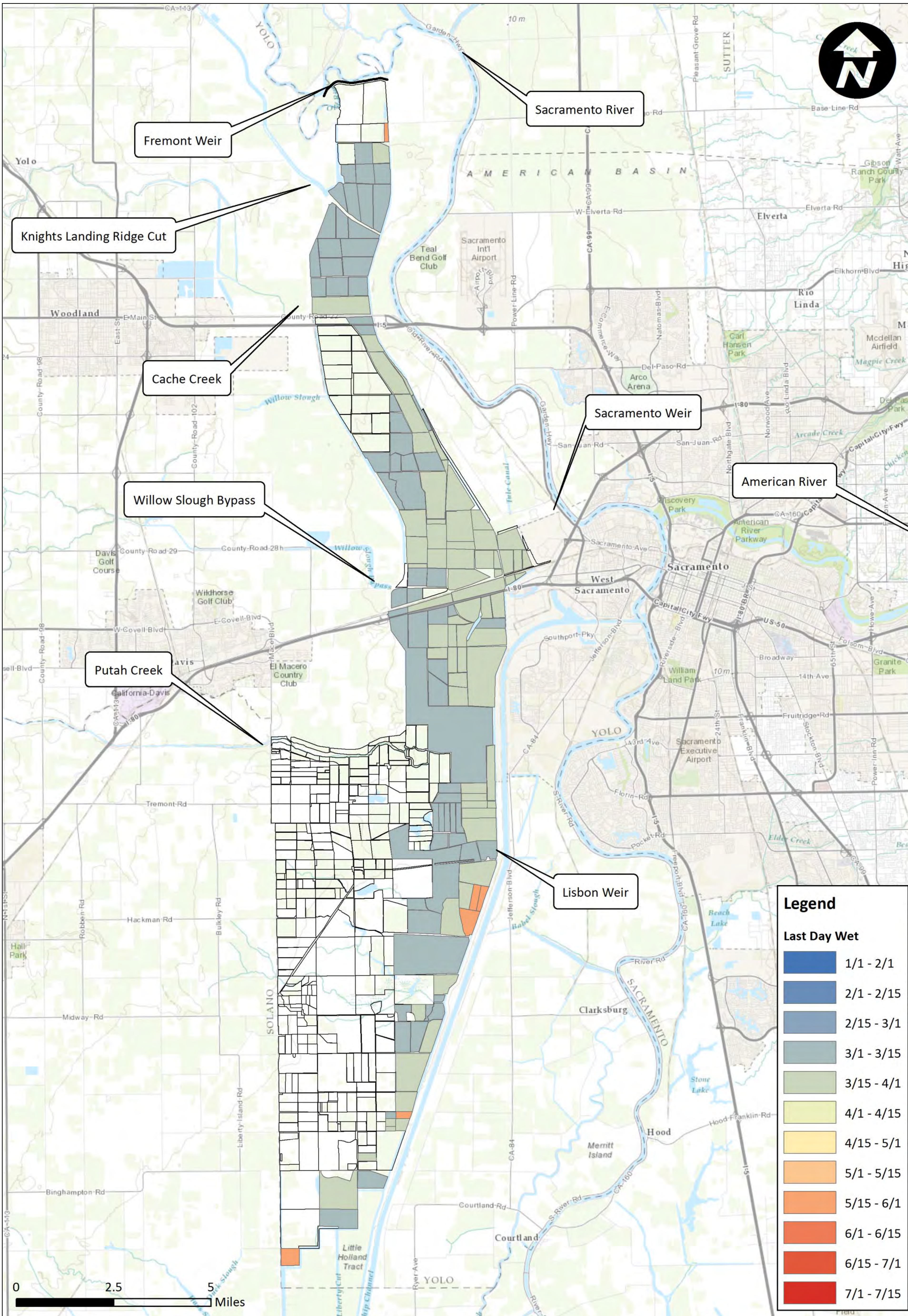
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet FreMed Closure 4/30 WY 2001

Prepared for DWR | Created By: RDJ

Figure 7-19

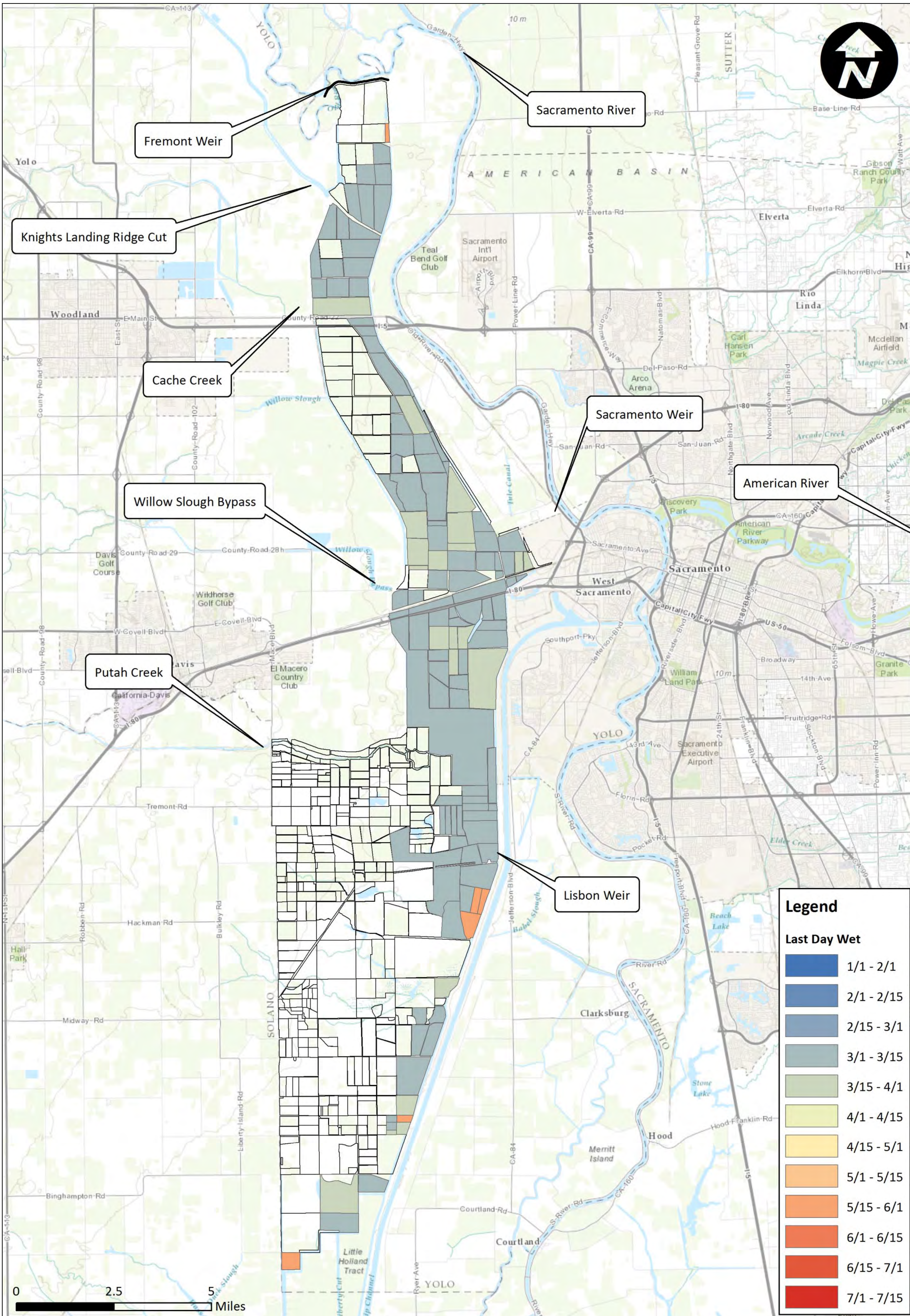


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet FreSm Channel 4/30 Closure 2001

Prepared for DWR	Created By: RDJ	**Figure 7-20**



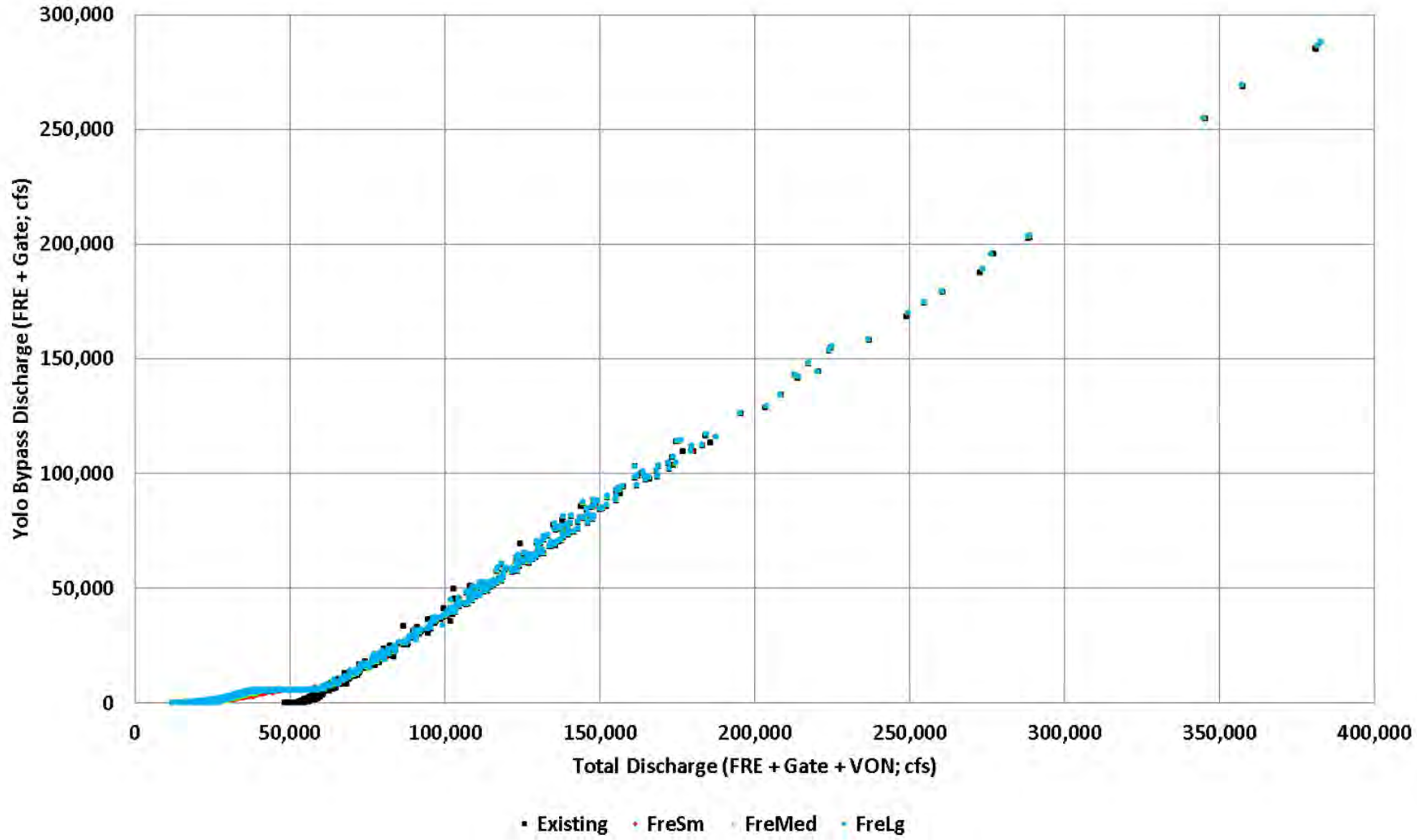
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

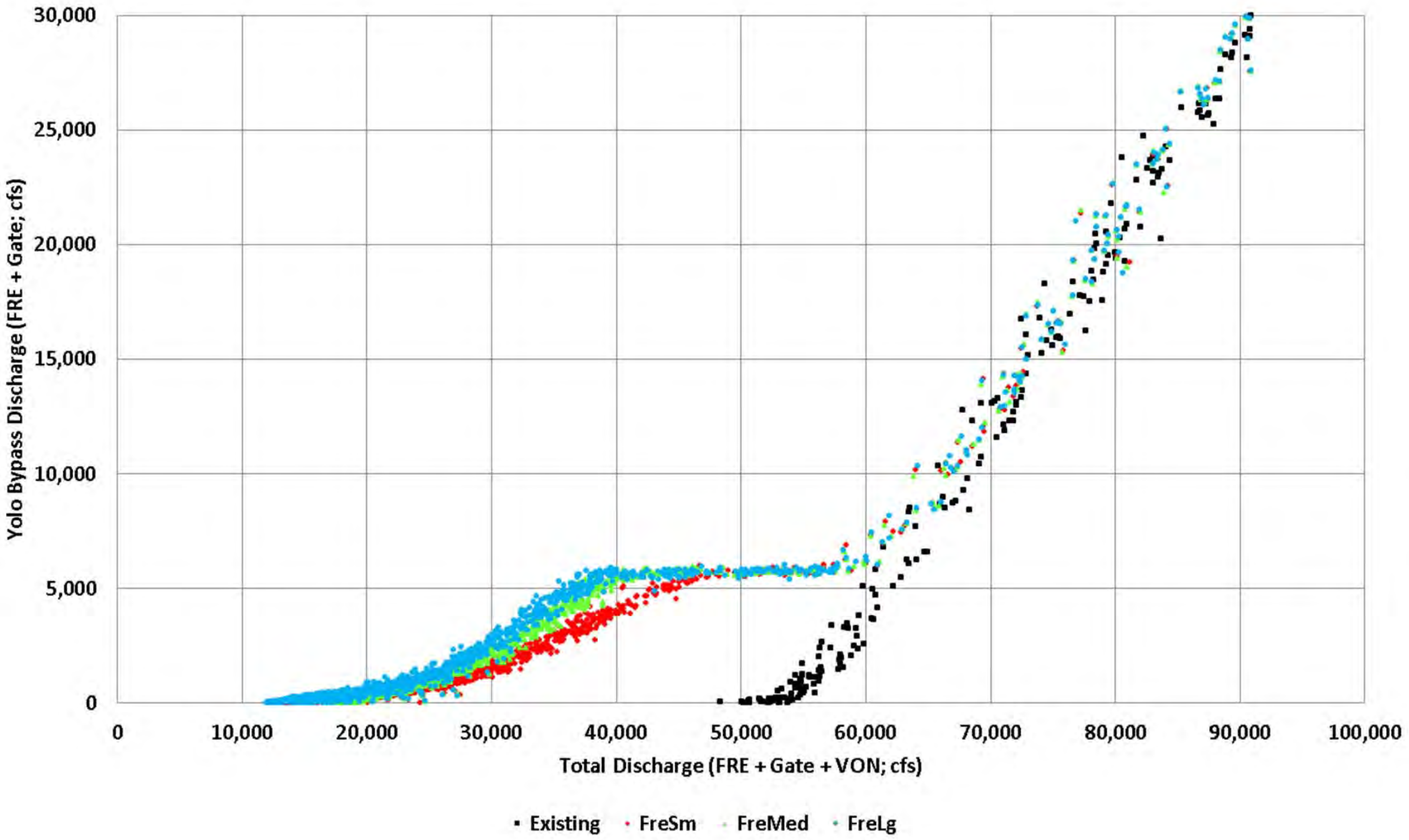
Last Day Wet SacW 4/30 Closure 2001

Prepared for DWR | Created By: RDJ

Figure 7-21



Notes: Flow entering the Yolo Bypass vs total discharge going into the bypass or down the Sacramento River.	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Flow Rating Curves for Fremont Weir**		
		Prepared for DWR	Created By: RDJ	**Figure 7-22**

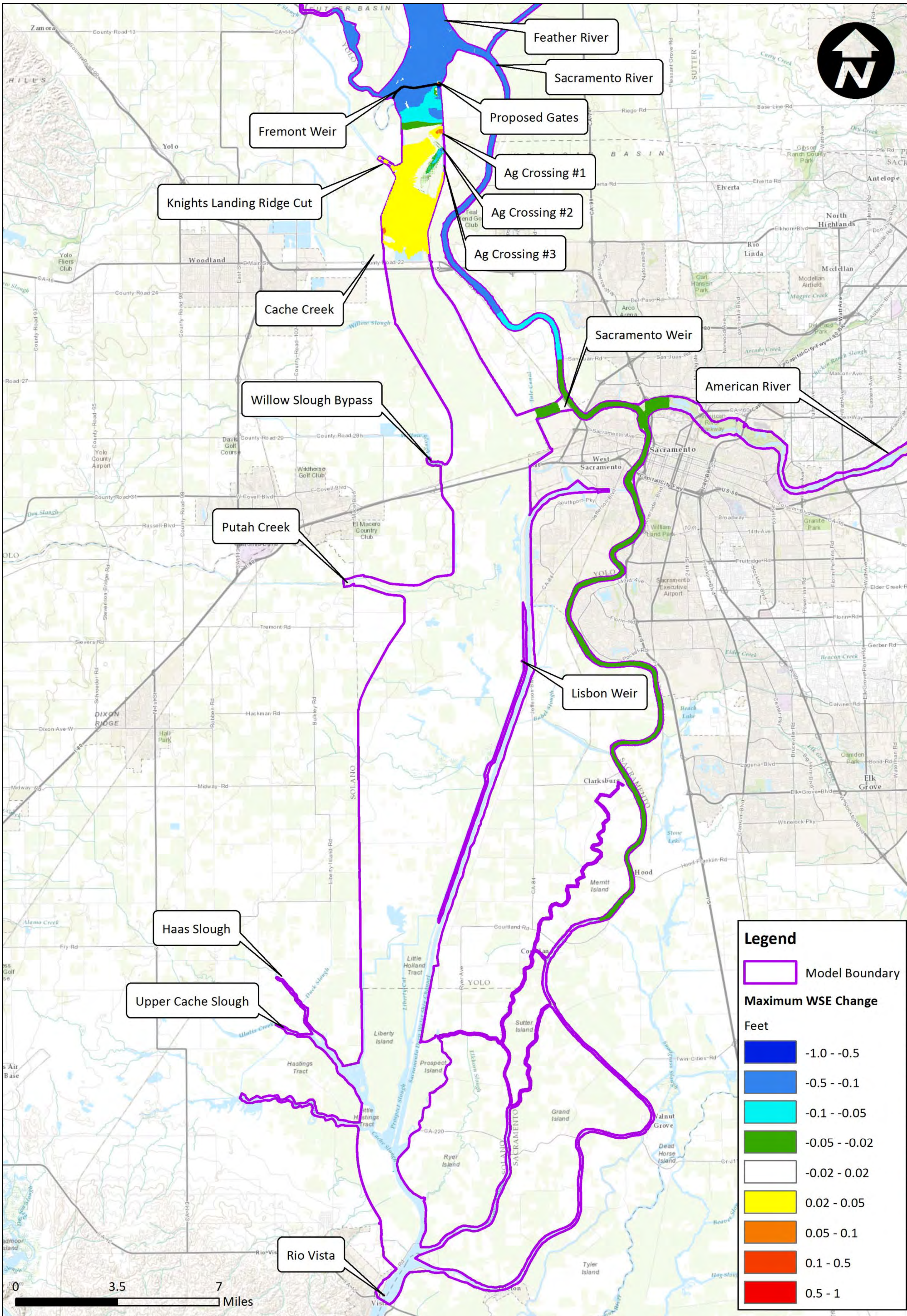


Notes: Flow entering the Yolo Bypass vs total discharge going into the bypass or down the Sacramento River.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Flow Rating Curves for Fremont Weir Zoomed

Prepared for DWR | Created By: RDJ | **Figure 7-23**



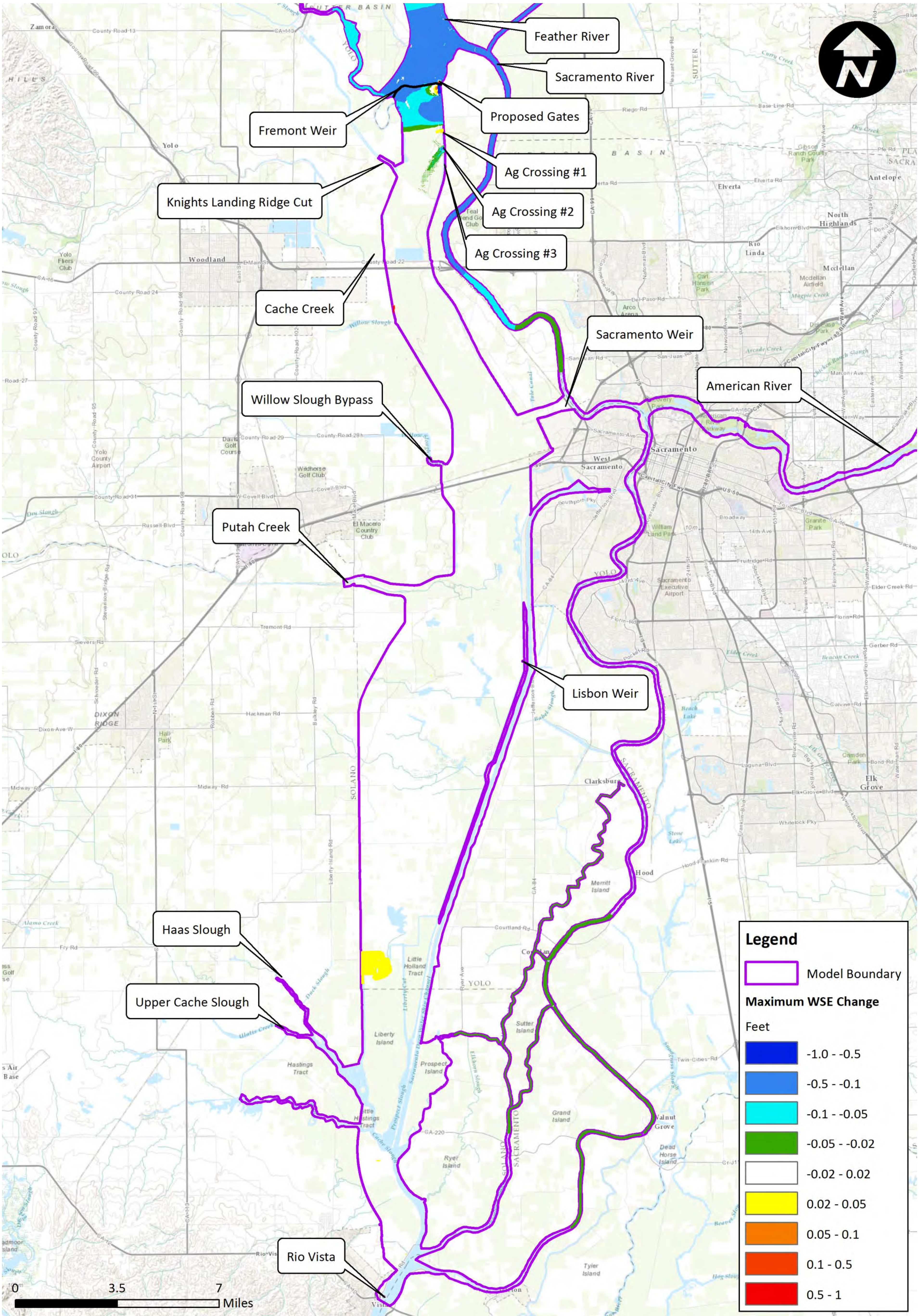
Notes: Comparing Large Channel configuration with existing conditions. Positive values indicate increases in maximum water surface elevations.

HDR cbec eco engineering

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Change in Maximum WSE for Large Channel 1997

Prepared for DWR | Created By: RDJ | **Figure 7-24**



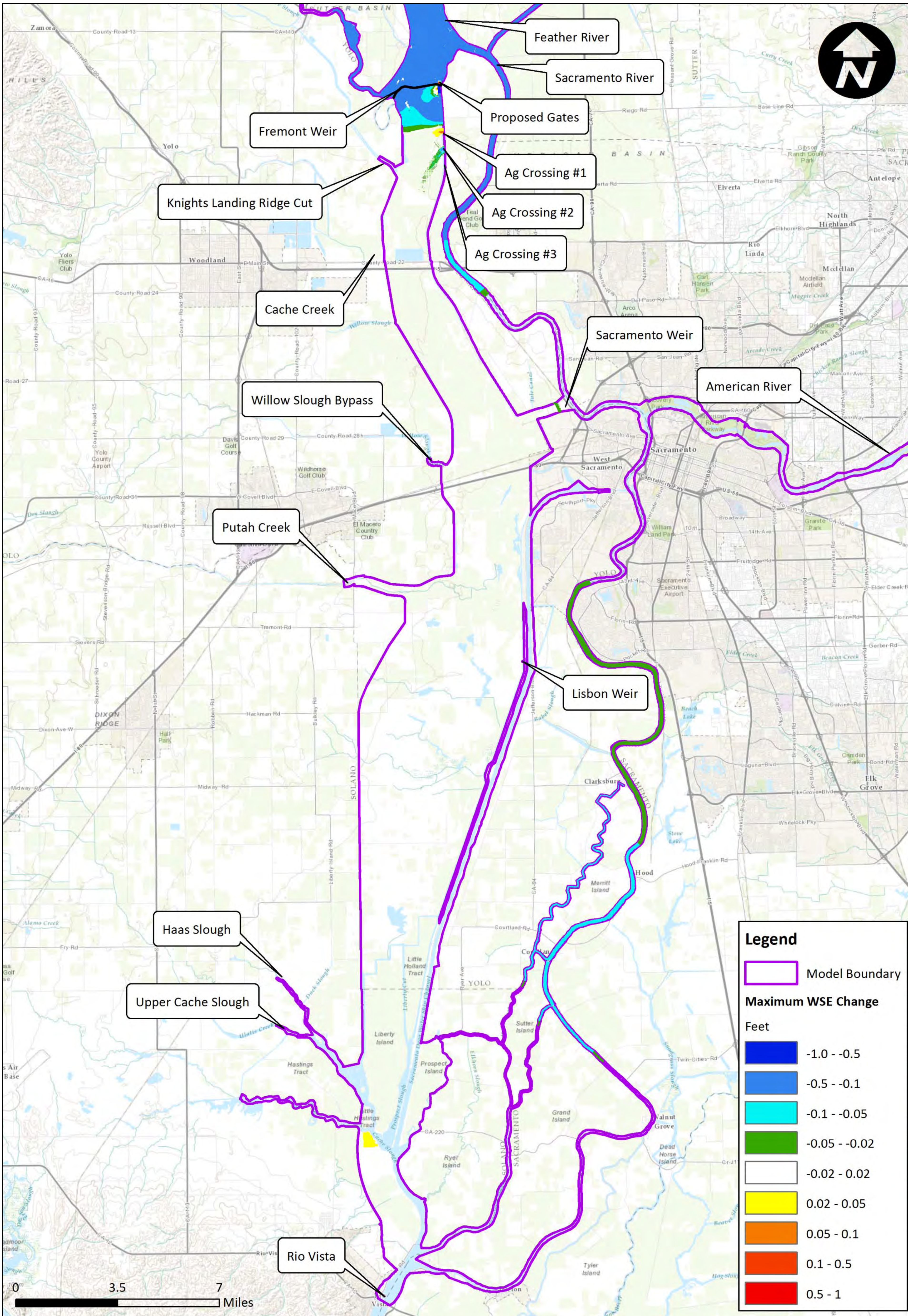
Notes: Comparing Large Channel configuration with existing conditions. Positive values indicate increases in maximum water surface elevations.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Change in Maximum WSE for Large Channel 1998

Prepared for DWR | Created By: RDJ

Figure 7-25



Notes: Comparing Large Channel configuration with existing conditions. Positive values indicate increases in maximum water surface elevations.

HDR cbec eco engineering

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Change in Maximum WSE for Large Channel 2006

Prepared for DWR | Created By: RDJ

Figure 7-26

8.0 Sensitivity Analyses

Two sensitivity analyses were performed to determine the impact of changes upon model results. The concern has been raised that the proposed project will inundate the Bypass later in the year thus delaying the planting of crops and negatively impacting yields. The first sensitivity analysis evaluates whether removal or changes to structures within the Bypass could reduce drainage time for the Bypass. The second sensitivity analysis evaluates the effect that increases and decreases in inflow discharges have upon model results.

8.1 Drain Time Sensitivity (Sensitivity to Lisbon Weir and Ag Crossing Removal)

There are five structures included in the model along the Tule Canal/Toe Drain: three agricultural crossings on the northern end, Swanston Ranch check dam, and Lisbon Weir. A sensitivity analysis was performed to evaluate the reduction in drainage times if all of the structures were removed. The upstream and downstream cross-section geometries were interpolated to provide the geometry for the channel sections replacing the structures. While complete removal of the structures is not practical, this analysis without structures provides an estimate of the maximum decrease in drain time that could be achieved and gives some insight of potential decrease in drain time that could be achieved by modifying the structures.

The five Toe Drain/Tule Canal structures were removed for existing and all alternate configurations simulations for the 2001 and 2011 water years. The wet area through time and LDW post-processing results were compared to the original results for each simulation.

The comparison of wet area through time for the simulations with and without structures for the 2001 and 2011 water years is shown in Figure 8-1 and Figure 8-2. The results are nearly identical and it is often impossible to differentiate between them.

The impacts on LDW for the FreLg configuration for the 2001 and 2011 water years are shown in Figure 8-3and Figure 8-4. Light to dark blue colors indicate decreases to the LDW compared to the original structure configuration. Yellow to red represent increases to LDW values with dark red representing fields that became wet but were dry during the original simulation.

For the 2001 simulation 5 field units had an earlier LDW, 7 field units had a later LDW, and 438 field units showed no change. For the 2011 simulation 11 field units had an earlier LDW, 12 had a later LDW, and 427 field units showed no change. The unexpected later LDW values occurred because the model setup created small changes to drainage changing the timing of when the wet/dry threshold was crossed.

The results suggest that the structures included in the sensitivity analysis do not significantly affect drainage time in the Bypass. Comparing the WSEs upstream and downstream of the Lisbon Weir for the existing conditions 2011 simulations, as shown in Figure 8-5, suggests that the Lisbon Weir effectively increases WSEs at lower discharges but has no significant difference if the water levels rise above 8 feet (NAVD88), which is approximately 3 feet below the adjacent floodplain.

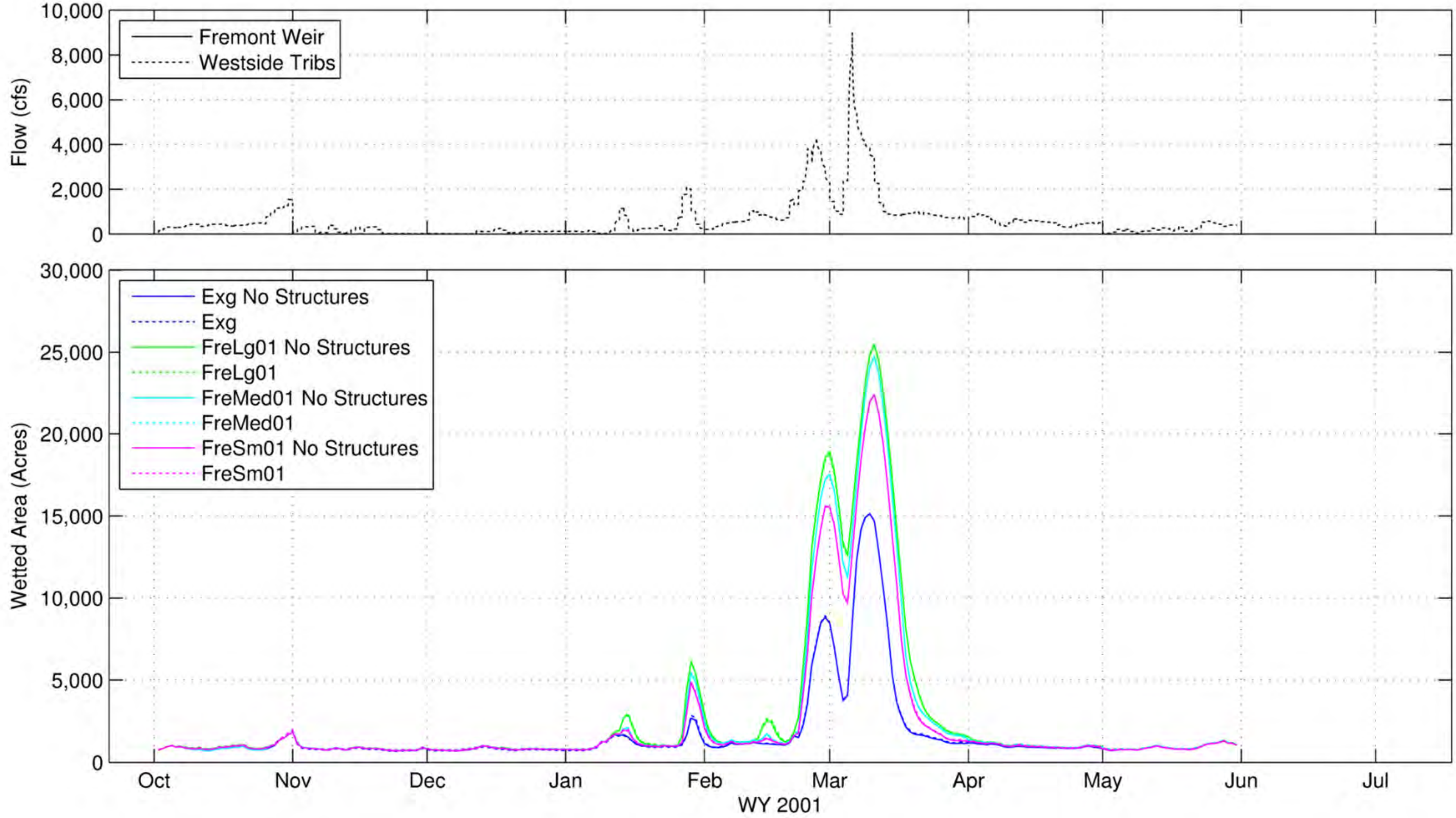
The project alternatives modeled included changing the agricultural crossings to railcar bridges increasing conveyance at these locations. A separate simulation was run using the large channel configuration for the 2011 water year that has Swanston Ranch check dam and Lisbon Weir removed but keeps the proposed railcar bridges. The wetted area through time results shown in Figure 8-6 illustrate that the railcar crossings have a negligible effect upon wetted area within the Bypass.

8.2 Sensitivity to Changes in Inflow Hydrographs

To assess the sensitivity of the results to inflow changes, simulations with increases and decreases of 10 percent for all boundary inflows were evaluated for the 2001 and 2011 water years under existing conditions. Water year 2001 represents a dry period when Fremont Weir did not overtop and inflows to the Yolo Bypass are limited to the Westside tributaries. As such, changes in Yolo Bypass inundation are directly linked to changes in the Westside tributary inflows. Water year 2011 is a wet year when there were significant contributions from Fremont Weir.

A comparison of the change in wetted area through time due to increases or decreases in inflow discharges is shown in Figure 8-7 and Figure 8-8. During low flow periods (e.g., when contributions are limited to the westside tributaries), there is a small change in inundation (i.e., ± 500 acres below 5,000 acres and ± 1,000 acres above 5,000 acres) because the flows are contained in the channels. The change in inundation area during very high flow periods is small because so much of the floodplain is already inundated. The most notable changes occur when the flows are too large to be contained in the channel but not large enough to fill a majority of the Bypass. The event between December and January in the 2011 water year illustrates the large effect that a 10 percent change can make on inundation, with increases and decreases of up to 10,000 acres.

The effect of a 10 percent increase or decrease on LDW for the 2001 and 2011 water years is shown in Figures 8-9 to 8-12. In these figures, light to dark blue symbolizes earlier LDW and yellow to red symbolizes later LDW values. Dark blue indicates fields that had been inundated during the original run but remained dry for the sensitivity run. Bright red indicates fields that were dry during the original run but became wet during the sensitivity run. The LDW for a significant number of fields is impacted but nearly all of the LDW values change by less than one week.



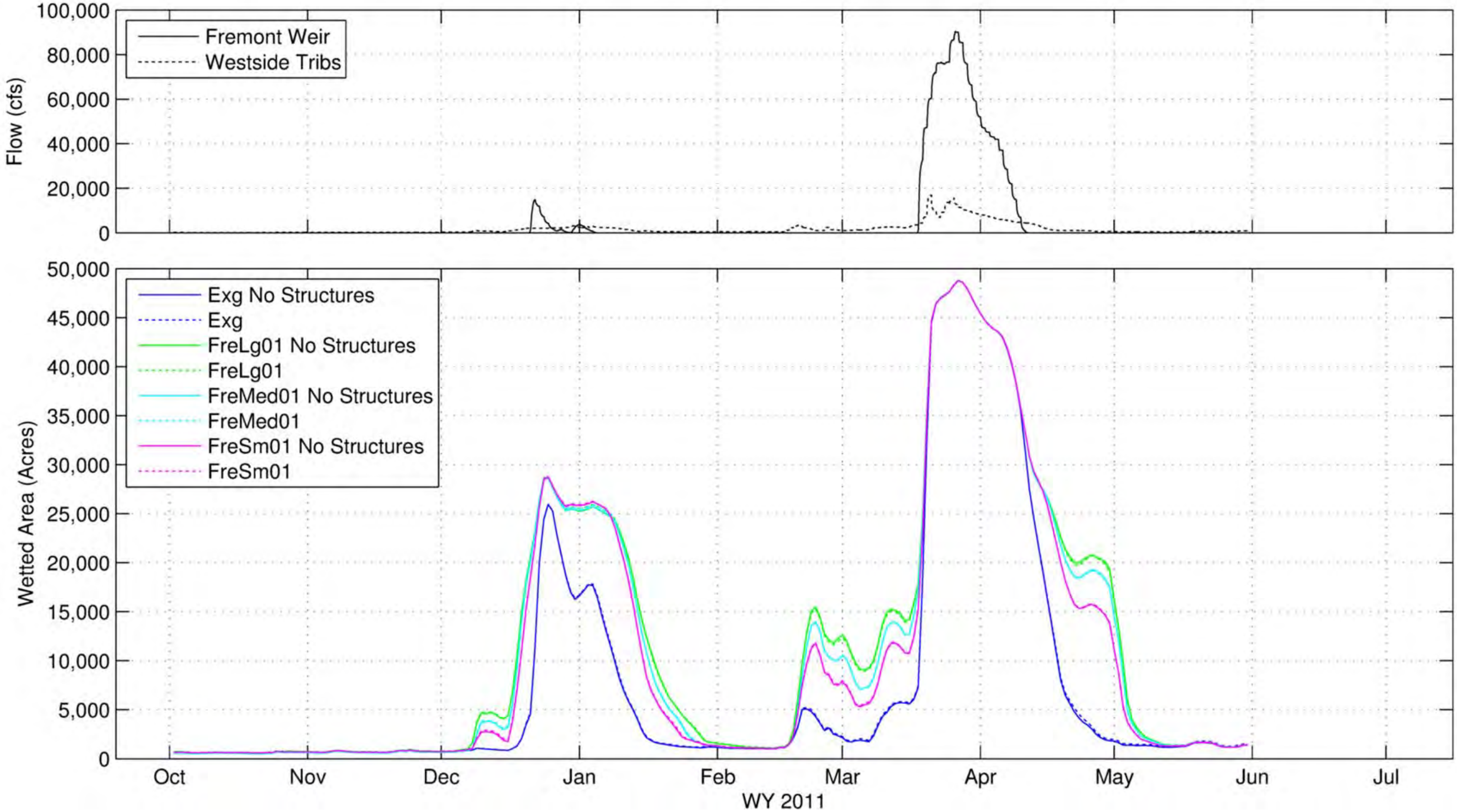
Notes: Simulations without structures do not include Lisbon Weir, Swanston Ranch Weir, and the three Agriculture crossings in the northern end of the bypass.

HDR cbec eco engineering

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Sensitivity Analysis Structures and Drainage 2001

Prepared for DWR	Created By: RDJ	**Figure 8-1**

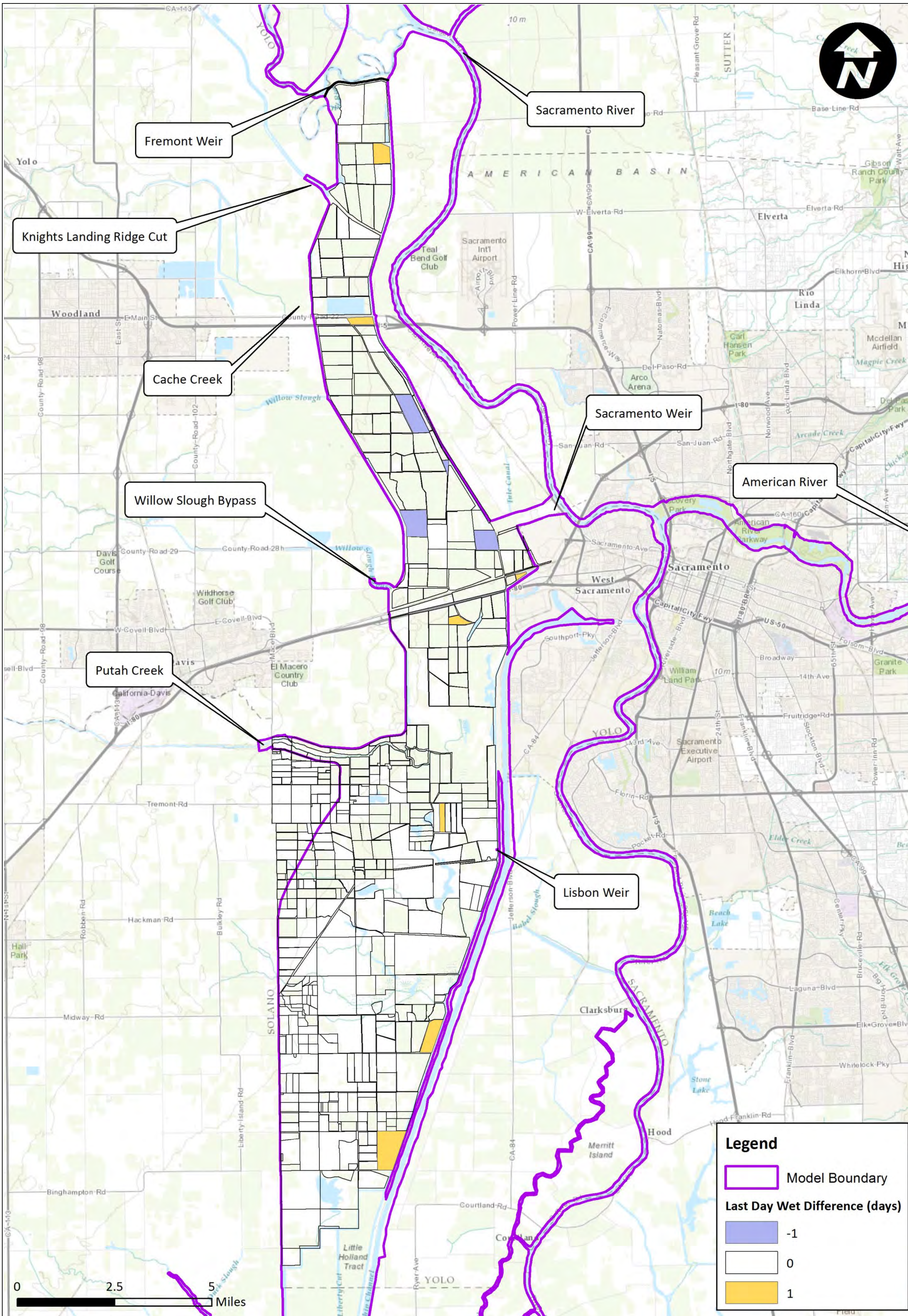


Notes: Simulations without structures do not include Lisbon Weir, Swanston Ranch Weir, and the three Agriculture crossings in the northern end of the bypass.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Sensitivity Analysis Structures and Drainage 2011

Prepared for DWR	Created By: RDJ	**Figure 8-2**

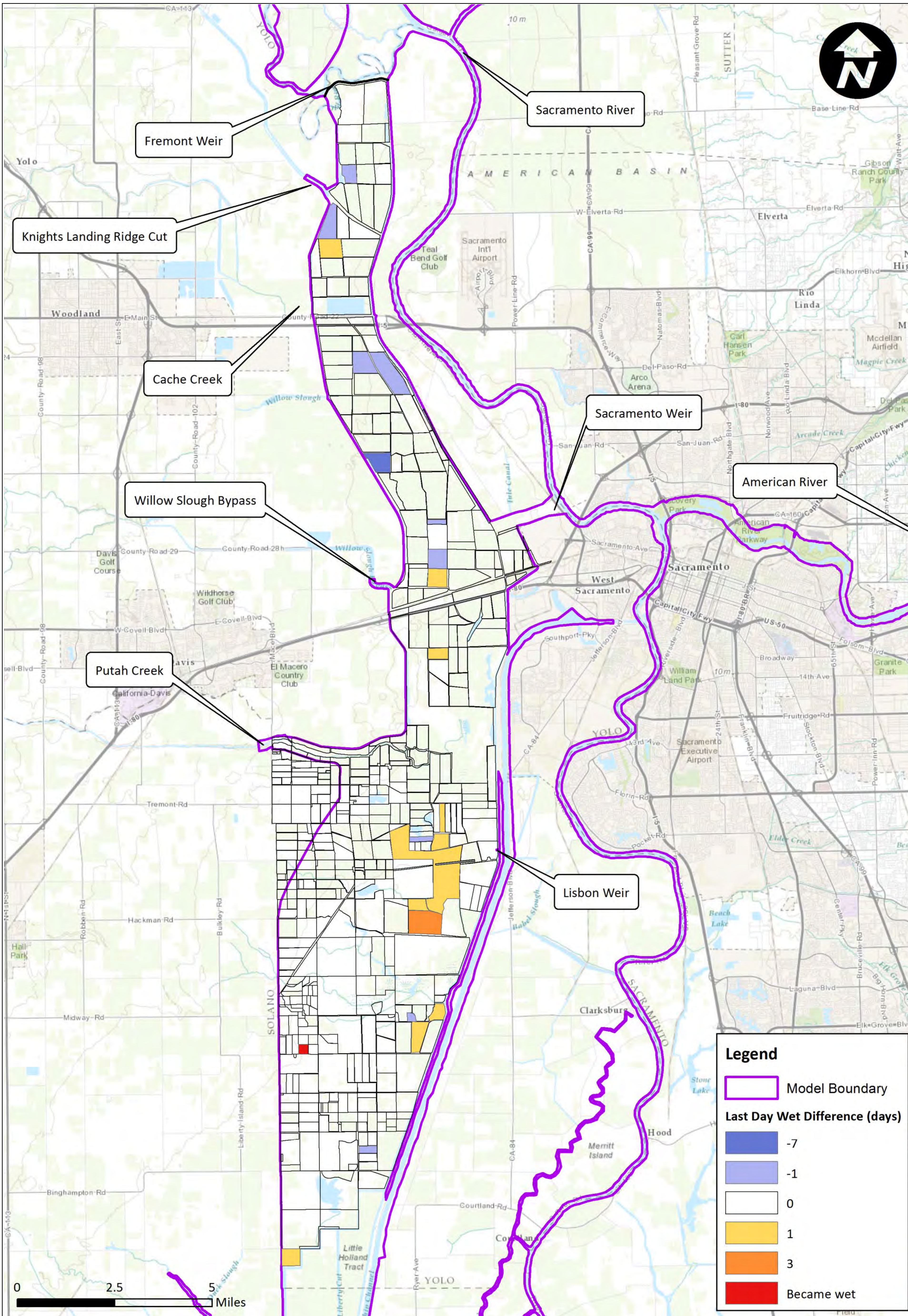


Notes: Differences to Last Day Wet after removing structures from the Yolo Bypass. Negative values indicate earlier Last Day Wet.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

FreLg LDW Diff Sensitivity Drain Structures WY 2001

Prepared for DWR | Created By: RDJ | **Figure 8-3**

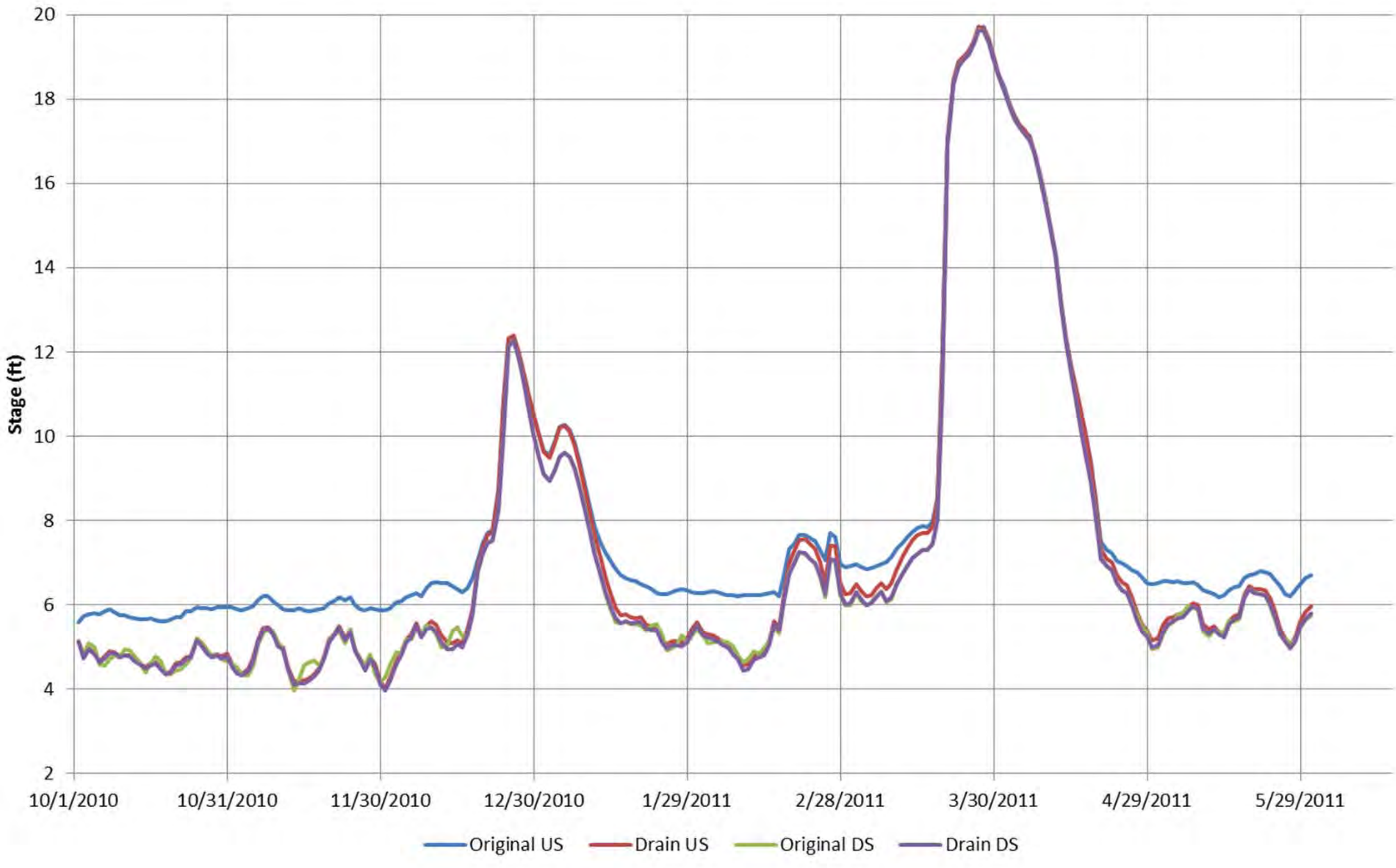


Notes: Differences to Last Day Wet after removing structures from the Yolo Bypass. Negative values indicate earlier Last Day Wet.

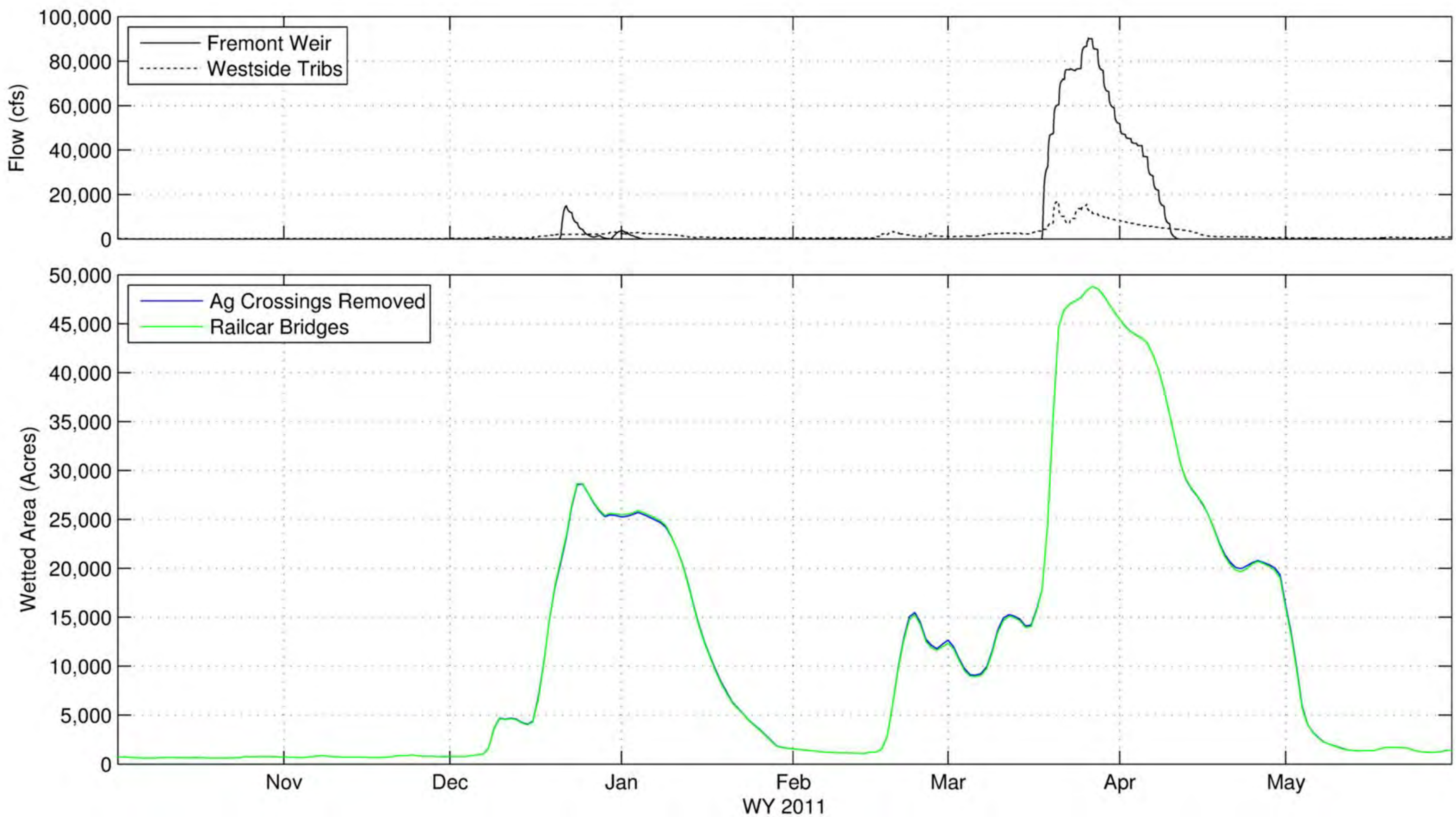
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

FreLg LDW Diff Sensitivity Drain Structures WY 2011

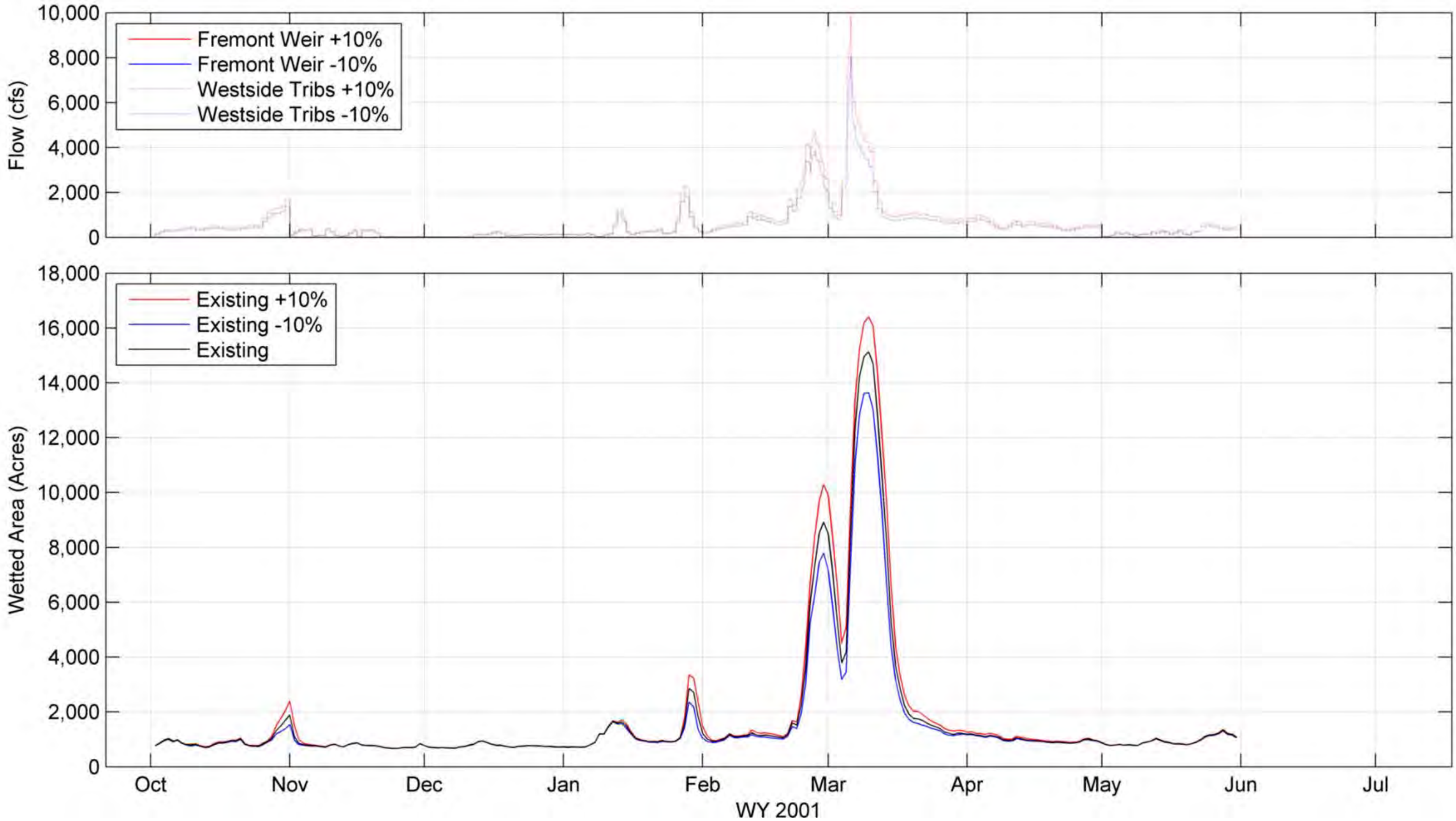
Prepared for DWR | Created By: RDJ | **Figure 8-4**



Notes: Water surface elevations measured upstream and downstream of Lisbon Weir existing conditions and with Yolo Bypass structures removed.	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Exg Stage US/DS of Lisbon Weir Sensitivity Drain**
		Prepared for DWR · Created By: RDJ · **Figure 8-5**



Notes: The large channel configuration was used for these sensitivity runs.	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **FreLg Wet Area Sensitivity to Railcar Bridges 2011**
	Prepared for DWR / Created By: RDJ / **Figure 8-6**

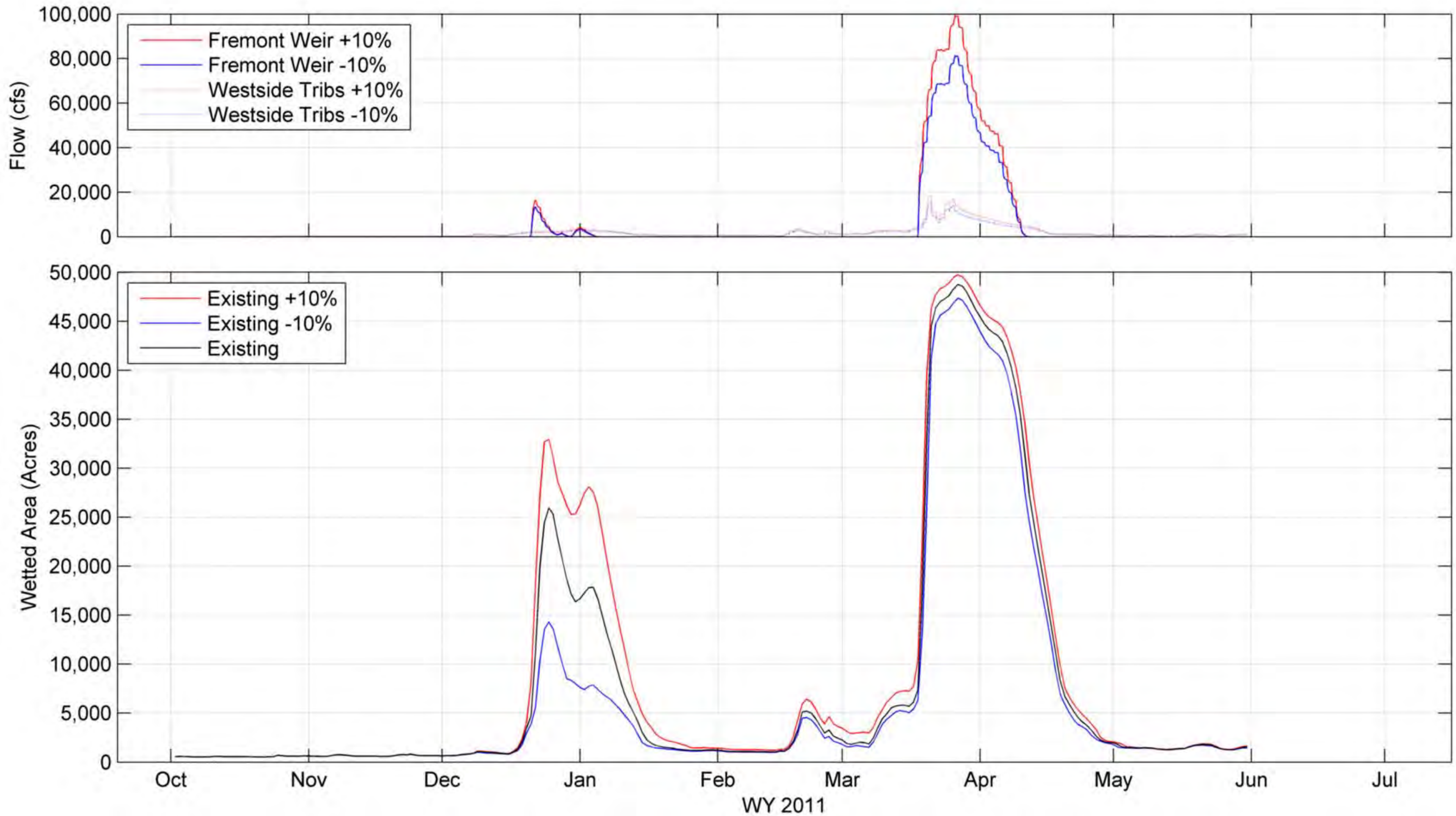


Notes: Simulations were run increasing and decreasing all of the inflow boundary conditions 10%. The Fremont Weir did not overtop in 2001.

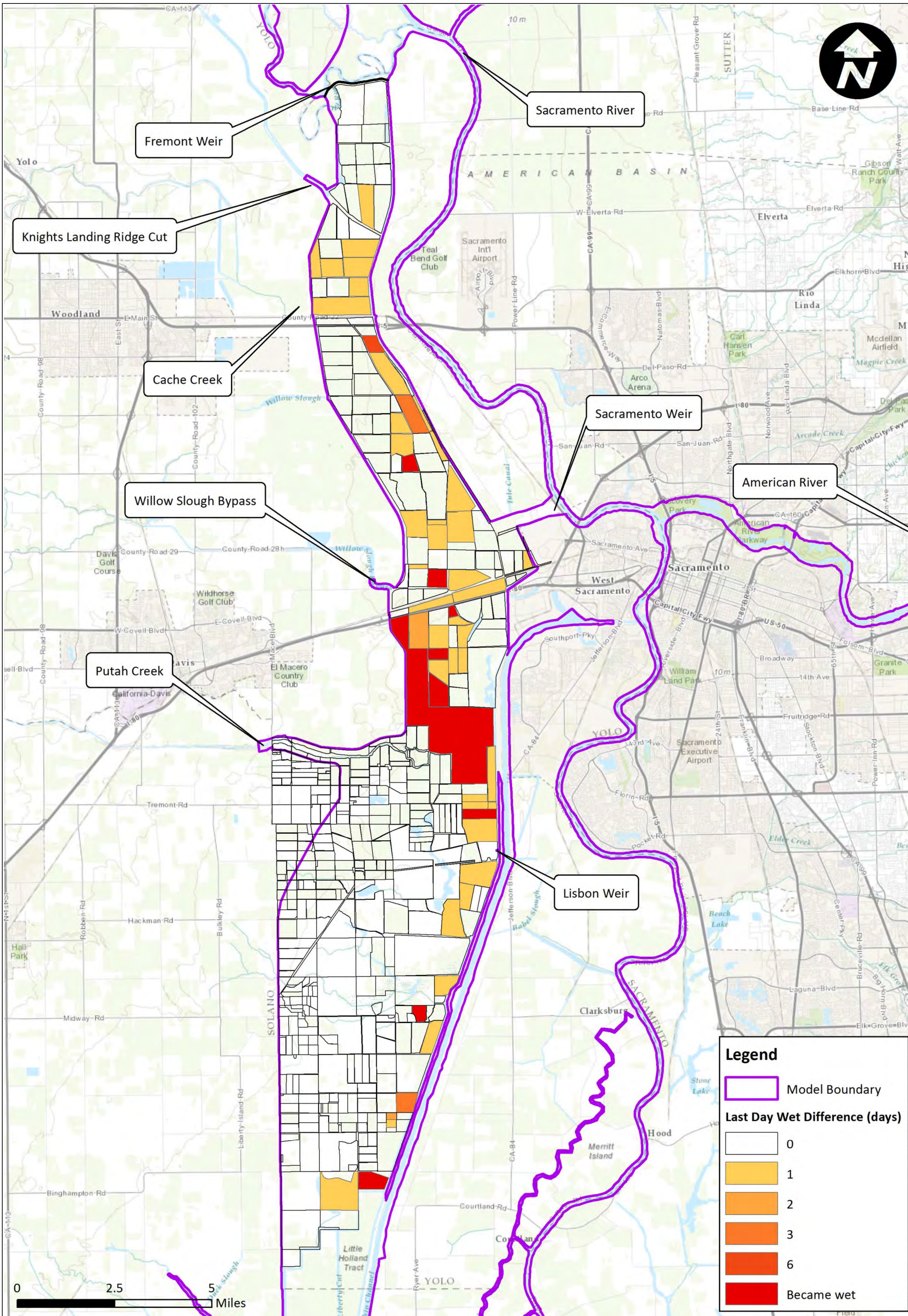
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Exg Sensitivity Analysis Wetted Area Flows 2001

Prepared for DWR | Created By: RDJ | **Figure 8-7**



Notes: Simulations were run increasing and decreasing all of the inflow boundary conditions 10%.		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Exg Sensitivity Analysis Wetted Area Flows 2011**		
		Prepared for DWR	Created By: RDJ	**Figure 8–8**

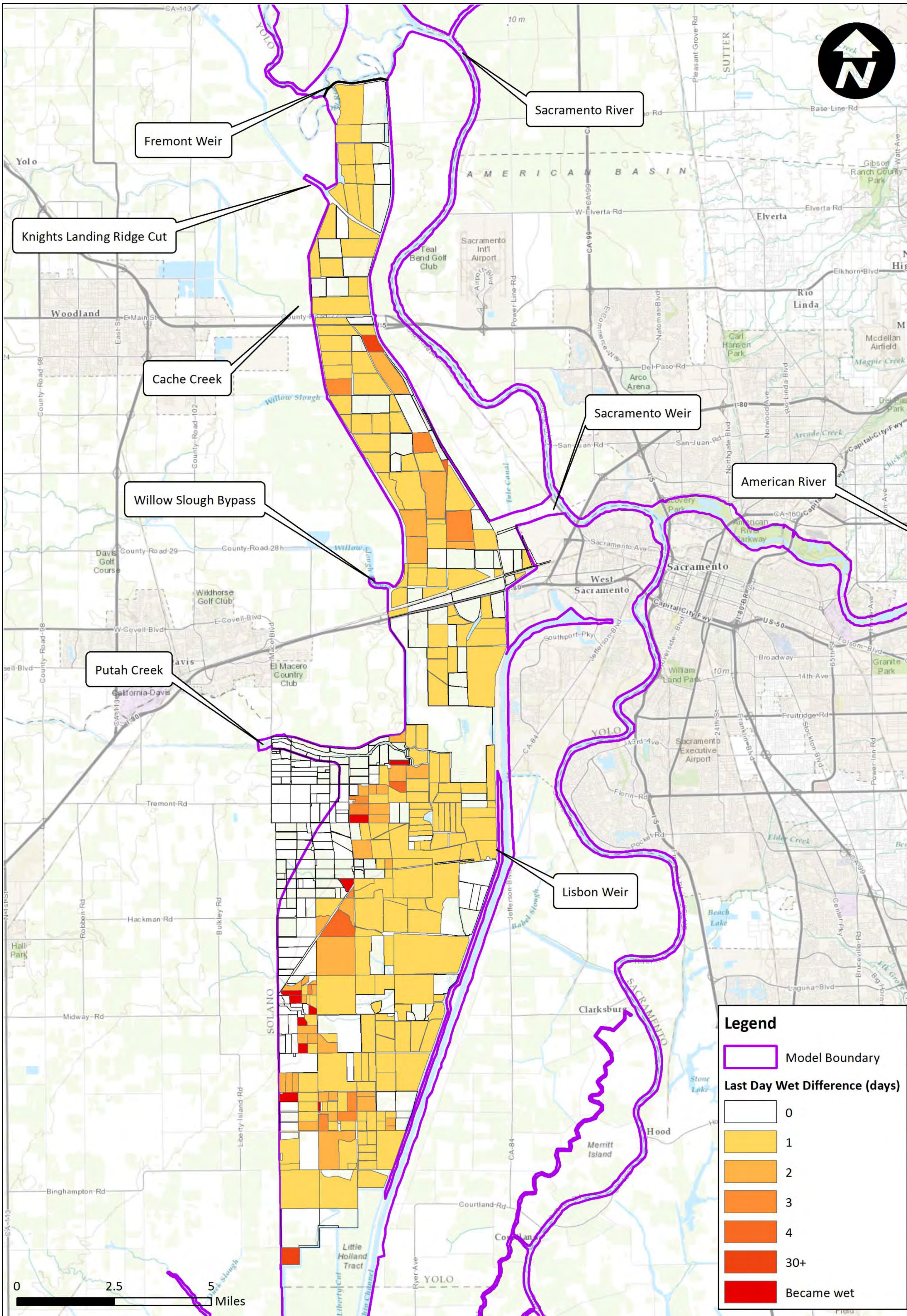


Notes: Differences to Last Day Wet for existing conditions when increasing inflows 10%. Positive values indicate later Last Day Wet.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Existing LDW Sensitivity to 10% Increase in Flow WY 2001

Prepared for DWR | Created By: RDJ | **Figure 8-9**



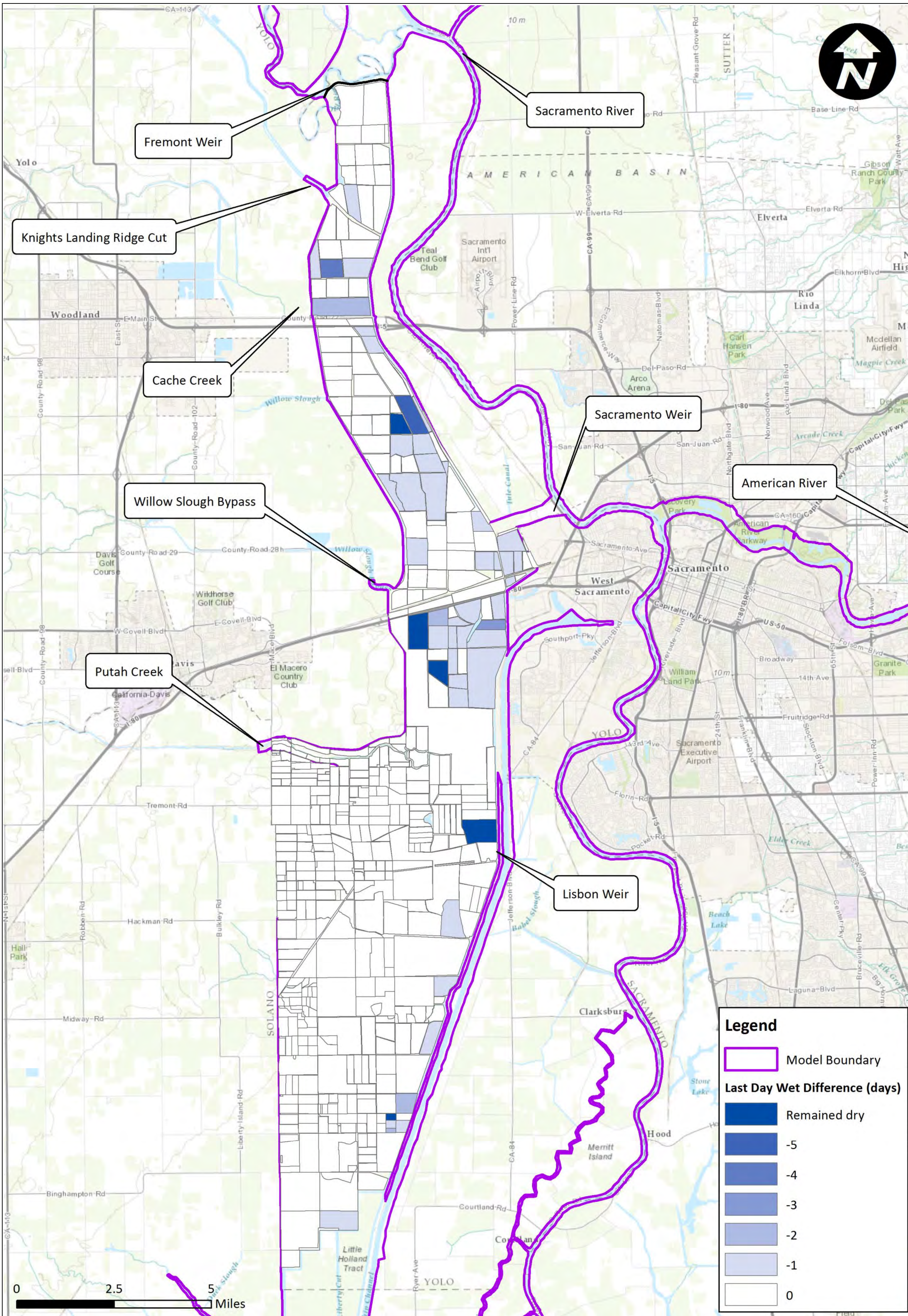
Notes: Differences to Last Day Wet for existing conditions when increasing inflows 10%. Positive values indicate later Last Day Wet.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Existing LDW Sensitivity to 10% Increase in Flow WY 2011

Prepared for DWR | Created By: RDJ

Figure 8-10



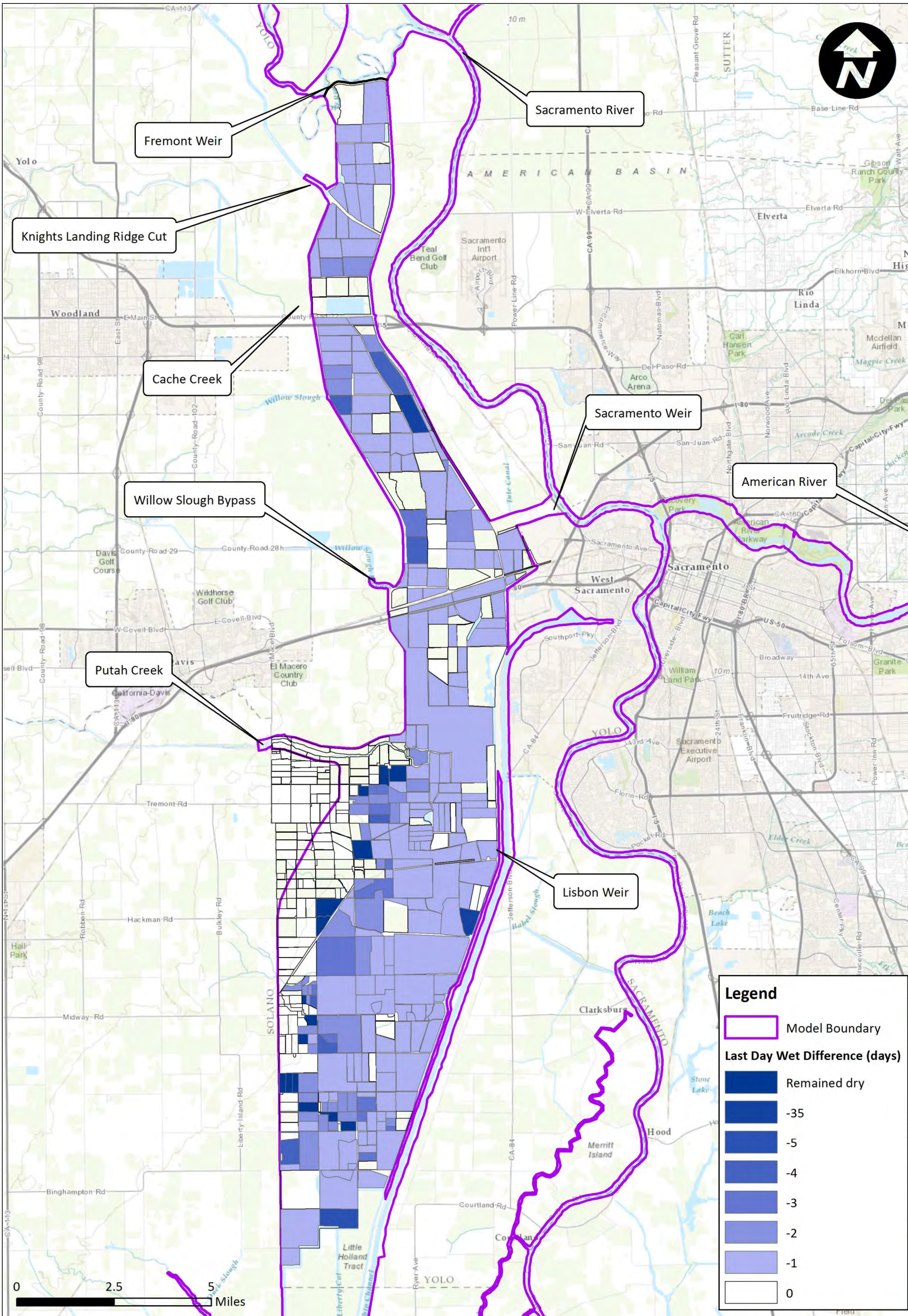
Notes: Differences to Last Day Wet for existing conditions when decreasing inflows 10%. Negative values indicate earlier Last Day Wet.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Existing LDW Sensitivity to 10% Decrease in Flow 2001

Prepared for DWR | Created By: RDJ

Figure 8-11



Notes: Differences to Last Day Wet for existing conditions when decreasing inflows 10%. Negative values indicate earlier Last Day Wet.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Existing LDW Sensitivity to 10% Decrease in Flow WY 2011

Prepared for DWR | Created By: RDJ | **Figure 8-12**

9.0 Conclusions

A TUFLOW classic hydrodynamic model has been developed to help evaluate impacts and benefits of potential alternatives for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project. Three alternatives for channel and gate designs at the Fremont Weir and an alternative with channels and gates at the Sacramento Weir were evaluated. The model domain extends along the Sacramento River just South of Tisdale Bypass to near Rio Vista, includes the Yolo Bypass, and includes portions of the Feather River, Sutter Bypass, American River and various North Delta sloughs.

Model results have been provided for use in analyses to quantify the impacts and benefits of the four alternatives modeled. While the benefits and impacts will be evaluated by other analyses, some observations can be made from the TUFLOW model results. All of the alternatives increase the extent and duration of inundation events within the Bypass. The three Fremont Weir alternatives provide similar increases in inundation. The FreLg alternative provides the largest inundation benefit of 7,700 acres in 2 out of 3 years. The SacW alternative typically provides half the inundation increase of the Fremont Weir alternatives.

Potential changes to sediment erosion and deposition within the Bypass and in the Sacramento River are currently being evaluated.

The comprehensive nature of the model makes it a useful tool to serve as a basis for future analyses.

9.1 Summary of Modeling Work/Data Passed Along

Post-processed model results have been provided to other teams to inform other analyses. The Agriculture Economics team has been provided GIS data indicating the last day of inundation anticipated for individual field units within the Bypass. The fisheries team has been provided daily GIS raster data for depths and velocity magnitudes within the Bypass and time-series discharge data at specific locations within the model. The CALSIM Modeling team has been provided discharge versus discharge scatter plots for the each of the modeled alternatives to define rating curves for CALSIM model input.

9.2 Recommendations for Future Model Improvements

The gate/channel designs and operations used for this study are preliminary and this modeling effort focused on identifying the relative differences between alternatives. Changes to the design and operation may impact the results.

A datum error for some of the water years at the downstream WSE versus time boundary condition at Rio Vista are discussed in Section 6.2. Sensitivity analysis confirmed that the change would have had little impact on the results but future analyses should use the corrected boundary data.

Bridges inside and outside of the Bypass were not represented in the model. Most bridges are not submerged even in large floods but pier losses could be added in appropriate places. It was learned through the modeling that the County Road 22 bridge over the Tule Canal is low enough to become submerged in large floods. Model calibration suggests that incorporating this change is not important for large scale analysis. Should the need for bridges or bridge piers to be incorporated more explicitly in model arise, it should be recognized that calibration may need to be revisited.

The number and length of simulations greatly constrained cell sizes and time steps. Smaller cells within the Bypass would have better represented the topography, particularly features incorporated using polylines which are smaller than the 100 feet elevation spacing (i.e., berms and drainage ditches). Local WSE oscillations which occurred near 1D/2D domain boundaries during high discharge periods due to differences in the 1D/2D time steps may benefit from adjusting 2D cell-sizes and time steps. Future modeling efforts involving fewer simulations and/or shorter durations should attempt to make this refinement.

Hydraulic structures (e.g., culverts, gates) along the drainage features within the Bypass could be added to more accurately represent flow constrictions and impediments to drainage, however, it should be recognized that culverts and gates for individual fields may change from season to season.

The model was calibrated to three events specifically chosen to represent a high flow period, a low-flow period, and a receding limb period. Data is available for other flood events such as the 2006 flood which could be used to further calibrate or validate the model. In addition, the USGS maintains a comprehensive network of gauges recording stage and flow in the slough system south of the Stair Step and Courtland that can be used to calibrate the flow splits within the Cache Slough Complex.

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Appendix A

Sacramento Slough and Willow Slough Bathymetric Survey

Technical Memorandums

TECHNICAL MEMORANDUM

Date:	June 6, 2014
To:	Project File
From:	Chris Campbell, MS, Benjamin Taber, BS, PE
Project:	13-1027 – Yolo Bypass Salmonid Habitat Restoration and Fish Passage
Subject:	Sacramento Slough Bathymetric Survey

1 INTRODUCTION

cbec, inc., eco engineering (cbec) performed a bathymetric survey of Sacramento Slough on September 6th, 2013 to support hydrodynamic model development for the Yolo Bypass Modeling Project. The objective of the survey was to define the geometry of the slough channel bed such that the slough could be represented in 1D as a series of cross sections or transects. The surveyed reach extends from the confluence with the Sacramento River upstream approximately 8.5 miles. Transects were taken at select locations with a spacing of approximately 2,000 feet on the lower reach (from the confluence to the RD 1500 pumps) and a spacing of approximately 4,000 feet on the upper reach (upstream of the RD 1500 pumps). Transects were field fitted to select areas with minimal riparian vegetation on the banks with the assumption that the Central Valley Floodplain Evaluation and Delineation (CVFED) LiDAR data would be used to represent the overbank areas at each transect. Transects on the upper section were chosen to capture the constrictions in channel geometry where the existing earthen spur dikes protrude into the channel, and also because dense aquatic vegetation was present between the spur dikes, which preclude bathymetric data collection. Additional cross sections were recorded on the upstream and downstream sides of the two bridges within the study reach, as well as additional survey data to characterize the bridge geometry. See Figure 1 for a map of Sacramento Slough showing the extents of the surveyed reach and transect locations.

2 METHODS

2.1 BATHYMETRY

The bathymetric survey was performed utilizing an Ohmex Sonarmite echosounder integrated with a Trimble R8 Global Navigation Satellite System (GNSS) receiver mounted to a boat. The echosounder produces sound pulses that measure the distance from the transducer to the bottom of the water body being surveyed. Real Time Kinematic (RTK) Global Positioning System (GPS) was used in conjunction with

California Survey and Drafting Supply (CSDS) VSN mobile base network to provide positional corrections to the Trimble receiver. Both position and depth were recorded on a mobile data collector in real time while performing the survey. Equipment data sheets are provided in Appendix A.

2.2 CONTROL AND DATUMS

Prior to surveying, the cbec field crew occupied two benchmarks reported in the CVFED LiDAR survey control documentation (see Table 1) to correct for horizontal and vertical variations in the observations. These variations are caused by atmospheric conditions as well as specific satellite geometry at the time of data acquisition.

Table 1. CVFED benchmarks (this survey)

Benchmark	Reported Northing[1]	Reported Easting[1]	Reported Elevation (ft,NAVD88)[2]	Observed Northing[1]	Observed Easting[1]	Observed Elevation (ft,NAVD88)[2]
NGS (AI5071)	2067336.22	6632368.27	25.09	2067336.26	6632368.19	25.12
WR168	2034616.71	6649412.49	42.74	2034594.71	6648606.76	42.71

[1] California State Planes, Zone 2, NAD 83, US Survey feet
[2] North American Vertical Datum 1988 (NAVD88), Geoid 2009

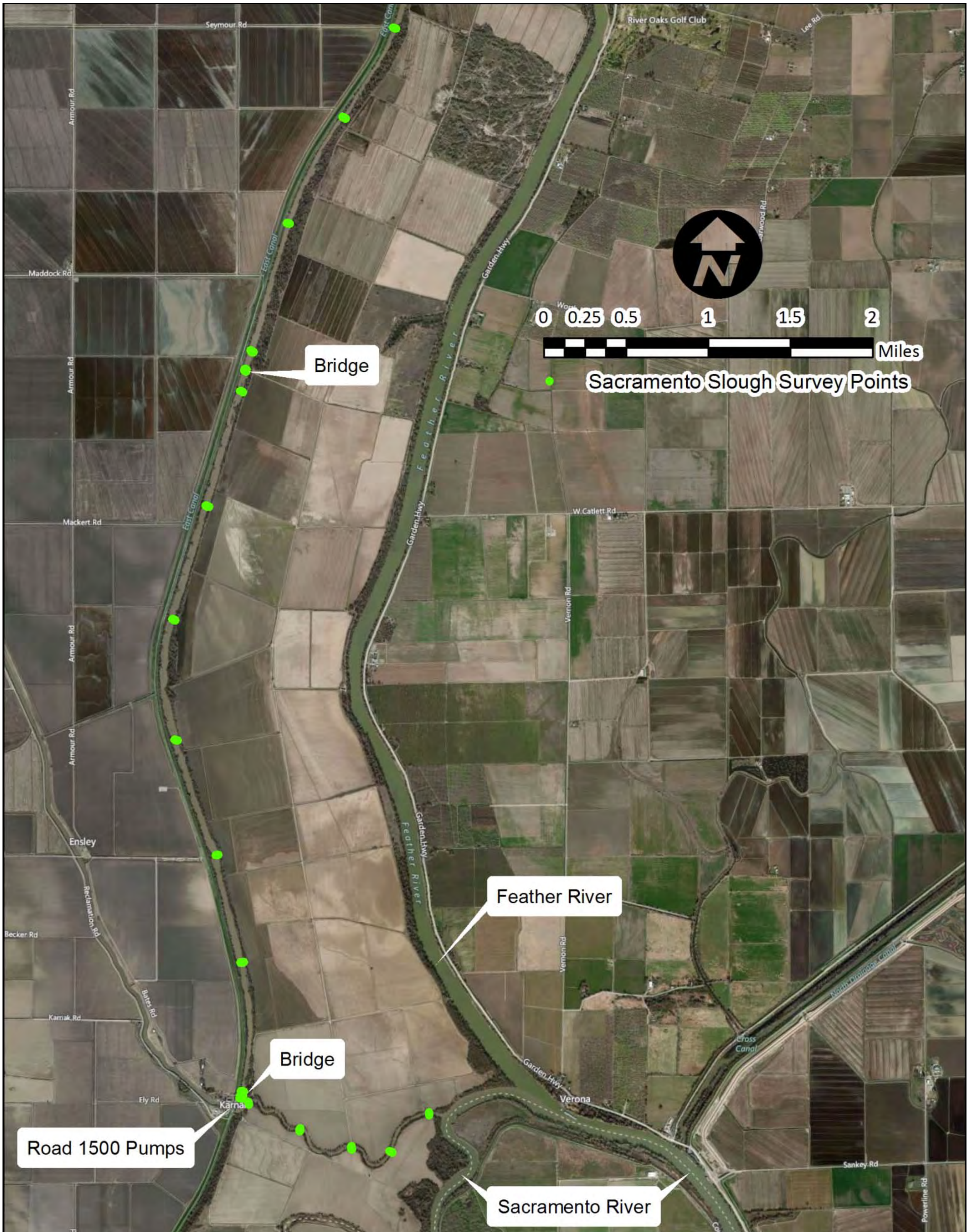
2.3 QUALITY ASSURANCE / QUALITY CONTROL

Quality assurance and quality control is a priority task when performing bathymetric surveys. A standard bar check was performed prior to collecting data to calibrate the sonar for local site conditions as they relate to sound velocity. As transects were being recorded, recorded depths and positions were reviewed for irregularities and the potential effects of submerged aquatic vegetation. Once in the office, post processing involved calibrating the positional data to the local CVFED benchmarks and visually inspecting the data for erroneous readings.

3 RESULTS SUMMARY

Quality control results showed an acceptable range when tying into control less than or equal to the accuracy of the instrumentation (i.e., H: 0.10 ft and V: 0.15 ft). The sounding data also passed an in-house quality control standard of less than 5% bad or missing depths. All suspected vegetation returns were manually filtered from the data set prior to exporting and the corrected points are provided in the attached file. Twenty cross sections and two bridges were recorded in total. The surveyed transects provide sufficient channel geometry to characterize 1D flows in Sacramento Slough for the purpose of the Yolo Bypass Fish Passage Project.

Attachment: 13-1027_SacSl_090613_88_g09_QCcadeport.csv



Notes: image courtesy of Bing Maps	HDR cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Sacramento Slough Transect Locations**

Prepared for DWR	Created By: BST	**Figure 1**

APPENDIX A

DATASHEET

KEY FEATURES

Advanced Trimble R-Track technology

Unmatched GNSS tracking performance

Includes Trimble Maxwell 6 chip with 220 channels

Remote configuration and access

Base and rover communications options to suit any application

The Trimble® R8 GNSS Receiver sets the new standard for full-featured GNSS (Global Navigation Satellite System) receiver technology. This integrated system delivers unmatched power, accuracy and performance in a rugged, compact unit.

ADVANCED TRIMBLE R-TRACK TECHNOLOGY

The Trimble R8 GNSS delivers the latest advancements in R-Track™ technology, designed to deliver reliable, precise positioning performance. In challenging areas for GNSS surveying, such as tree cover or limited sky view, Trimble R-Track provides unmatched tracking performance of GNSS satellite signals.

Trimble R-Track with Signal Prediction™ compensates for intermittent or marginal RTK correction signals, enabling extended precision operation after an RTK signal is interrupted.

The new CMRx communications protocol provides unprecedented correction compression for optimized bandwidth and full utilization all of the satellites in view, giving you the most reliable positioning performance.

Featuring the Trimble Maxwell™ 6 chip, the Trimble R8 GNSS advances the industry with more memory and more GNSS channels. Trimble delivers business confidence with a sound GNSS investment for today and into the future.

Broad GNSS Support

The Trimble R8 GNSS supports a wide range of satellite signals, including GPS L2C and L5 and GLONASS L1/L2 signals. In addition, Trimble is committed to the next generation of modernized GNSS configurations by providing Galileo-compatible products available for customers well in advance of Galileo system availability[1,2]. In support of this plan, the new Trimble R8 GNSS is capable of tracking the experimental GIOVE-A and GIOVE-B test satellites for signal evaluation and test purposes.

FLEXIBLE SYSTEM DESIGN

The Trimble R8 GNSS receiver combines the most comprehensive feature set into an integrated and flexible system for demanding surveying applications. The Trimble R8 GNSS includes a built-in transmit/receive UHF radio, enabling ultimate flexibility for rover or base operation. As a base station, the internal NTRIP caster provides you with customized access[3] to base station corrections via the internet.

Trimble's exclusive, Web UI™ eliminates travel requirements for routine monitoring of base station receivers. Now you can assess the health and status of base receivers and perform remote configurations from the office. Likewise, you can download post-processing data through Web UI and save additional trips out to the field.

ENABLING THE CONNECTED SITE

Pair the speed and accuracy of the Trimble R8 GNSS receiver with flexibility and collaboration tools of Trimble Access™ software. Trimble Access brings field and office teams closer by enabling data sharing and collaboration in a secure, web-based environment. With optional streamlined workflows, Trimble Access further empowers surveyors and survey teams for success. Now it is easier than ever to realize the potential of the Trimble Connected Site. Connecting the right tools, techniques, services and relationships enables surveying businesses to achieve more every day.

1 ***Galileo Commercial Authorization***
Receiver technology having Galileo capability to operate in the Galileo frequency bands and using information from the Galileo system for future operational satellites is restricted in the publicly available Galileo Open Service Signal-In-Space Interface Control Document (GAL OS SIS ICD) and is not currently authorized for commercial use.
Receiver technology that tracks the GIOVE-A and GIOVE-B test satellites uses information that is unrestricted in the public domain in the GIOVE A + B Navigation Signals-In-Space Interface Control Document. Receiver technology having developmental GIOVE-A and B capability is intended for signal evaluation and test purposes.

2 *For more information about Trimble and GNSS modernization, please visit* ***http://www.trimble.com/srv_new_era.shtml.***

3 *Cellular modem required.*

Trimble.

PERFORMANCE SPECIFICATIONS

Measurements

- Trimble R-Track technology
- Advanced Trimble Maxwell 6 Custom Survey GNSS chip with 220 channels
- High precision multiple correlator for GNSS pseudorange measurements
- Unfiltered, unsmoothed pseudorange measurements data for low noise, low multipath error, low time domain correlation and high dynamic response
- Very low noise GNSS carrier phase measurements with <1 mm precision in a 1 Hz bandwidth
- Signal-to-Noise ratios reported in dB-Hz
- Proven Trimble low elevation tracking technology
- Satellite signals tracked simultaneously:
  - GPS: L1C/A, L2C, L2E (Trimble method for tracking L2P), L5
  - GLONASS: L1C/A, L1P, L2C/A (GLONASS M only), L2P
  - SBAS: L1C/A, L5
  - Galileo GIOVE-A and GIOVE-B

Code differential GNSS positioning[1]

Horizontal .... 0.25 m + 1 ppm RMS
Vertical .... 0.50 m + 1 ppm RMS
WAAS differential positioning accuracy[2] .... typically <5 m 3DRMS

Static and FastStatic GNSS surveying[1]

Horizontal .... 3 mm + 0.1 ppm RMS
Vertical .... 3.5 mm + 0.4 ppm RMS

Kinematic surveying[1]

Horizontal .... 10 mm + 1 ppm RMS
Vertical .... 20 mm + 1 ppm RMS
Initialization time[3] .... typically <10 seconds
Initialization reliability[4] .... typically >99.9%

HARDWARE

Physical

Dimensions (W×H) .... 19 cm × 11.2 cm (7.5 in x 4.4 in), including connectors
Weight .... 1.34 kg (2.95 lb) with internal battery, internal radio, standard UHF antenna.
3.70 kg (8.16 lb) entire RTK rover including batteries, range pole, controller and bracket
Temperature[5]
Operating .... –40 °C to +65 °C (–40 °F to +149 °F)
Storage .... –40 °C to +75 °C (–40 °F to +167 °F)
Humidity .... 100%, condensing
Water/dustproof .... IP67 dustproof, protected from temporary immersion to depth of 1 m (3.28 ft)

Shock and vibration .... Tested and meets the following environmental standards:
Shock .... Non-operating: Designed to survive a 2 m (6.6 ft) pole drop onto concrete. Operating: to 40 G, 10 msec, sawtooth
Vibration MIL-STD-810F, FIG.514.5C-1

Electrical

- Power 11 to 28 V DC external power input with over-voltage protection on Port 1 (7-pin Lemo)
- Rechargeable, removable 7.4 V, 2.4 Ah Lithium-Ion battery in internal battery compartment. Power consumption is 3.2 W, in RTK rover mode with internal radio. Operating times on internal battery:
  - 450 MHz receive only option .... 5.8 hours[7]
  - 450 MHz receive/transmit option .... 3.7 hours[8]
  - GSM/GPRS .... 4.1 hours[7]
- Certification Class B Part 15, 22, 24 FCC certification, 850/1900 MHz. Class 10 GSM/GPRS module. CE Mark approval, and C-tick approval

Communications and Data Storage

- 3-wire serial (7-pin Lemo) on Port 1. Full RS-232 serial on Port 2 (Dsub 9 pin)
- Fully Integrated, fully sealed internal 450 MHz receiver/transmitter option:
  - Transmit power: 0.5 W
  - Range[6]: 3–5 km typical / 10 km optimal
- Fully integrated, fully sealed internal GSM/GPRS option[7]
- Fully integrated, fully sealed 2.4 GHz communications port (Bluetooth®)[9]
- External cellphone support for GSM/GPRS/CDPD modems for RTK and VRS operations
- Data storage on 57 MB internal memory: 40.7 days of raw observables (approx. 1.4 MB /Day), based on recording every 15 seconds from an average of 14 satellites
- 1 Hz, 2 Hz, 5 Hz, 10 Hz, and 20 Hz positioning
- CMR+, CMRx, RTCM 2.1, RTCM 2.3, RTCM 3.0, RTCM 3.1 Input and Output
- 16 NMEA outputs, GSOF, RT17 and RT27 outputs. Supports BINEX and smoothed carrier

1 Accuracy and reliability may be subject to anomalies due to multipath, obstructions, satellite geometry, and atmospheric conditions. Always follow recommended survey practices.
2 Depends on WAAS/EGNOS system performance.
3 May be affected by atmospheric conditions, signal multipath, obstructions and satellite geometry.
4 May be affected by atmospheric conditions, signal multipath, and satellite geometry. Initialization reliability is continuously monitored to ensure highest quality.
5 Receiver will operate normally to –40 °C, internal batteries are rated to –20 °C.
6 Varies with terrain and operating conditions.
7 Varies with temperature.
8 Varies with temperature and wireless data rate.
9 Bluetooth type approvals are country specific. Contact your local Trimble Authorized Distribution Partner for more information.

Specifications subject to change without notice.

Bluetooth®

TRIMBLE AUTHORIZED DISTRIBUTION PARTNER

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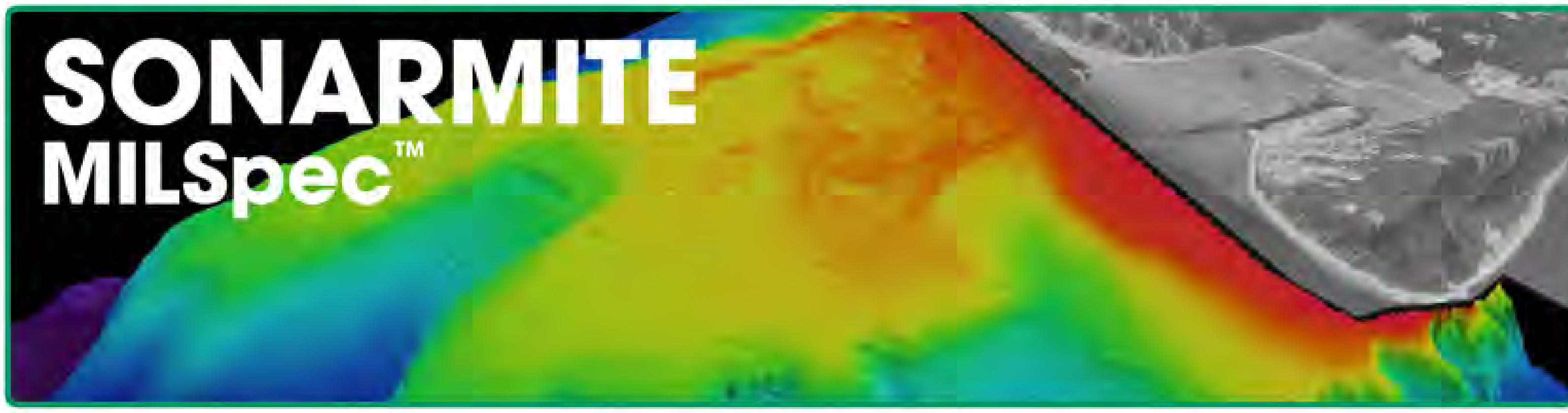
+65-6348-2232 Fax

Trimble.

www.trimble.com

PRODUCT DATASHEET



ABOUT

The SonarMite MILSpec™ Echo Sounder is result of nearly two years research and development tofurther extend the boundaries of shallow water hydrographic surveying equipment. The introduction by Ohmex in 1997 of the SonarLite, the worlds first truly portable echo sounder system, has been a hard act to follow and it remains the portable instrument of choice in many survey companies around the world. The release of the SonarMite instrument marks the next stage introducing a series of equipment designed around the WinSTRUMENT concept using the latest portable computer integrated with new measurment technologies.

FEATURES

- Rugged, field-proven survey grade echosounder
- Bluetooth technology integrated with Windows Pocket PC devices
- Proven 'Smart' transducer design with QA output
- Internal rechargeable battery for all day use
- Easily integrated with other modern software & GPS technology

OPTIONS

- Data collection software
- Heave, Pitch and Roll measurements
- Sound velocimeter
- Portable mounting bracket
- Rugged shipping case
- Extended warranty

SPECS

ECHOSOUNDER

- Frequency: 200-KHz
- Beam width: 4-degrees
- Ping Rate: 6 Hz
- Depth Accuracy: 1cm /0.1% of depth
- Output Formats: NMEA, ASCII
- Range: 0.3m-75m
- I/O: Serial, Bluetooth
- Environmental: IP-65
- Power: Rechargable 12V battery

PHOTOS

3941 Park Drive, Suite 20-218. El Dorado Hills, CA 95762 | info@seafloorSystems.com, www.seafloorsystems.com | (530) 677-1019

TECHNICAL MEMORANDUM

Date:	June 6, 2014
To:	Project File
From:	Chris Campbell, MS, Benjamin Taber, BS, PE
Project:	13-1027 – Yolo Bypass Salmonid Habitat Restoration and Fish Passage
Subject:	Willow Slough Bathymetric Survey

1 INTRODUCTION

cbec, inc., eco engineering (cbec) performed a bathymetric survey of Willow Slough on October 8th, 2013 to support hydrodynamic model development for the Yolo Bypass Modeling Project. The objective of the survey was to define the geometry of the slough channel bed such that the slough could be represented in 1D as a series of cross sections or transects. The surveyed reach extends from the confluence with the Tule Canal upstream approximately 3.75 miles where transects were taken at select locations with a spacing of approximately 2,000 feet. Surveyed cross sections were field fitted to select areas with minimal riparian vegetation on the banks with the assumption that the Central Valley Floodplain Evaluation and Delineation (CVFED) LiDAR data would be used to represent the overbank areas at each transect. Additional cross sections were recorded on the upstream and downstream sides of the two bridges within the study reach, as well as additional survey data to characterize the bridge geometry. See Figure 1 for a map of Willow Slough showing the extents of the surveyed reach and transect locations.

2 METHODS

2.1 BATHYMETRY

The bathymetric survey was performed utilizing Real Time Kinematic (RTK) Global Positioning System (GPS) terrestrial wading, as well as employing an inflatable kayak with a longer stadia rod for areas with greater depths. RTK GPS was used in conjunction with California Survey and Drafting Supply (CSDS) VSN mobile base network to provide positional corrections to the Trimble receiver. Equipment data sheets are provided in Appendix A.

2544 Industrial Blvd, West Sacramento, CA 95691 USA
T/F 916.231.6052
www.cbecoeng.com

2.2 CONTROL AND DATUMS

Prior to surveying, the cbec field crew occupied one benchmark reported in the CVFED LiDAR survey control documentation (see Table 1) to correct for horizontal and vertical variations in the observations. These variations are caused by atmospheric conditions as well as specific satellite geometry at the time of data acquisition.

Table 1. CVFED benchmarks (this survey)

Benchmark	Reported Northing[1]	Reported Easting[1]	Reported Elevation (ft,NAVD88)[2]	Observed Northing[1]	Observed Easting[1]	Observed Elevation (ft,NAVD88)[2]
WR145	1967746.71	6664280.36	24.777	1967746.896	6664280.142	24.491
[1] California State Planes, Zone 2, NAD 83, US Survey feet						
[2] North American Vertical Datum 1988 (NAVD88), Geoid 2009						

2.3 QUALITY ASSURANCE / QUALITY CONTROL

Quality assurance and quality control is a priority task when performing bathymetric and topographic surveys. Field software is programmed to only store points within the accuracy of the instrumentation (i.e., H: 0.10 ft and V: 0.15 ft). Upon completion of the survey, cbec staff provided an in house visual inspection of the field data in order to identify potentially erroneous data by plotting cross sections in processing software. All observed data was calibrated in order to match the local CVFED benchmark.

3 RESULTS SUMMARY

Sufficient data to characterize nineteen cross sections and two bridges/crossings were recorded in total. The surveyed transects provide sufficient channel geometry to characterize 1D flows in Willow Slough for the purpose of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage.

Attachment: 13-1027_WillowSl_100813_88_g09.csv

Notes: image courtesy of Bing Maps

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Willow Slough Transect Locations

Prepared for DWR	Created By: BST	**Figure 1**

APPENDIX A

DATASHEET

TRIMBLE R8 GNSS RECEIVER

KEY FEATURES

Advanced Trimble R-Track technology

Unmatched GNSS tracking performance

Includes Trimble Maxwell 6 chip with 220 channels

Remote configuration and access

Base and rover communications options to suit any application

The Trimble® R8 GNSS Receiver sets the new standard for full-featured GNSS (Global Navigation Satellite System) receiver technology. This integrated system delivers unmatched power, accuracy and performance in a rugged, compact unit.

ADVANCED TRIMBLE R-TRACK TECHNOLOGY

The Trimble R8 GNSS delivers the latest advancements in R-Track™ technology, designed to deliver reliable, precise positioning performance. In challenging areas for GNSS surveying, such as tree cover or limited sky view, Trimble R-Track provides unmatched tracking performance of GNSS satellite signals.

Trimble R-Track with Signal Prediction™ compensates for intermittent or marginal RTK correction signals, enabling extended precision operation after an RTK signal is interrupted.

The new CMRx communications protocol provides unprecedented correction compression for optimized bandwidth and full utilization all of the satellites in view, giving you the most reliable positioning performance.

Featuring the Trimble Maxwell™ 6 chip, the Trimble R8 GNSS advances the industry with more memory and more GNSS channels. Trimble delivers business confidence with a sound GNSS investment for today and into the future.

Broad GNSS Support

The Trimble R8 GNSS supports a wide range of satellite signals, including GPS L2C and L5 and GLONASS L1/L2 signals. In addition, Trimble is committed to the next generation of modernized GNSS configurations by providing Galileo-compatible products available for customers well in advance of Galileo system availability[1,2]. In support of this plan, the new Trimble R8 GNSS is capable of tracking the experimental GIOVE-A and GIOVE-B test satellites for signal evaluation and test purposes.

FLEXIBLE SYSTEM DESIGN

The Trimble R8 GNSS receiver combines the most comprehensive feature set into an integrated and flexible system for demanding surveying applications. The Trimble R8 GNSS includes a built-in transmit/receive UHF radio, enabling ultimate flexibility for rover or base operation. As a base station, the internal NTRIP caster provides you with customized access[3] to base station corrections via the internet.

Trimble's exclusive, Web UI™ eliminates travel requirements for routine monitoring of base station receivers. Now you can assess the health and status of base receivers and perform remote configurations from the office. Likewise, you can download post-processing data through Web UI and save additional trips out to the field.

ENABLING THE CONNECTED SITE

Pair the speed and accuracy of the Trimble R8 GNSS receiver with flexibility and collaboration tools of Trimble Access™ software. Trimble Access brings field and office teams closer by enabling data sharing and collaboration in a secure, web-based environment. With optional streamlined workflows, Trimble Access further empowers surveyors and survey teams for success. Now it is easier than ever to realize the potential of the Trimble Connected Site. Connecting the right tools, techniques, services and relationships enables surveying businesses to achieve more every day.

1 ***Galileo Commercial Authorization***
Receiver technology having Galileo capability to operate in the Galileo frequency bands and using information from the Galileo system for future operational satellites is restricted in the publicly available Galileo Open Service Signal-In-Space Interface Control Document (GAL OS SIS ICD) and is not currently authorized for commercial use.
Receiver technology that tracks the GIOVE-A and GIOVE-B test satellites uses information that is unrestricted in the public domain in the GIOVE A + B Navigation Signals-In-Space Interface Control Document. Receiver technology having developmental GIOVE-A and B capability is intended for signal evaluation and test purposes.

2 *For more information about Trimble and GNSS modernization, please visit* ***http://www.trimble.com/srv_new_era.shtml.***

3 *Cellular modem required.*

Trimble.

PERFORMANCE SPECIFICATIONS

Measurements

- Trimble R-Track technology
- Advanced Trimble Maxwell 6 Custom Survey GNSS chip with 220 channels
- High precision multiple correlator for GNSS pseudorange measurements
- Unfiltered, unsmoothed pseudorange measurements data for low noise, low multipath error, low time domain correlation and high dynamic response
- Very low noise GNSS carrier phase measurements with <1 mm precision in a 1 Hz bandwidth
- Signal-to-Noise ratios reported in dB-Hz
- Proven Trimble low elevation tracking technology
- Satellite signals tracked simultaneously:
  - GPS: L1C/A, L2C, L2E (Trimble method for tracking L2P), L5
  - GLONASS: L1C/A, L1P, L2C/A (GLONASS M only), L2P
  - SBAS: L1C/A, L5
  - Galileo GIOVE-A and GIOVE-B

Code differential GNSS positioning[1]

Horizontal . . . . 0.25 m + 1 ppm RMS
Vertical . . . . 0.50 m + 1 ppm RMS
WAAS differential positioning accuracy[2] . . . . typically <5 m 3DRMS

Static and FastStatic GNSS surveying[1]

Horizontal . . . . 3 mm + 0.1 ppm RMS
Vertical . . . . 3.5 mm + 0.4 ppm RMS

Kinematic surveying[1]

Horizontal . . . . 10 mm + 1 ppm RMS
Vertical . . . . 20 mm + 1 ppm RMS
Initialization time[3] . . . . typically <10 seconds
Initialization reliability[4] . . . . typically >99.9%

HARDWARE

Physical

Dimensions (W×H) . . . . 19 cm × 11.2 cm (7.5 in x 4.4 in), including connectors
Weight . . . . 1.34 kg (2.95 lb) with internal battery, internal radio, standard UHF antenna.
3.70 kg (8.16 lb) entire RTK rover including batteries, range pole, controller and bracket
Temperature[5]
Operating . . . . –40 °C to +65 °C (–40 °F to +149 °F)
Storage . . . . –40 °C to +75 °C (–40 °F to +167 °F)
Humidity . . . . 100%, condensing
Water/dustproof . . . . IP67 dustproof, protected from temporary immersion to depth of 1 m (3.28 ft)
Shock and vibration . . . . Tested and meets the following environmental standards:
Shock . . . . Non-operating: Designed to survive a 2 m (6.6 ft) pole drop onto concrete. Operating: to 40 G, 10 msec, sawtooth
Vibration MIL-STD-810F, FIG.514.5C-1

Electrical

- Power 11 to 28 V DC external power input with over-voltage protection on Port 1 (7-pin Lemo)
- Rechargeable, removable 7.4 V, 2.4 Ah Lithium-Ion battery in internal battery compartment. Power consumption is 3.2 W, in RTK rover mode with internal radio. Operating times on internal battery:
  - 450 MHz receive only option . . . . 5.8 hours[7]
  - 450 MHz receive/transmit option . . . . 3.7 hours[8]
  - GSM/GPRS . . . . 4.1 hours[7]
- Certification Class B Part 15, 22, 24 FCC certification, 850/1900 MHz. Class 10 GSM/GPRS module. CE Mark approval, and C-tick approval

Communications and Data Storage

- 3-wire serial (7-pin Lemo) on Port 1. Full RS-232 serial on Port 2 (Dsub 9 pin)
- Fully Integrated, fully sealed internal 450 MHz receiver/transmitter option:
  - Transmit power: 0.5 W
  - Range[6]: 3–5 km typical / 10 km optimal
- Fully integrated, fully sealed internal GSM/GPRS option[7]
- Fully integrated, fully sealed 2.4 GHz communications port (Bluetooth®)[9]
- External cellphone support for GSM/GPRS/CDPD modems for RTK and VRS operations
- Data storage on 57 MB internal memory: 40.7 days of raw observables (approx. 1.4 MB /Day), based on recording every 15 seconds from an average of 14 satellites
- 1 Hz, 2 Hz, 5 Hz, 10 Hz, and 20 Hz positioning
- CMR+, CMRx, RTCM 2.1, RTCM 2.3, RTCM 3.0, RTCM 3.1 Input and Output
- 16 NMEA outputs, GSOF, RT17 and RT27 outputs. Supports BINEX and smoothed carrier

1 Accuracy and reliability may be subject to anomalies due to multipath, obstructions, satellite geometry, and atmospheric conditions. Always follow recommended survey practices.
2 Depends on WAAS/EGNOS system performance.
3 May be affected by atmospheric conditions, signal multipath, obstructions and satellite geometry.
4 May be affected by atmospheric conditions, signal multipath, and satellite geometry. Initialization reliability is continuously monitored to ensure highest quality.
5 Receiver will operate normally to –40 °C, internal batteries are rated to –20 °C.
6 Varies with terrain and operating conditions.
7 Varies with temperature.
8 Varies with temperature and wireless data rate.
9 Bluetooth type approvals are country specific. Contact your local Trimble Authorized Distribution Partner for more information.

Specifications subject to change without notice.

PN 022543-079J (11/09)

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Appendix B

Sacramento Weir Information

E. Pratt

SUPPLEMENT TO STANDARD OPERATION AND MAINTENANCE MANUAL

SACRAMENTO RIVER
FLOOD CONTROL PROJECT
UNIT NO. 158
SACRAMENTO WEIR
SACRAMENTO RIVER, CALIFORNIA

SACRAMENTO DISTRICT
CORPS OF ENGINEERS
U. S. ARMY
SACRAMENTO, CALIFORNIA

CORPS OF ENGINEERS
U. S. ARMY

SUPPLEMENT TO STANDARD OPERATION AND MAINTENANCE MANUAL SACRAMENTO RIVER FLOOD CONTROL PROJECT

UNIT NO. 158
SACRAMENTO WEIR
SACRAMENTO RIVER, CALIFORNIA

Prepared by the Sacramento District
Corps of Engineers, U. S. Army
August 1955

UNIT NO. 158

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SECTION II - FEATURES OF THE PROJECT SUBJECT TO FLOOD CONTROL REGULATIONS

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SUPPLEMENT TO STANDARD
OPERATION AND MAINTENANCE MANUAL
SACRAMENTO RIVER FLOOD CONTROL PROJECT

UNIT NO. 158
SACRAMENTO WEIR
SACRAMENTO RIVER, CALIFORNIA

SECTION I - INTRODUCTION

1-01. Location. - The improvement covered by this manual is that part of the Sacramento River Flood Control Project which comprises the Sacramento Weir together with its adjoining channel, levees at the abutments, railroad bridge, highway bridge and appurtenances, as shown on the location map, Exhibit A-1 and drawings of Exhibit B. The weir is located in Yolo County, California along the right bank of the Sacramento River near Bryte, California and about 3.1 miles northwesterly from the City of Sacramento.

1-02. Project Works. - The Sacramento Weir is a reinforced concrete weir with wooden needles that provide a movable crest. There are 48 weir sections each 38 feet long. A highway bridge 20 feet wide and a single track railroad traverses the length of the weir. Concrete abutments at each end tie into the west levee of the Sacramento River and the north and south levees of the Sacramento Bypass. For more complete details of these structures see drawings of Exhibit B.

1-03. Protection Provided. - The Sacramento Weir is designed to protect the City of Sacramento and adjacent area from flood damage by providing means for release of excess over-flow waters of the Sacramento and American Rivers into the Yolo Bypass system. The project design capacity of the Sacramento Weir is 112,000 cubic feet per second.

1-04. Construction Data and Contractor. - The Sacramento Weir was constructed by Teichert & Ambrose under contract which was awarded by the City of Sacramento in June 1916. Subsequently the City was reimbursed for the costs of construction by the Sacramento District.

1-05. Flood Flows. - For purpose of this manual, the term "flood" or "high water period" shall refer to flows when the water surface in the Sacramento River reaches or exceeds the reading of 25.0 on the continuous water stage recorder and staff gage of the U. S. Weather Bureau and State Division of Water Resources located on the left bank of the Sacramento River at the foot of "I" Street, City of Sacramento. Zero of staff gage and recorders is set at elevation 3.10 U. S. Corps of Engineers datum and 0.03 foot U.S.G.S. datum. The term "flood" or "high water period" may also apply when the water surface in the Sacramento River reaches or exceeds the reading of 29.0 on the continuous water stage recorder and staff gage of the U. S. Corps of Engineers and the State Division of Water Resources located on a pile dolphin on the right bank of the Sacramento River 100 feet downstream from the Sacramento Weir. Zero of this gage is set at 0.00 feet U. S. Corps of Engineers datum and minus 3.07 feet U.S.G.S. datum.

1-06. Assurances Provided by Local Interests. - Assurances of cooperation by local interests is provided by State legislation as contained in Chapter 3, Part 2, Division 5 of the State Water Code (see paragraph 2-02a of the Standard Manual).

1-07. Acceptance by State Reclamation Board. - Responsibility for operating and maintaining the completed works was officially accepted by the Reclamation Board of the State of California on 18 December 1951, as shown on the attached letter of acceptance, Exhibit F.

1-08. Superintendent. - The name and address of the Superintendent appointed by the State or acting as a representative of the State Division of Water Resources for the continuous inspection, operation and maintenance of the Project works shall be furnished the District Engineer, and in case of any change of Superintendent, The District Engineer shall be so notified.

SECTION II

FEATURES OF THE PROJECT SUBJECT TO FLOOD CONTROL REGULATIONS

2-01. Drainage and Weir Structure.

a. Description. The Sacramento Weir is a reinforced fixed concrete structure located along the right bank of the Sacramento River about 3.1 miles northwesterly from the City of Sacramento. A concrete sheet pile cut-off wall extends the full length of the weir, a distance of 1,980 feet. The weir crest elevation is 24.75 feet. Hinged 3" x 12" wooden needles backed by a 20" x 28" wooden needle beam make it possible to raise the crest to elevation 31.0. ~~A float release mechanism capable of dropping the needle gates to elevation 25.0 can be adjusted to release when the water level reaches any elevation from 31.0 to 38.0.~~ Concrete piers on 41.25 foot centers carry highway and railroad bridges across the weir. Concrete abutments at each end of the weir tie into the levees on the west side of the Sacramento River at this location. The abutments also tie into the north and south levees of the Sacramento Bypass. The leveed bypass has an average channel width of 1,800 feet and extends southwesterly from the weir to the Yolo Bypass. For more complete details of these structures see drawings of Exhibit B.

b. For pertinent Requirements of the Code of Federal Regulations and other requirements see the following:

(1) Maintenance - Paragraph 5-02 of the Standard Manual.

(2) Check Lists - Exhibit E of this Supplement Manual.

(3) Operation - Paragraph 5-04 of the Standard Manual.

(4) Additional Requirements - Paragraph 5-05 of the Standard Manual.

(5) Safety Requirements - Paragraph 5-06 of the Standard Manual.

c. Special requirements pertaining to the Sacramento Weir:

(1) All missing parts of the hinged needles shall be replaced immediately following each flood period and that another inspection is made prior to the next flood season to be certain that all missing posts have been replaced.

(2) On the tripping devices the Superintendent shall make certain that:

(a) No parts are missing.

(b) Metal parts are adequatly covered with paint.

(c) All movable parts are in satisfactory working order.

(d) All padlocks are not corroded and can be opened with a proper key.

(e) Sufficient replacement materials are on hand and will be readily available in times of emergency.

(3) A sufficient stockpile of needle beams, hinged needles, and cable is available for replacement in times of emergency. The extra beam used for raising needles is readily available and in good operating condition at all times. Make certain that arrangements have been made to employ a mobile crane capable of handling the needle beams if and when needed.

(4) There are no encreachments upon the right-of-way which might endanger the structure or hinder its functioning in time of flood.

(5) A schedule of operation for the movable top of the Sacramento Weir is contained in Exhibit H of this manual.

2-02. Channel.

a. Description. For purpose of this manual the channel will be considered as that portion which extends from the Sacramento River to a point 200 feet downstream from the lower face of the weir structure. Beyond this point the channel maintenance is covered by other manuals.

b. For pertinent Requirements of the Code of Federal Regulations and other requirements see the following:

(1) Maintenance - Paragraph 6-02 of the Standard Manual.

(2) Check Lists - Exhibit E of this Supplement Manual.

(3) Operation - Paragraph 6-04 of the Standard Manual.

(4) Safety Requirements - Paragraph 6-05 of the Standard Manual.

It shall be the duty of the Superintendent to maintain a patrol of the project works during all periods of flood flow in excess of a reading of 25.0 on the gage located at the foot of "I" Street or 29.0 on a gage located 100 feet downstream from the Sacramento Weir, as indicated in paragraph 1-05 of this manual. The Superintendent shall dispatch a message by the most suitable means to the District Engineer whenever the water surface in the Sacramento River reaches the gage readings indicated above. The Superintendent shall cause readings to be taken at intervals of two to four hours during the period when the water surface is above flood-flow stage and record the time of the observations. One copy of the readings shall be forwarded to the District Engineer immediately following the flood, and a second copy transmitted as an inclosure to the semi-annual report in compliance with paragraph 3-06 of the Standard Manual.

2-03. Levees.

a. Description. The bypass levees will not be described in this manual, except that portion of the north and south levees of the Sacramento Weir north and south abutments and which may be considered a part thereof.

b. For pertinent Requirements of the Code of Federal Regulations and other requirements see the following:

(1) Maintenance - Paragraph 4-02 of the Standard Manual.

(2) Check Lists - Exhibit E of this Supplement Manual.

(3) Operation - Paragraph 4-04 of the Standard Manual.

(4) Special Instructions - Paragraph 4-05 of the Standard Manual.

2-04. Miscellaneous Facilities.

a. Description. Miscellaneous structures or facilities which were constructed as a part of, or in conjunction with, the protective works, and which might affect their functioning, include the following:

(1) Bridges.

(a) A reinforced concrete bridge over the Sacramento Weir 20 feet wide that carries traffic of State Highway No. 16 and No. 24.

(b) A steel plate girder single track, bridge of the Sacramento Northern Railroad.

(2) Utility Relocation.

(a) A power pole line anchored to four wing walls. This line crosses the Sacramento Bypass channel and is parallel to and about 400 feet downstream from the railroad trestle.

(3) Hydrographic Facilities. Water level gages to be maintained by the following Government agencies within this unit are listed as follows:

(a) U. S. Weather Bureau and State Division of Water Resources gage located on the Sacramento River at the foot of "I" Street, City of Sacramento.

(b) U. S. Corps of Engineers and State Division of Water Resources gage located on the right bank of the Sacramento River about 100 feet downstream from the Sacramento Weir.

b. For pertinent Requirements of the Code of Federal Regulations and other requirements see the following:

(1) Maintenance - Paragraph 7-02 of the Standard Manual.

(2) Check Lists - Paragraph 7-03 of the Standard Manual.

(3) Operation - Paragraph 7-04 of the Standard Manual.

SECTION III
REPAIR OF DAMAGE TO PROJECT WORKS AND METHODS OF COMBATING FLOOD CONDITIONS

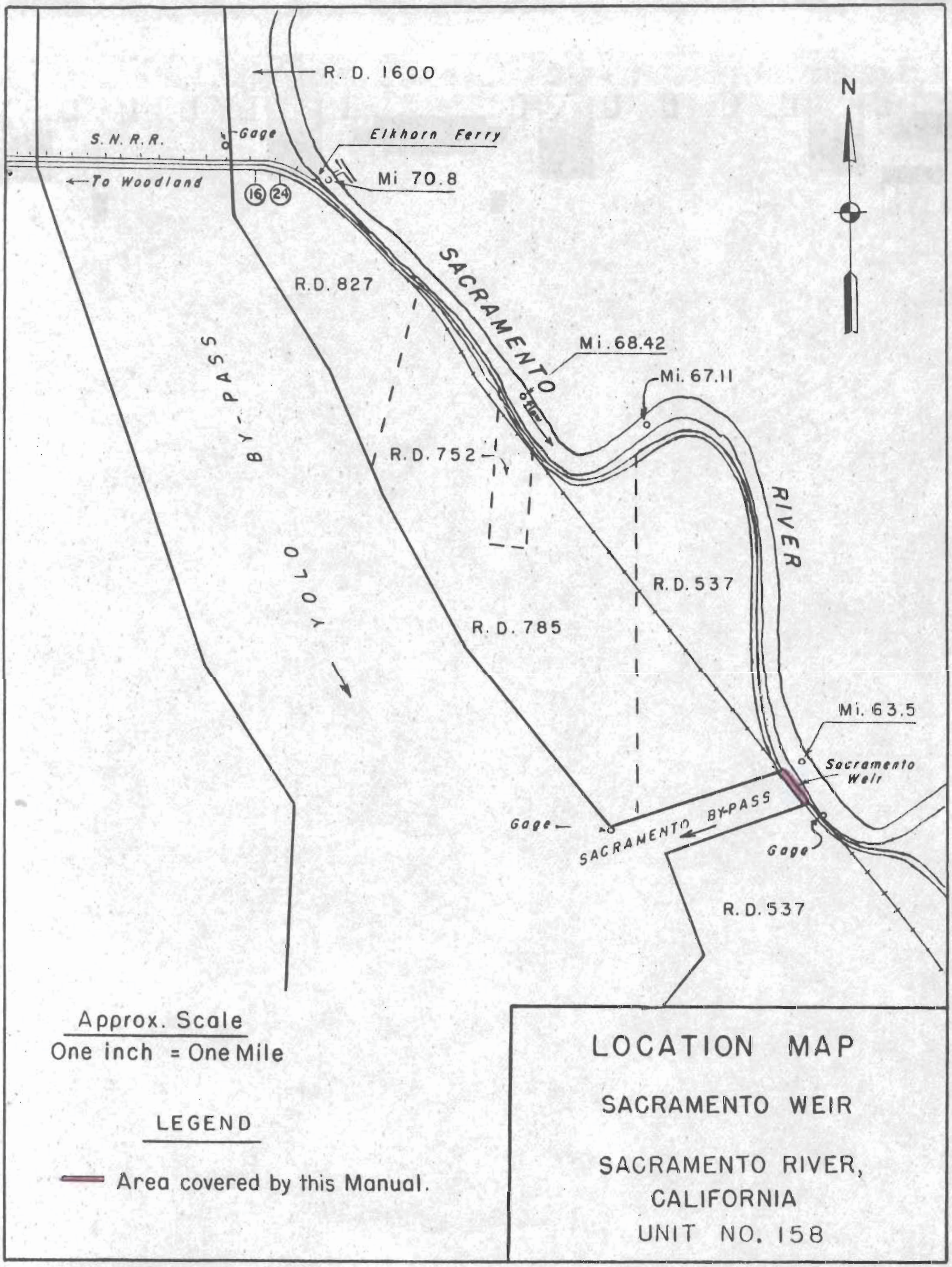
3-01. Repair of Damage. In the event of damage to the project works, whether due to flood conditions or other causes, and which may be beyond the capability of local interests to repair, the Superintendent will contact a representative of the Division of Water Resources, State of California, who coordinates maintenance of project works of the Sacramento River Flood Control Project. The State representative will give assistance or advice, or will determine appropriate action to be taken.

3-02. Applicable Methods of Combating Floods. For applicable methods of combating flood conditions reference is made to Section VIII of the Revised Standard Manual, where the subject is fully covered.

EXHIBIT A

FLOOD CONTROL REGULATIONS

(See Standard Manual)



LOCATION MAP

SACRAMENTO WEIR

SACRAMENTO RIVER, CALIFORNIA

UNIT NO. 158

EXHIBIT A-1

EXHIBIT B

"AS CONSTRUCTED"
DRAWINGS

See separate folder for the following drawings:

File No.	Title
50-9-2985	General Location Plan - - - - - 1 sheet
50-9-2985	General Plan and Arrangement of Weirs and Levees - - - - - - - Sheet No. 1c
50-9-2985	General Plan for Weir and Piers Sheet C2
50-9-2985	Details of Abutments - - - - - - Sheet C3
50-9-2985	Details of Hinged Needle Connections - - - - - - - - - - - Sheet C4
50-9-2985	General Details of Railway and Highway Bridges - - - - - - Sheet C5
50-9-2985	Details of Float and Tripping Device - - - - - - - - - - - - Sheet C6
50-9-2985	Details of Highway Bridge Skew Spans - - - - - - - - - - - - - Sheet C7

EXHIBIT B
Unattached

EXHIBIT D

CHECK LIST NO. 1
LEVEE INSPECTION REPORT

(See Standard Manual)

EXHIBIT E

CHECK LISTS OF LEVEES,
CHANNEL AND STRUCTURES

For definition of "flood" or "high water period" see paragraph 1-05 of this manual

CHECK LIST NO. 2

SACRAMENTO WEIR

Inspector's Report Sheet No. _____ Inspector ______________

Date ____________________________ Superintendent ______________

Item	Remarks
(a) Location by Station	
(b) Settlement, sloughing, or loss of grade	
(c) Erosion of both slopes	
(d) Condition of roadways, including ramps	
(e) Evidence of seepage	
(f) Condition of gates and fencing	
(g) Maintenance measures taken since last inspection	
(h) Comments	

INSTRUCTIONS FOR COMPLETING SHEET 2, EXHIBIT E
(To be printed on back of sheet 2)

Item (a) Indicate levee station of observation, obtained by pacing from nearest reference point; indicate right or left Bank.

Item (b) If sufficient settlement of earthwork has taken place to be noticeable by visual observation, indicate amount of settlement in tenths of a foot. If sloughing has caused a change in slope of the embankment sections, determine the new slope. Note areas where erosion or gullying of the section has occurred.

Item (c) If sufficient erosion or gullying of back face of back toe of levee has taken place to be noticeable by visual inspection, indicate area affected and depth.

Item (d) Note any natural change in any section of roadway or ramps. Indicate any inadequacy in surface drainage system.

Item (e) Indicate any evidence of seepage through the embankment section.

Item (f) Indicate the serviceability of all farm gates across the embankments and roadway, and indicate if repainting is required.

Item (g) Indicate maintenance measures that have been performed since last inspection and their condition at the time of this inspection.

Item (h) Record opinion, if any, of contributory causes for conditions observed and also any observations not covered under other columns.

NOTE: One copy of the Inspector's Report is to be mailed to the District Engineer immediately on completion, and one copy is to be attached to and submitted with the Superintendent's semi-annual report.

INSTRUCTION FOR COMPLETING SHEET 4, EXHIBIT E
(To be printed on back sheet 4)

Item (a) Indicate station of observation obtained by pacing from nearest reference point.

Item (b) Note nature, extent, and size of vegetal growth within the limits of flood flow channel.

Item (c) Note nature and extent of debris and refuse that might cause fouling of the bridges over the channel.

Item (d) Report any construction along or above the diversion channel that has come to the attention of the inspector and that might affect the functioning of the project.

Item (e) Indicate any change in grade or alignment of the channels, either by deposition of sediment or scour, that is noticeable by visual inspection. Estimate amount and extent.

Item (f) Indicate any change that has taken place in the riprap such as disintegration of the rock, erosion, or movement of the rock. Note the presence of vegetal growth through the riprap.

Item (g) Note any damage or settlement of the footings of the bridges. Indicate condition of wooden structures and if repainting is required. Indicate condition of bridge approaches, headwalls, other appurtenances.

Item (h) Indicate maintenance measures that have been performed since the last inspection and their condition at time of this inspection.

Item (i) Record opinion, if any, of contributory causes for conditions observed, also any observations not covered under other columns.

NOTE: One copy of the Inspector's Report is to be mailed to the District Engineer immediately on completion and one copy is to be attached to and submitted with the Superintendent's semi-annual report.

CHECK LIST NO. 4

WEIR STRUCTURE

SACRAMENTO WEIR

Inspector's Report Sheet No. ________ Inspector ________________

Date ____________________________ Superintendent ________________

Item	Remarks
(a) Condition of concrete weir section stilling basin and abutments	
(b) Condition of concrete highway bridge	
(c) Condition of railroad bridge	
(d) Condition of needles, beams and tripping devices	
(e) Condition of concrete revetment	
(f) Vegetal growth	
(g) Accumulation of trash and debris	
(h) Measures taken since last inspection	
(i) Comments	

INSTRUCTIONS FOR COMPLETING SHEET 6, EXHIBIT E
(To be printed on back of sheet 6)

Item (a) Inspect condition of concrete weir, stilling basin and abutments with respect to abraision, chipping or spalling and record observations.

Item (b) Note condition of highway bridge for abraision, chipping, road surfacing or damage due to traffic.

Item (c) Note condition of railroad tracks, ties and beams or structural members of bridge.

Item (d) Note conditions of needles and beams as to state of preservation of wood and mechanical tripping mechanism.

Item (e) Note condition of concrete revetment such as erosion, undue settlement or mis-alignment.

Item (f) Note nature, extent, and size of vegetal growth in and around the weir structure with particular emphasis on growth on the upstream side between the weir and the Sacramento River.

Item (g) Note nature and extent of debris that might cause scour around the weir section or abutments or tend to decrease the channel capacity.

Item (h) Indicate maintenance measures that have been performed since the last inspection and their condition at time of this inspection.

Item (i) Record opinion, if any, of contributory causes for conditions observed, also any observations not covered under other items. A copy of the Inspector's Report is to be mailed to the District Engineer immediately on completion.

EXHIBIT F

LETTER OF ACCEPTANCE
BY STATE RECLAMATION BOARD

THE RECLAMATION BOARD
OF THE
STATE OF CALIFORNIA

March 11, 1953

District Engineer
Sacramento District
Corps of Engineers, U.S. Army
P.O. Box 1739
Sacramento 8, California

Dear Sir:

Reference your letters file No. SPKKO-P 824.3 (Sac. R.F.C.P.) dated 1 December 1951, 3 December 1951, 4 December 1951, three letters dated 6 December 1951, 7 December 1951 and six letters dated 8 December 1951. Subject letters transferred to The Reclamation Board for operation and maintenance, various levee units of the Sacramento River Flood Control Project.

The Reclamation Board at its 18 December 1951 meeting, on behalf of the State of California, accepted certain of the transferred units together with their contiguous banks for operation and maintenance, and rejected others. A tabulation of the units so accepted or rejected is attached hereto.

Yours very truly,

THE RECLAMATION BOARD
A. M. BARTON
Chief Engineer and General Manager

Signed D. M. Carr
D. M. CARR

EXHIBIT F
Sheet 1 of 2

December 18, 1951

The Board accepted the transfer from the Corps of Engineer, in letters of dates listed below, the following reaches of levees and their contiguous waterway banks where applicable for flood control operation and maintenance, as complete and meeting the requirements of the Sacramento River Flood Control Project.

No.	Date of letter	Levee Location	Remarks
*	************	***************	******************
11	8 Dec. 1951	Sacramento Weir	Maintained by State
*	************	***************	******************

NOTE: Only item pertaining to Operation and Maintenance Manual No. 158 is included in the above copy.

EXHIBIT F
Sheet 2 of 2

EXHIBIT G

SUGGESTED SEMI-ANNUAL REPORT FORM

TO: The District Engineer
Sacramento District
Corps of Engineers
1209 - 8th Street
Sacramento, California

(1 May 19____)
(1 Nov 19____)

Dear Sir:

The semi-annual report for the period (1 May 19__ to 31 October 19__) (1 November 19___ to 30 April 19__) Sacramento River Flood Control Project, Sacramento Weir is as follows:

a. The physical condition of the protective works is indicated by the inspector's report, copies of which are inclosed, and may be summarized as follows:

(Superintendent's summary of conditions)

It is our intention to perform the following maintenance work in order to repair or correct the conditions indicated:

(Outline the anticipated maintenance operations for the following 6 months.)

b. During this report period, major high water stages (water level at 25.0 on the gage at foot of "I" Street or 29.0 on the gage 100 feet downstream from Sacramento Weir) occurred on the following dates:

Dates	Maximum Elevation
________	________
________	________
________	________

EXHIBIT G
Sheet 1 of 2

Comments on the behavior of the protective works during such high water periods are as follows:

(Superintendent's log of flood observations)

During the high water stages when the water level reached a height of ________, on the gage or excess thereof (dates)_______, it was necessary to organize and carry out flood operations as follows:

(See Maintenance Manual____________.)

c. The inspections have indicated (no) or (the following) encroachments or trespasses upon the project right-of-way.

d. (No) (__________) permits have been issued for (the following) improvements or construction within the project right-of-way.

Executed copies of the permit documents issued are transmitted for your files.

e. The status of maintenance measures, indicated in the previous semi-annual report as being required or as suggested by the representatives of the District Engineer, is as follows:

(Statement of maintenance operations, item by item with percent completion.)

f. The fiscal statement of the Superintendent's operations for the current report period is as follows:

	Labor	Material	Equipment	Overhead	Total
1. Inspection					
2. Maintenance					
3. Flood fighting operations					
TOTAL					

Respectfully submitted,

____
Superintendent of Works

EXHIBIT G
Sheet 2 of 2

EXHIBIT H

SCHEDULE OF OPERATION, SACRAMENTO WEIR

(Letterhead)

November 25, 1940

WAR DEPARTMENT
Calif. Debris Comm.
Sacramento, Calif.

File No. 662.8 (FC)1

Subject: Schedule of Operation, Sacramento Weir.

Mr. Edward Hyatt, State Engineer
Division of Water Resources
401 Public Works Building
Sacramento, Calif.

Dear Sir:

Reference is made to the proposed schedule for the operation of the movable top of the Sacramento Weir, as outlined in our letter of November 4, 1940.

The California Debris Commission has formally adopted this schedule, which reads as follows:

> "None of the weir gates shall be opened before a gage height of 27.5 feet is reached on the U. S. Weather Bureau gage at Sacramento, and the movable crest shall be operated in such a manner that the maximum flood height in the Sacramento River does not exceed 29.0 feet on this gage insofar as this is possible. In any event, on a rising stage only such gates shall be opened as required to hold the water surface in the river at Sacramento Weir at Elevation 31.0 U.S.E.D. Datum. The closing of the gates opened to effect the control outlined above shall be started as soon as the river stage at Sacramento Weir recedes to Elevation 28.5 U.S.E.D. Datum, and shall be prosecuted with faithfulness and energy, using adequate equipment, so that all gates are closed within as short a period as practicable."

In accordance with the terms and provisions of the existing law, it is requested that the State of California operate the Sacramento Weir in accordance with the above schedule.

FOR THE CALIFORNIA DEBRIS COMMISSION:

Yours very truly

R. C. Hunter
Lt. Col., Corps of Engineers
Member and Secretary

EXHIBIT H

STANDARD OPERATION PROCEEDURES

FOR THE

SACRAMENTO WEIR

SACRAMENTO RIVER FLOOD CONTROL PROJECT

NOVEMBER 1965

MANUAL NO.158 FOLDER NO. 63

STANDARD OPERATION PROCEDURES FOR THE
SACRAMENTO WEIR,
SACRAMENTO RIVER FLOOD CONTROL PROJECT

STANDARD OPERATION PROCEDURES FOR THE
SACRAMENTO WEIR,
SACRAMENTO RIVER FLOOD CONTROL PROJECT

Purpose

The purpose of the Standard Operation Procedures for the Sacramento Weir is to set forth the operational criteria and procedures to be followed by the Department of Water Resources during high water periods.

Additional miscellaneous information concerning the Sacramento Weir, including a description of the facilities, maintenance and inspection requirements, and various check lists and reports is contained in the "Supplement to Standard Operation and Maintenance Manual, Sacramento River Flood Control Project, Unit No. 158, Sacramento Weir," a publication of the Corps of Engineers.

Authority

State legislation authorizing the Department to maintain and operate the Sacramento Weir with its adjoining channel is contained in Sections 8360 and 8361 under Division 5, Part 2, Chapter 3, Article 2 of the Water Code.

Schedule of Operation

The recommendation to the Chief of Flood Operations for the opening or closing of either all or part of the 48 flood gates comprising the Sacramento Weir shall be determined by the Forecasting Unit of the Flood Operations Center. This recommendation will be made using criteria as set forth in the letter from the Corps of Engineers on schedule of operation, Sacramento Weir, dated November 19, 1963, as follows:

"The objectives of the operation of Sacramento Weir are to limit flood stages in Sacramento River from Verona to Isleton to the project flood plane, insofar as possible, with maximum feasible utilization of the flood capacity of the Sacramento River channel below that weir. In order to accomplish these objectives, the following schedule of operation shall be used. None of the weir gates shall be opened before a gage height of 28.0 feet m.s.l. datum is reached on the I Street Gage at Sacramento. When this 28.0 foot stage at I Street Gage is exceeded with a further rise anticipated, the gates shall be opened progressively to maintain the I Street stage between 28.0 and 29.0 feet and to limit the maximum I Street stage to 29.0 feet, insofar as this is possible. The number of gates opened to accomplish these criteria shall be kept to a practical minimum. After the peak of the flood has passed and the river stage at Sacramento Weir has receded to 28.0 feet C of E datum, the closing of the gates shall be initiated and prosecuted with dispatch so that, insofar as practicable, all gates in excess of minimum anticipated requirements are closed before the arrival of the next flood wave that might require a new cycle of weir operation in accordance with the provisions of these regulations.

"This schedule of operation is subject to temporary modification by the District Engineer, Corps of Engineers, if found necessary."

Chain of Command

Upon the recommendation of the Forecasting Unit, the Chief of Flood Operations or his appointed assistant will make the decision for the opening or closing of the flood gates and transmit the command to the person in charge at the Sacramento Weir Maintenance Yard. The number of gates to be opened or closed and time of same will be given to the person in charge at the Maintenance Yard by the Chief of Flood Operations by radio or phone and confirmed in writing. The physical operation of the flood gates will be carried out by personnel from the Sacramento Weir Maintenance Yard.

Safety Requirements

Only those personnel trained in the proper operation of the weir and instructed in the proper safety measures to be employed may participate in operating the flood gates. Stringent safety measures will be adhered to which will be the responsibility of the person in charge at the Sacramento Maintenance Yard. The person in charge of the physical opening and closing of the weir gates shall provide any necessary precautions with regard to traffic control.

Forms

Attached are samples of two forms which are for use in recording data pertinent to the operation of the weir. The first, DWR 1886, "Weir and Flood Data," shall be used to record date and time of opening or closing of individual weir gates, with the corresponding staff gage reading. On the second form, DWR 2127, "Flood Data - Gage Heights," a gage height reading of the Sacramento Weir staff gage shall be noted hourly during the entire period of flow over the weir.

After the flood gates of the weir are secured in a closed position, copies of both forms shall be transmitted in duplicate to the Flood Operations Center.

Responsibility of the Flood Operations Center

The Chief of Flood Operations shall be responsible for transmitting a report to the Corps of Engineers, Sacramento, after the operation of the flood gates. The report shall contain all pertinent data concerning the operation of the weir.

The Flood Operations Center shall be responsible for disseminating information and coordination of efforts regarding the operation of the weir.

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
FLOOD OPERATIONS CENTER

WEIR AND FLOOD DATA

Sacramento Weir
Sacramento River Flood Control Project

Date	Time	Gate No.* (opened or closed)	Sacto. Weir Staff Reading	Entered by	Remarks

*Gates numbered consecutively from north end

DWR 1886

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
FLOOD OPERATIONS CENTER

FLOOD DATA – GAGE HEIGHTS–

Sacramento Weir
Sacramento River Flood Control Project

Number of Gates Opened During Period____________________

Number of Gates Closed During Period____________________

Date________________, 19_____

GAGE HEIGHTS

Time	G.H.	Time	G.H.	Time	G.H.	Time	G.H.
0000		0600		1200		1800	
0030		0630		1230		1830	
0100		0700		1300		1900	
0130		0730		1330		1930	
0200		0800		1400		2000	
0230		0830		1430		2030	
0300		0900		1500		2100	
0330		0930		1530		2130	
0400		1000		1600		2200	
0430		1030		1630		2230	
0500		1100		1700		2300	
0530		1130		1730		2330	

E——

STATE OF CALIFORNIA—RESOURCES AGENCY EDMUND G. BROWN, Governor

DEPARTMENT OF WATER RESOURCES
P. O. BOX 388
SACRAMENTO

December 19, 1966

Mr. A. Gomez, Chief
Engineering Division
Sacramento District, Corps of Engineers
650 Capitol Mall
Sacramento, California 95814

Attention: Hydrology Section

Dear Mr. Gomez:

The purpose of this letter is to clarify operational procedures necessitated by the datum change at the Sacramento Weir staff gage.

As you are aware, Standard Operating Procedures for the Sacramento Weir were reviewed and minor revisions made in the fall of 1963. These revised operating procedures were documented in a letter from the Corps of Engineers dated November 19, 1963.

Subsequent to that date all staff gages in the Sacramento-San Joaquin tidal influence area set at, or near, U.S.E.D. datum were reset. These gages were reset so that zero on the gage equals -3.00 feet U.S.C. & G.S. datum.

The gage at the Sacramento Weir was one of those that was reset. The effect of this resetting is that a stage of 28.0 feet as previously set would now read 27.5 feet.

The Standard Operating Procedures for the Sacramento Weir (as referred to above) require that gate closing activities begin when the stage has receded to 28.0 feet at the weir. The equivalent stage of 27.5 feet will, therefore, be used henceforth as the stage to initiate gate closing activities.

In summary, it seems pertinent to note that this stage of 27.5 feet (with the changed datum) results in the same flow of water over the weir as resulted from the previous stage of 28.0 feet. As documented in previous operating procedures, it is this flow of water over the weir which has been established as being most effective and safe for gate closing operations.

Sincerely yours,

William L. Horn

William L. Horn, Chief
Flood Operations
Statewide Operations Office

December 1966

UNIT NO. 158

SACRAMENTO WEIR

The Sacramento Weir will be operated by the Department of Water Resources of the State of California in accordance with the following schedule adopted in 1963:

SCHEDULE OF OPERATION - SACRAMENTO WEIR

The objectives of the operation of Sacramento Weir are to limit flood stages in Sacramento River from Verona to Isleton to the project flood plane, insofar as possible, with maximum feasible utilization of the flood capacity of the Sacramento River channel below that weir. In order to accomplish these objectives, the following schedule of operation shall be used. None of the weir gates shall be opened before a gage height of 28.0 feet m.s.l. datum is reached on the I Street Gage at Sacramento. When this 28.0 foot stage at I Street Gage is exceeded with a further rise anticipated, the gates shall be opened progressively to maintain the I Street stage between 28.0 and 29.0 feet and to limit the maximum I Street stage to 29.0 feet, insofar as this is possible. The number of gates opened to accomplish these criteria shall be kept to a practical minimum. After the peak of the flood has passed and the river stage at Sacramento Weir has receded to 27.5 feet C of E datum, the closing of the gates shall be initiated and prosecuted with dispatch so that, insofar as practicable, all gates in excess of minimum anticipated requirements are closed before the arrival of the next flood wave that might require a new cycle of weir operation in accordance with the provisions of these regulations.

This schedule of operation is subject to temporary modification by the District Engineer, Corps of Engineers, if found necessary.

EXHIBIT H
Sheet 1 of 1
(revised 1966)

EXHIBIT H

SCHEDULE OF OPERATION, SACRAMENTO WEIR

December 1966

UNIT NO. 158

SACRAMENTO WEIR

The Sacramento Weir will be operated by the Department of Water Resources of the State of California in accordance with the following schedule adopted in 1963:

SCHEDULE OF OPERATION - SACRAMENTO WEIR

The objectives of the operation of Sacramento Weir are to limit flood stages in Sacramento River from Verona to Isleton to the project flood plane, insofar as possible, with maximum feasible utilization of the flood capacity of the Sacramento River channel below that weir. In order to accomplish these objectives, the following schedule of operation shall be used. None of the weir gates shall be opened before a gage height of 28.0 feet m.s.l. datum is reached on the I Street Gage at Sacramento. When this 28.0 foot stage at I Street Gage is exceeded with a further rise anticipated, the gates shall be opened progressively to maintain the I Street stage between 28.0 and 29.0 feet and to limit the maximum I Street stage to 29.0 feet, insofar as this is possible. The number of gates opened to accomplish these criteria shall be kept to a practical minimum. After the peak of the flood has passed and the river stage at Sacramento Weir has receded to 27.5 feet C of E datum, the closing of the gates shall be initiated and prosecuted with dispatch so that, insofar as practicable, all gates in excess of minimum anticipated requirements are closed before the arrival of the next flood wave that might require a new cycle of weir operation in accordance with the provisions of these regulations.

This schedule of operation is subject to temporary modification by the District Engineer, Corps of Engineers, if found necessary.

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
650 CAPITOL MALL
SACRAMENTO, CALIFORNIA 95814

IN REPLY REFER TO
SPKGD-L

4 January 1967

Department of Water Resources
State of California
ATTN: Mr. W. L. Horn
Sacramento, California

221.1
9t 16

Gentlemen:

Reference is made to your letter of 19 December 1966 requesting a revision for Standard Operating Procedures for the Sacramento Weir.

In compliance with your request a revision has been made to our Standard Operating Procedures for the Sacramento Weir to conform to the new gage setting so that a stage of 28.0 feet as previously set would now read 27.5 feet. There are inclosed four copies of a revision for Unit No. 158 of the Supplement to the Standard Operation and Maintenance Manual for the Sacramento River Flood Control Project, and eleven copies of a corresponding revision of page 20-a in the Master Manual of Reservoir Regulation for Sacramento River Basin, California.

Copies of the revision to Unit No. 158 are also being furnished the State Reclamation Board at this time.

Sincerely yours,

A. GOMEZ
Chief, Engineering Division

2 Incl
1. Revision to Unit No. 158 (4 cys)
2. Revision to R.R. Manual (11 cys)

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STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

C
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January 28, 1975

Mr. George C. Weddell
Chief of Engineering Division
Sacramento District, Corps of Engineers
Department of the Army
650 Capitol Mall
Sacramento, California 95814

Dear Mr. Weddell:

This letter is in regard to the proposal considered by our staffs to modify the operating criteria for the Sacramento Weir to reduce the effects on improvements within the channel in the vicinity of the Weir.

We have no objection to reverting back to the approved weir operating criteria that were used for operation of the Weir from 1940 to 1963, as set forth in the War Department's letter of November 25, 1940, subject to a one-half foot datum change that was made at the Weir in 1966.

We understand that you intend to document in a memorandum the reasons for reverting back to the earlier operating criteria, and that you will coordinate this with the Department of Water Resources and the State Reclamation Board.

We have appreciated your close coordination on this subject, and will work with you as necessary to complete action on it.

Sincerely yours,

/s/ Herbert W. Greydanus
HERBERT W. GREYDANUS
Division Engineer
Division of Resources
Development

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
650 CAPITOL MALL
SACRAMENTO, CALIFORNIA 95814

REPLY TO
ATTENTION OF SPKED-T

28 January 1975

Mr. Stanley J. Gale
Gale & Goldstein, Inc.
1214 F Street
Sacramento, CA 95814

Dear Mr. Gale:

This is in further reply to your prior letters regarding operation of the Sacramento Weir.

We have completed an investigation of the operation of the Sacramento Weir. The study has included an evaluation of the existing operating criteria and of the effects that modifications of these criteria (including your proposal) would have on the flow regimen of the Sacramento River. The study was conducted with the objective of determining the operating schedule that would best serve the overall public interest. Our findings have been coordinated with the California Department of Water Resources and with the California State Reclamation Board.

In your initial letter you requested two specific modifications to the existing criteria:

a. Operating the Weir to maintain a maximum stage of 26 feet m.s.l. in the Sacramento River between the Sacramento Weir and I Street gage, insofar as possible.

b. Using an upstream gage (at either the Interstate 880 Bridge or the Elkhorn Bridge) as an index in addition to the I Street gage. Adoption of these suggestions would reduce river stages up to 3 feet in the vicinity of your property during moderate flood events. River stages would not be reduced during large floods (February 1963 and December 1964 events for example) nor during small floods where flows below Verona do not exceed 70,000 cfs (approximately 50% of the years). This plan of operation would have detrimental effects both to landowners along the Sacramento River and landowners in the Yolo Bypass. During those years in which a stage reduction would be effected, the velocities in the Sacramento River could be increased approximately 20 to 25% in the channel between Verona and the Sacramento Weir.

These increased velocities would accelerate bank and channel erosion. In addition, the peak and volume of flows to the bypass would be substantially increased during these same years, thereby increasing the frequency, depth and duration of flooding in the bypass, which affects landowners there. Primarily because of these hydraulic factors, together with legal and operational considerations, adoption of your proposed modifications is not considered to be in the overall public interest.

During investigation of your suggested proposal we studied several other possible modifications to the existing criteria, in addition to an intensive study of existing criteria. On the basis of these studies we have concluded that substantially following the operating criteria in effect prior to 1963 would best serve all interests. These criteria are as follows:

a. No gates shall be opened until the stage at the I Street gage exceeds 27.5 feet m.s.l.

b. Gates shall be opened so that the stage at I Street does not exceed 29 feet m.s.l., insofar as possible.

c. Subject to provisions a. and b. above, the stage at the Sacramento Weir shall be maintained during the gate-opening period at 30.5 feet CofE Datum (equivalent to 27.5 feet m.s.l.) insofar as possible.

d. Gates shall be closed as rapidly as practicable when the stage drops below 28.0 feet CofE Datum (25.0 m.s.l.) at the Sacramento Weir.

Reverting to the pre-1963 operating criteria will provide a river stage reduction in the vicinity of the Sacramento Weir of 1.5 feet (maximum). This is in addition to the stage reduction presently provided under existing criteria. The maximum reduction will only be achieved or approached during certain moderate floods. We plan to change the operation of the Sacramento Weir in the near future to the operation described in the preceding paragraph. The criteria may be modified in the future as additional data are obtained.

Again, I would like to stress that our primary objective in prescribing operating criteria for the Sacramento River Flood Control project is to serve the overall public interest, giving consideration to all concerns of interested groups and agencies.

SPKED-T
Mr. Stanley J. Gale

28 January 1975

Should you wish further discussions on the operation of the Sacramento Weir, I would be happy to meet with you.

Sincerely yours,

F. G. ROCKWELL, JR.
Colonel, CE
District Engineer

CF:
DWR
Rec Board

SUPPLEMENT TO STANDARD
OPERATION AND MAINTENANCE MANUAL
SACRAMENTO RIVER FLOOD CONTROL PROJECT

UNIT NO. 158

SACRAMENTO WEIR
SACRAMENTO RIVER, CALIFORNIA

REVISIONS OR ADDITIONS

REVISIONS	DATE
Delete Exhibit H dated December 1966	May 1975
*Add Exhibit H dated March 1975	May 1975
Add letter from State Department of Water Resources dated 28 January 1975	May 1975

* This revision for operation of the Sacramento Weir was made to conform with the revision (sheet 20a) dated March 1975, to the Master Manual of Reservoir Regulation, Sacramento River Basin, California.

UNIT NO. 158

SACRAMENTO WEIR

The Sacramento Weir will be operated by the Department of Water Resources of the State of California in accordance with the following schedule adopted in 1975:

SCHEDULE OF OPERATION - SACRAMENTO WEIR

The operational objectives of the Sacramento Weir are to limit flood stages in the Sacramento River to the project flood plane, insofar as possible, with maximum feasible utilization of the flood capacity of the Sacramento River Channel below the weir. In order to accomplish these objectives, the following schedule of operation shall be used.

1. Opening of the weir gates will not be initiated until a stage of 27.5 feet msl datum is exceeded at the I Street gage, Sacramento.

2. As many gates as necessary shall be opened so that the stage at I Street does not exceed 29.0 feet msl datum, insofar as possible.

3. Subject to provisions 1 and 2 above, the stage at the Sacramento Weir shall be maintained during the gate opening period at 27.5 feet msl datum, insofar as practicable.

4. Gates shall be closed at the stage drops below 25.0 feet msl datum at the Sacramento Weir. The gate closing shall be prosecuted with dispatch so that all gates are closed within as short a period as practicable.

This schedule of operation is subject to temporary modification by the District Engineer, Corps of Engineers, if found necessary.

Sacramento Weir		Flow in 1000 cfs																							
Flow per	Sac Weir	# of Gates opened																							
Gate	Stage	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	22.1	0.01	0.02	0.04	0.05	0.06	0.07	0.08	0.1	0.11	0.12	0.13	0.14	0.16	0.17	0.18	0.19	0.2	0.22	0.23	0.24	0.25	0.26	0.28	0.29
12	22.2	0.02	0.05	0.07	0.1	0.12	0.14	0.17	0.19	0.22	0.24	0.26	0.29	0.31	0.34	0.36	0.38	0.41	0.43	0.46	0.48	0.5	0.53	0.55	0.58
18	22.3	0.04	0.07	0.11	0.14	0.18	0.22	0.25	0.29	0.32	0.36	0.4	0.43	0.47	0.5	0.54	0.58	0.61	0.65	0.68	0.72	0.76	0.79	0.83	0.86
24	22.4	0.05	0.1	0.14	0.19	0.24	0.29	0.34	0.38	0.43	0.48	0.53	0.58	0.62	0.67	0.72	0.77	0.82	0.86	0.91	0.96	1.01	1.06	1.1	1.15
30	22.5	0.06	0.12	0.18	0.24	0.3	0.36	0.42	0.48	0.54	0.6	0.66	0.72	0.78	0.84	0.9	0.96	1.02	1.08	1.14	1.2	1.26	1.32	1.38	1.44
40	22.6	0.08	0.16	0.24	0.32	0.4	0.48	0.56	0.64	0.72	0.8	0.88	0.96	1.04	1.12	1.2	1.28	1.36	1.44	1.52	1.6	1.68	1.76	1.84	1.92
50	22.7	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4
60	22.8	0.12	0.24	0.36	0.48	0.6	0.72	0.84	0.96	1.08	1.2	1.32	1.44	1.56	1.68	1.8	1.92	2.04	2.16	2.28	2.4	2.52	2.64	2.76	2.88
70	22.9	0.14	0.28	0.42	0.56	0.7	0.84	0.98	1.12	1.26	1.4	1.54	1.68	1.82	1.96	2.1	2.24	2.38	2.52	2.66	2.8	2.94	3.08	3.22	3.36
80	23	0.16	0.32	0.48	0.64	0.8	0.96	1.12	1.28	1.44	1.6	1.76	1.92	2.08	2.24	2.4	2.56	2.72	2.88	3.04	3.2	3.36	3.52	3.68	3.84
96	23.1	0.19	0.38	0.58	0.77	0.96	1.15	1.34	1.54	1.73	1.92	2.11	2.3	2.5	2.69	2.88	3.07	3.26	3.46	3.65	3.84	4.03	4.22	4.42	4.61
111	23.2	0.22	0.44	0.67	0.89	1.11	1.33	1.55	1.78	2	2.22	2.44	2.66	2.89	3.11	3.33	3.55	3.77	4	4.22	4.44	4.66	4.88	5.11	5.33
127	23.3	0.25	0.51	0.76	1.02	1.27	1.52	1.78	2.03	2.29	2.54	2.79	3.05	3.3	3.56	3.81	4.06	4.32	4.57	4.83	5.08	5.33	5.59	5.84	6.1
142	23.4	0.28	0.57	0.85	1.14	1.42	1.7	1.99	2.27	2.56	2.84	3.12	3.41	3.69	3.98	4.26	4.54	4.83	5.11	5.4	5.68	5.96	6.25	6.53	6.82
158	23.5	0.32	0.63	0.95	1.26	1.58	1.9	2.21	2.53	2.84	3.16	3.48	3.79	4.11	4.42	4.74	5.06	5.37	5.69	6	6.32	6.64	6.95	7.27	7.58
177	23.6	0.35	0.71	1.06	1.42	1.77	2.12	2.48	2.83	3.19	3.54	3.89	4.25	4.6	4.96	5.31	5.66	6.02	6.37	6.73	7.08	7.43	7.79	8.14	8.5
197	23.7	0.39	0.79	1.18	1.58	1.97	2.36	2.76	3.15	3.55	3.94	4.33	4.73	5.12	5.52	5.91	6.3	6.7	7.09	7.49	7.88	8.27	8.67	9.06	9.46
216	23.8	0.43	0.86	1.3	1.73	2.16	2.59	3.02	3.46	3.89	4.32	4.75	5.18	5.62	6.05	6.48	6.91	7.34	7.78	8.21	8.64	9.07	9.5	9.94	10.4
236	23.9	0.47	0.94	1.42	1.89	2.36	2.83	3.3	3.78	4.25	4.72	5.19	5.66	6.14	6.61	7.08	7.55	8.02	8.5	8.97	9.44	9.91	10.4	10.9	11.3
255	24	0.51	1.02	1.53	2.04	2.55	3.06	3.57	4.08	4.59	5.1	5.61	6.12	6.63	7.14	7.65	8.16	8.67	9.18	9.69	10.2	10.7	11.2	11.7	12.2
278	24.1	0.56	1.11	1.67	2.22	2.78	3.34	3.89	4.45	5	5.56	6.12	6.67	7.23	7.78	8.34	8.9	9.45	10	10.6	11.1	11.7	12.2	12.8	13.3
300	24.2	0.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6	6.6	7.2	7.8	8.4	9	9.6	10.2	10.8	11.4	12	12.6	13.2	13.8	14.4
323	24.3	0.65	1.29	1.94	2.58	3.23	3.88	4.52	5.17	5.81	6.46	7.11	7.75	8.4	9.04	9.69	10.3	11	11.6	12.3	12.9	13.6	14.2	14.9	15.5
345	24.4	0.69	1.38	2.07	2.76	3.45	4.14	4.83	5.52	6.21	6.9	7.59	8.28	8.97	9.66	10.4	11	11.7	12.4	13.1	13.8	14.5	15.2	15.9	16.6
368	24.5	0.74	1.47	2.21	2.94	3.68	4.42	5.15	5.89	6.62	7.36	8.1	8.83	9.57	10.3	11	11.8	12.5	13.2	14	14.7	15.5	16.2	16.9	17.7
394	24.6	0.79	1.58	2.36	3.15	3.94	4.73	5.52	6.3	7.09	7.88	8.67	9.46	10.2	11	11.8	12.6	13.4	14.2	15	15.8	16.5	17.3	18.1	18.9
420	24.7	0.84	1.68	2.52	3.36	4.2	5.04	5.88	6.72	7.56	8.4	9.24	10.1	10.9	11.8	12.6	13.4	14.3	15.1	16	16.8	17.6	18.5	19.3	20.2
445	24.8	0.89	1.78	2.67	3.56	4.45	5.34	6.23	7.12	8.01	8.9	9.79	10.7	11.6	12.5	13.4	14.2	15.1	16	16.9	17.8	18.7	19.6	20.5	21.4
471	24.9	0.94	1.88	2.83	3.77	4.71	5.65	6.59	7.54	8.48	9.42	10.4	11.3	12.2	13.2	14.1	15.1	16	17	17.9	18.8	19.8	20.7	21.7	22.6
497	25	0.99	1.99	2.98	3.98	4.97	5.96	6.96	7.95	8.95	9.94	10.9	11.9	12.9	13.9	14.9	15.9	16.9	17.9	18.9	19.9	20.9	21.9	22.9	23.9

Flow per	Sac Weir	# of Gates opened																							
Gate	Stage	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
526	25.1	1.05	2.1	3.16	4.21	5.26	6.31	7.36	8.42	9.47	10.5	11.6	12.6	13.7	14.7	15.8	16.8	17.9	18.9	20	21	22.1	23.1	24.2	25.2
555	25.2	1.11	2.22	3.33	4.44	5.55	6.66	7.77	8.88	9.99	11.1	12.2	13.3	14.4	15.5	16.7	17.8	18.9	20	21.1	22.2	23.3	24.4	25.5	26.6
583	25.3	1.17	2.33	3.5	4.66	5.83	7	8.16	9.33	10.5	11.7	12.8	14	15.2	16.3	17.5	18.7	19.8	21	22.2	23.3	24.5	25.7	26.8	28
612	25.4	1.22	2.45	3.67	4.9	6.12	7.34	8.57	9.79	11	12.2	13.5	14.7	15.9	17.1	18.4	19.6	20.8	22	23.3	24.5	25.7	26.9	28.2	29.4
641	25.5	1.28	2.56	3.85	5.13	6.41	7.69	8.97	10.3	11.5	12.8	14.1	15.4	16.7	17.9	19.2	20.5	21.8	23.1	24.4	25.6	26.9	28.2	29.5	30.8
673	25.6	1.35	2.69	4.04	5.38	6.73	8.08	9.42	10.8	12.1	13.5	14.8	16.2	17.5	18.8	20.2	21.5	22.9	24.2	25.6	26.9	28.3	29.6	31	32.3
705	25.7	1.41	2.82	4.23	5.64	7.05	8.46	9.87	11.3	12.7	14.1	15.5	16.9	18.3	19.7	21.2	22.6	24	25.4	26.8	28.2	29.6	31	32.4	33.8
736	25.8	1.47	2.94	4.42	5.89	7.36	8.83	10.3	11.8	13.2	14.7	16.2	17.7	19.1	20.6	22.1	23.6	25	26.5	28	29.4	30.9	32.4	33.9	35.3
768	25.9	1.54	3.07	4.61	6.14	7.68	9.22	10.8	12.3	13.8	15.4	16.9	18.4	20	21.5	23	24.6	26.1	27.6	29.2	30.7	32.3	33.8	35.3	36.9
800	26	1.6	3.2	4.8	6.4	8	9.6	11.2	12.8	14.4	16	17.6	19.2	20.8	22.4	24	25.6	27.2	28.8	30.4	32	33.6	35.2	36.8	38.4
834	26.1	1.67	3.34	5	6.67	8.34	10	11.7	13.3	15	16.7	18.3	20	21.7	23.4	25	26.7	28.4	30	31.7	33.4	35	36.7	38.4	40
868	26.2	1.74	3.47	5.21	6.94	8.68	10.4	12.2	13.9	15.6	17.4	19.1	20.8	22.6	24.3	26	27.8	29.5	31.2	33	34.7	36.5	38.2	39.9	41.7
903	26.3	1.81	3.61	5.42	7.22	9.03	10.8	12.6	14.4	16.3	18.1	19.9	21.7	23.5	25.3	27.1	28.9	30.7	32.5	34.3	36.1	37.9	39.7	41.5	43.3
937	26.4	1.87	3.75	5.62	7.5	9.37	11.2	13.1	15	16.9	18.7	20.6	22.5	24.4	26.2	28.1	30	31.9	33.7	35.6	37.5	39.4	41.2	43.1	45
971	26.5	1.94	3.88	5.83	7.77	9.71	11.7	13.6	15.5	17.5	19.4	21.4	23.3	25.2	27.2	29.1	31.1	33	35	36.9	38.8	40.8	42.7	44.7	46.6
1009	26.6	2.02	4.04	6.05	8.07	10.1	12.1	14.1	16.1	18.2	20.2	22.2	24.2	26.2	28.3	30.3	32.3	34.3	36.3	38.3	40.4	42.4	44.4	46.4	48.4
1047	26.7	2.09	4.19	6.28	8.38	10.5	12.6	14.7	16.8	18.8	20.9	23	25.1	27.2	29.3	31.4	33.5	35.6	37.7	39.8	41.9	44	46.1	48.2	50.3
1084	26.8	2.17	4.34	6.5	8.67	10.8	13	15.2	17.3	19.5	21.7	23.8	26	28.2	30.4	32.5	34.7	36.9	39	41.2	43.4	45.5	47.7	49.9	52
1122	26.9	2.24	4.49	6.73	8.98	11.2	13.5	15.7	18	20.2	22.4	24.7	26.9	29.2	31.4	33.7	35.9	38.1	40.4	42.6	44.9	47.1	49.4	51.6	53.9
1160	27	2.32	4.64	6.96	9.28	11.6	13.9	16.2	18.6	20.9	23.2	25.5	27.8	30.2	32.5	34.8	37.1	39.4	41.8	44.1	46.4	48.7	51	53.4	55.7
1198	27.1	2.4	4.79	7.19	9.58	12	14.4	16.8	19.2	21.6	24	26.4	28.8	31.1	33.5	35.9	38.3	40.7	43.1	45.5	47.9	50.3	52.7	55.1	57.5
1236	27.2	2.47	4.94	7.42	9.89	12.4	14.8	17.3	19.8	22.2	24.7	27.2	29.7	32.1	34.6	37.1	39.6	42	44.5	47	49.4	51.9	54.4	56.9	59.3
1274	27.3	2.55	5.1	7.64	10.2	12.7	15.3	17.8	20.4	22.9	25.5	28	30.6	33.1	35.7	38.2	40.8	43.3	45.9	48.4	51	53.5	56.1	58.6	61.2
1312	27.4	2.62	5.25	7.87	10.5	13.1	15.7	18.4	21	23.6	26.2	28.9	31.5	34.1	36.7	39.4	42	44.6	47.2	49.9	52.5	55.1	57.7	60.4	63
1350	27.5	2.7	5.4	8.1	10.8	13.5	16.2	18.9	21.6	24.3	27	29.7	32.4	35.1	37.8	40.5	43.2	45.9	48.6	51.3	54	56.7	59.4	62.1	64.8
1392	27.6	2.78	5.57	8.35	11.1	13.9	16.7	19.5	22.3	25.1	27.8	30.6	33.4	36.2	39	41.8	44.5	47.3	50.1	52.9	55.7	58.5	61.2	64	66.8
1434	27.7	2.87	5.74	8.6	11.5	14.3	17.2	20.1	22.9	25.8	28.7	31.5	34.4	37.3	40.2	43	45.9	48.8	51.6	54.5	57.4	60.2	63.1	66	68.8
1476	27.8	2.95	5.9	8.86	11.8	14.8	17.7	20.7	23.6	26.6	29.5	32.5	35.4	38.4	41.3	44.3	47.2	50.2	53.1	56.1	59	62	64.9	67.9	70.8
1518	27.9	3.04	6.07	9.11	12.1	15.2	18.2	21.3	24.3	27.3	30.4	33.4	36.4	39.5	42.5	45.5	48.6	51.6	54.6	57.7	60.7	63.8	66.8	69.8	72.9
1560	28	3.12	6.24	9.36	12.5	15.6	18.7	21.8	25	28.1	31.2	34.3	37.4	40.6	43.7	46.8	49.9	53	56.2	59.3	62.4	65.5	68.6	71.8	74.9
1604	28.1	3.21	6.42	9.62	12.8	16	19.2	22.5	25.7	28.9	32.1	35.3	38.5	41.7	44.9	48.1	51.3	54.5	57.7	61	64.2	67.4	70.6	73.8	77
1648	28.2	3.3	6.59	9.89	13.2	16.5	19.8	23.1	26.4	29.7	33	36.3	39.6	42.8	46.1	49.4	52.7	56	59.3	62.6	65.9	69.2	72.5	75.8	79.1
1692	28.3	3.38	6.77	10.2	13.5	16.9	20.3	23.7	27.1	30.5	33.8	37.2	40.6	44	47.4	50.8	54.1	57.5	60.9	64.3	67.7	71.1	74.4	77.8	81.2

Appendix C

Gate Technical Memorandums

Hydrology | Hydraulics | Geomorphology | Design | Field Services

TECHNICAL MEMORANDUM

Date:	April 14, 2014
To:	Project File
From:	Chris Campbell
Project:	13-1027 – Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project
Subject:	Sacramento Weir Alternative and Gate Configuration

1 SACRAMENTO WEIR GATED CHANNEL

This Technical Memorandum (TM) details the development of the Sacramento Weir Gated Channel Alternative in HEC-RAS (RAS) for use in the calibrated and validated TUFLOW Classic hydrodynamic model developed to support the California Department of Water Resources (DWR) and US Bureau of Reclamation (USBR) Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (Project) Environmental Impact Statement and Environmental Impact Report (EIS/EIR). The Sacramento Weir Gated Channel Alternative is one of four alternatives being carried forward through the screening phase.

The Sacramento Weir Gated Channel Alternative was assumed to be constructed just north of the southern Sacramento Bypass levee, connecting the Sacramento River with the Tule Canal (see Figure 1). The proposed channel has an invert elevation of 7 feet NAVD88 with a 225 foot bottom width and 3:1 side slopes (see Figure 2). The channel profile and the gate configuration were analyzed in RAS to 1) understand the backwater effects on the gates from Yolo Bypass inundation given that proposed upstream inverts at the river are below the baseline water levels in the Tule Canal, and 2) optimize the gate openings for non-overtopping flows with the objective to maximize diversions from the Sacramento River up to 6000 cfs while minimizing head losses across the gate. Gate optimization was performed in RAS because such a function is not yet available in TUFLOW and gate logic is relatively new in TUFLOW.

2 WATER SURFACE PROFILES

For this analysis, the Tule Canal was assumed to have baseline flow contributions of 500 cfs, 350 cfs, 50 cfs, and 300 cfs from KLRC, Cache Creek Settling Basin, Willow Slough, and Putah Creek, respectively. To better understand system performance and hydraulic constraints prior to proceeding with configuring the gates, three steady state inflows of 500cfs, 1500 cfs and 6000 cfs were introduced into the

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Sacramento Bypass. The water surface elevations in the RAS model at the confluence with the Tule Canal were based on calibrated TUFLOW simulations using the above stated flow conditions. Steady state water surface profiles for the Sacramento Bypass Gated Channel Alternative are shown in Figure 3.

Water surface profiles in the Sacramento Bypass are controlled by the low flow conveyance capacity within Tule Canal and the Yolo Bypass. The minimum water surface elevation in Tule Canal at the confluence with the Sacramento Bypass during baseline flows (i.e., 850 cfs as contributed by KLRC and Cache Creek) was 10.65 feet NAVD88. At stages below 11 feet NAVD88, flow through the Sacramento Bypass was limited due to the assumed backwater from Tule Canal, and was not included in the reported tables. It should also be noted that 2300 feet downstream of the gated channel connection to the Tule Canal is an agricultural crossing maintained by Swanston Ranch. The earthen crossing impounds water in the canal for diversion and consists of three culverts, one six foot open culvert and two four foot culverts with boards at the intakes and earth fill. If the earthen fill is not removed and stockpiled at the beginning of the wet season, it will be washed out as flows increase in the canal. The culvert features are more permanent. The washed out condition is included in the TUFLOW model based on the cbec 2010 survey with the invert measuring 8.5 feet NAVD88, which is approximately 5 feet higher than the bed profile in the vicinity of the gated channel connection to the canal.

3 GATE CONFIGURATION

A series of 6 new gates at the Sacramento Weir were used to regulate flows into the Sacramento Bypass up to 6000 cfs. For this analysis, it was assumed that the new gates were installed directly below the existing bays of the Sacramento Weir on the southern end of the weir (see Figure 4). The new gate dimensions are provided in Table 1, and generally consist of 30 foot wide gates with inverts of 7 feet NAVD88. Gate operations were optimized to maximize discharges into the Sacramento Bypass up to 6000 cfs for river stages in front of the Sacramento Weir up to elevations corresponding to the I Street water surface elevation trigger of 30.04 feet NAVD88. After the I Street elevation trigger is met, the Sacramento Weir is opened and the new gates will remain open per their last know configuration.

Sluice gates or radial gates could be used, but radial gates may offer the greatest flexibility in terms of real-time operations as well as constructability to minimize debris accumulation on the lift components. A gate optimization routine in RAS (see Section 4) was used to configure the size and number of gates as well as determine the individual gate openings relative to river stage. In general, gate widths were limited to 30 feet with 12 foot pillars between them. The pillars are wider than the Fremont Weir alternatives because the 30 foot new gates are situated directly beneath individual bays of the Sacramento Weir which are generally 40 feet wide. Gates 1 and 2 were limited in height to prevent the top of the gate from extending above the existing weir sill (24 feet NAVD 88) during a flood event when the Sacramento Weir is open and the new gate is open. The resulting gate configuration is shown in Table 1 and depicted in Figure 4. The gate opening schedules are shown in Table 2. The river stage versus total gate flow relationship is shown in Figure 5.

Table 1. Gate Configuration

Gate #	Gate Invert (NAVD 88 ft)	Gate Height (ft)	Gate Width (ft)
Gate 1	7	7	30
Gate 2	7	11	30
Gate 3 to Gate 6	7	14	30

Table 2. Gate Operations

Sacramento River Stage (ft)	Total flow (cfs)	Gate 1 Opening (ft)	Gate 2 Opening (ft)	Gate 3 Opening (ft)	Gate 4 Opening (ft)	Gate 5 Opening (ft)	Gate 6 Opening (ft)	Gate 1 Velocity (fps)	Gate 2 Velocity (fps)	Gate 3 Velocity (fps)	Gate 4 Velocity (fps)	Gate 5 Velocity (fps)	Gate 6 Velocity (fps)
11.0	131	7	11	14	14	14	14	0.2	0.2	0.2	0.2	0.2	0.2
12.0	498	7	11	14	14	14	14	0.6	0.6	0.6	0.6	0.6	0.6
13.0	1005	7	11	14	14	14	14	0.9	0.9	0.9	0.9	0.9	0.9
14.0	1566	7	11	14	14	14	14	1.24	1.2	1.2	1.2	1.2	1.2
15.0	2715	7	11	14	14	14	14	1.79	1.9	1.9	1.9	1.9	1.9
16.0	3719	7	11	14	14	14	14	1.73	2.5	2.5	2.5	2.5	2.5
17.0	5180	7	11	14	14	14	14	2.08	3.2	3.2	3.2	3.2	3.2
17.1	5387	7	11	14	14	14	14	2.13	3.3	3.3	3.3	3.3	3.3
17.2	5623	7	11	14	14	14	14	2.20	3.4	3.4	3.4	3.4	3.4
17.3	5852	7	11	14	14	14	14	2.29	3.5	3.5	3.5	3.5	3.5
17.4	5952	7	11	14	14	9.8	0	2.80	4.4	4.4	4.4	4.22	
17.5	5955	7	11	14	9.8	0	0	3.45	5.8	5.8	5.41		
17.6	5952	7	11	14	7.5	0	0	4.01	6.6	6.6	4.01		
17.7	5953	7	11	14	2.5	0	0	4.49	7.3	7.3	4.49		
17.8	5965	7	11	10.5	0	0	0	4.91	7.8	7.65			
17.9	5973	7	11	9.8	0	0	0	5.30	8.2	7.41			
18.0	5983	7	11	9.3	0	0	0	5.68	8.49	6.86			
18.1	5965	7	11	9.1	0	0	0	6.04	8.77	6.61			
18.2	5957	7	11	8.6	0	0	0	6.38	9.00	6.38			
18.3	5958	7	11	7.5	0	0	0	6.70	9.23	6.70			
18.4	5961	7	11	6.6	0	0	0	6.99	9.42	6.99			
18.5	5958	7	11	5.8	0	0	0	7.29	9.57	7.29			
18.6	5958	7	11	5.1	0	0	0	7.56	9.73	7.56			

Table 2. Gate Operations (continued)

Sacramento River Stage (ft)	Total flow (cfs)	Gate 1 Opening (ft)	Gate 2 Opening (ft)	Gate 3 Opening (ft)	Gate 4 Opening (ft)	Gate 5 Opening (ft)	Gate 6 Opening (ft)	Gate 1 Velocity (fps)	Gate 2 Velocity (fps)	Gate 3 Velocity (fps)	Gate 4 Velocity (fps)	Gate 5 Velocity (fps)	Gate 6 Velocity (fps)
18.7	5952	7	11	4.5	0	0	0	7.84	9.84	7.84			
18.8	5955	7	11	4	0	0	0	8.09	9.95	8.09			
18.9	5951	7	11	3.5	0	0	0	8.35	10.07	8.35			
19.0	5959	7	11	3.1	0	0	0	8.58	10.18	8.58			
20.0	5960	7	10.9	0	0	0	0	10.82	11.28				
21.0	5953	7	8.2	0	0	0	0	13.06	13.06				
22.0	5976	7	6.2	0	0	0	0	15.09	15.09				
23.0	5968	7	5.4	0	0	0	0	16.04	16.04				
24.0	5953	7	5	0	0	0	0	16.54	16.54				
25.0	5973	7	4.7	0	0	0	0	17.02	17.02				
26.0	5979	7	4.4	0	0	0	0	17.48	17.48				
27.0	5973	7	4.1	0	0	0	0	17.94	17.94				
28.0	5955	7	3.8	0	0	0	0	18.38	18.38				
29.0	5982	7	3.6	0	0	0	0	18.81	18.81				
30.0	6001	7	3.3	0	0	0	0	19.24	19.24				

4 GATE LOGIC

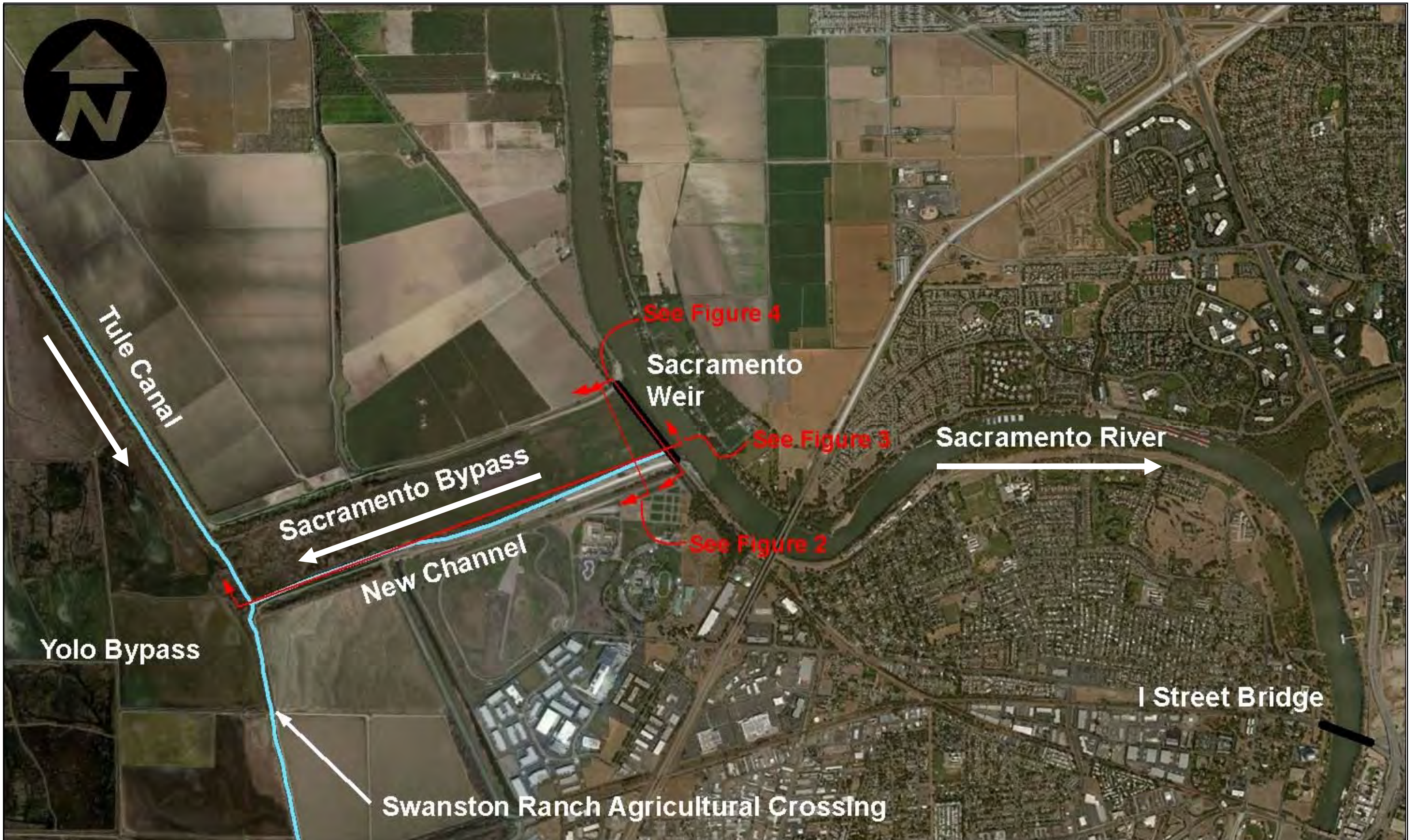
Rule operations in the RAS unsteady flow editor were used to optimize gate operations. For this analysis, the gates were allowed to open and close at a rate of one foot per minute during an unsteady flow analysis that used a stepped stage time series at the Sacramento River and a stage-discharge rating curve at Tule Canal based on calibrated TUFLOW simulations. The relatively quick opening rate of one foot per minute was used to speed up solution convergence, but can be set to something larger in TUFLOW to represent realistic rates or to accommodate model stability. The following logic was used in RAS to determine gate operations to maximize flows up to 6000 cfs based on Yolo Bypass and Sacramento River water surface elevations:

Define variable: TotalGateFlow = Sum of flow for all gates at current time step
Define variable: Gate1Opening = Opening of gate 1 at current time step
Define variable: Gate2Opening = Opening of gate 2 at current time step
Define variable: Gate3Opening = Opening of gate 3 at current time step
Define variable: Gate4Opening = Opening of gate 4 at current time step
Define variable: Gate5Opening = Opening of gate 5 at current time step
Define variable: Gate6Opening = Opening of gate 6 at current time step
Define variable: MaximumGateOpening = maximum gate opening of gates 3 to 6
Define variable: MaximumGateOpening1 = maximum gate opening of gate 1
Define variable: MaximumGateOpening2 = maximum gate opening of gate 2

If TotalGateFlow < 5950 Then
If Gate1Opening < MaximumGateOpening1 Then
Set Opening of Gate 1 = Gate1Opening + 0.5
Else, If Gate2Opening < MaximumGateOpening2 Then
Set Opening of Gate 2 = Gate2Opening + 0.5
Else, If Gate3Opening < MaximumGateOpening Then
Set Opening of Gate 3 = Gate3Opening + 0.5
Else, If Gate4Opening < MaximumGateOpening Then
Set Opening of Gate 4 = Gate4Opening + 0.5
Else, If Gate5Opening < MaximumGateOpening Then
Set Opening of Gate 5 = Gate5Opening + 0.5
Else, If Gate6Opening < MaximumGateOpening Then
Set Opening of Gate 6 = Gate6Opening + 0.5
End If
Else, If TotalGateFlow > 6000 Then
If Gate6Opening > 0 Then
Set Opening of Gate 6 = Gate6Opening - 0.5
Else, If Gate5Opening > 0 Then
Set Opening of Gate 5 = Gate5Opening - 0.5
Else, If Gate4Opening > 0 Then
Set Opening of Gate 4 = Gate4Opening - 0.5

Else, If Gate3Opening > 0 Then
Set Opening of Gate 3 = Gate3Opening - 0.5
Else, If Gate2Opening > 0 Then
Set Opening of Gate 2 = Gate2Opening - 0.5
Else, If Gate1Opening > 0 Then
Set Opening of Gate 1 = Gate1Opening - 0.5
End If

End If

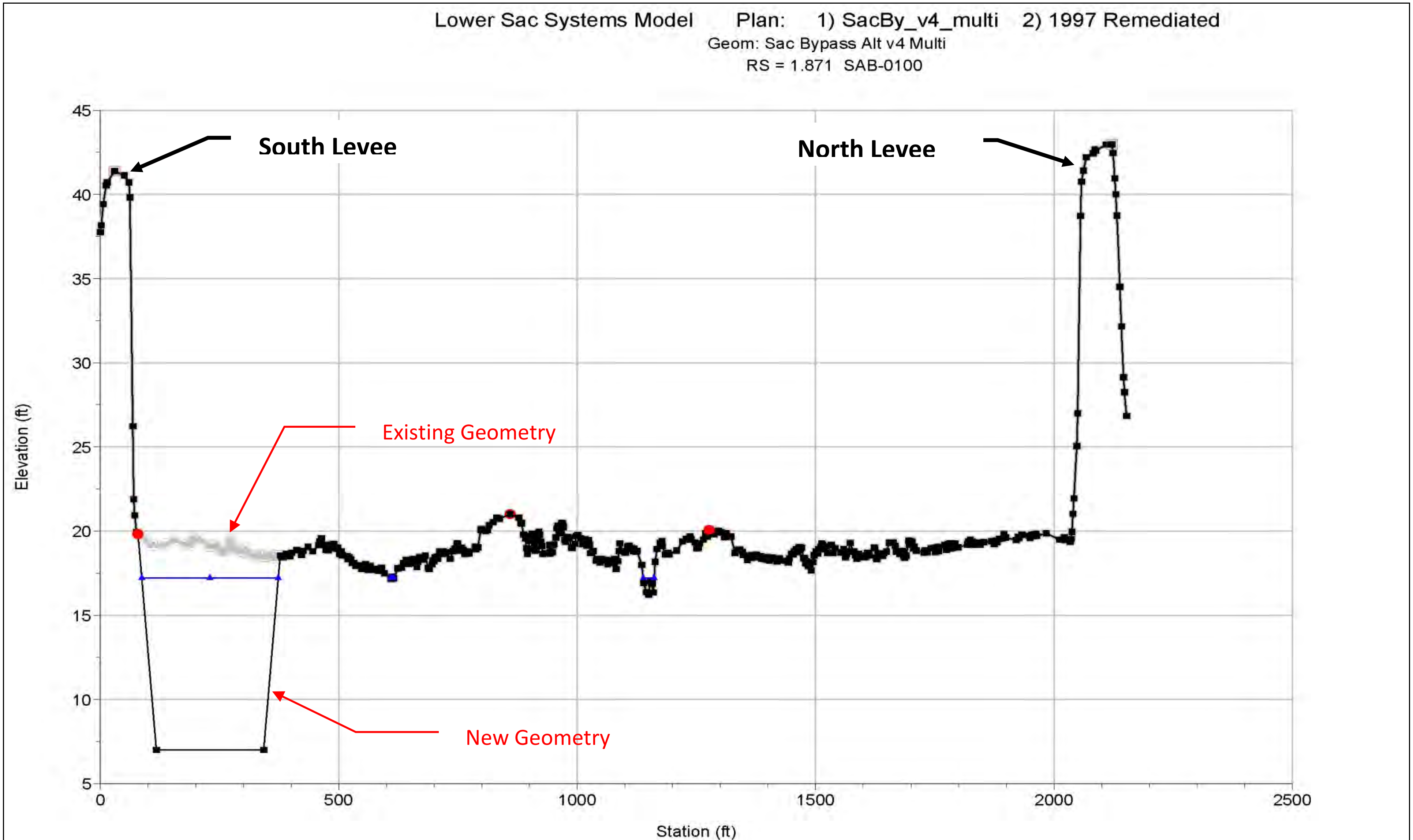


Notes: background courtesy of Bing Maps

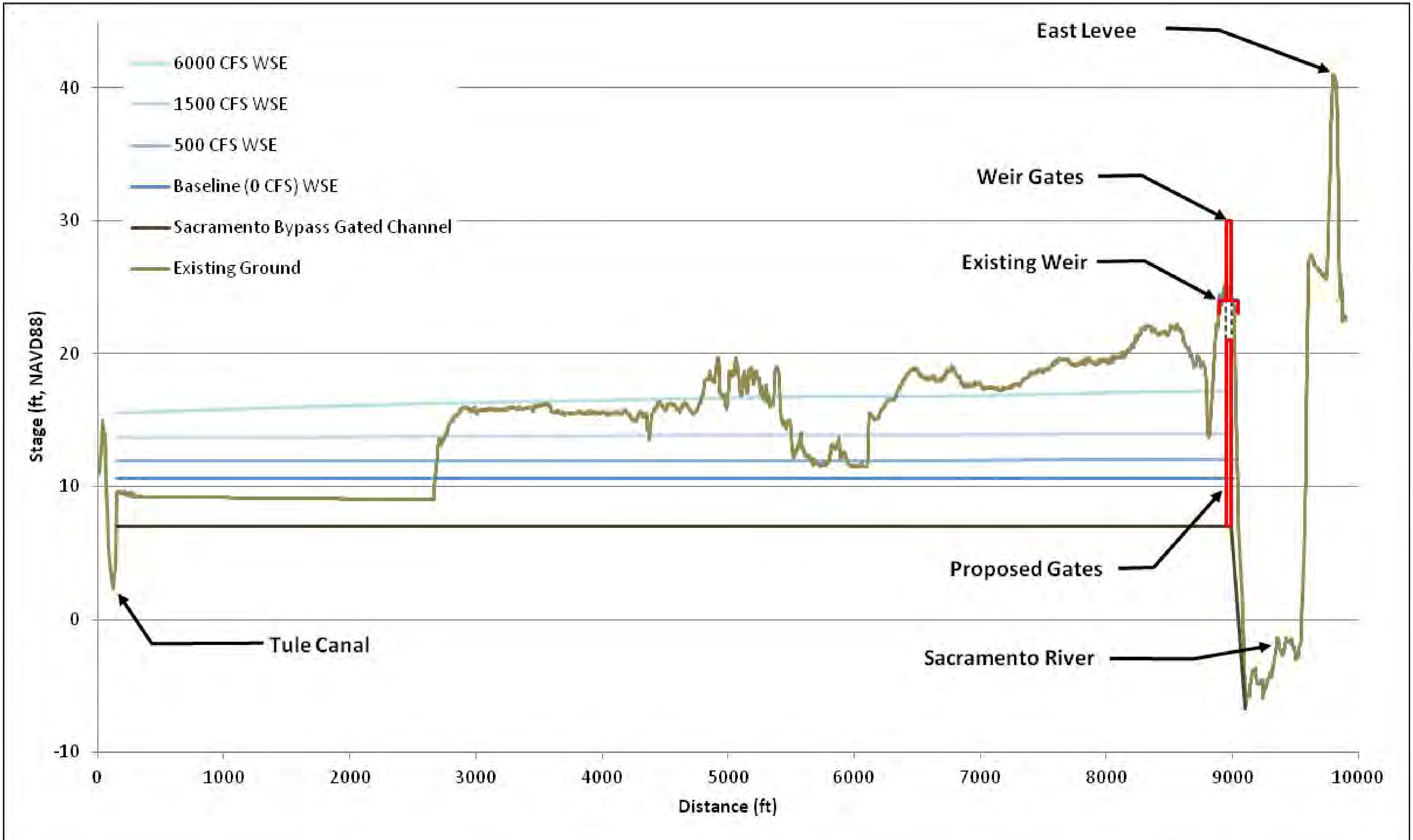
Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Sacramento Weir Alternative Location Map

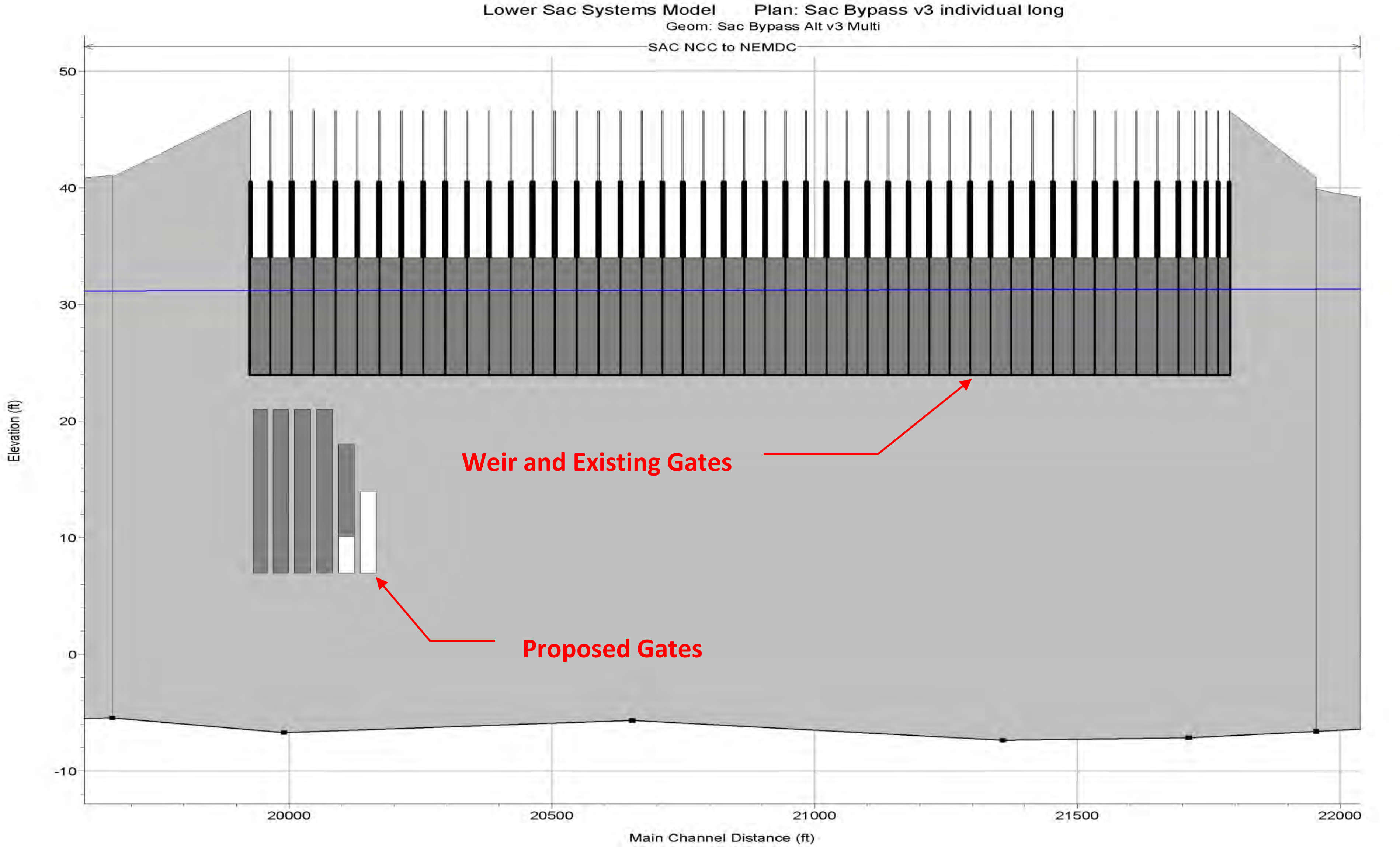
Project No. 13-1027	Created By: CRC	**Figure 1**



Notes: elevations are NAVD 88	cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* **Sacramento Bypass Channel Cross Section**		
		Project No. 13-1027	Created By: CRC	**Figure 2**



Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* **Sacramento Bypass Water Surface Profiles**		
		Project No. 13-1027	Created By: CRC	**Figure 3**

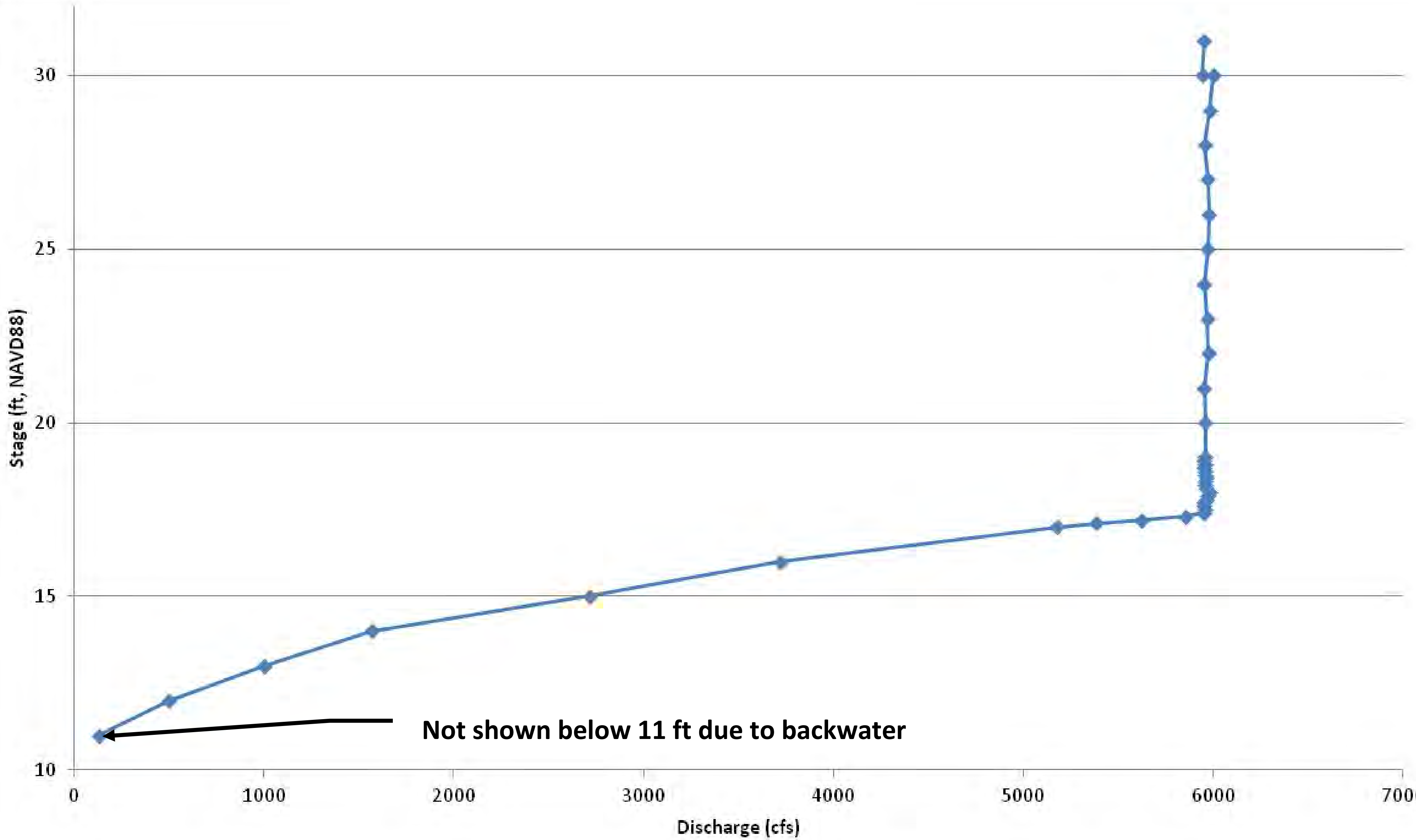


Notes: Elevations are NAVD 88

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Sacramento Weir Alternative – Proposed Gates

Project No. 13-1027	Created By: CRC	**Figure 4**



Notes: gate operations are optimized for 6000 cfs flow rate

cbec eco engineering

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Sacramento Weir Alternative Gate Rating Curve

Project No. 13-1027	Created By: CRC	**Figure 5**

TECHNICAL MEMORANDUM

Date:	April 14, 2014
To:	Project File
From:	Chris Campbell
Project:	13-1027 – Yolo Bypass Salmonid Habitat Restoration and Fish Passage Projects
Subject:	Fremont Weir Channel Alternatives and Gate Configurations

1 CHANNEL ALTERNATIVES

This Technical Memorandum (TM) details the development of the Fremont Weir Gated Channel Alternatives in HEC-RAS (RAS) for use in the calibrated and validated TUFLOW Classic hydrodynamic model developed to support the California Department of Water Resources (DWR) and US Bureau of Reclamation (USBR) Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (Project) Environmental Impact Statement and Environmental Impact Report (EIS/EIR). The Fremont Weir Gated Channel Alternatives include three of four alternatives being carried forward through the screening phase.

For the Fremont Weir Gated Channel Alternatives, each alternative was assumed to be graded along the east end of Fremont Weir and parallel to the flood levee, connecting the Sacramento River with the Tule Canal (see Figure 1). The channel profile and the gate configuration were analyzed in RAS to 1) understand the backwater effects on the gates from Yolo Bypass inundation given that proposed upstream inverts at the river are below the baseline water levels in the Tule Canal, and 2) optimize the gate openings for non-overtopping flows with the objective to maximize diversions from the Sacramento River up to 6000 cfs while minimizing head losses across the gate. Gate optimization was performed in RAS because such a function is not yet available in TUFLOW and gate logic is relatively new in TUFLOW.

The channel dimensions of the three Fremont Weir alternatives are provided in Table 1. For the reach of the proposed channels between the Sacramento River and Fremont Weir, a length of approximately 800 feet, the channel was graded from Fremont Weir to the Sacramento River at a slope of 0.0025 with a bottom width of 225 feet and 3:1 side slopes. This was done to reduce head losses within the channel upstream of the gate and minimize the change in the water surface elevation between the river and the weir.

Table 1. Fremont Weir Alternatives Channel Dimensions

Channel Size	Invert at Fremont Weir (ft, NAVD88)	Bottom Width (ft)	Slope	Side Slopes
Small	14.0	20	0.00016	3:1
Medium	17.5	225	0.00035	3:1
Large	14.0	225	0.00016	3:1

Downstream of the gated channel, there are three agricultural crossings on the Tule Canal between Tule Pond and the confluence with Knights Landing Ridge Cut (KLRC) (see Figure 1). Ag Crossing #1 is an earthen berm at the bottom of Tule Pond that impounds irrigation water for RD 1600 so it can be conveyed through the levee to the Elkhorn Basin. This berm can become degraded during Fremont Weir overtopping events. Ag Crossing#2 is 0.5 miles further south and is an earthen berm with one 32-inch culvert. Ag Crossing #3 is 0.6 miles further south and is an earthen berm with three 24-inch culverts.

The Small and Large channels tie into the Tule Canal just downstream of Ag Crossing #2. The Medium channel ties into the Tule Canal just upstream of Ag Crossing #2. As a result, all three channel alternatives require the partial removal and modification of the earthen berm forming Ag Crossing #1, but only the Small and Large channels require the additional modification to Ag Crossing #2. For the purposes of this analysis, and as demonstrated by the backwater effects from the existing channel capacity on the future gate location at the river during low flows in the canal (see Section 2), it was assumed that all three agricultural crossings were replaced with railcar bridges as part of the alternatives to maximize the frequency of inundation from the Sacramento River. The railcar bridges were assumed to be 90 feet long, 3 feet deep, and situated on 2 foot wide abutments with wing walls. Figures 2 to 7 show the paired existing and future crossings for Ag Crossing #1, #2, and #3, respectively. Under gate operations, all future agricultural crossings were assumed to be fully open. Only Ag Crossing #1 has a hardened bed or concrete sill to accommodate the potential use of flashboards for water level control during the irrigation season.

2 WATER SURFACE PROFILES

For this analysis, the Tule Canal was assumed to have flow contributions of 500 cfs, 350 cfs, 50 cfs, and 300 cfs from KLRC, Cache Creek Settling Basin, Willow Slough, and Putah Creek, respectivley, for existing conditions and all three alternatives. To better understand system performance and hydraulic constraints prior to proceeding with configuring the gates, three steady state inflows of 500 cfs, 1,500 cfs, and 6,000 cfs were introduced at the northern end of Tule Pond. The water surface elevations in the RAS model at the confluence with KLRC were based on calibrated TUFLOW simulations using the above stated flow conditions. Water surface profile comparisons for existing conditions and the Small, Medium, and Large channel alternatives are shown in Figures 8 to 10, respectively. Table 2 lists the water surface elevations at the northern limit of Tule Pond as well as at Ag Crossing #1, #2, and #3.

The differences in water surface elevations between existing conditions and the alternatives are largely controlled by the backwater effects from the limited capacity of the Tule Canal downstream of KLRC and the agricultural crossings upstream of KLRC. For gate flows of 500 cfs, the existing agricultural crossings, especially Ag Crossing #1, control the water surface condition upstream of Tule Pond near the proposed gate and create as much as 3 feet of backwater relative to the Large channel. This is somewhat reduced for the Small channel with only 2 feet of backwater, but this is because the capacity of the Small channel is the limiting factor. For gate flows of 1,500 cfs, backwater from KLRC and Ag Crossing #1 create as much as 1 foot of backwater relative to the Large channel. For gate flows of 6,000 cfs under non-overtopping events, backwater from KLRC and Ag Crossing #1 create as much as 1 foot of backwater relative to the Large channel. Due to the desire to maximize the frequency of Yolo Bypass inundation, and limit backwater effects during gate operations, this water surface profile comparison reinforces the need to improve the conveyance capacity at the three agricultural crossings (i.e., rail car bridges).

Table 2. Water Surface Elevation Comparisons

Water Surface Elevation at Northern Limit of Tule Pond (ft, NAVD88)			
Channel / Discharge (cfs)	**500**	**1500**	**6000**
Existing	21.1	21.9	24.4
Small	19.3	21.3	24.3
Medium	18.6	21.0	23.9
Large	18.3	20.7	23.5
Water Surface Elevation at Ag Crossing #1 (ft, NAVD88)			
Channel / Discharge (cfs)	**500**	**1500**	**6000**
Existing	21.0	21.6	23.0
Small	18.4	20.6	23.0
Medium	18.4	20.8	22.9
Large	18.3	20.6	22.9
Water Surface Elevation at Ag Crossing #2 (ft, NAVD88)			
Channel / Discharge (cfs)	**500**	**1500**	**6000**
Existing	18.4	20.4	22.8
Small	18.3	20.5	22.8
Medium	18.3	20.6	22.8
Large	18.2	20.4	22.8
Water Surface Elevation at Ag Crossing #3 (ft, NAVD88)			
Channel / Discharge (cfs)	**500**	**1500**	**6000**
Existing	18.3	20.4	22.7
Small	18.2	20.4	22.7
Medium	18.2	20.4	22.7
Large	18.2	20.4	22.7

3 GATE CONFIGURATION

A series of gates at the channel connection with the Sacramento River were used to maximize the flow into the Yolo Bypass for non-overtopping flow events up to 6,000 cfs. A gate optimization routine in RAS (see Section 4) was used to configure the size and number of gates as well as determine the individual gate openings relative to river stage. In general, gate widths were limited to 30 ft in width with 3 ft pillars between them. Some of the gates were limited in height to prevent them from extending above the existing weir crest (32.8 feet NAVD 88) during an overtopping event. After Fremont Weir overtops, the gates will remain open per their last know configuration. Sluice gates or radial gates could be used, but radial gates may offer the greatest flexibility in terms of real-time operations as well as constructability to minimize debris accumulation on the lift components. The gates could also be operated individually or in unison. For the Small channel, the bottom width of the channel was widened to accommodate three gates to minimize the head loss across the gate structure. The resulting gate configurations are shown in Table 3 for individual and unison operations. The gate configurations for individual operation are shown in Figures 11, 14, and 16 for the Small, Medium, and Large channels, respectively. The gate configurations for the unison operation are shown in Figures 12, 15, and 17 for the Small, Medium, and Large channels, respectively. The resulting gate opening schedules are shown in Tables 4, 5, and 6 for the Small, Medium, and Large channels, respectively. However, for the purposes of the TUFLOW modeling, the gates were assumed 1) to be radial such that lift components do not protrude above the top of the weir crest, and 2) operate individually assuming that a few gates with taller openings would be more favorable to fish passage than all gates open with potentially very short openings.

The river stage versus gate flow relationships are shown in Figure 18. For example, at a river stage of 24 feet NAVD88, the Small, Medium, and Large gated channels can convey 2201 cfs, 4313 cfs, and 5886 cfs, respectively. Relative to the Small channel, the Medium channel conveys twice as much flow and the Large channel conveys three times as much flow at elevation 24 feet.

Table 3. Gate Configurations

Channel Size	Invert at River (ft, 88)	Bottom Width at Gate (ft)	Gate Invert (ft)	Gate Height (ft)	Gate Width (ft)	Number of Gates
Individual Operation						
Small	14	115	14	8, 14	30	3
Medium	17.5	225	17.5	6, 12	30	6
Large	14	225	14	7.5, 10	30	6
Unison Operation						
Small	14	115	14	11.5	30	3
Medium	17.5	225	17.5	7.5	30	6
Large	14	225	14	10	30	6

Table 4. Small Individual Gate Operations

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate 1 Opening (ft)	Gate 2 Opening (ft)	Gate 3 Opening (ft)	Gate 1 Velocity (fps)	Gate 2 Velocity (fps)	Gate 3 Velocity (fps)
15.5	5	8	8	14	0.04	0.04	0.04
16.0	42	8	8	14	0.2	0.2	0.2
17.0	112	8	8	14	0.4	0.4	0.4
18.0	198	8	8	14	0.5	0.5	0.5
19.0	321	8	8	14	0.7	0.7	0.7
20.0	518	8	8	14	1.0	1.0	1.0
21.0	805	8	8	14	1.3	1.3	1.3
22.0	1111	8	8	14	1.5	1.5	1.5
23.0	1590	8	8	14	2.1	2.1	2.2
24.0	2201	8	8	14	2.3	2.3	3.6
25.0	2957	8	8	14	3.0	3.0	4.6
26.0	3910	8	8	14	3.7	3.7	5.9
27.0	5001	8	8	14	4.6	4.6	7.2
27.1	5119	8	8	14	4.7	4.7	7.3
27.2	5237	8	8	14	4.7	4.7	7.5
27.3	5355	8	8	14	4.8	4.8	7.6
27.4	5473	8	8	14	4.9	4.9	7.8
27.5	5591	8	8	14	5.0	5.0	7.9
27.6	5706	8	8	14	5.1	5.1	8.0
27.7	5822	8	8	14	5.2	5.2	8.1
27.8	5938	8	8	14	5.3	5.3	8.2
27.9	5951	8	8	13.01	5.6	5.6	7.8
28.0	5951	8	8	12.47	6.0	6.0	7.3
28.1	5952	8	8	12.14	6.3	6.3	8.0
28.2	5950	8	8	11.87	6.6	6.6	7.8
28.3	5951	8	8	11.66	6.9	6.9	7.5
28.4	5951	8	8	11.43	7.2	7.2	7.2
28.5	5950	8	8	10.4	7.5	7.5	7.5
28.6	5951	8	8	9.5	7.8	7.8	7.8
28.7	5951	8	8	8.68	8.0	8.0	8.0
28.8	5951	8	8	7.93	8.3	8.3	8.3
28.9	5951	8	8	7.25	8.5	8.5	8.5
29.0	5951	8	8	6.62	8.8	8.8	8.8
29.1	5951	8	8	6.04	9.0	9.0	9.0
29.2	5951	8	8	5.50	9.2	9.2	9.2

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate 1 Opening (ft)	Gate 2 Opening (ft)	Gate 3 Opening (ft)	Gate 1 Velocity (fps)	Gate 2 Velocity (fps)	Gate 3 Velocity (fps)
29.3	5951	8	8	5.00	9.4	9.4	9.4
29.4	5950	8	8	4.53	9.7	9.7	9.7
29.5	5951	8	8	4.10	9.9	9.9	9.9
29.6	5951	8	8	3.68	10.1	10.1	10.1
29.7	5951	8	8	3.29	10.3	10.3	10.3
29.8	5951	8	8	2.92	10.5	10.5	10.5
29.9	5952	8	8	2.58	10.7	10.7	10.7
30.0	5952	8	8	2.25	10.9	10.9	10.9
30.1	5950	8	8	1.93	11.1	11.1	11.1
30.2	5951	8	8	1.64	11.2	11.2	11.2
30.3	5952	8	8	1.36	11.4	11.4	11.4
30.4	5952	8	8	1.09	11.6	11.6	11.6
30.5	5951	8	8	0.78	11.8	11.8	11.8
30.6	5952	8	8	0.49	12.0	12.0	12.0
30.7	5950	8	8	0.20	12.2	12.2	12.2
30.8	5950	8	7.93	0.00	12.5	12.5	0.0
30.9	5952	8	7.68	0.00	12.7	12.7	0.0
31.0	5952	8	7.43	0.00	12.9	12.9	0.0
31.1	5952	8	7.19	0.00	13.1	13.1	0.0
31.2	5952	8	6.96	0.00	13.3	13.3	0.0
31.3	5952	8	6.74	0.00	13.5	13.5	0.0
31.4	5950	8	6.52	0.00	13.7	13.7	0.0
31.5	5952	8	6.32	0.00	13.9	13.9	0.0
31.6	5951	8	6.12	0.00	14.0	14.0	0.0
31.7	5952	8	5.93	0.00	14.2	14.2	0.0
31.8	5951	8	5.7399	0.00	14.4	14.4	0.0
31.9	5950	8	5.5599	0.00	14.6	14.6	0.0
32.0	5951	8	5.3899	0.00	14.8	14.8	0.0
32.1	5951	8	5.22	0.0	15.0	15.0	0.0
32.2	5952	8	5.06	0.0	15.2	15.2	0.0
32.3	5951	8	4.90	0.0	15.4	15.4	0.0
32.4	5952	8	4.75	0.0	15.6	15.6	0.0
32.5	5951	8	4.60	0.0	15.7	15.7	0.0
32.6	5953	8	4.46	0.0	15.9	15.9	0.0
32.7	5953	8	4.32	0.0	16.1	16.1	0.0
32.8	5998	8	4.32	0.0	16.2	16.2	0.0

Table 5. Medium Individual Gate Operations

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate 1 Opening (ft)	Gate 2 Opening (ft)	Gate 3 Opening (ft)	Gate 4 Opening (ft)	Gate 5 Opening (ft)	Gate 6 Opening (ft)	Gate 1 Velocity (fps)	Gate 2 Velocity (fps)	Gate 3 Velocity (fps)	Gate 4 Velocity (fps)	Gate 5 Velocity (fps)	Gate 6 Velocity (fps)
17.8	60	6	6	6	12	12	12	1.1	1.1	1.1	1.1	1.1	1.1
18.0	150	6	6	6	12	12	12	1.7	1.7	1.7	1.7	1.7	1.7
19.0	466	6	6	6	12	12	12	1.7	1.7	1.7	1.7	1.7	1.7
20.0	841	6	6	6	12	12	12	1.9	1.9	1.9	1.9	1.9	1.9
21.0	1286	6	6	6	12	12	12	2.0	2.0	2.0	2.0	2.0	2.0
22.0	1995	6	6	6	12	12	12	2.5	2.5	2.5	2.5	2.5	2.5
23.0	3079	6	6	6	12	12	12	3.1	3.1	3.1	3.1	3.1	3.1
24.0	4313	6	6	6	12	12	12	3.8	3.8	3.8	3.8	3.8	3.8
25.0	5549	6	6	6	12	12	12	3.9	3.9	3.9	5.1	5.1	5.1
25.3	5925	6	6	6	12	12	12	3.8	3.8	3.8	5.5	5.5	5.5
25.4	5952	6	6	6	12	12	5.5	4.2	4.2	4.2	6.3	6.3	4.2
25.5	5952	6	6	6	12	12	0.7	4.7	4.7	4.7	6.9	6.9	4.7
25.6	5951	6	6	6	12	7.0	0	5.1	5.1	5.1	7.3	6.7	0.0
25.7	5937	6	6	6	12	6.5	0	5.6	5.6	5.6	7.6	5.8	0.0
25.8	5952	6	6	6	12	4.6	0	5.9	5.9	5.9	7.8	5.9	0.0
25.9	5956	6	6	6	12	3.0	0	6.2	6.2	6.2	8.0	6.2	0.0
26.0	5953	6	6	6	12	1.6	0	6.6	6.6	6.6	8.2	6.6	0.0
26.1	5952	6	6	6	12	0.4	0	6.9	6.9	6.9	8.3	6.9	0.0
26.2	5960	6	6	6	8.0	0.0	0	7.2	7.2	7.2	8.6	0.0	0.0
26.3	5959	6	6	6	7.5	0.0	0	7.5	7.5	7.5	8.5	0.0	0.0
26.4	5966	6	6	6	7.2	0.0	0	7.8	7.8	7.8	8.2	0.0	0.0
26.5	5954	6	6	6	6.6	0.0	0	8.1	8.1	8.1	8.1	0.0	0.0
26.6	5951	6	6	6	5.8	0.0	0	8.3	8.3	8.3	8.3	0.0	0.0

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate 1 Opening (ft)	Gate 2 Opening (ft)	Gate 3 Opening (ft)	Gate 4 Opening (ft)	Gate 5 Opening (ft)	Gate 6 Opening (ft)	Gate 1 Velocity (fps)	Gate 2 Velocity (fps)	Gate 3 Velocity (fps)	Gate 4 Velocity (fps)	Gate 5 Velocity (fps)	Gate 6 Velocity (fps)
26.7	5951	6	6	6	5.1	0.0	0	8.6	8.6	8.6	8.6	0.0	0.0
26.8	5956	6	6	6	4.4	0.0	0	8.9	8.9	8.9	8.9	0.0	0.0
26.9	5957	6	6	6	3.7	0.0	0	9.2	9.2	9.2	9.2	0.0	0.0
27.0	5952	6	6	6	3.0	0.0	0	9.4	9.4	9.4	9.4	0.0	0.0
27.1	5953	6	6	6	2.4	0.0	0	9.7	9.7	9.7	9.7	0.0	0.0
27.2	5961	6	6	6	1.9	0.0	0	10.0	10.0	10.0	10.0	0.0	0.0
27.3	5951	6	6	6	1.3	0.0	0	10.3	10.3	10.3	10.3	0.0	0.0
27.4	5966	6	6	6	0.9	0.0	0	10.5	10.5	10.5	10.5	0.0	0.0
27.5	5960	6	6	6	0.4	0.0	0	10.8	10.8	10.8	10.8	0.0	0.0
27.6	5967	6	6	6	0.0	0.0	0	11.0	11.0	11.0	0.0	0.0	0.0
27.7	5952	6	6	5.5	0.0	0.0	0	11.3	11.3	11.3	0.0	0.0	0.0
27.8	5968	6	6	5.2	0.0	0.0	0	11.6	11.6	11.6	0.0	0.0	0.0
27.9	5962	6	6	4.8	0.0	0.0	0	11.8	11.8	11.8	0.0	0.0	0.0
28.0	5952	6	6	4.4	0.0	0.0	0	12.1	12.1	12.1	0.0	0.0	0.0
29.0	5978	6	6	2.7	0.0	0.0	0	13.6	13.6	13.6	0.0	0.0	0.0
30.0	5984	6	6	2.1	0.0	0.0	0	14.1	14.1	14.1	0.0	0.0	0.0
31.0	5958	6	6	1.5	0.0	0.0	0	14.7	14.7	14.7	0.0	0.0	0.0
32.0	5995	6	6	1.1	0.0	0.0	0	15.3	15.3	15.2	0.0	0.0	0.0
32.8	5972	6	6	0.7	0.0	0.0	0	15.7	15.7	15.7	0.0	0.0	0.0

Table 6. Large Individual Gate Operations

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate 1 Opening (ft)	Gate 2 Opening (ft)	Gate 3 Opening (ft)	Gate 4 Opening (ft)	Gate 5 Opening (ft)	Gate 6 Opening (ft)	Gate 1 Velocity (fps)	Gate 2 Velocity (fps)	Gate 3 Velocity (fps)	Gate 4 Velocity (fps)	Gate 5 Velocity (fps)	Gate 6 Velocity (fps)
15.5	15	7.5	7.5	7.5	10	10	10	0.1	0.1	0.1	0.1	0.1	0.1
16.0	94	7.5	7.5	7.5	10	10	10	0.3	0.3	0.3	0.3	0.3	0.3
17.0	260	7.5	7.5	7.5	10	10	10	0.5	0.5	0.5	0.5	0.5	0.5
18.0	434	7.5	7.5	7.5	10	10	10	0.6	0.6	0.6	0.6	0.6	0.6
19.0	725	7.5	7.5	7.5	10	10	10	0.8	0.8	0.8	0.8	0.8	0.8
20.0	1138	7.5	7.5	7.5	10	10	10	1.1	1.1	1.1	1.1	1.1	1.1
21.0	1713	7.5	7.5	7.5	10	10	10	1.4	1.4	1.4	1.4	1.4	1.4
22.0	2899	7.5	7.5	7.5	10	10	10	2.1	2.1	2.1	2.1	2.1	2.1
23.0	4335	7.5	7.5	7.5	10	10	10	2.5	2.5	2.5	3.3	3.3	3.3
24.0	5886	7.5	7.5	7.5	10	10	10	2.9	2.9	2.9	4.4	4.4	4.4
24.1	5951	7.5	7.5	7.5	10	10	4.7	3.3	3.3	3.3	5.4	5.4	3.3
24.2	5955	7.5	7.5	7.5	10	9	0	3.9	3.9	3.9	6.2	5.4	0
24.3	5952	7.5	7.5	7.5	10	6.9	0	4.4	4.4	4.4	7.0	4.4	0
24.4	5952	7.5	7.5	7.5	10	3.1	0	4.8	4.8	4.8	7.5	4.8	0
24.5	5954	7.5	7.5	7.5	10	0.4	0	5.2	5.2	5.2	7.8	5.2	0
24.6	5960	7.5	7.5	7.5	9.5	0	0	5.6	5.6	5.6	7.6	0	0
24.7	5946	7.5	7.5	7.5	9.1	0	0	6.0	6.0	6.0	7.3	0	0
24.8	5958	7.5	7.5	7.5	8.7	0	0	6.3	6.3	6.3	6.5	0	0
24.9	5958	7.5	7.5	7.5	7.5	0	0	6.6	6.6	6.6	6.6	0	0
25.0	5959	7.5	7.5	7.5	6.2	0	0	6.9	6.9	6.9	6.9	0	0
25.1	5954	7.5	7.5	7.5	5	0	0	7.2	7.2	7.2	7.2	0	0
25.2	5957	7.5	7.5	7.5	4	0	0	7.5	7.5	7.5	7.5	0	0
25.3	5958	7.5	7.5	7.5	3.1	0	0	7.8	7.8	7.8	7.8	0	0

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate 1 Opening (ft)	Gate 2 Opening (ft)	Gate 3 Opening (ft)	Gate 4 Opening (ft)	Gate 5 Opening (ft)	Gate 6 Opening (ft)	Gate 1 Velocity (fps)	Gate 2 Velocity (fps)	Gate 3 Velocity (fps)	Gate 4 Velocity (fps)	Gate 5 Velocity (fps)	Gate 6 Velocity (fps)
25.4	5962	7.5	7.5	7.5	2.3	0	0	8.0	8.0	8.0	8.0	0	0
25.5	5956	7.5	7.5	7.5	1.5	0	0	8.3	8.3	8.3	8.3	0	0
25.6	5955	7.5	7.5	7.5	0.8	0	0	8.5	8.5	8.5	8.5	0	0
25.7	5959	7.5	7.5	7.5	0.2	0	0	8.8	8.8	8.8	8.8	0	0
25.8	5957	7.5	7.5	7.1	0	0	0	9.0	9.0	9.0	0	0	0
25.9	5963	7.5	7.5	6.6	0	0	0	9.2	9.2	9.2	0	0	0
26.0	5964	7.5	7.5	6.1	0	0	0	9.4	9.4	9.4	0	0	0
26.1	5959	7.5	7.5	5.6	0	0	0	9.6	9.6	9.6	0	0	0
26.2	5966	7.5	7.5	5.2	0	0	0	9.8	9.8	9.8	0	0	0
26.3	5952	7.5	7.5	4.7	0	0	0	10.1	10.1	10.1	0	0	0
26.4	5963	7.5	7.5	4.3	0	0	0	10.3	10.3	10.3	0	0	0
26.5	5953	7.5	7.5	3.8	0	0	0	10.6	10.6	10.6	0	0	0
26.6	5956	7.5	7.5	3.4	0	0	0	10.8	10.8	10.8	0	0	0
26.7	5955	7.5	7.5	3	0	0	0	11.0	11.0	11.0	0	0	0
26.8	5970	7.5	7.5	2.7	0	0	0	11.2	11.2	11.2	0	0	0
26.9	5962	7.5	7.5	2.3	0	0	0	11.5	11.5	11.5	0	0	0
27.0	5970	7.5	7.5	2	0	0	0	11.7	11.7	11.7	0	0	0
27.1	5954	7.5	7.5	1.6	0	0	0	12.0	12.0	12.0	0	0	0
27.2	5956	7.5	7.5	1.3	0	0	0	12.2	12.2	12.2	0	0	0
27.3	5954	7.5	7.5	1	0	0	0	12.4	12.4	12.4	0	0	0
27.4	5973	7.5	7.5	0.8	0	0	0	12.6	12.6	12.6	0	0	0
27.5	5966	7.5	7.5	0.5	0	0	0	12.8	12.8	12.8	0	0	0
27.6	5956	7.5	7.5	0.2	0	0	0	13.1	13.1	13.1	0	0	0
27.7	5968	7.5	7.5	0	0	0	0	13.3	13.3	0	0	0	0

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate 1 Opening (ft)	Gate 2 Opening (ft)	Gate 3 Opening (ft)	Gate 4 Opening (ft)	Gate 5 Opening (ft)	Gate 6 Opening (ft)	Gate 1 Velocity (fps)	Gate 2 Velocity (fps)	Gate 3 Velocity (fps)	Gate 4 Velocity (fps)	Gate 5 Velocity (fps)	Gate 6 Velocity (fps)
27.8	5952	7.5	7.2	0	0	0	0	13.5	13.5	0	0	0	0
27.9	5960	7.5	7	0	0	0	0	13.7	13.7	0	0	0	0
28.0	5965	7.5	6.8	0	0	0	0	13.9	13.9	0	0	0	0
29.0	5960	7.5	5.3	0	0	0	0	15.5	15.5	0	0	0	0
30.0	5964	7.5	4.9	0	0	0	0	16.0	16.0	0	0	0	0
31.0	5950	7.5	4.5	0	0	0	0	16.5	16.5	0	0	0	0
32.0	5970	7.5	4.2	0	0	0	0	17.0	17.0	0	0	0	0
32.8	5997	7.5	4	0	0	0	0	17.4	17.4	0	0	0	0

Table 7. Small Unison Gate Operations

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate Opening (ft)	Gate Velocity (fps)
14.1	1	11.5	0.08
14.3	2	11.5	0.09
14.5	5	11.5	0.11
14.8	11.4	11.5	0.16
15	15.8	11.5	0.18
16	39.8	11.5	0.22
17	107	11.5	0.39
18	190	11.5	0.53
19	308	11.5	0.68
20	491	11.5	0.91
21	759	11.5	1.21
22	1030	11.5	1.43
23	1325	11.5	1.64
24	1806	11.5	2.01
25	2458	11.5	2.48
26	3248	11.5	3.14
27	4151	11.5	4.01
28	4988	11.5	4.82
29	5725	11.5	5.53
29.1	5801	11.5	5.60
29.2	5877	11.5	5.68
29.3	5951	11.5	5.76
29.4	5951	10.8	6.11
29.5	5951	10.3	6.43
29.6	5952	9.8	6.75
29.7	5951	9.4	7.05
29.8	5951	9.0	7.34
29.9	5951	8.7	7.62
30.0	5952	8.4	7.88
30.1	5951	8.1	8.14
30.2	5952	7.9	8.39
30.3	5952	7.7	8.63
30.4	5951	7.5	8.87
30.5	5950	7.3	9.11
30.6	5952	7.1	9.33
30.7	5953	6.9	9.54

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate Opening (ft)	Gate Velocity (fps)
30.8	5954	6.8	9.76
30.9	5951	6.6	9.97
31.0	5953	6.5	10.18
31.1	5951	6.4	10.38
31.2	5950	6.3	10.58
31.3	5952	6.1	10.77
31.4	5955	6.0	10.95
31.5	5950	5.93	11.15
31.6	5954	5.84	11.33
31.7	5955	5.75	11.51
31.8	5954	5.66	11.69
31.9	5956	5.58	11.86
32.0	5950	5.49	12.04
32.1	5954	5.42	12.21
32.2	5953	5.33	12.41
32.3	5950	5.24	12.62
32.4	5951	5.16	12.81
32.5	5956	5.09	13.00
32.6	5953	5.01	13.20
32.7	5955	4.94	13.39
32.8	5999	4.94	13.49

Table 8. Medium Unison Gate Operations

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate Opening (ft)	Gate Velocity (fps)
17.6	11	7.5	0.87
17.8	50	7.5	0.93
18	109	7.5	1.21
19	466	7.5	1.73
20	842	7.5	1.87
21	1286	7.5	2.04
22	1995	7.5	2.46
23	3070	7.5	3.10
24	4321	7.5	3.69
25	5635	7.5	4.17
25.1	5773	7.50	4.28
25.2	5910	7.50	4.38
25.3	5951	6.75	4.90

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate Opening (ft)	Gate Velocity (fps)
25.4	5952	6.49	5.10
25.5	5957	6.40	5.17
25.6	5955	6.35	5.21
25.7	5951	5.97	5.54
25.8	5953	5.60	5.91
25.9	5954	5.29	6.25
26.0	5952	5.02	6.59
26.1	5955	4.79	6.91
26.2	5952	4.58	7.22
26.3	5952	4.40	7.52
26.4	5952	4.24	7.80
26.5	5954	4.10	8.07
26.6	5953	3.97	8.33
26.7	5951	3.85	8.59
26.8	5953	3.73	8.87
26.9	5952	3.61	9.16
27.0	5952	3.50	9.45
27.1	5953	3.40	9.73
27.2	5956	3.31	10.00
27.3	5954	3.22	10.27
27.4	5956	3.14	10.54
27.5	5954	3.06	10.81
27.6	5957	2.99	11.07
27.7	5955	2.92	11.33
27.8	5960	2.86	11.58
27.9	5962	2.80	11.83
28	5960	2.74	12.08
29	5954	2.44	13.56
30	5958	2.34	14.15
31	5958	2.25	14.71
32	5958	2.17	15.25
32.8	5981	2.12	15.67

Table 9. Large Unison Gate Operations

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate Opening (ft)	Gate Velocity (fps)
15.5	15	10.0	0.06
16	94	10.0	0.26

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate Opening (ft)	Gate Velocity (fps)
17	260	10.0	0.48
18	434	10.0	0.60
19	725	10.0	0.81
20	1138	10.0	1.05
21	1713	10.0	1.36
22	2901	10.0	2.01
23	4360	10.0	2.69
24	5951	9.18	3.60
24.1	5953	8.39	3.94
24.2	5955	8.20	4.03
24.3	5951	7.54	4.38
24.4	5951	6.84	4.83
24.5	5951	6.30	5.25
24.6	5952	5.88	5.62
24.7	5951	5.53	5.98
24.8	5952	5.24	6.31
24.9	5953	4.99	6.63
25.0	5952	4.77	6.93
25.1	5952	4.58	7.22
25.2	5952	4.41	7.50
25.3	5954	4.26	7.76
25.4	5952	4.12	8.03
25.5	5956	4.00	8.27
25.6	5952	3.88	8.52
25.7	5956	3.78	8.75
25.8	5954	3.68	8.99
25.9	5954	3.59	9.21
26.0	5957	3.51	9.43
26.1	5956	3.43	9.65
26.2	5959	3.36	9.85
26.3	5958	3.29	10.06
26.4	5956	3.21	10.31
26.5	5960	3.14	10.55
26.6	5960	3.07	10.79
26.7	5955	3.00	11.03
26.8	5958	2.94	11.26
26.9	5958	2.88	11.49

Sacramento River Stage (ft, 88)	Total Gate Flow (cfs)	Gate Opening (ft)	Gate Velocity (fps)
27	5953	2.82	11.73
28	5960	2.38	13.91
29	5978	2.14	15.52
30	5973	2.07	16.03
31	5979	2.01	16.53
32	5970	1.95	17.01
32.8	5976	1.91	17.38

4 GATE LOGIC

Rule operations in the RAS unsteady flow editor were used to optimize gate operations for the various gated channel alternatives. A special operational parameter available in RAS called *Structure-Flow (Desired)* was used to determine gate operations to maximize a flow up to 6,000 cfs. The operational parameter *Structure-Flow (Desired)* adjusts the gate openings based on the Sacramento River water surface elevations and the gate characteristics. For this analysis, the gates were allowed to open and close at a rate of one foot per minute during an unsteady flow analysis that used a stepped stage time series at the river and a stage-discharge rating curve as the downstream boundary condition at KLRC. The relatively quick opening rate of one foot per minute was used to speed up solution convergence, but can be set to something larger in TUFLOW to represent realistic rates or accommodate model stability. The following logic was used in RAS to determine gate operations to maximize flows up to 6000 cfs based on Yolo Bypass and Sacramento River water surface elevations:

Define variable: TotalGateFlow = Sum of flow for all gates at current time step
Define variable: Gate1Opening = Opening of gate 1 at current time step
Define variable: Gate2Opening = Opening of gate 2 at current time step
Define variable: Gate3Opening = Opening of gate 3 at current time step
Define variable: Gate4Opening = Opening of gate 4 at current time step
Define variable: Gate5Opening = Opening of gate 5 at current time step
Define variable: Gate6Opening = Opening of gate 6 at current time step
Define variable: MaximumGateOpening1 = maxium gate opening (size 1)
Define variable: MaximumGateOpening2 = maxium gate opening (size 2)

If TotalGateFlow < 5950 Then
    If Gate1Opening < MaximumGateOpening1 Then
    Set Opening of Gate 1 = Gate1Opening + 0.1
    Else, If Gate2Opening < MaximumGateOpening1 Then
    Set Opening of Gate 2 = Gate2Opening + 0.1
    Else, If Gate3Opening < MaximumGateOpening1 Then
    Set Opening of Gate 3 = Gate3Opening + 0.1

Else, If Gate4Opening < MaximumGateOpening2 Then

Set Opening of Gate 4 = Gate4Opening + 0.1

Else, If Gate5Opening < MaximumGateOpening2 Then

Set Opening of Gate 5 = Gate5Opening + 0.1

Else, If Gate6Opening < MaximumGateOpening2 Then

Set Opening of Gate 6 = Gate6Opening + 0.1

End If

Else, If TotalGateFlow > 6000 Then

If Gate6Opening > 0 Then

Set Opening of Gate 6 = Gate6Opening - 0.1

Else, If Gate5Opening > 0 Then

Set Opening of Gate 5 = Gate5Opening - 0.1

Else, If Gate4Opening > 0 Then

Set Opening of Gate 4 = Gate4Opening - 0.1

Else, If Gate3Opening > 0 Then

Set Opening of Gate 3 = Gate3Opening - 0.1

Else, If Gate2Opening > 0 Then

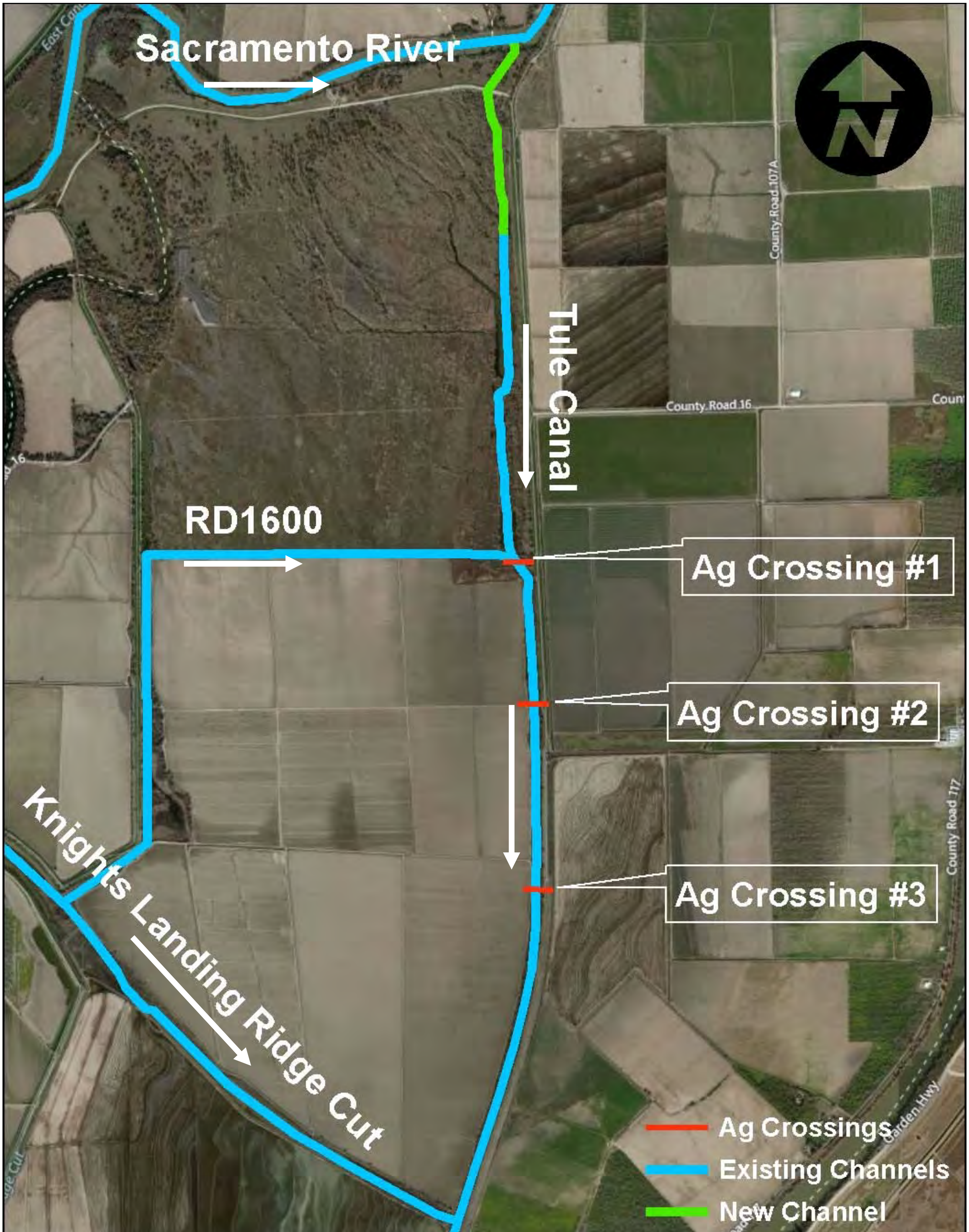
Set Opening of Gate 2 = Gate2Opening - 0.1

Else, If Gate1Opening > 0 Then

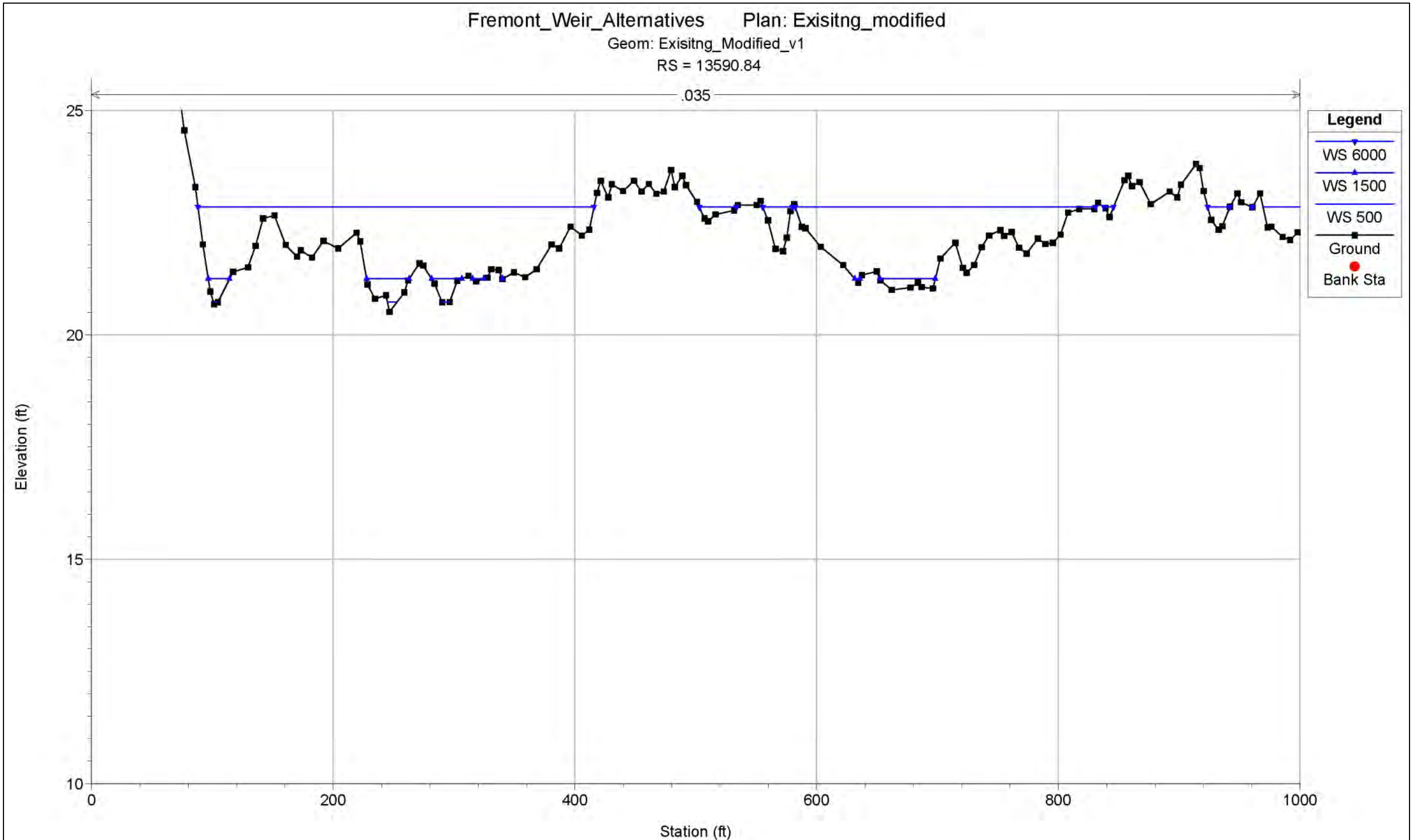
Set Opening of Gate 1 = Gate1Opening - 0.1

End If

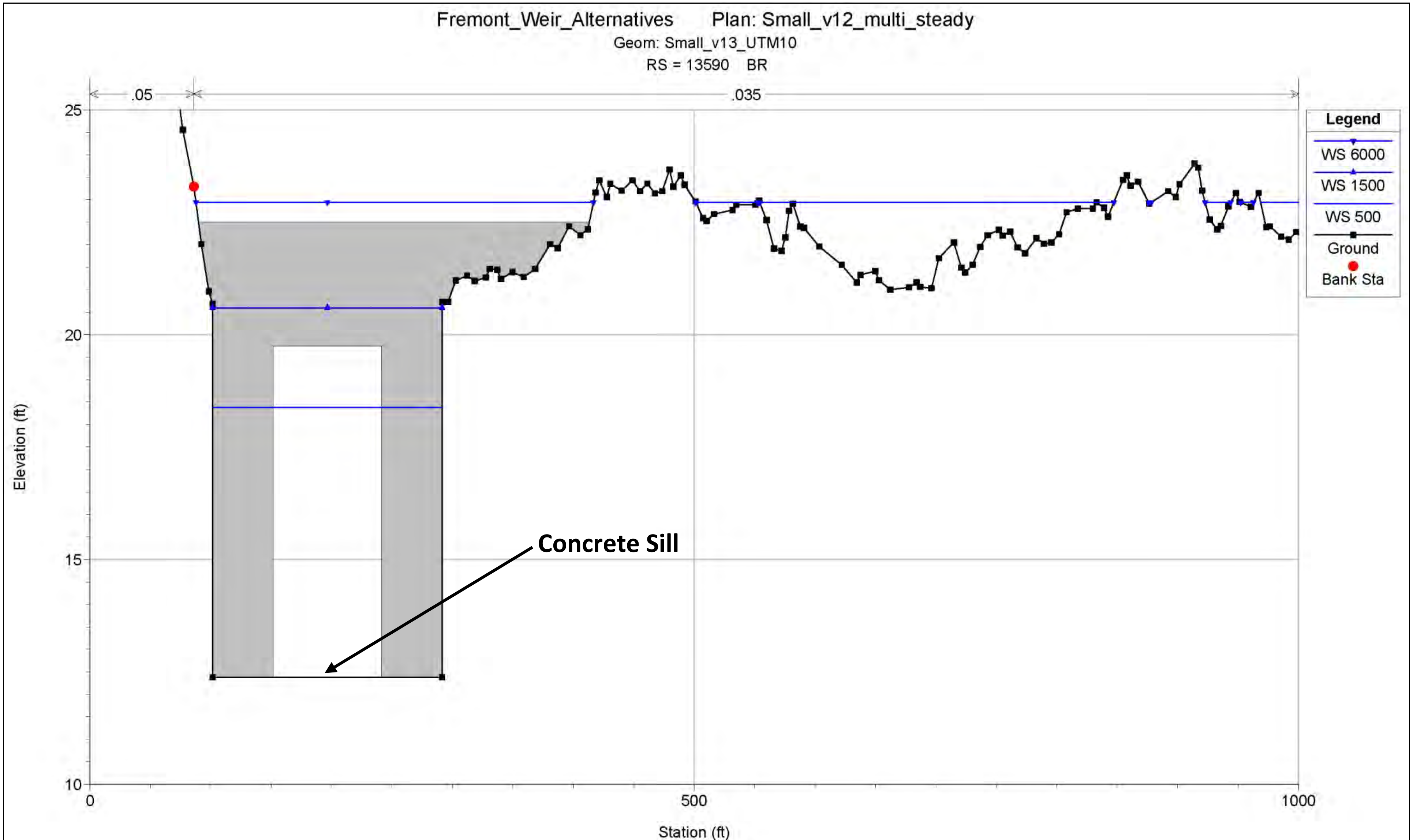
End If



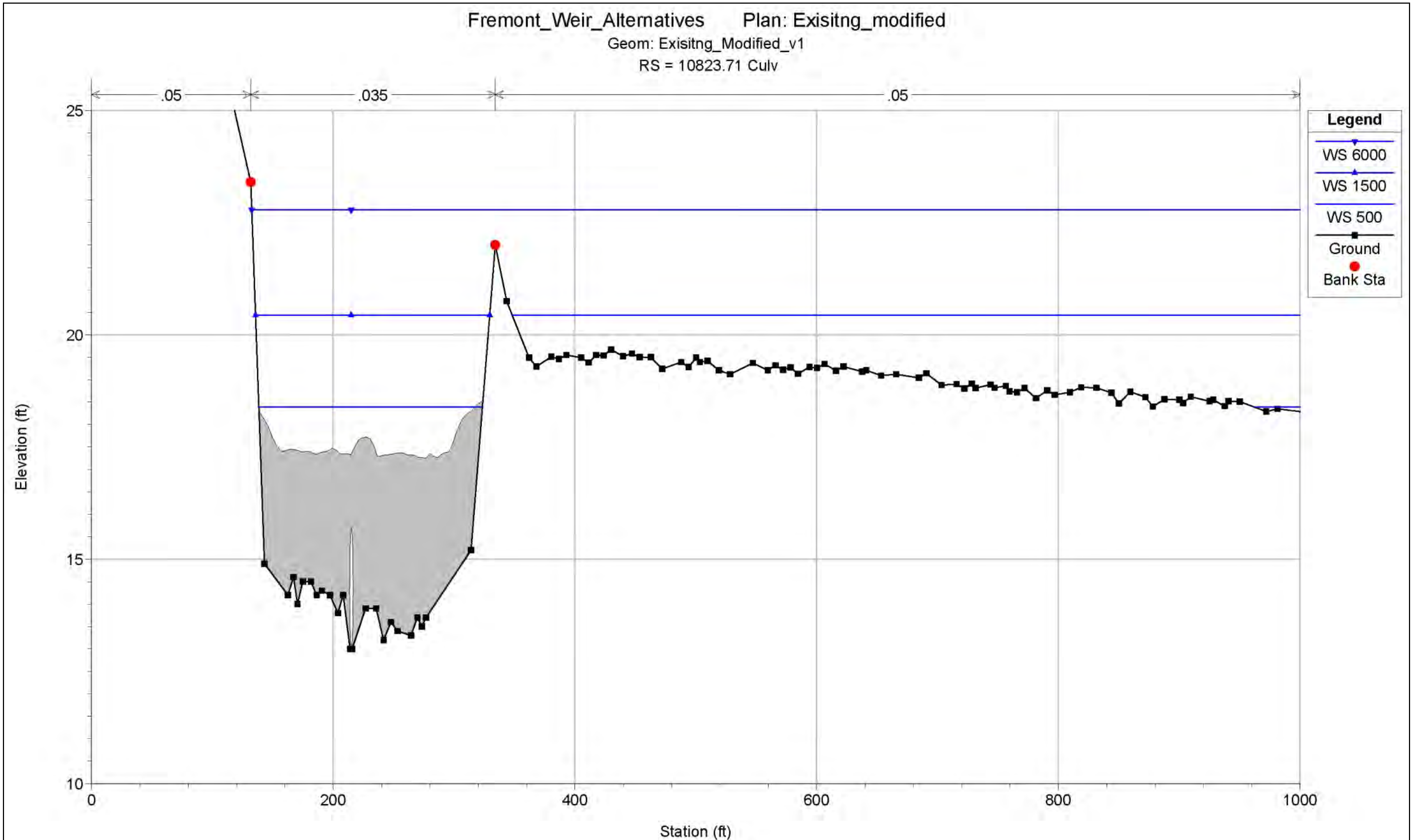
Notes: background courtesy of Bing Maps	cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* **Channel and Ag Crossing Locations**		
		Project No. 13-1027	Created By: CRC	**Figure 1**



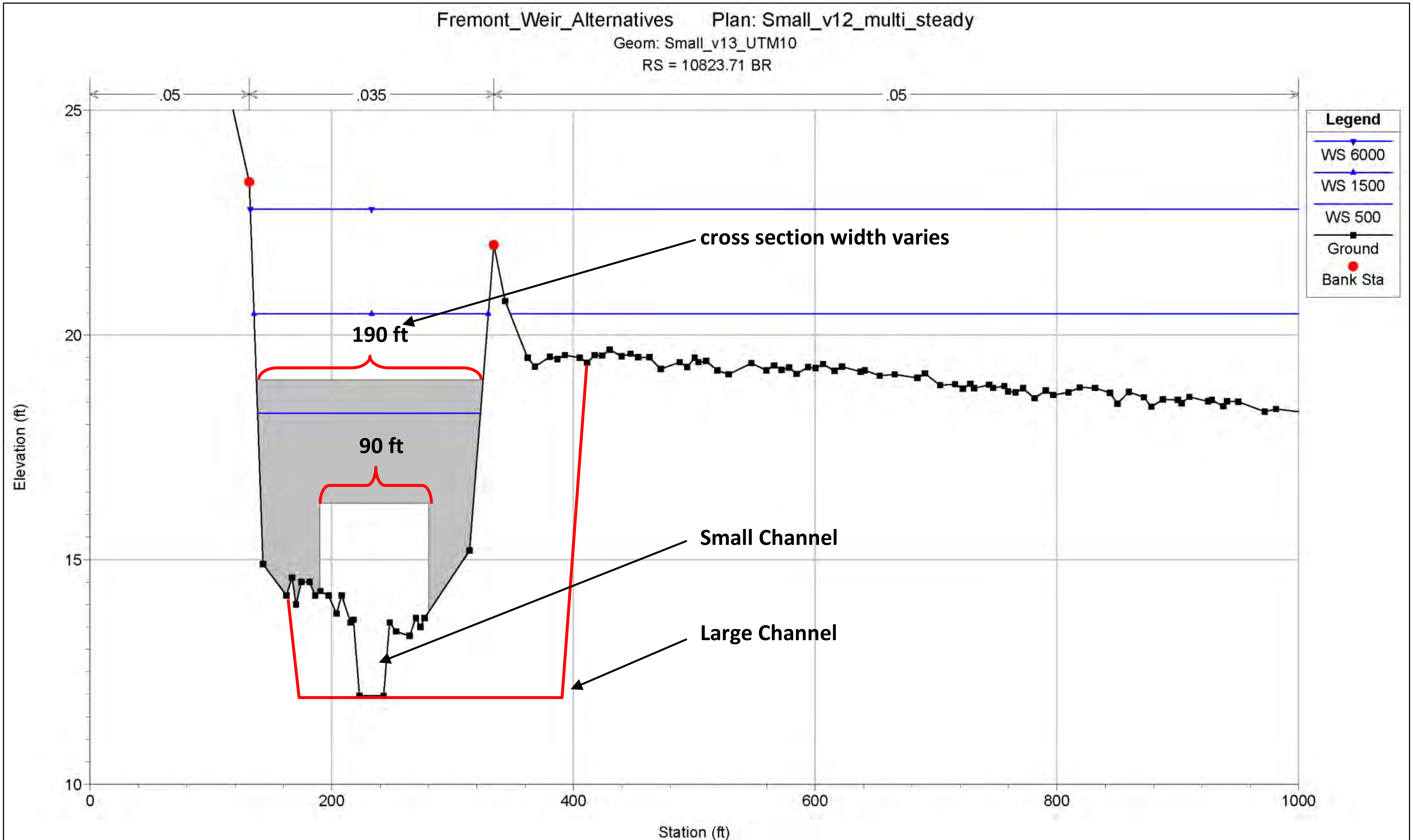
Notes:		*Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* **Ag Crossing #1 - Existing**		
		Project No. 13-1027	Created By: CRC	**Figure 2**



Notes: 90 foot long, 3 foot deep railcar bridge	cbec	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* **Ag Crossing #1 - Project**		
		Project No. 13-1027	Created By: CRC	**Figure 3**



Notes: earthen berm with 1, 2.7 foot diameter culvert	cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* **Ag Crossing #2 - Existing**	
		Project No. 13-1027	Created By: CRC	**Figure 4**



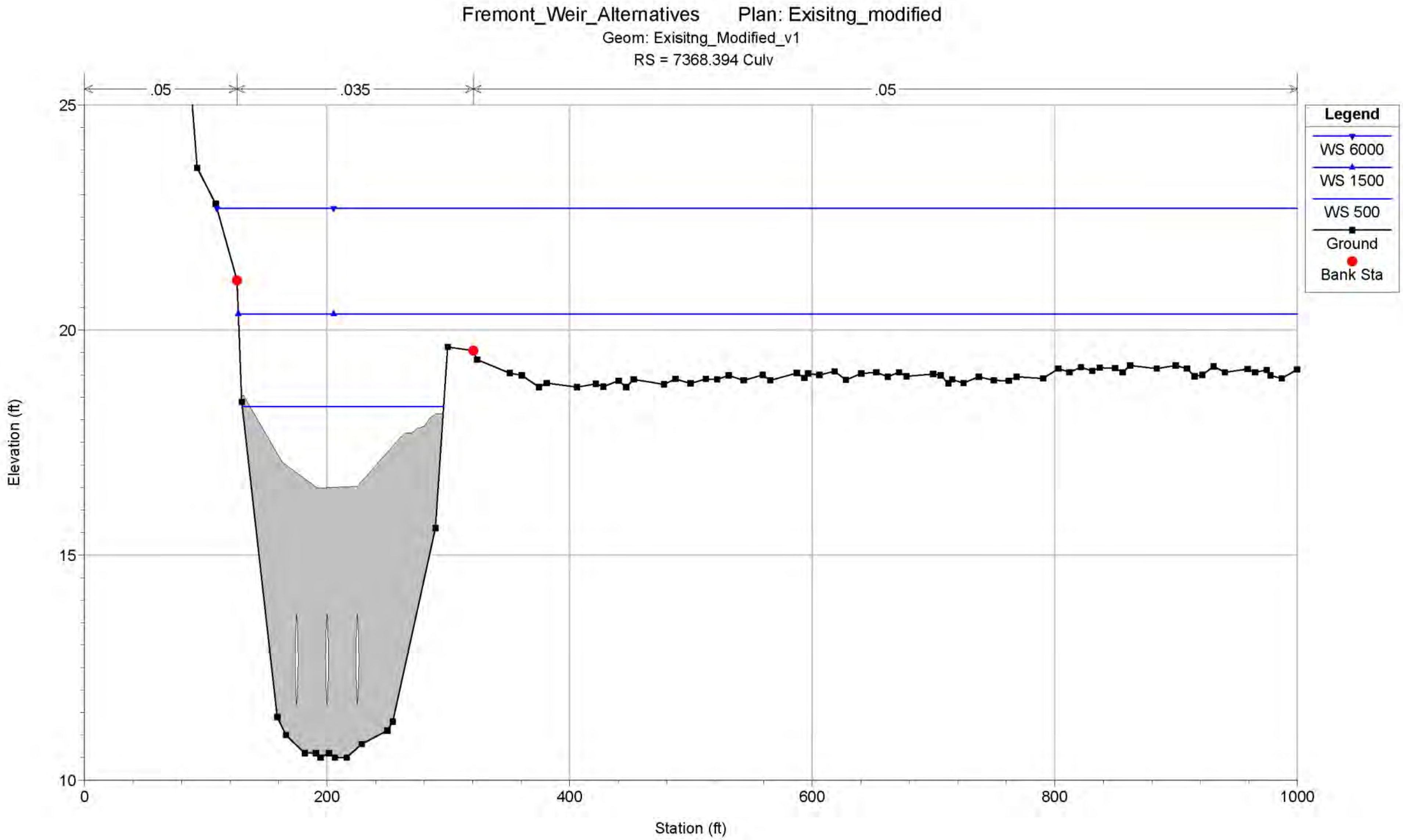
Notes: 90 foot long, 3 foot deep railcar bridge

cbec eco engineering

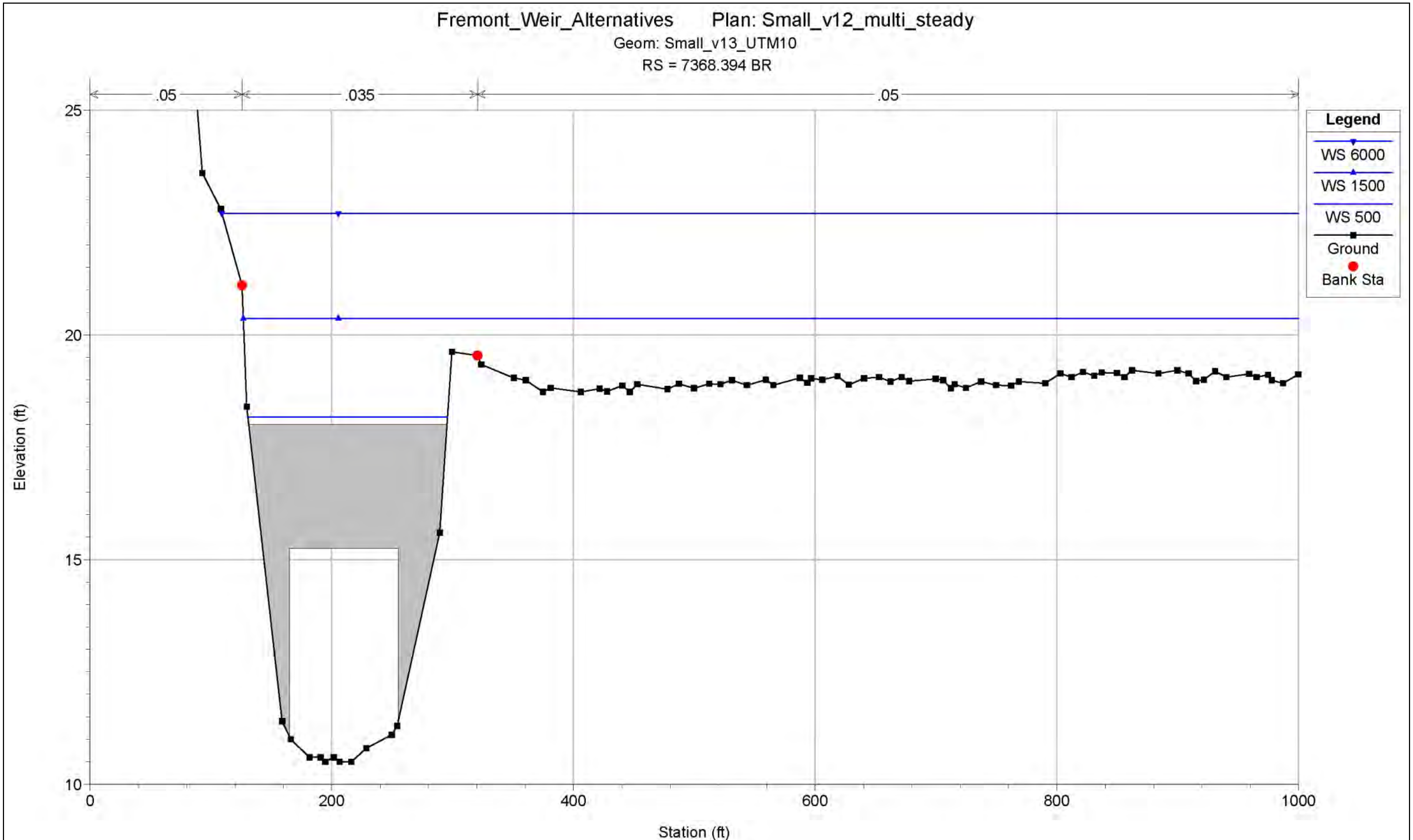
Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Ag Crossing #2 - Project

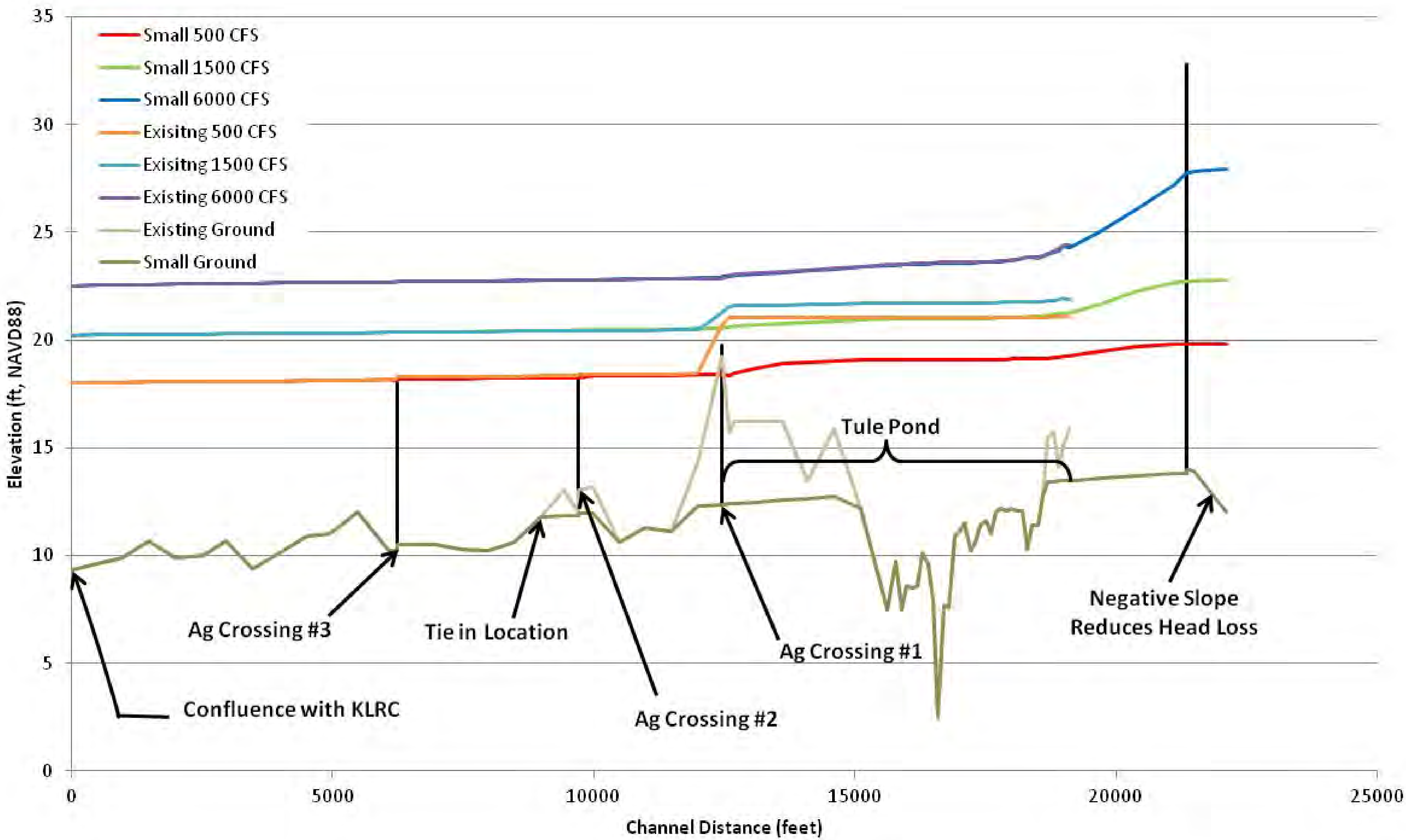
Project No. 13-1027	Created By: CRC	**Figure 5**



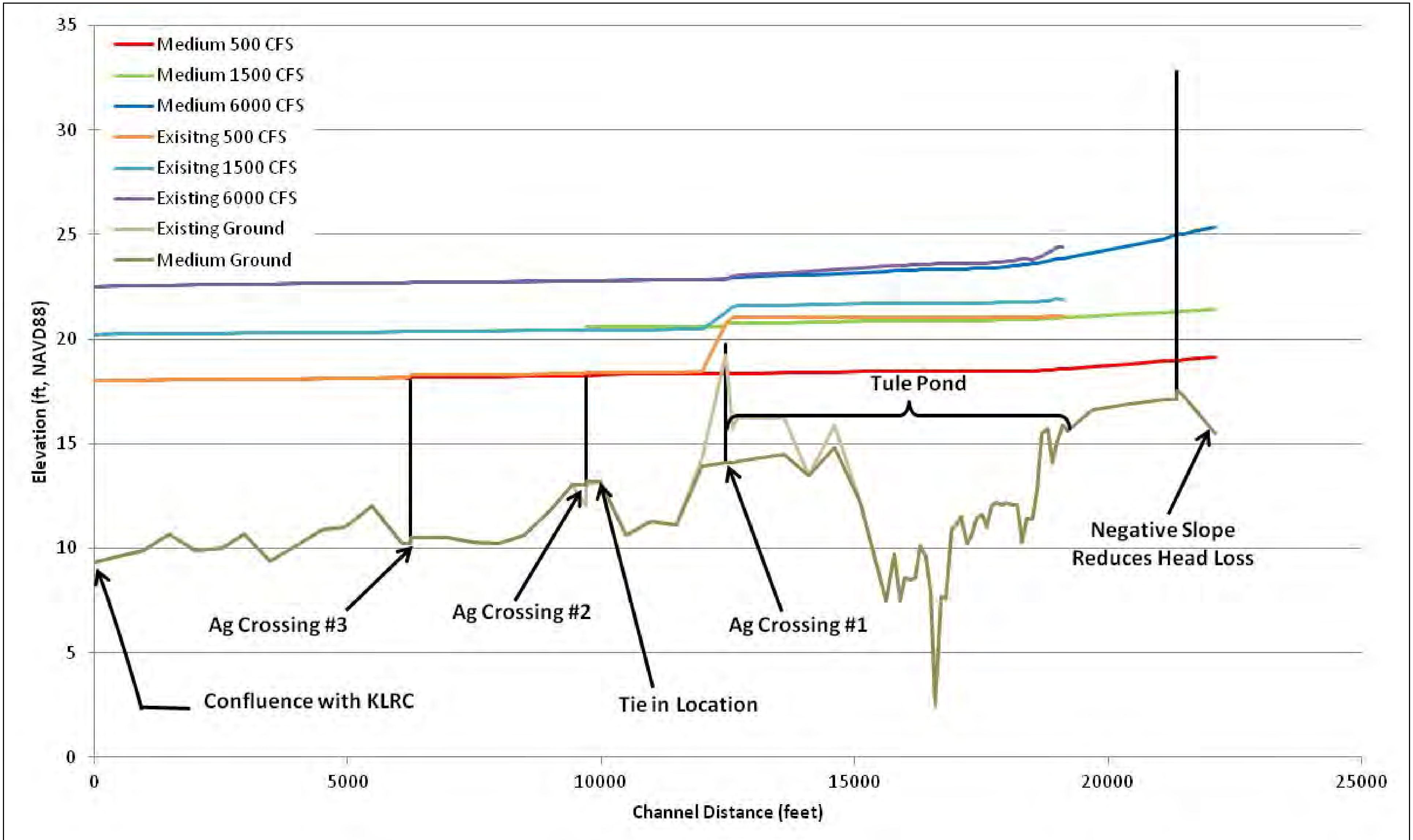
Notes: earthen berm with 3, 2 foot diameter culverts	cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* **Ag Crossing #3 - Existing**
	Project No. 13-1027 / Created By: CRC	**Figure 6**



Notes: 90 foot long, 3 foot deep railcar bridge	cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* **Ag Crossing #3 - Project**
		Project No. 13-1027 / Created By: CRC / **Figure 7**



Notes: Water surface profile comparison between existing conditions and the Small Channel alternative.	cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* **Small Channel Water Surface Profile Comparison**		
		Project No. 13-1027	Created By: CRC	**Figure 8**

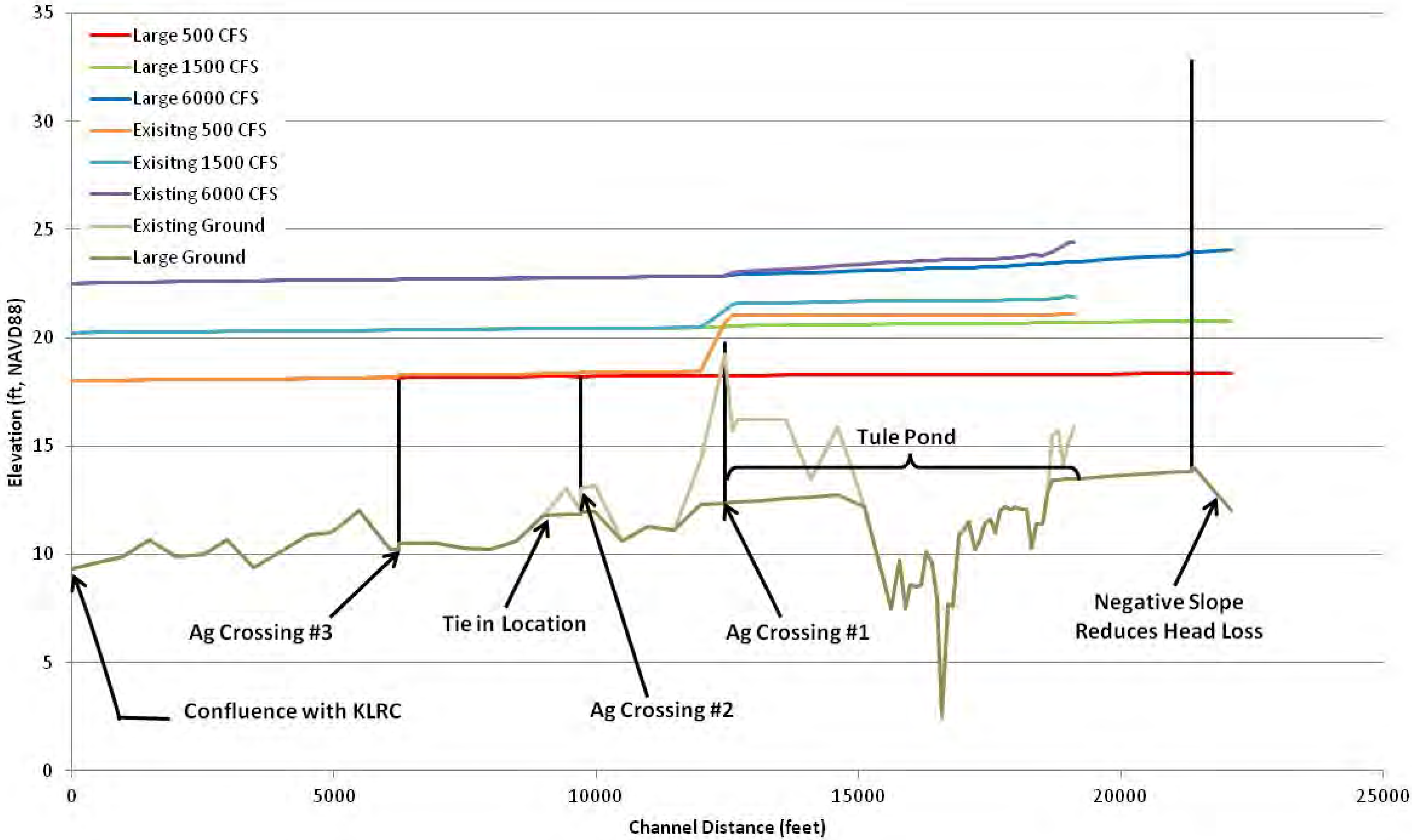


Notes: Water surface profile comparison between existing conditions and the Medium Channel alternative.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Medium Channel Water Surface Profile Comparison

Project No. 13-1027	Created By: CRC	**Figure 9**

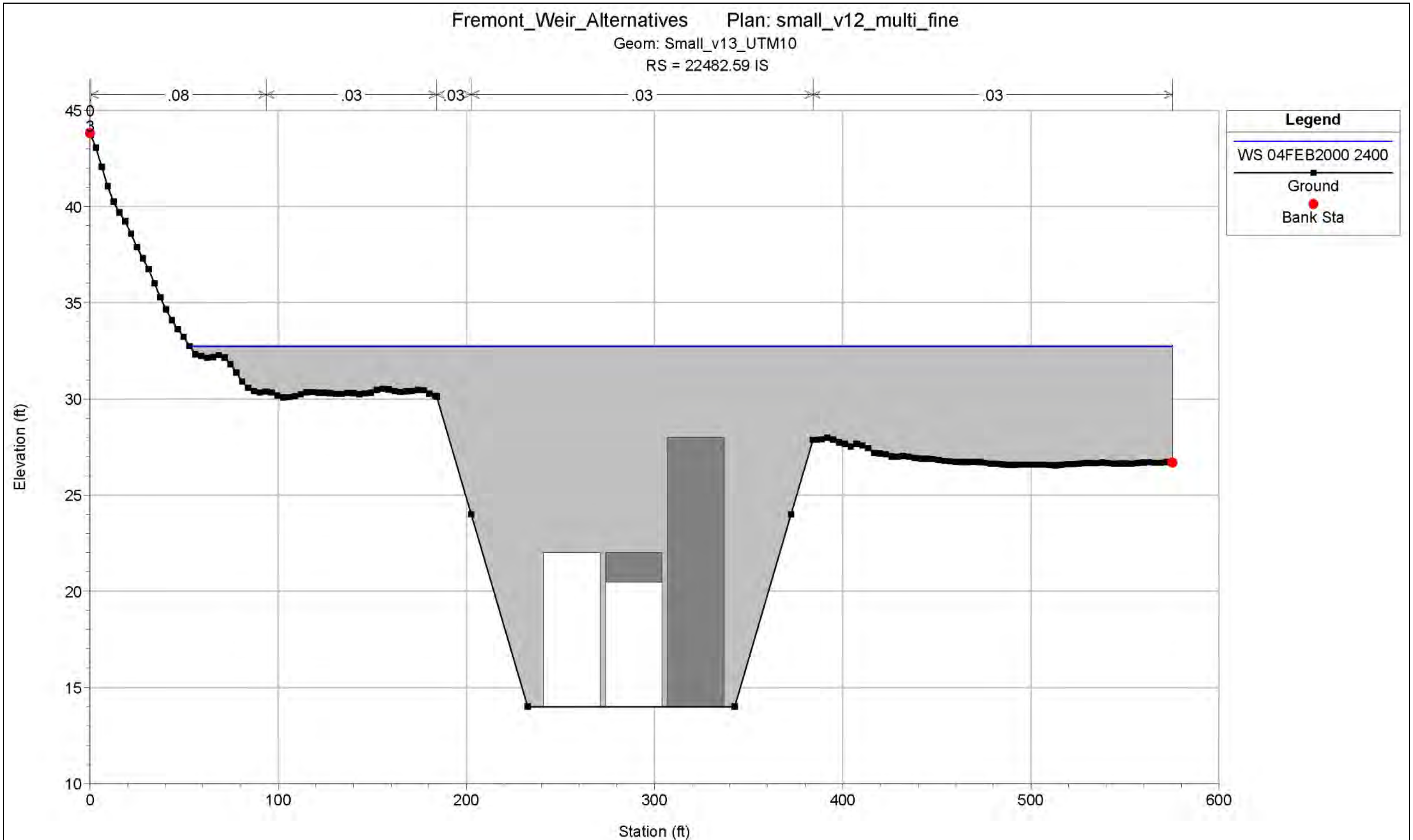


Notes: Water surface profile comparison between existing conditions and the Large Channel alternative.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Large Channel Water Surface Profile Comparison

Project No. 13-1027	Created By: CRC	**Figure 10**

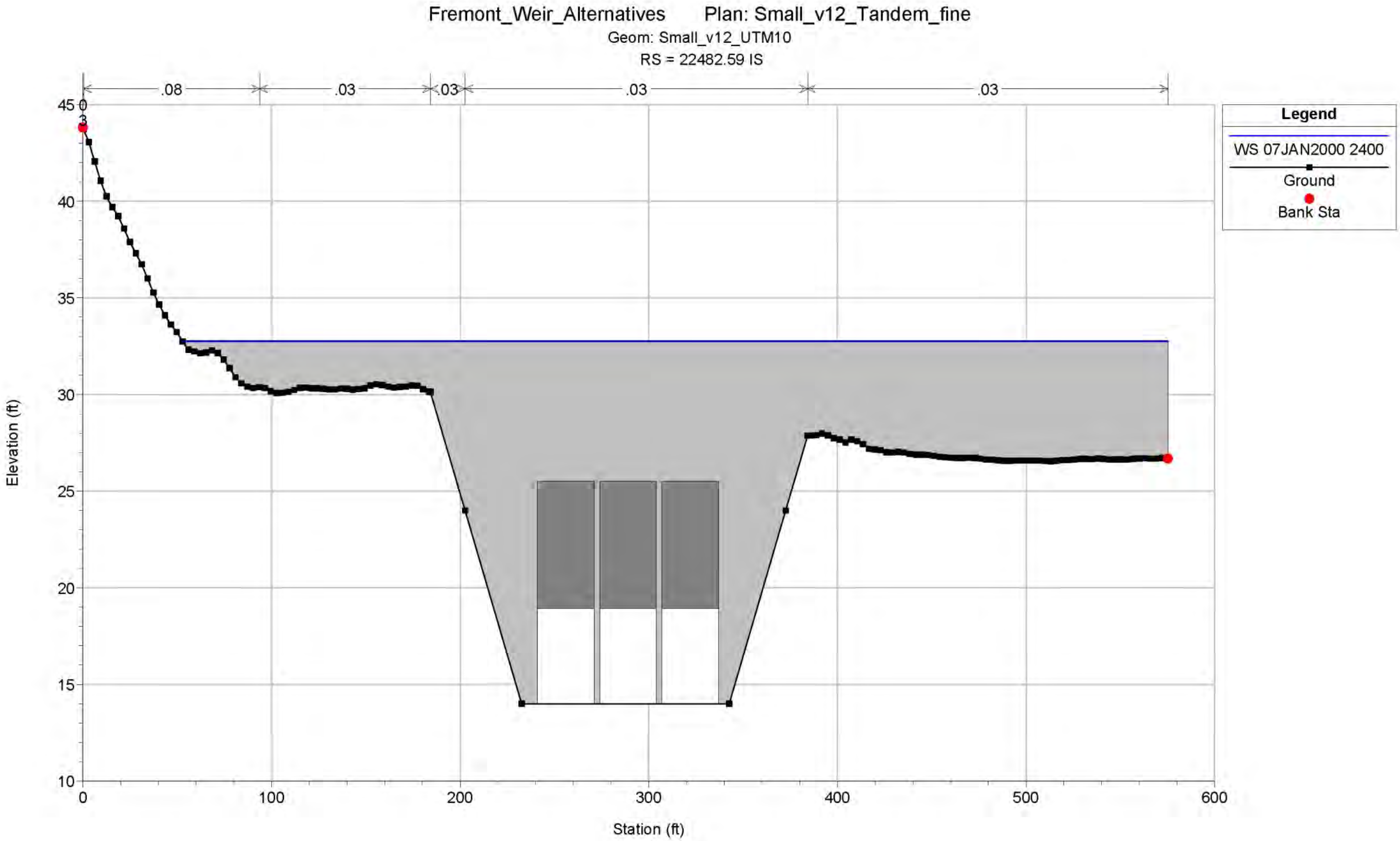


Notes: Gate closure shown represents 6000 cfs at maximum Sacramento River Stage before Fremont Weir begins to overtop for gates operated individually.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Small Individual Gate Configuration

Project No. 13-1027	Created By: CRC	**Figure 11**

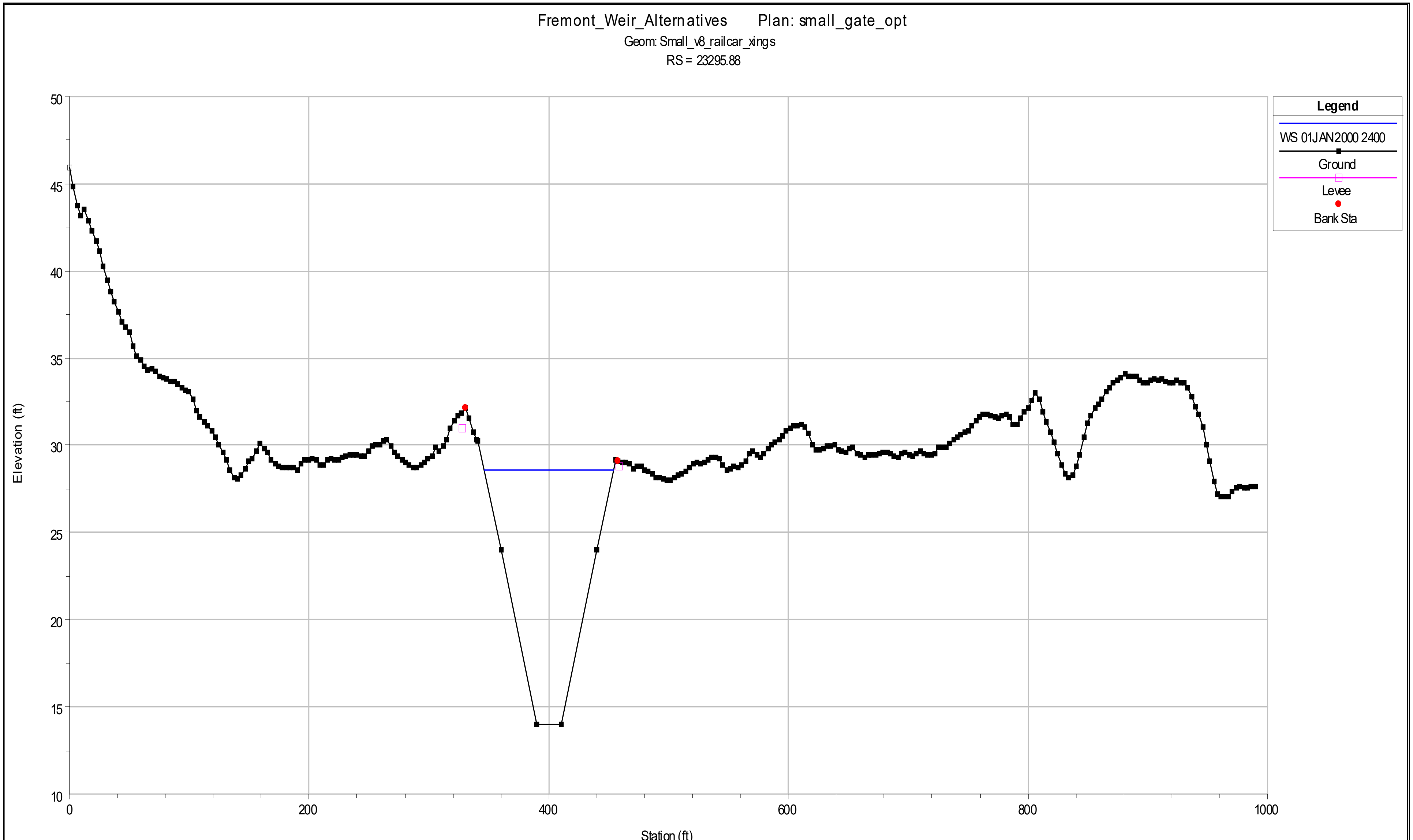


Notes: Gate closure shown represents 6000 cfs at maximum Sacramento River Stage before Fremont Weir begins to overtop for gates operated in tandem.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Small Unison Gate Configuration

Project No. 13-1027	Created By: CRC	**Figure 12**

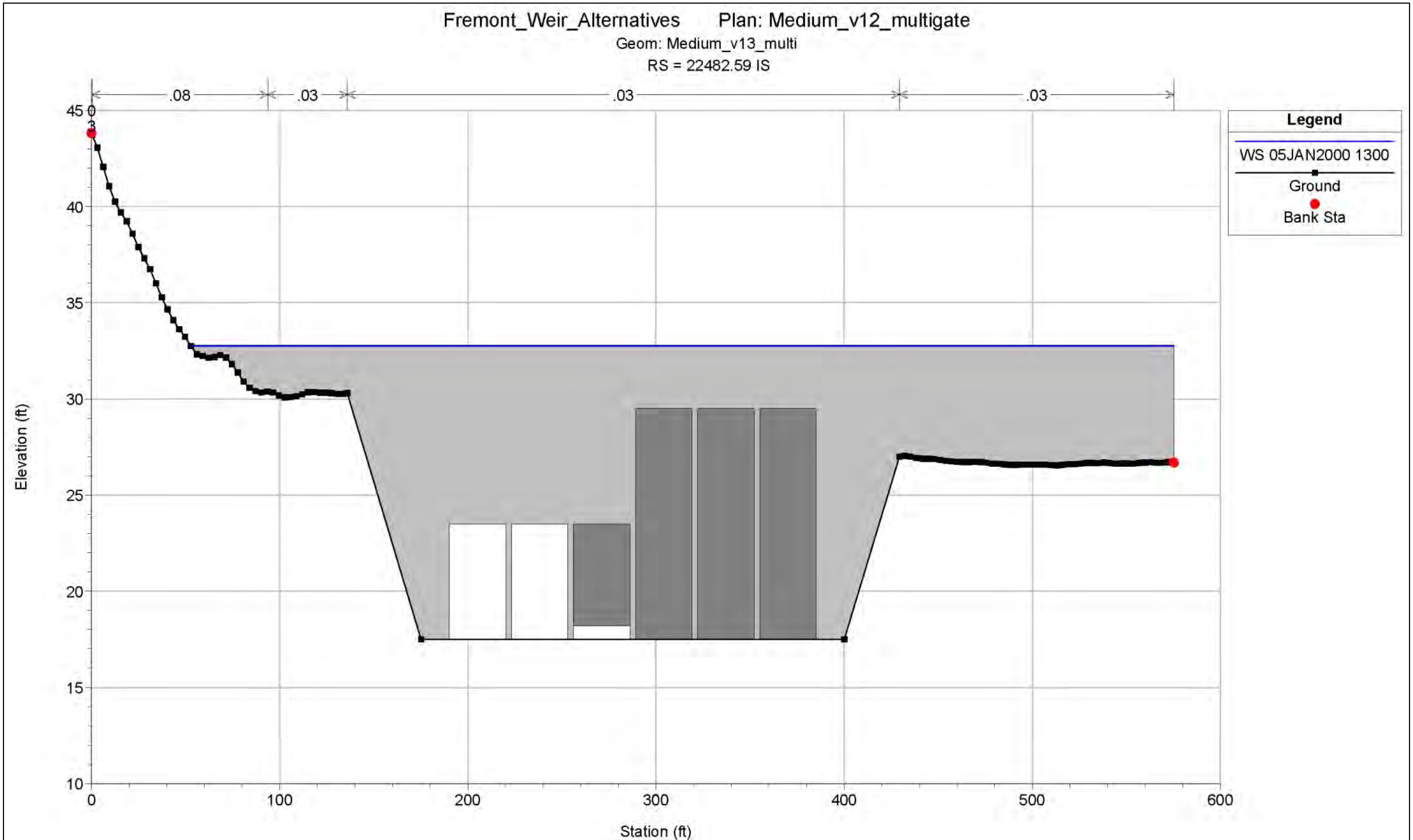


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Cross Section Downstream of Small Gate Structure

Project No. 13-1027	Created By: CRC	**Figure 13**

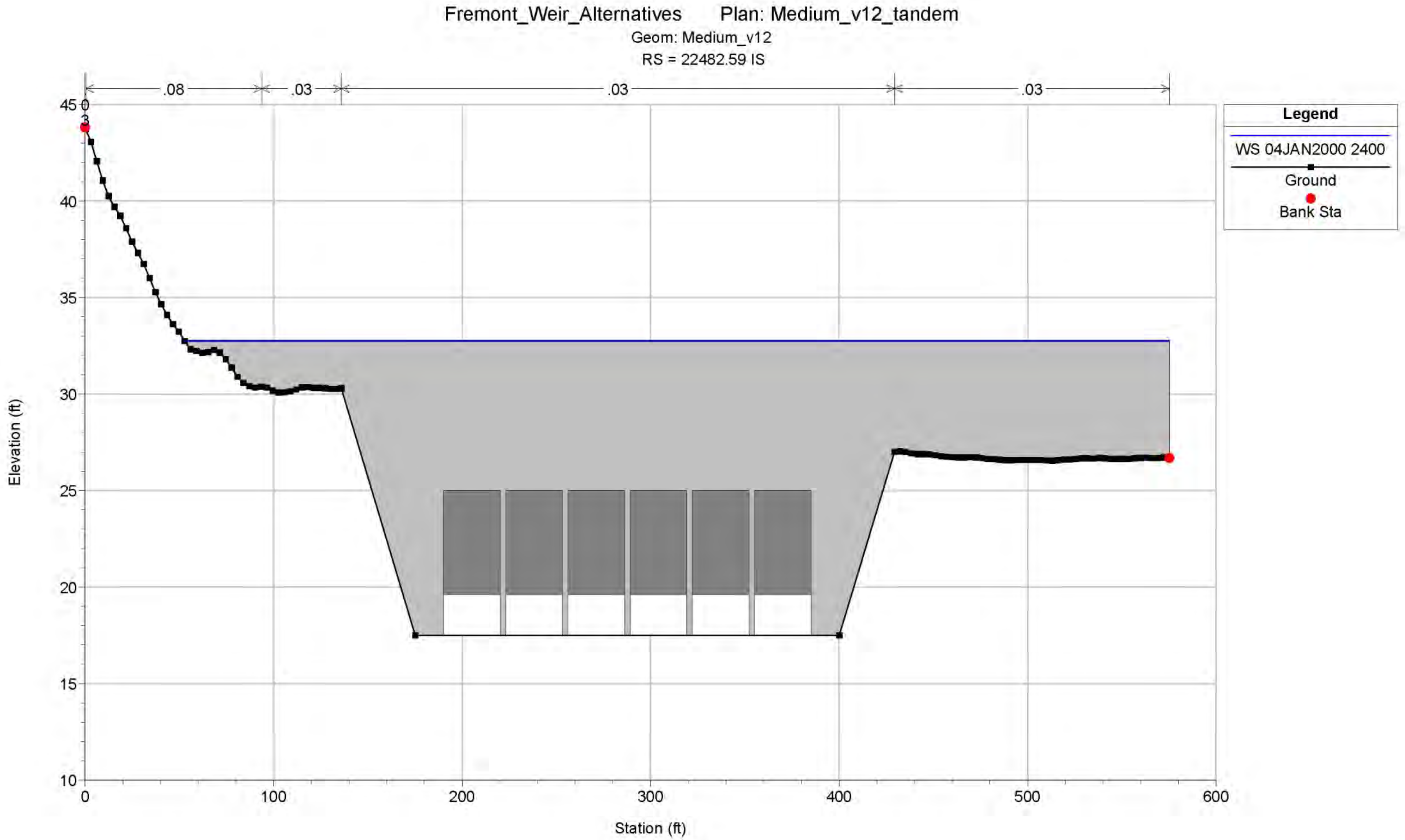


Notes: Gate closure shown represents 6000 cfs at maximum Sacramento River Stage before Fremont Weir begins to overtop for gates operated individually.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Medium Individual Gate Configuration

Project No. 13-1027	Created By: CRC	**Figure 14**

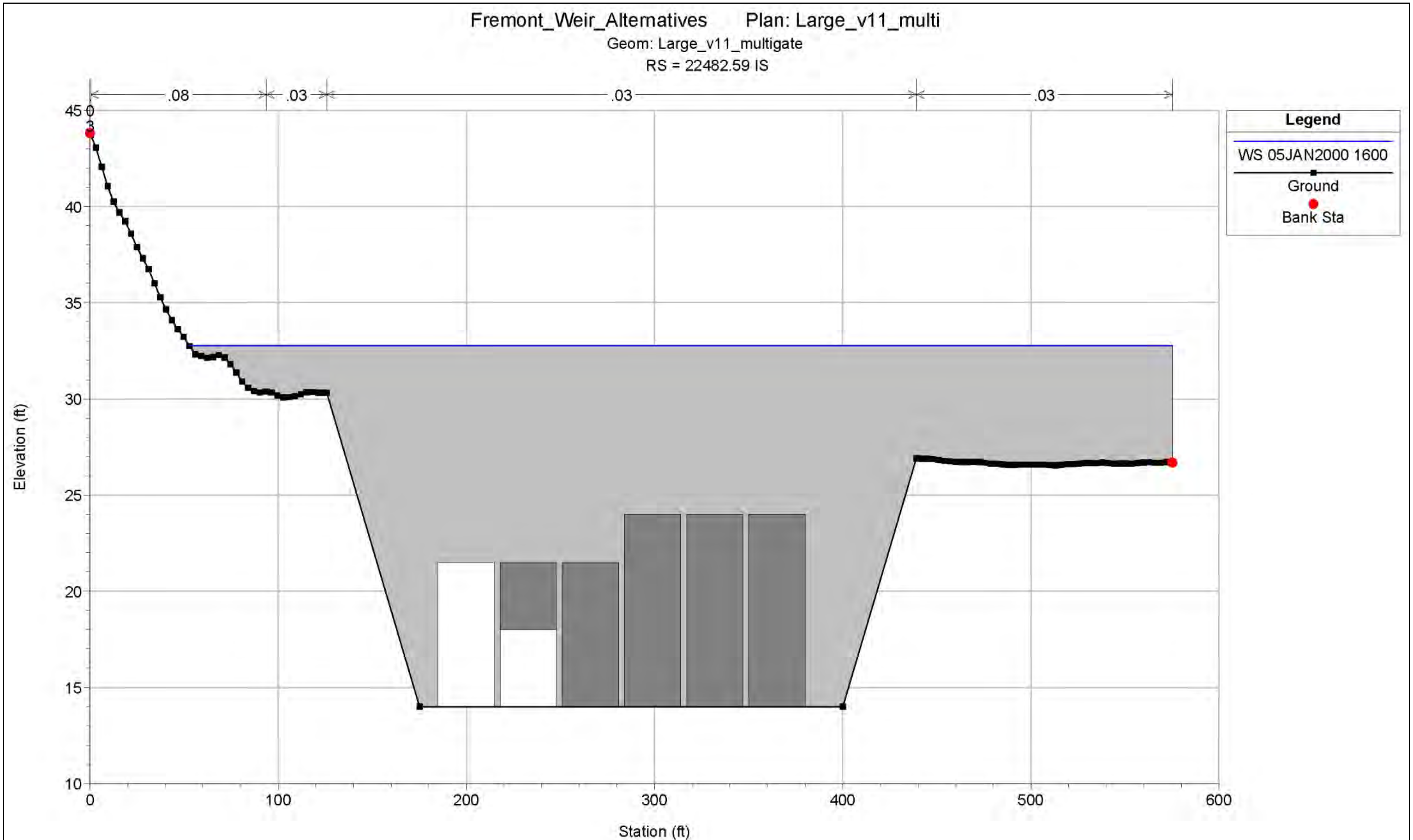


Notes: Gate closure shown represents 6000 cfs at maximum Sacramento River Stage before Fremont Weir begins to overtop for gates operated in tandem.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Medium Unison Gate Configuration

Project No. 13-1027	Created By: CRC	**Figure 15**

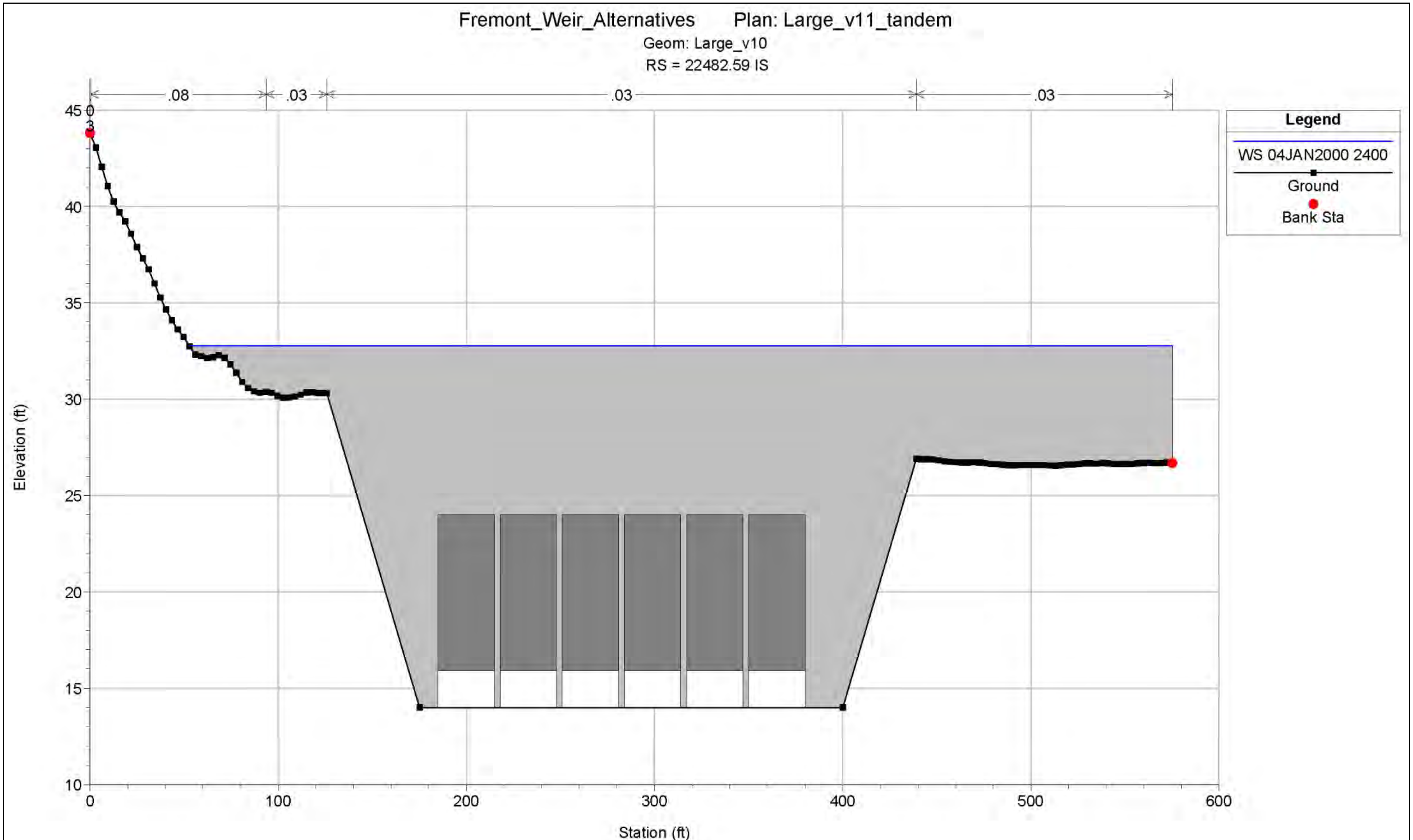


Notes: Gate closure shown represents 6000 cfs at maximum Sacramento River Stage before Fremont Weir begins to overtop for gates operated individually.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Large Individual Gate Configuration

Project No. 13-1027	Created By: CRC	**Figure 16**



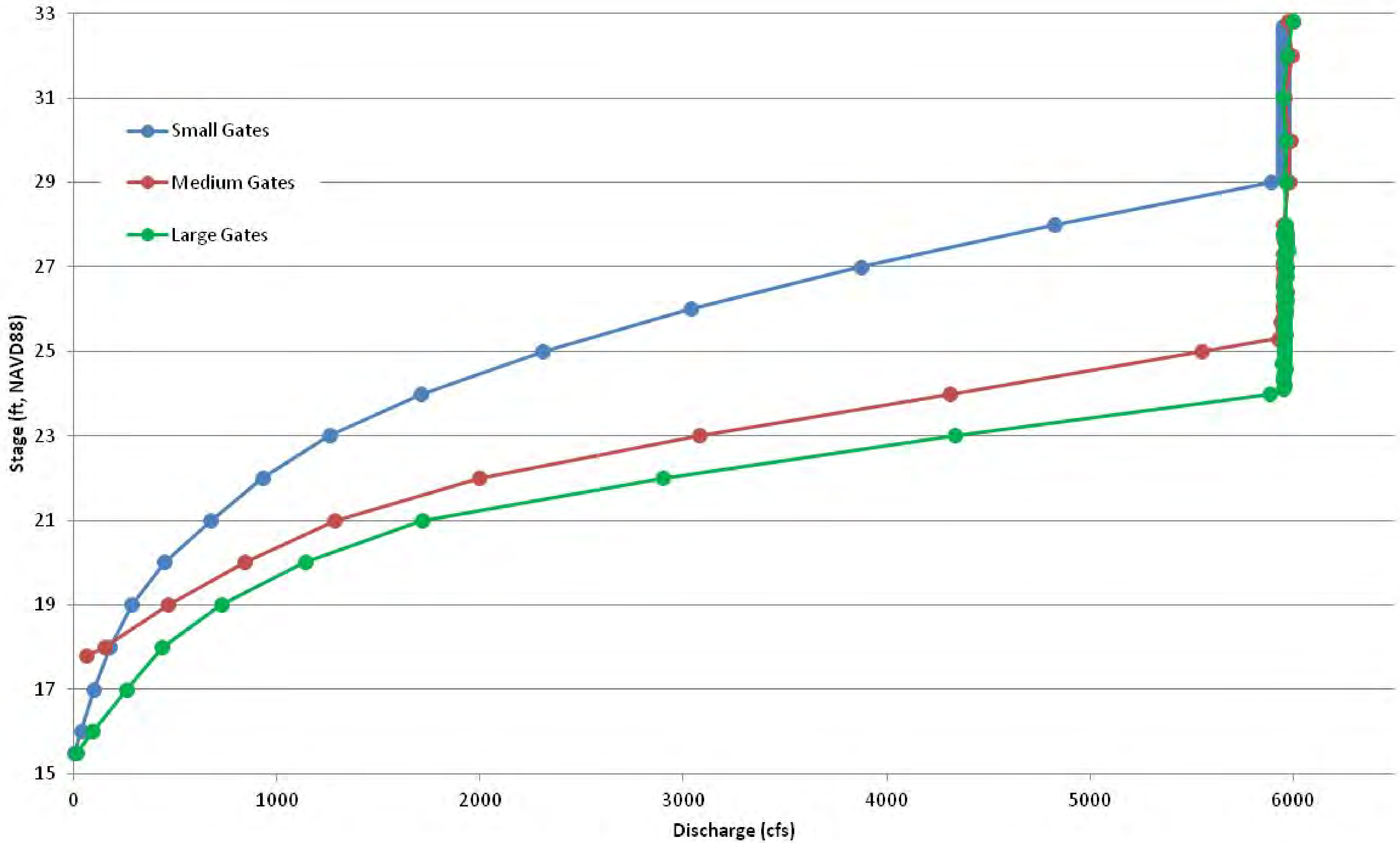
Notes: Gate closure shown represents 6000 cfs at maximum Sacramento River Stage before Fremont Weir begins to overtop for gates operated in tandem.

cbec eco engineering

Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Large Unison Gate Configuration

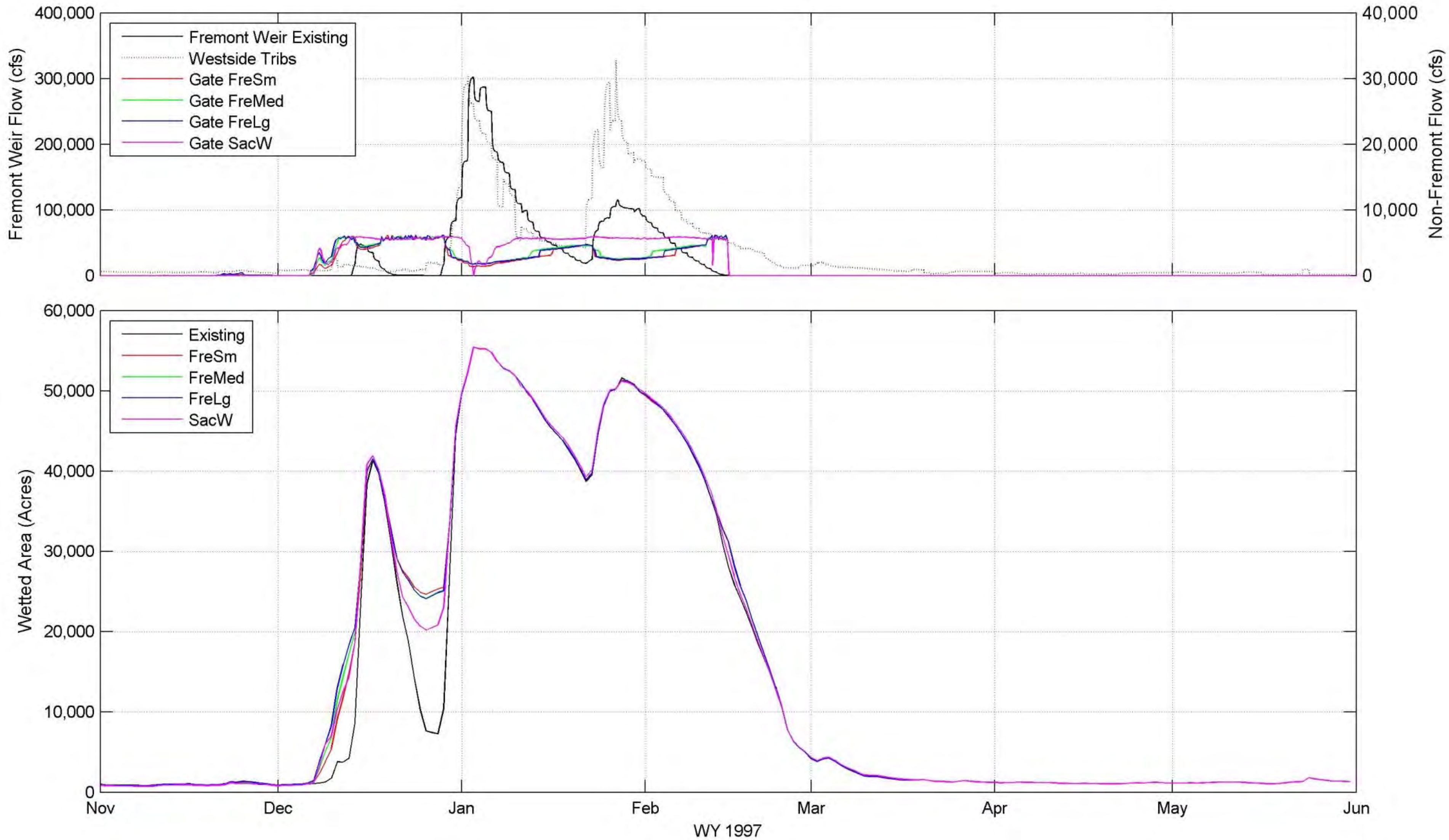
Project No. 13-1027	Created By: CRC	**Figure 17**



Notes: assumes gate operations are optimized for 6000 cfs flow rate	cbec eco engineering	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* **Gate Rating Curves**	
		Project No. 13-1027	Created By: CRC	**Figure 18**

Appendix D

All WY and Gate Closures

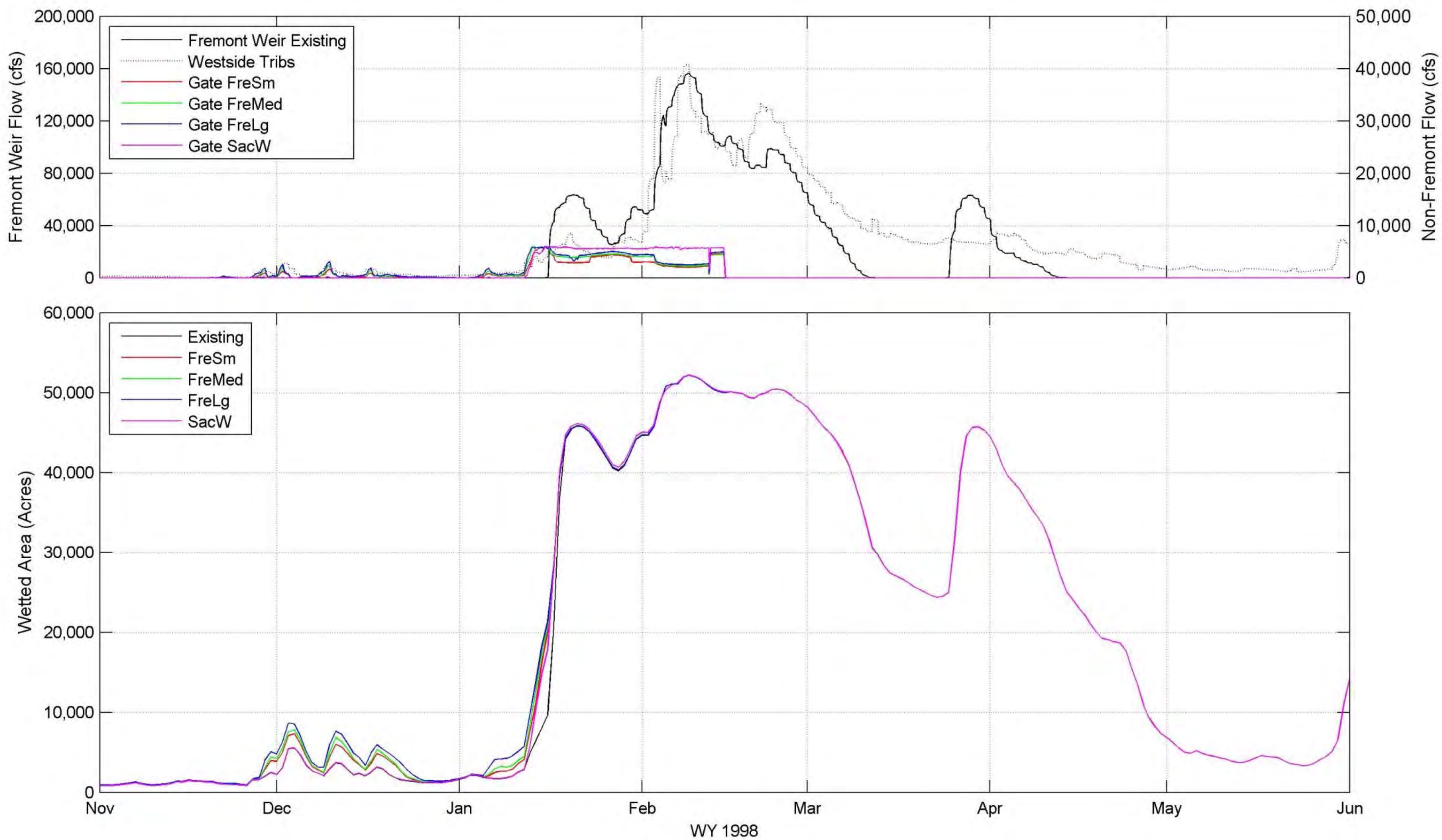


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1997 for Feb 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D1**

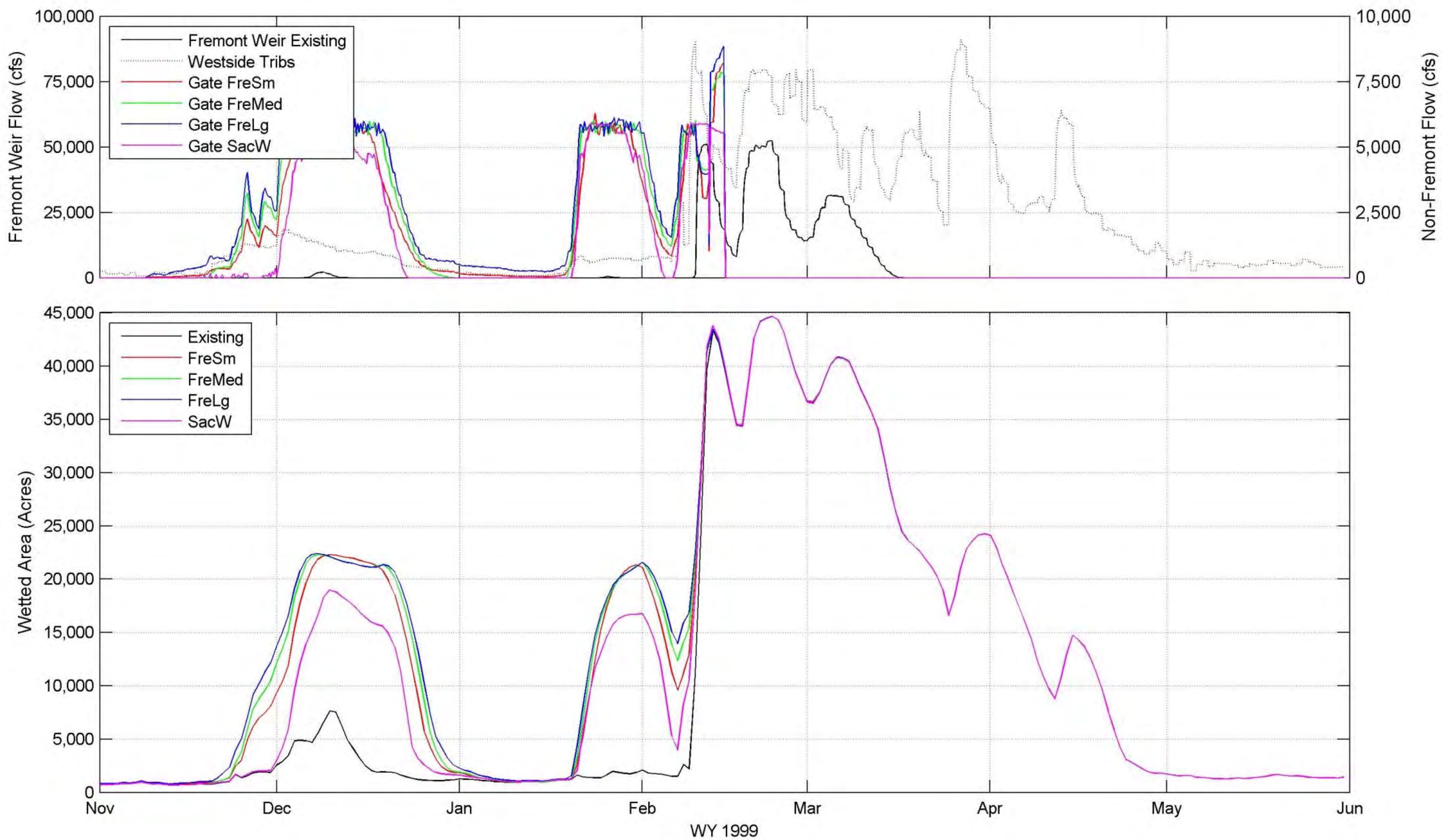


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1998 for Feb 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D2**

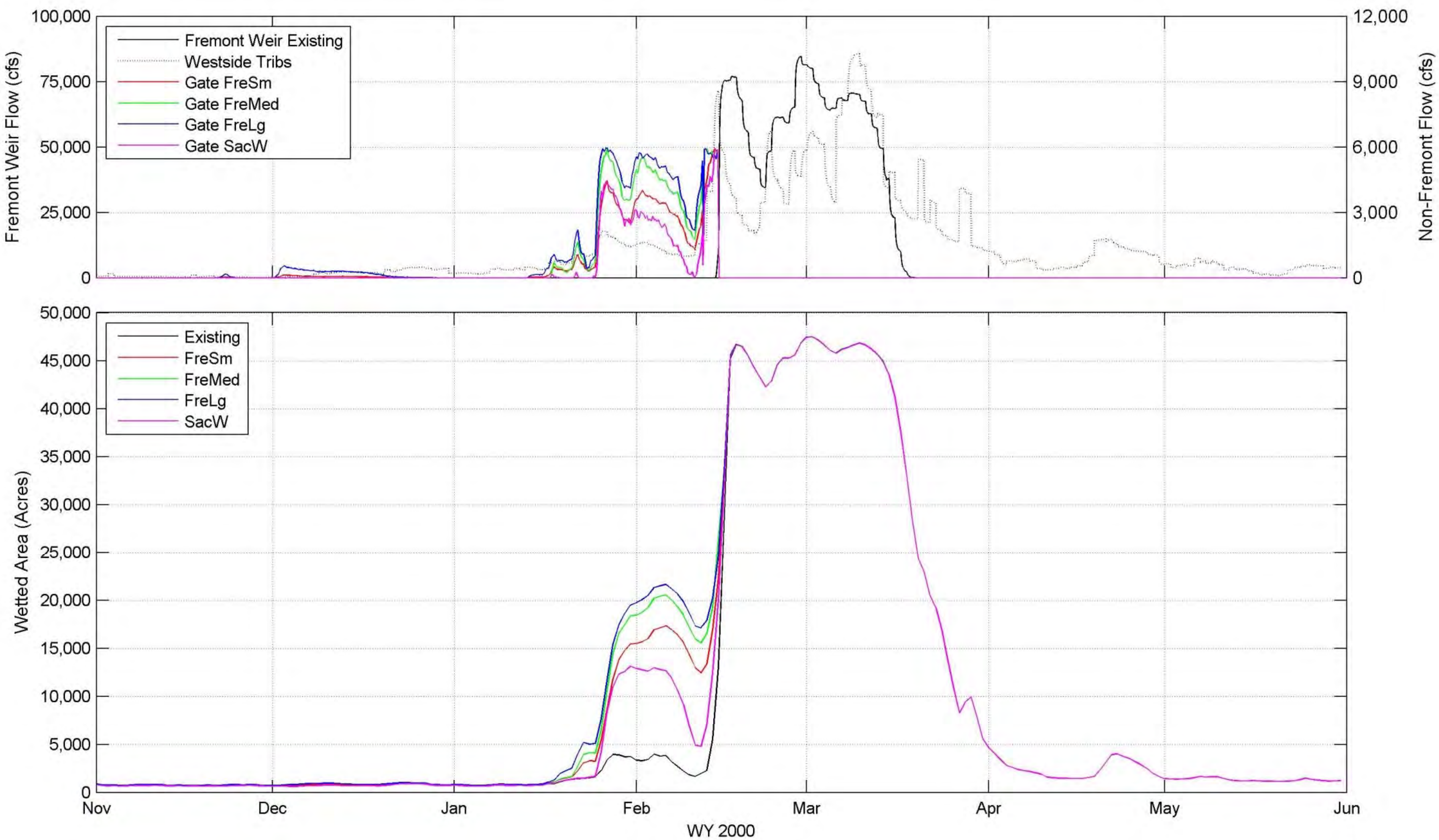


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1999 for Feb 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D3**

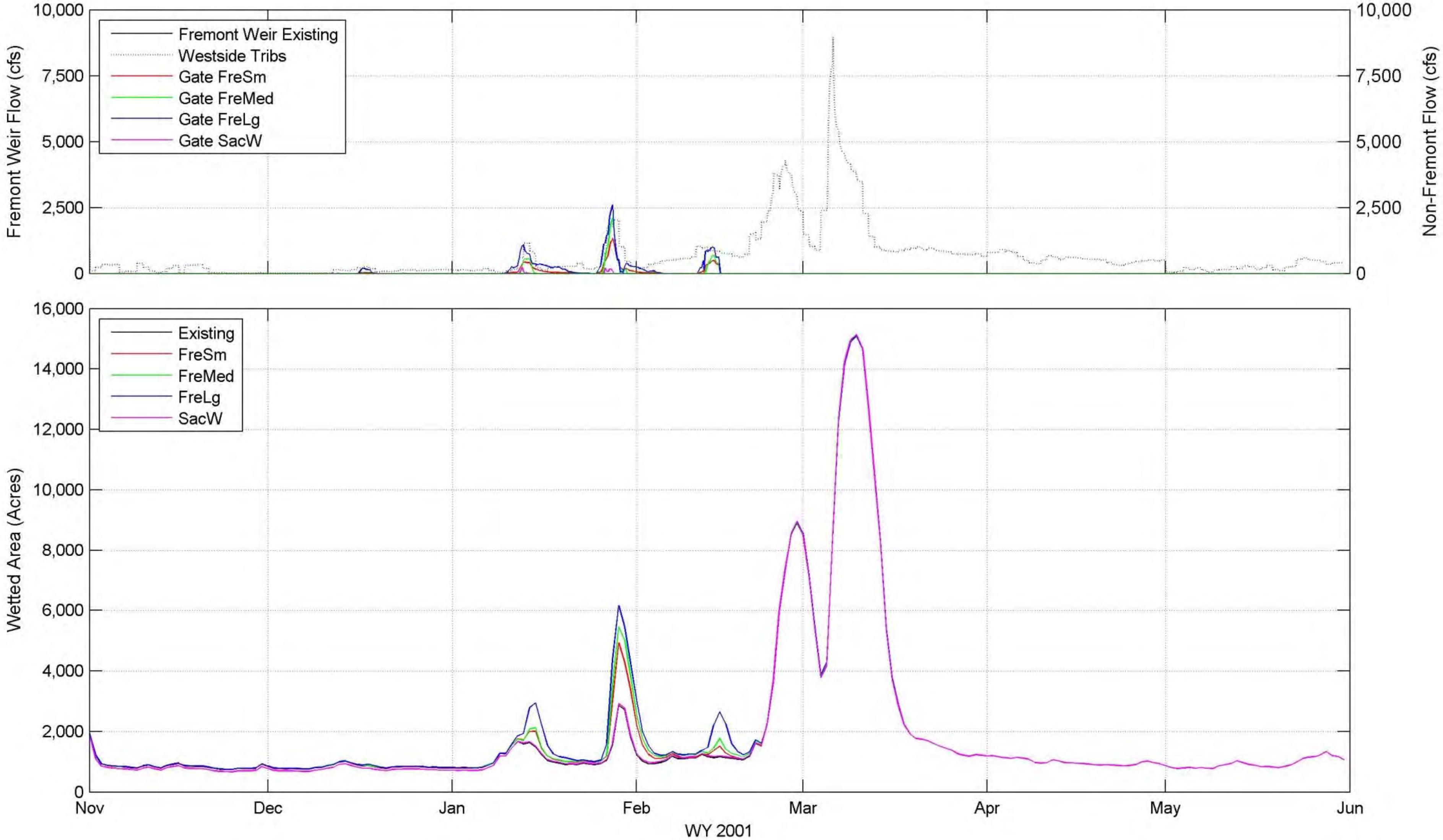


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2000 for Feb 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D4**



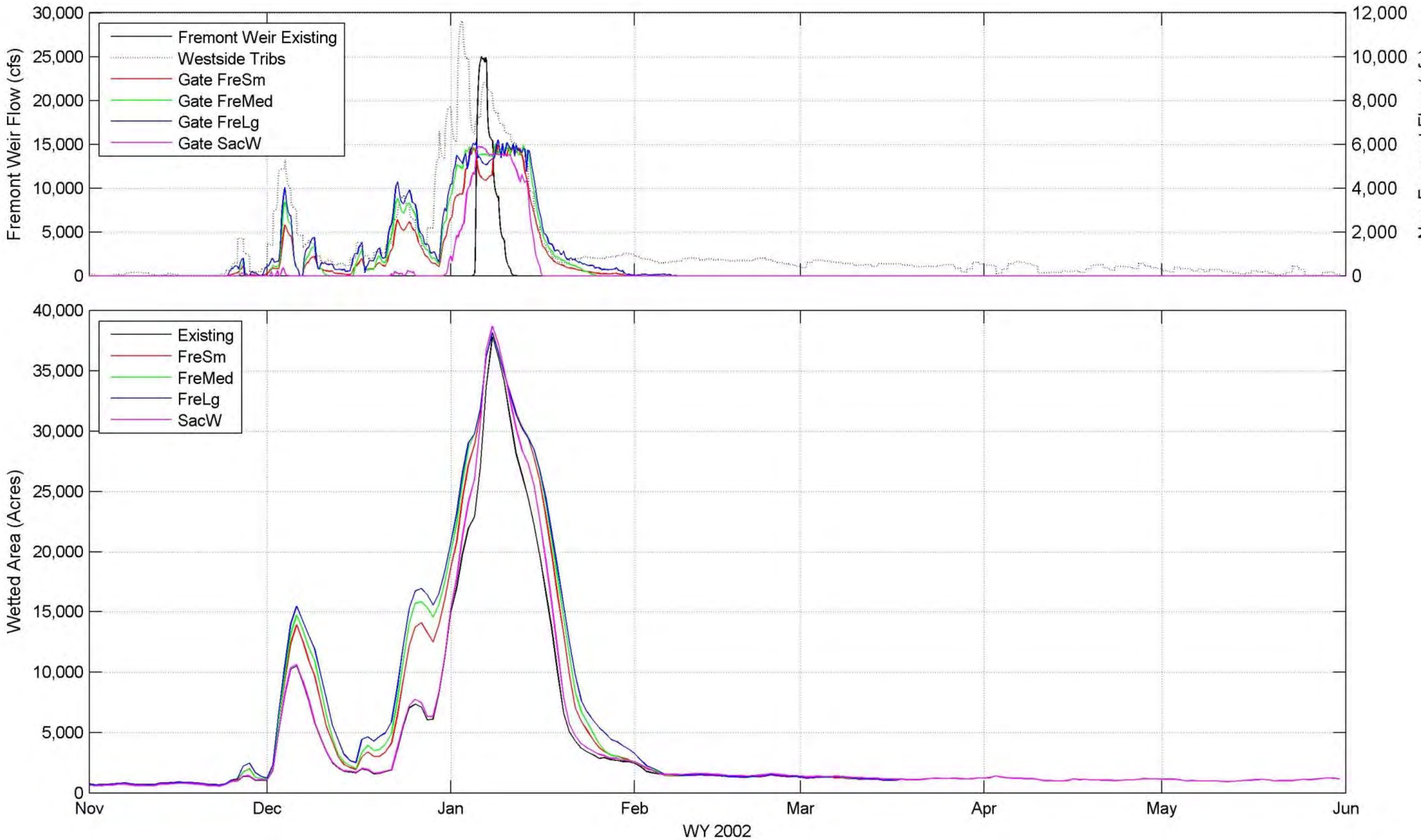
Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

HDR cbec eco engineering

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2001 for Feb 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D5**

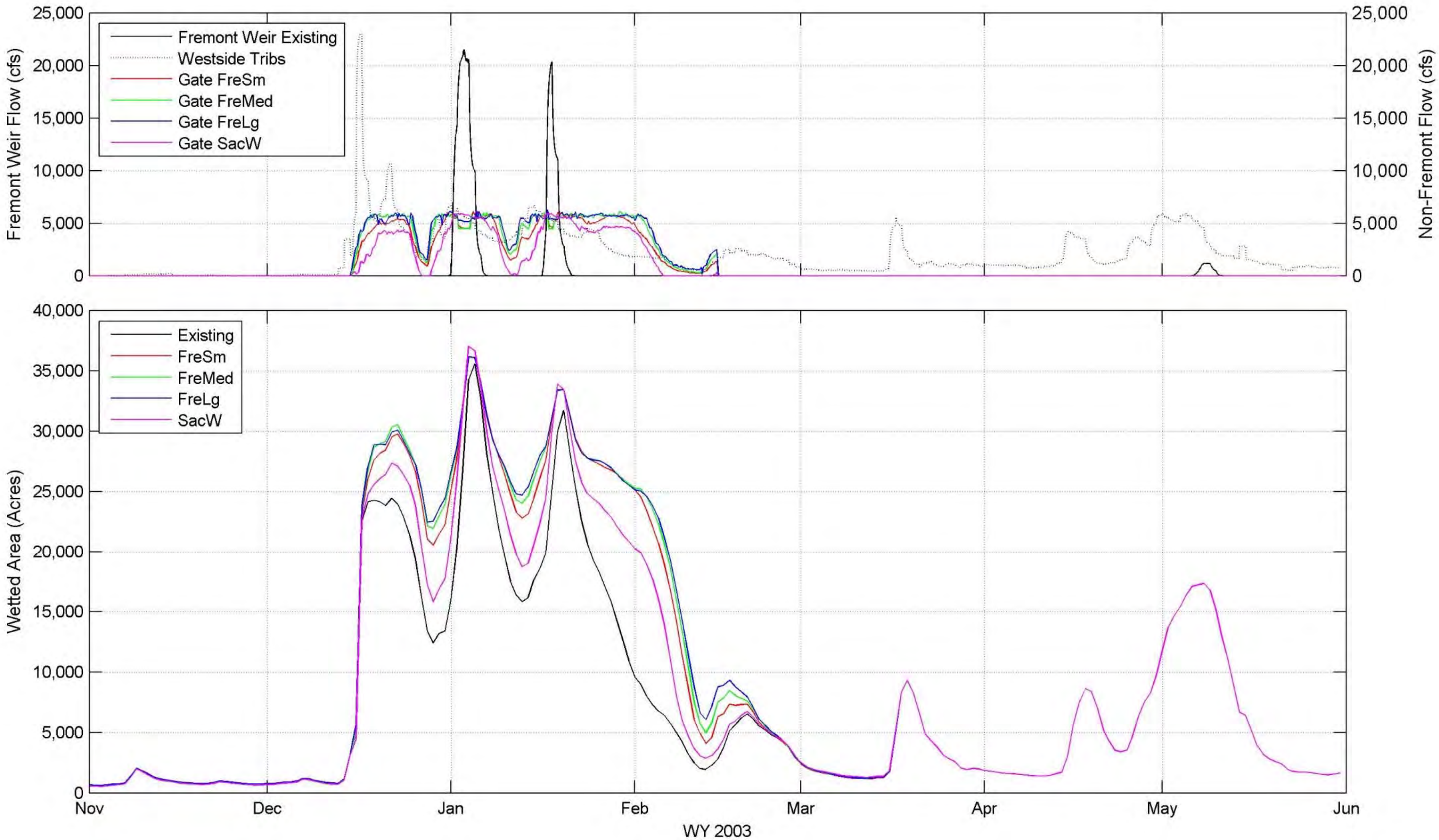


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2002 for Feb 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D6**

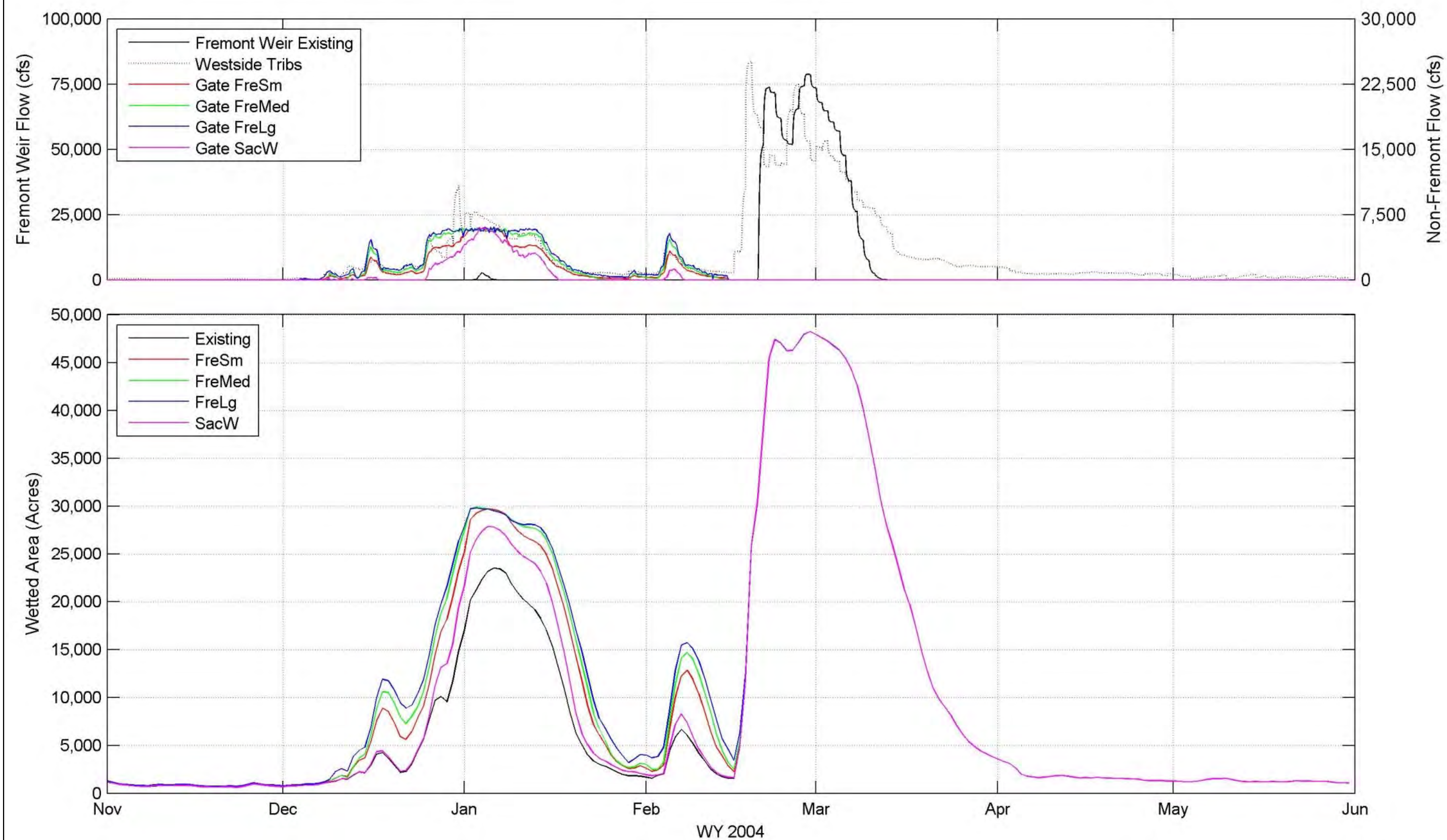


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2003 for Feb 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D7**

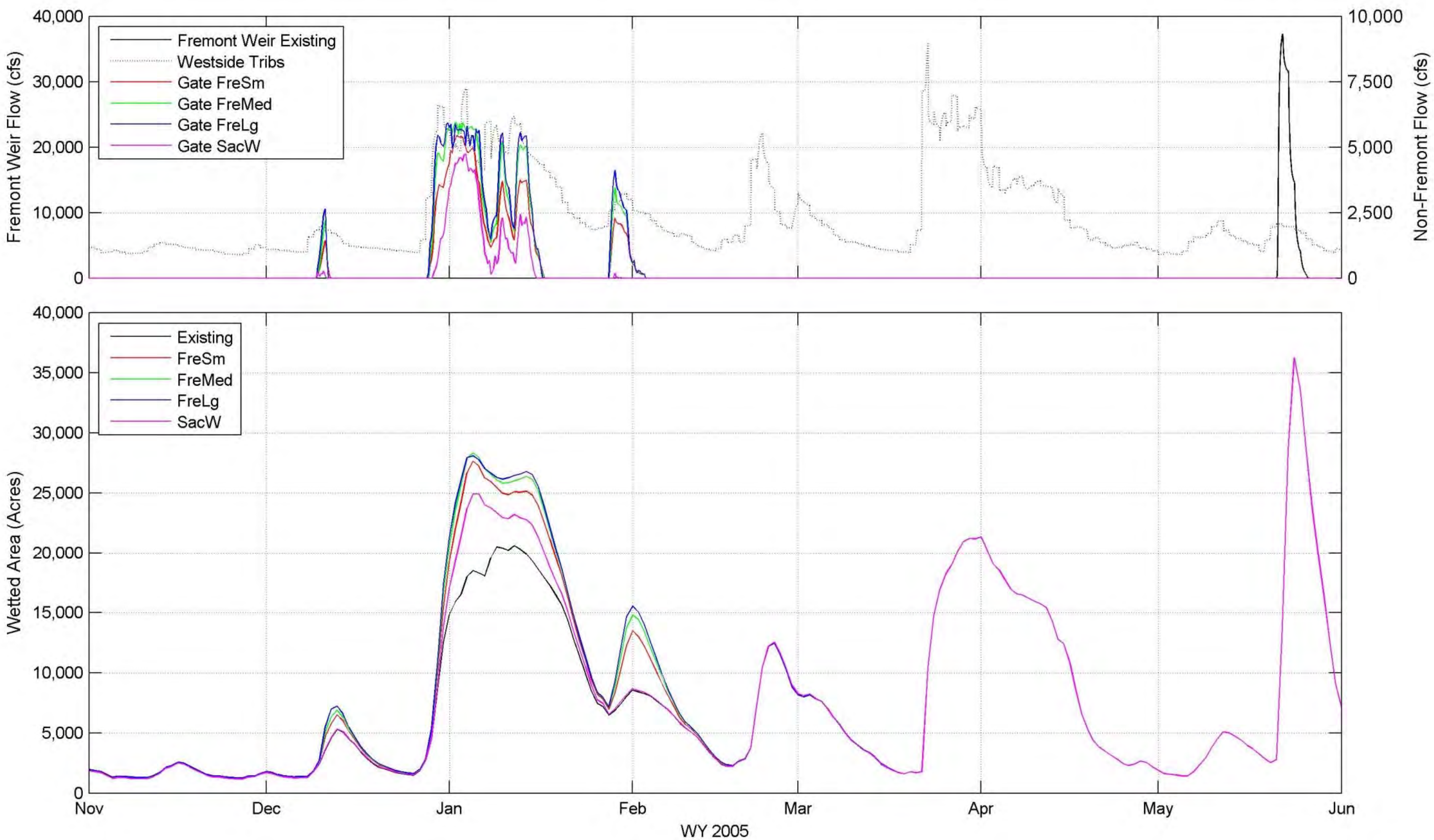


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2004 for Feb 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D8**

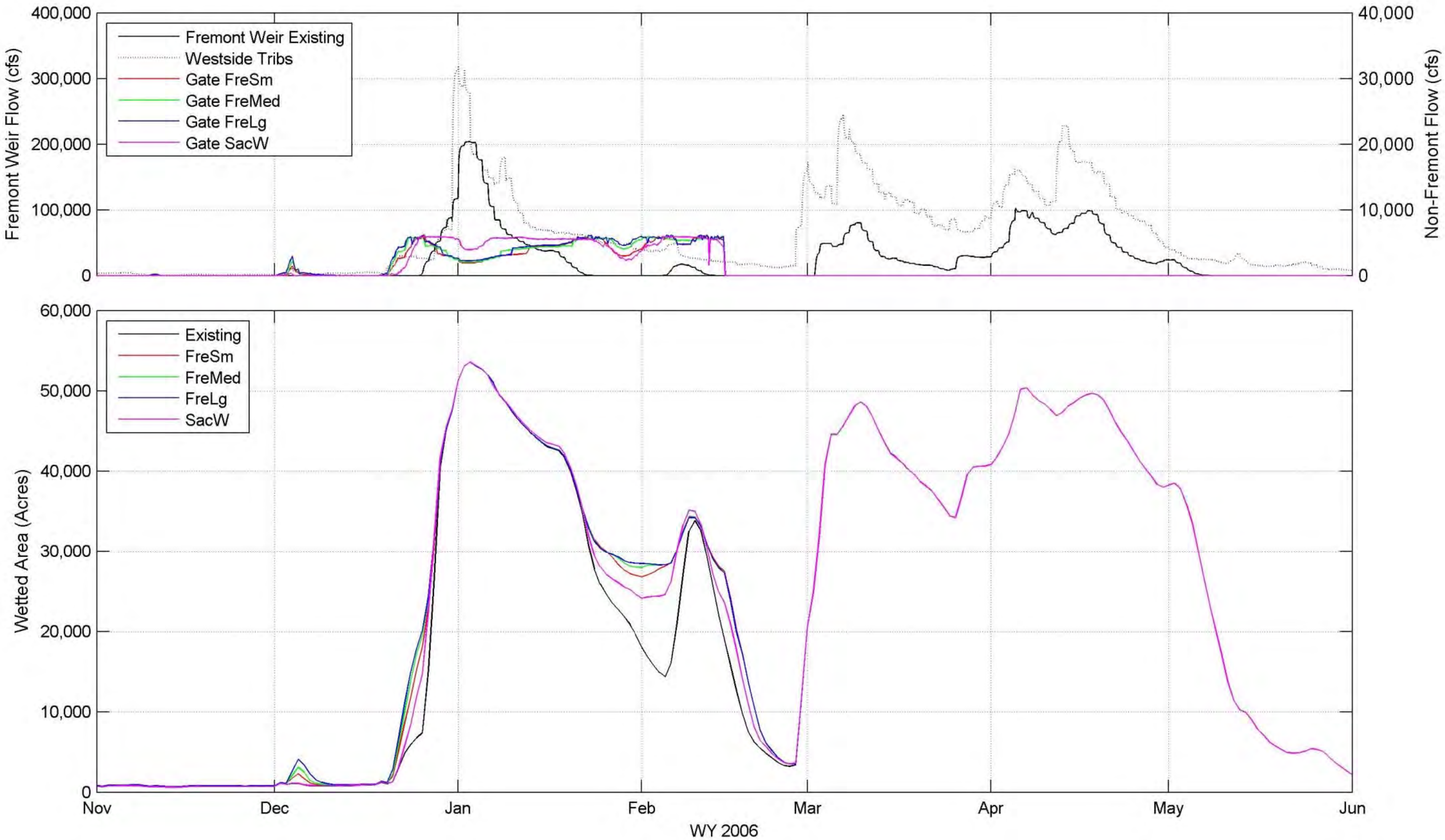


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2005 for Feb 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D9**

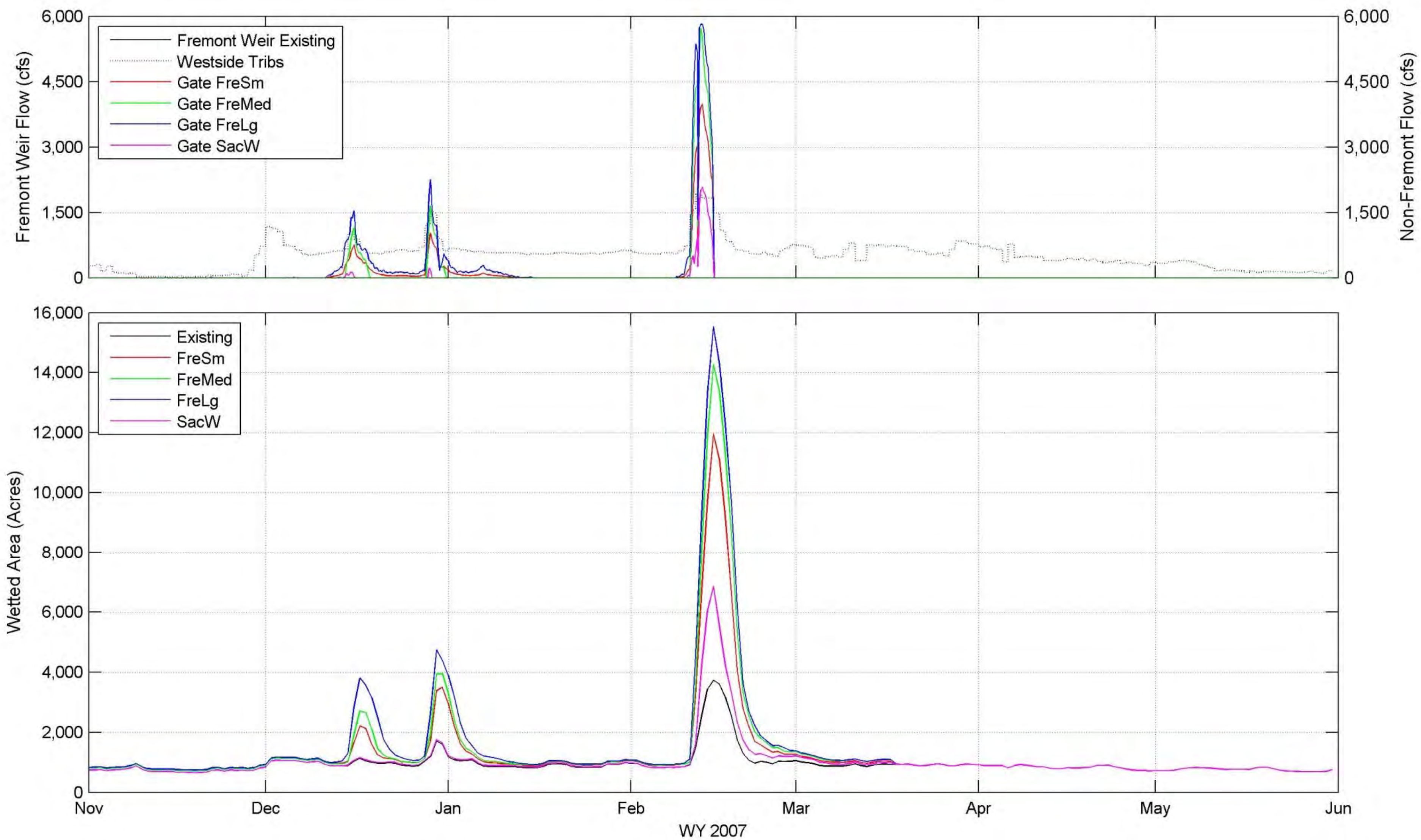


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2006 for Feb 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D10**

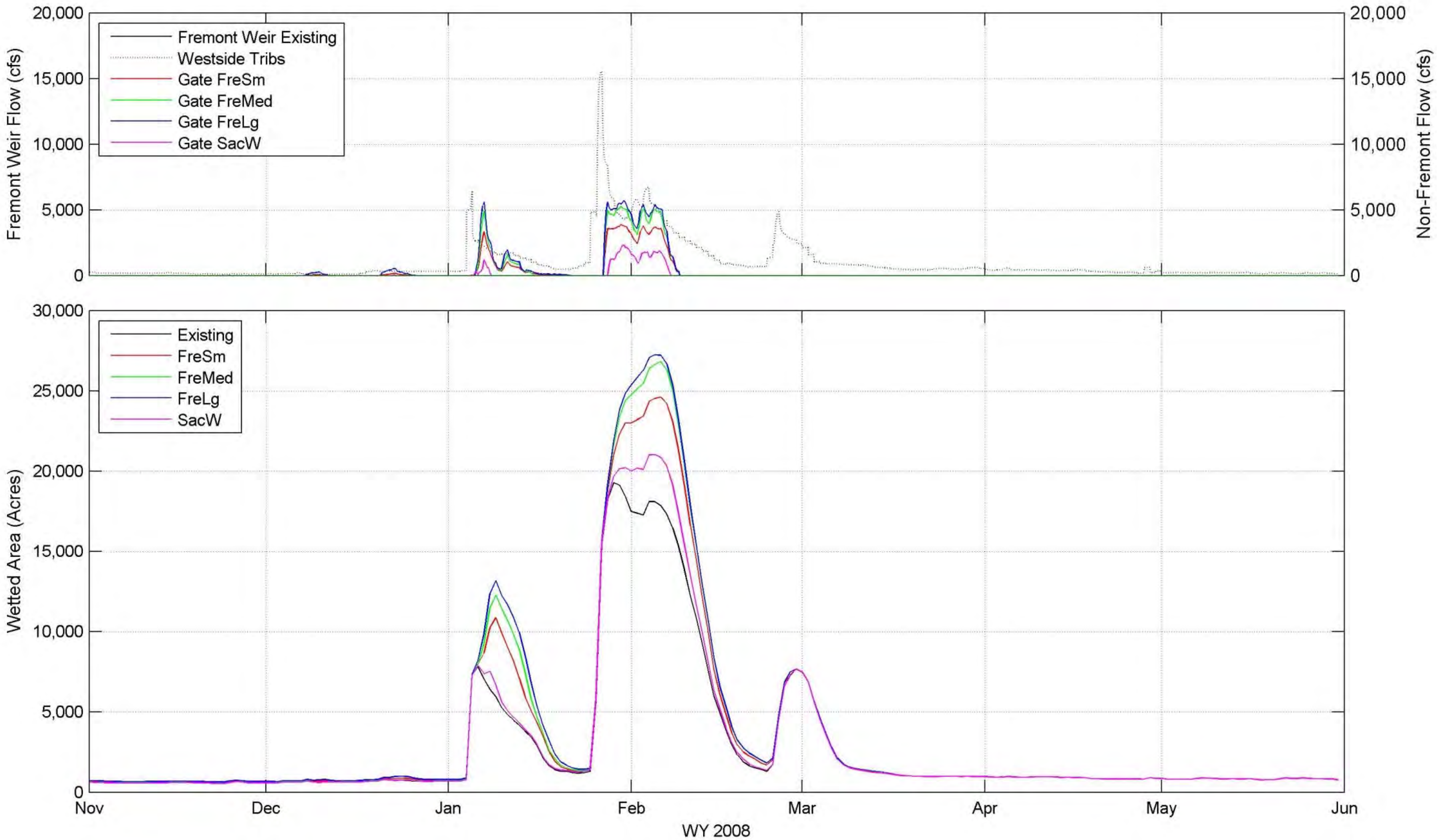


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2007 for Feb 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D11**

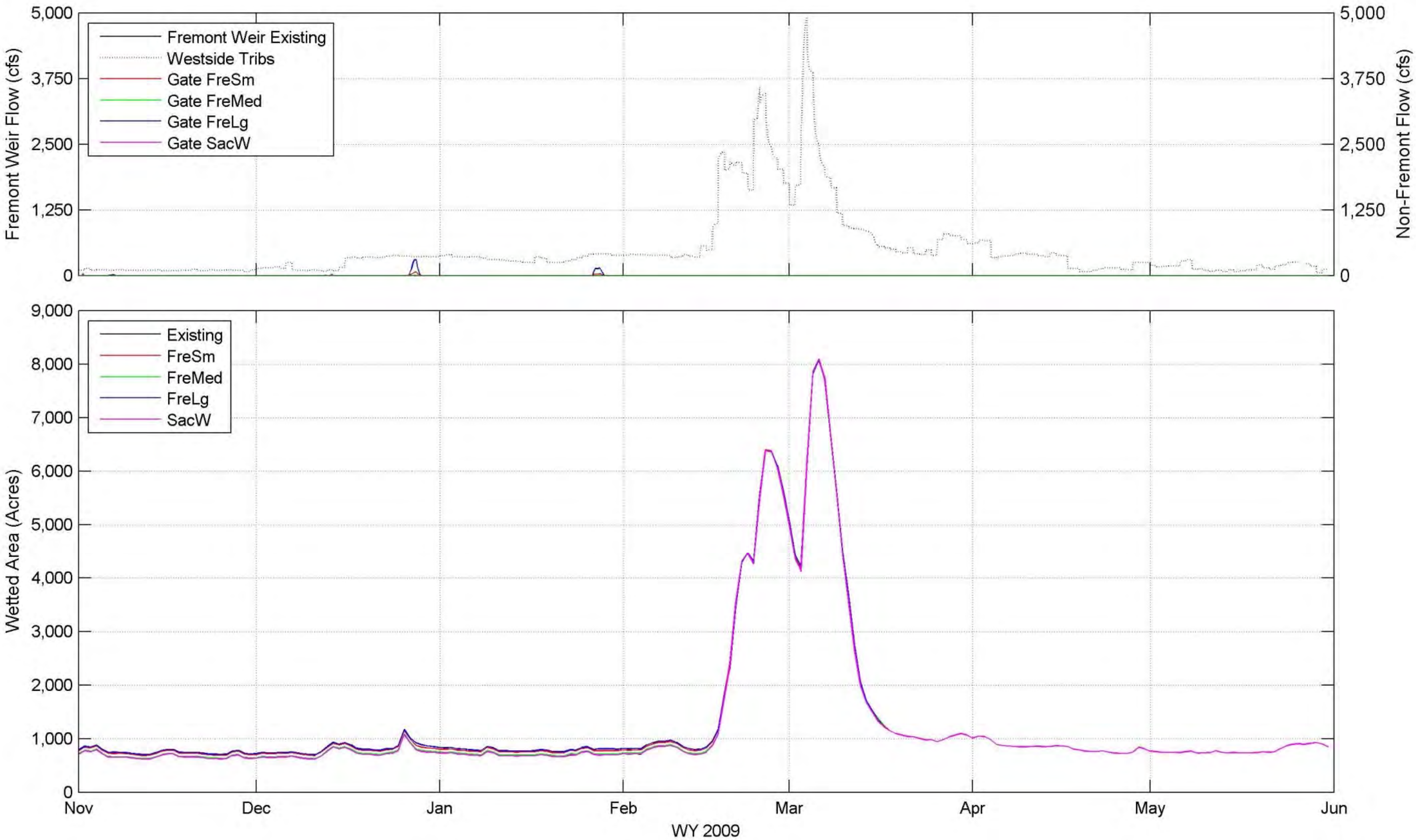


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2008 for Feb 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D12**

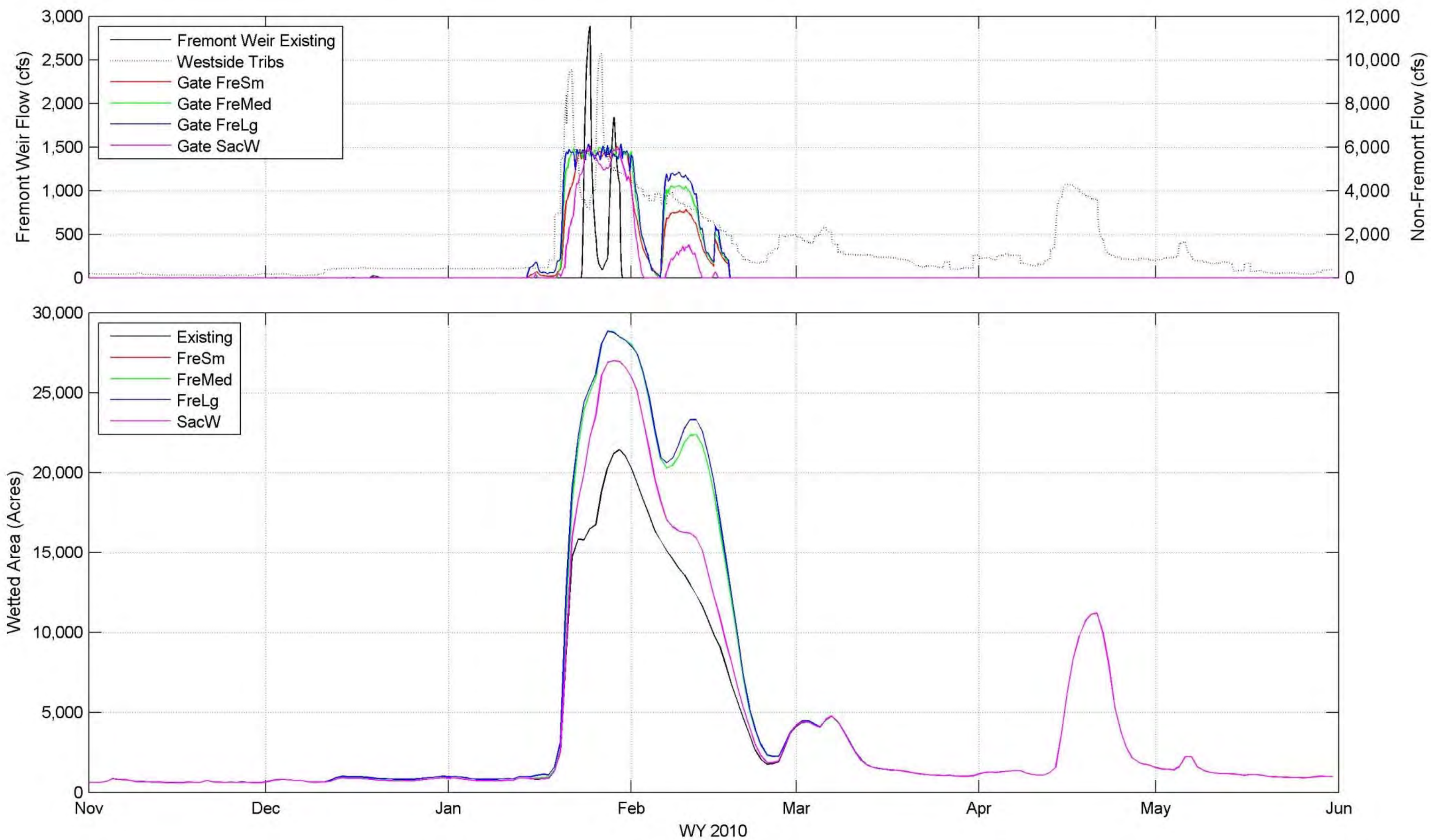


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2009 for Feb 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D13**

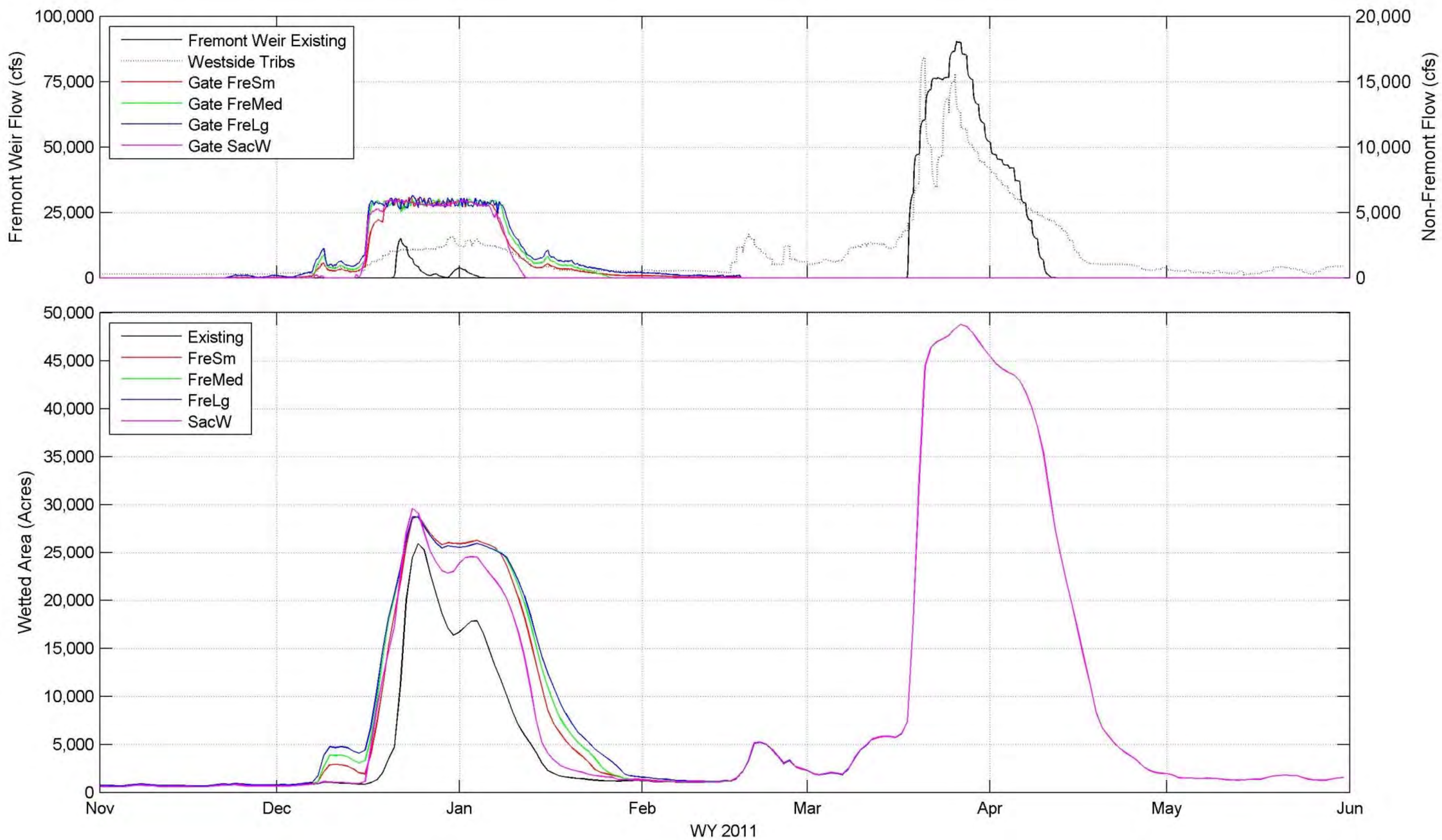


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2010 for Feb 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D14**



Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

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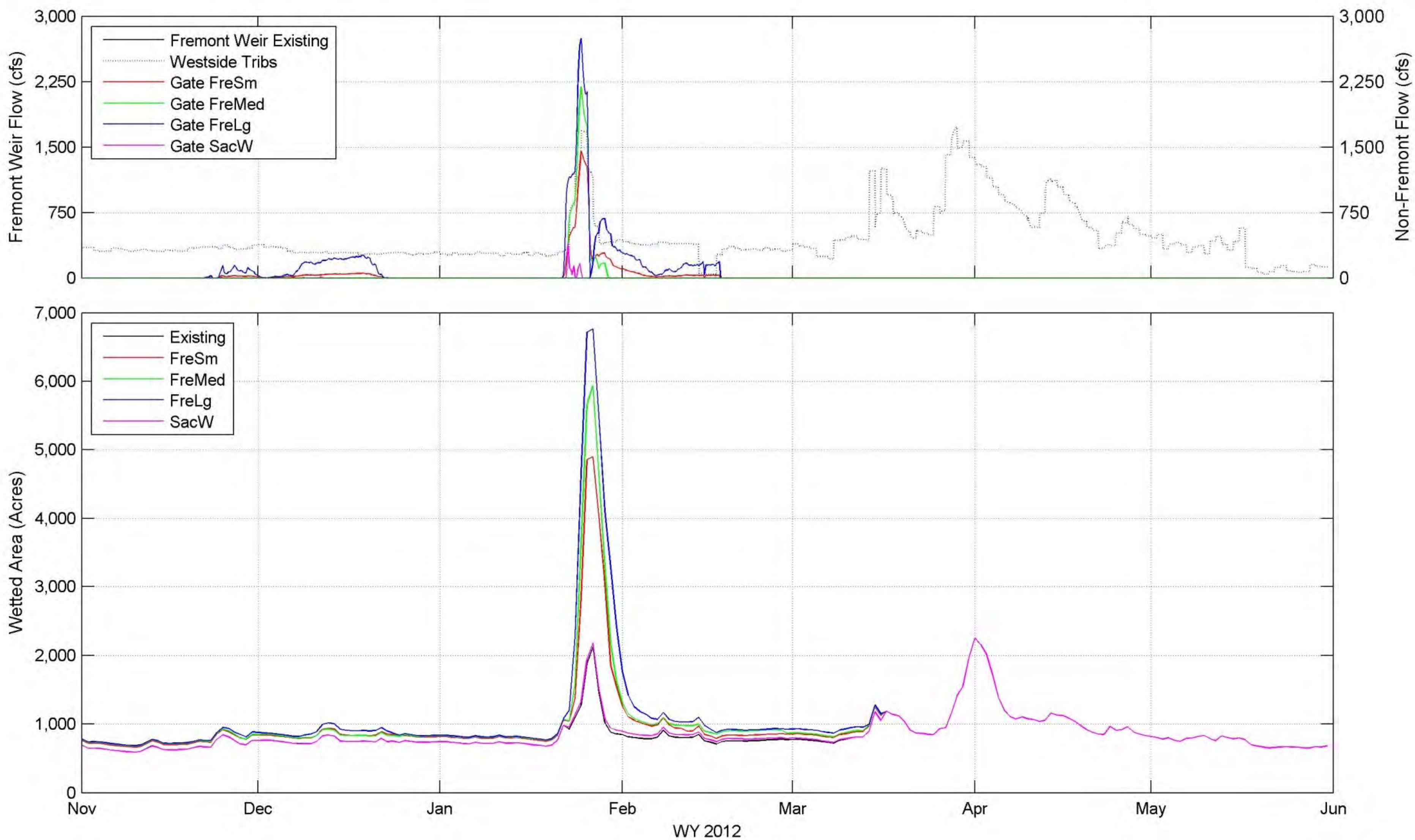
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2011 for Feb 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D15**

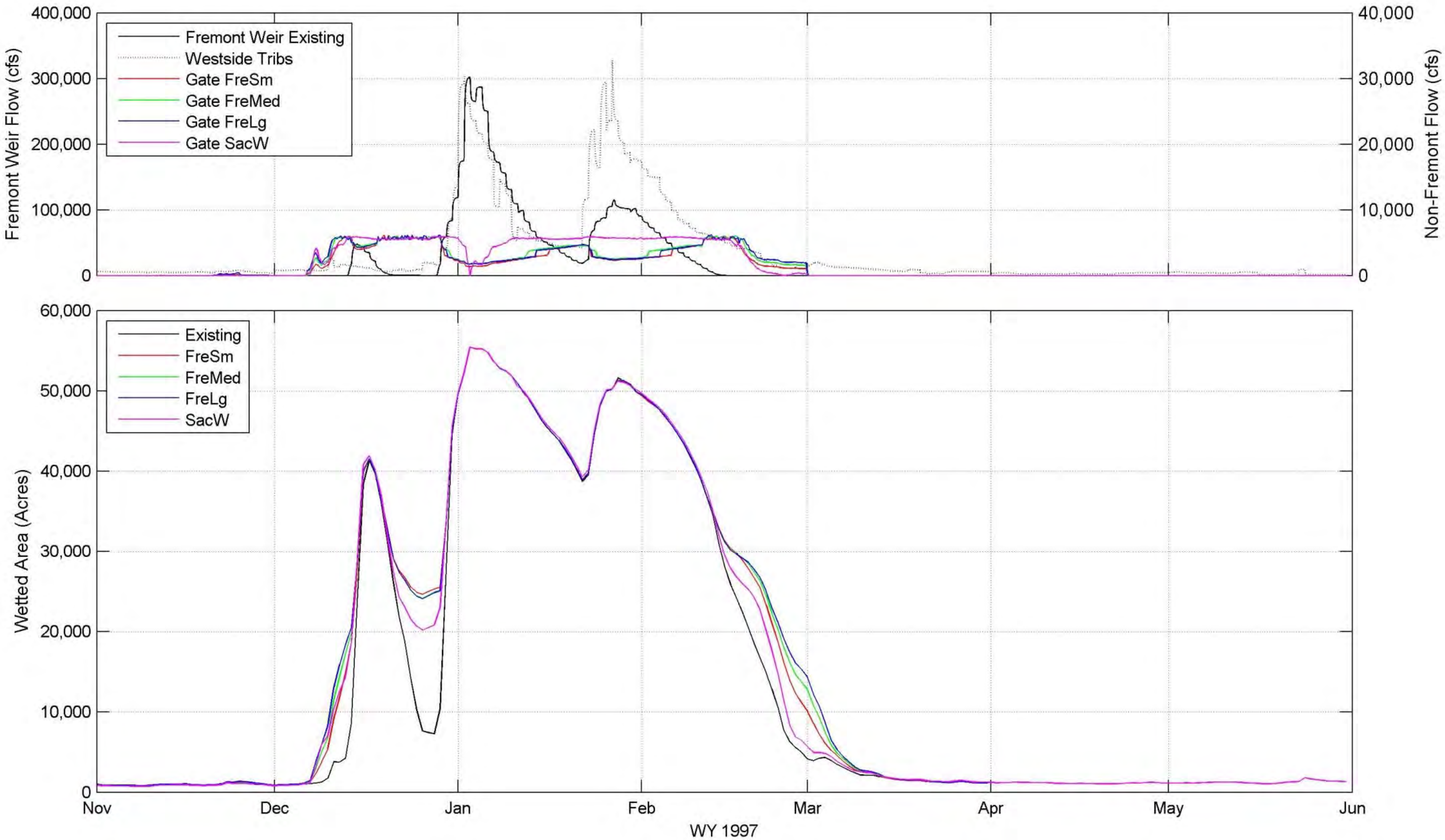


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2012 for Feb 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D16**

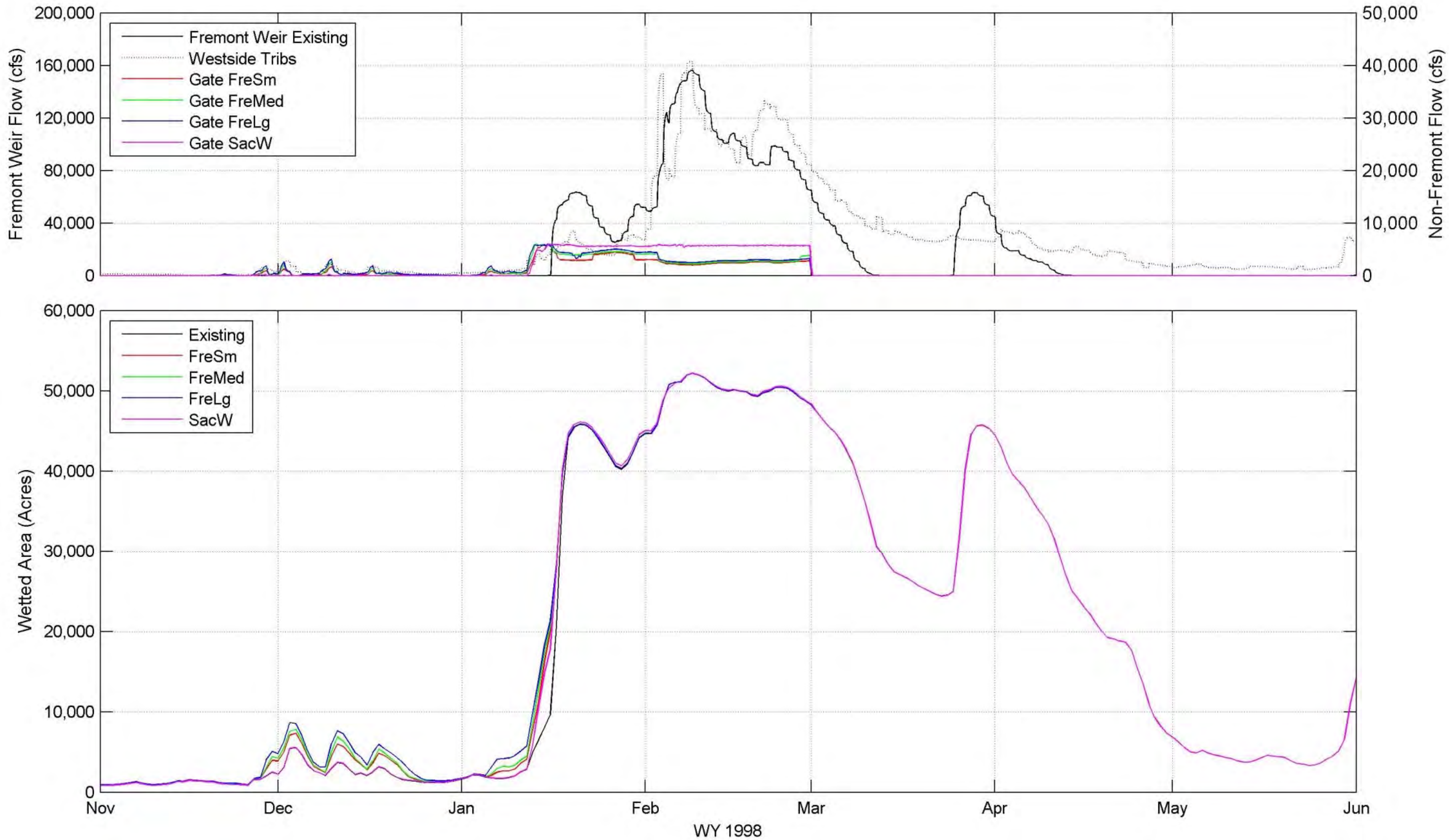


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1997 for Mar 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D17**



Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

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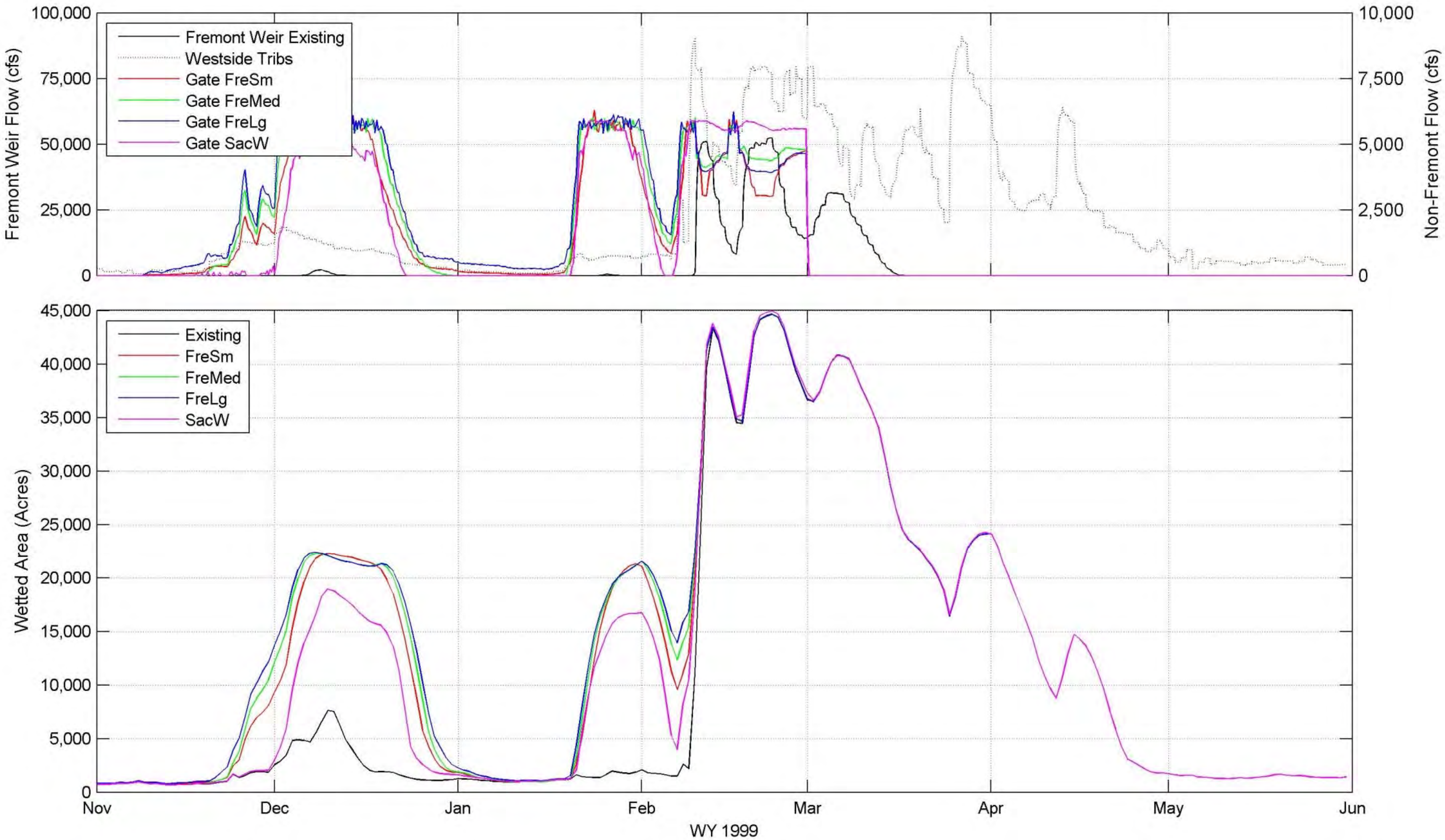
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1998 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D18**

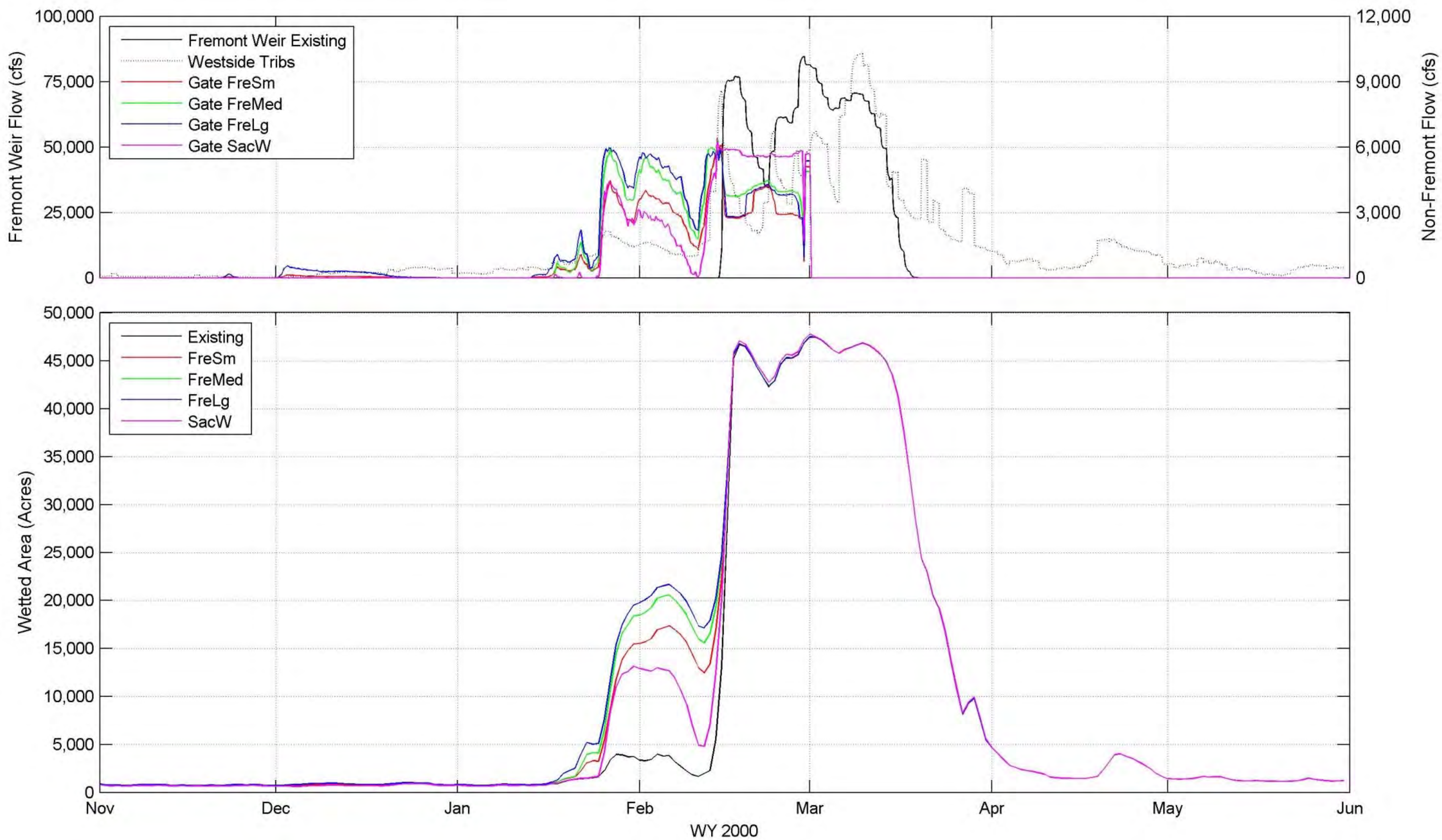


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1999 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D19**

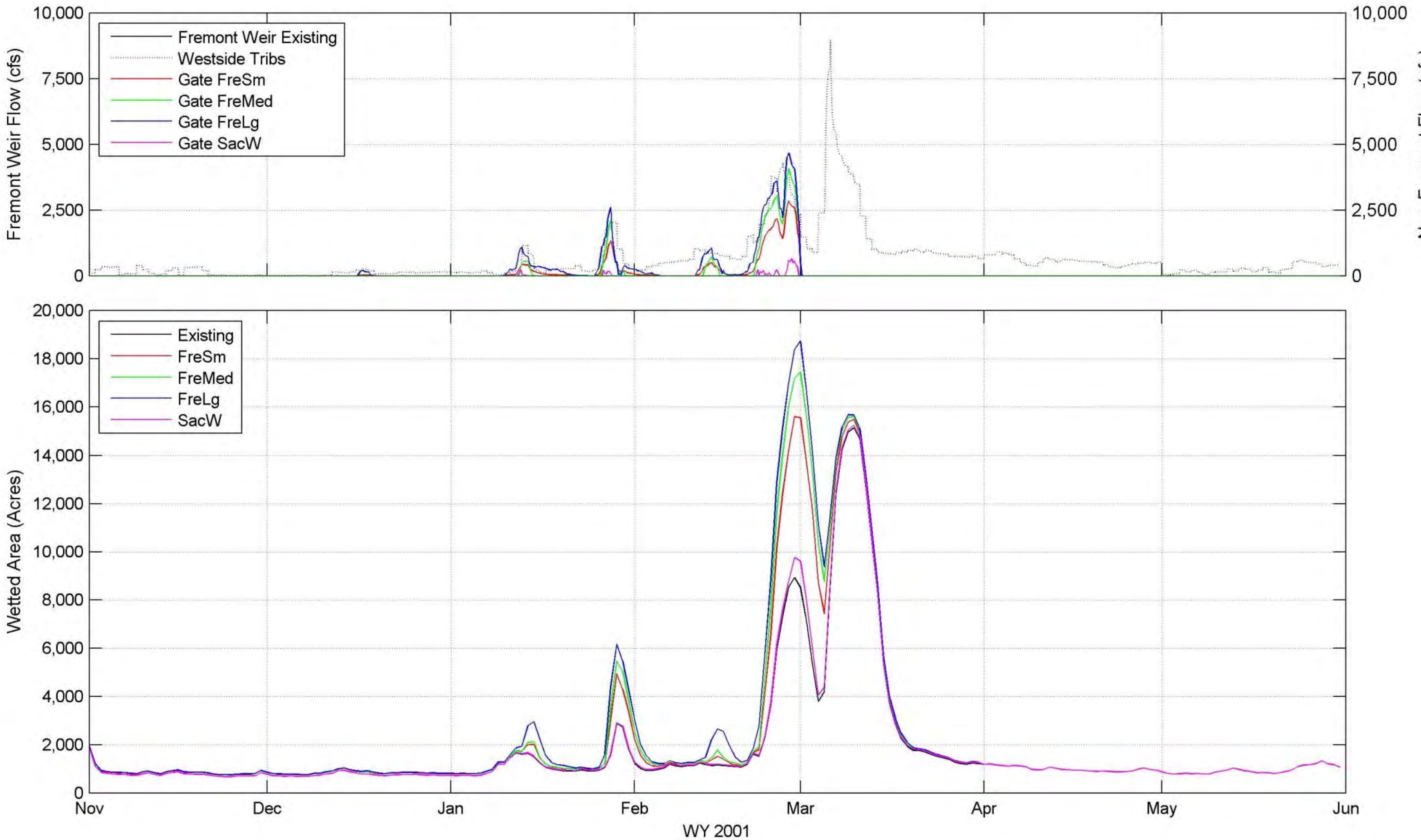


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2000 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D20**

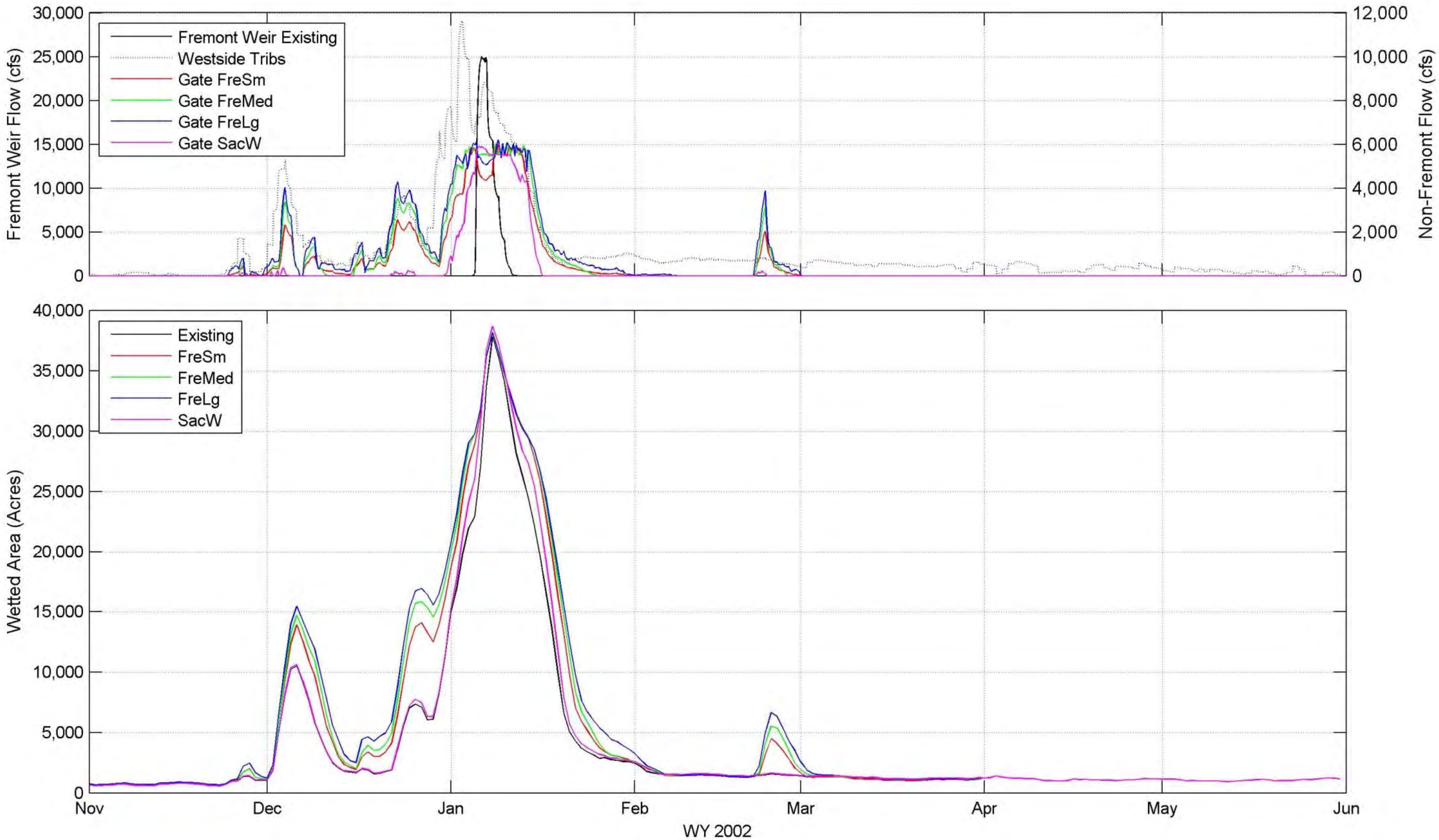


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2001 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D21**

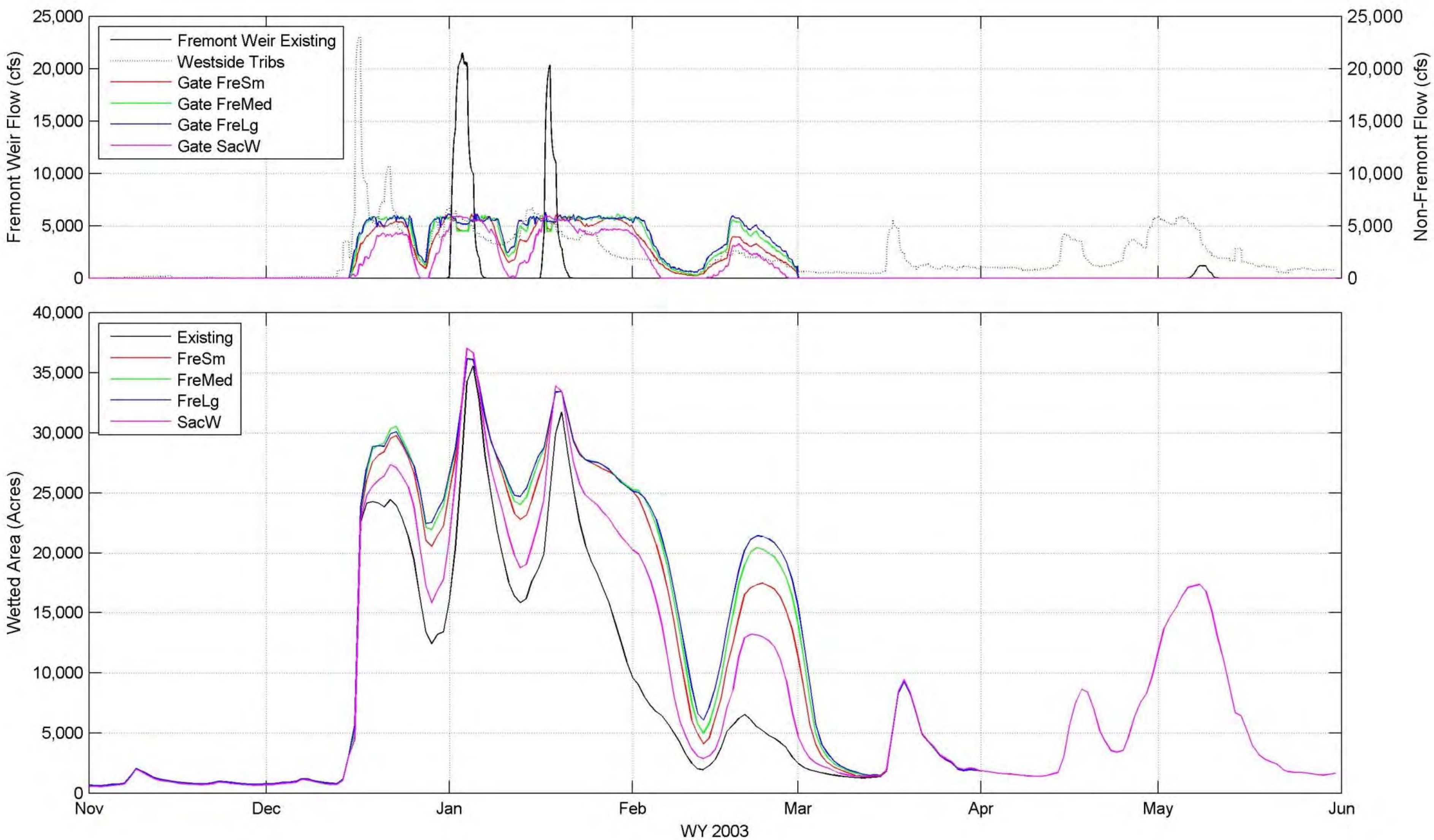


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2002 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D22**

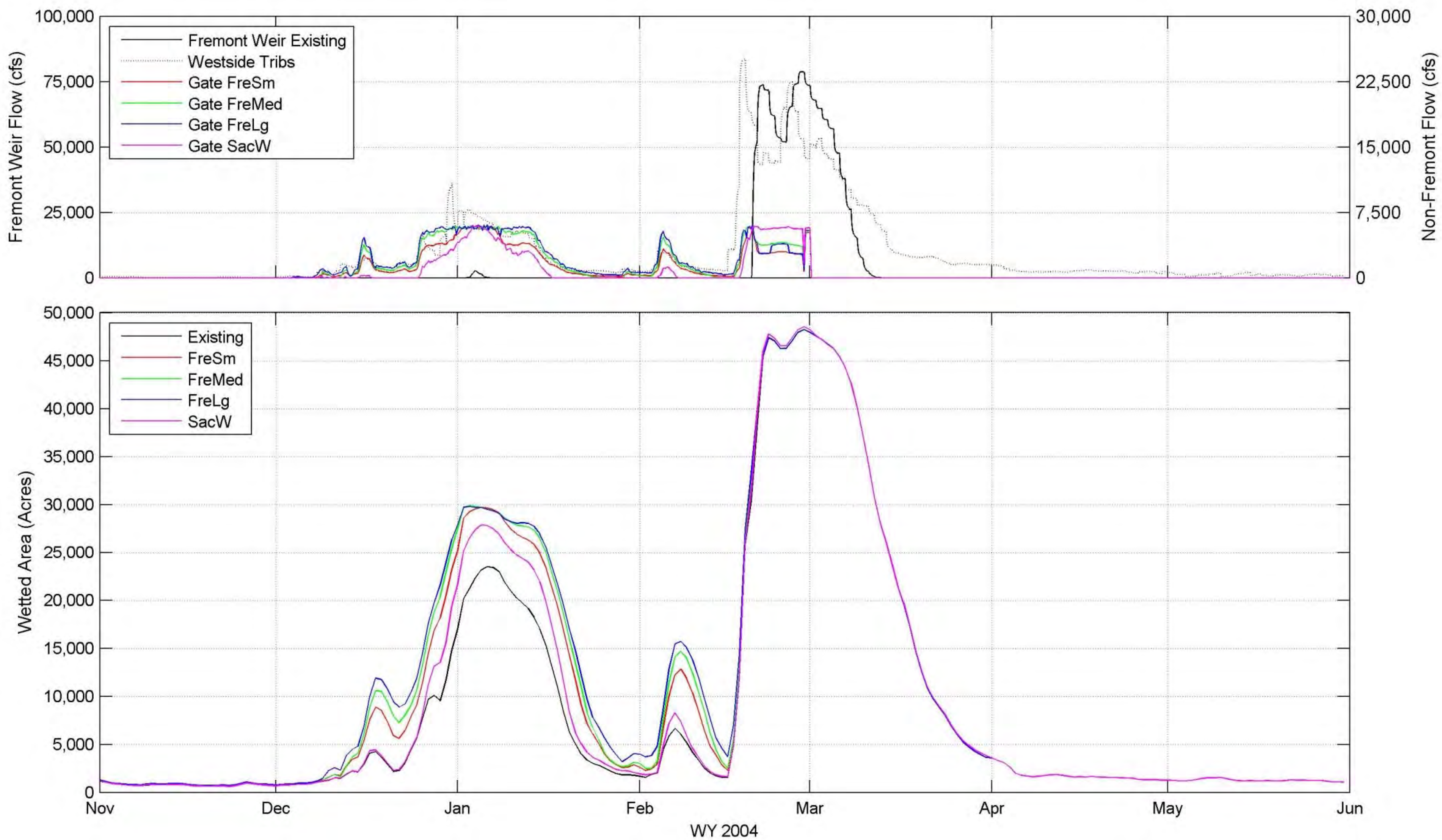


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2003 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D23**

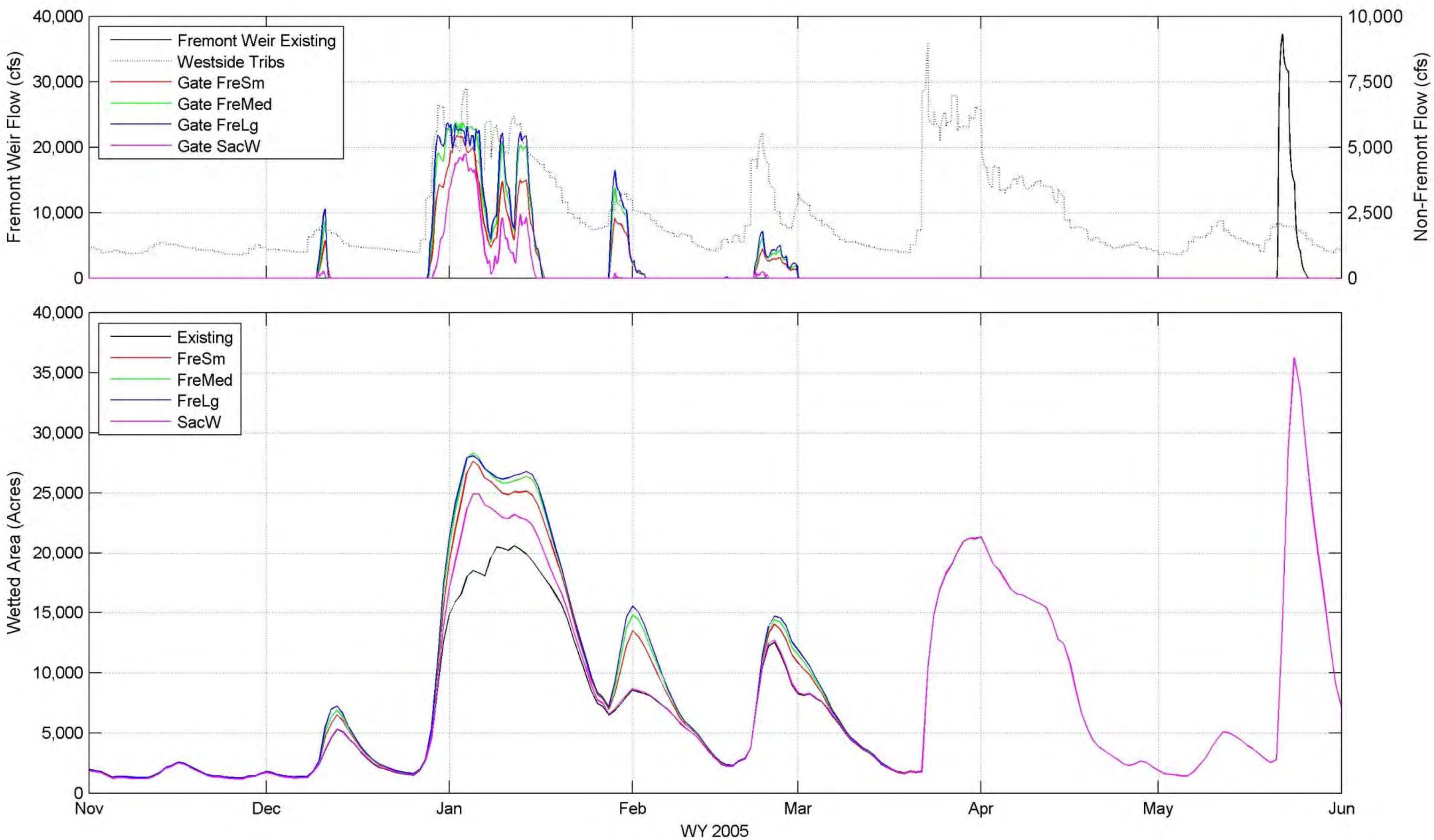


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2004 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D24**

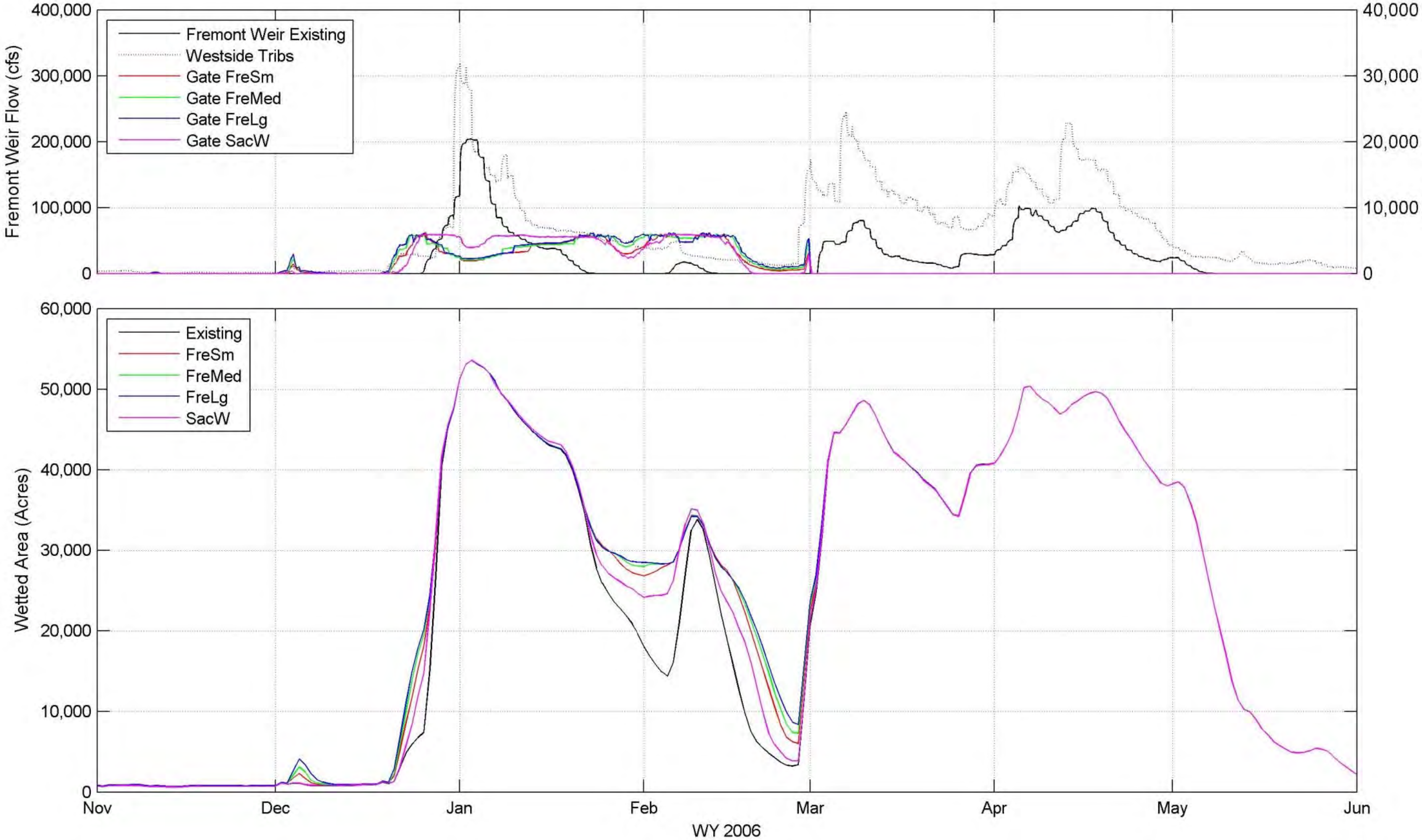


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2005 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D25**

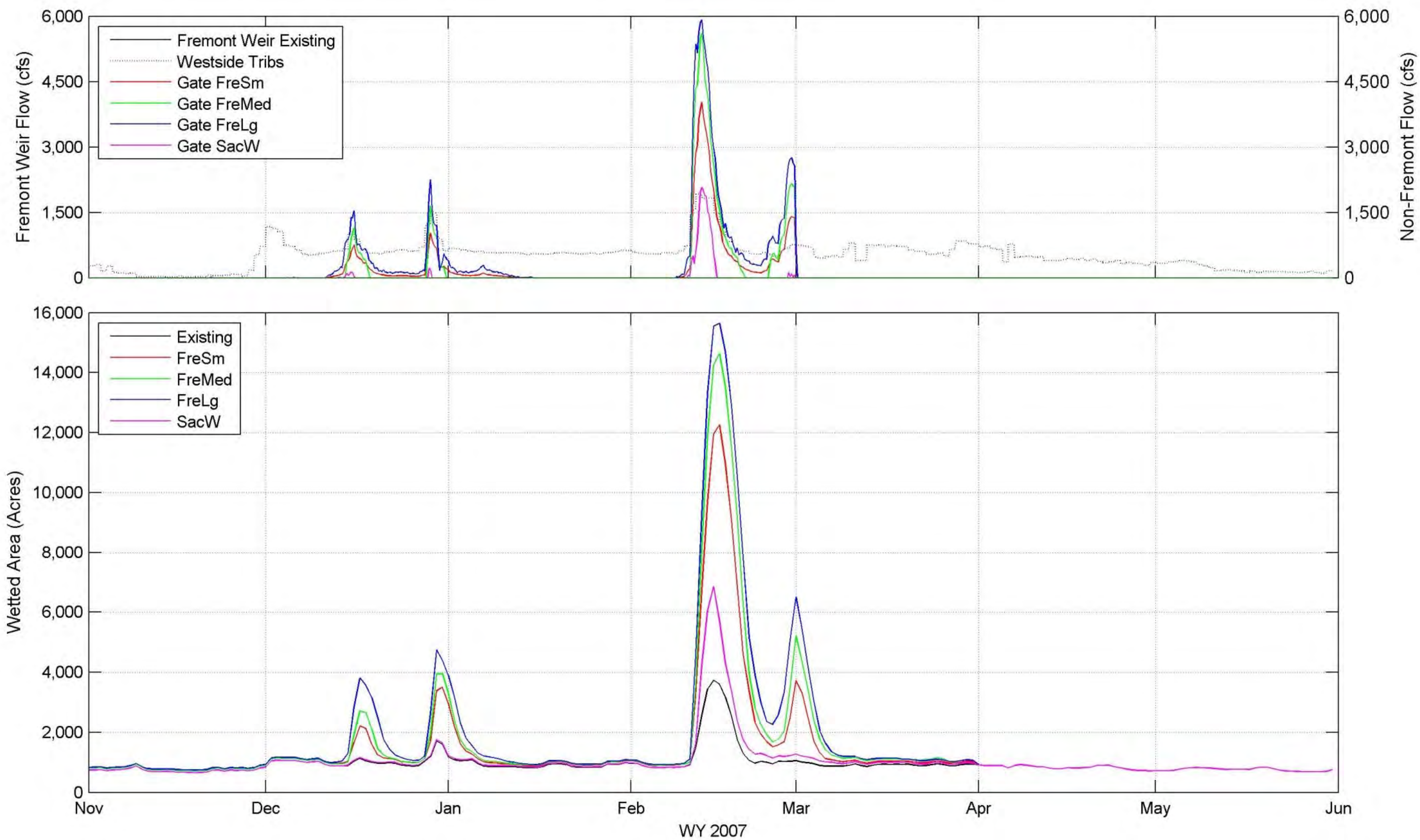


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2006 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D26**

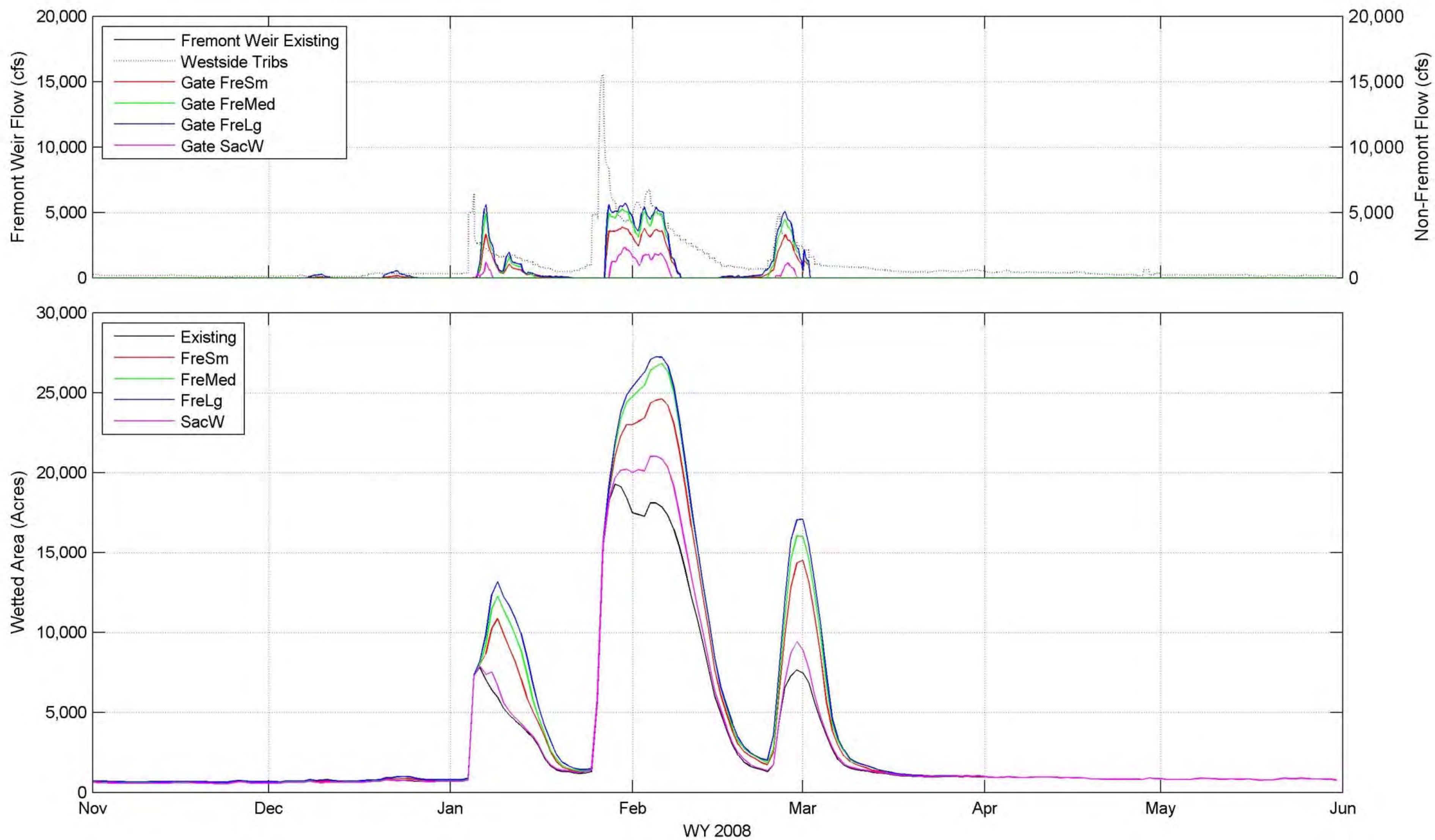


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2007 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D27**

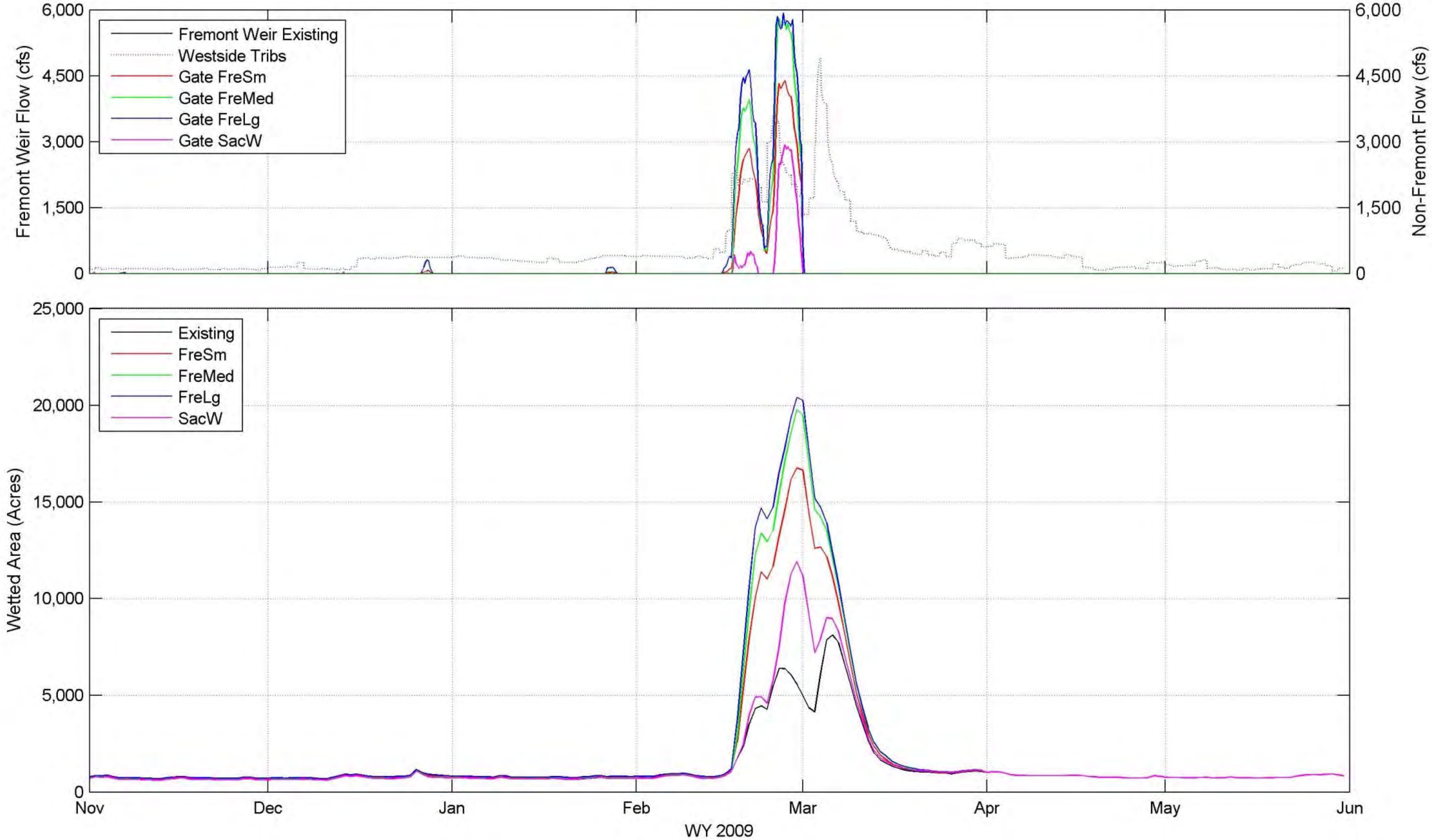


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2008 for Mar 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D28**

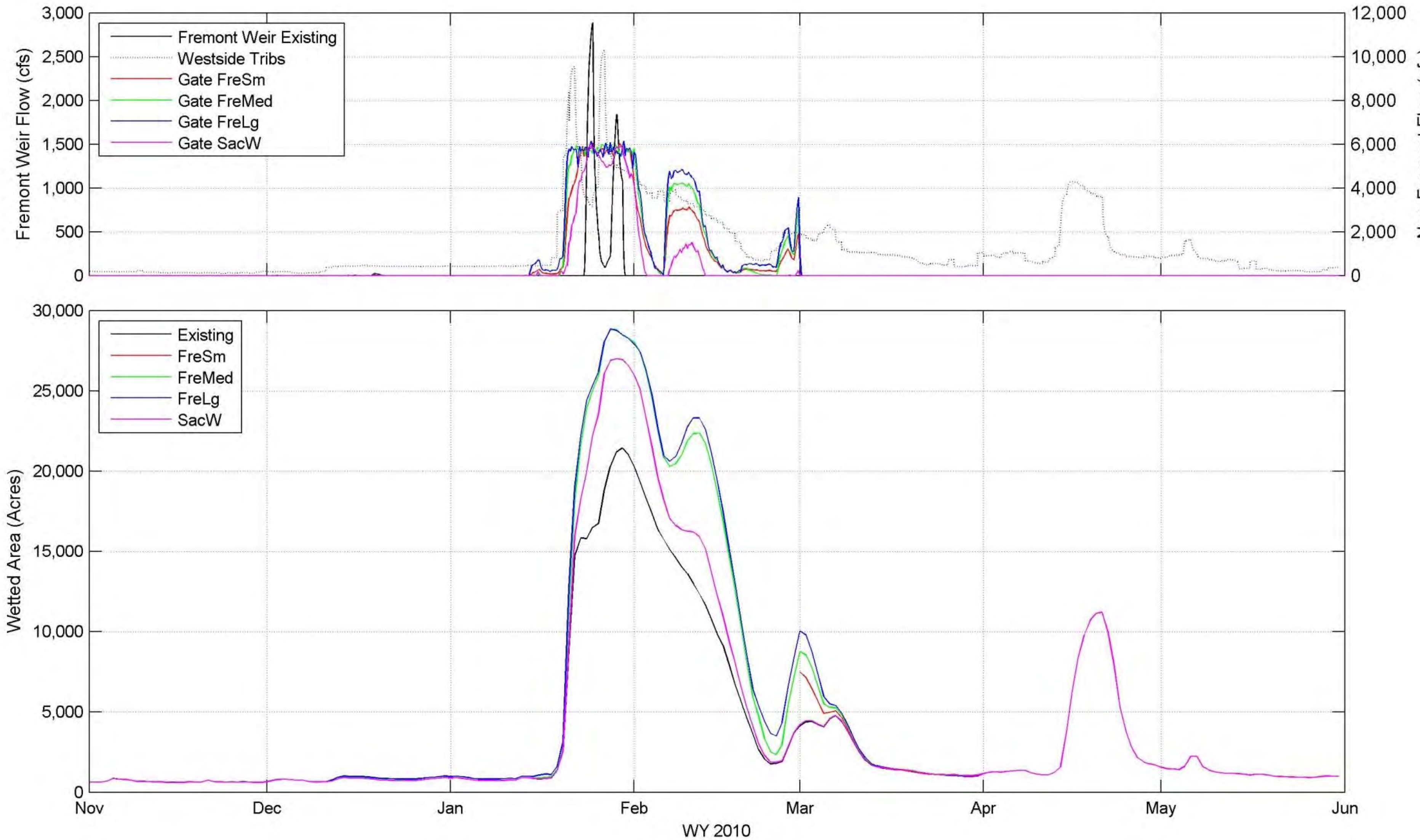


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2009 for Mar 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D29**

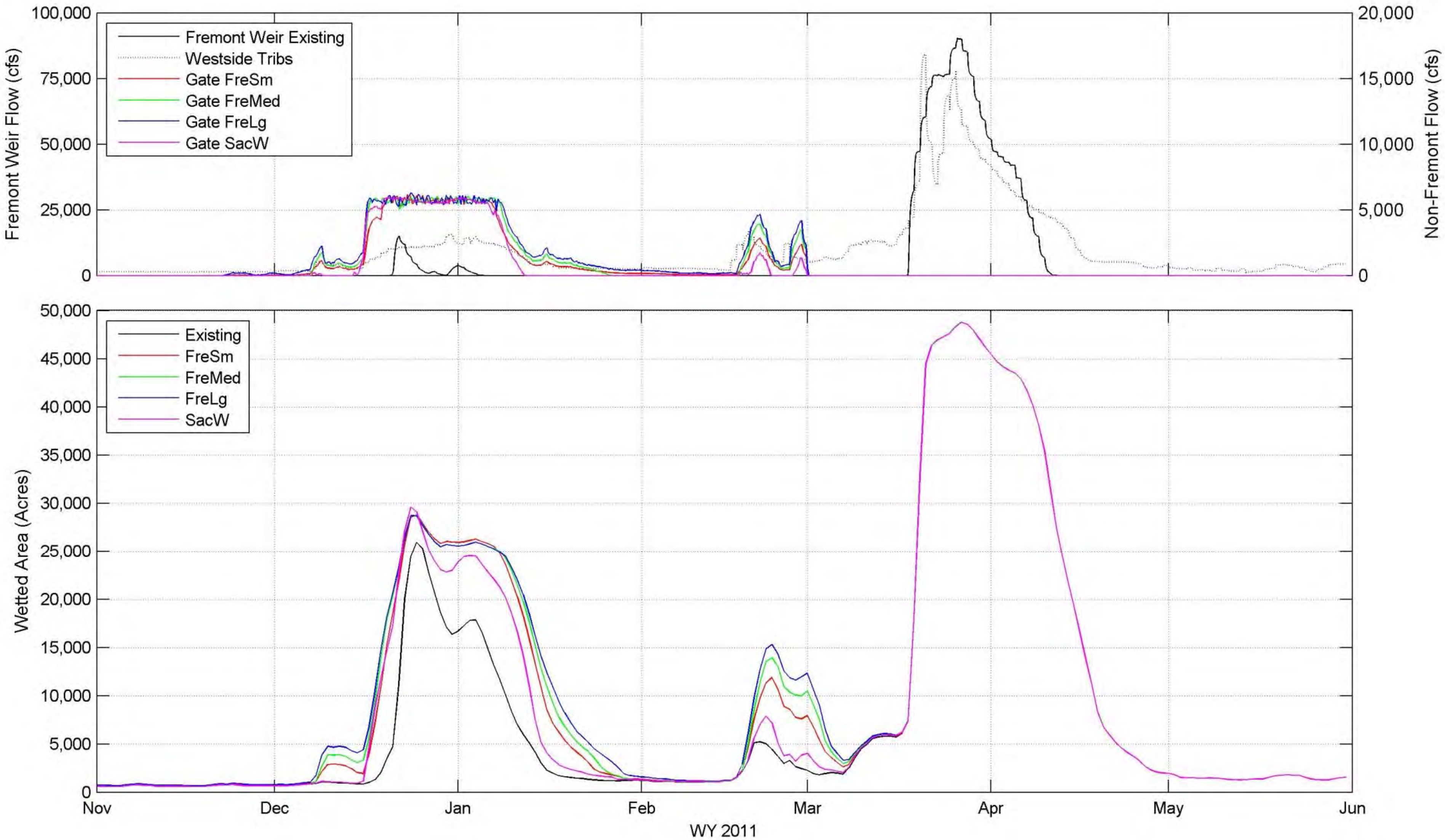


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2010 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D30**

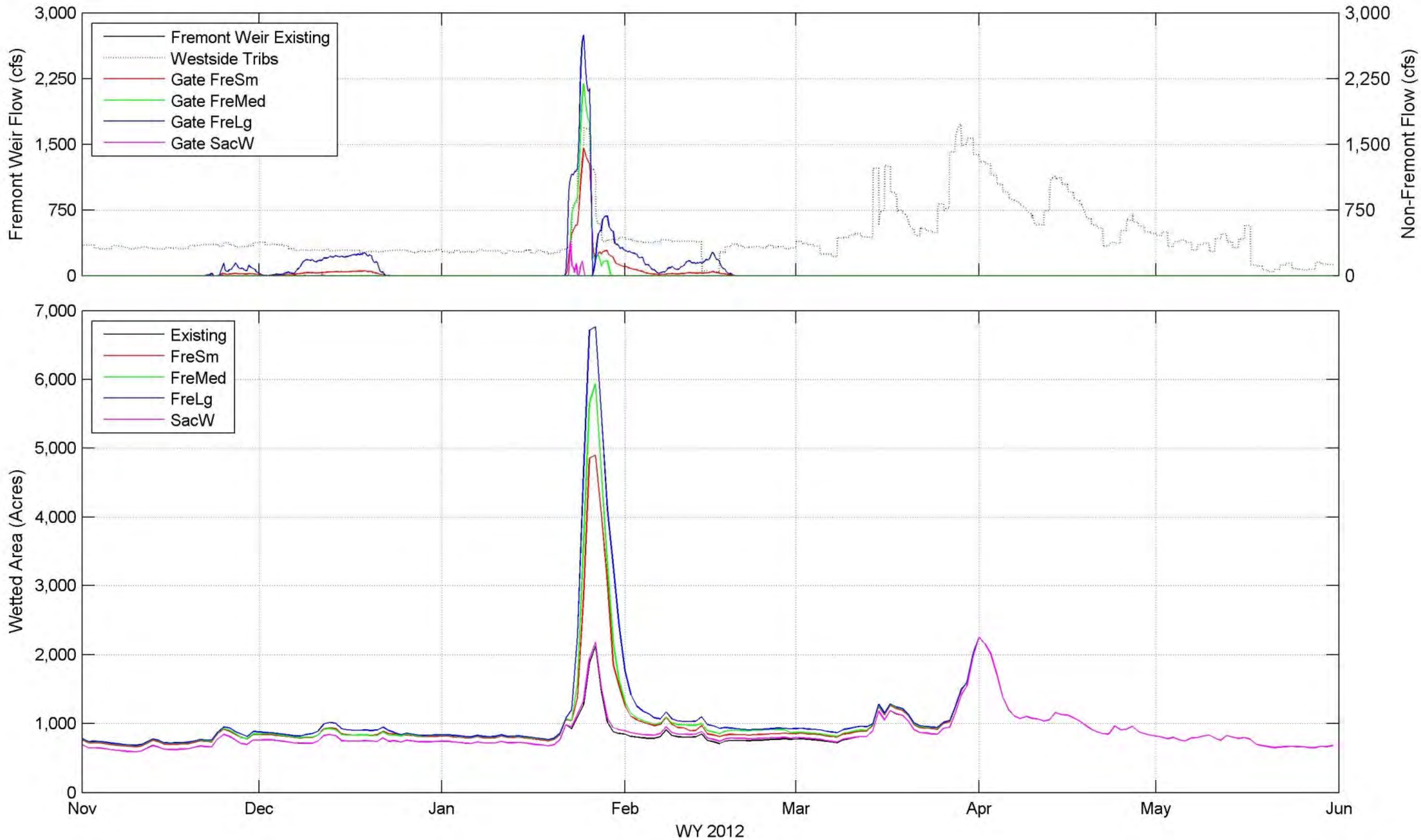


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2011 for Mar 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D31**

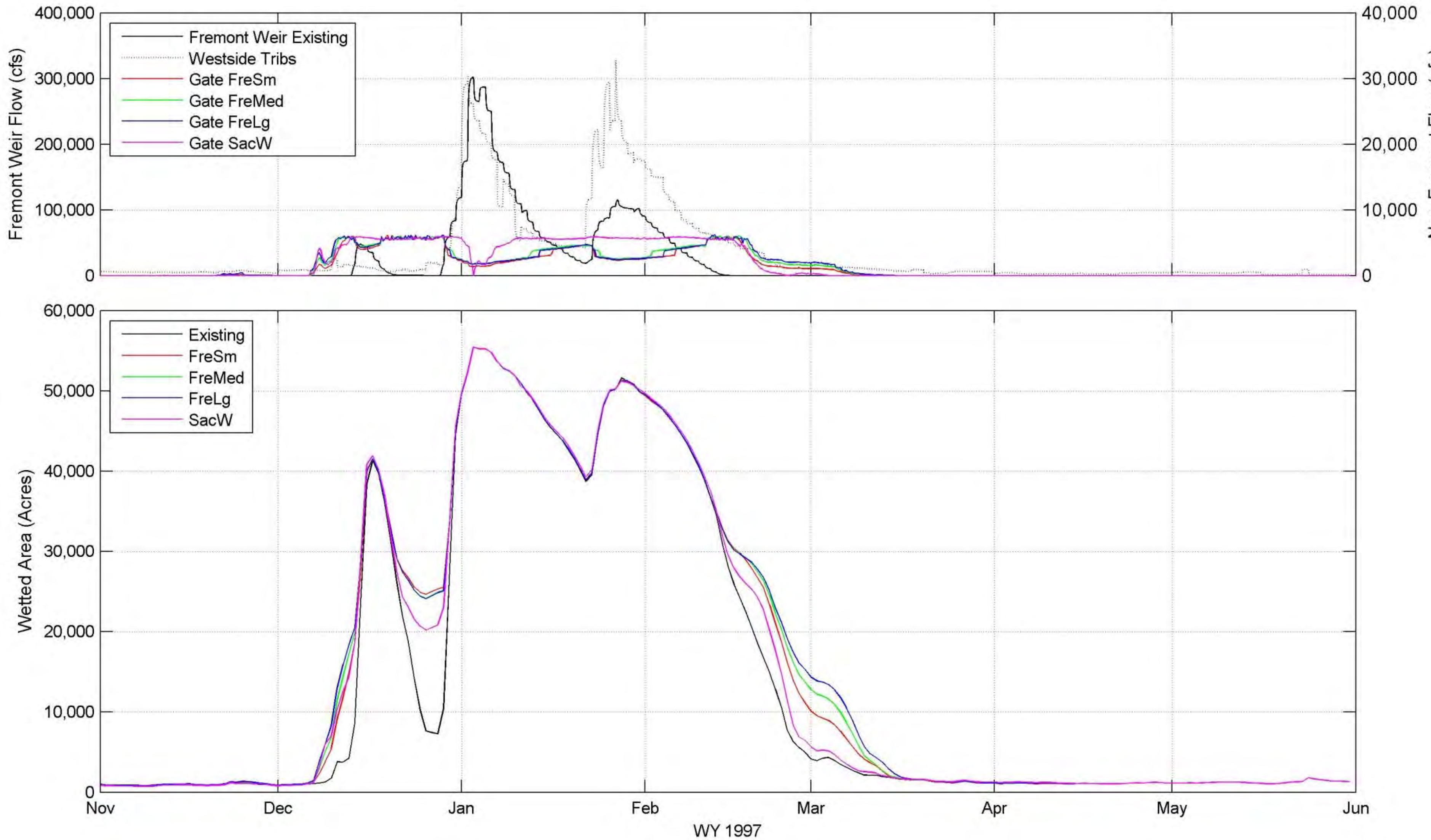


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2012 for Mar 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D32**

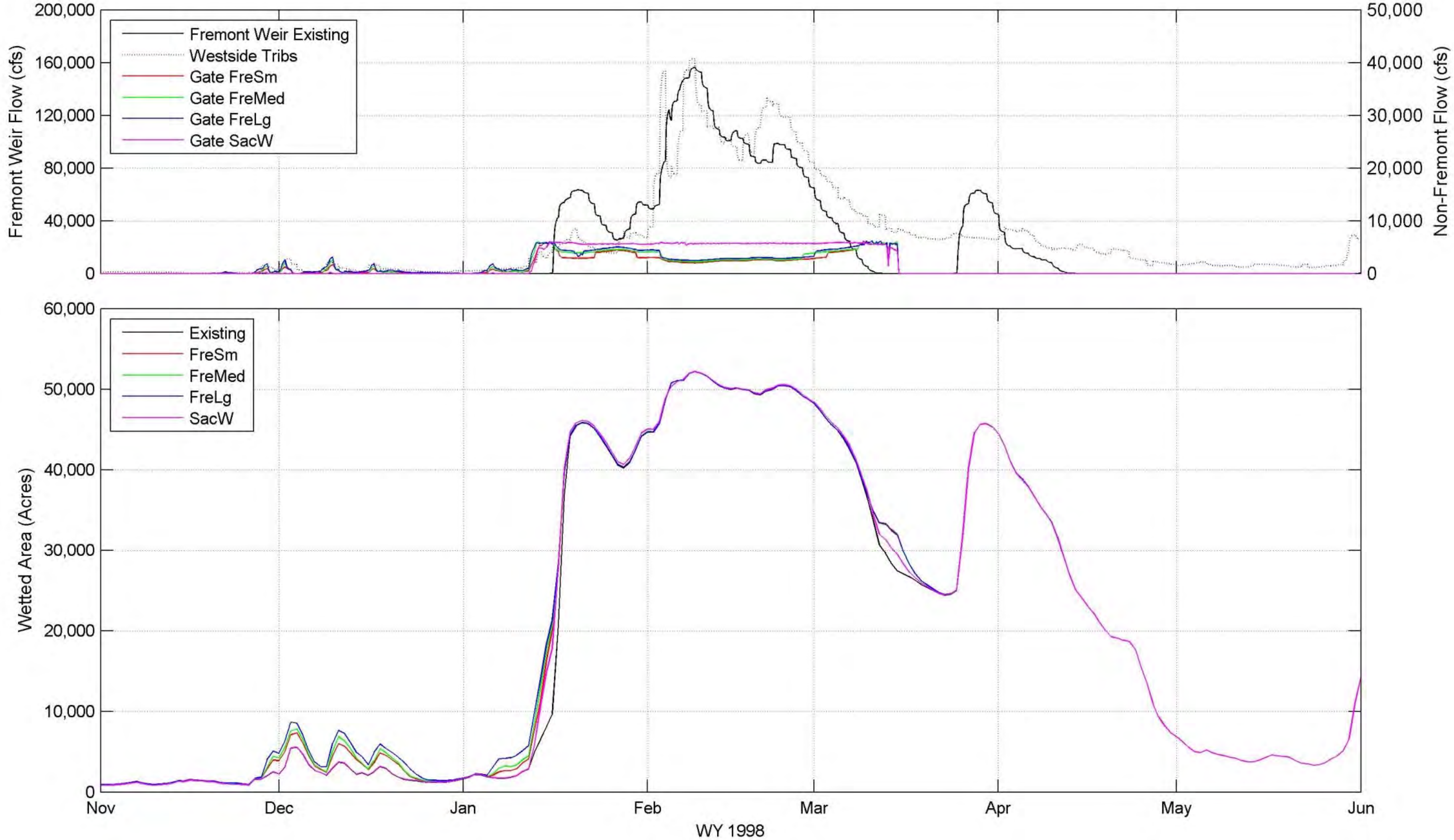


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1997 for Mar 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D33**

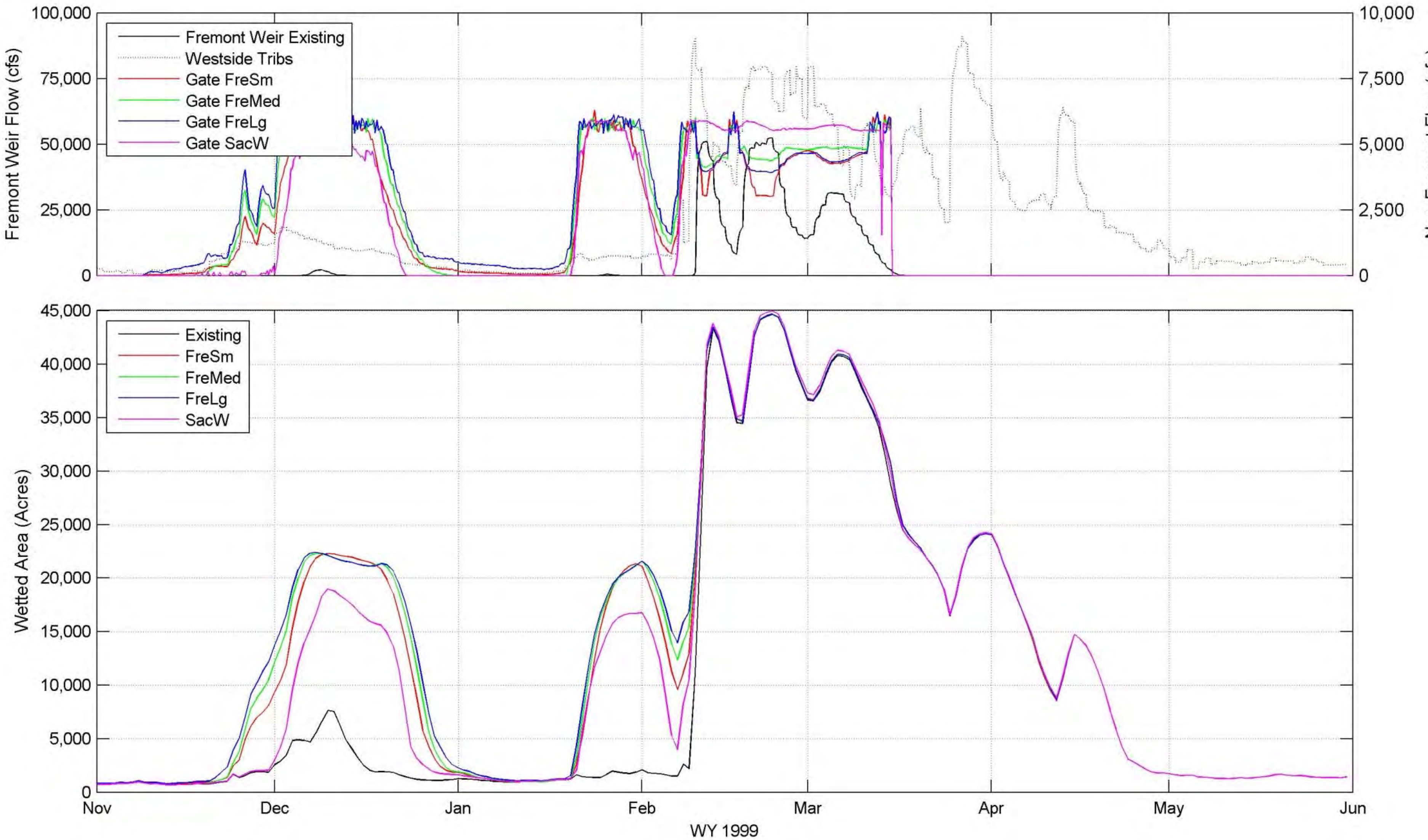


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1998 for Mar 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D34**

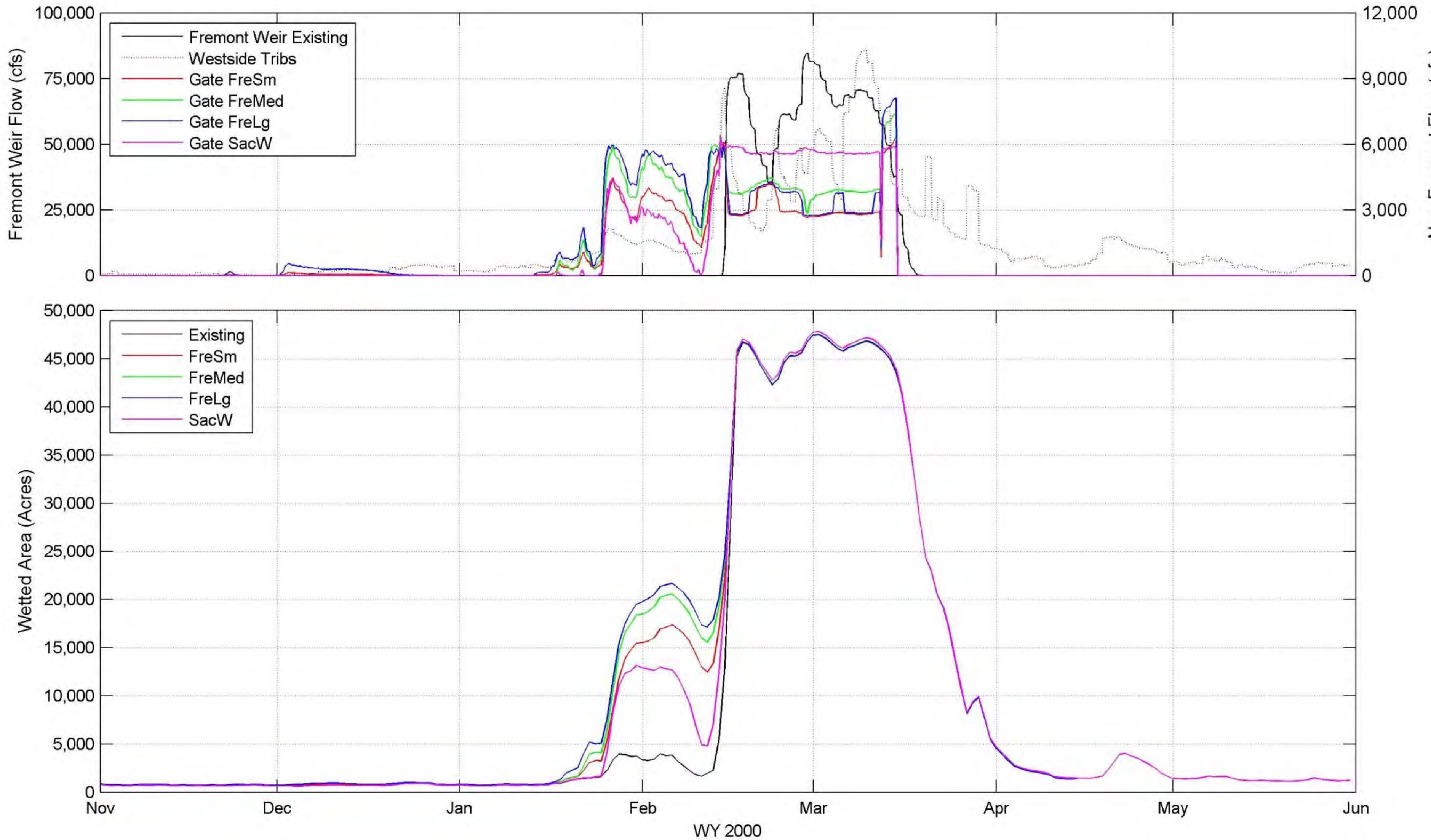


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1999 for Mar 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D35**

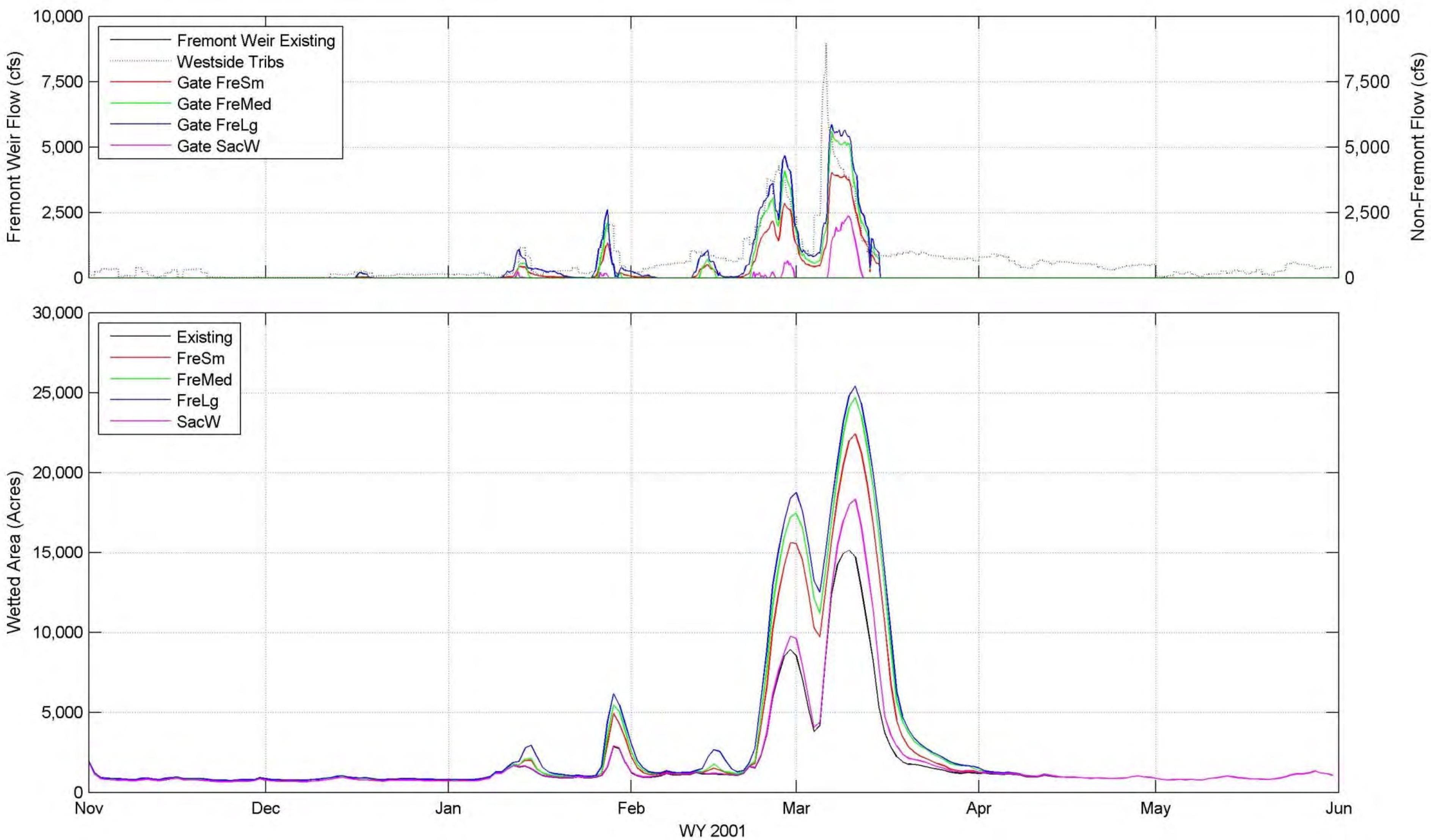


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2000 for Mar 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D36**



Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

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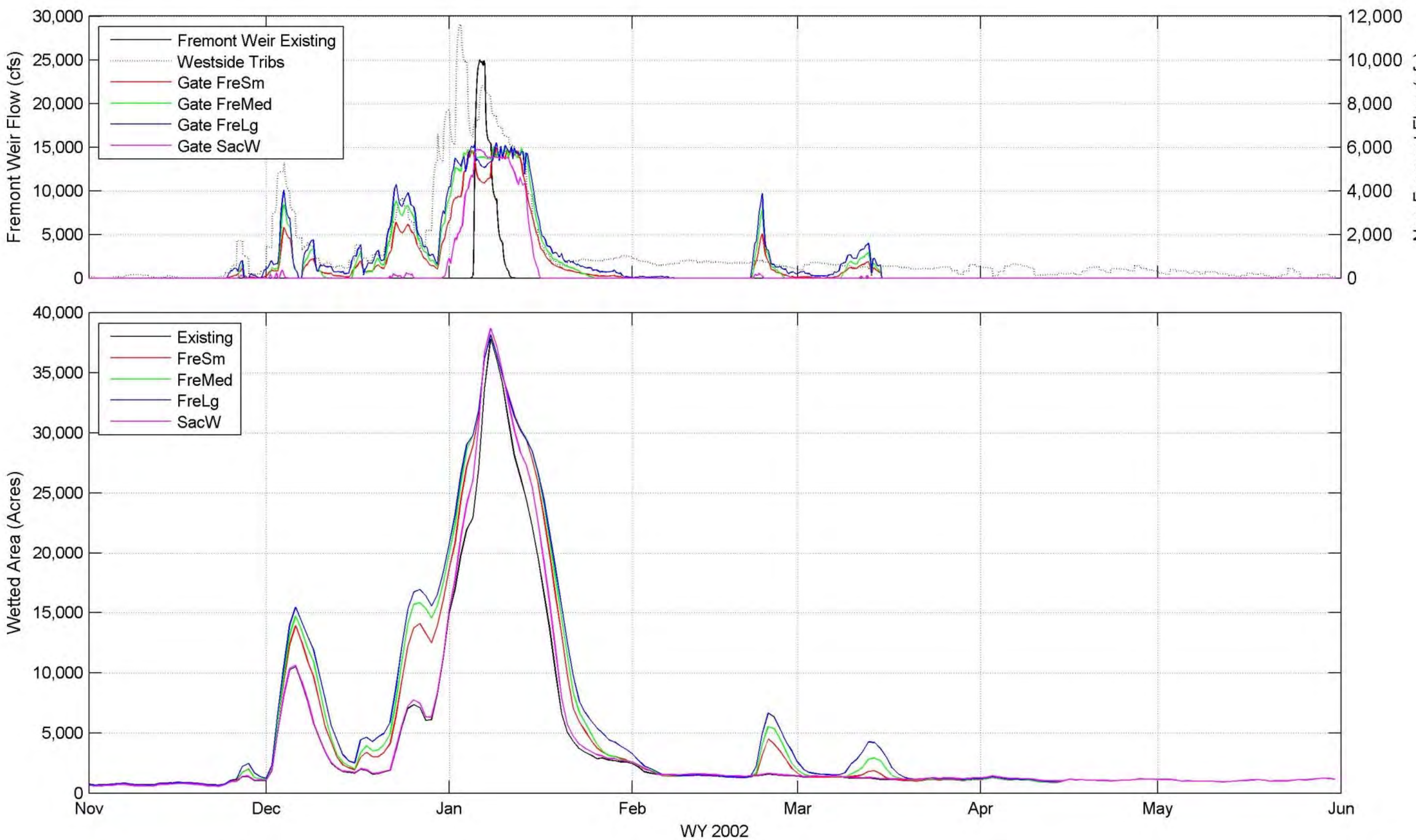
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2001 for Mar 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D37**

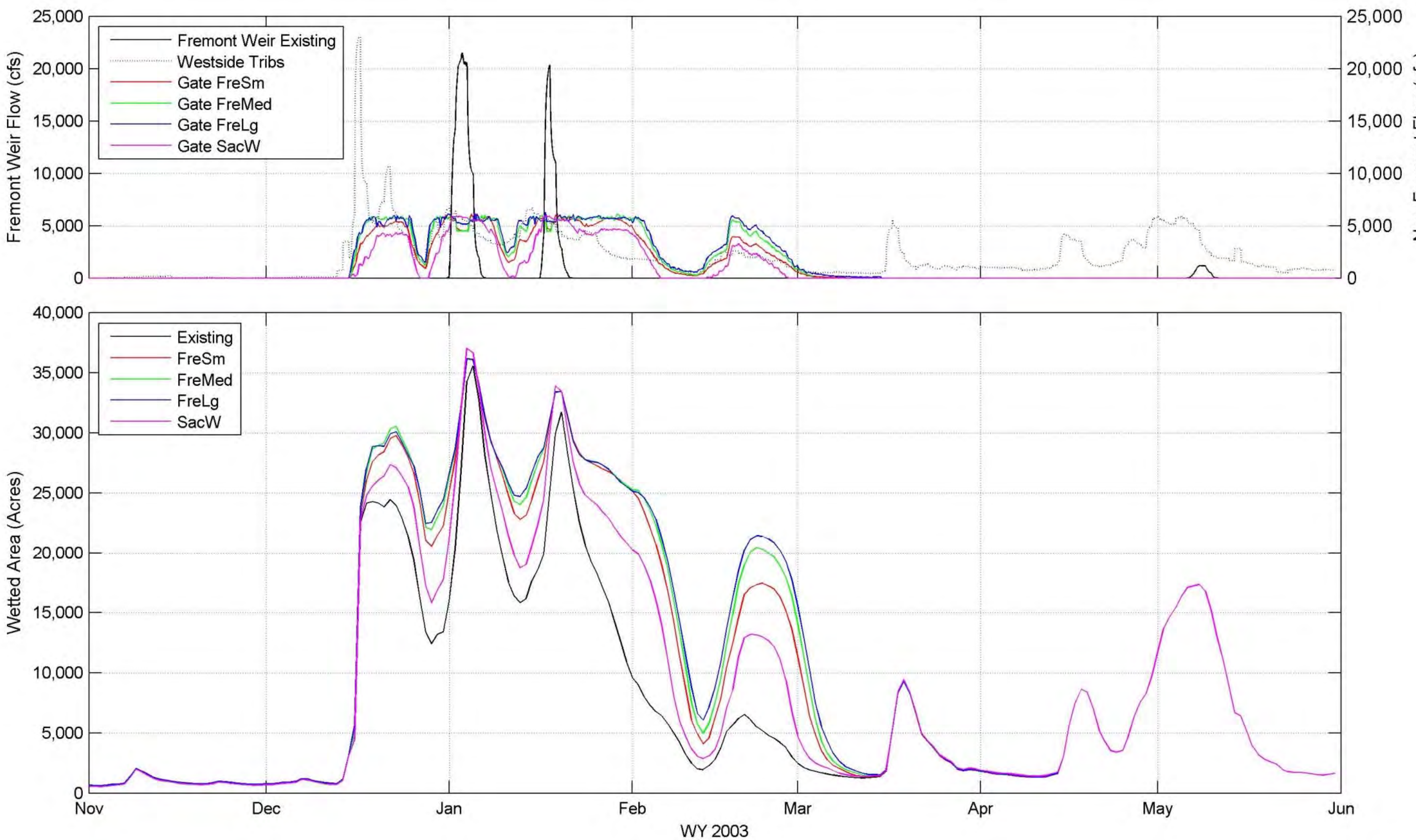


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2002 for Mar 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D38**

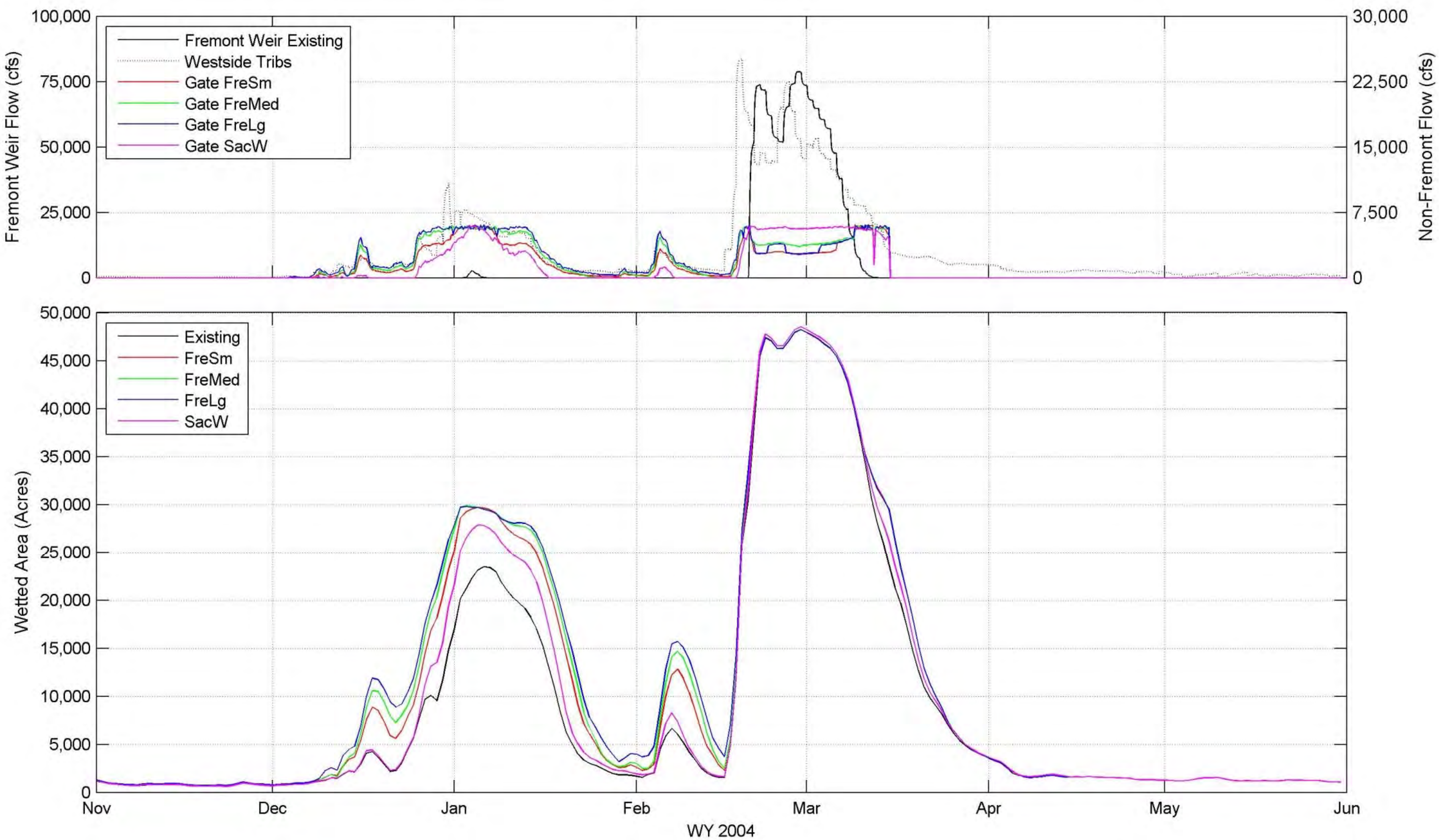


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2003 for Mar 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D39**

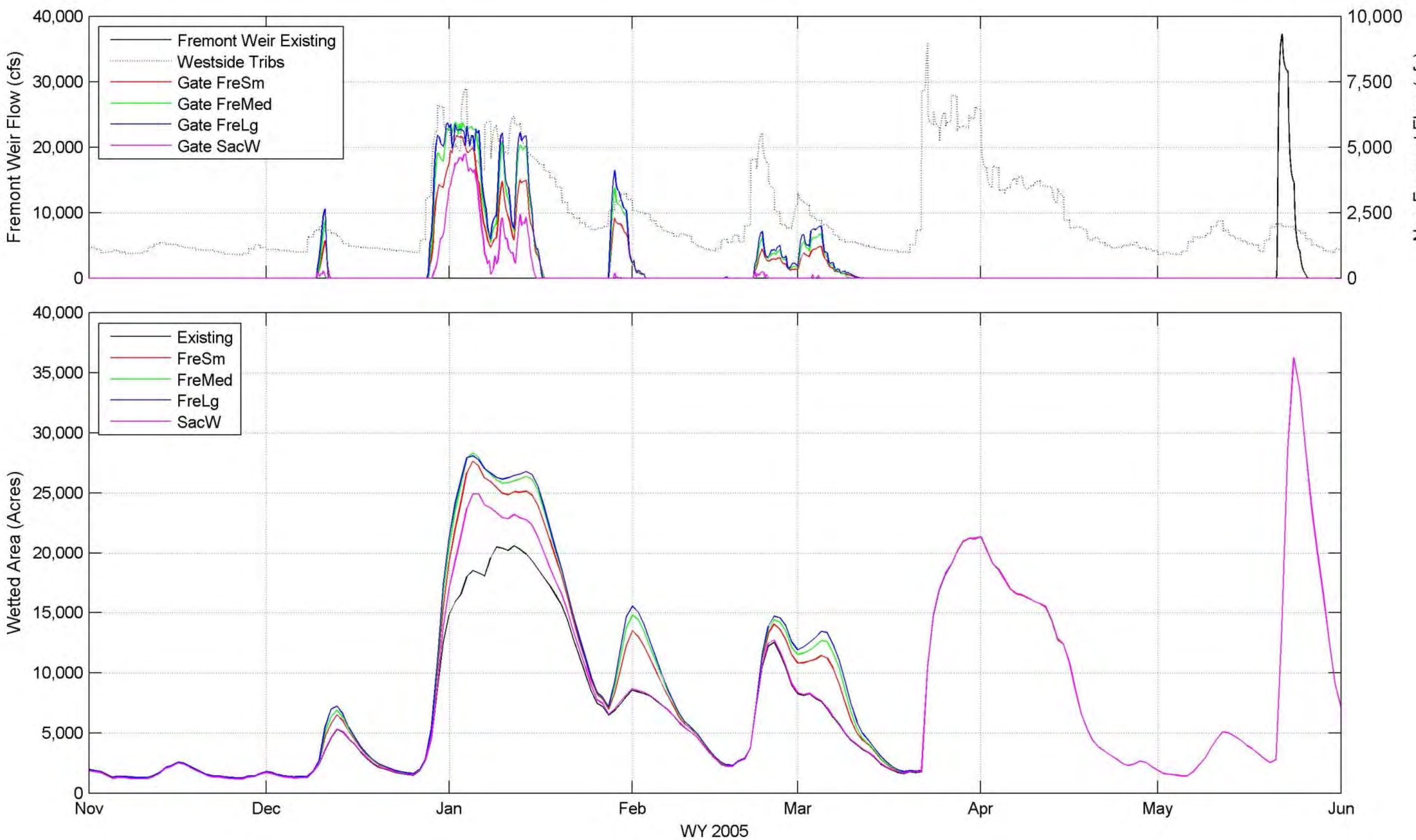


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2004 for Mar 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D40**



Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

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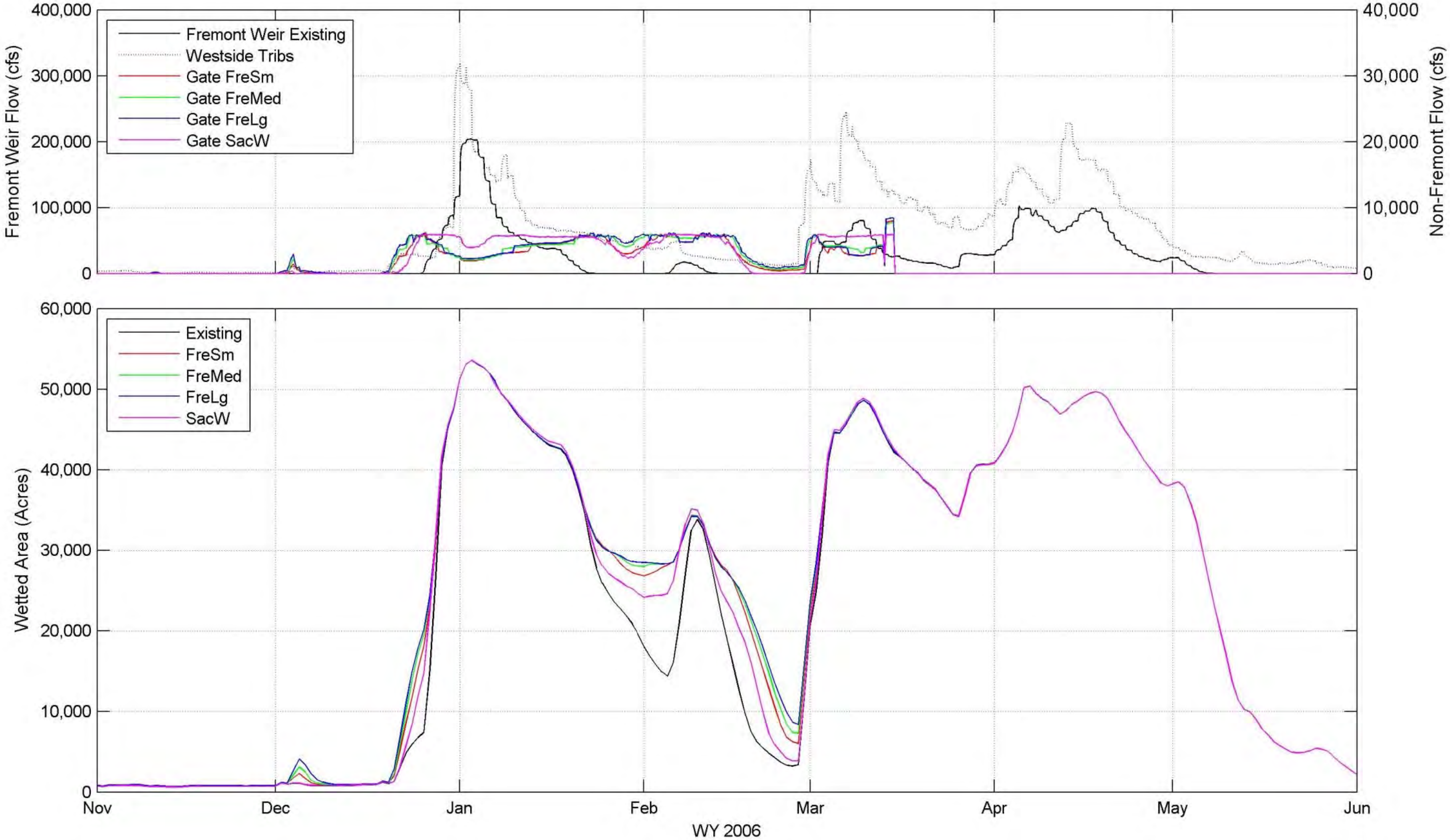
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2005 for Mar 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D41**

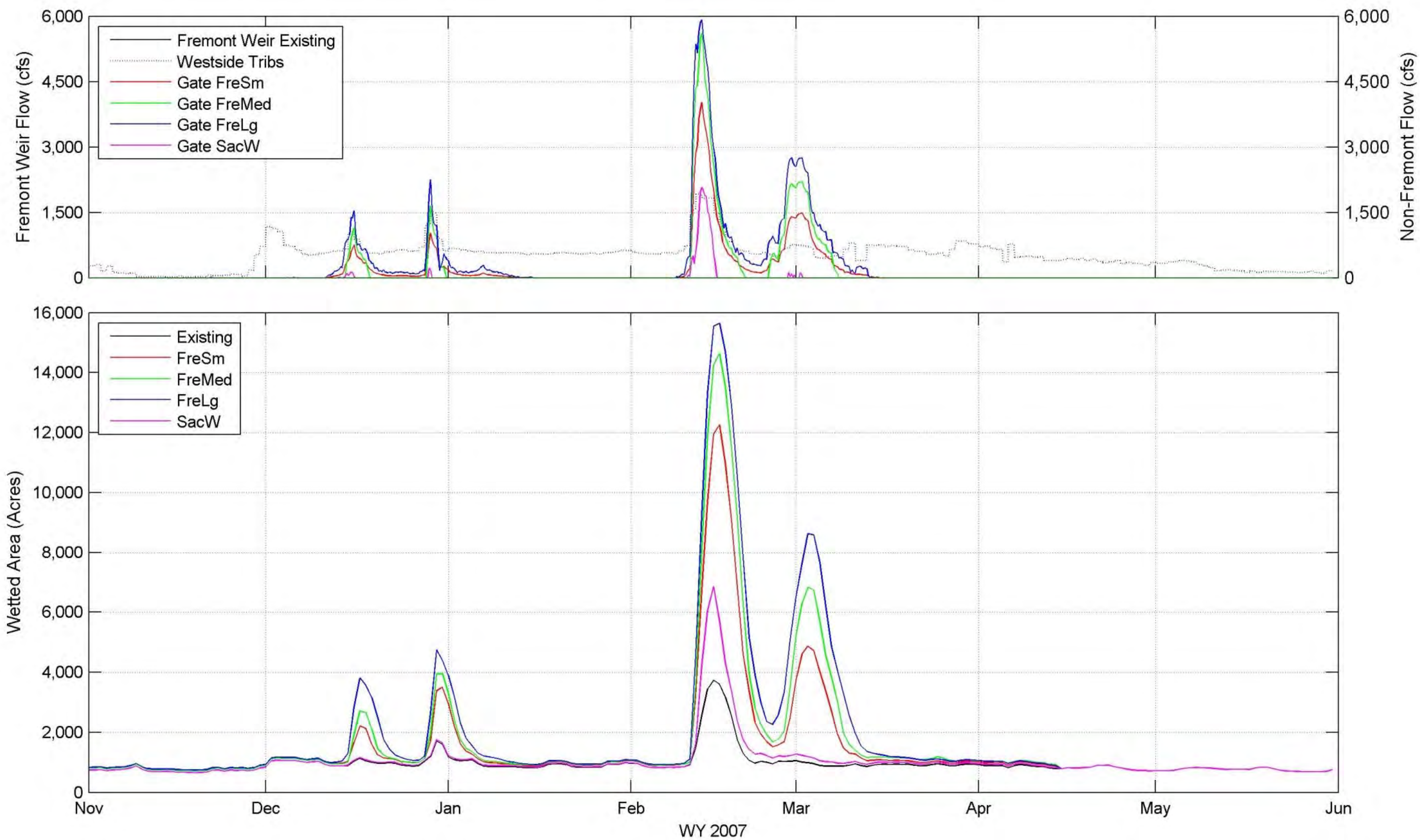


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2006 for Mar 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D42**

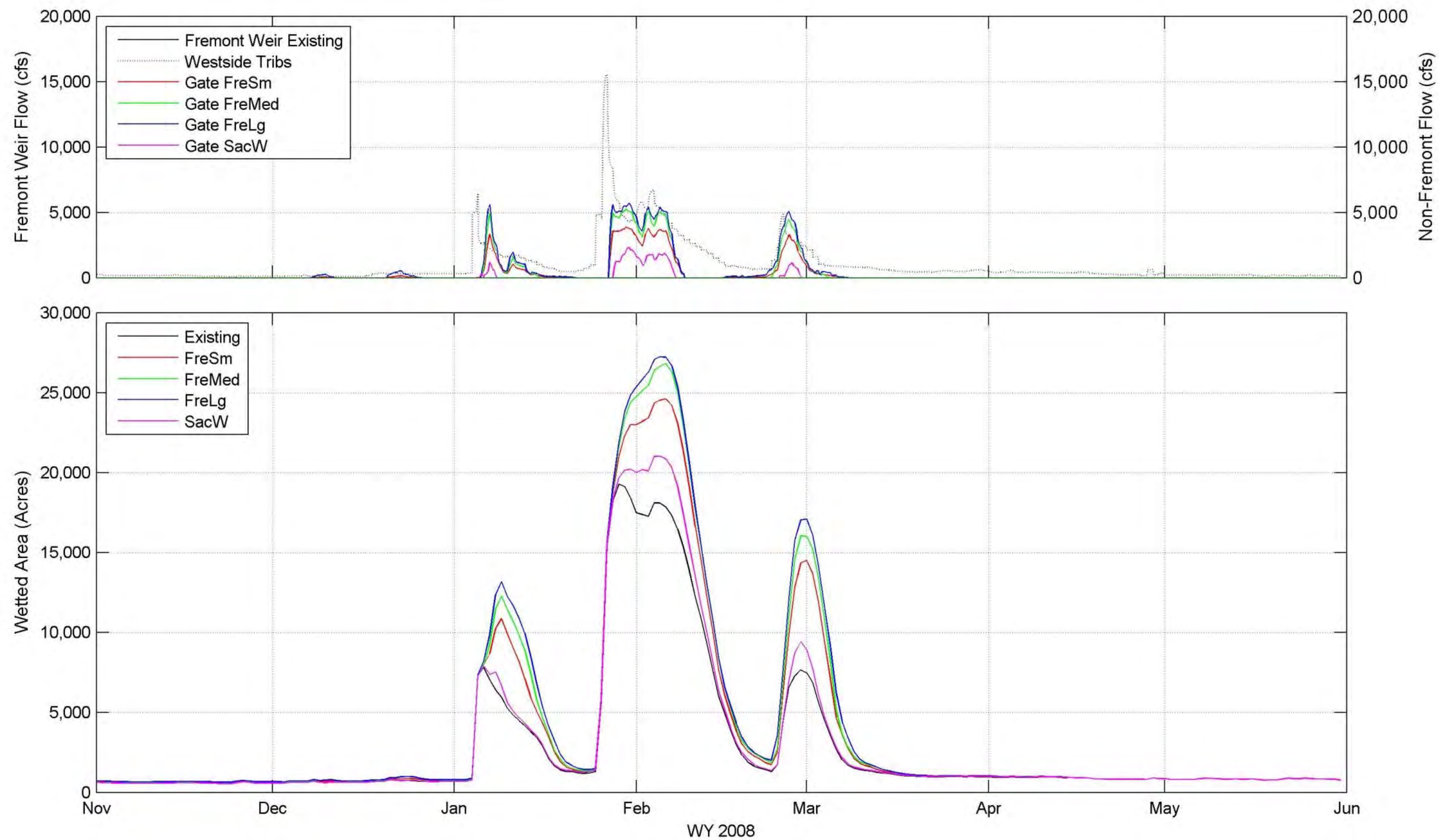


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2007 for Mar 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D43**

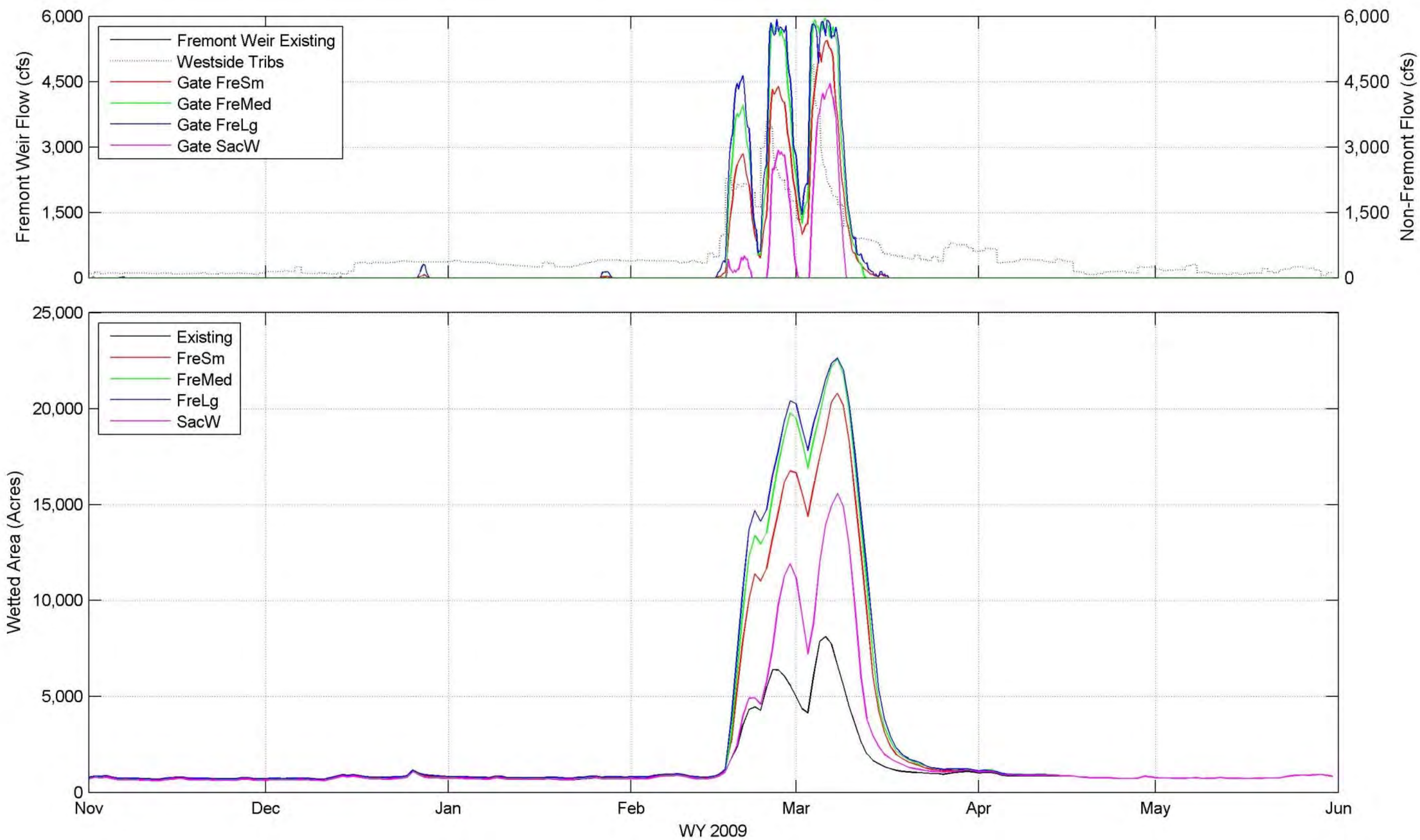


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2008 for Mar 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D44**

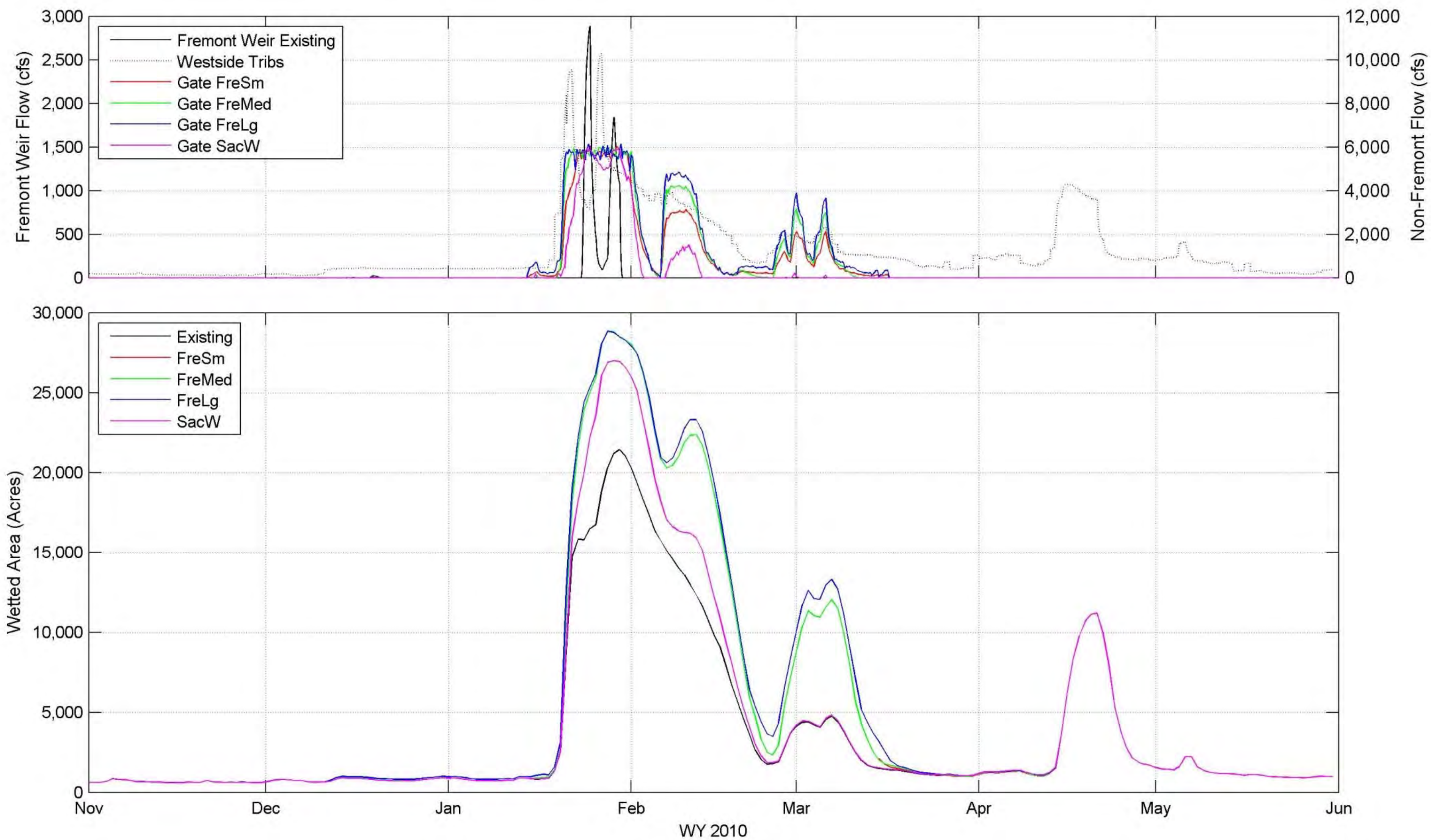


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2009 for Mar 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D45**

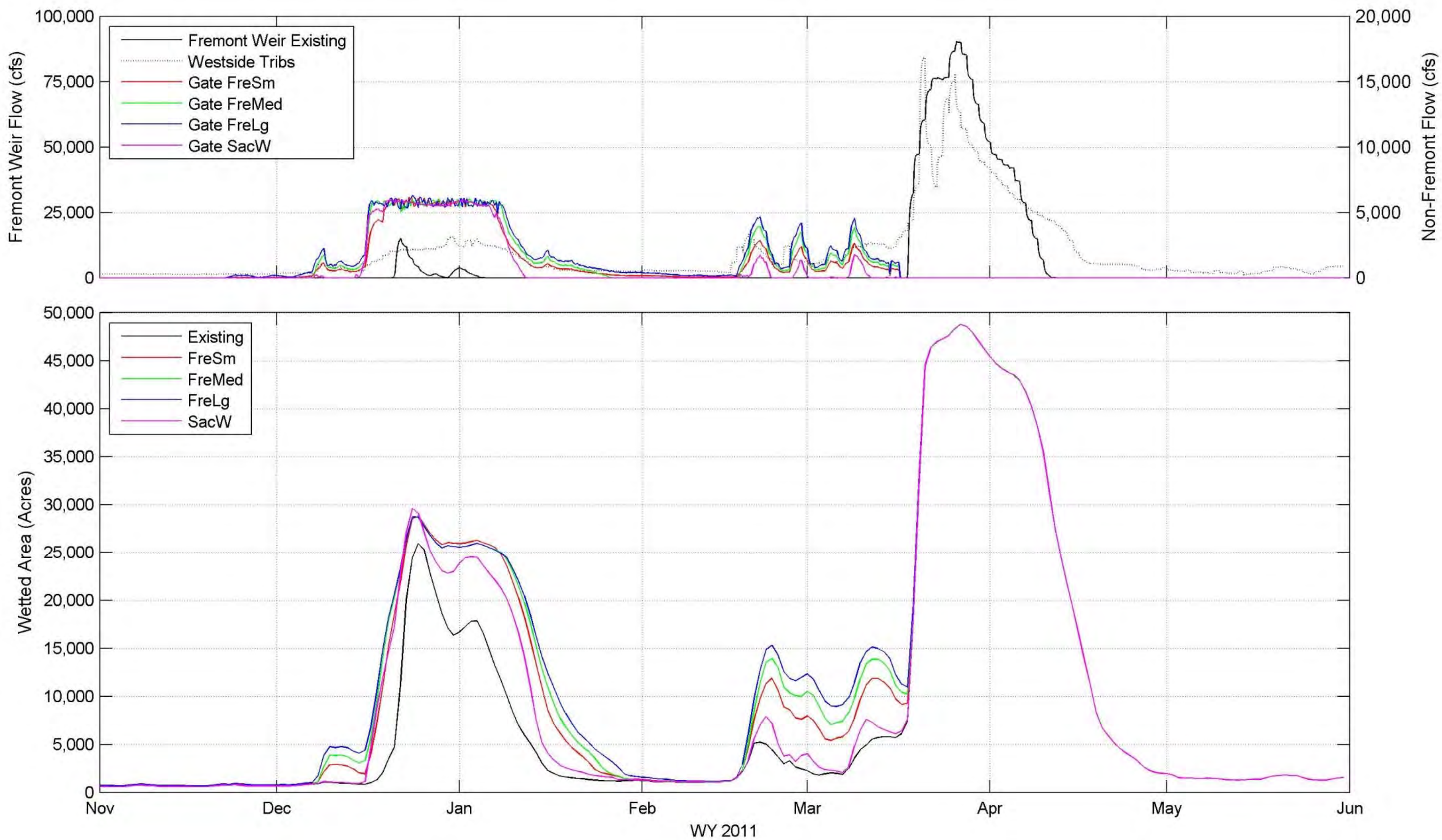


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2010 for Mar 15 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D46**

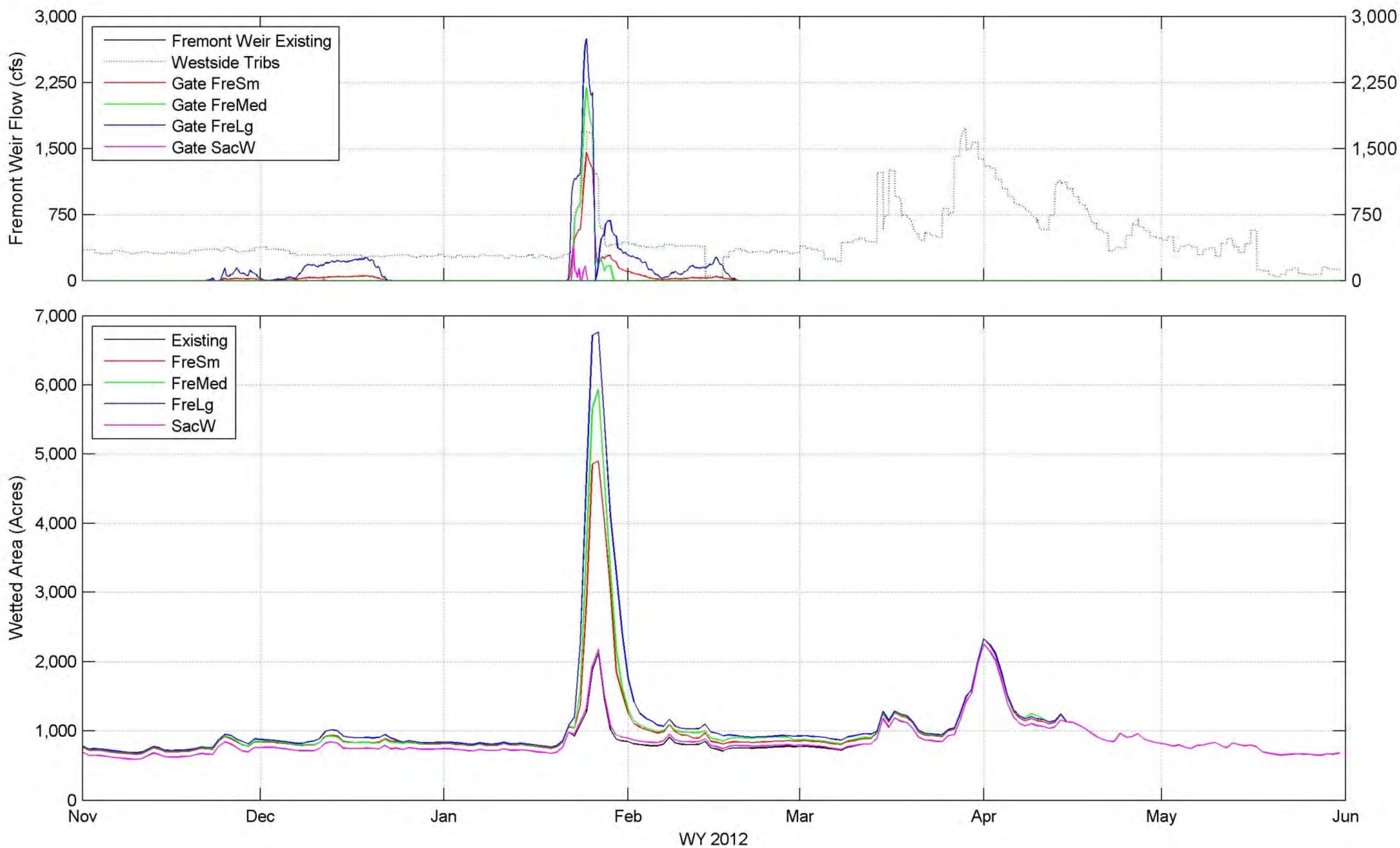


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2011 for Mar 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D47**



Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

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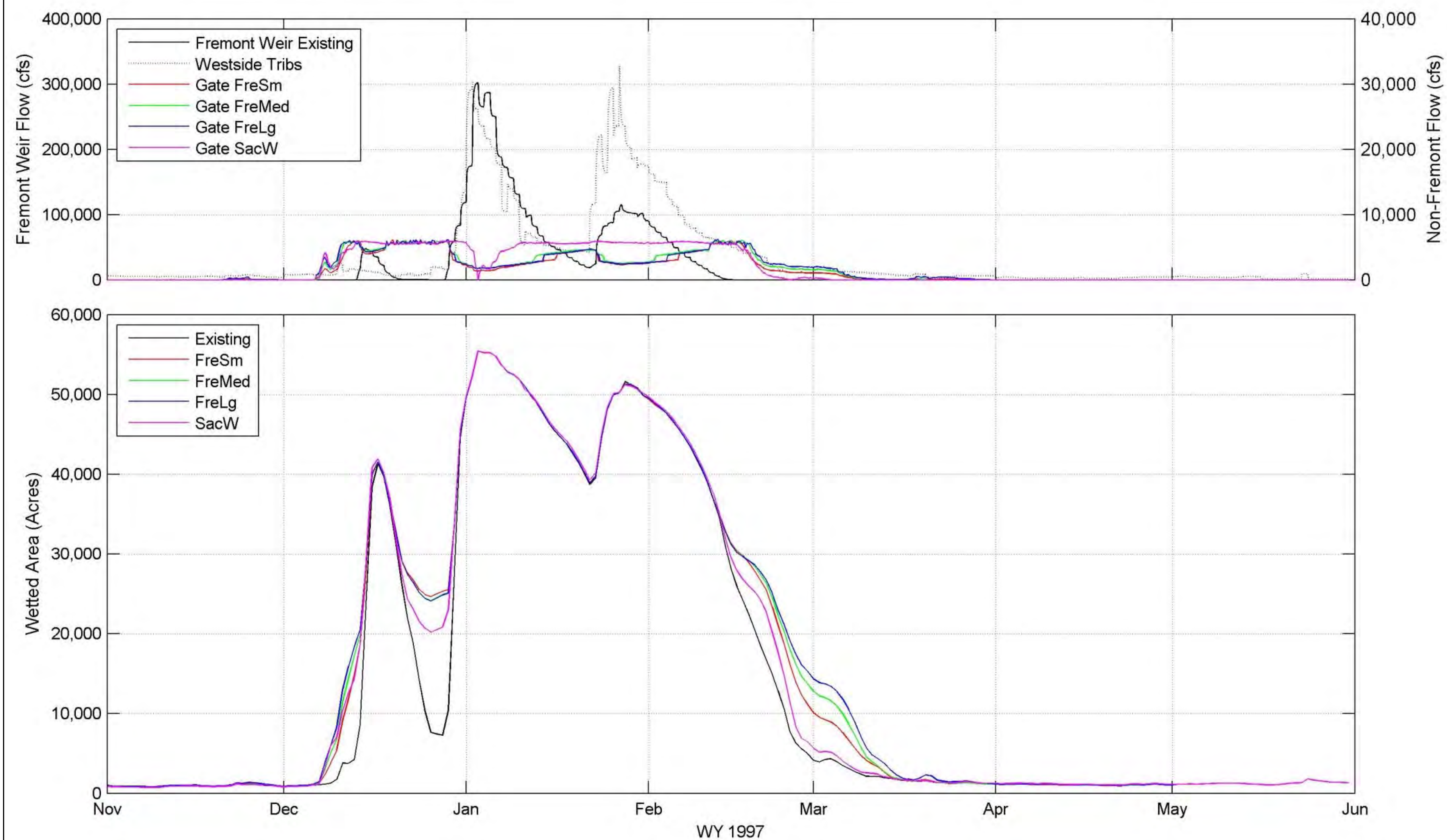
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2012 for Mar 15 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D48**

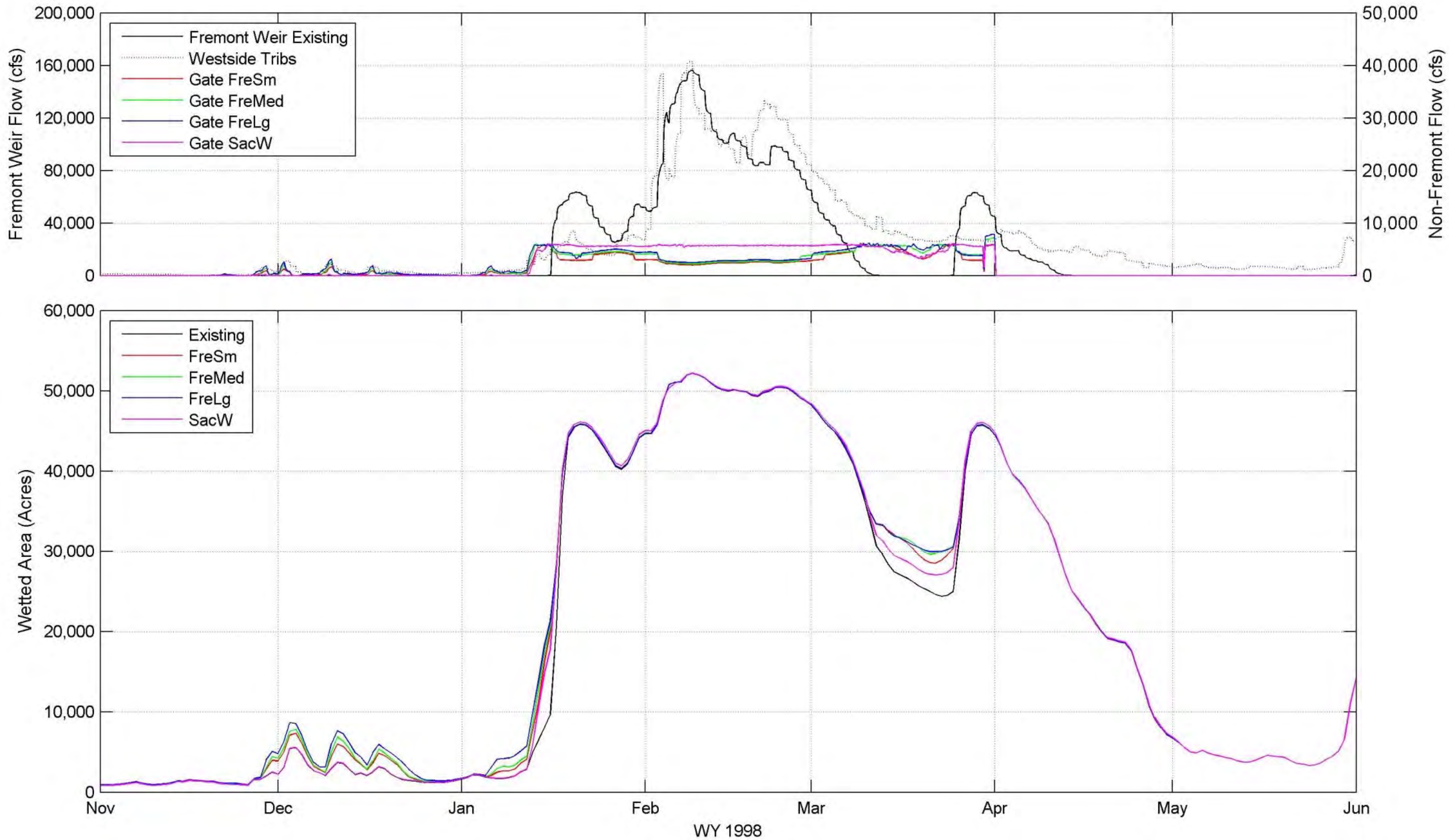


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1997 for Apr 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D49**

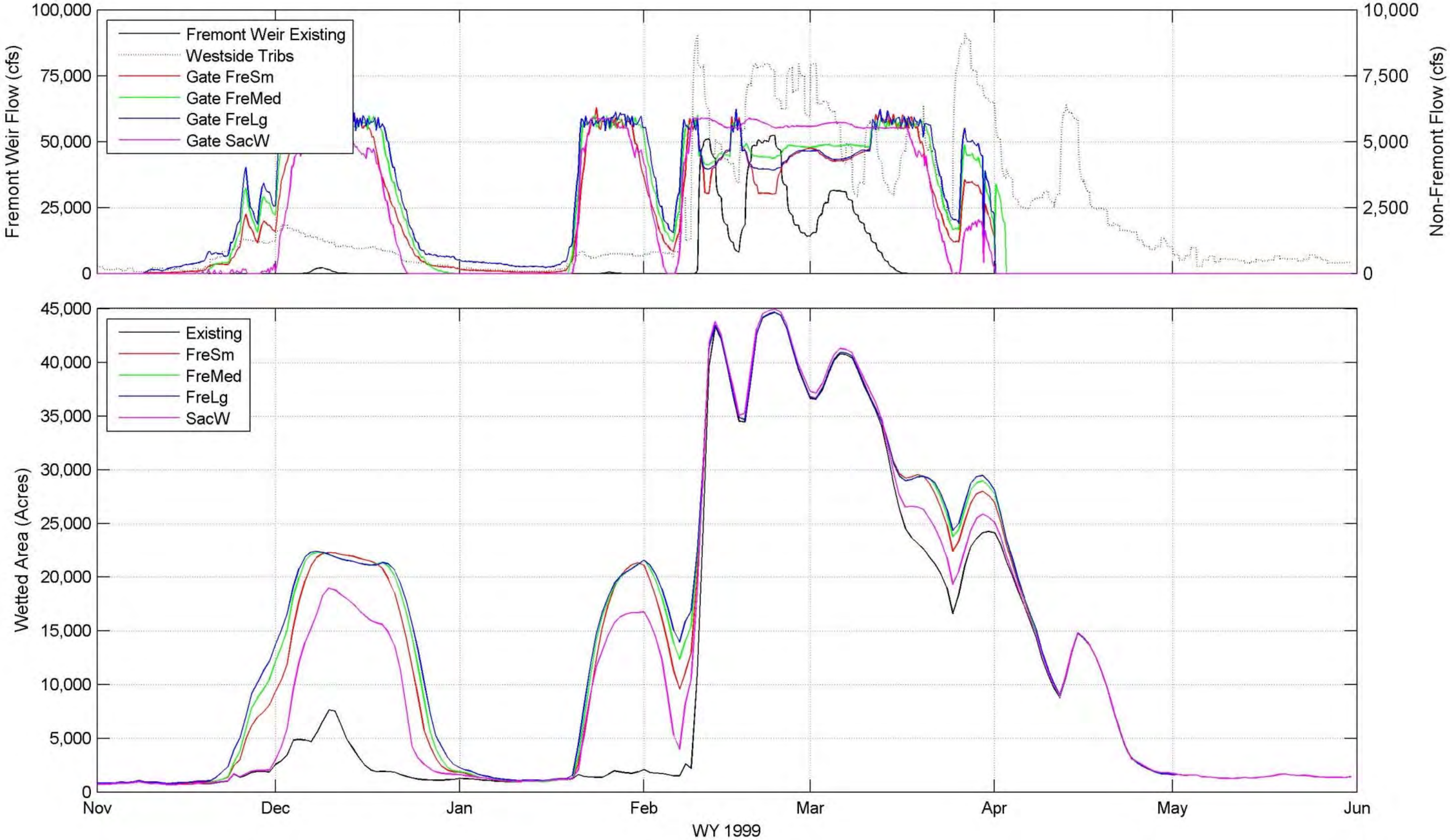


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1998 for Apr 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D50**

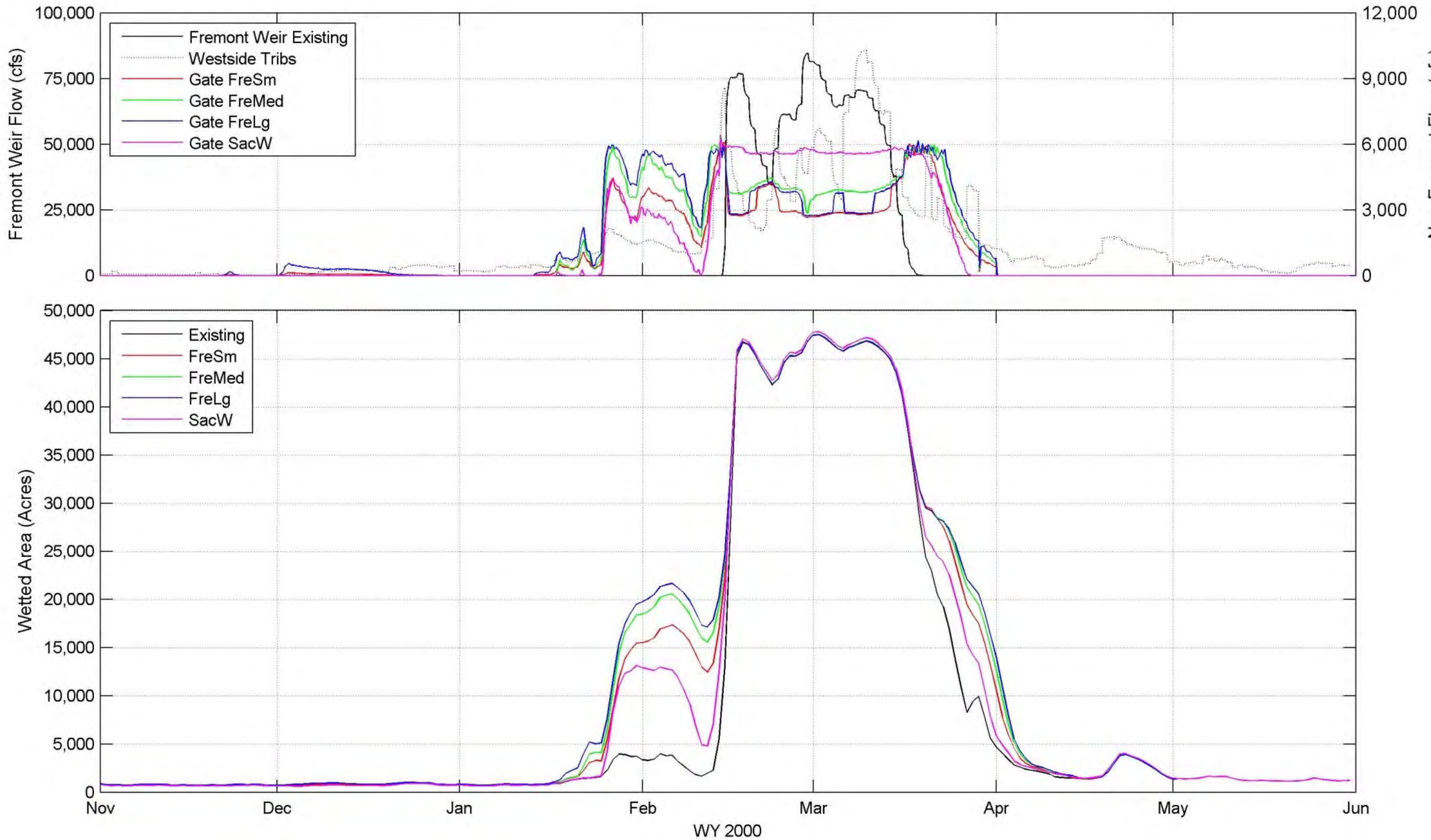


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1999 for Apr 1 Gate Closure

Prepared for DWR	Created By: SJB	Figure D51

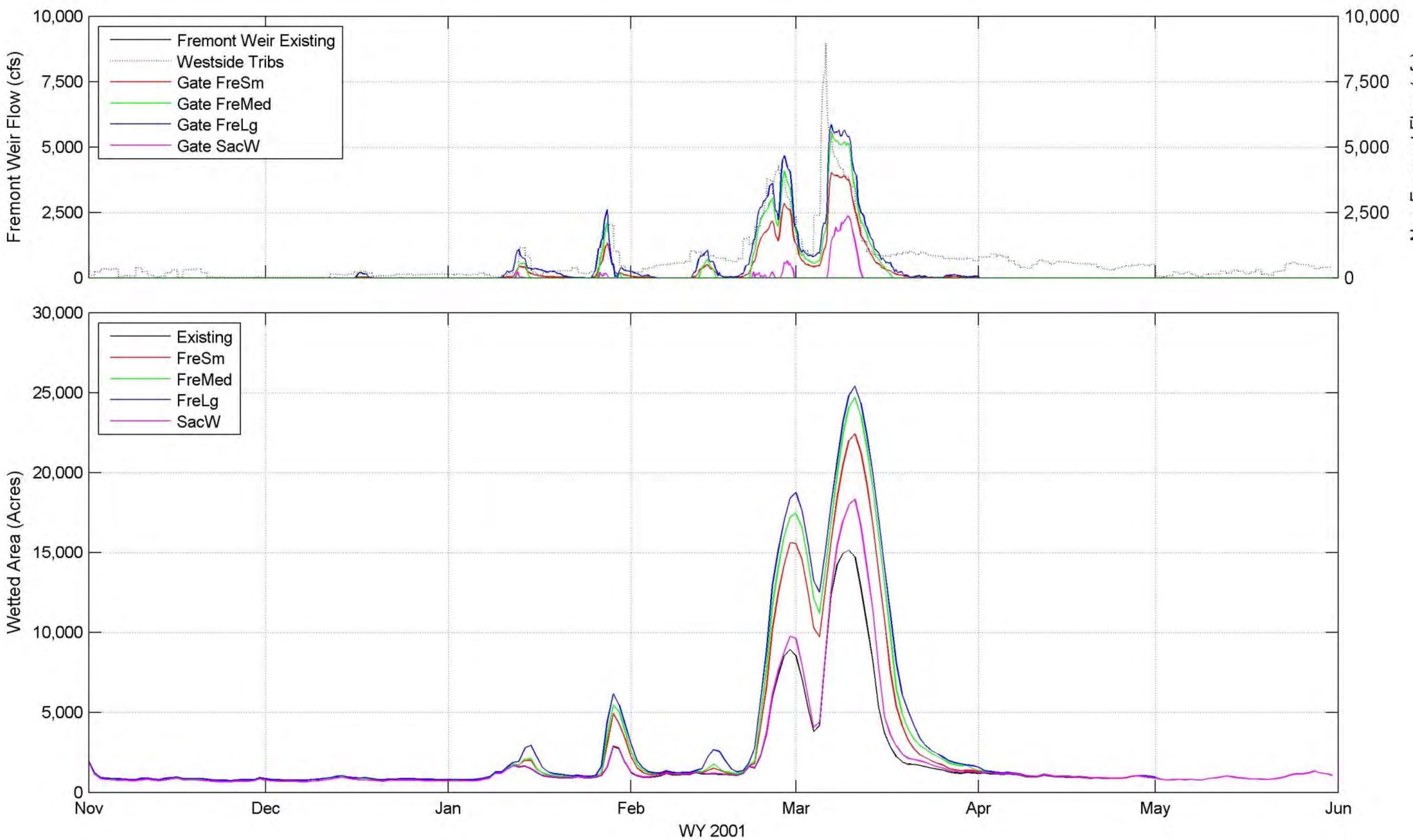


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2000 for Apr 1 Gate Closure

Prepared for DWR	Created By: SJB	Figure D52

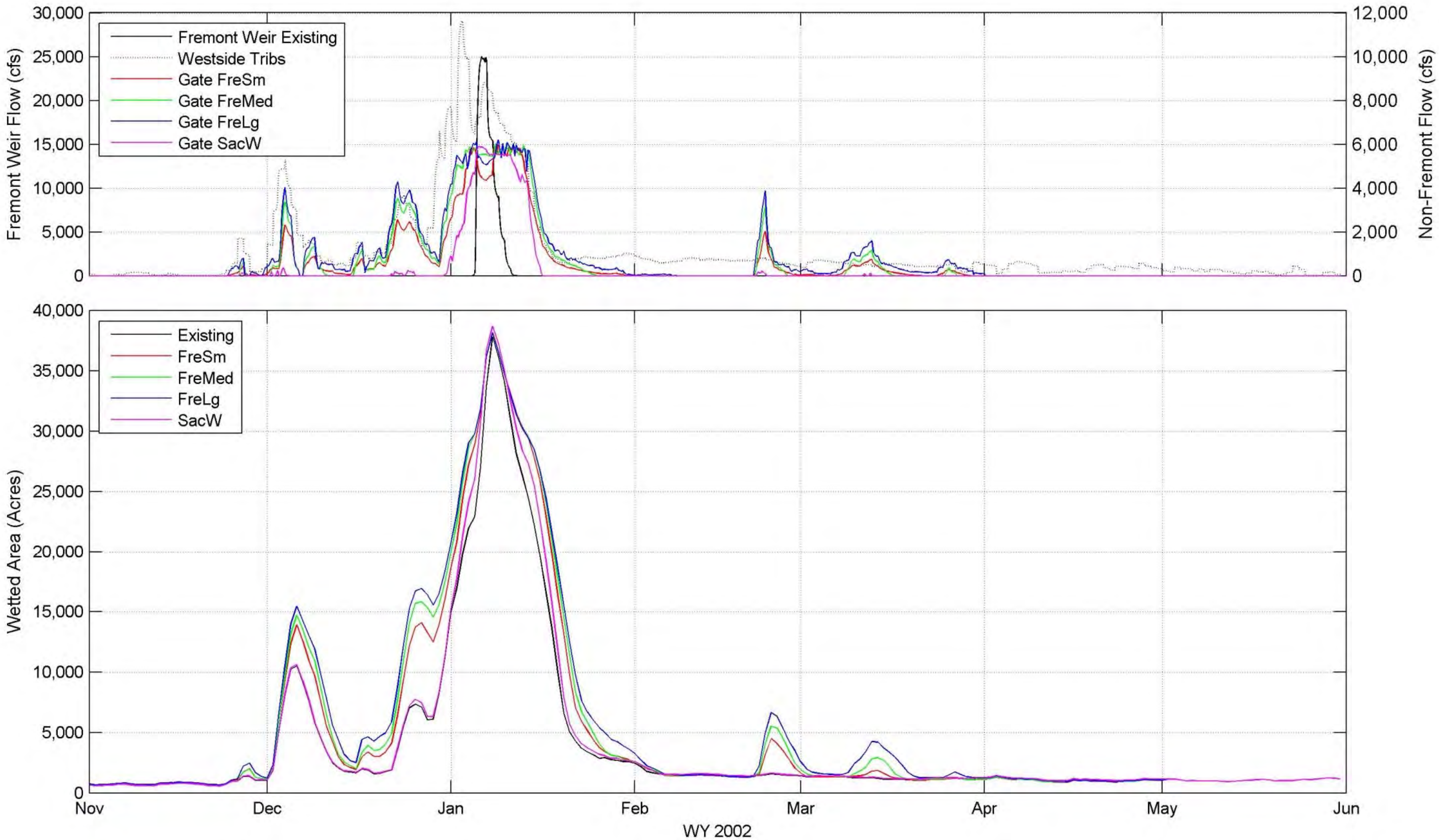


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2001 for Apr 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D53**

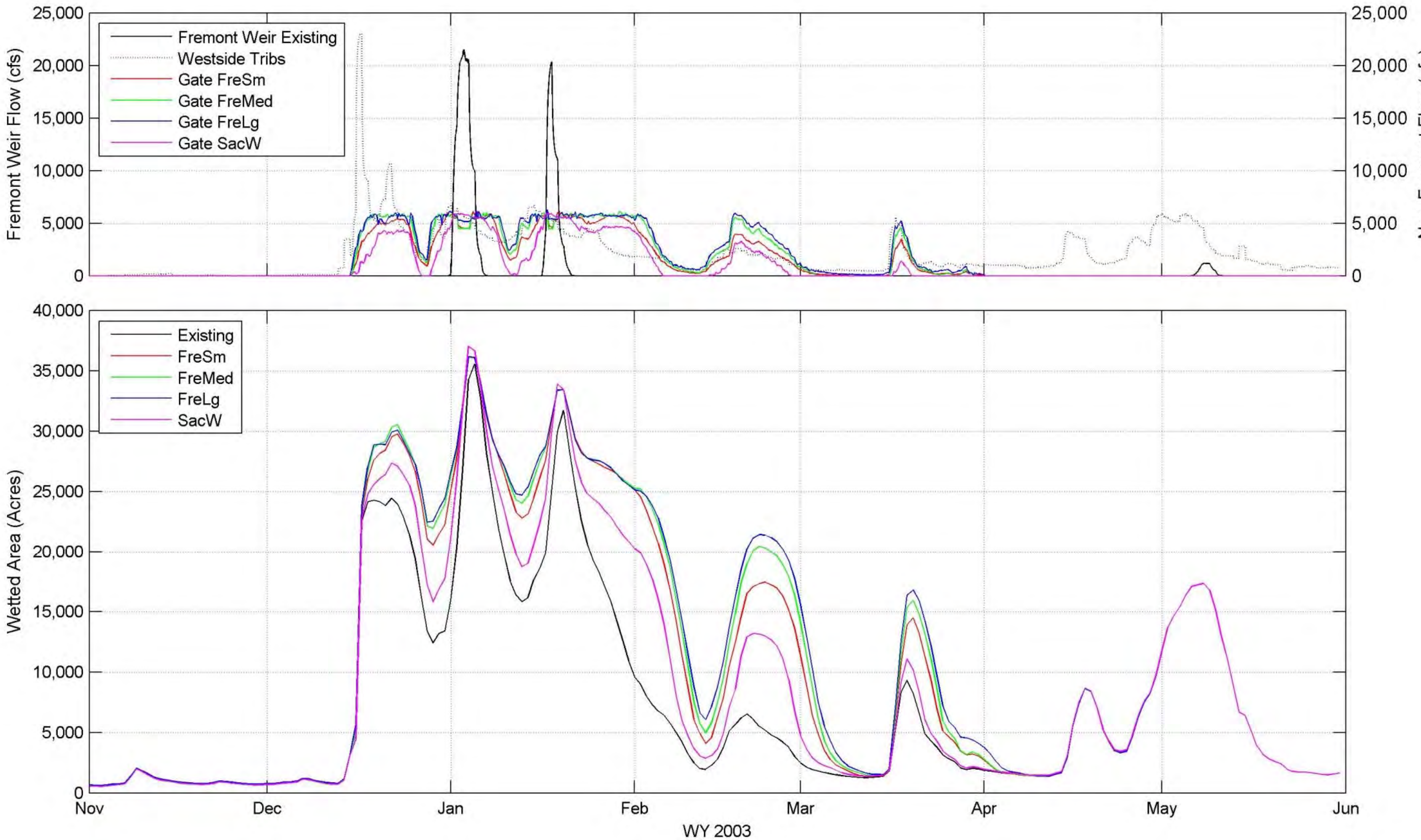


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2002 for Apr 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D54**

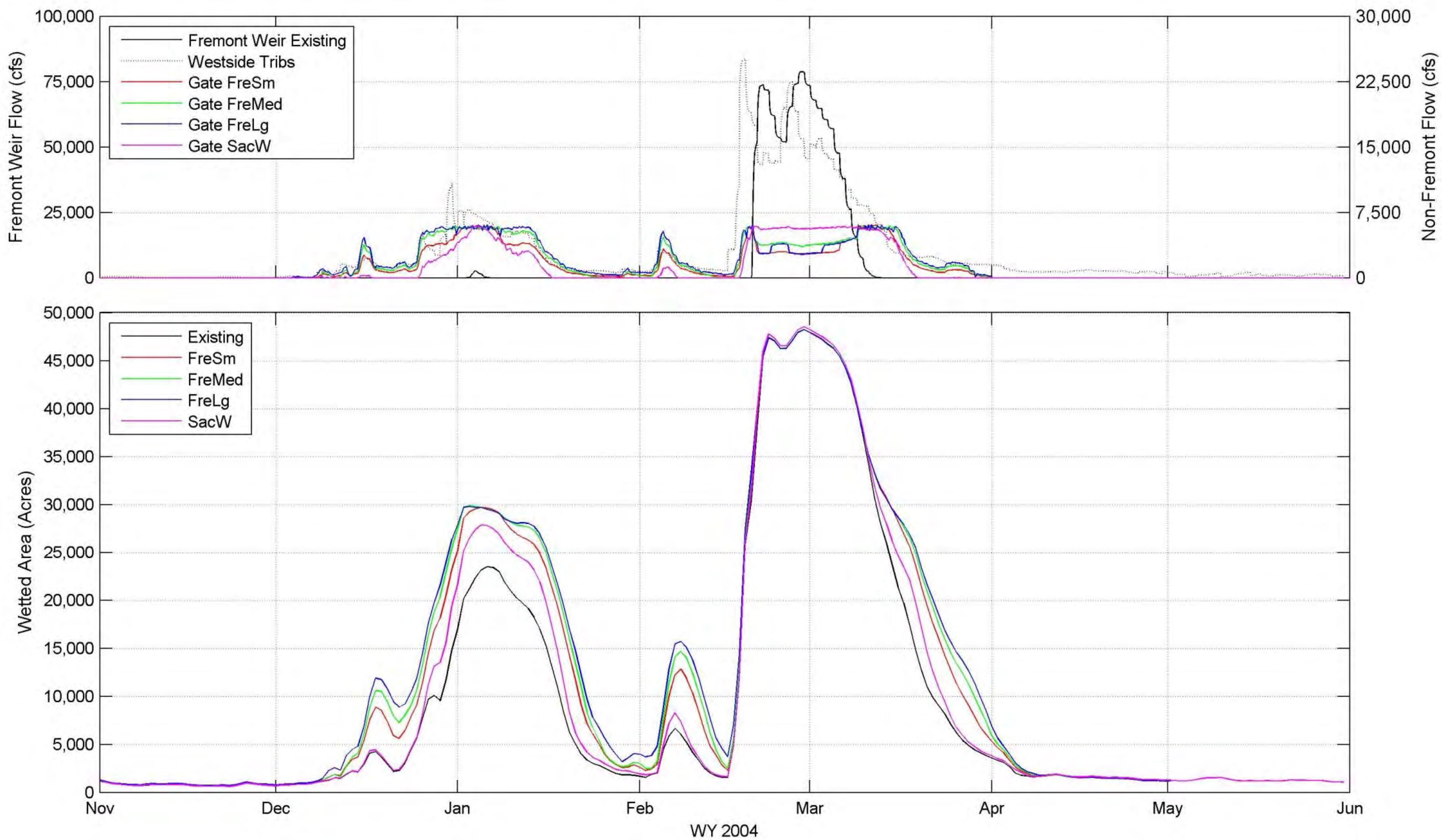


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2003 for Apr 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D55**

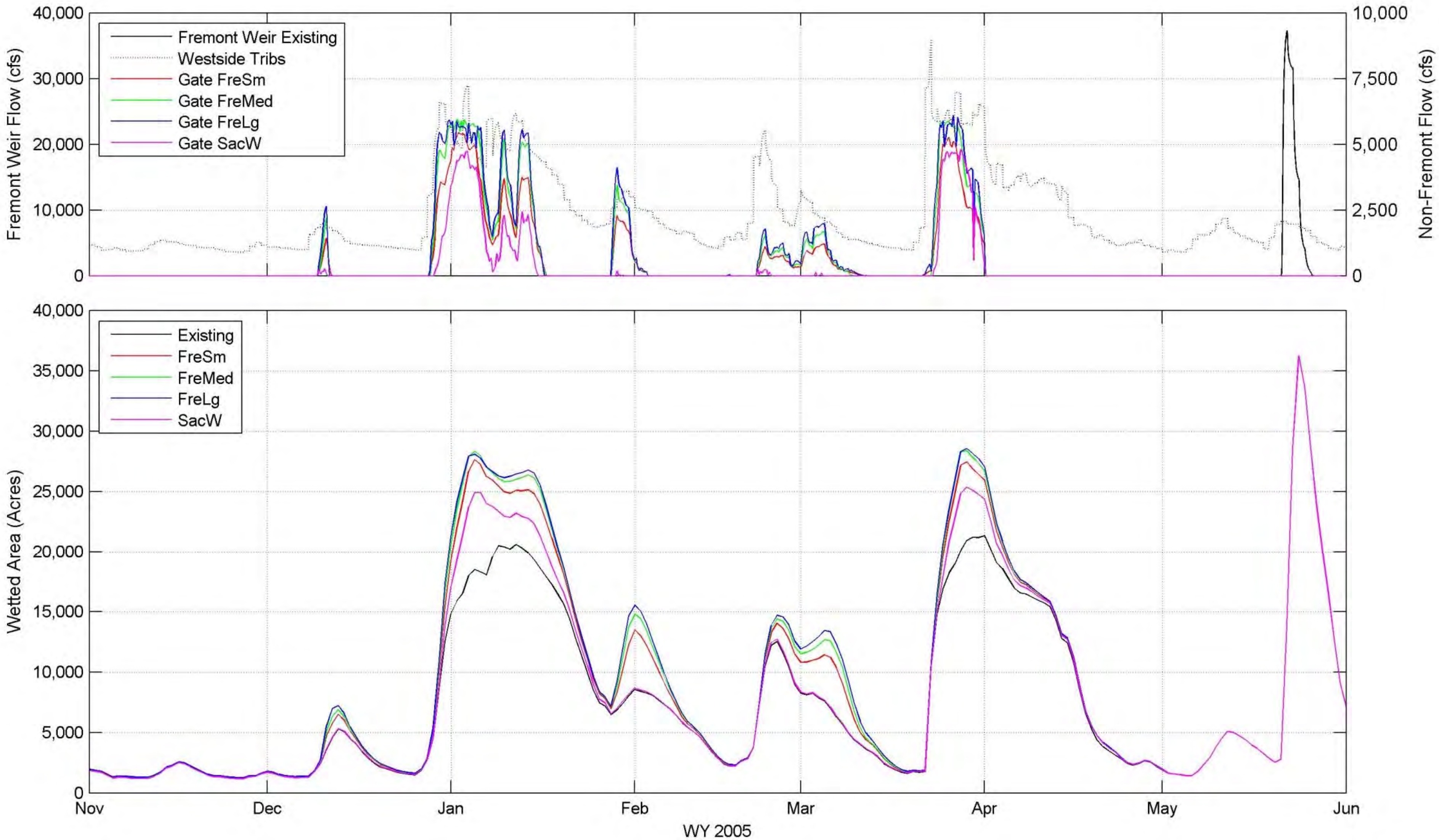


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2004 for Apr 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D56**

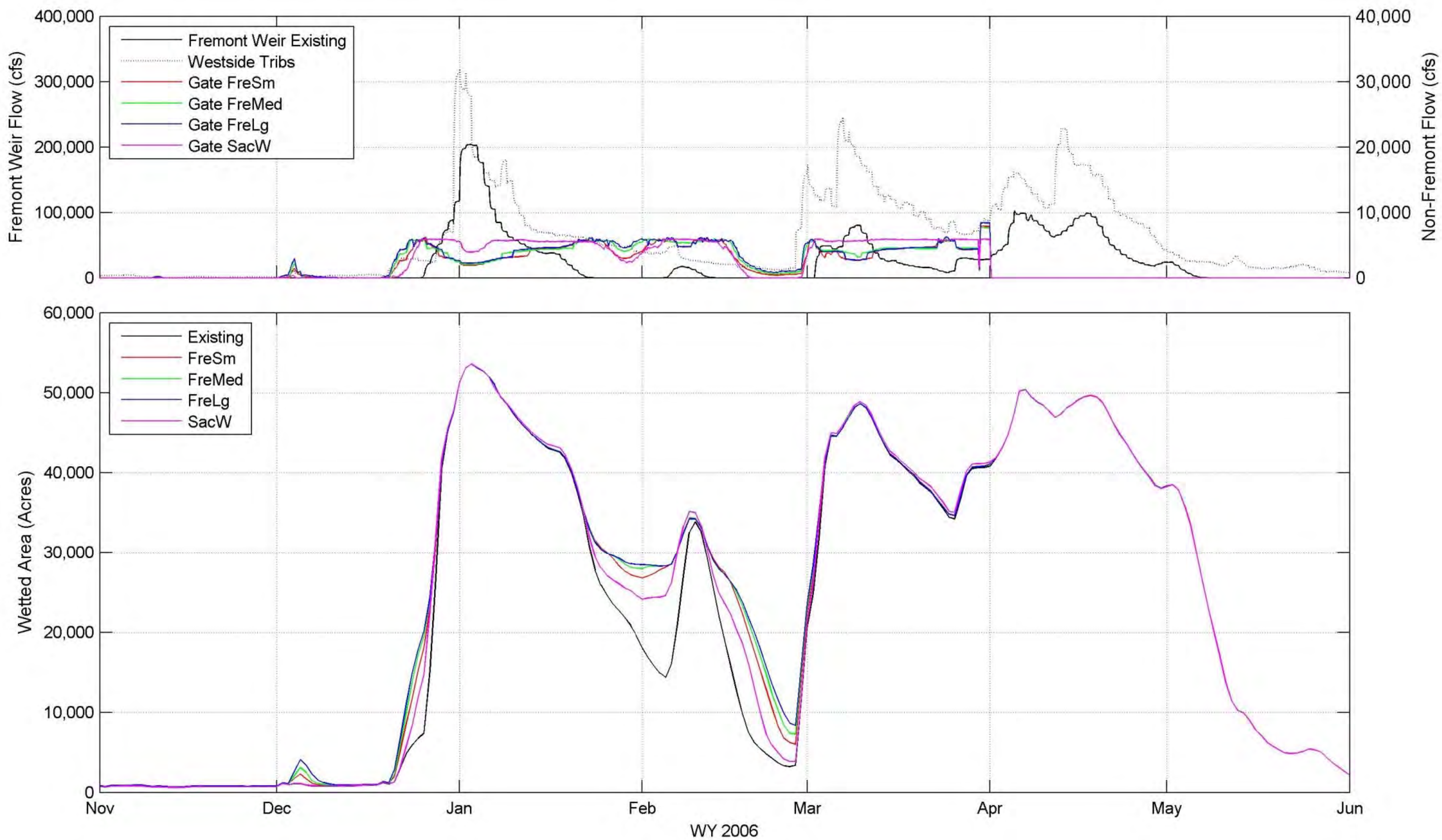


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2005 for Apr 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D57**

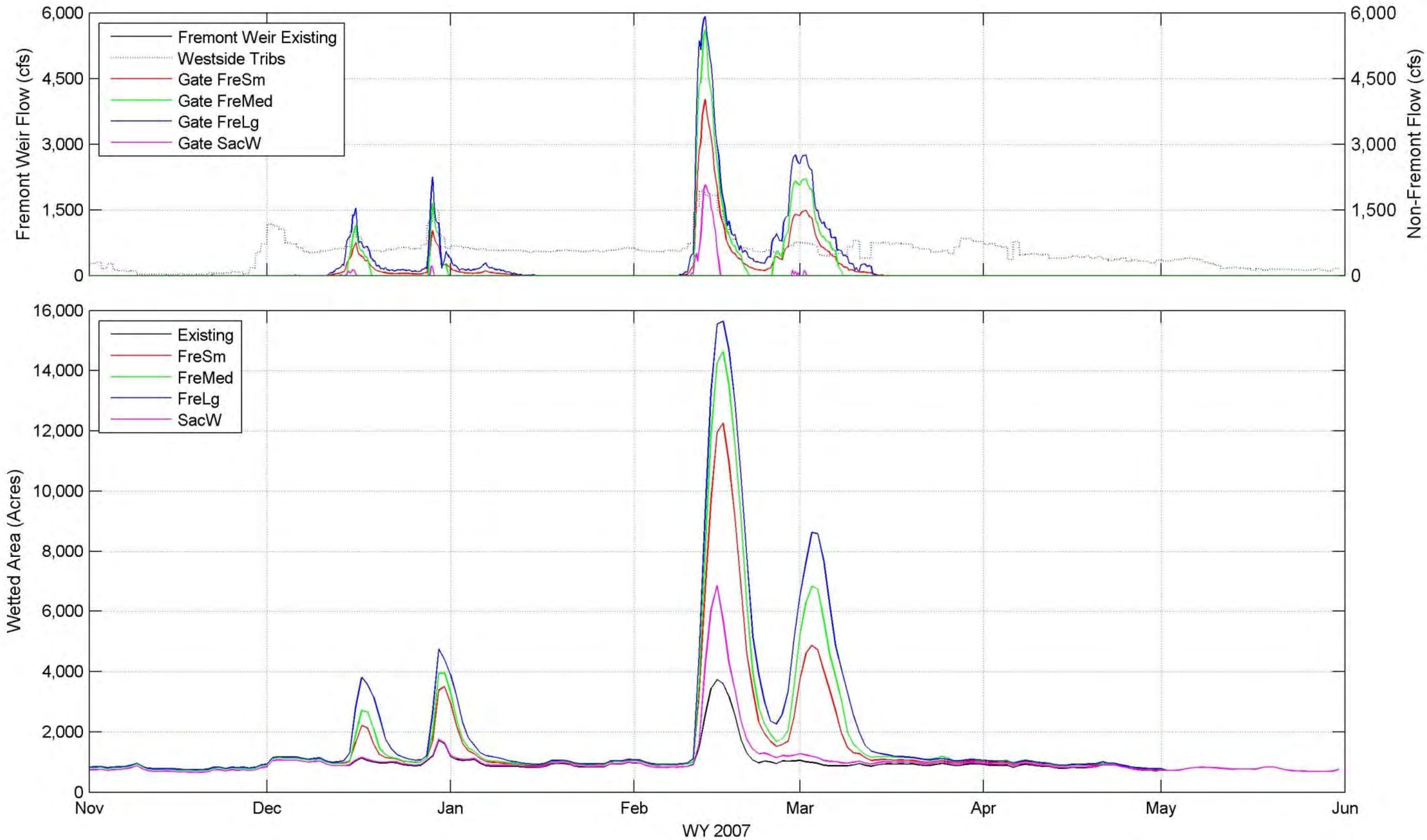


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2006 for Apr 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D58**

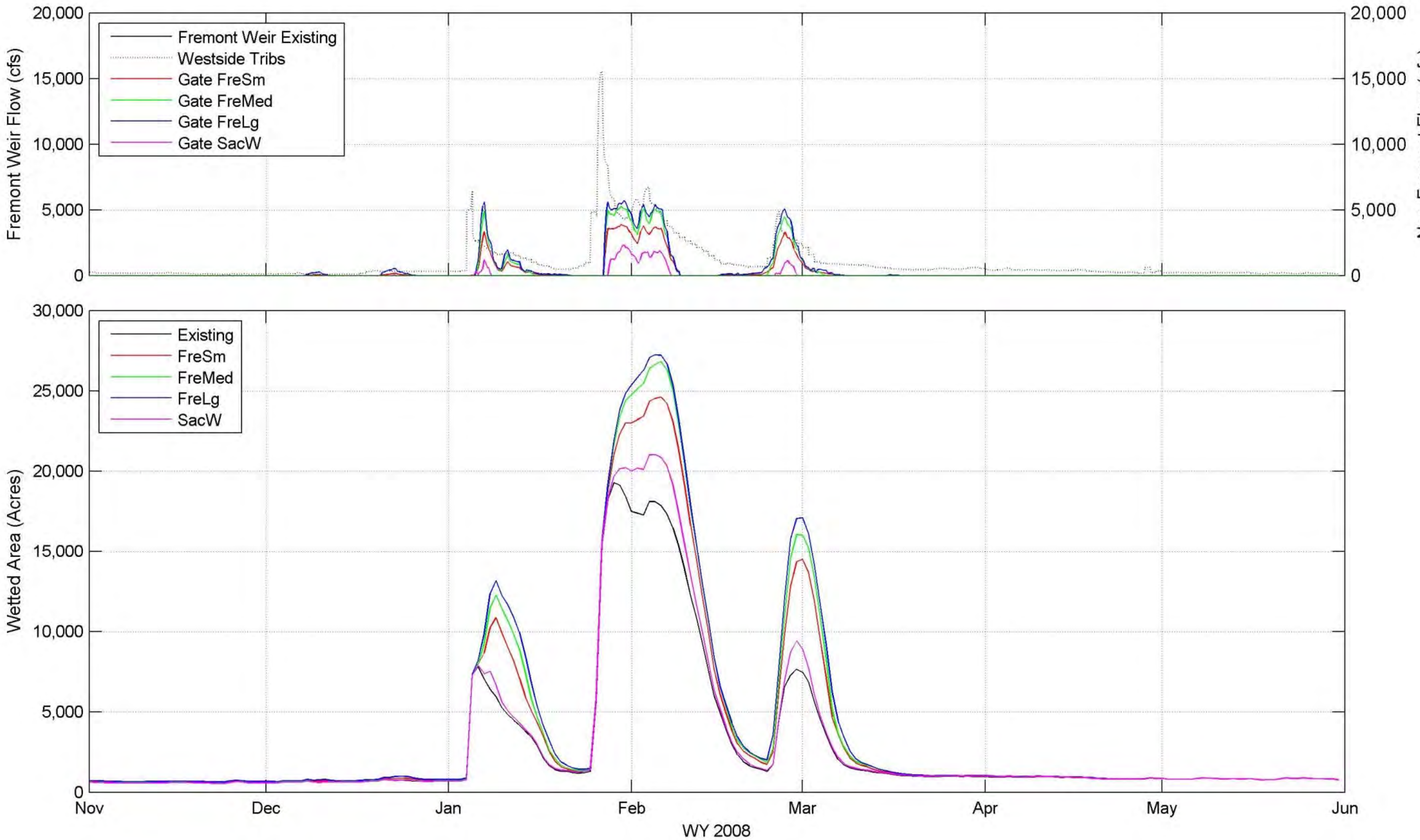


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2007 for Apr 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D59**



Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

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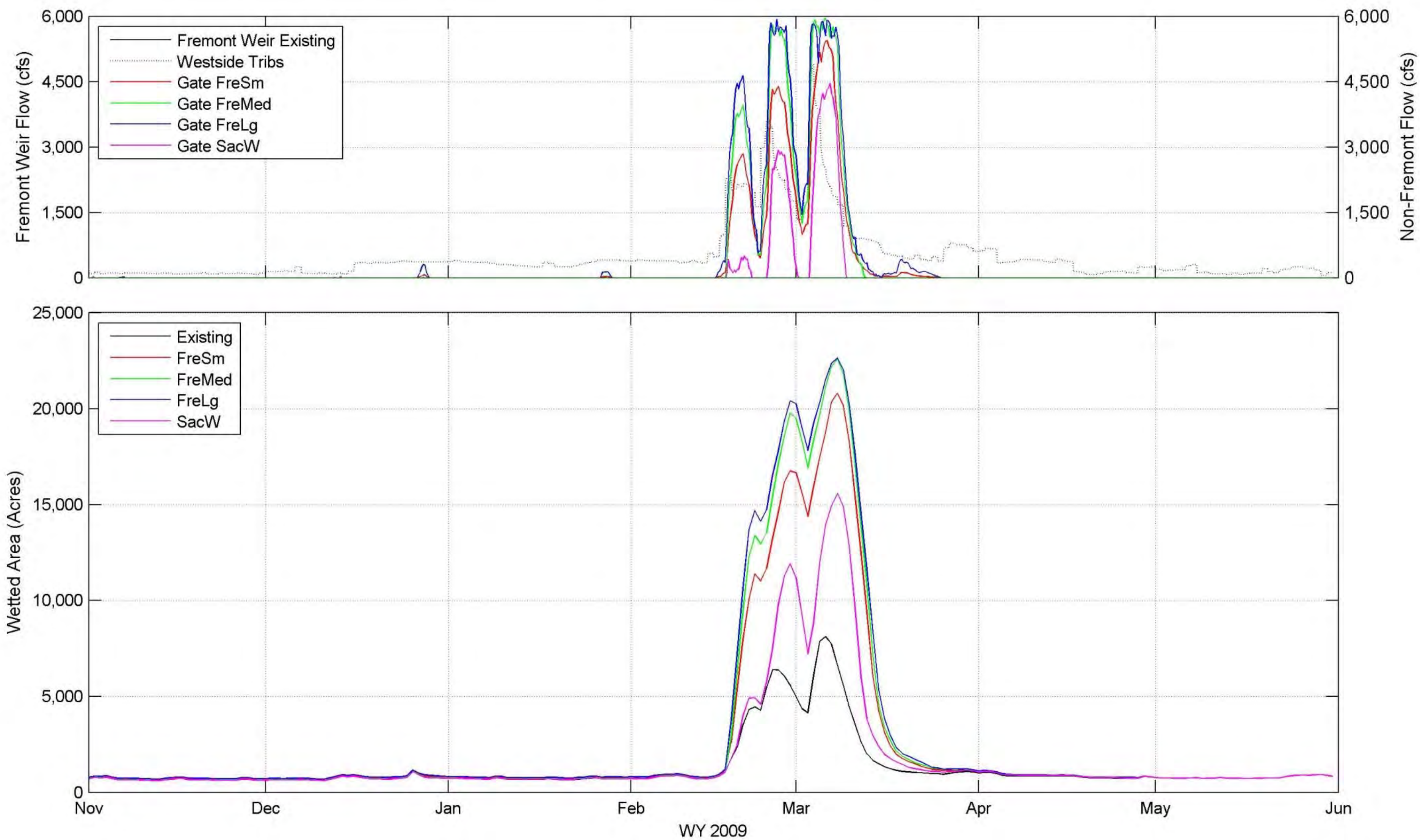
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2008 for Apr 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D60**

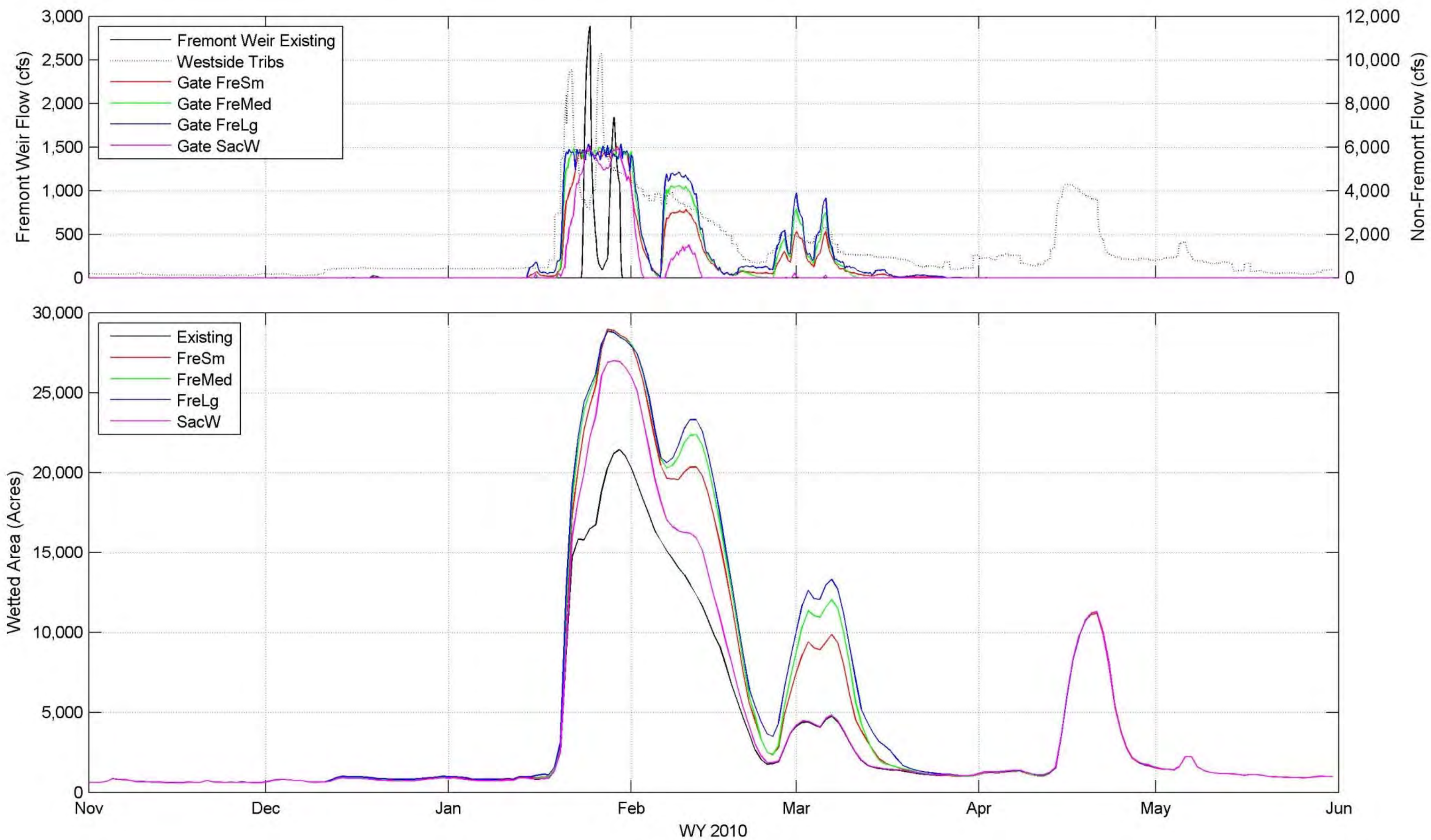


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2009 for Apr 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D61**

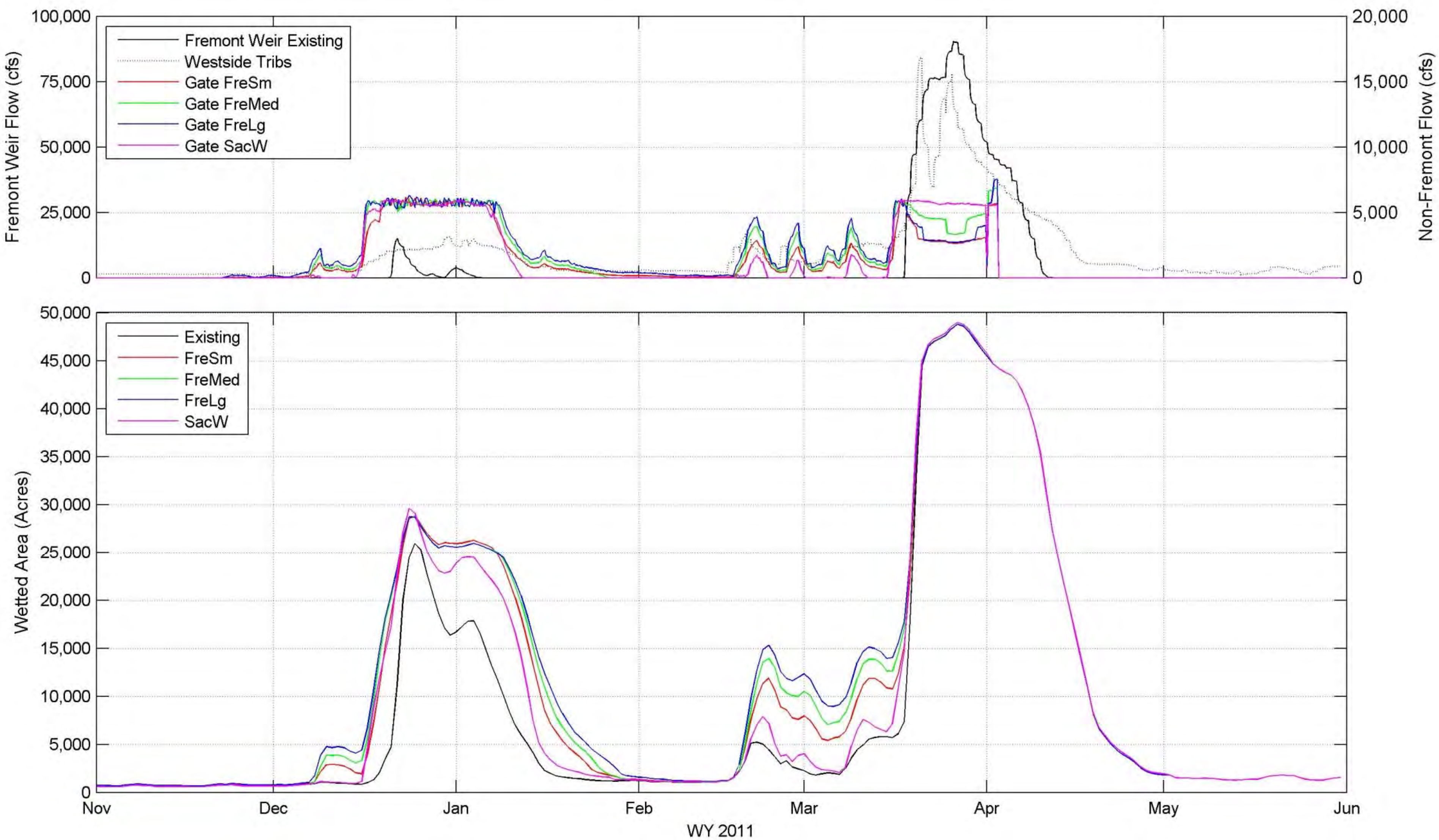


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2010 for Apr 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D62**

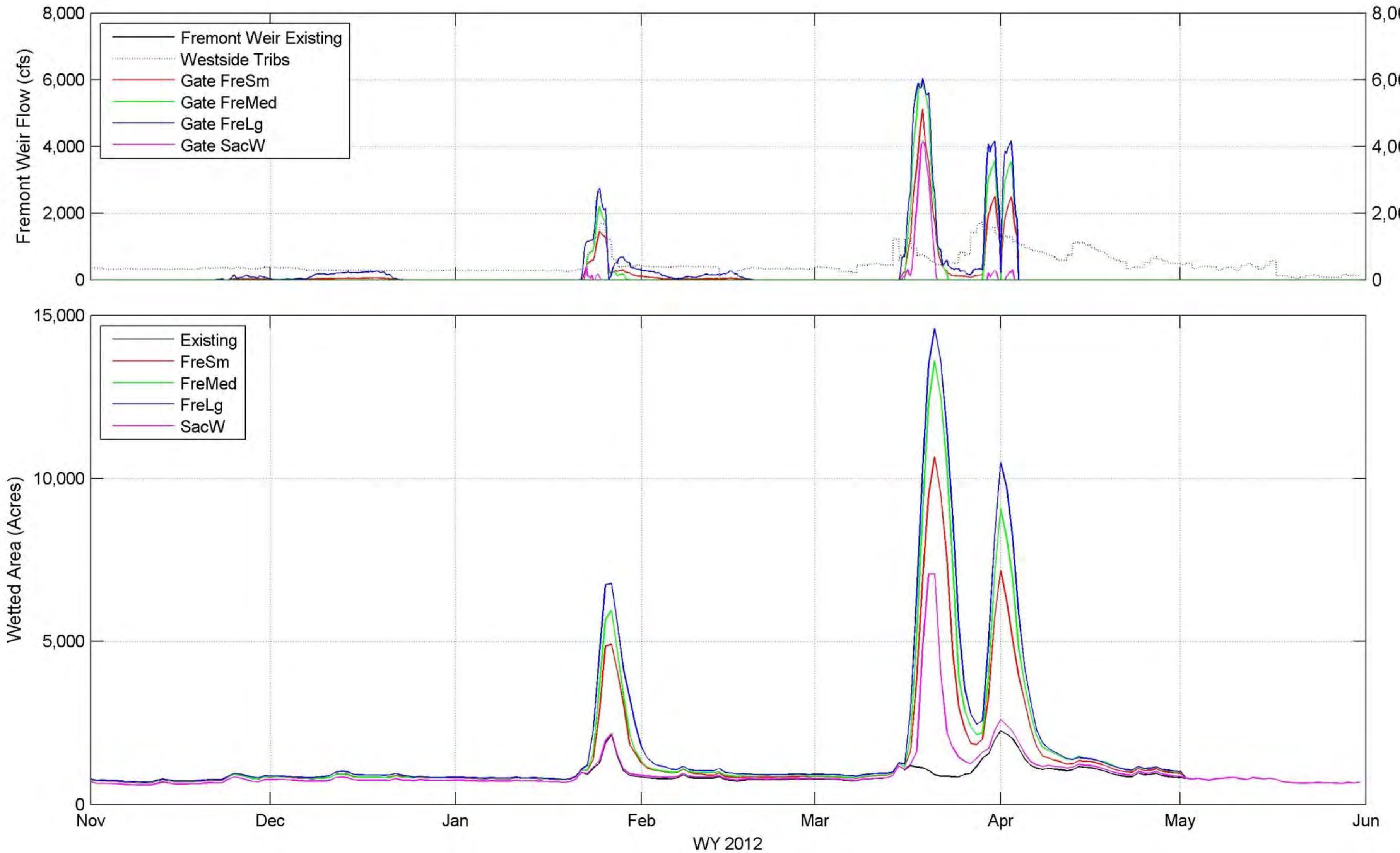


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2011 for Apr 1 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D63**

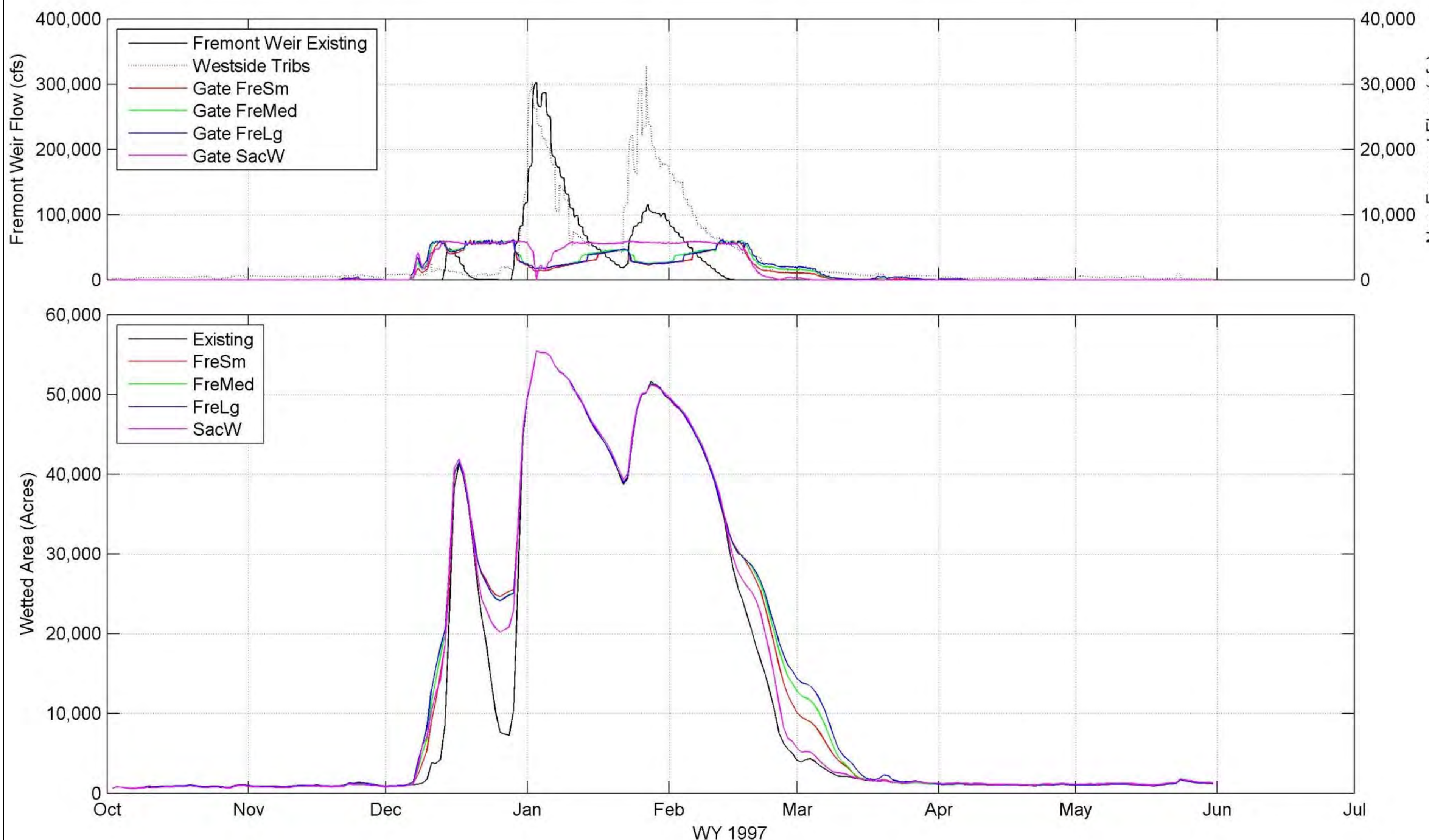


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2012 for Apr 1 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D64**

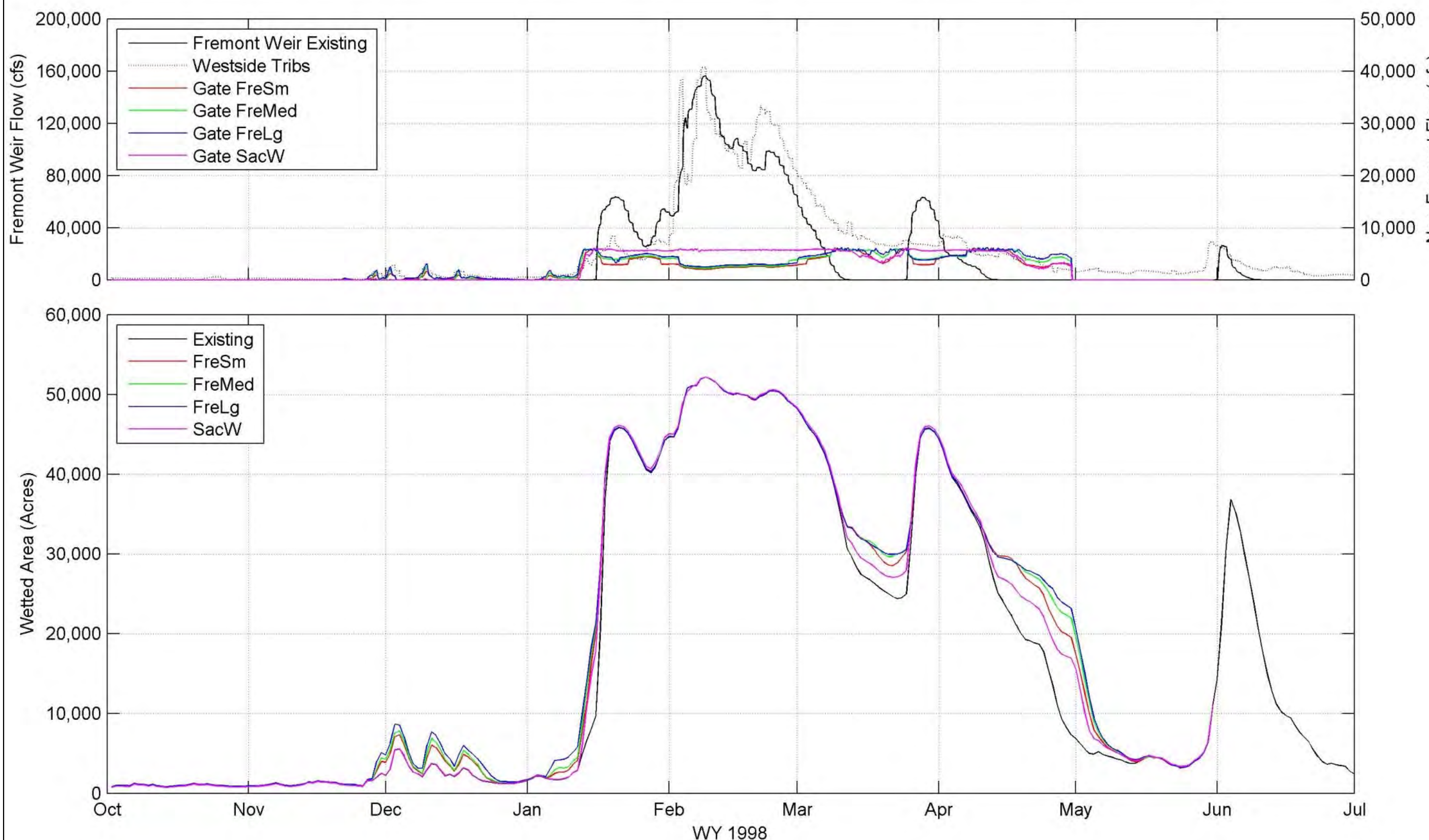


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1997 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D65**

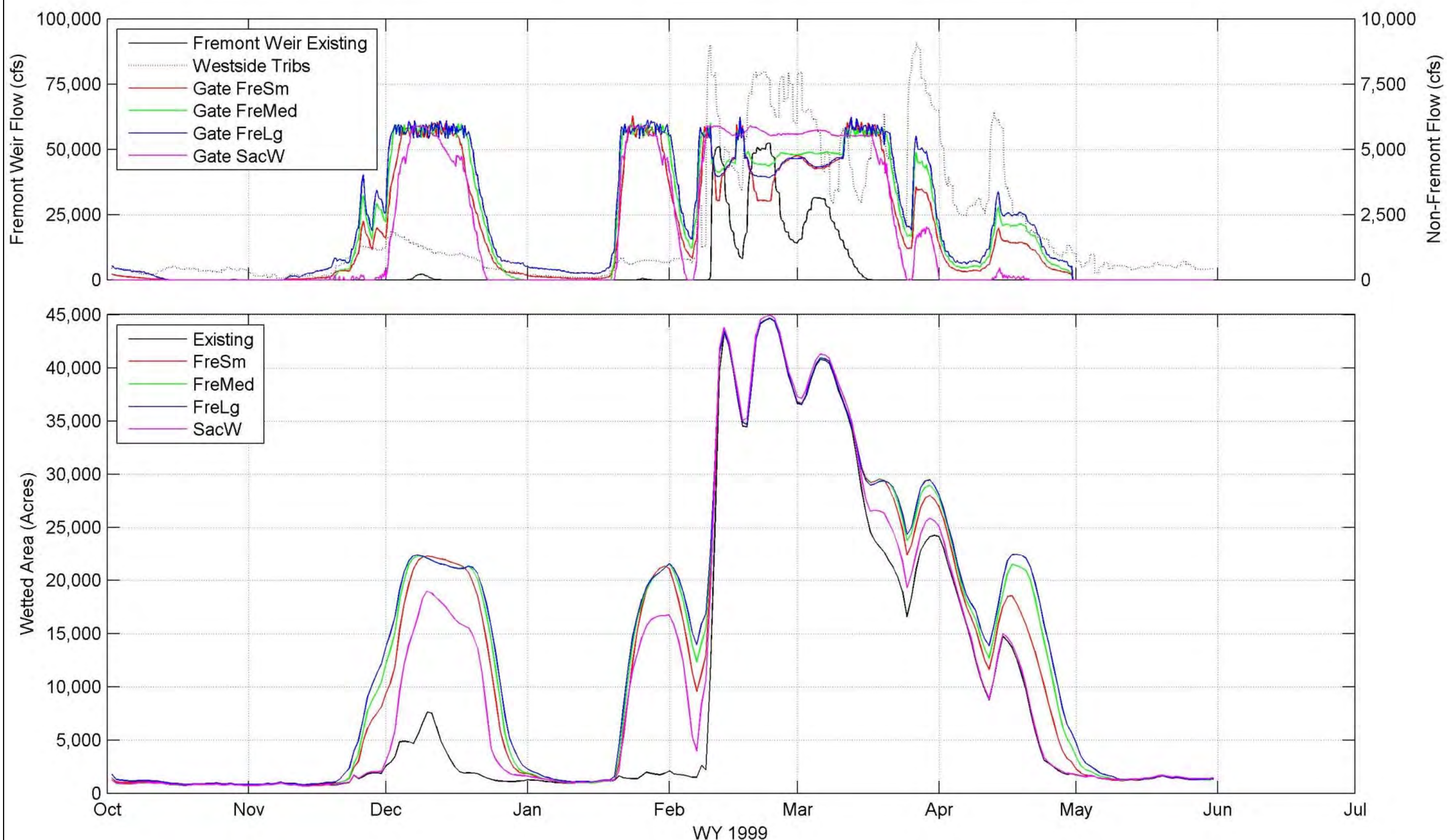


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1998 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D66**

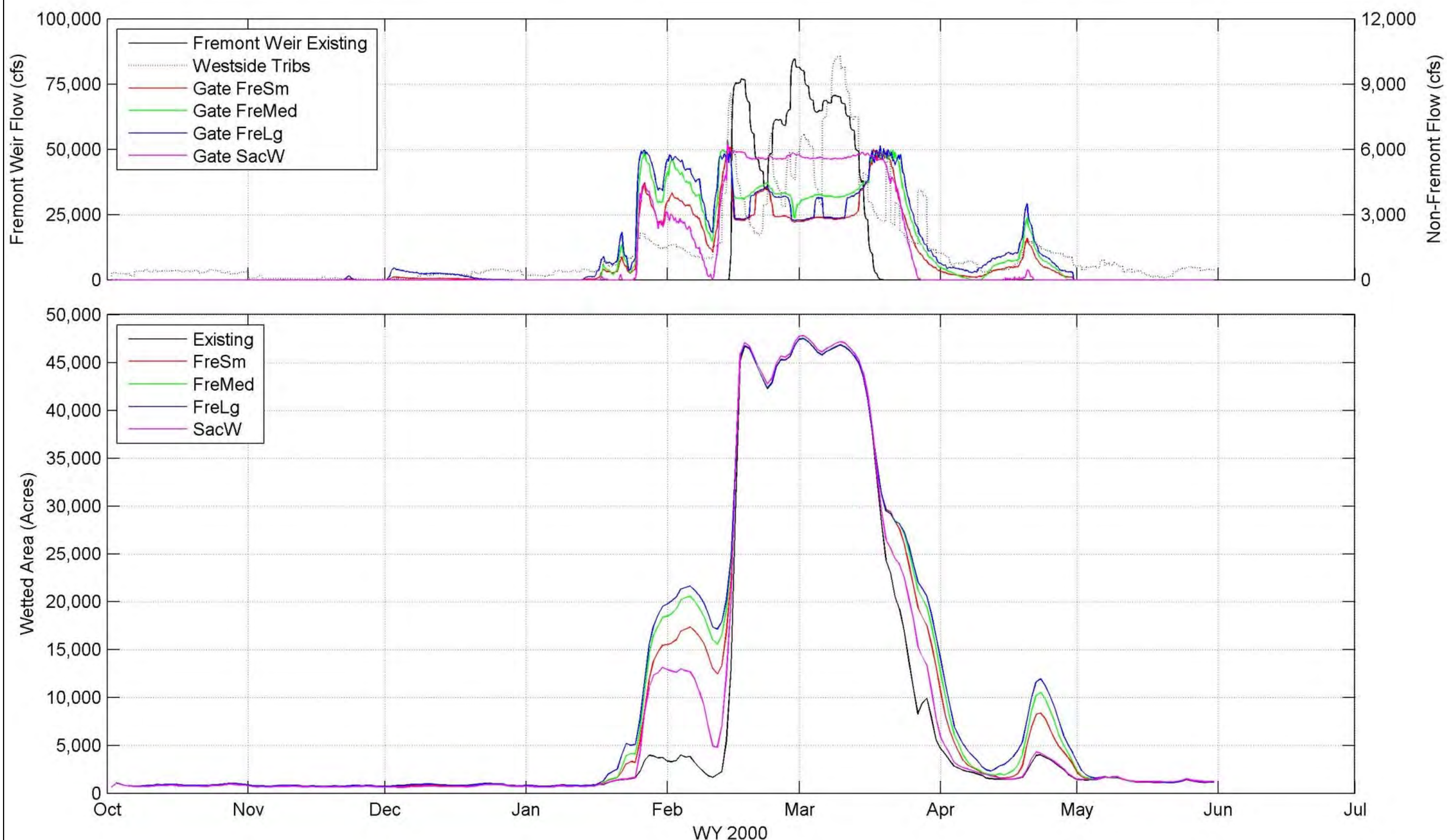


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 1999 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D67**

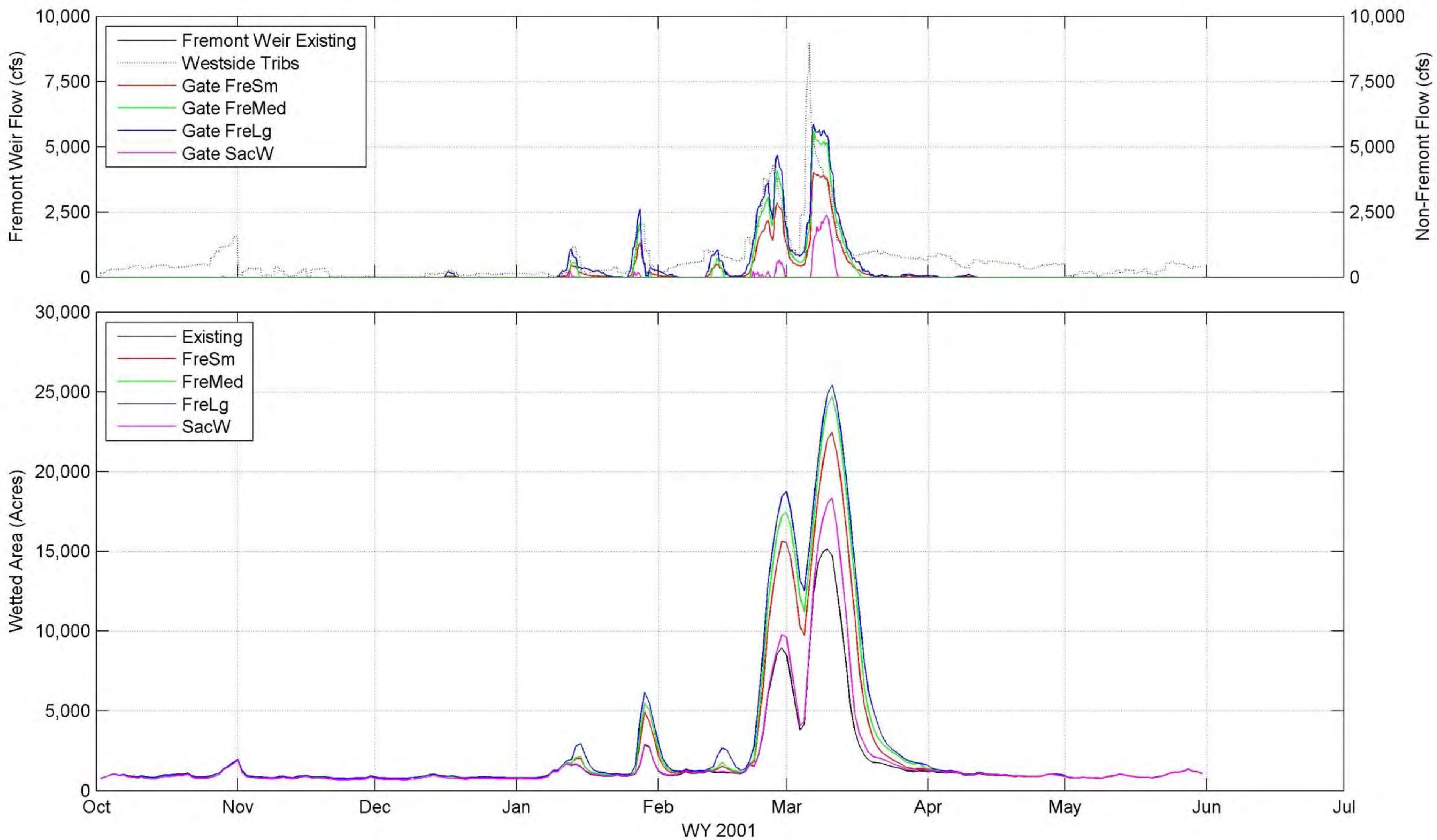


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2000 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D68**

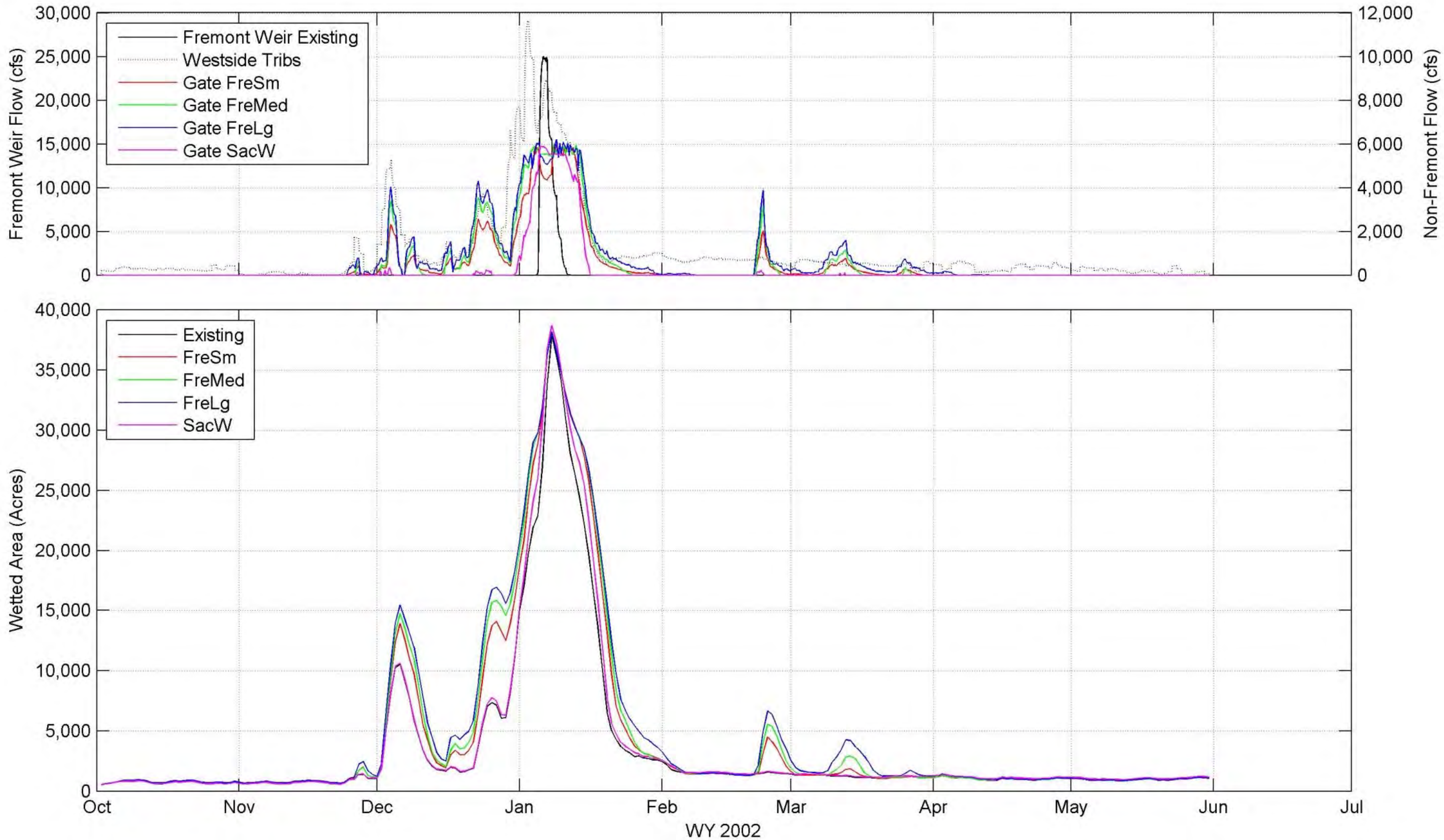


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2001 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D69**

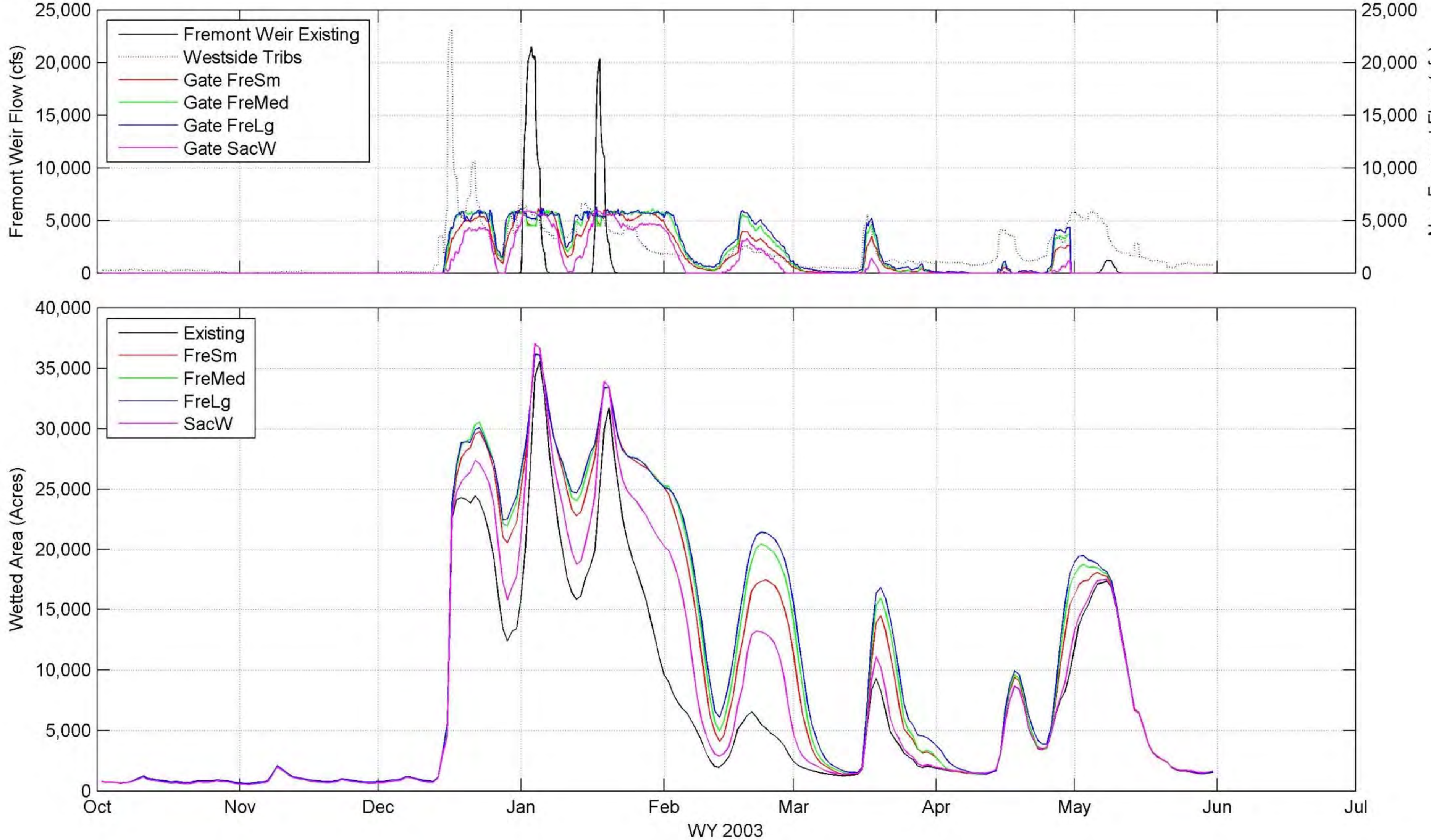


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2002 for Apr 30 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D70**

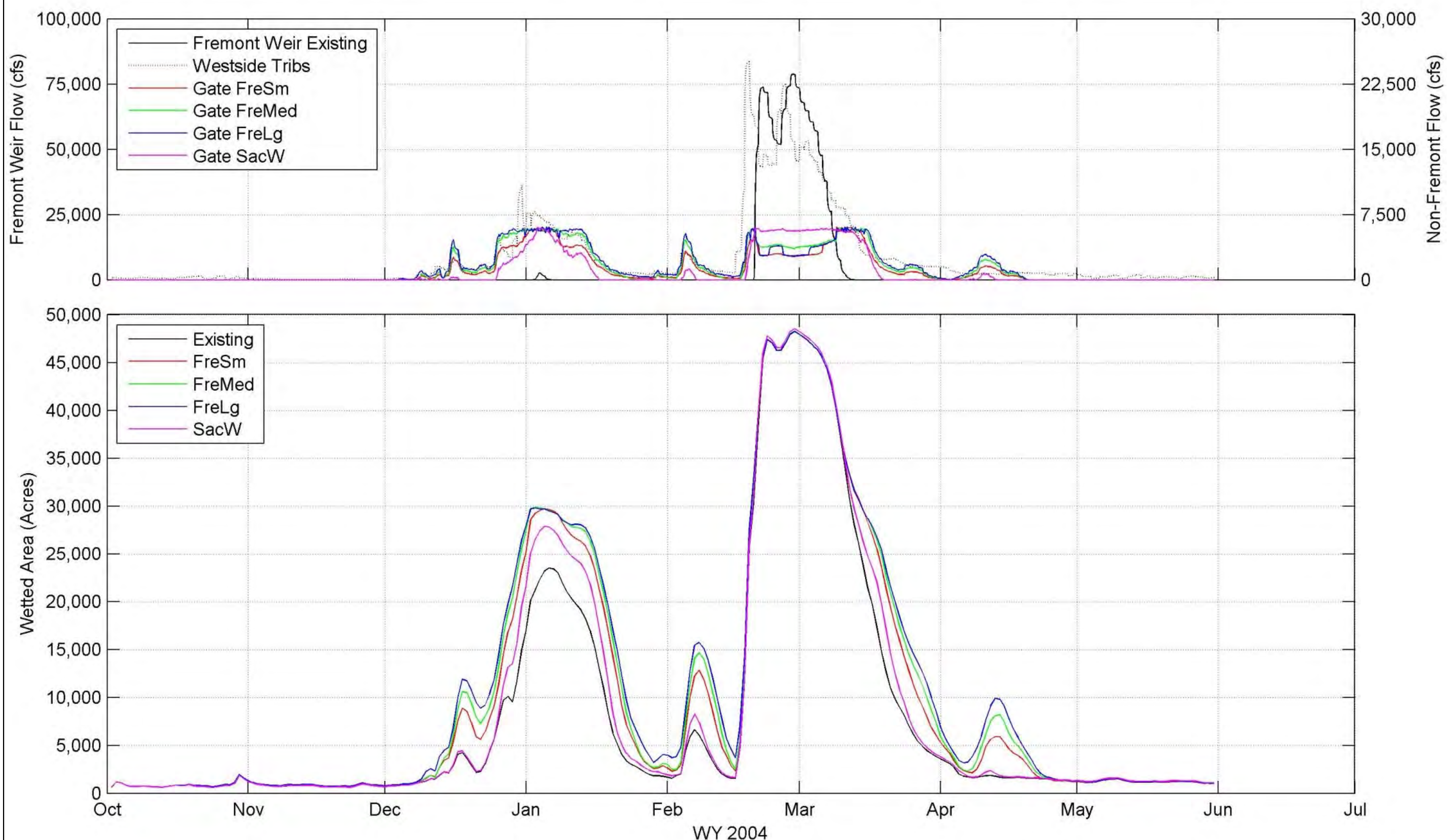


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2003 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D71**

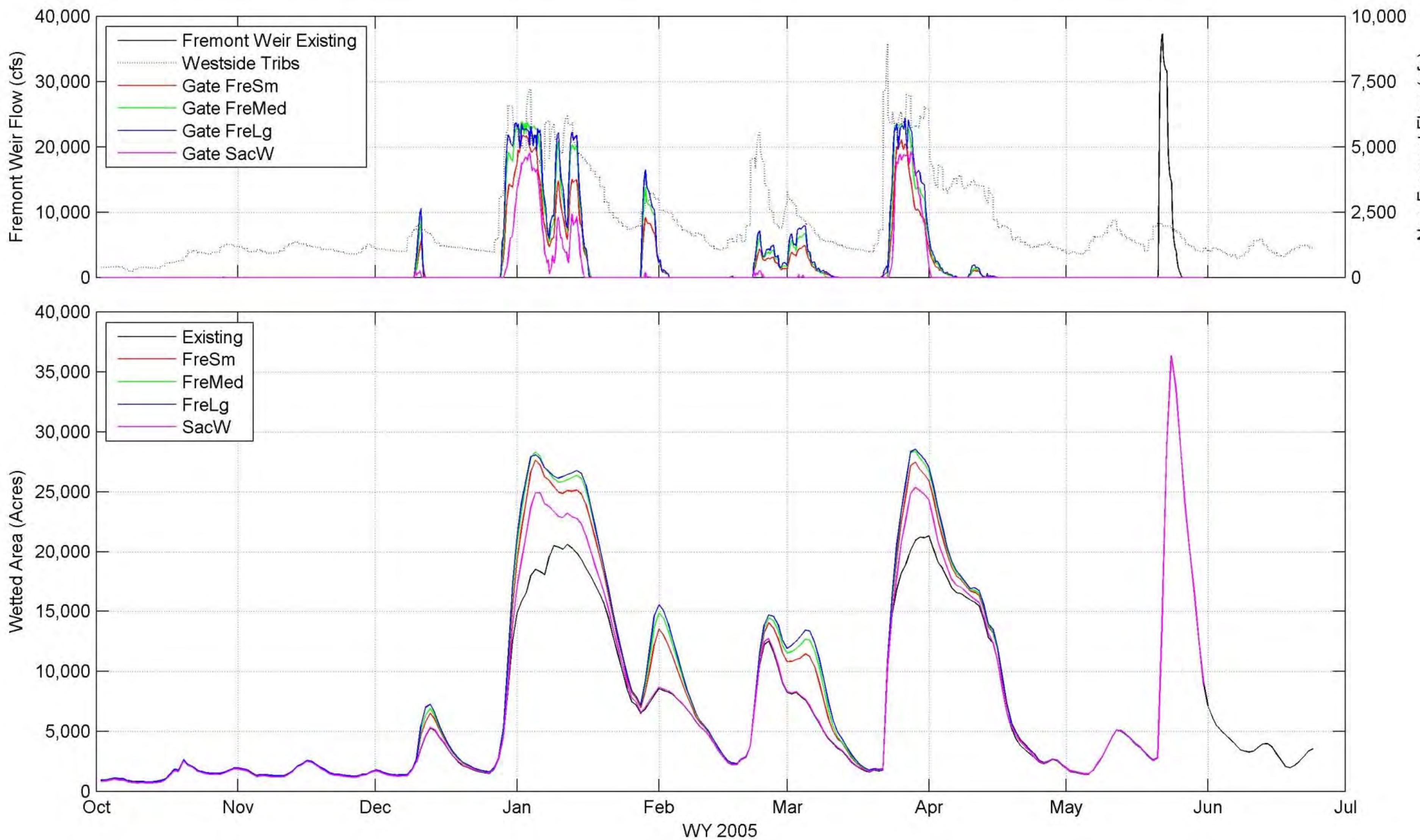


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2004 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D72**

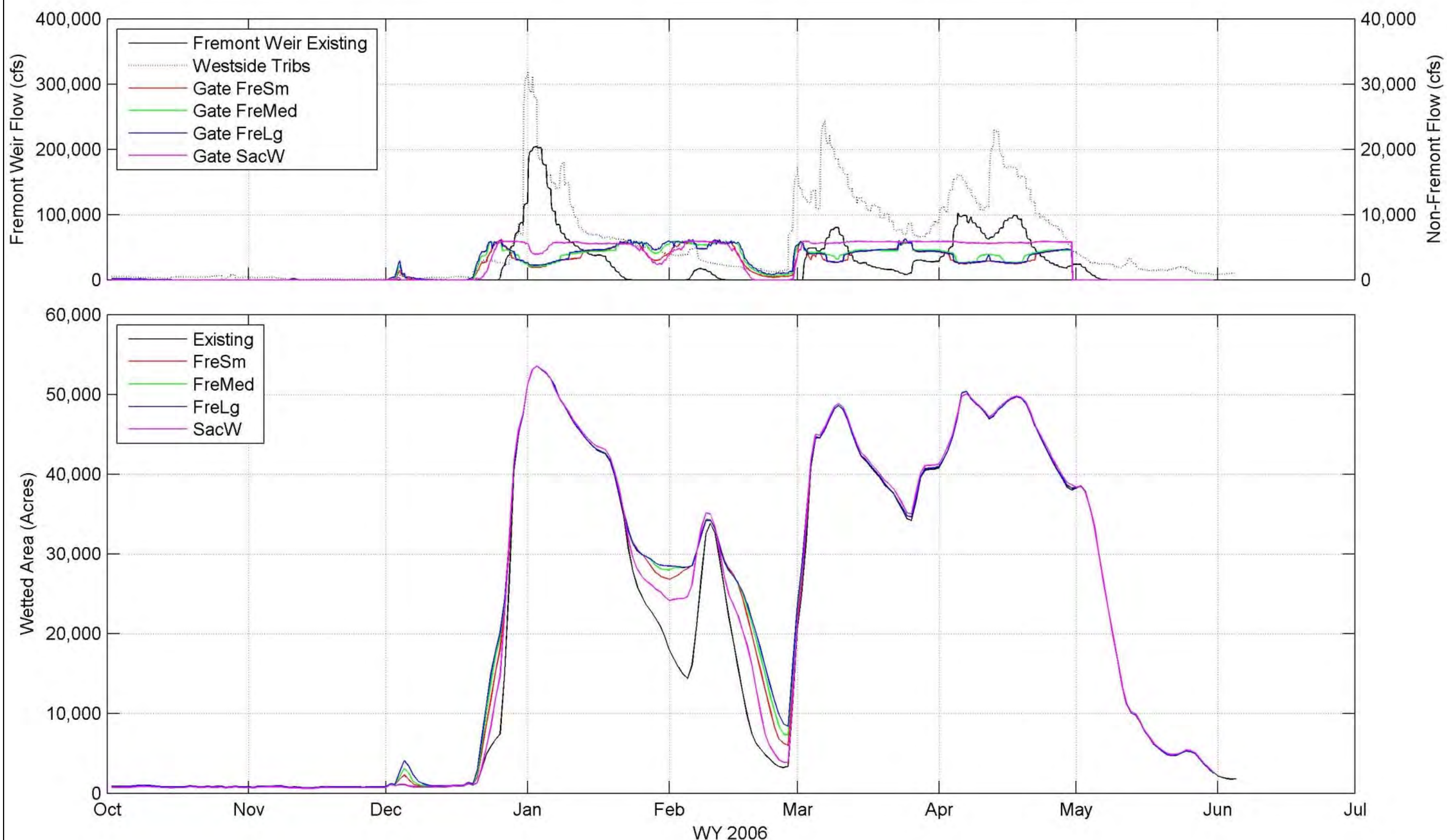


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2005 for Apr 30 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D73**

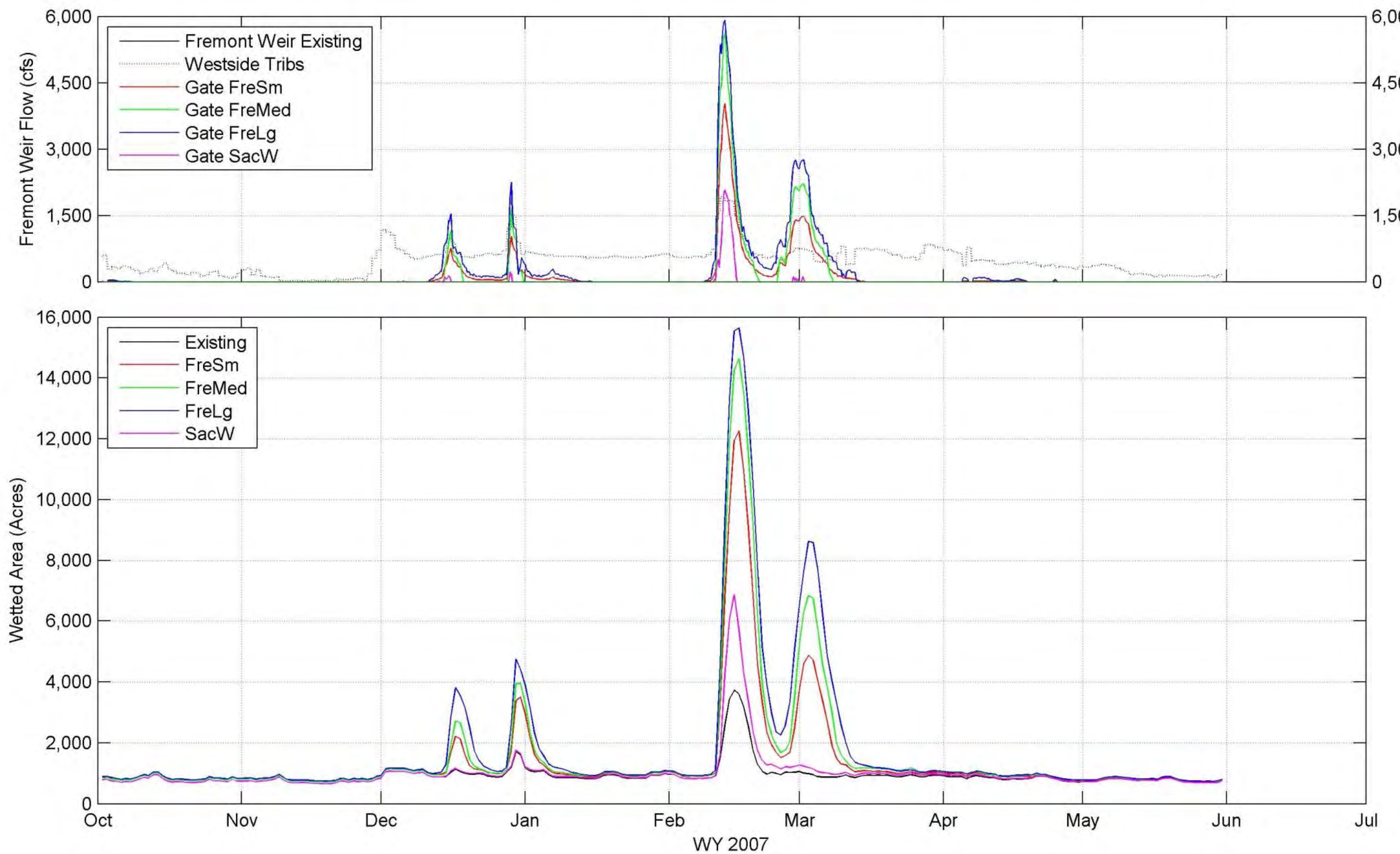


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2006 for Apr 30 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D74**

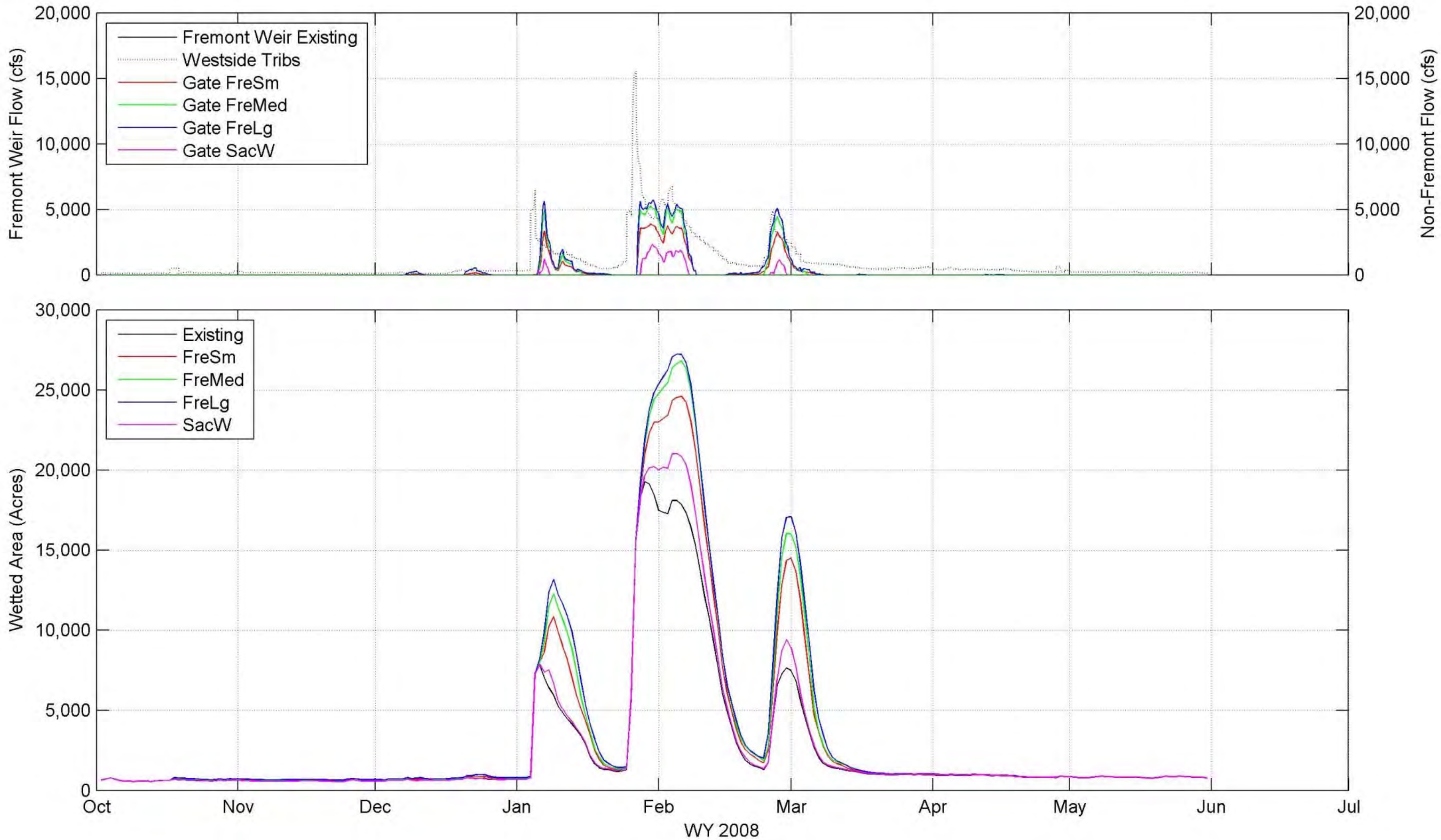


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2007 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D75**

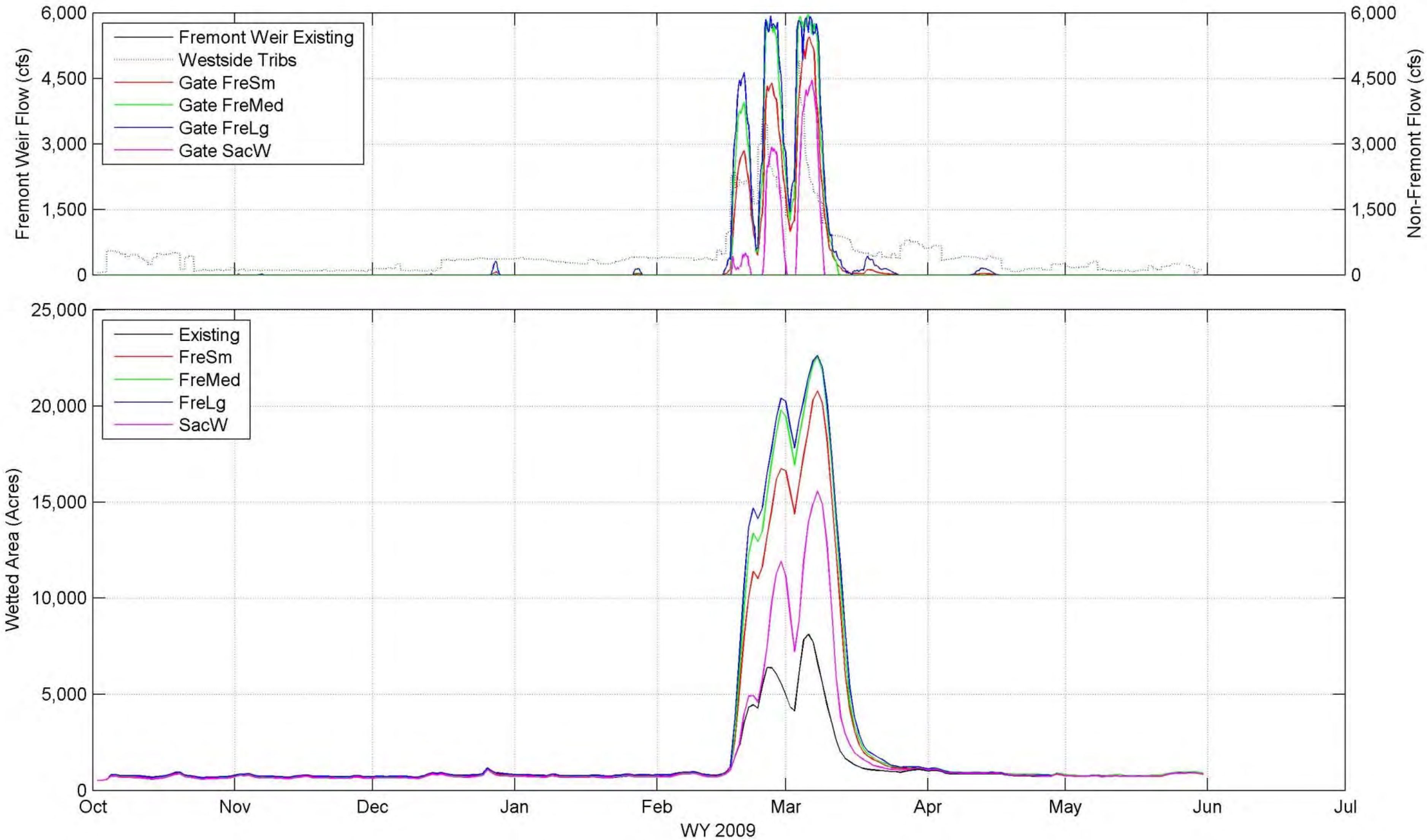


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2008 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D76**

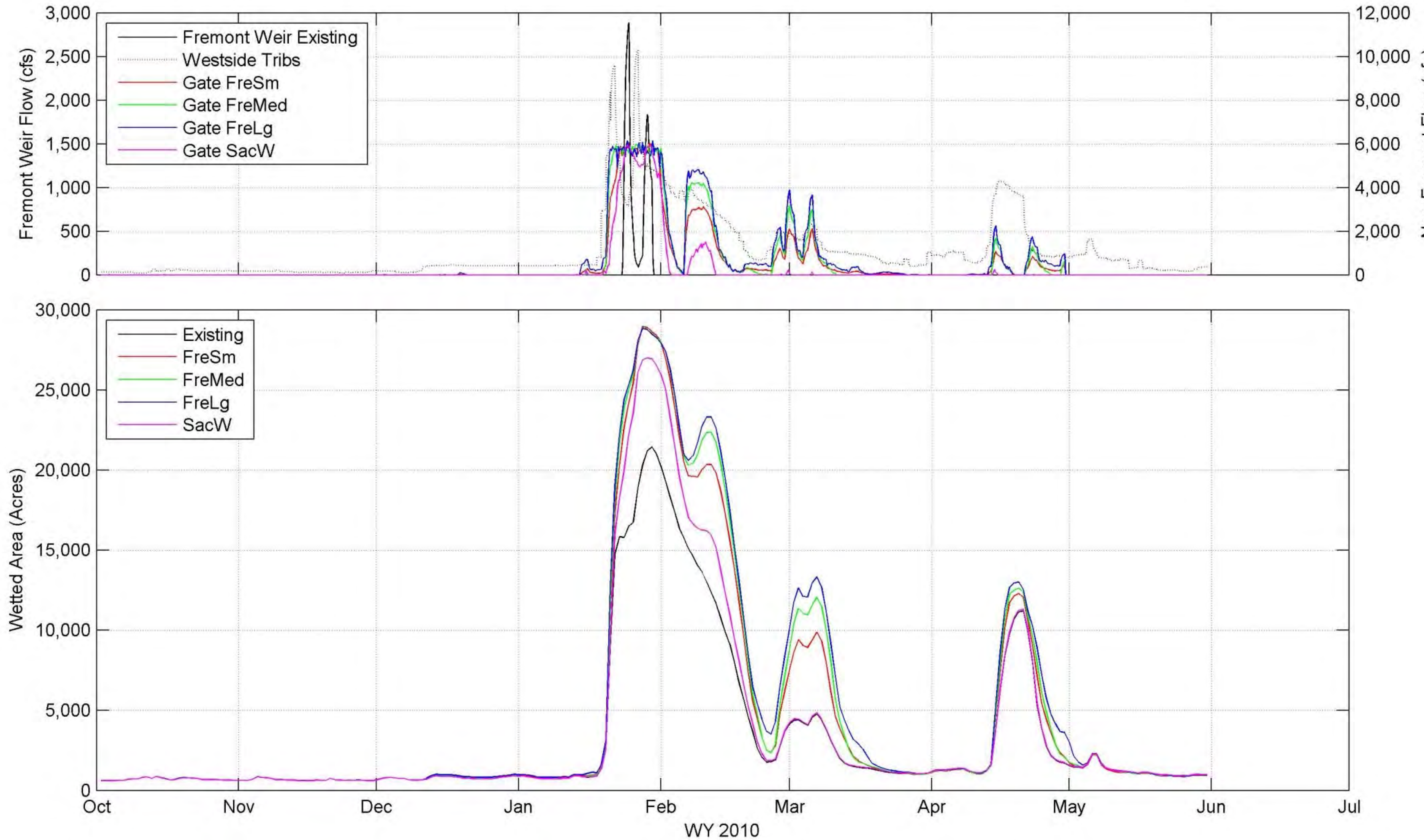


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2009 for Apr 30 Gate Closure

Prepared for DWR | Created By: SJB | **Figure D77**

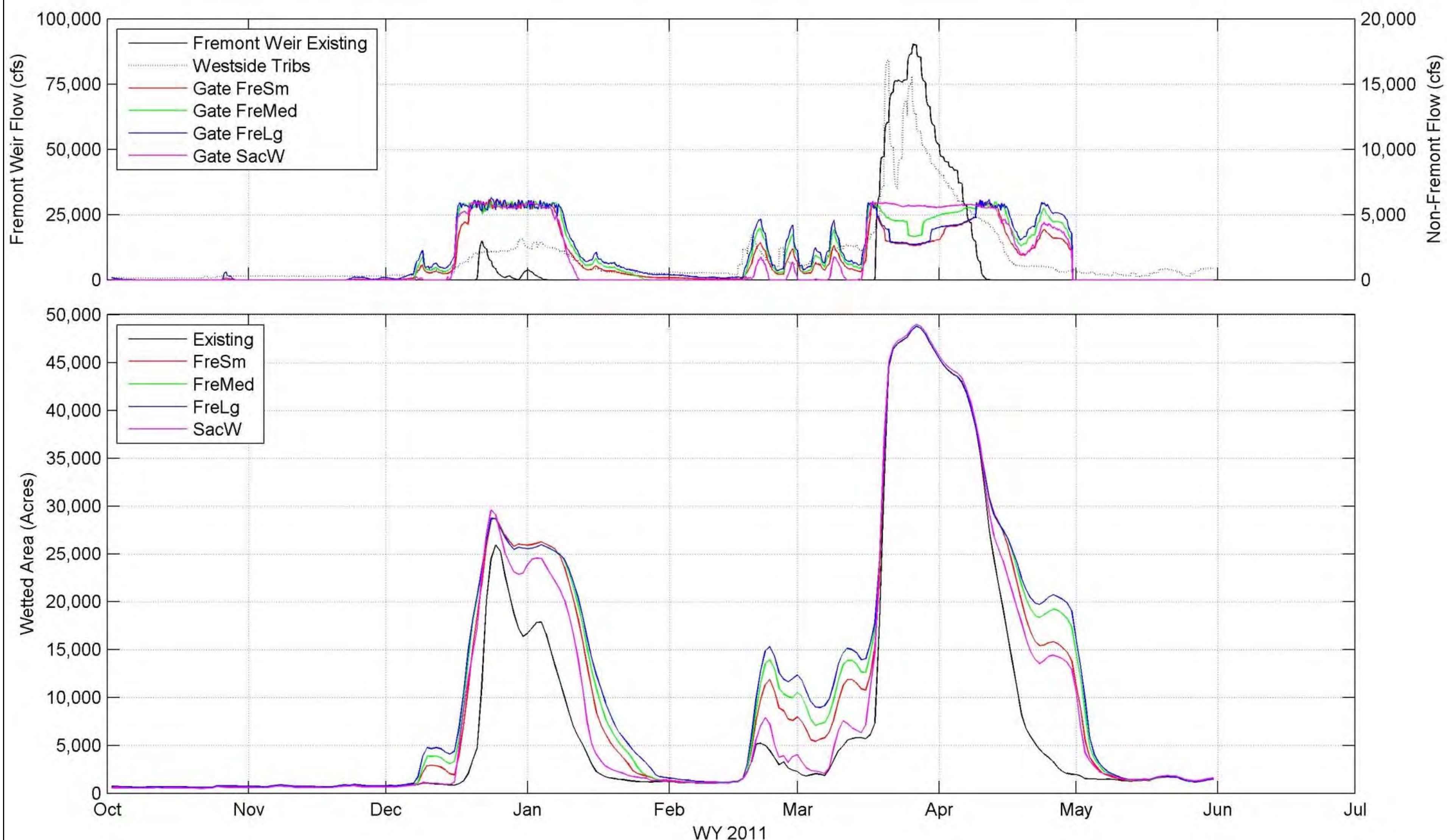


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2010 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	Figure D78

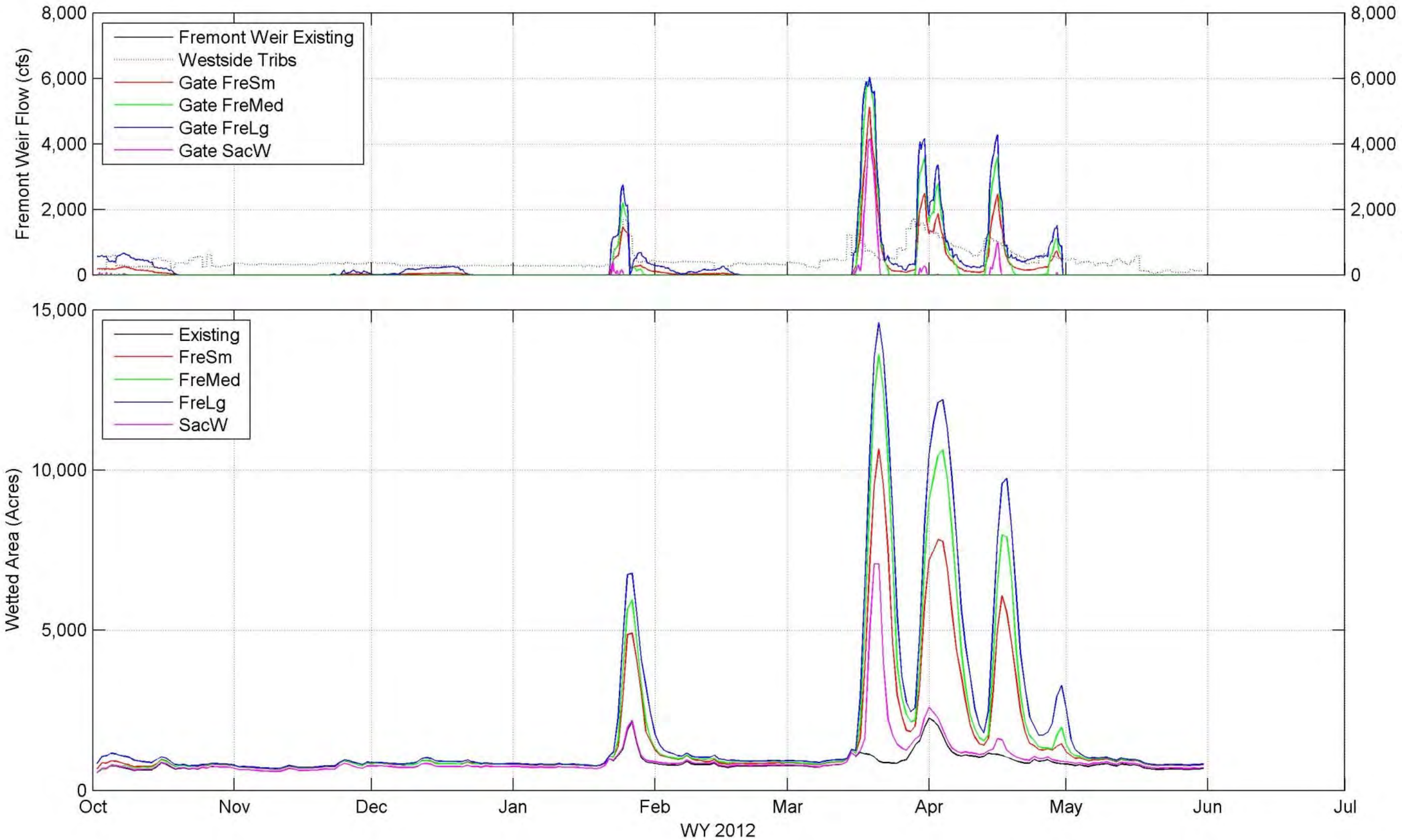


Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2011 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D79**



Notes: TUFLOW model results showing wetted area (lower) and gate flows (upper)

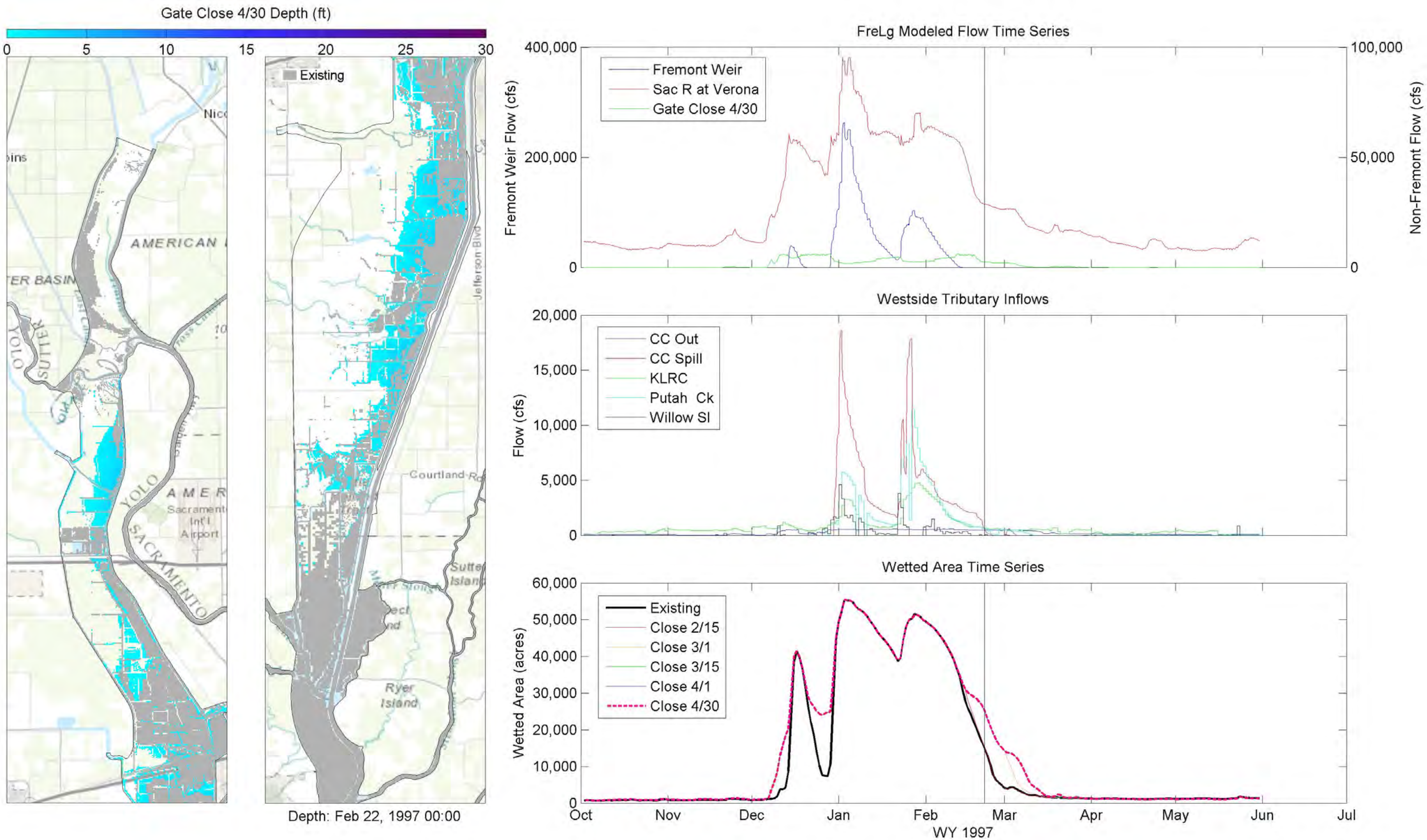
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area for WY 2012 for Apr 30 Gate Closure

Prepared for DWR	Created By: SJB	**Figure D80**

Appendix E

Animation Snapshots



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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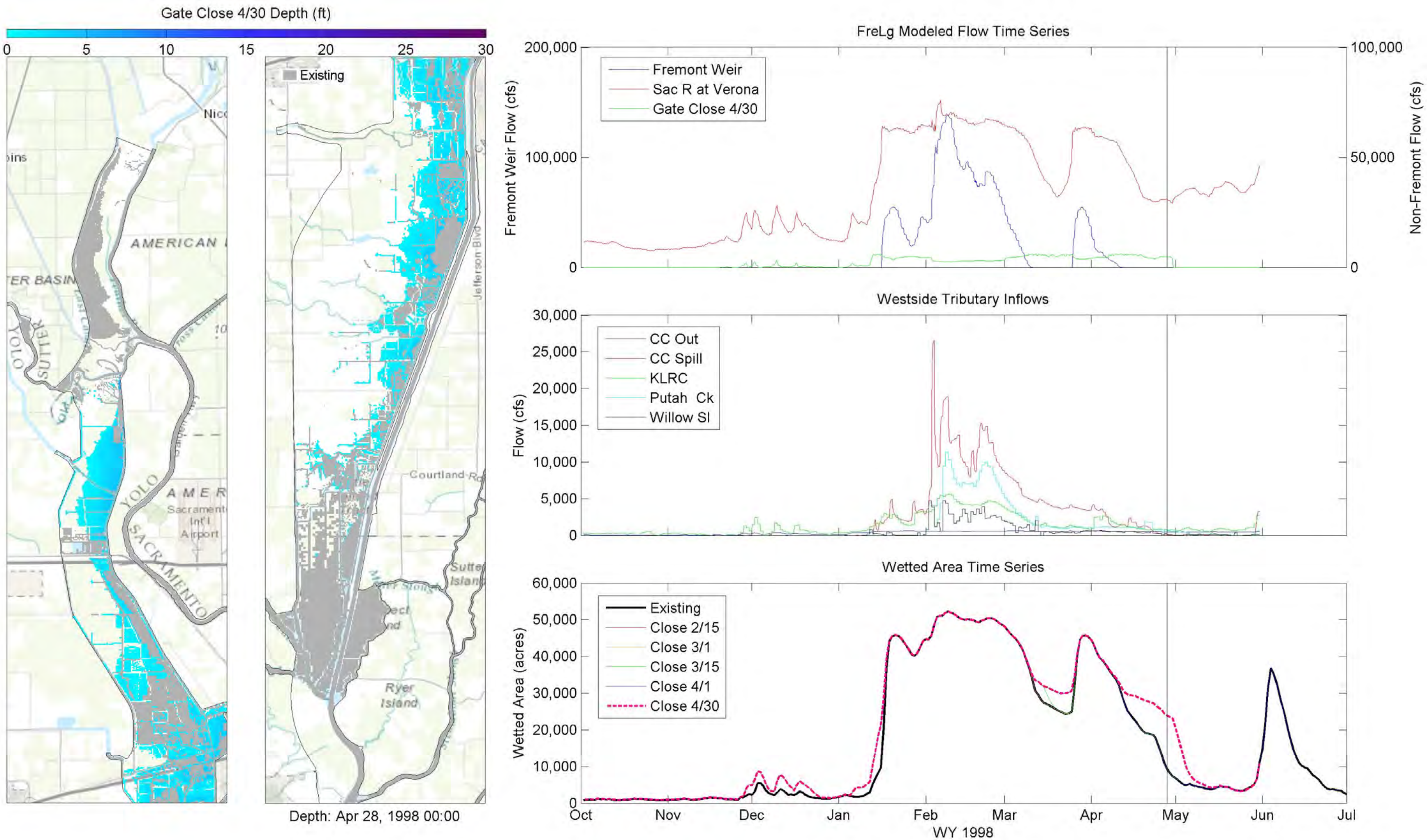
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1997 for FreLg

Prepared for DWR	Created By: SJB	**Figure E1**

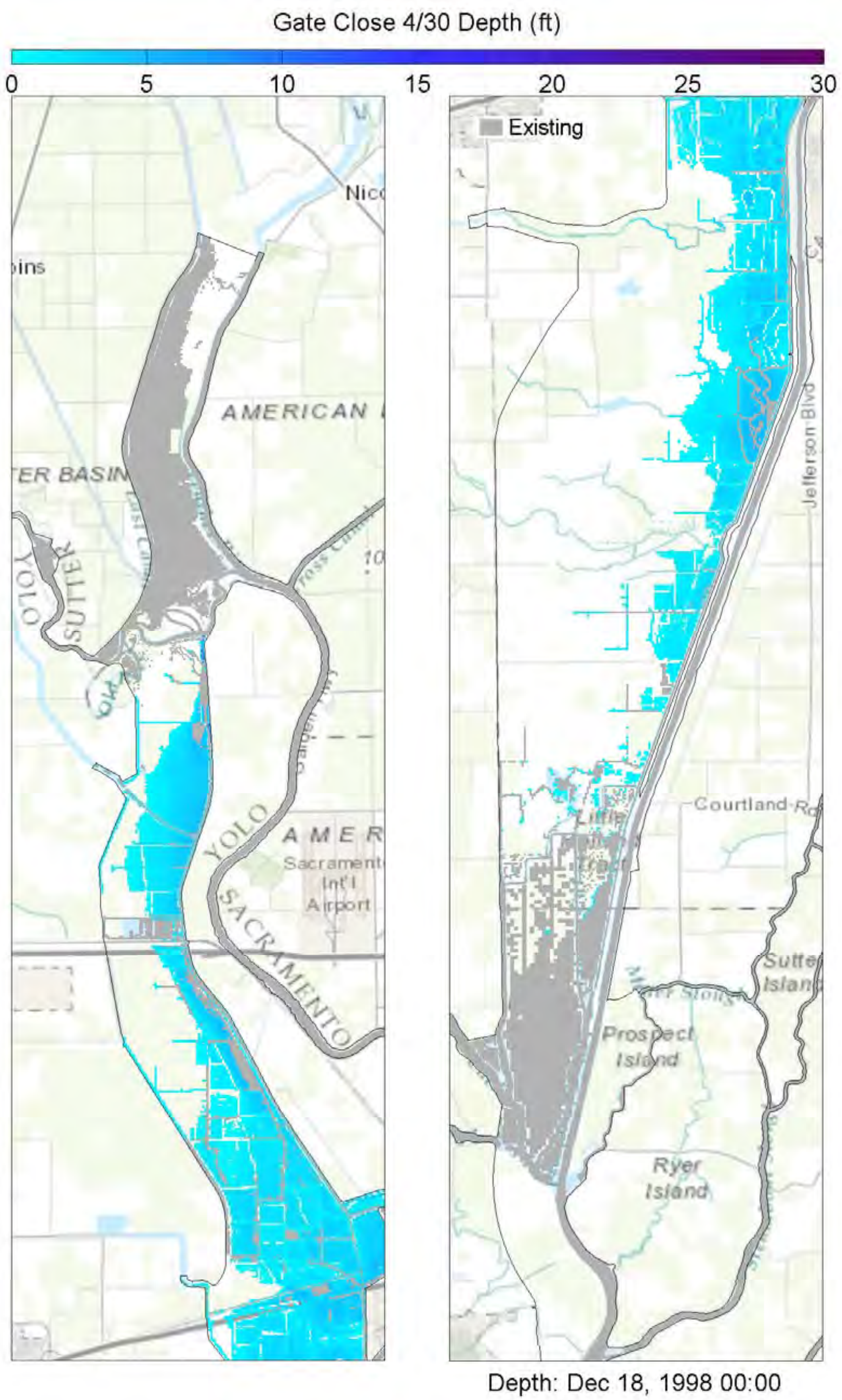


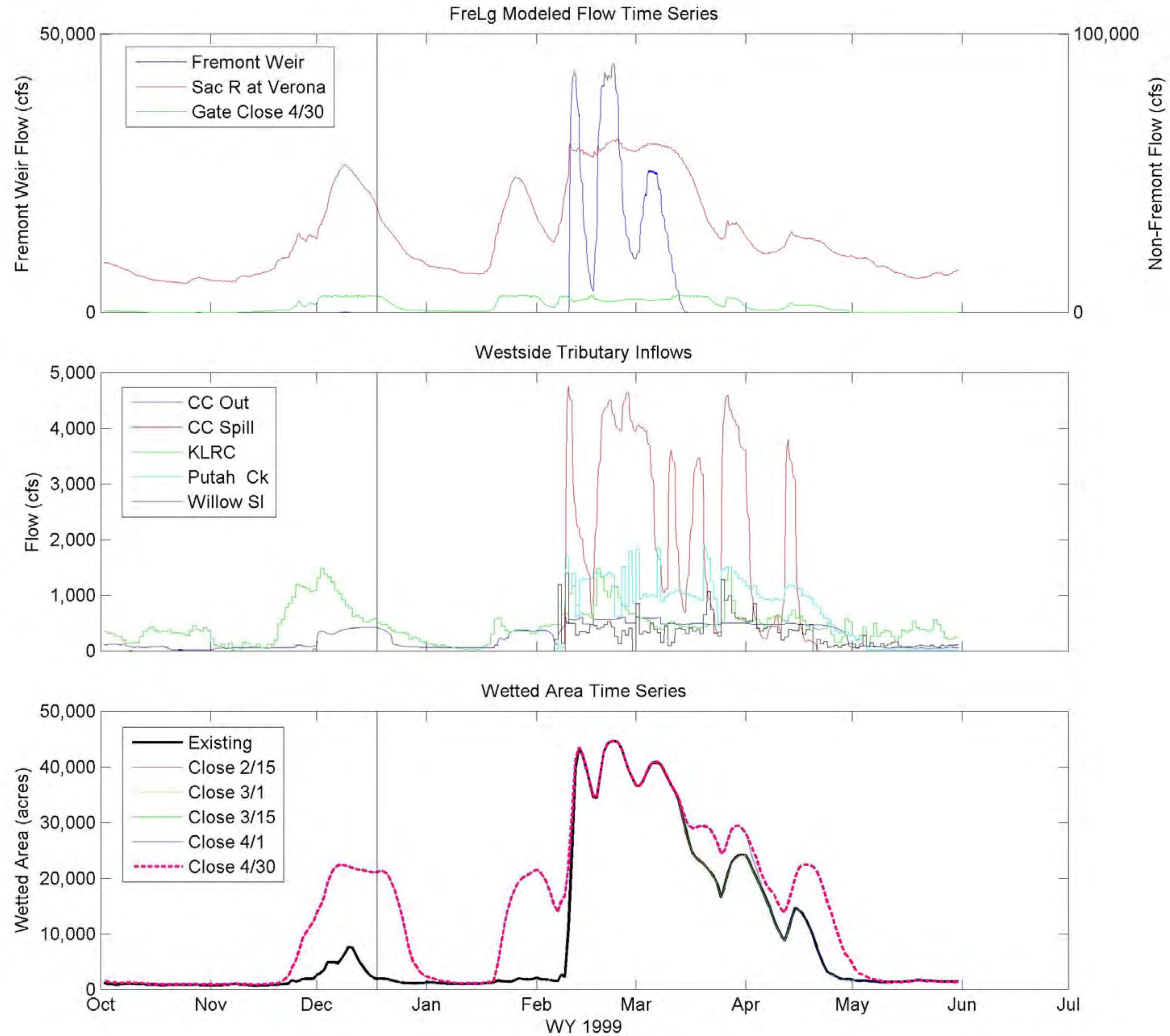
Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1998 for FreLg

Prepared for DWR | Created By: SJB | **Figure E2**



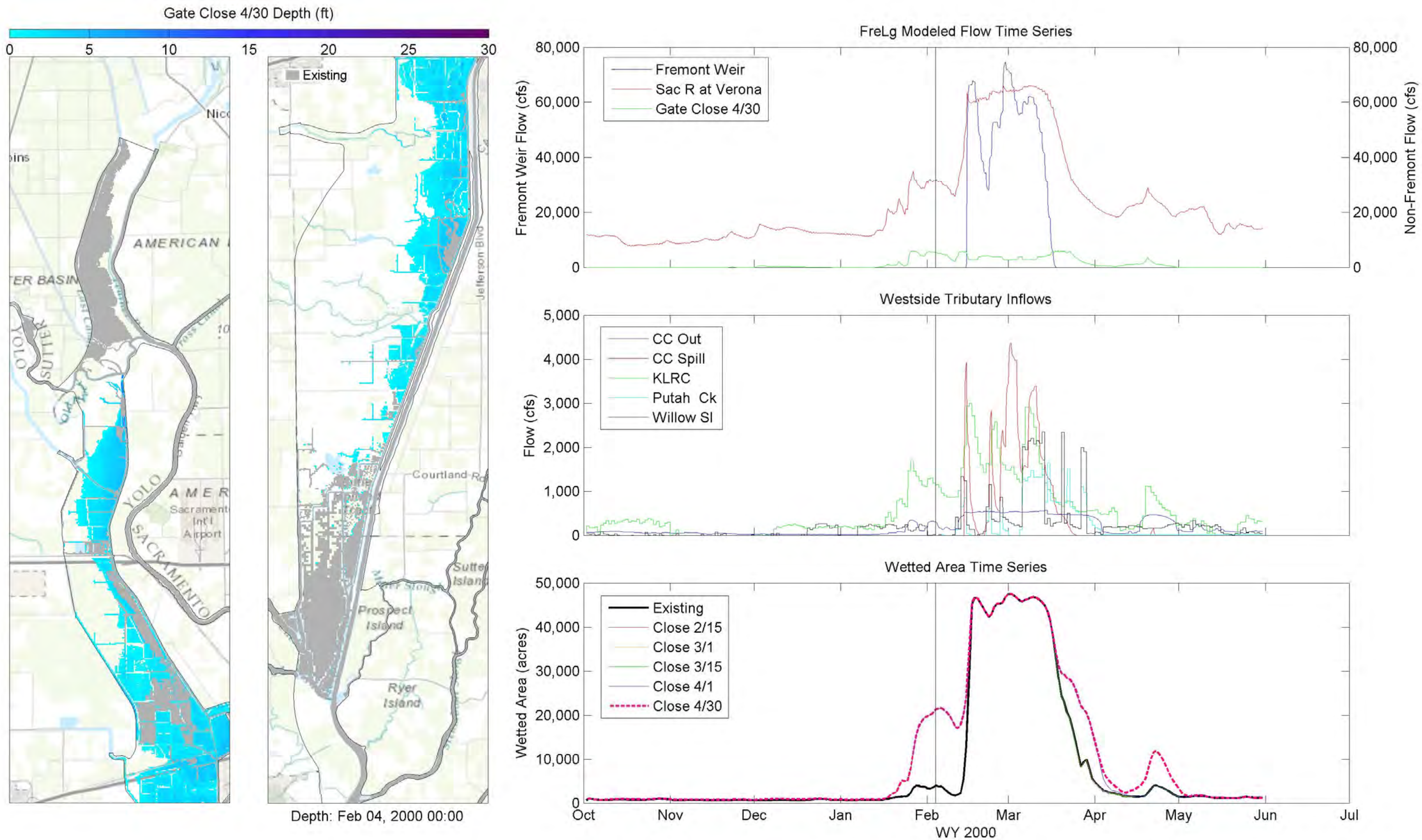


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1999 for FreLg

Prepared for DWR | Created By: SJB | **Figure E3**

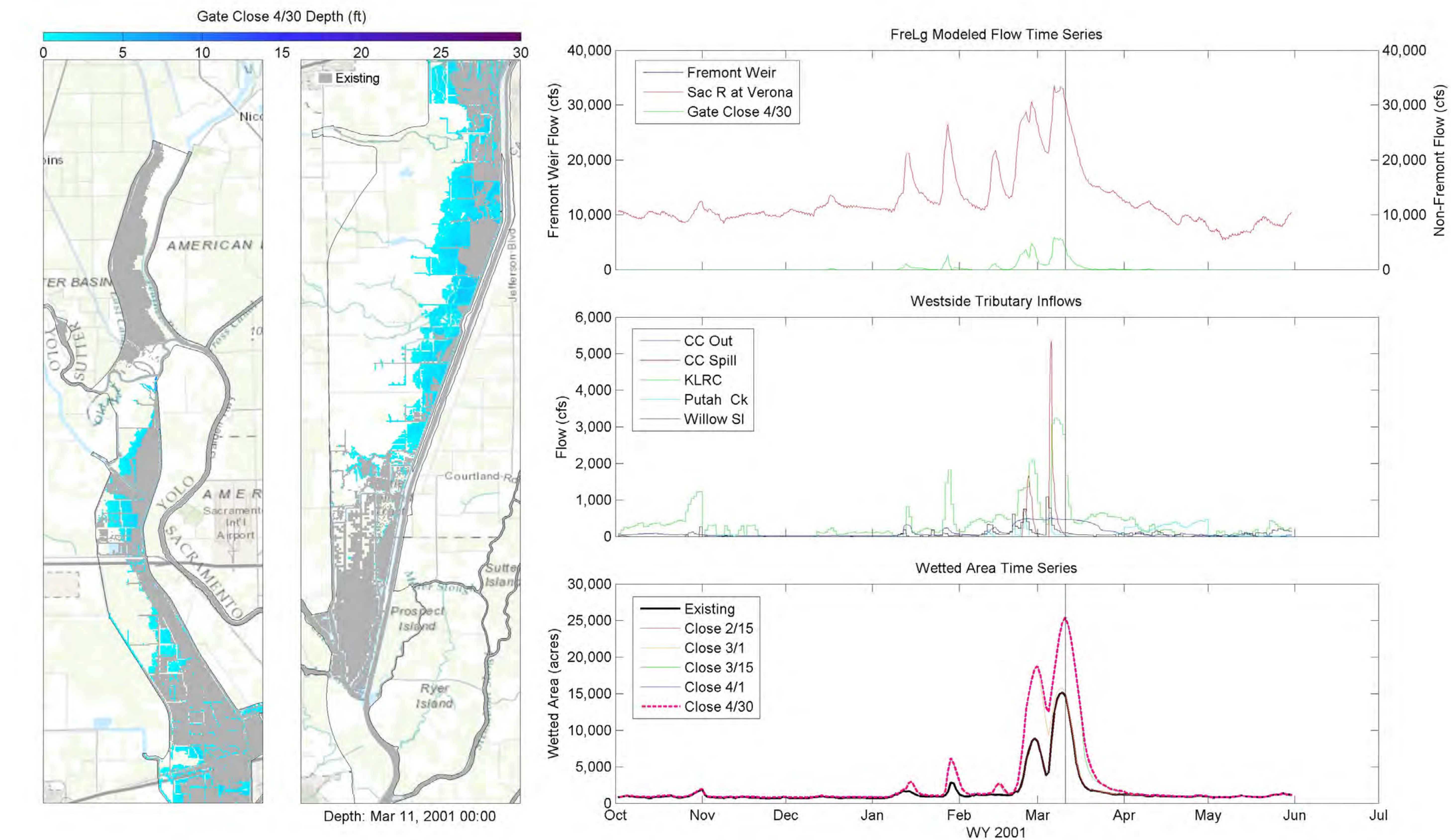


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2000 for FreLg

Prepared for DWR	Created By: SJB	**Figure E4**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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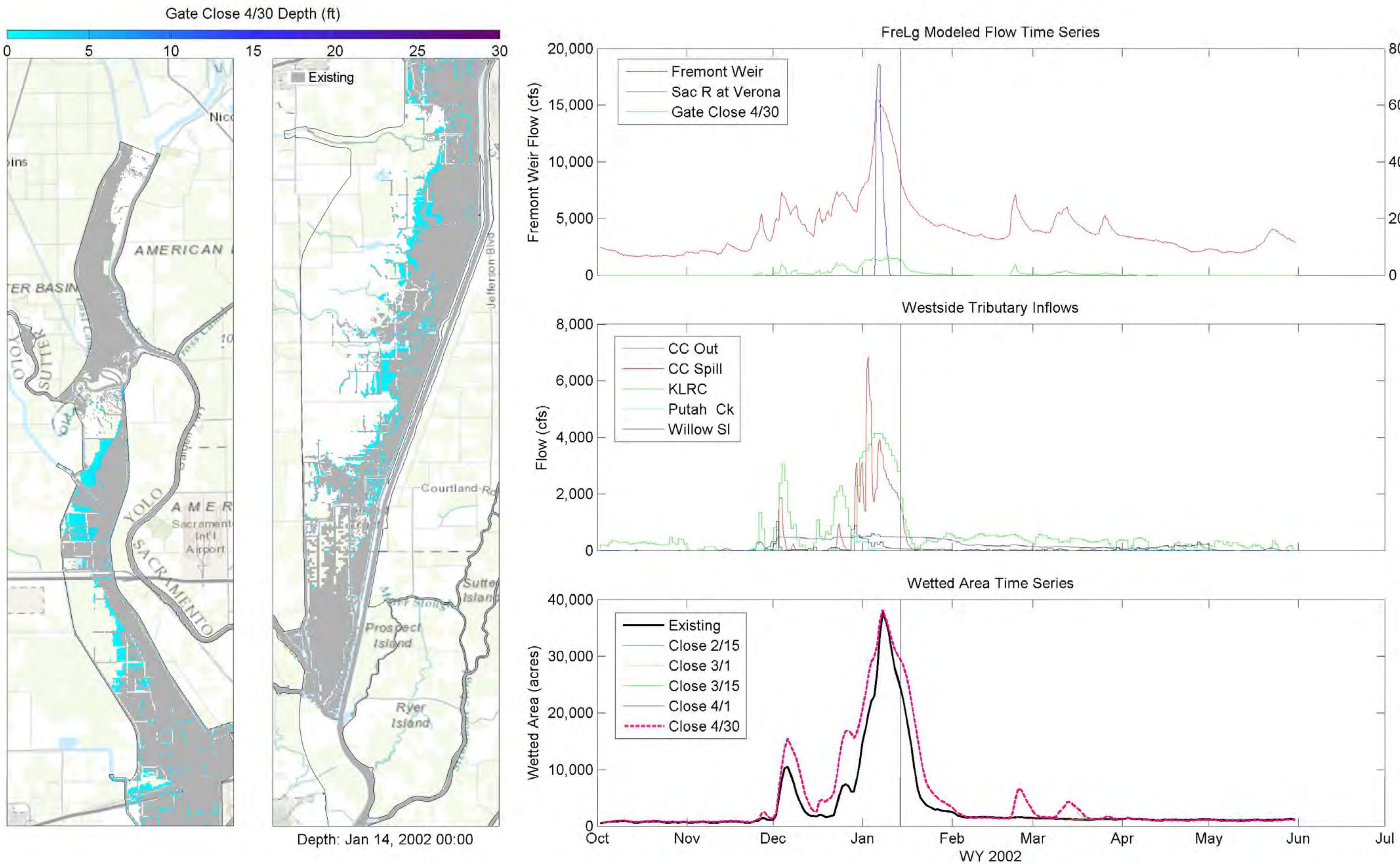
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2001 for FreLg

Prepared for DWR | Created By: SJB | **Figure E5**

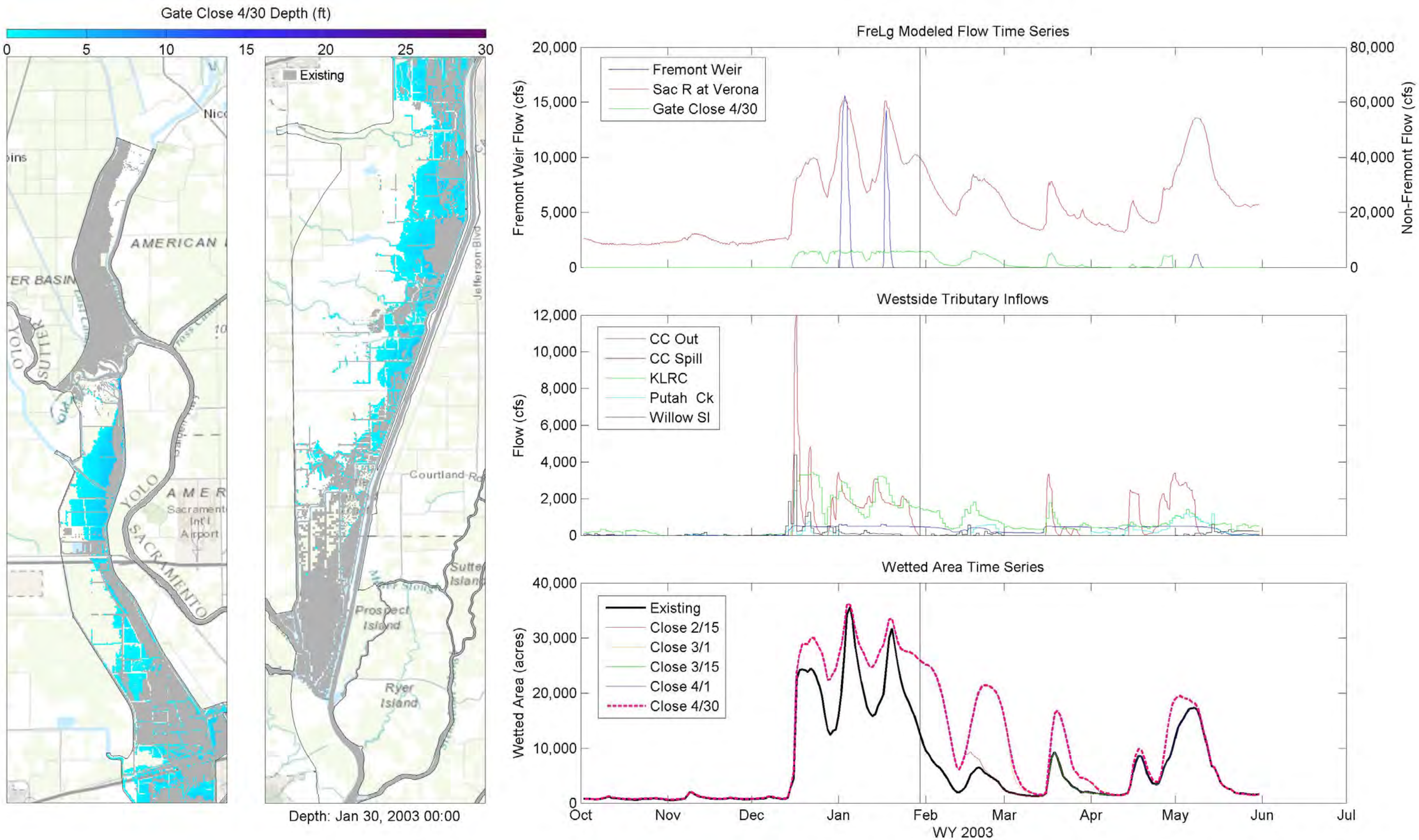


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2002 for FreLg

Prepared for DWR | Created By: SJB | **Figure E6**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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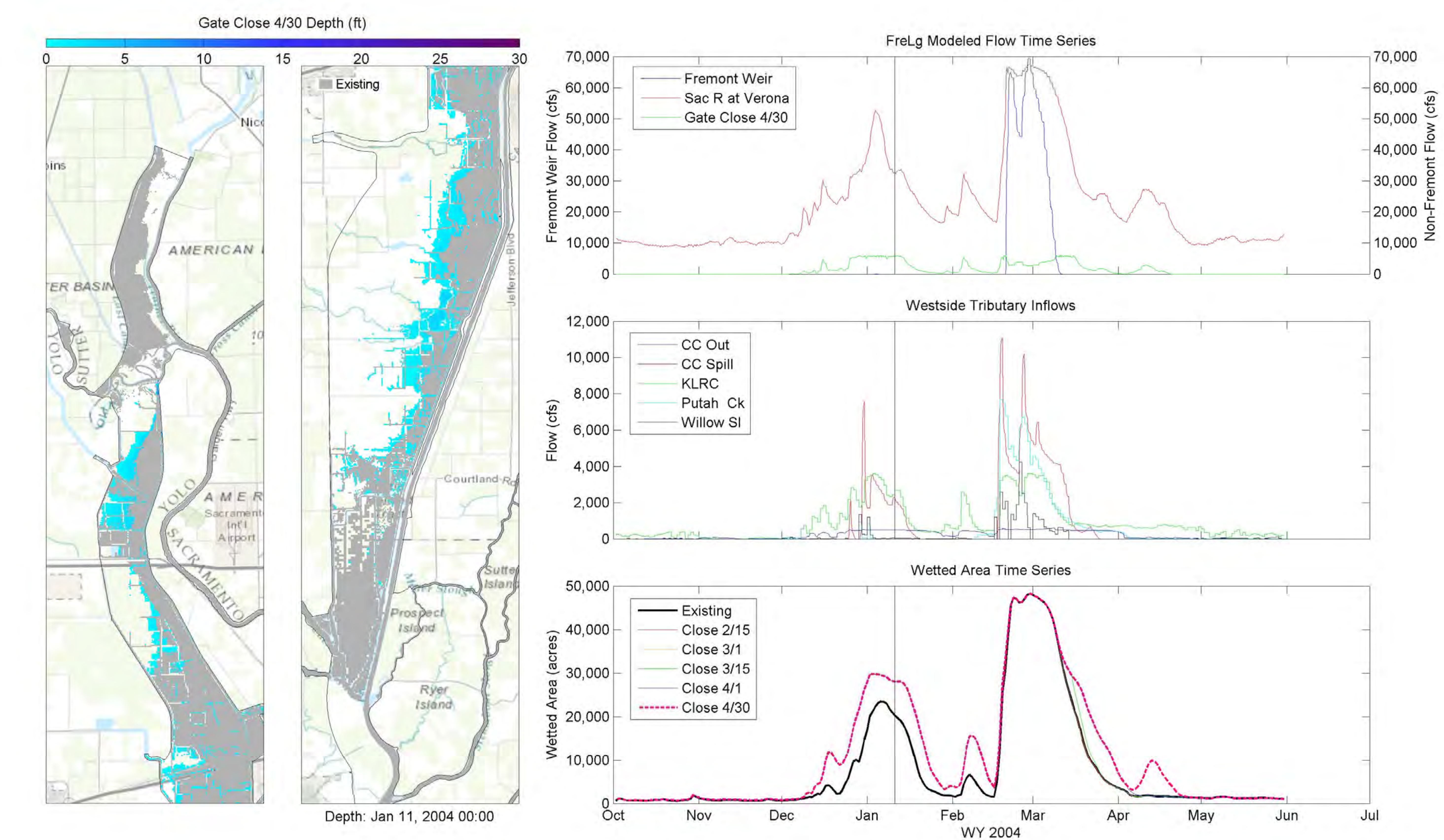
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2003 for FreLg

Prepared for DWR | Created By: SJB | **Figure E7**

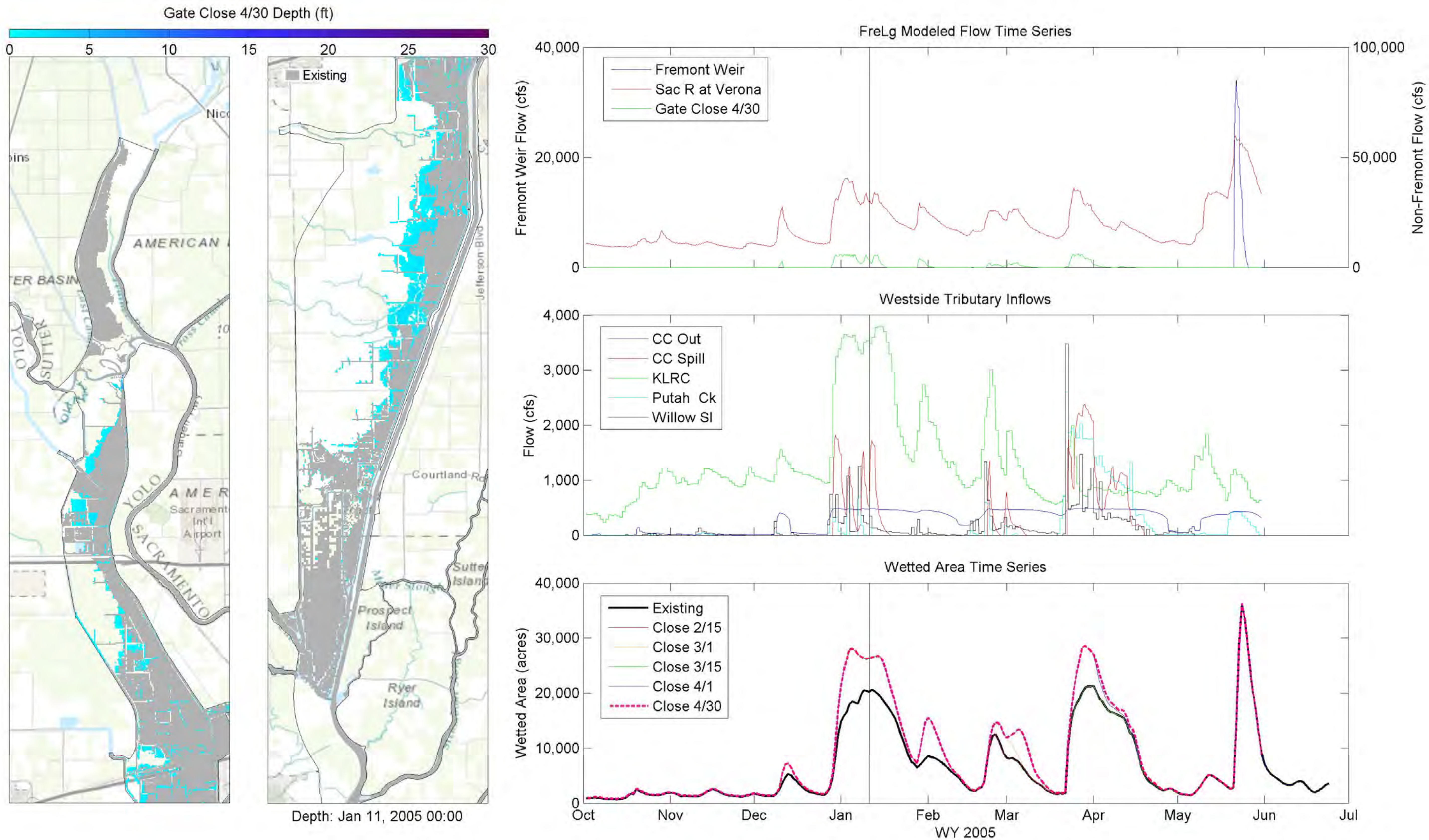


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2004 for FreLg

Prepared for DWR | Created By: SJB | **Figure E8**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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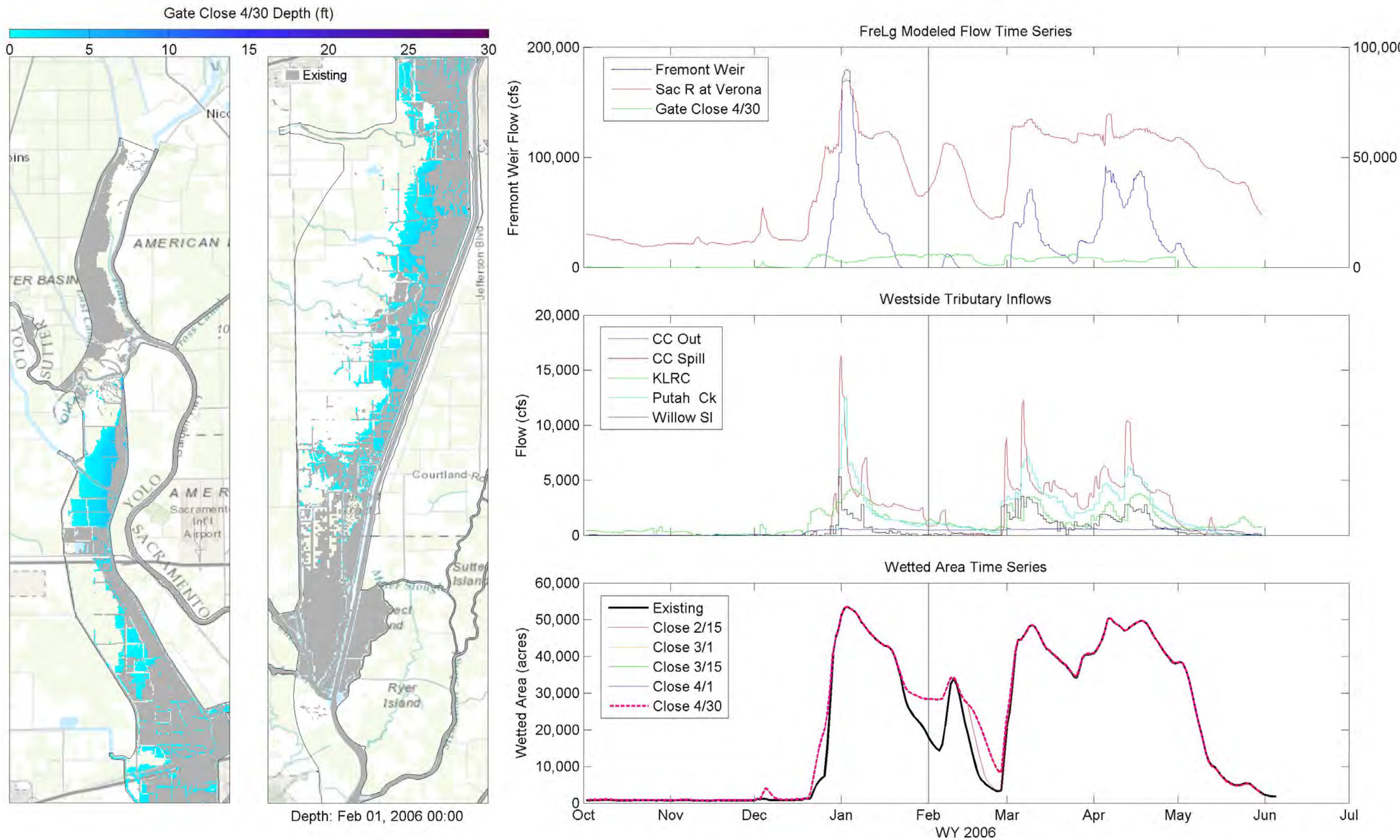
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2005 for FreLg

Prepared for DWR | Created By: SJB | **Figure E9**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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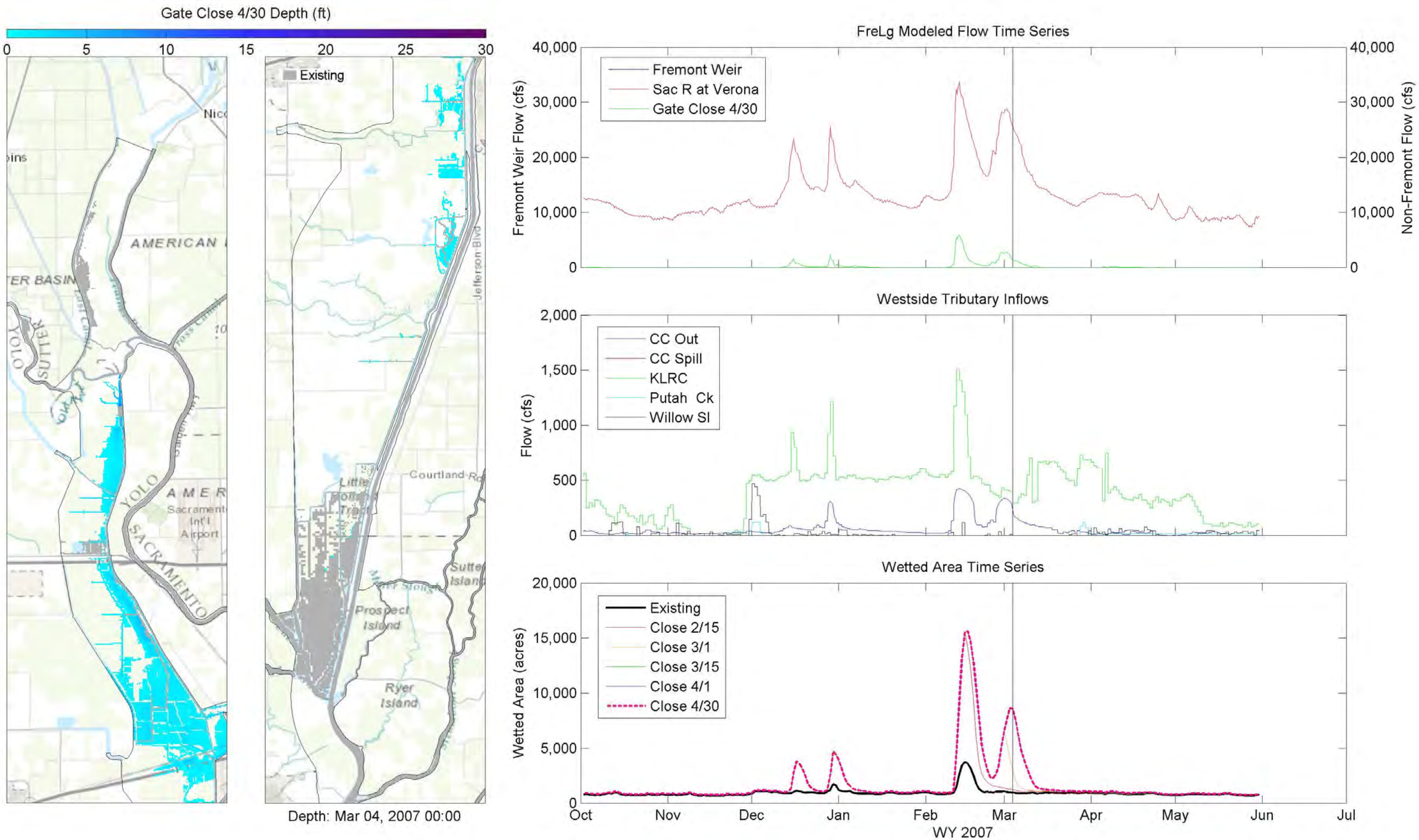
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2006 for FreLg

Prepared for DWR | Created By: SJB | **Figure E10**

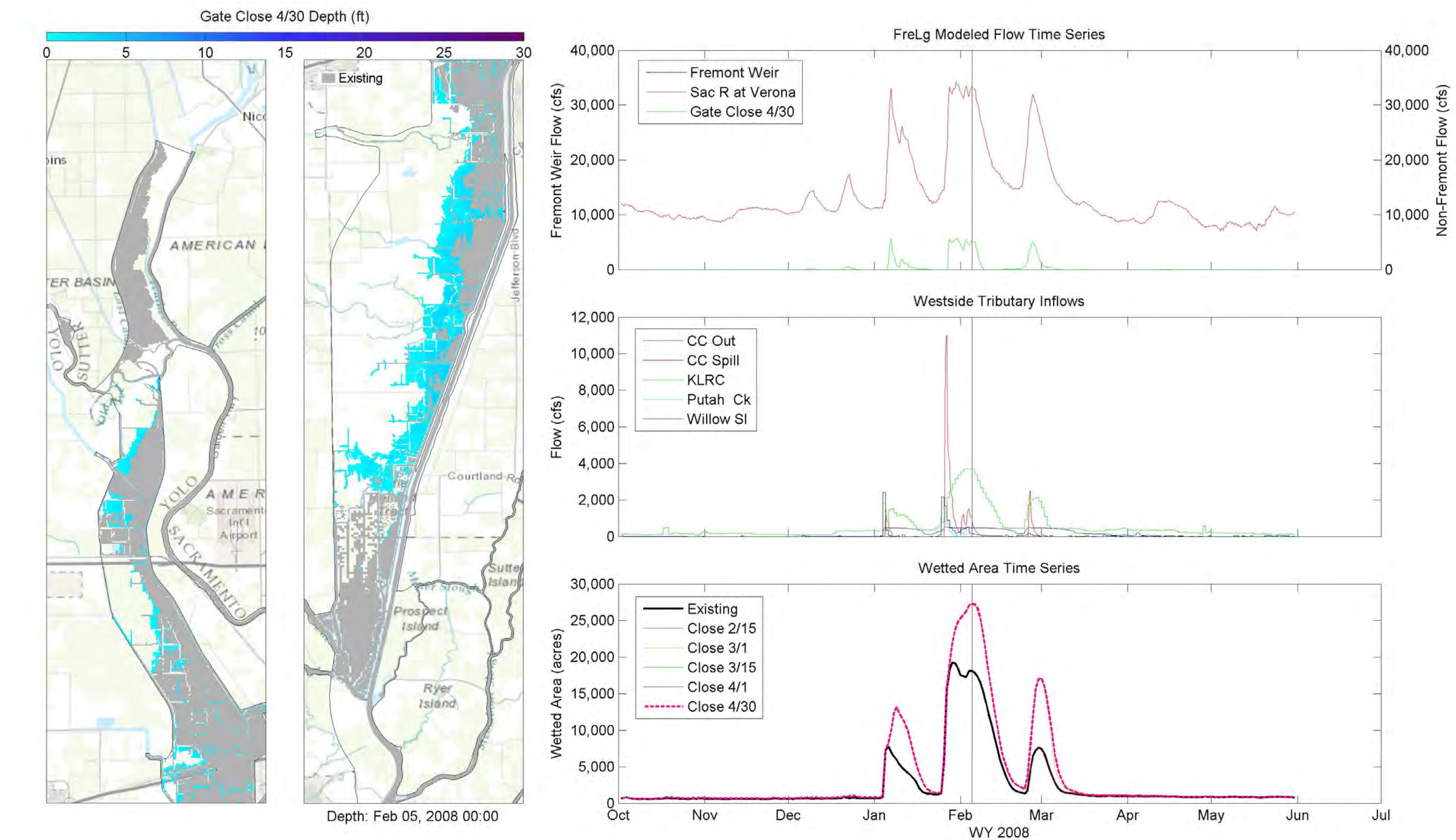


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2007 for FreLg

Prepared for DWR | Created By: SJB | **Figure E11**

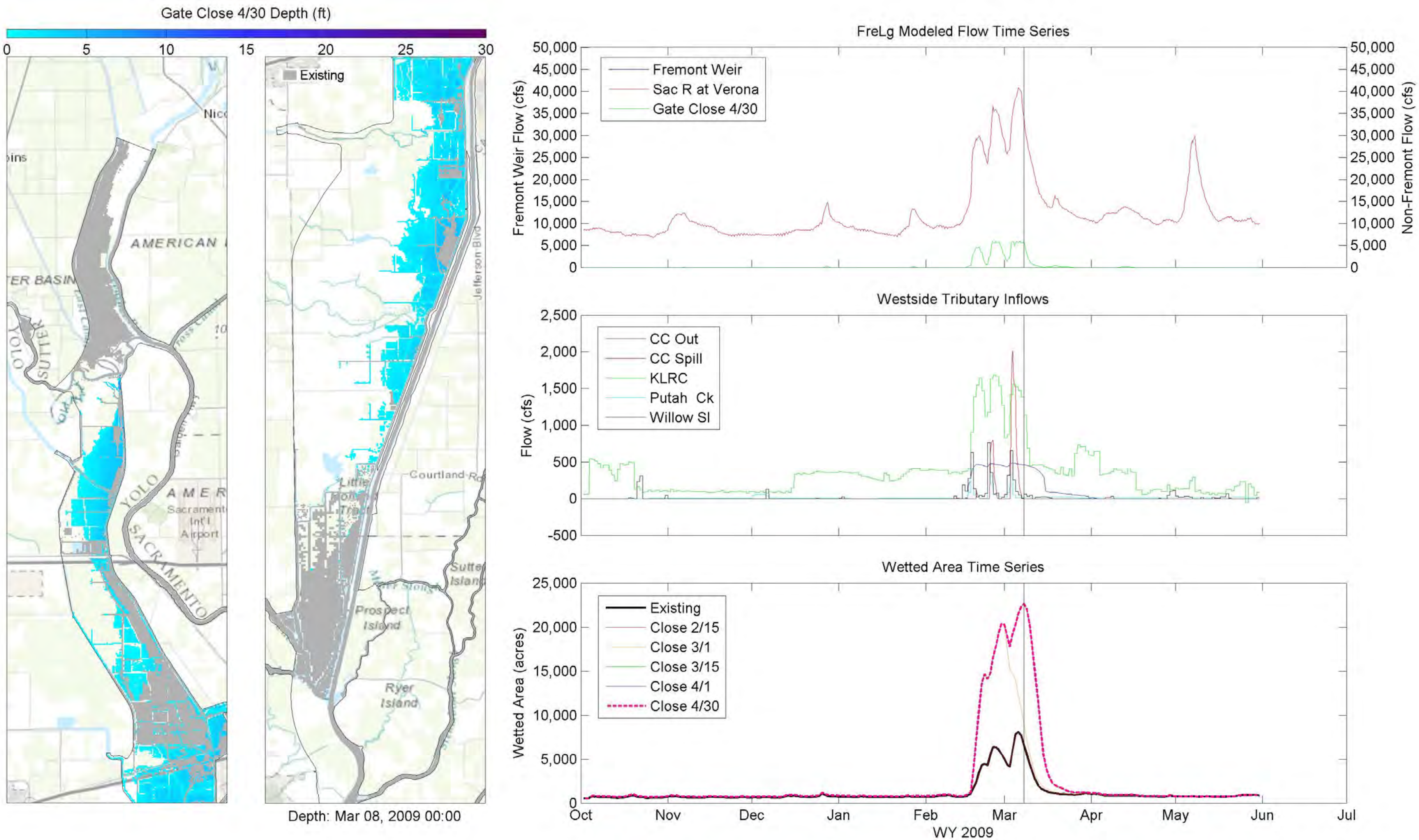


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2008 for FreLg

Prepared for DWR | Created By: SJB | **Figure E12**

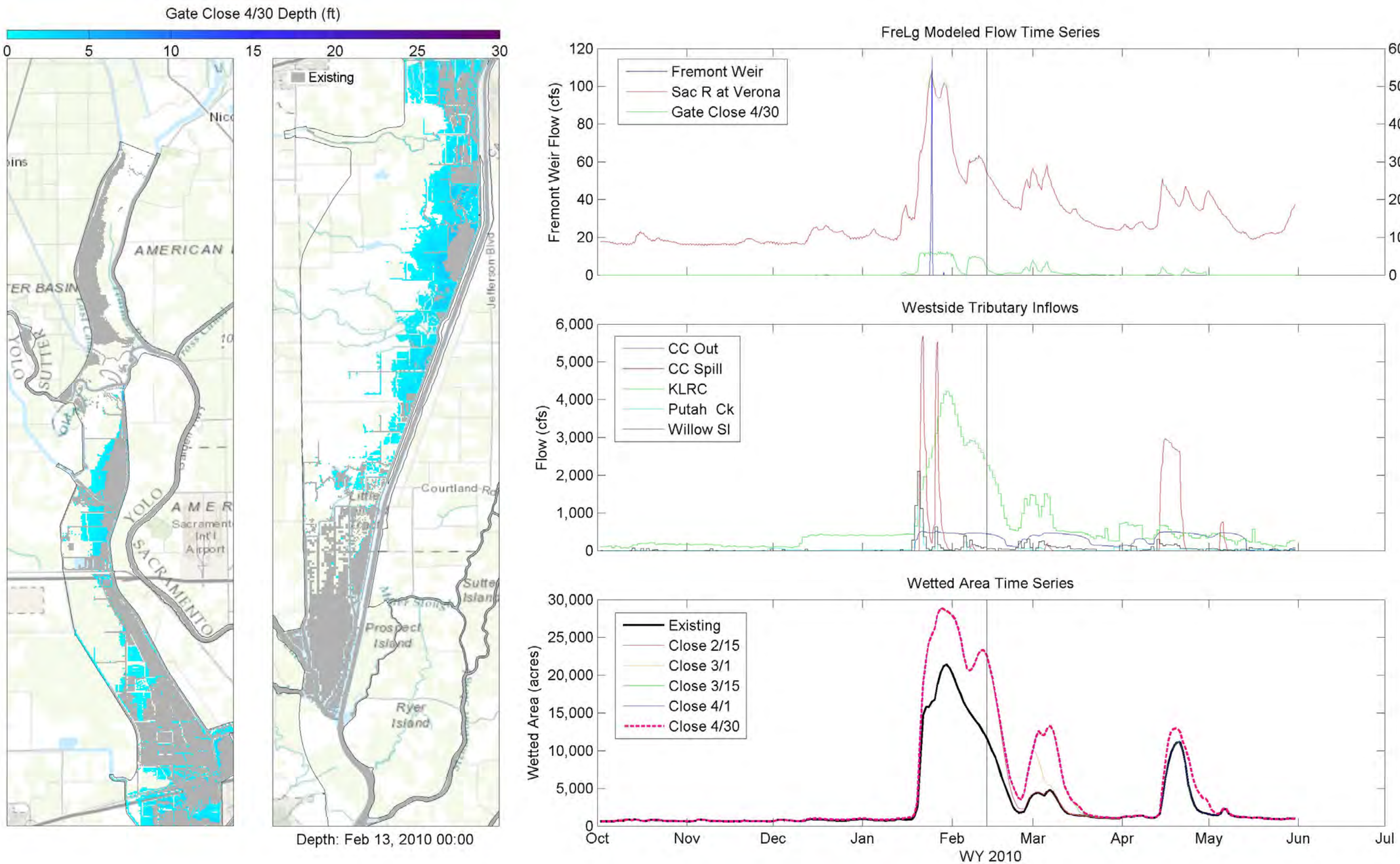


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2009 for FreLg

Prepared for DWR | Created By: SJB | **Figure E13**

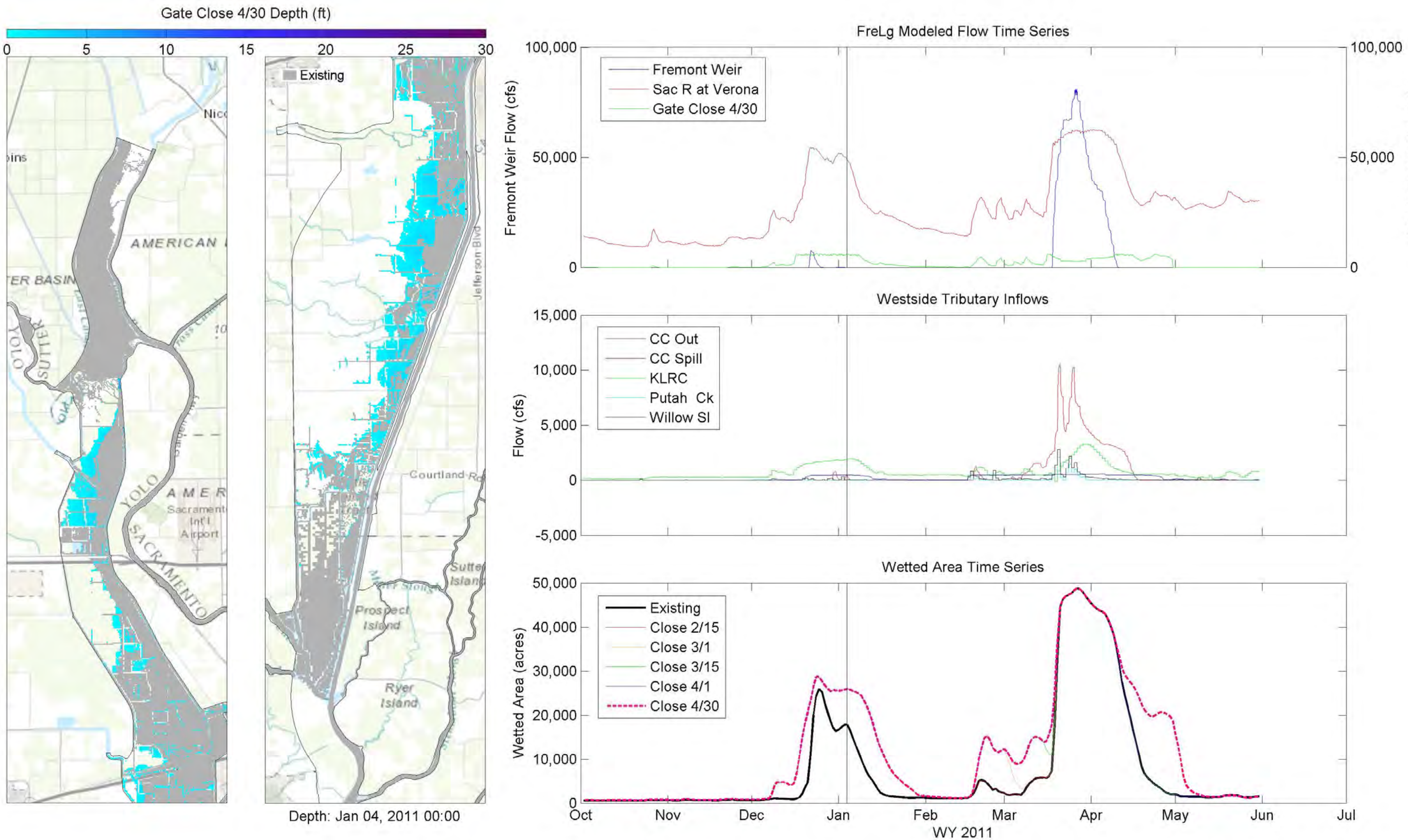


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2010 for FreLg

Prepared for DWR	Created By: SJB	**Figure E14**

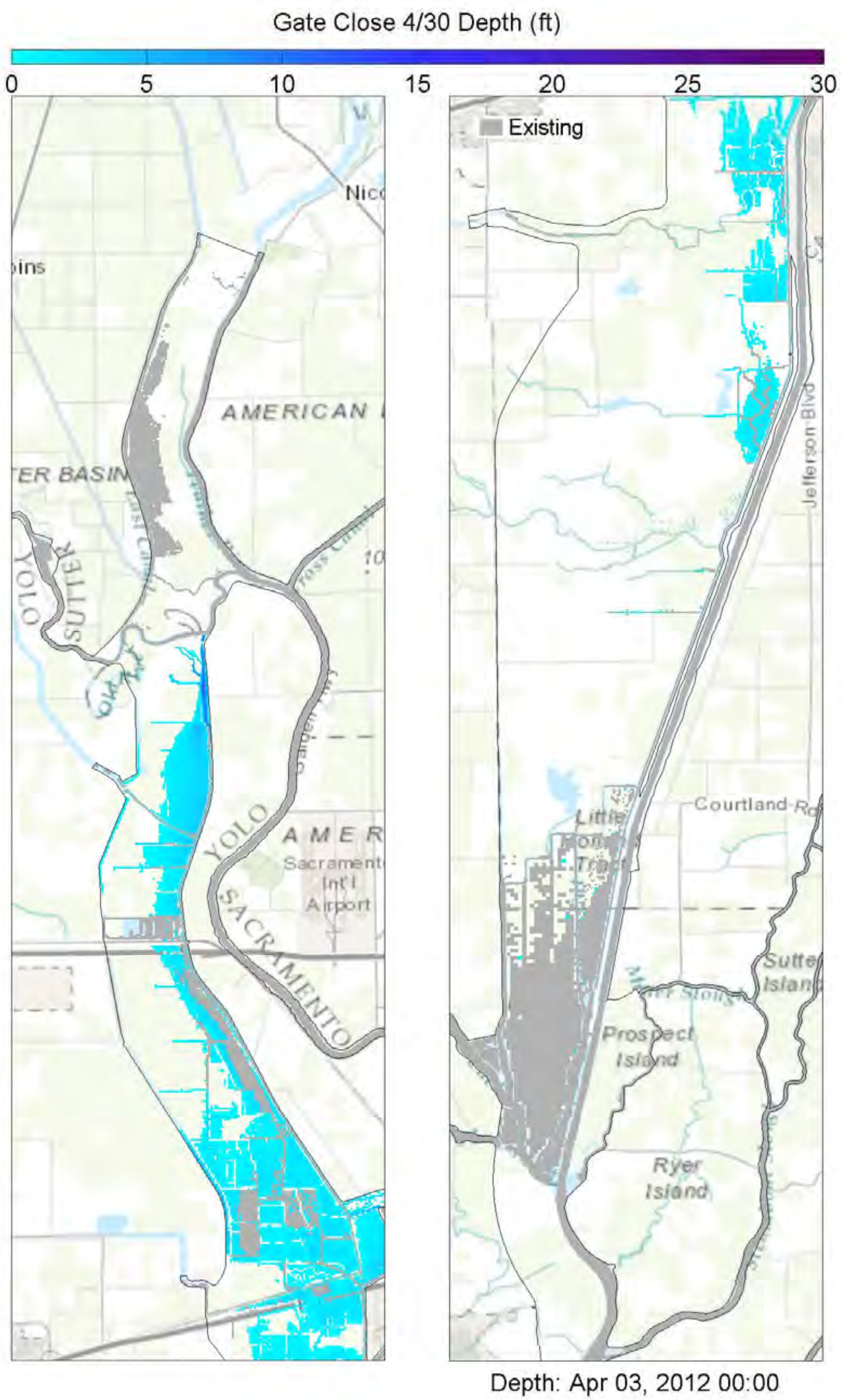


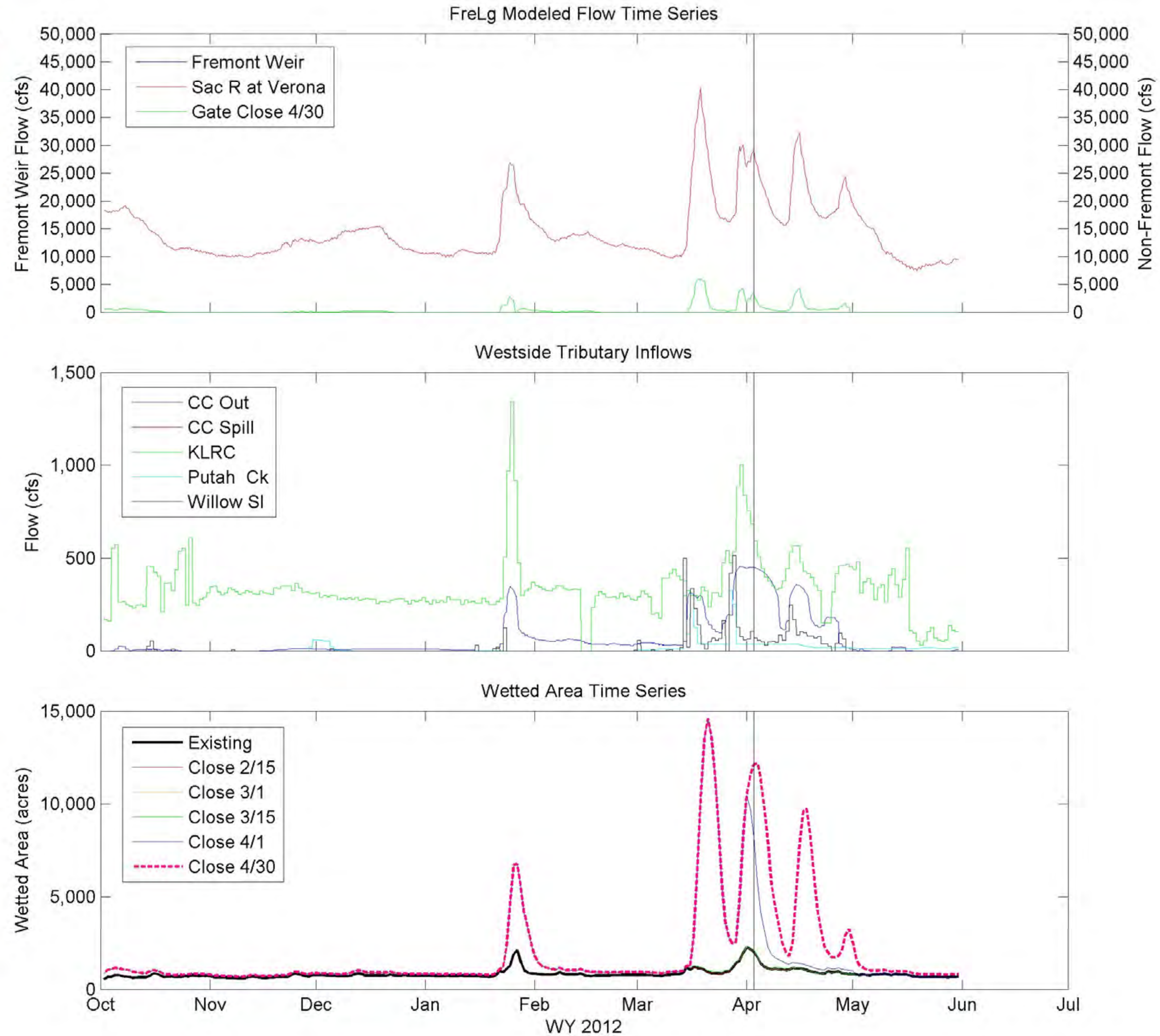
Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2011 for FreLg

Prepared for DWR	Created By: SJB	**Figure E15**





Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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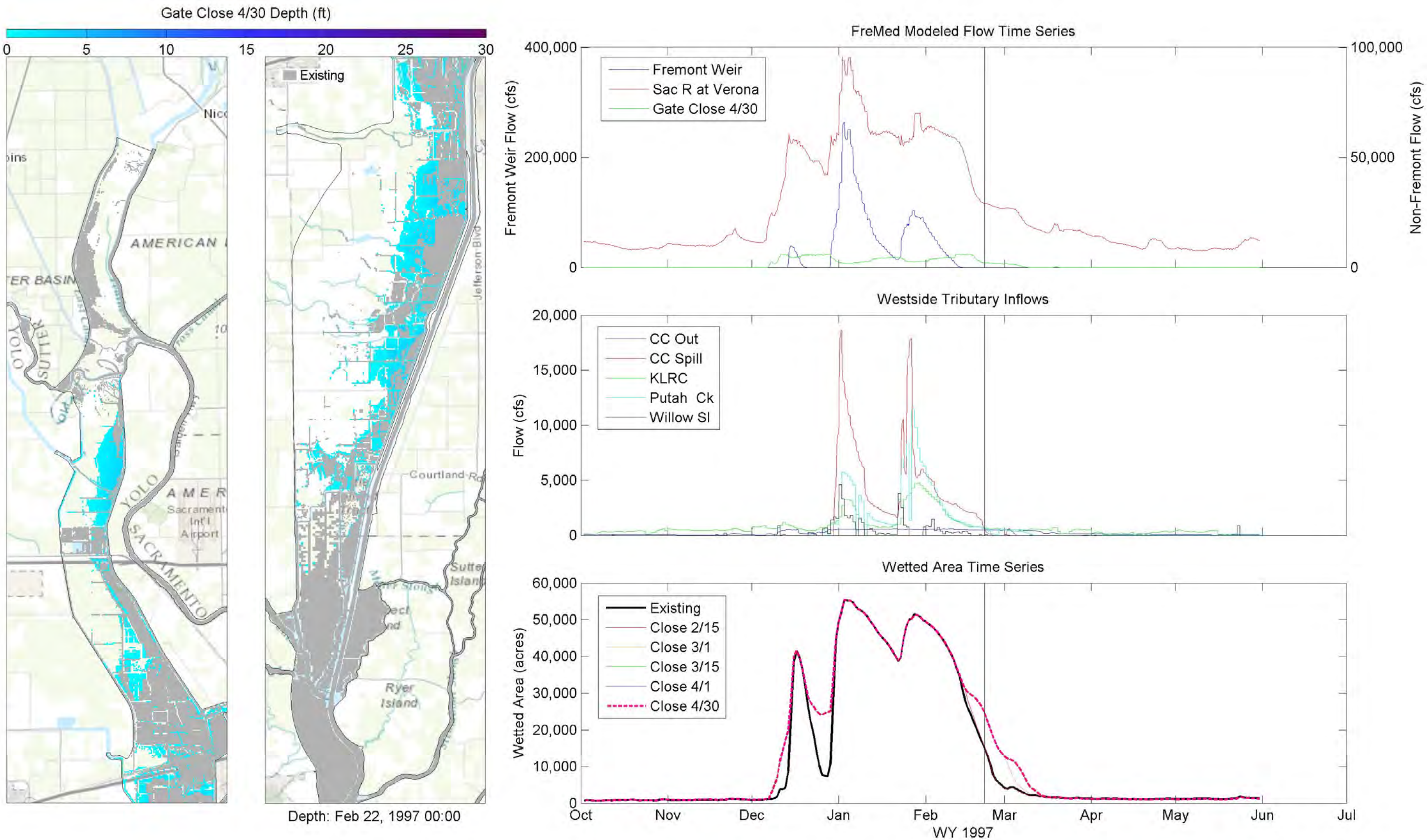
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2012 for FreLg

Prepared for DWR | Created By: SJB | **Figure E16**

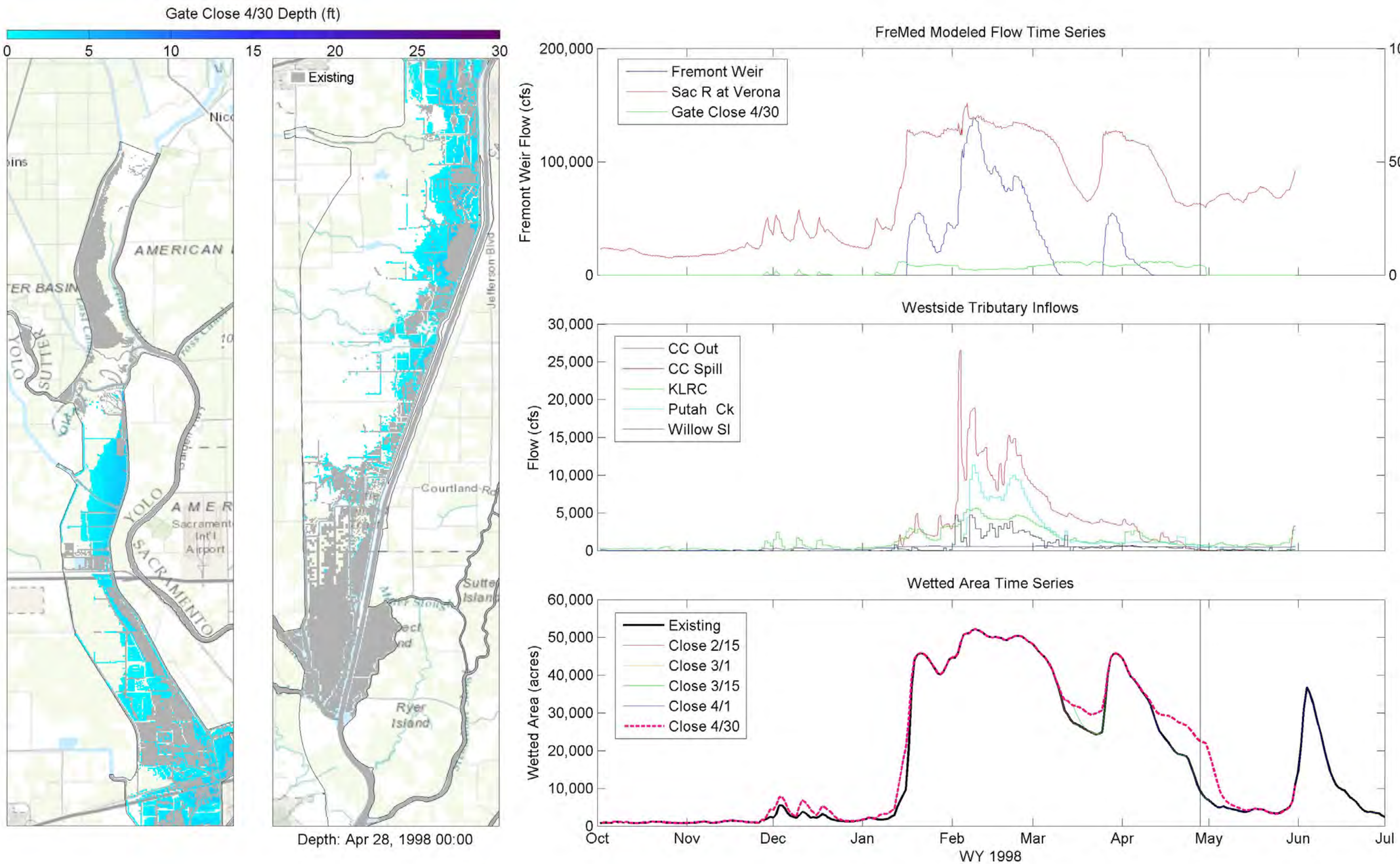


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1997 for FreMed

Prepared for DWR | Created By: SJB | **Figure E17**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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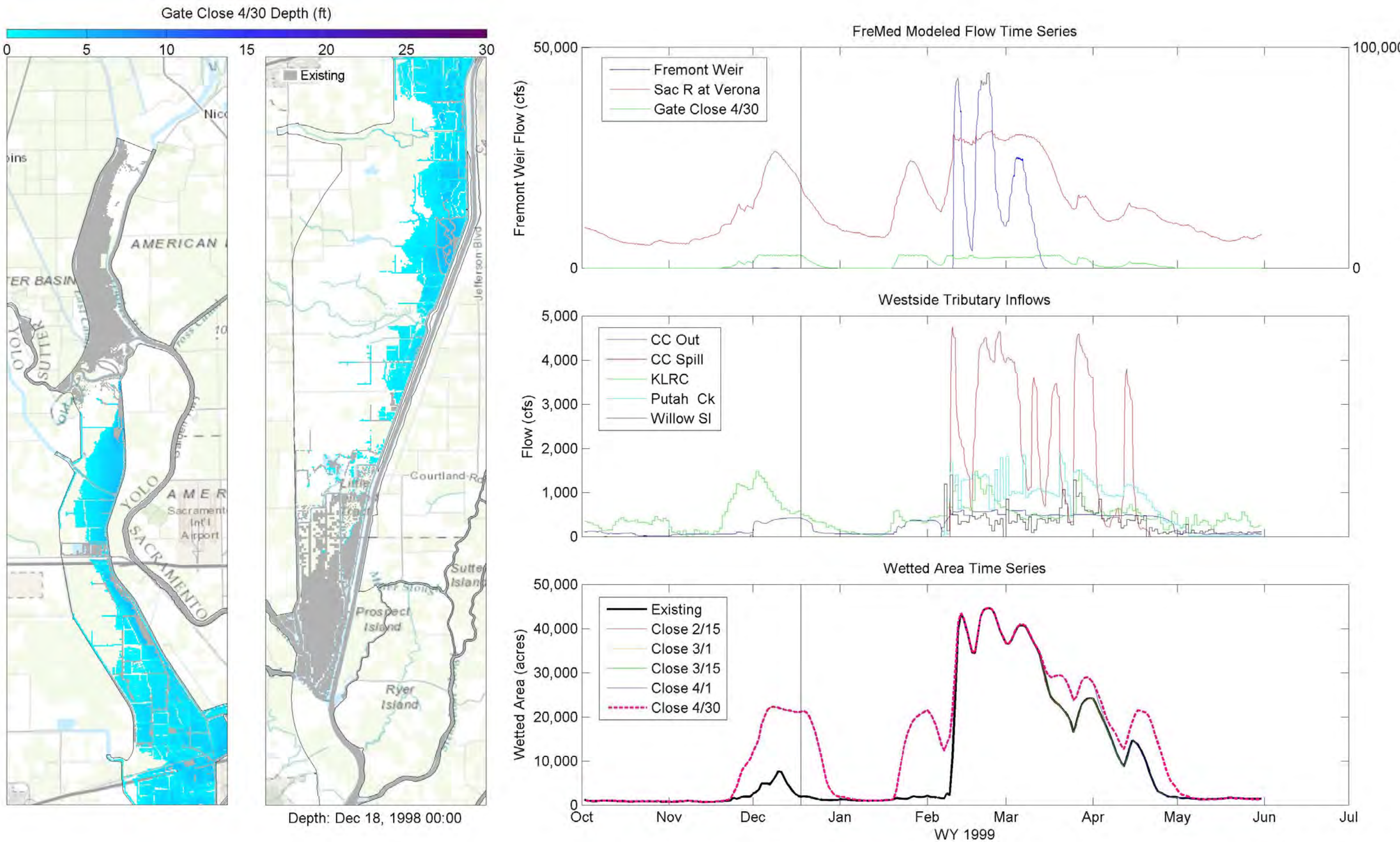
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1998 for FreMed

Prepared for DWR	Created By: SJB	**Figure E18**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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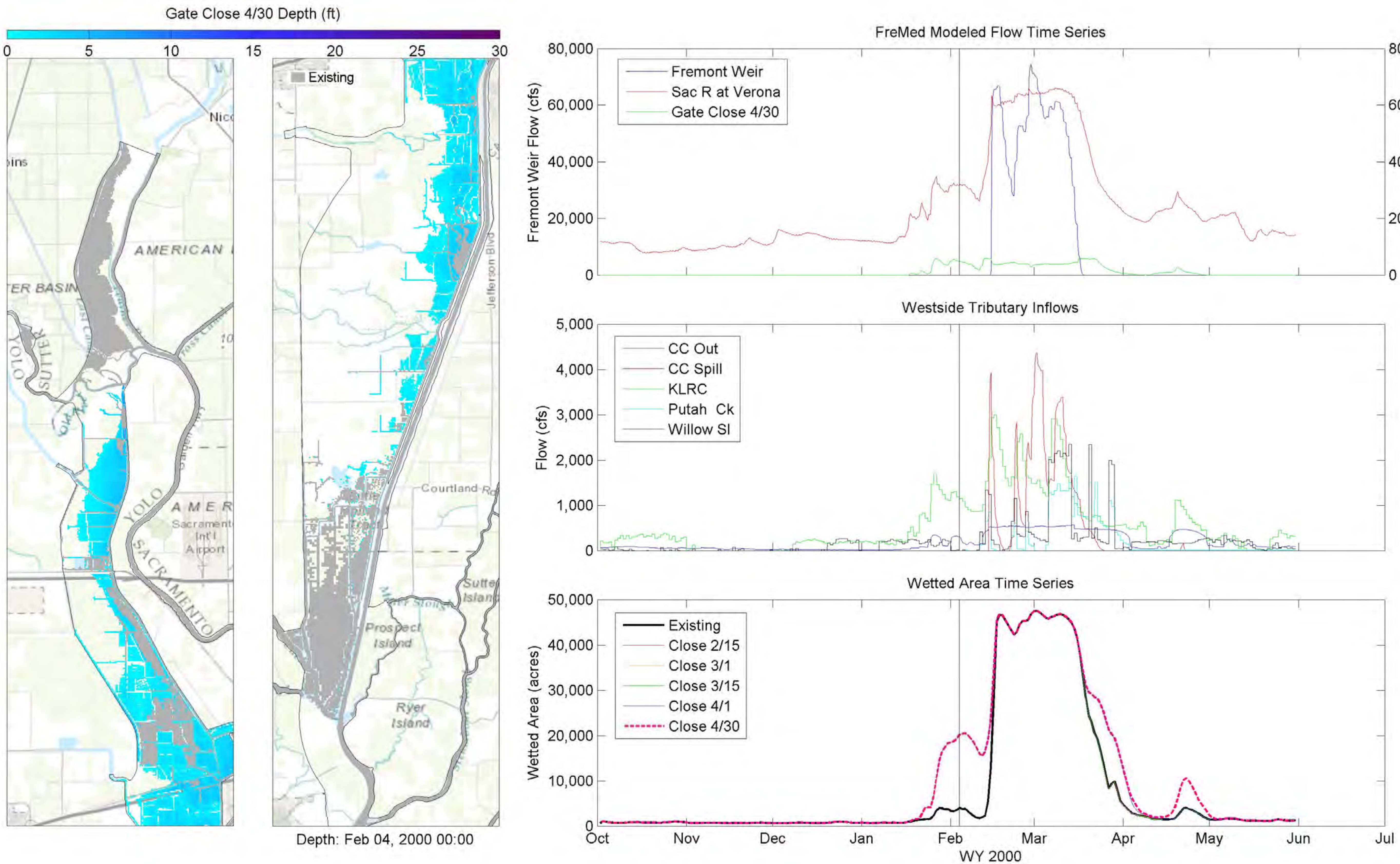
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1999 for FreMed

Prepared for DWR	Created By: SJB	**Figure E19**

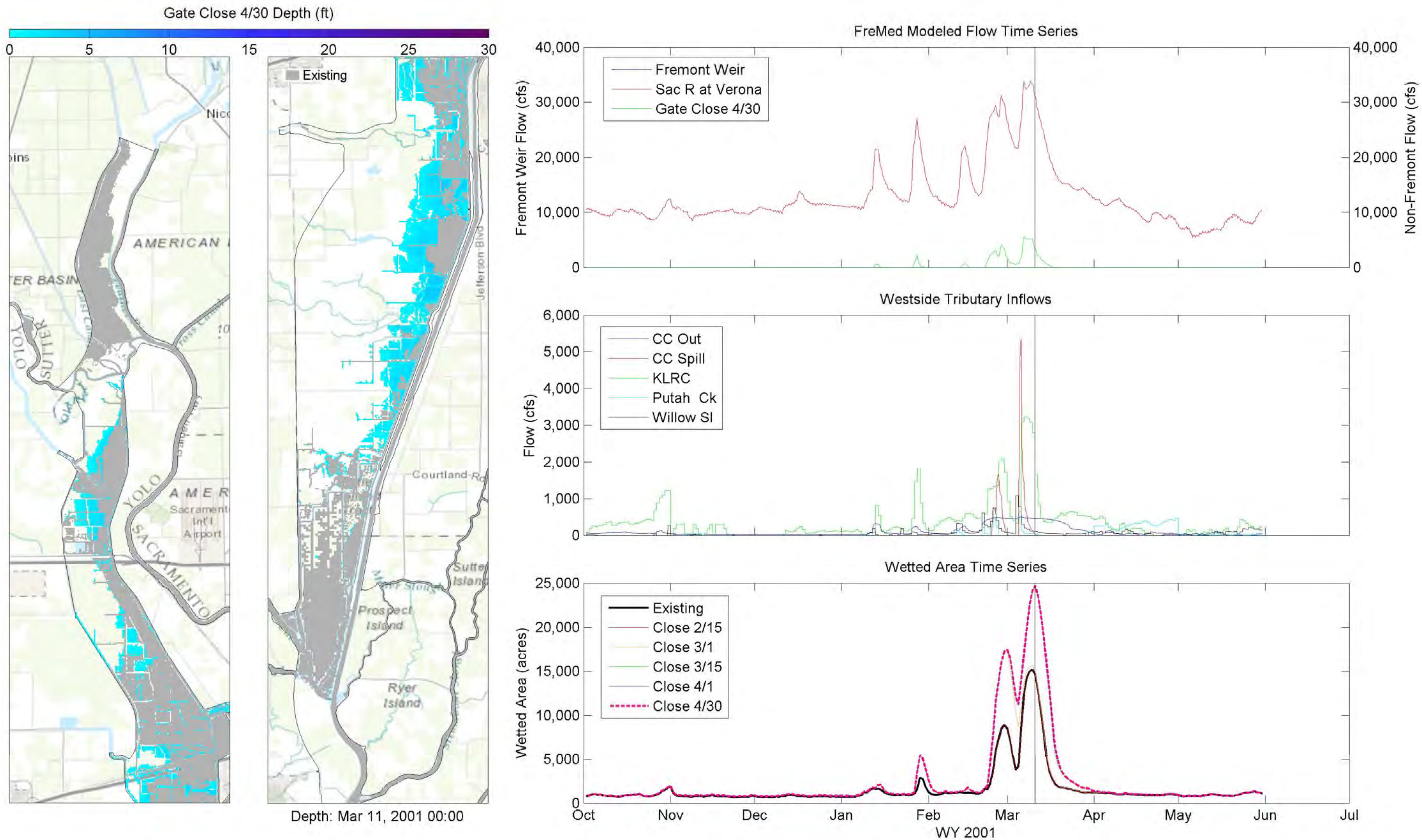


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2000 for FreMed

Prepared for DWR | Created By: SJB | **Figure E20**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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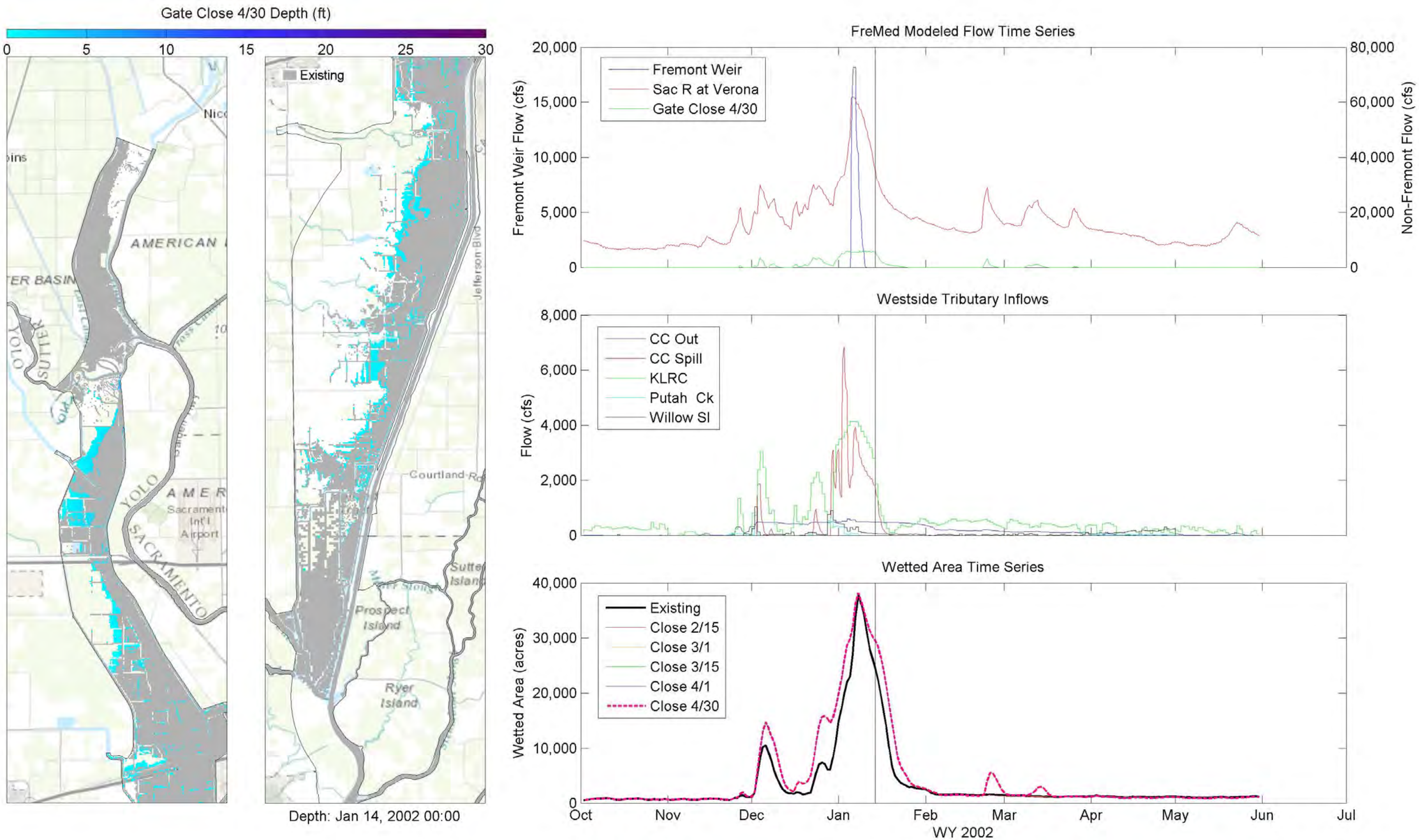
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2001 for FreMed

Prepared for DWR	Created By: SJB	**Figure E21**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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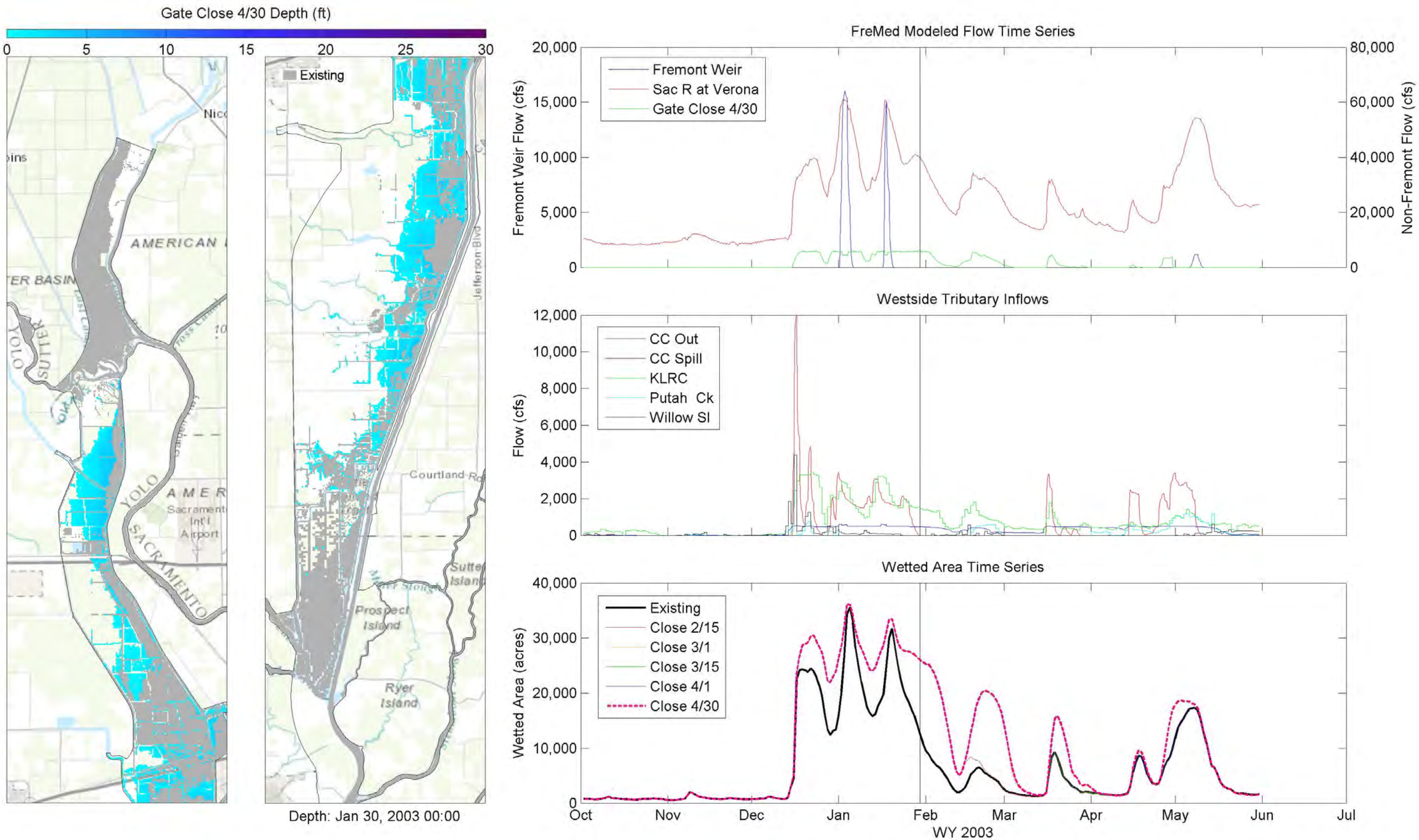
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2002 for FreMed

Prepared for DWR | Created By: SJB | **Figure E22**

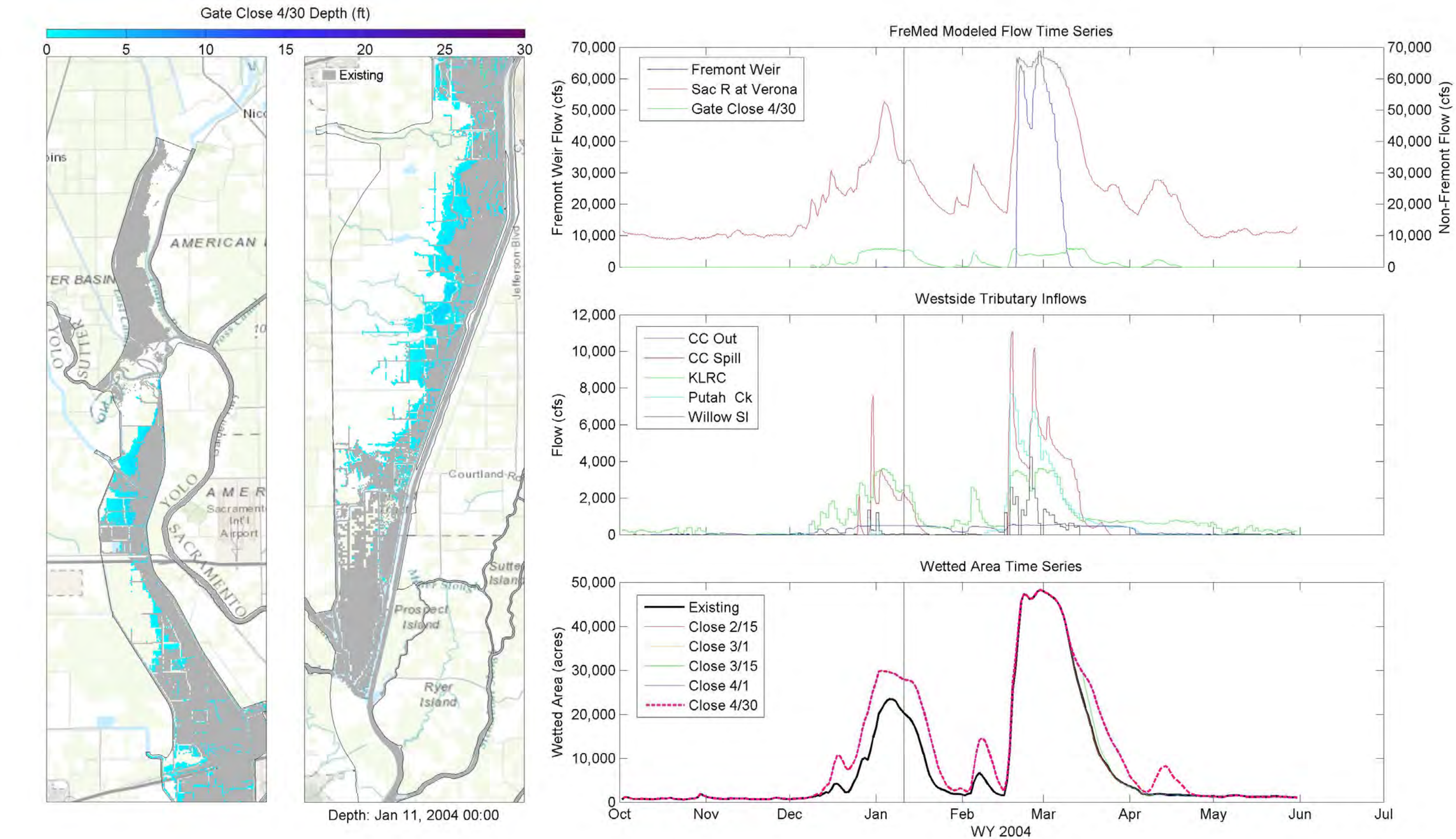


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2003 for FreMed

Prepared for DWR | Created By: SJB | **Figure E23**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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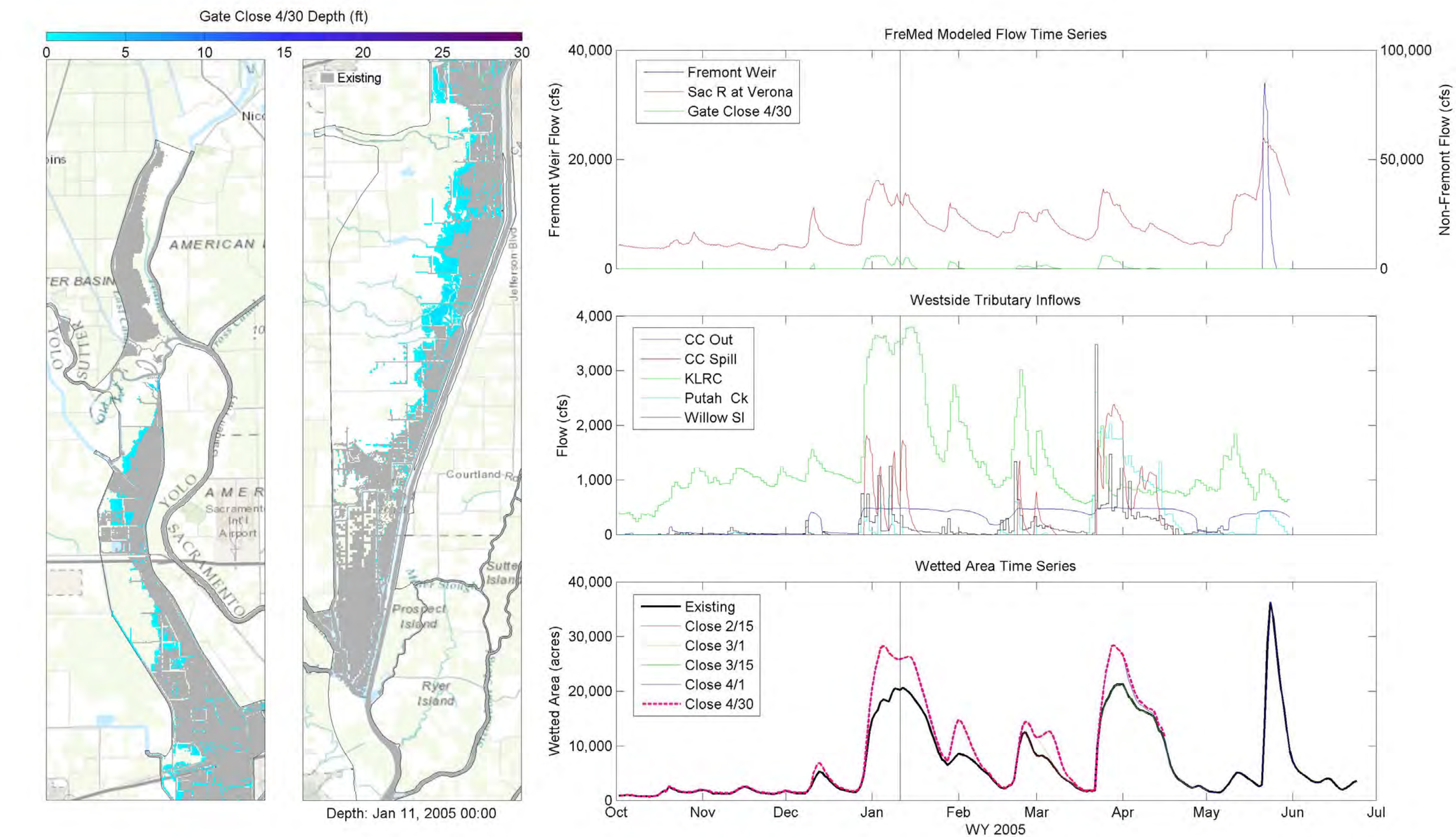
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2004 for FreMed

Prepared for DWR | Created By: SJB | **Figure E24**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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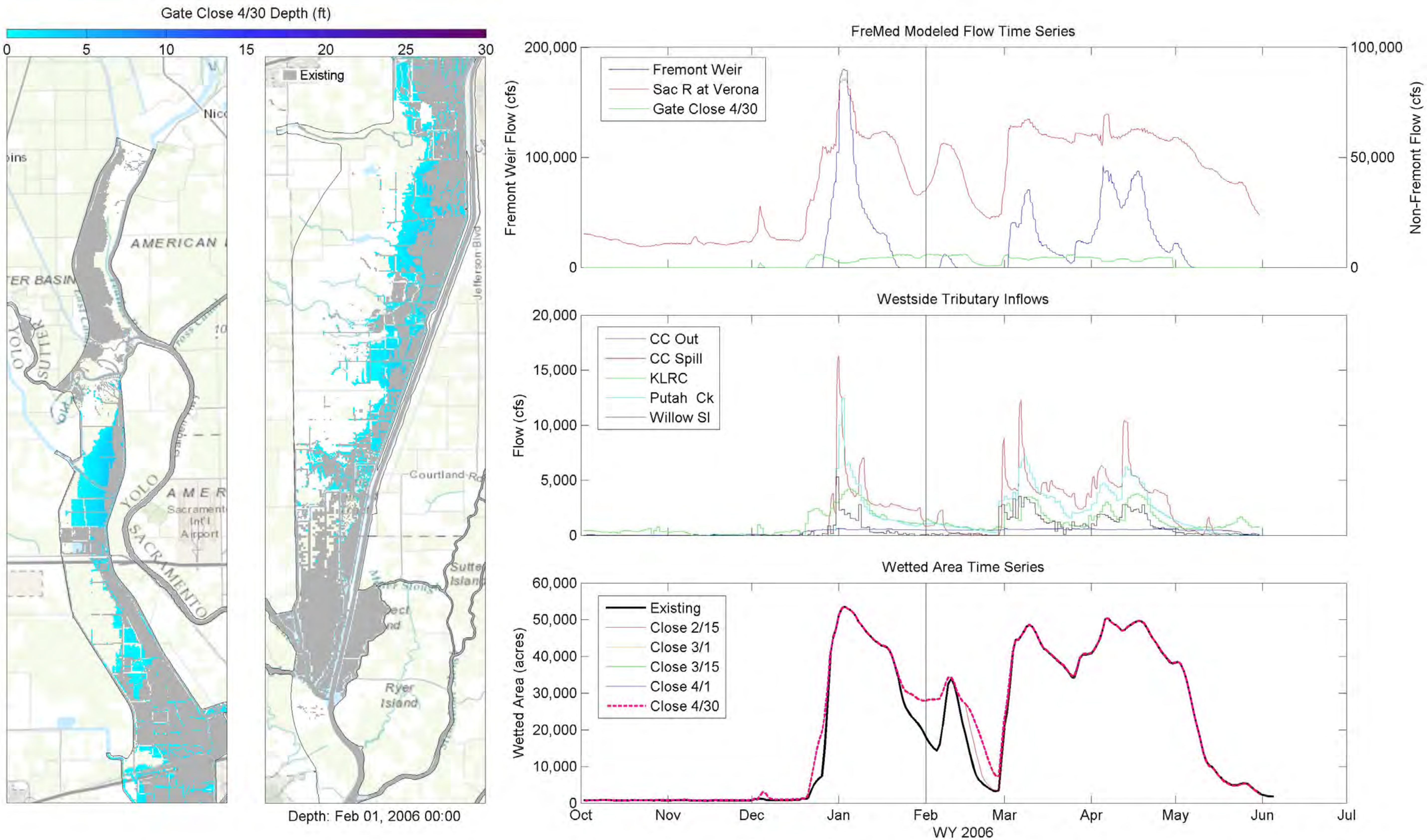
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2005 for FreMed

Prepared for DWR | Created By: SJB | **Figure E25**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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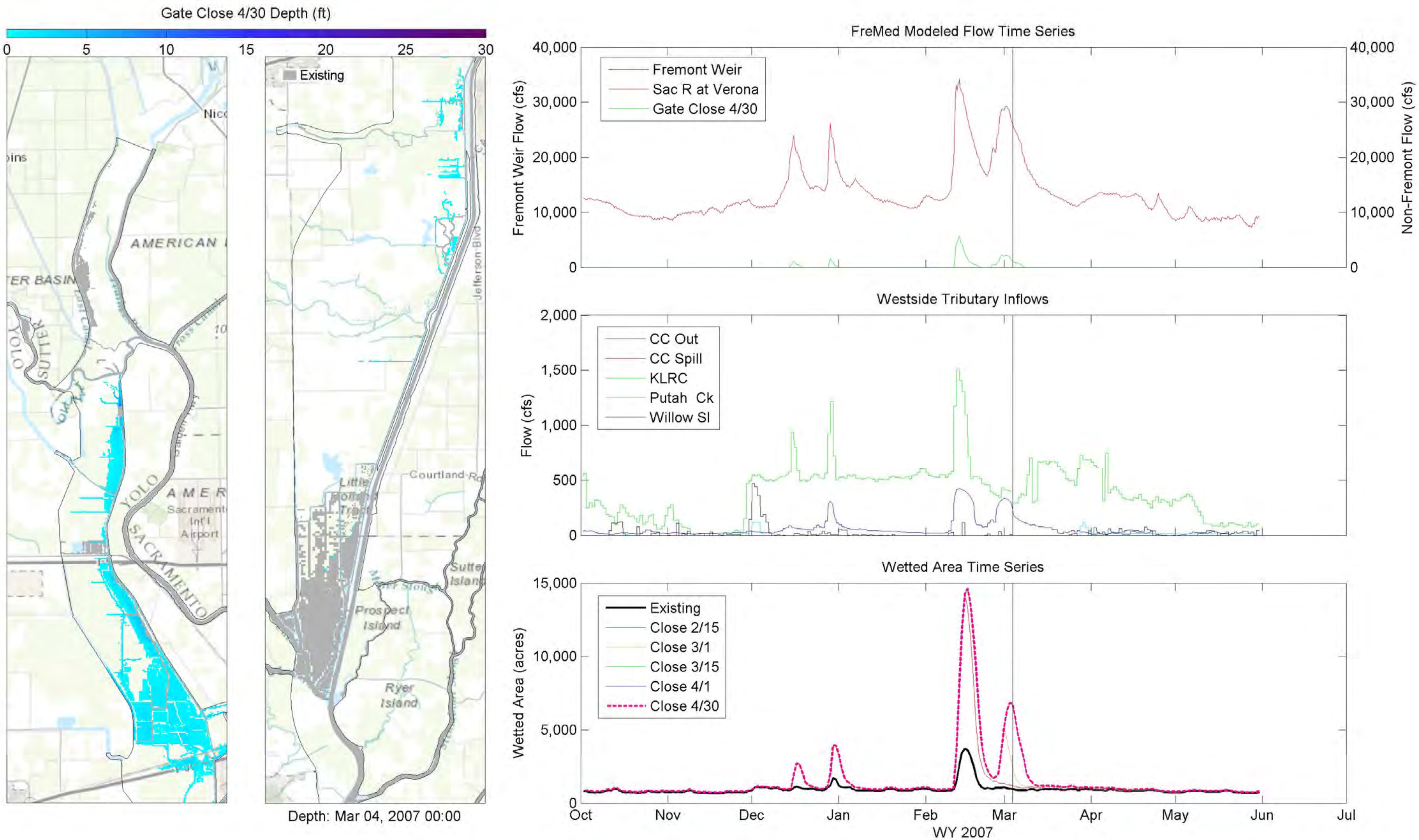
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2006 for FreMed

Prepared for DWR	Created By: SJB	**Figure E26**

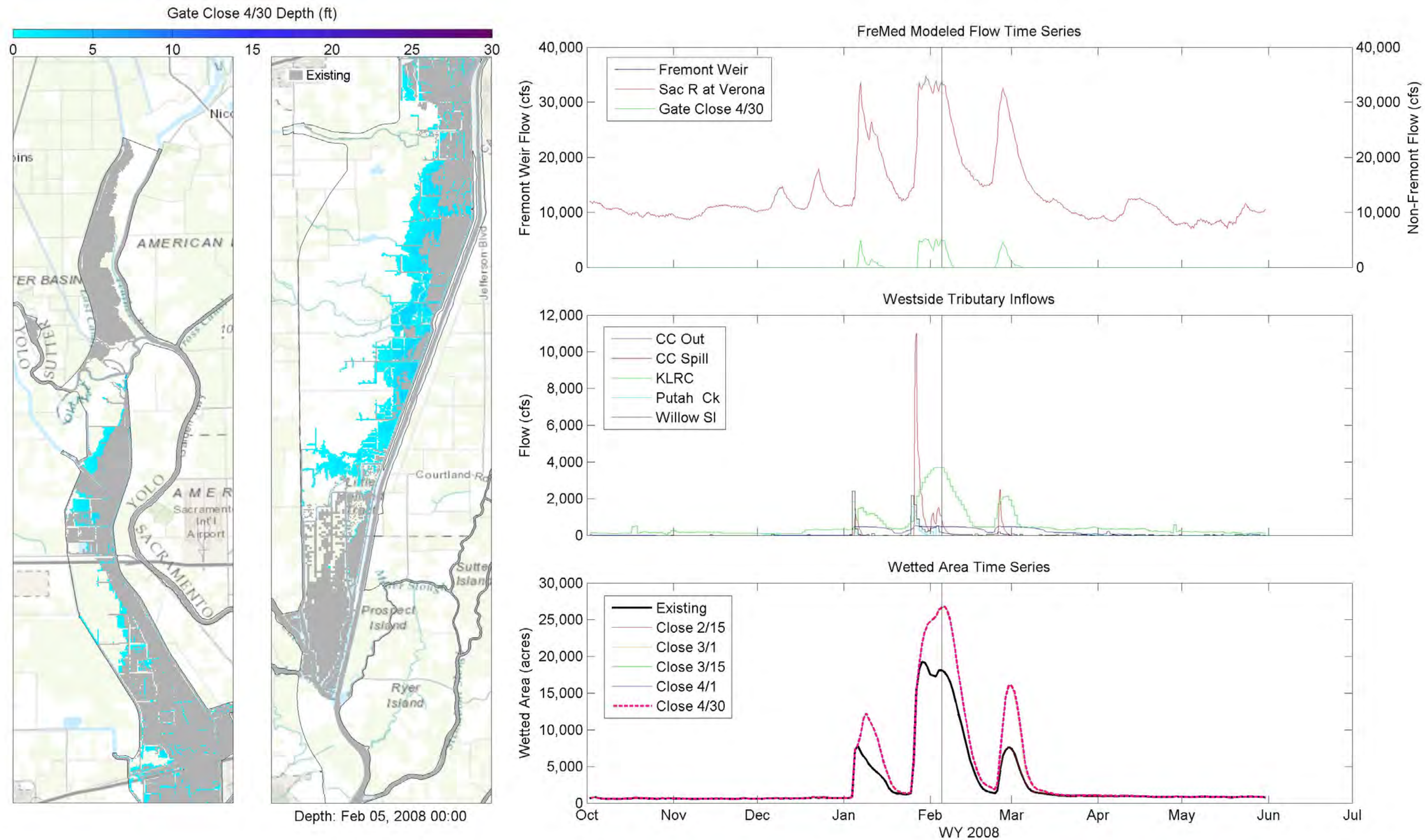


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2007 for FreMed

Prepared for DWR	Created By: SJB	**Figure E27**

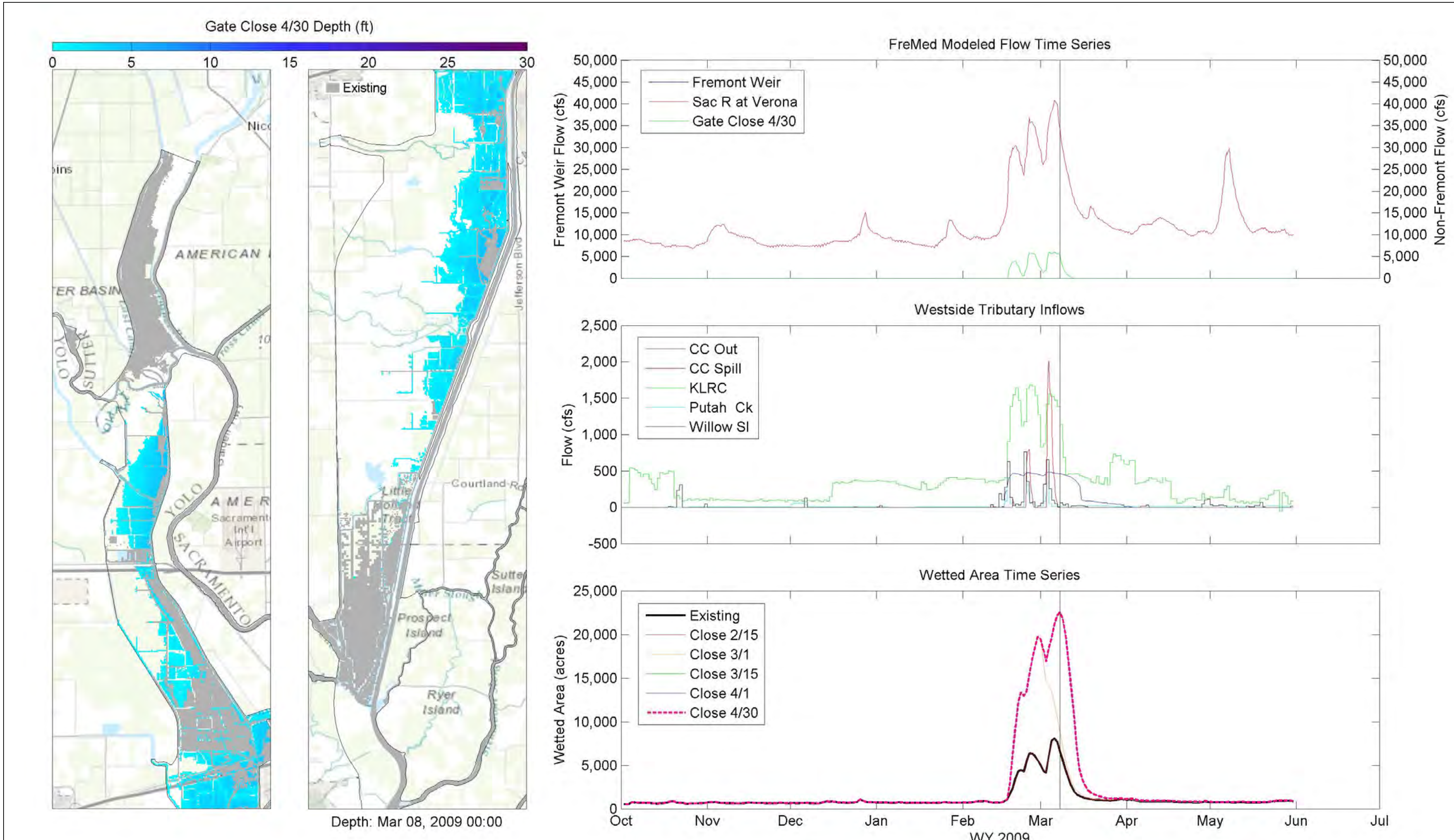


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2008 for FreMed

Prepared for DWR | Created By: SJB | **Figure E28**

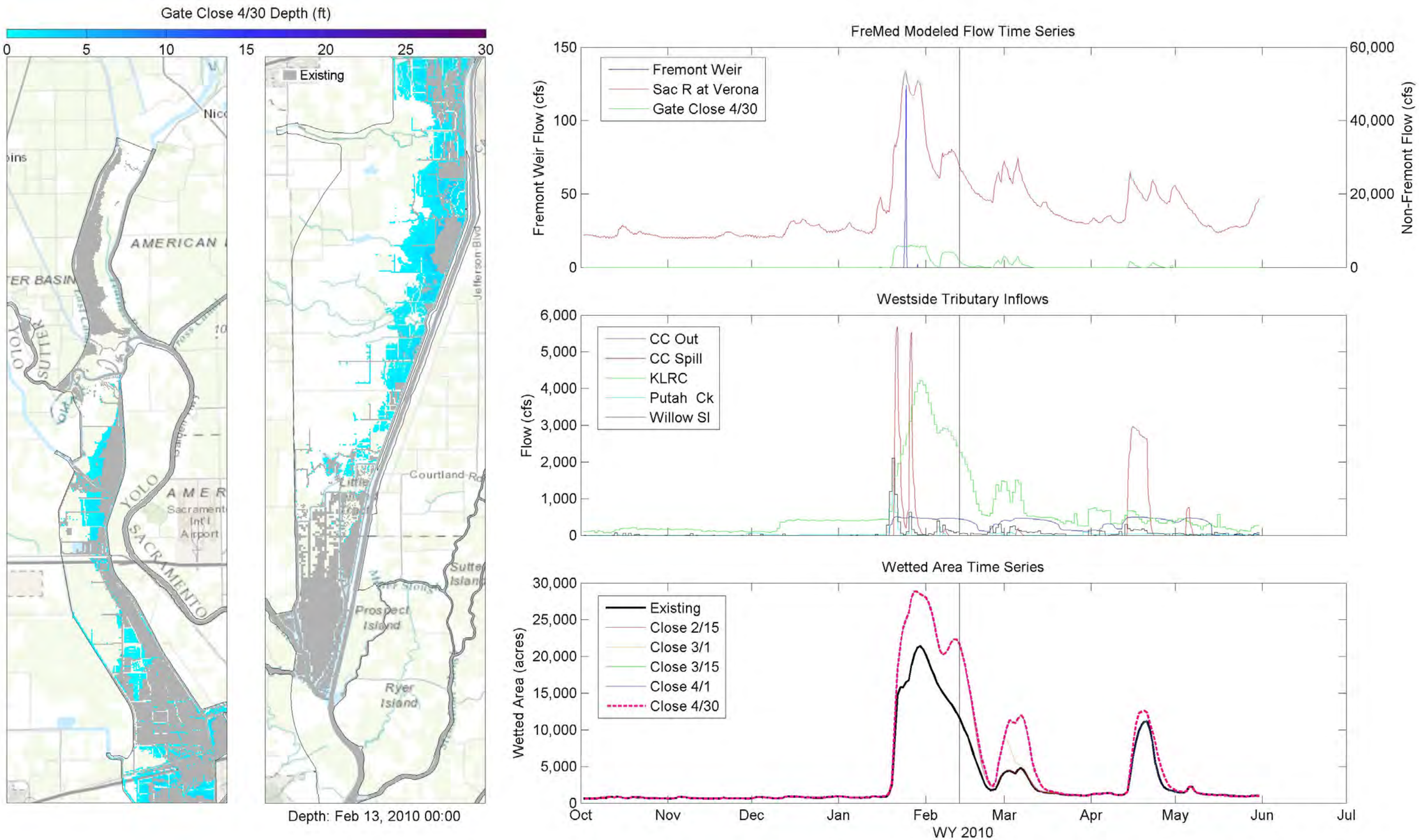


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2009 for FreMed

Prepared for DWR | Created By: SJB | **Figure E29**

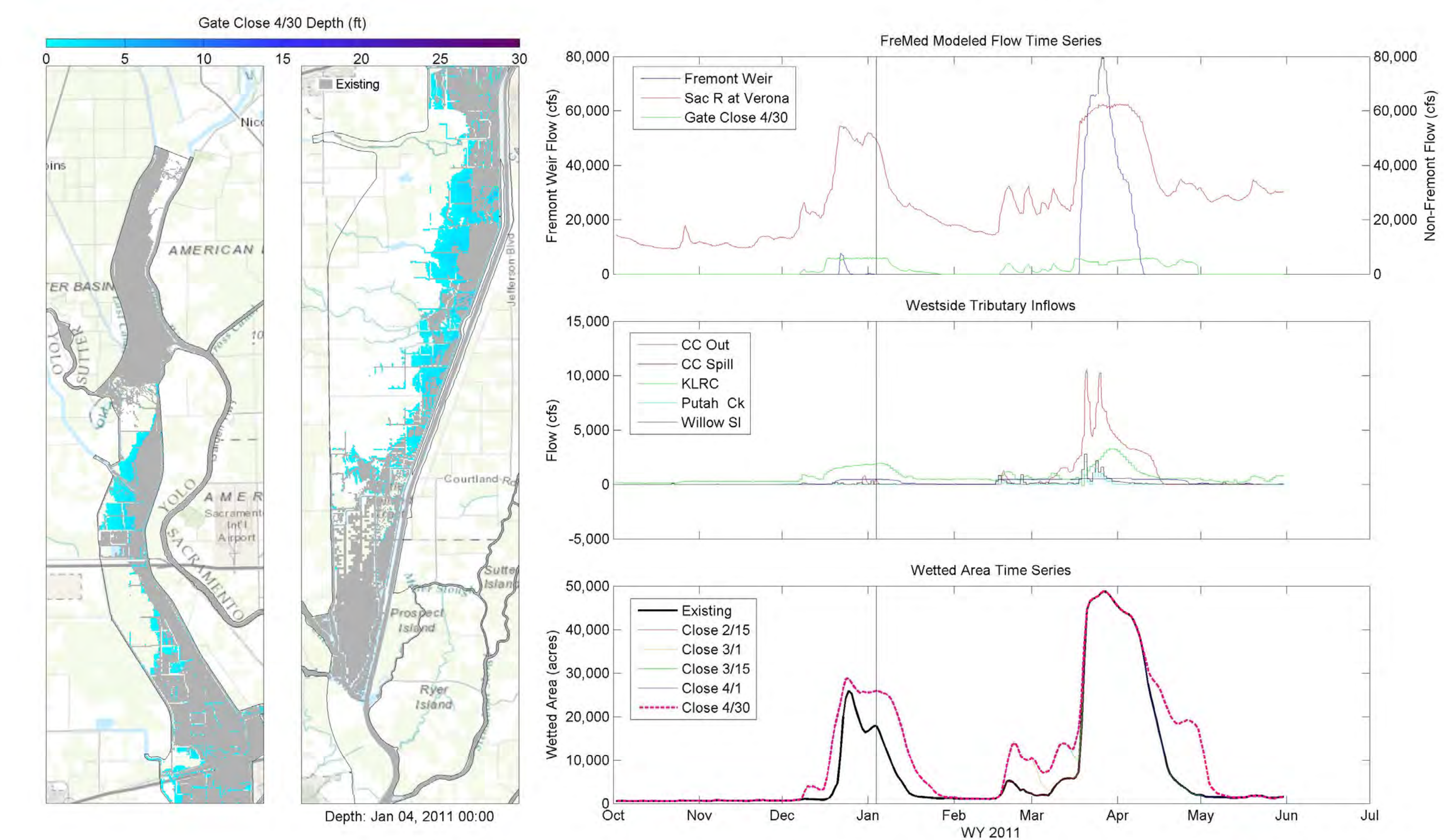


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2010 for FreMed

Prepared for DWR | Created By: SJB | **Figure E30**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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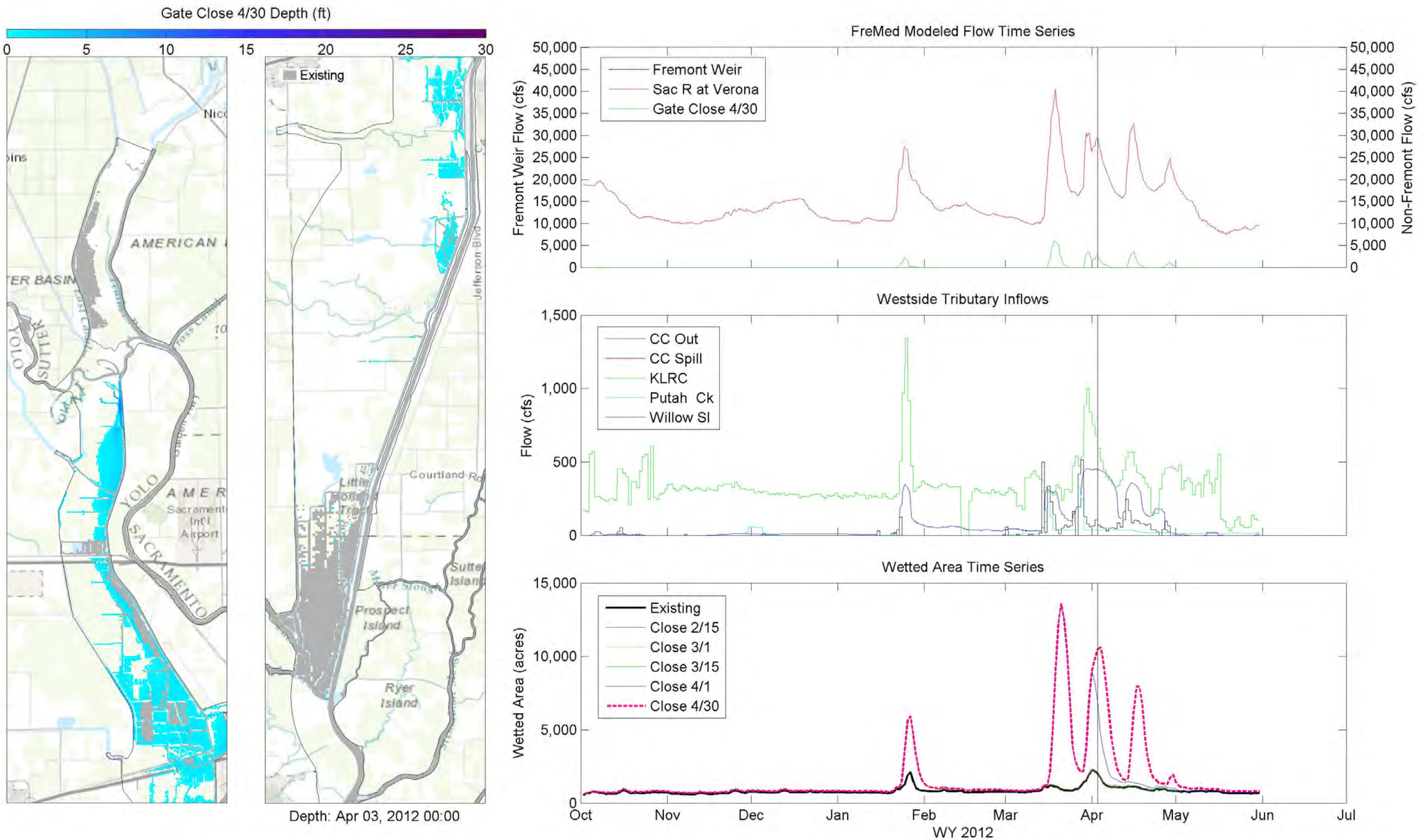
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2011 for FreMed

Prepared for DWR	Created By: SJB	**Figure E31**

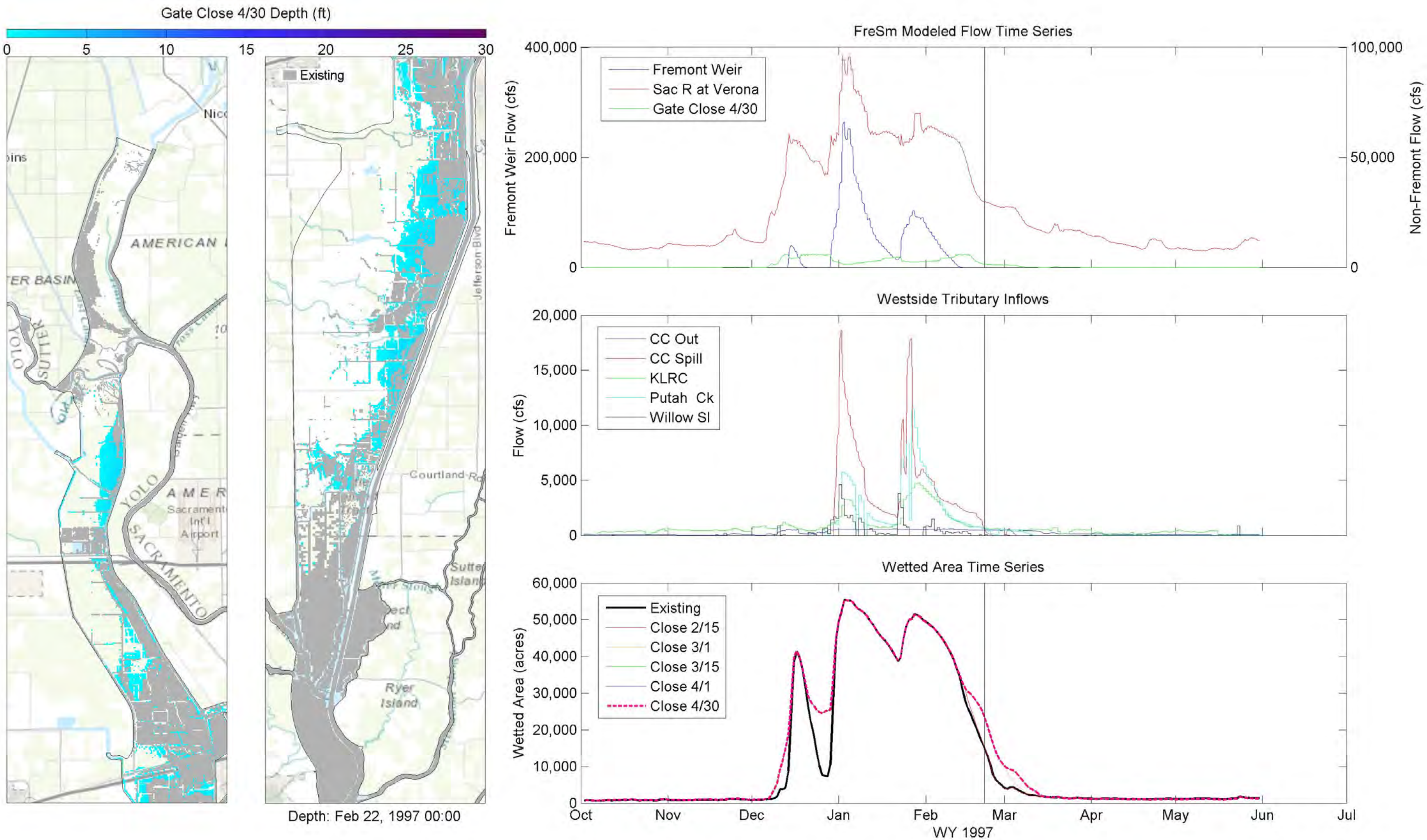


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2012 for FreMed

Prepared for DWR | Created By: SJB | **Figure E32**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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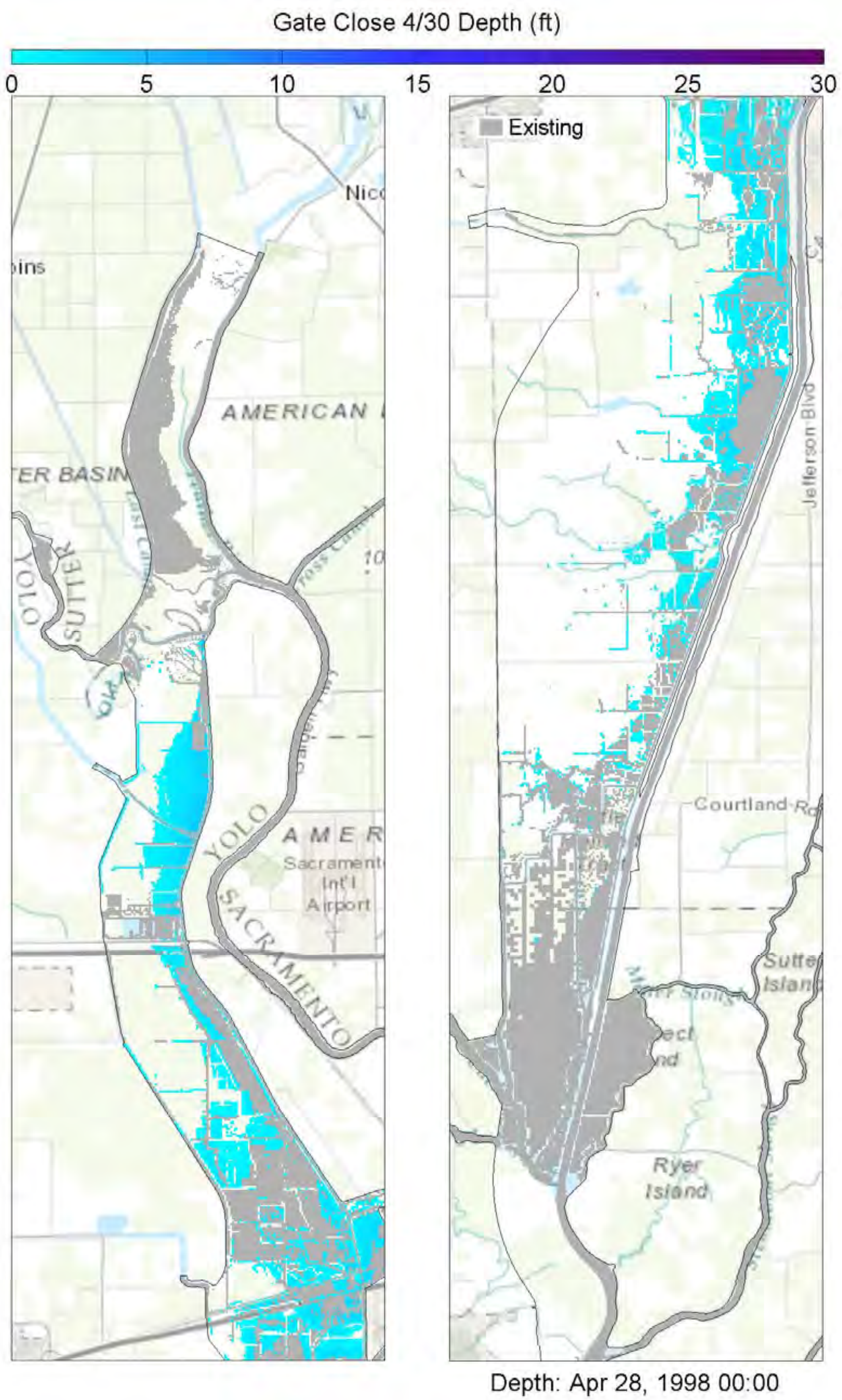
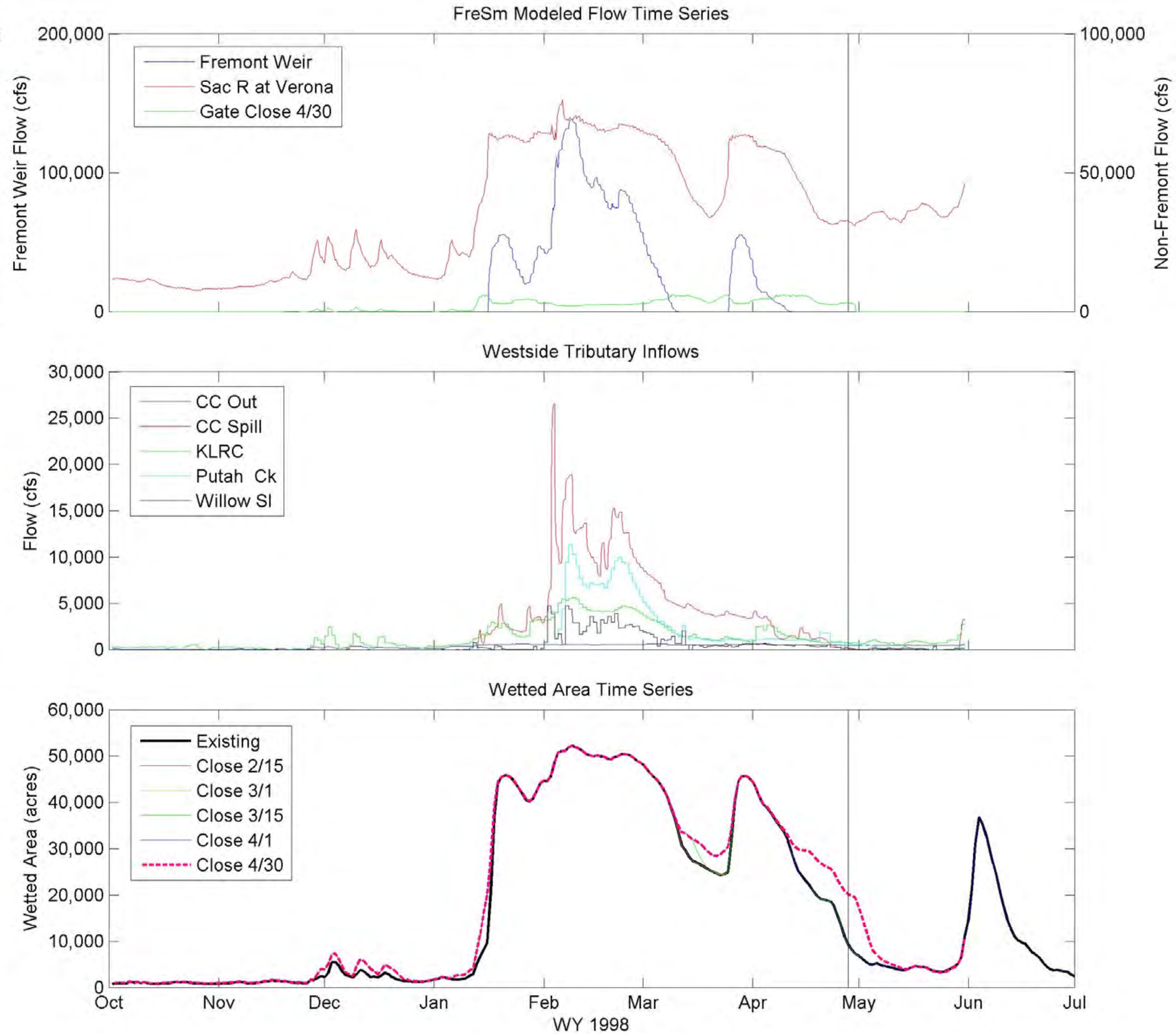
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1997 for FreSm

Prepared for DWR	Created By: SJB	**Figure E33**





Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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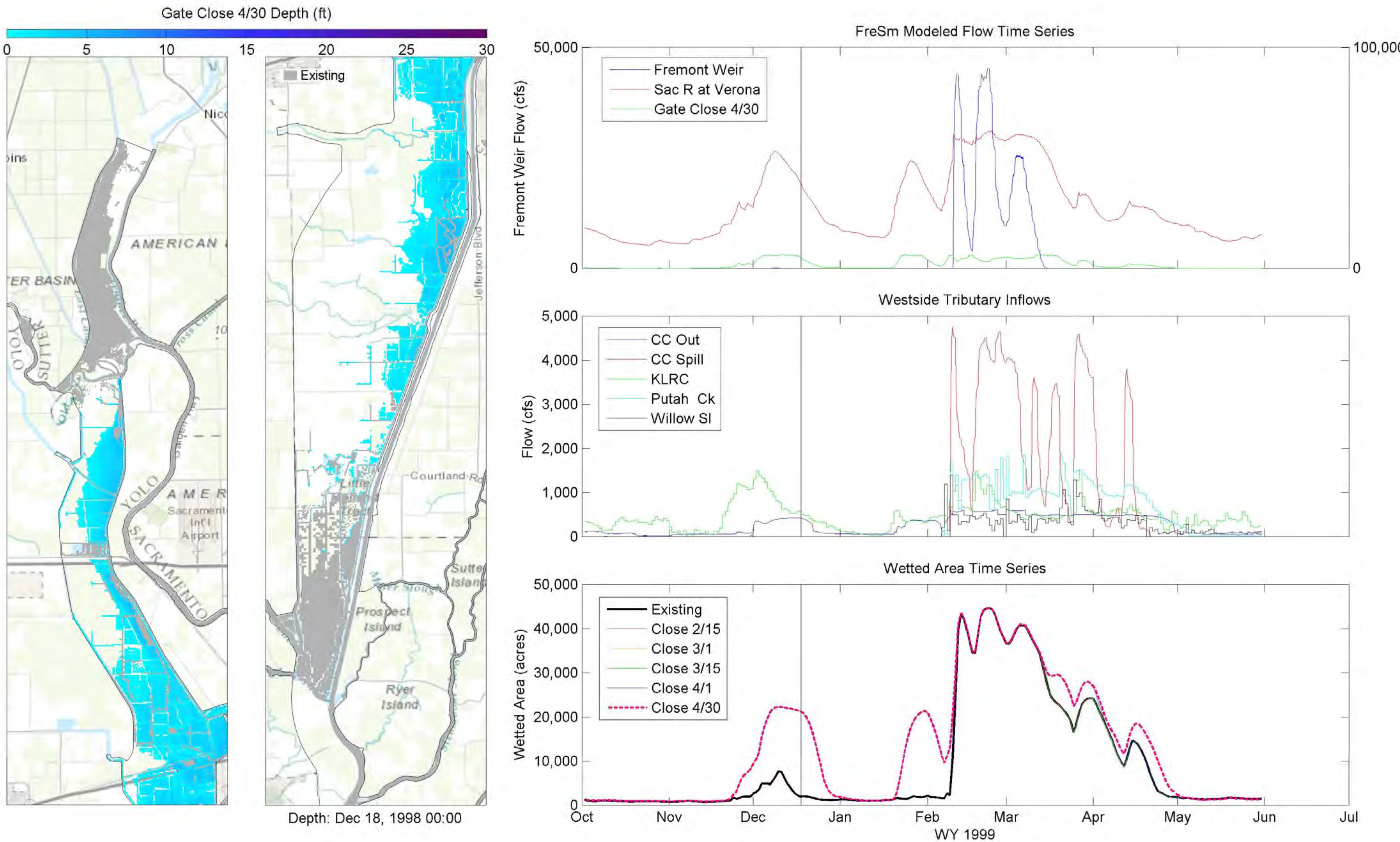
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1998 for FreSm

Prepared for DWR | Created By: SJB | **Figure E34**

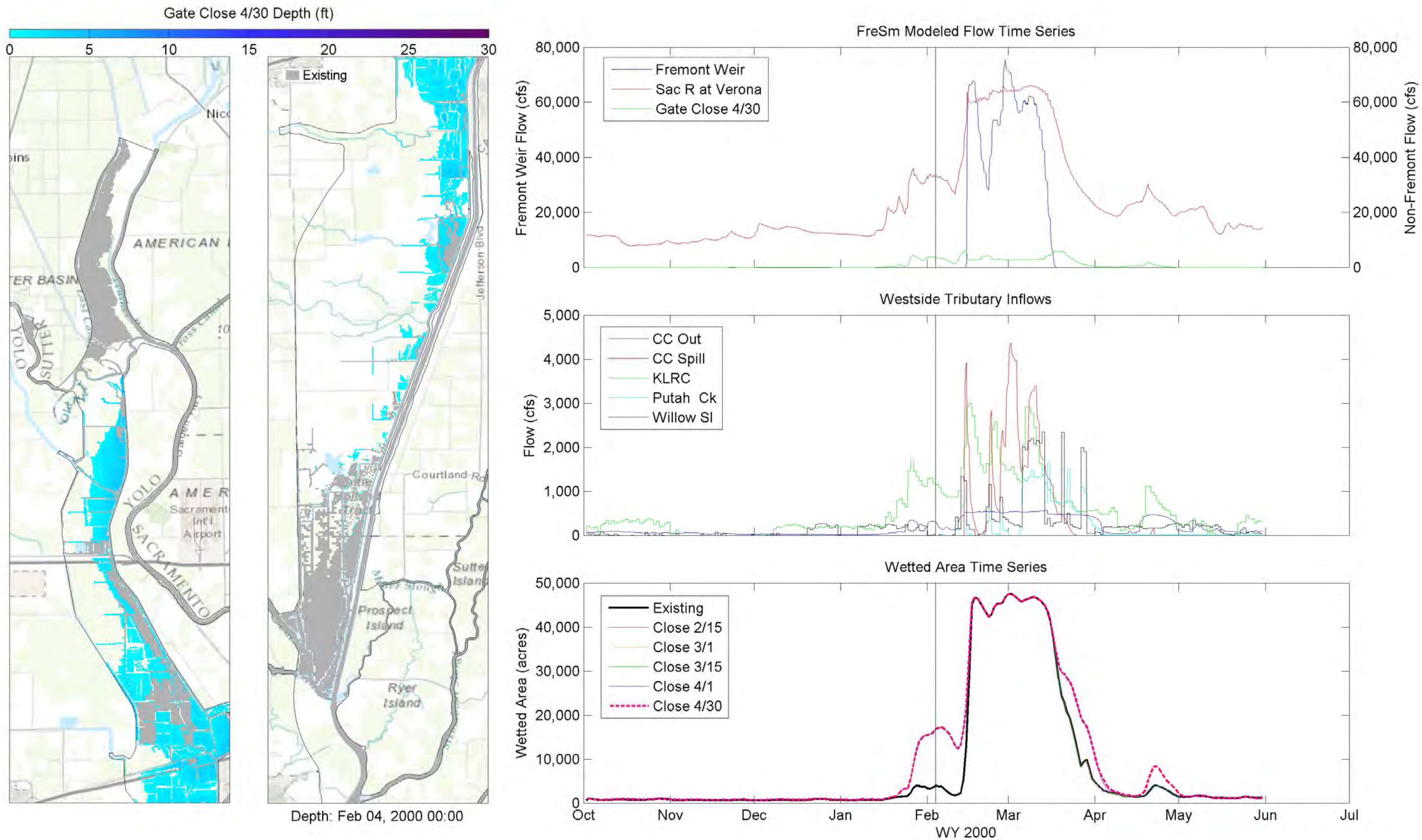


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1999 for FreSm

Prepared for DWR | Created By: SJB | **Figure E35**

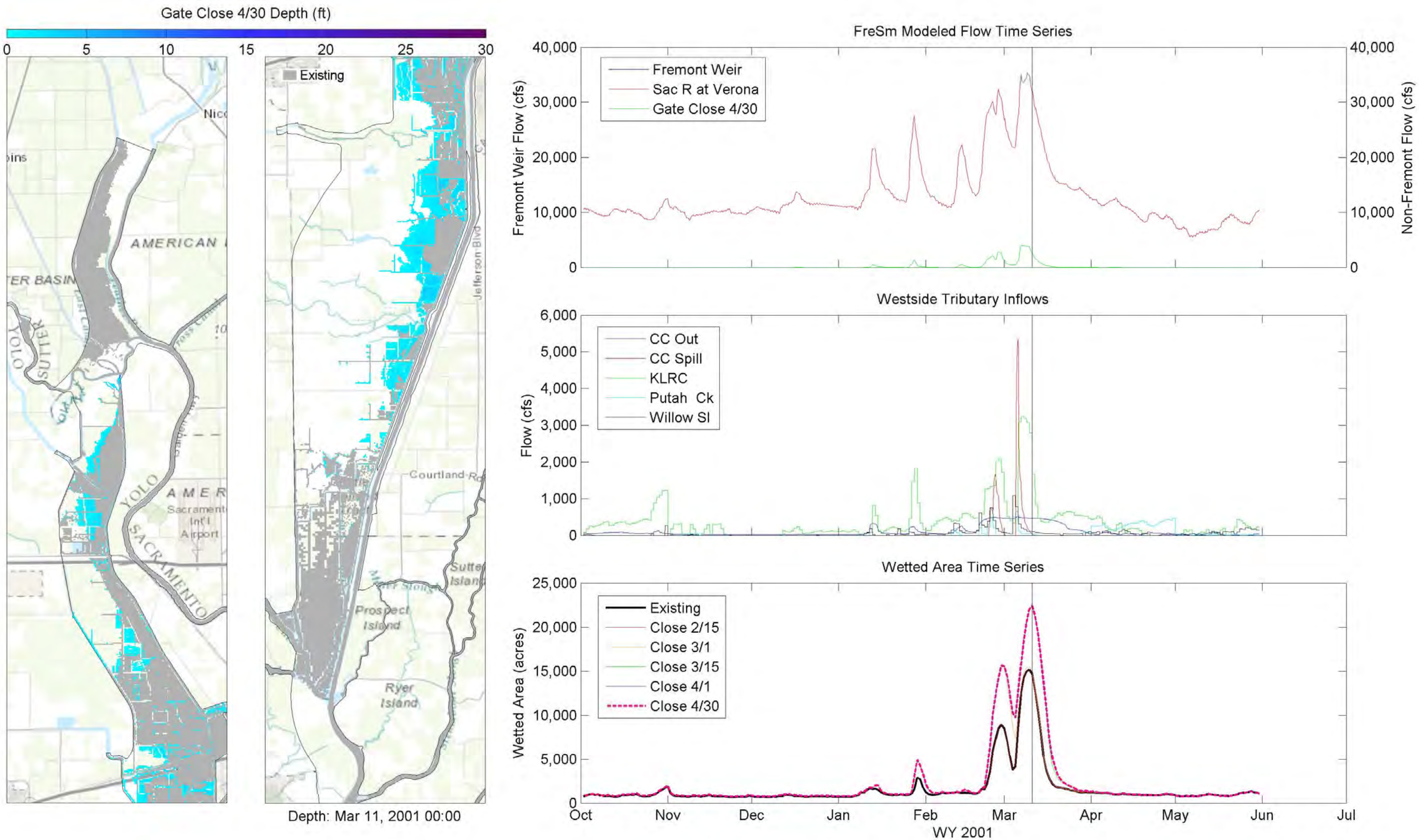


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2000 for FreSm

Prepared for DWR	Created By: SJB	**Figure E36**

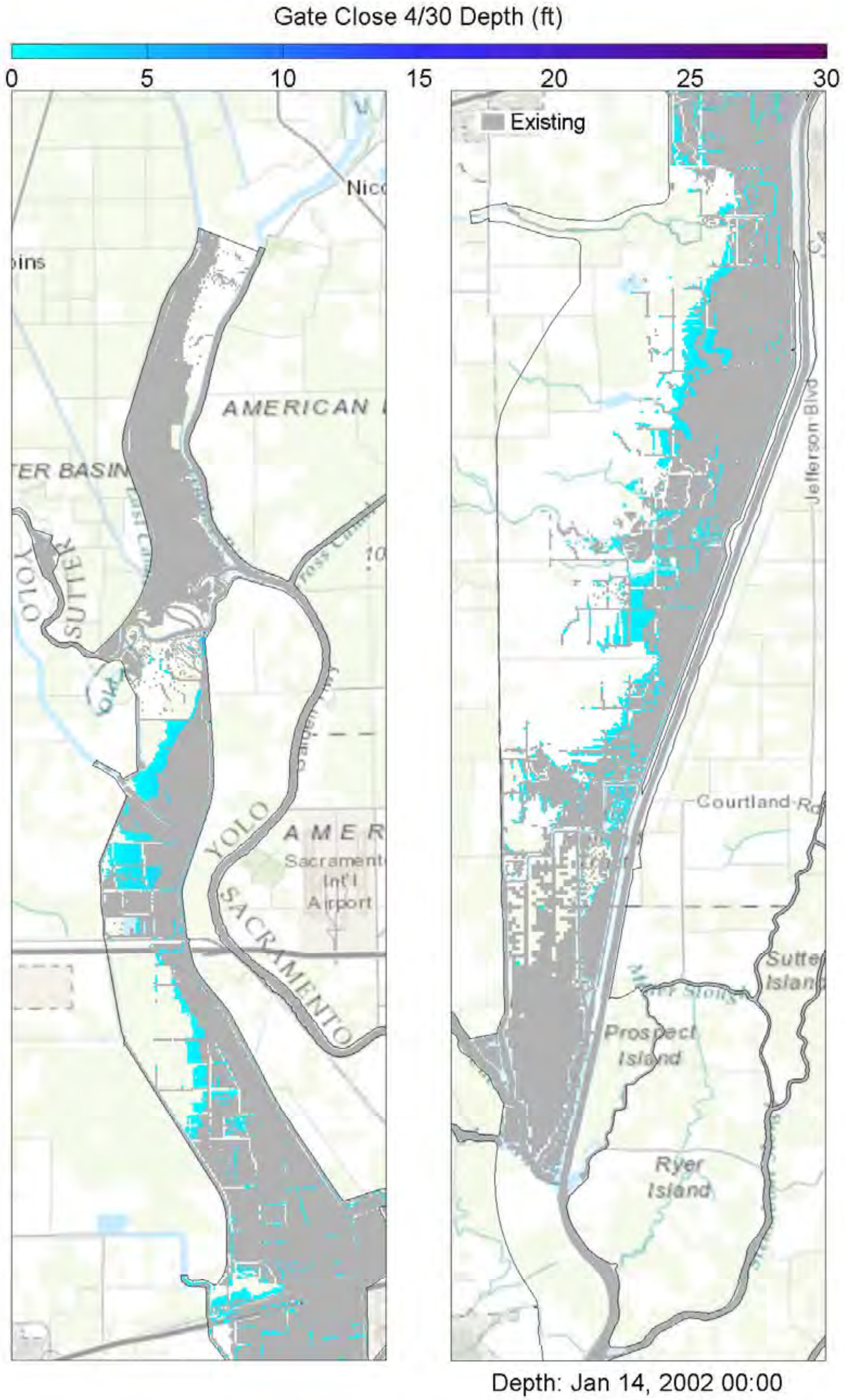


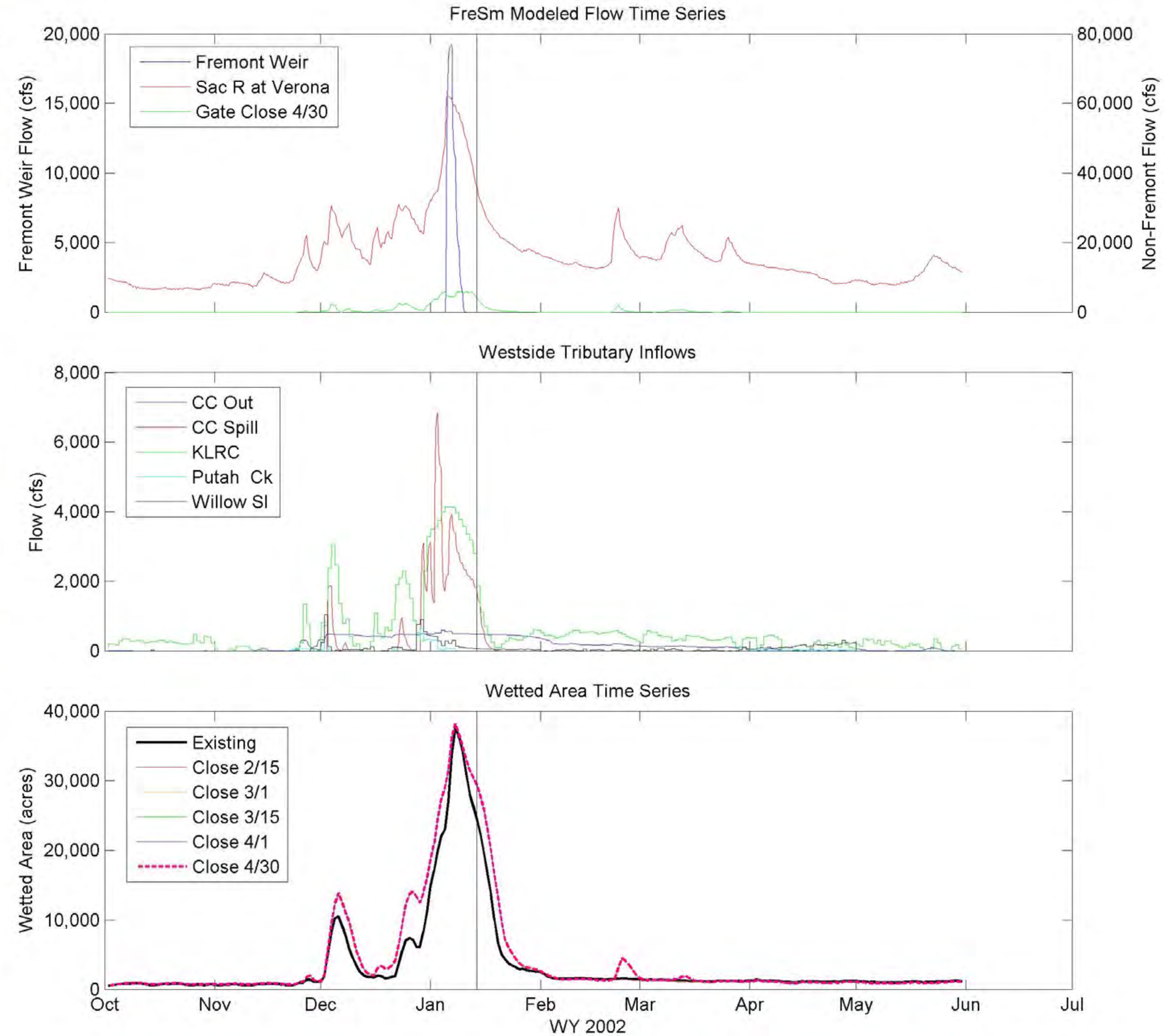
Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2001 for FreSm

Prepared for DWR | Created By: SJB | **Figure E37**





Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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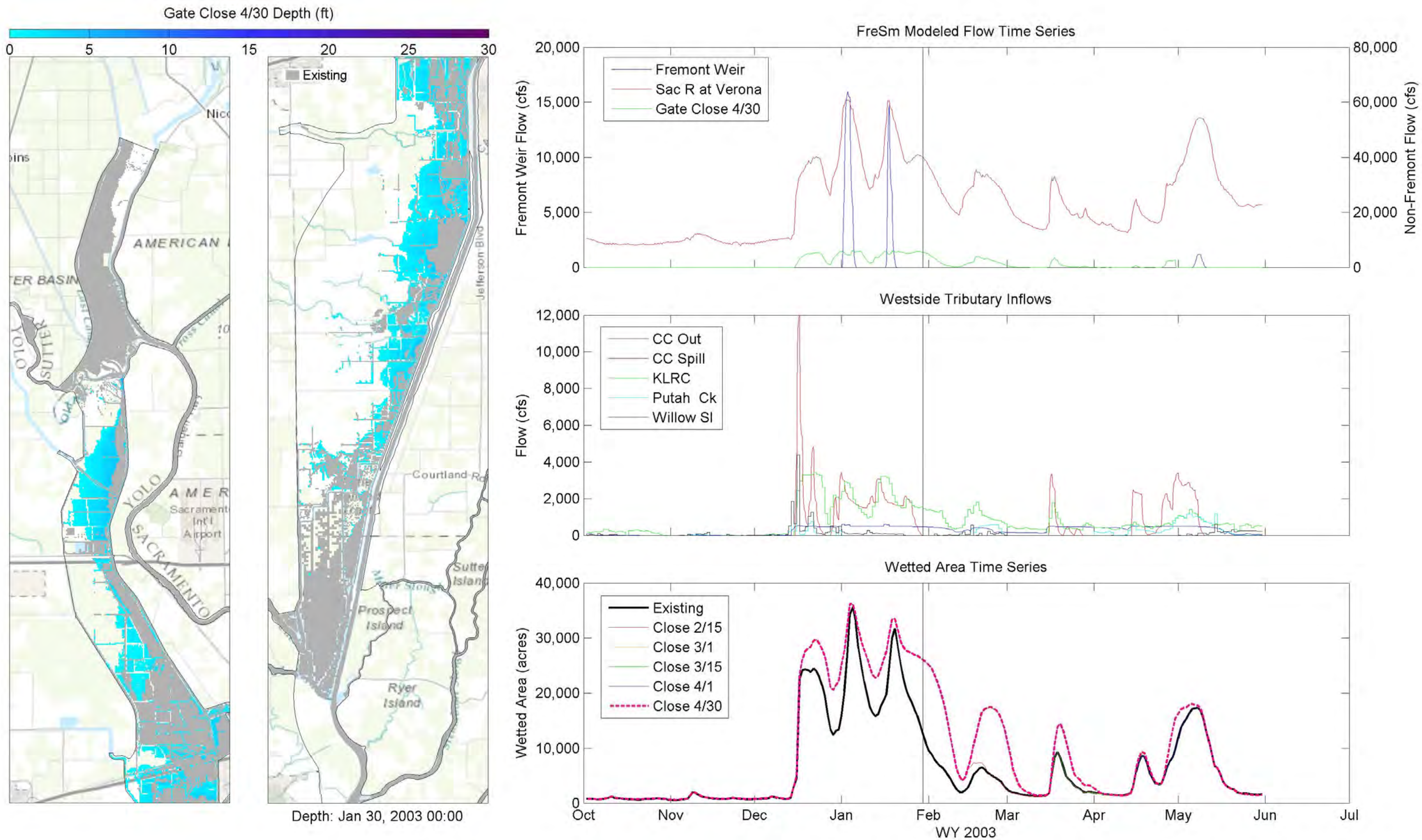
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2002 for FreSm

Prepared for DWR	Created By: SJB	**Figure E38**

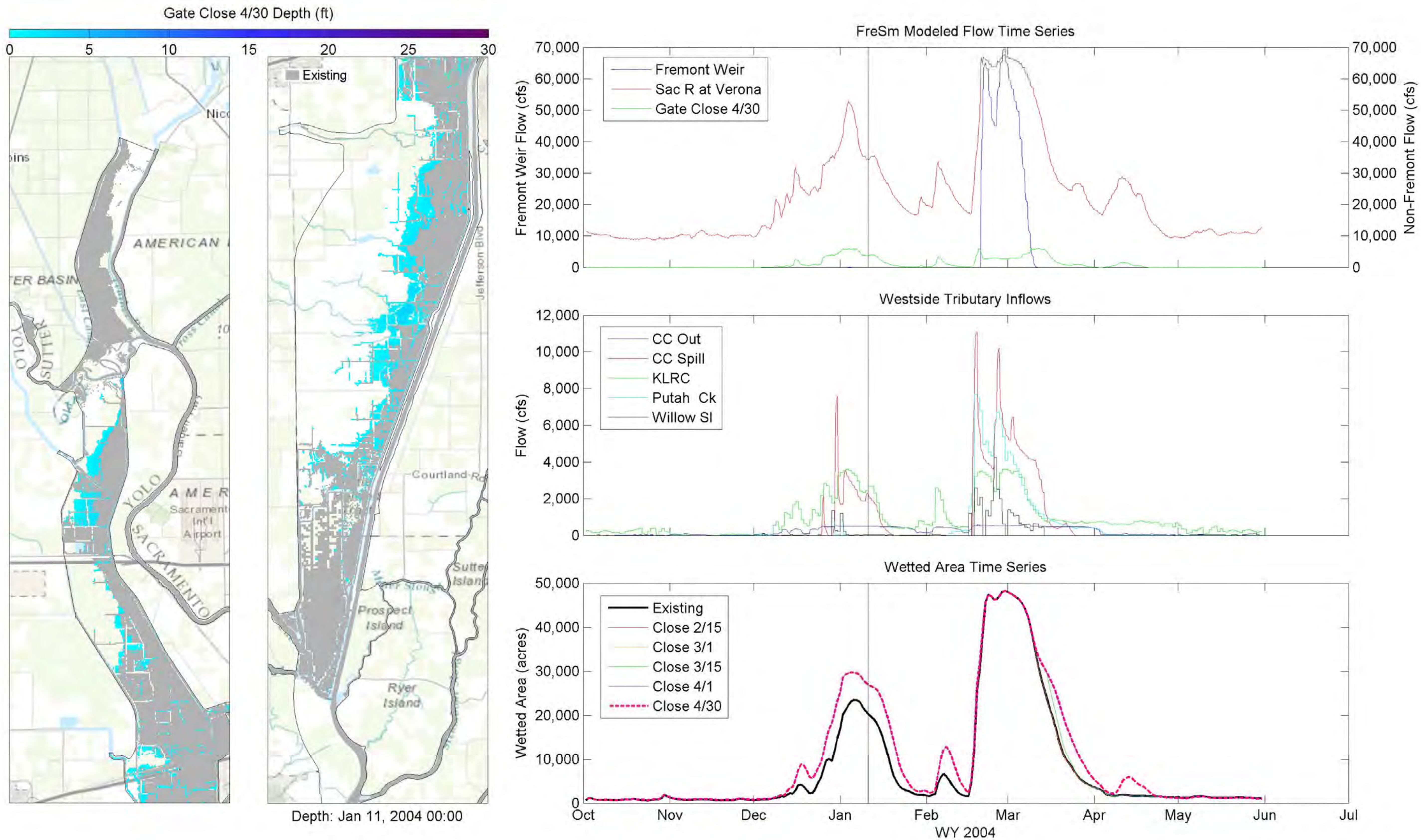


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2003 for FreSm

Prepared for DWR | Created By: SJB | **Figure E39**

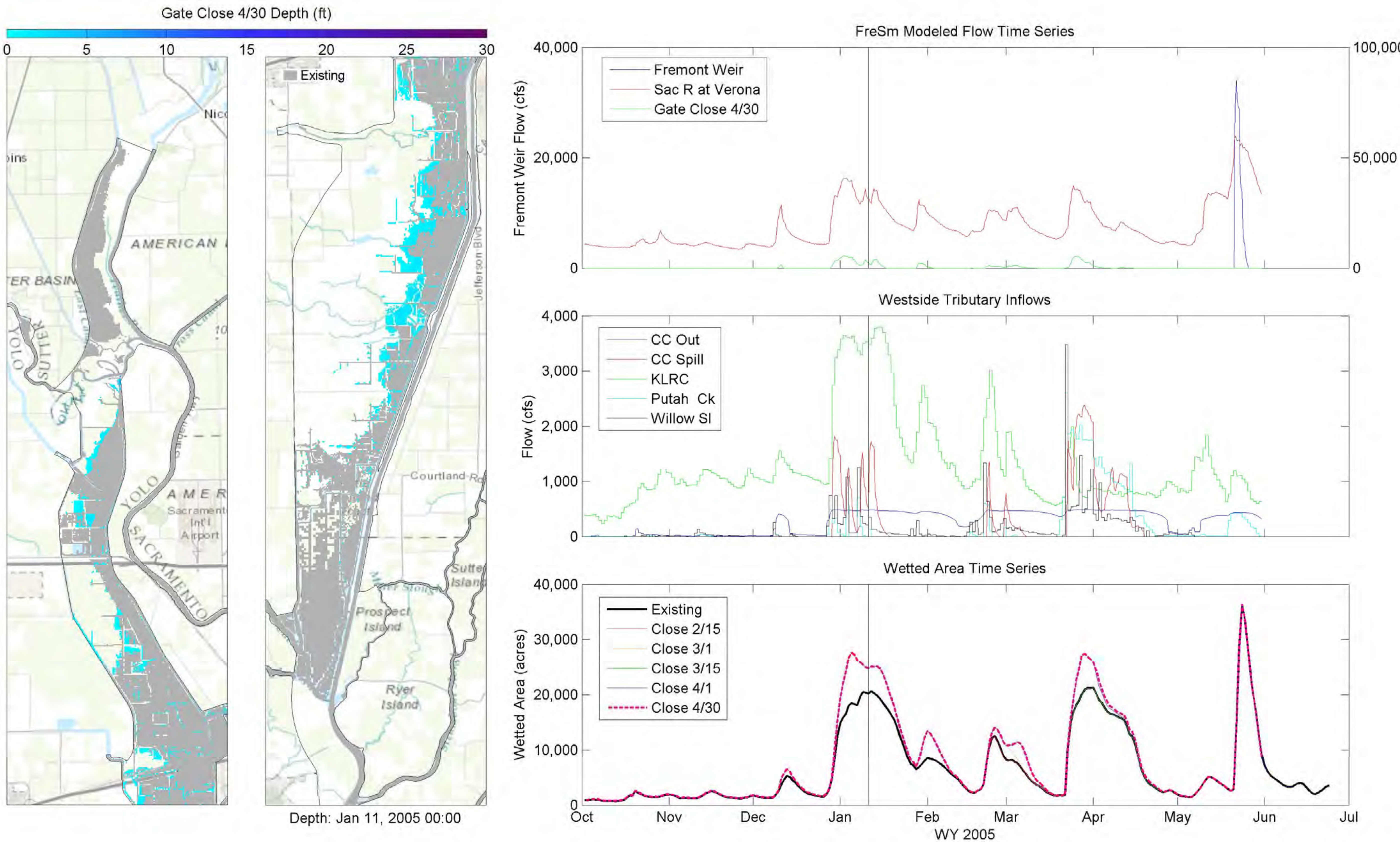


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2004 for FreSm

Prepared for DWR | Created By: SJB | **Figure E40**

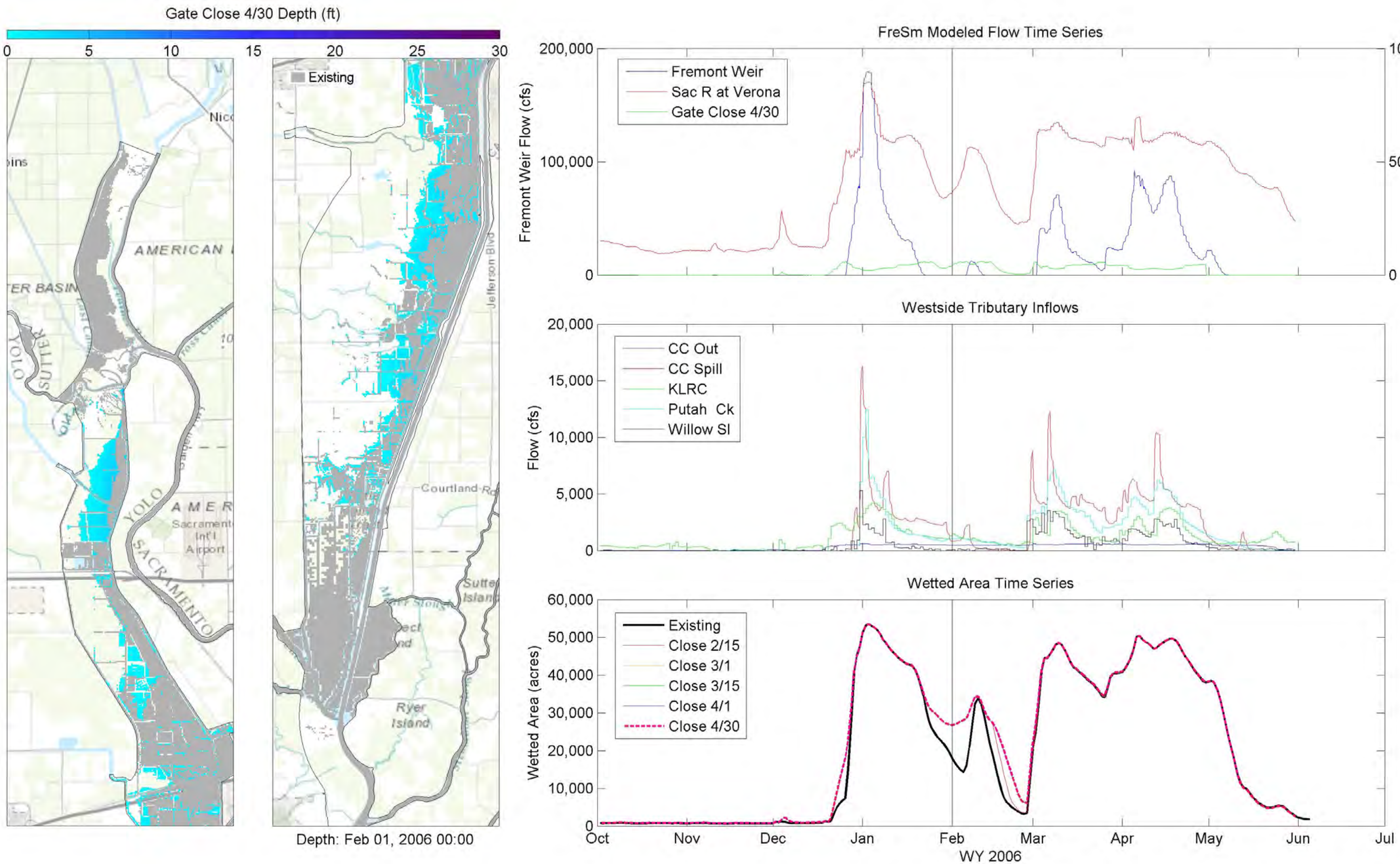


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2005 for FreSm

Prepared for DWR | Created By: SJB | **Figure E41**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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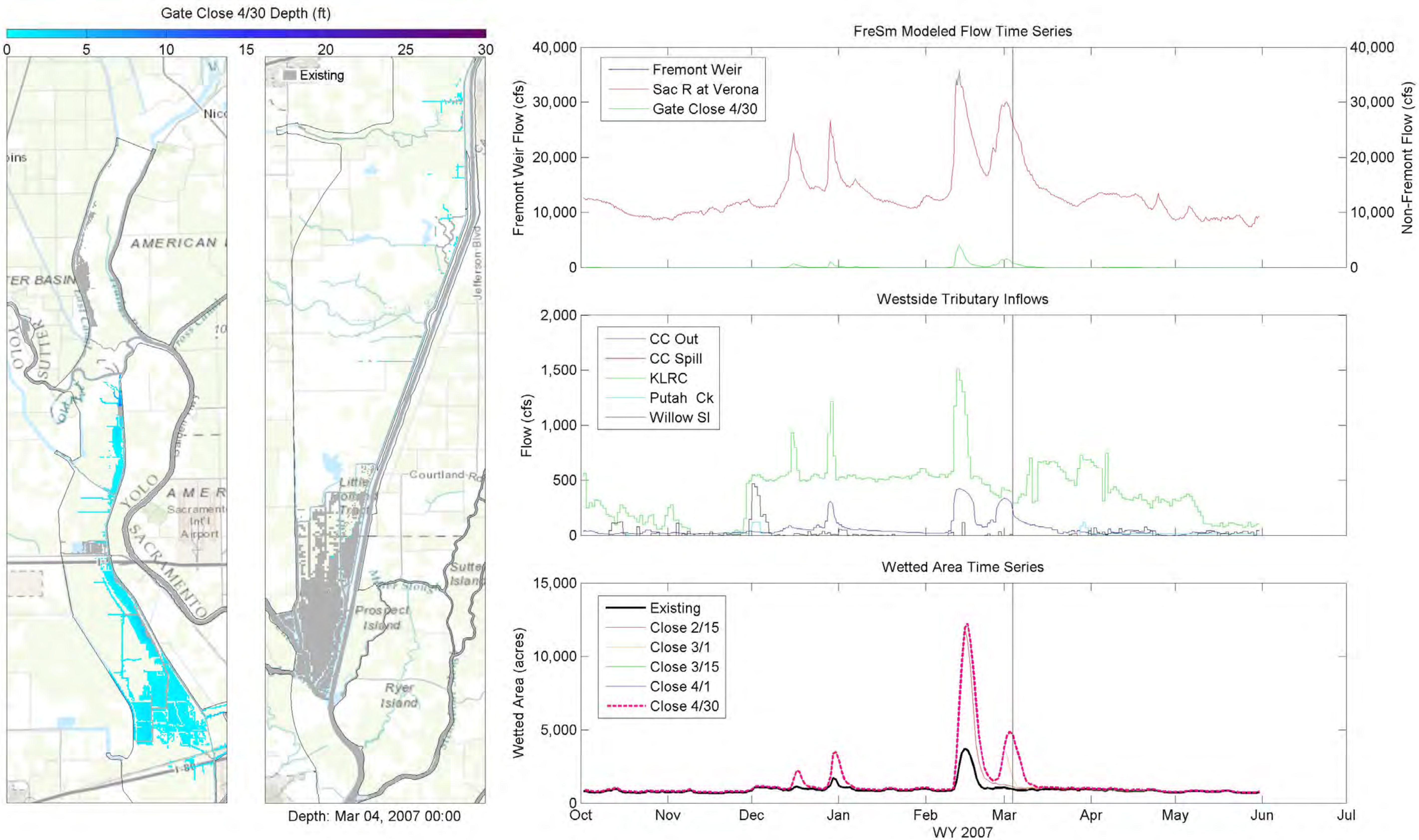
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2006 for FreSm

Prepared for DWR | Created By: SJB | **Figure E42**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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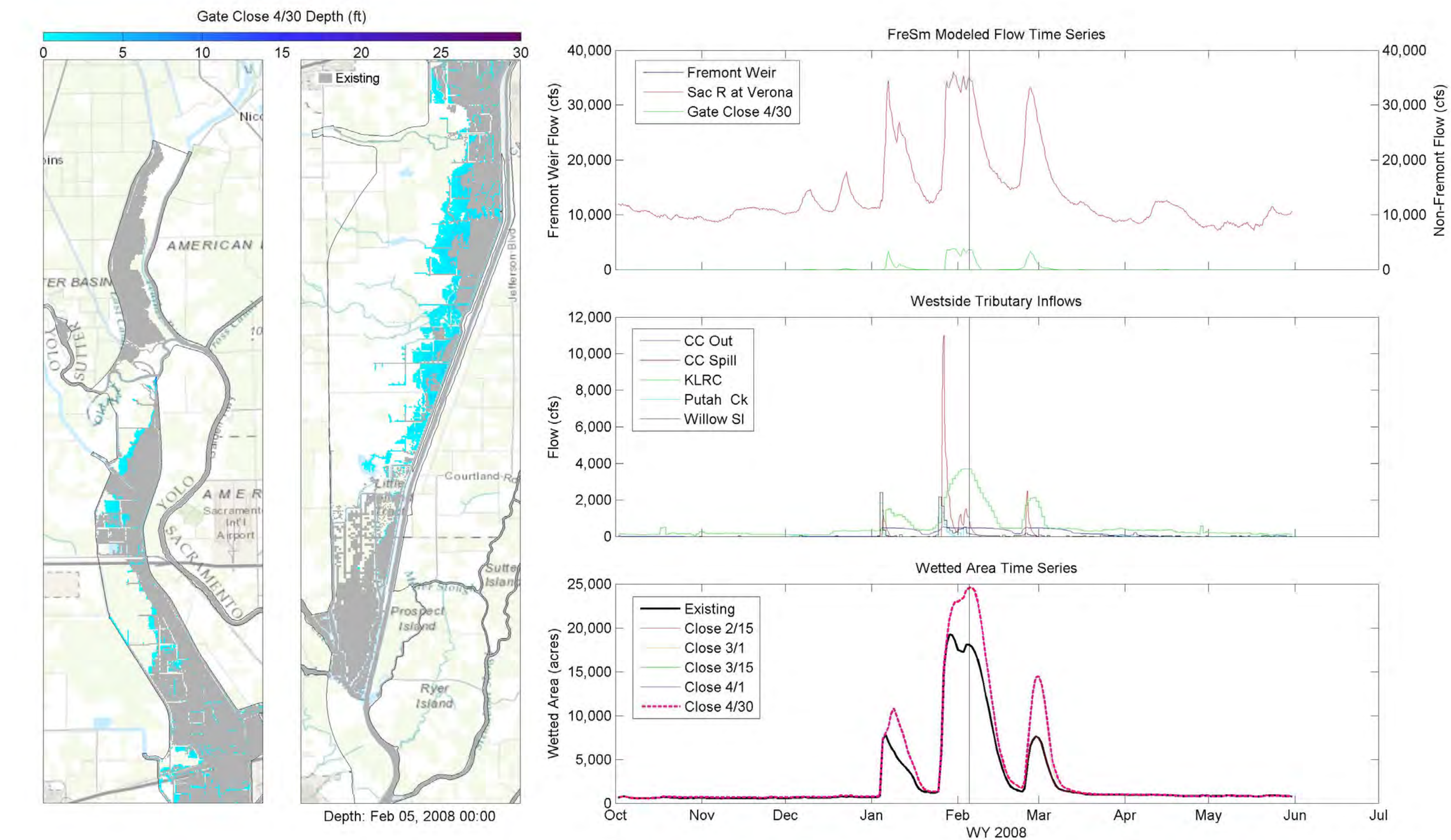
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2007 for FreSm

Prepared for DWR	Created By: SJB	**Figure E43**

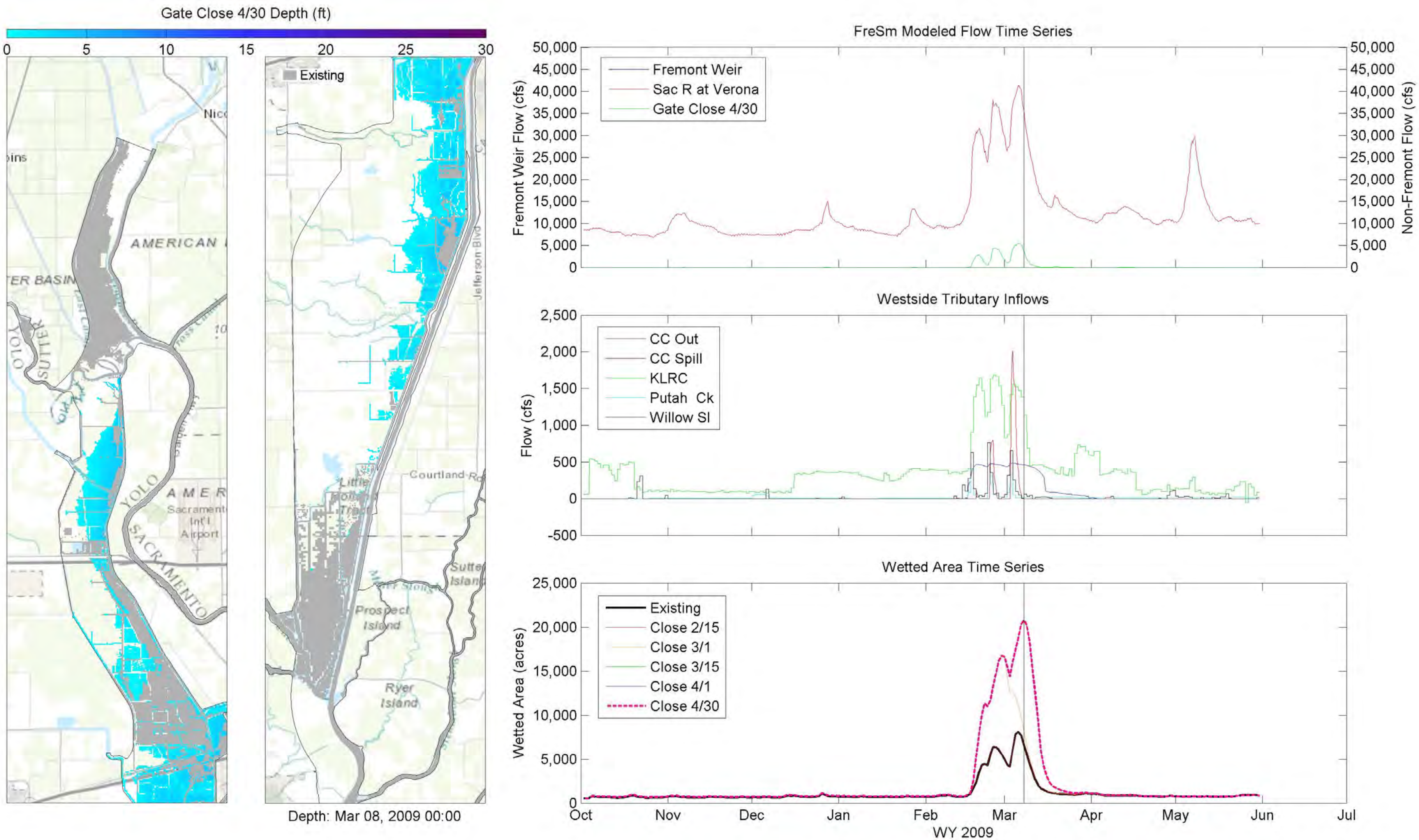


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2008 for FreSm

Prepared for DWR | Created By: SJB | **Figure E44**

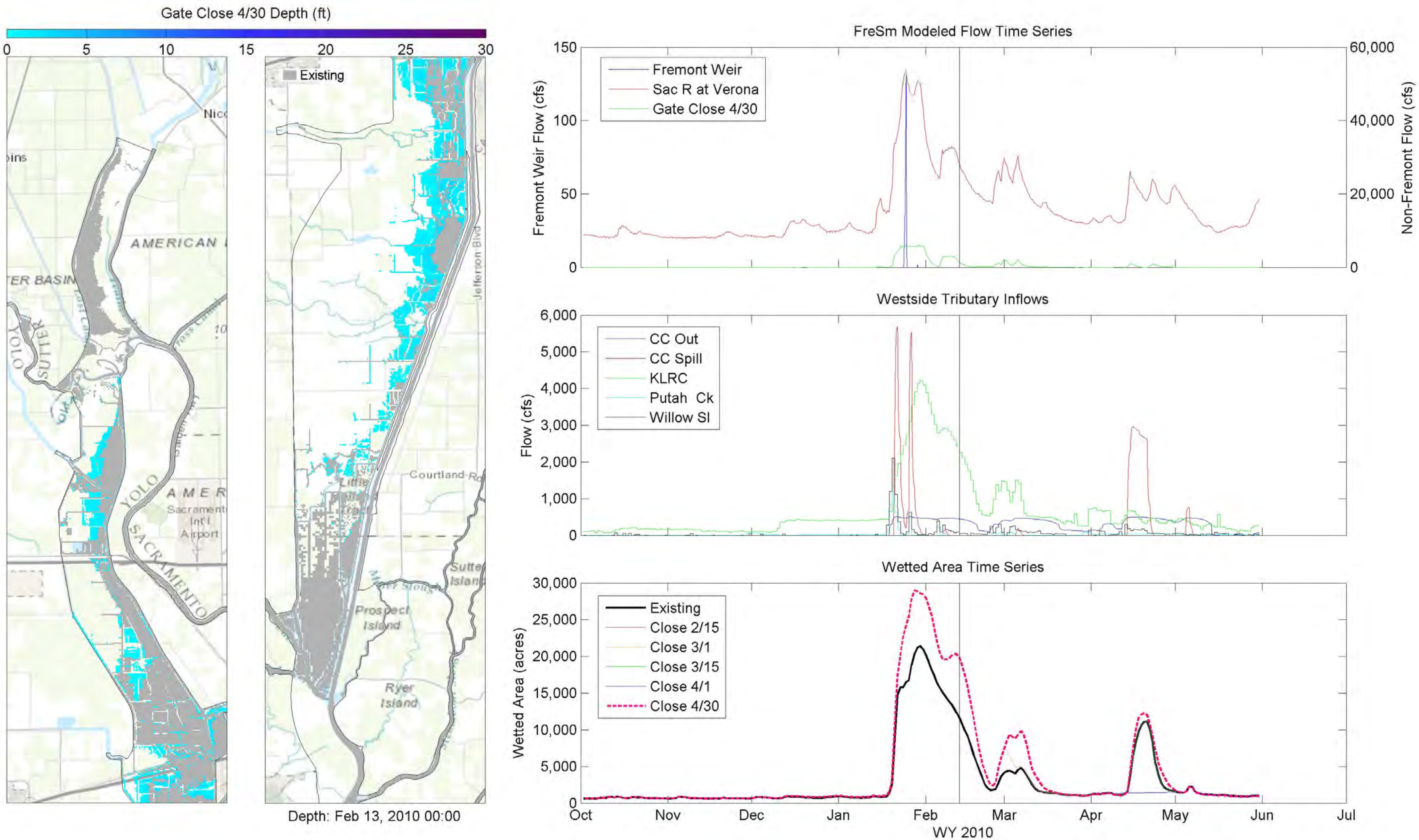


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2009 for FreSm

Prepared for DWR	Created By: SJB	**Figure E45**



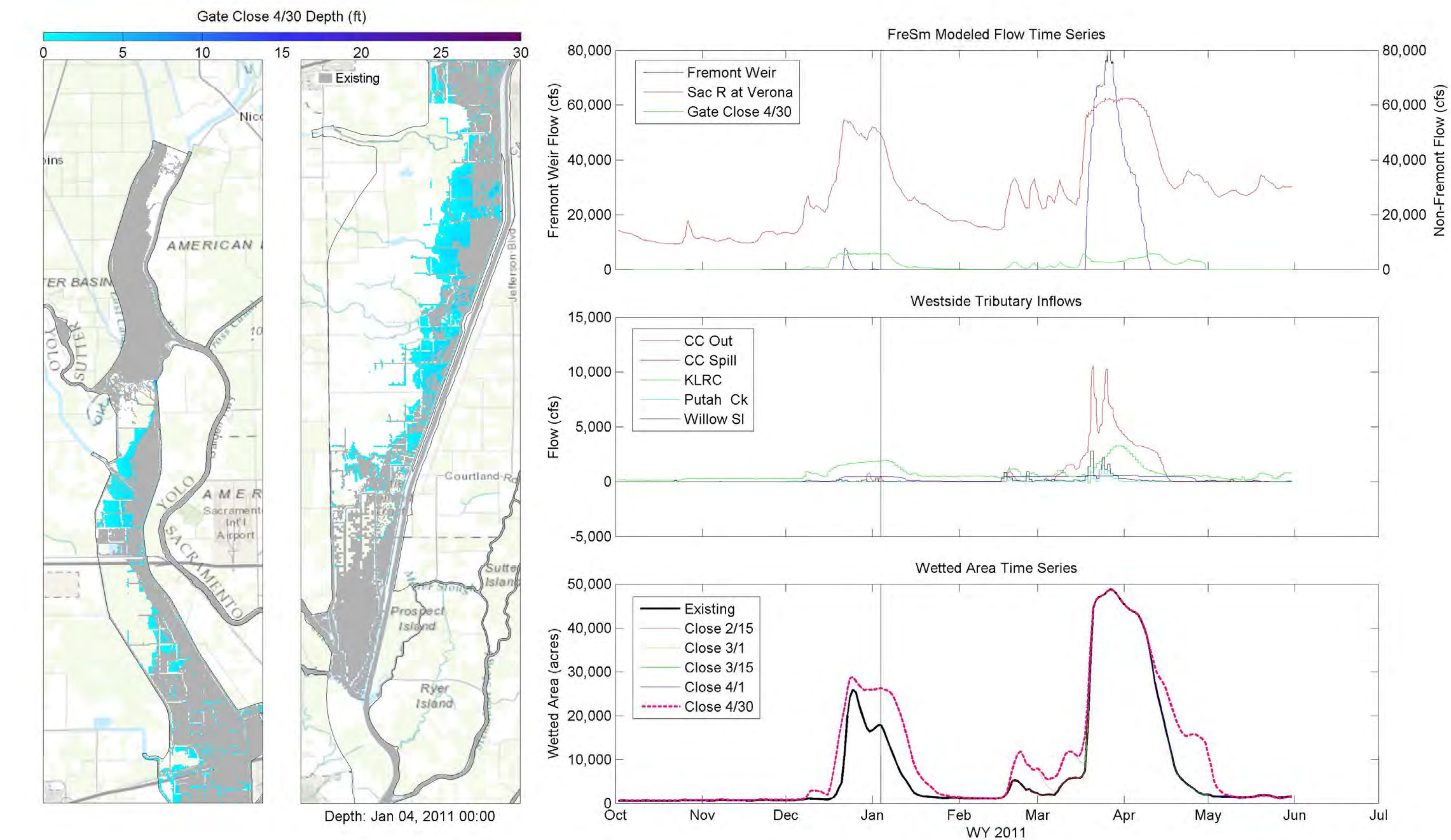
Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2010 for FreSm

Prepared for DWR	Created By: SJB	**Figure E46**

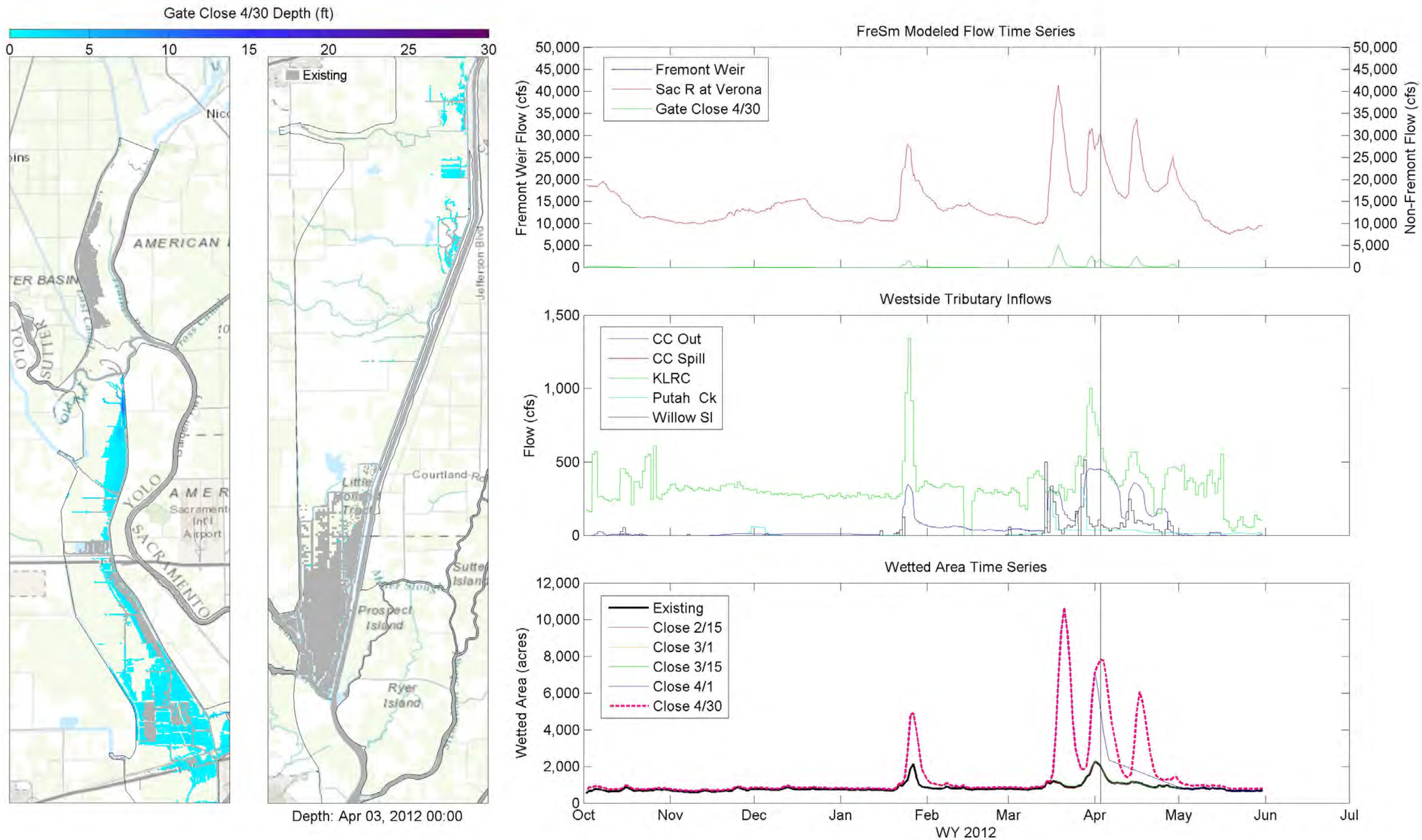


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2011 for FreSm

Prepared for DWR | Created By: SJB | **Figure E47**



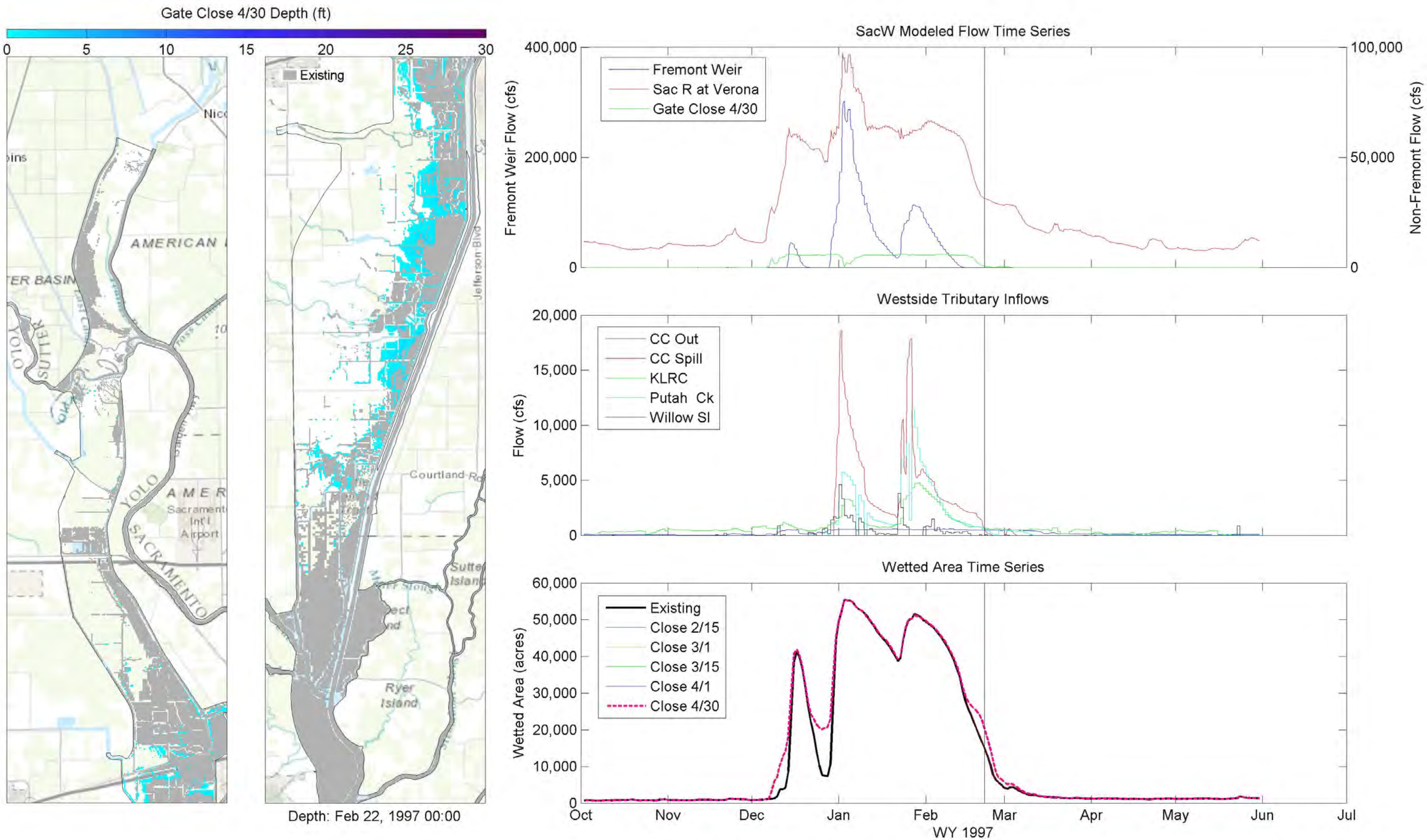
Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2012 for FreSm

Prepared for DWR | Created By: SJB | **Figure E48**

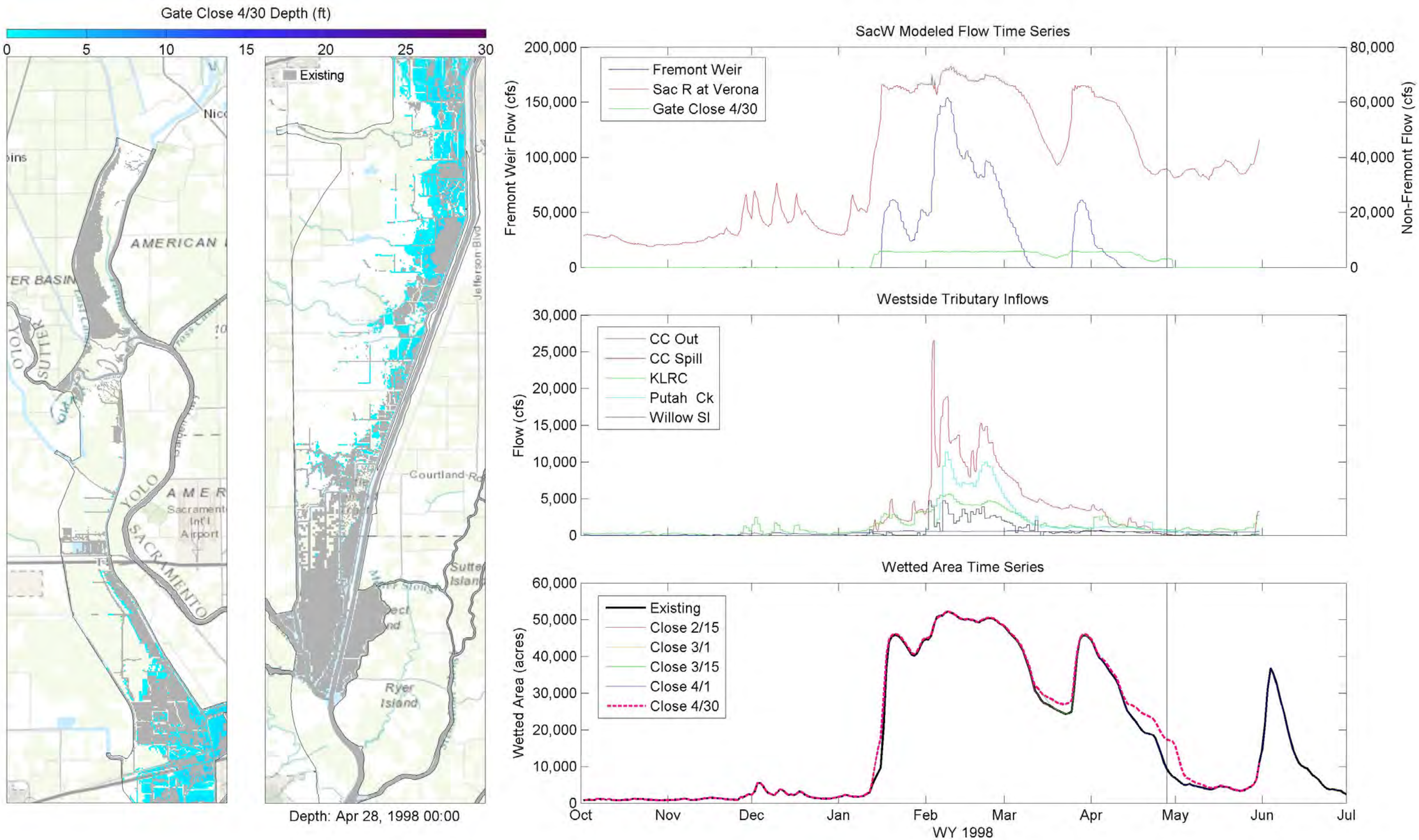


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1997 for SacW

Prepared for DWR	Created By: SJB	**Figure E49**

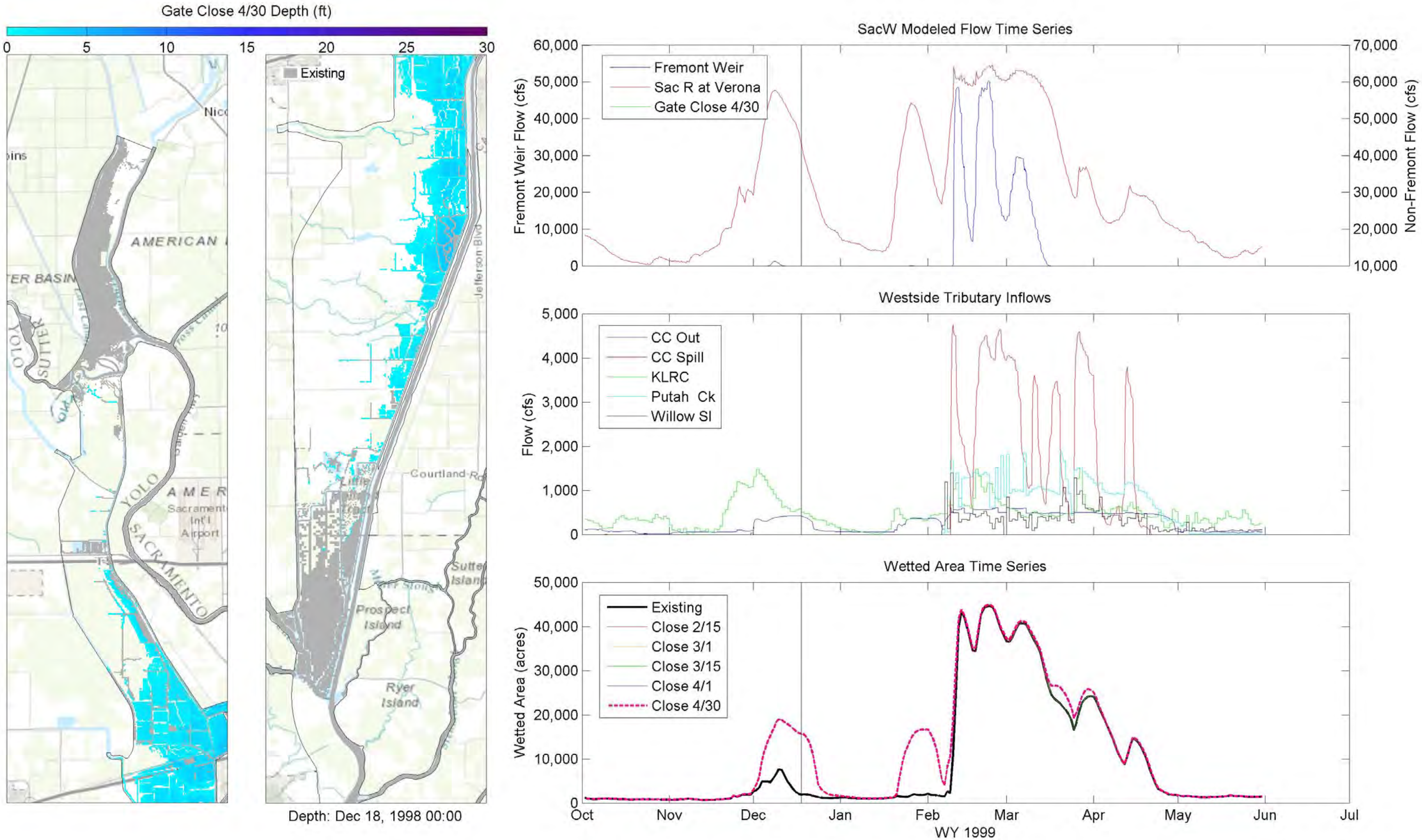


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1998 for SacW

Prepared for DWR | Created By: SJB | **Figure E50**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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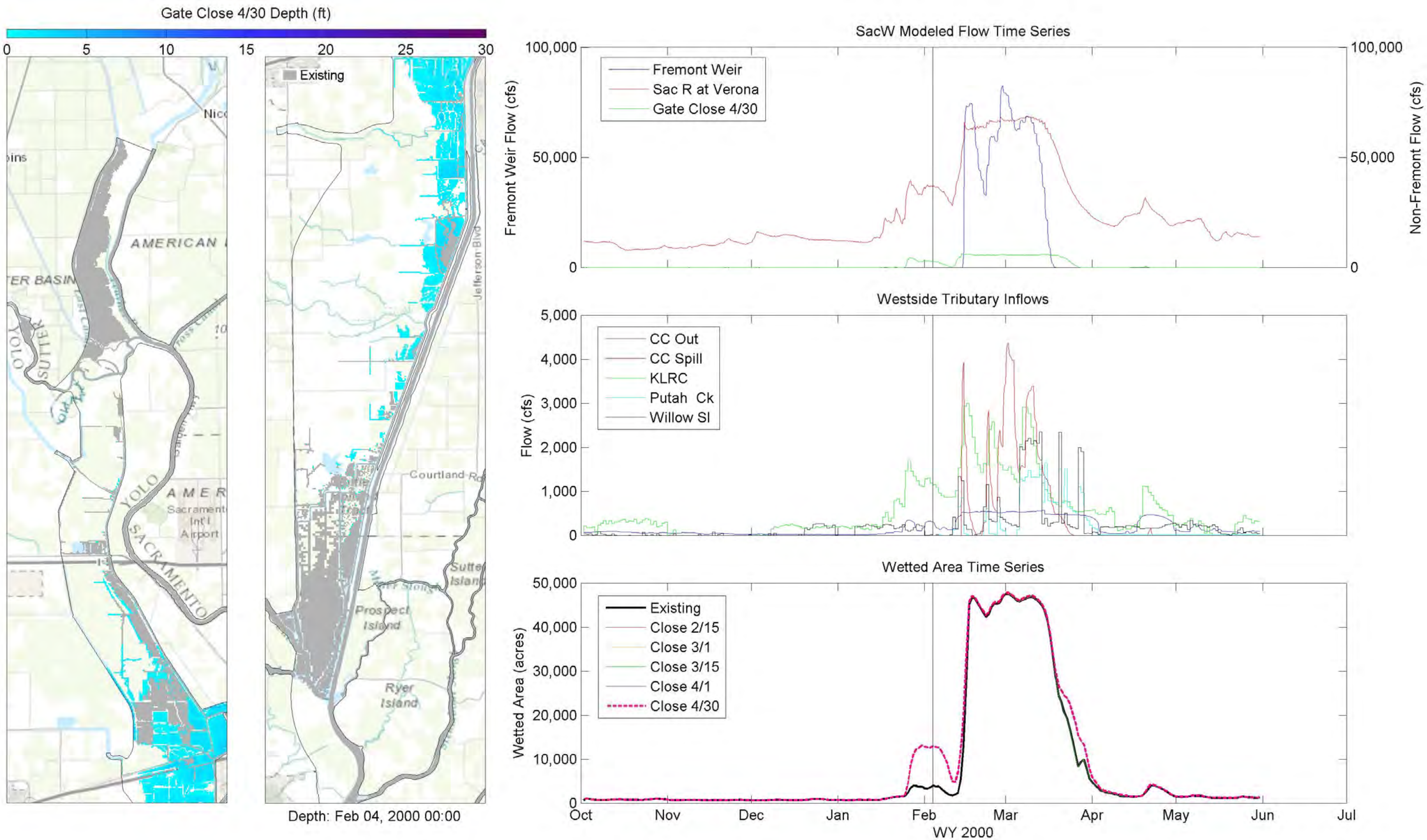
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 1999 for SacW

Prepared for DWR | Created By: SJB | **Figure E51**

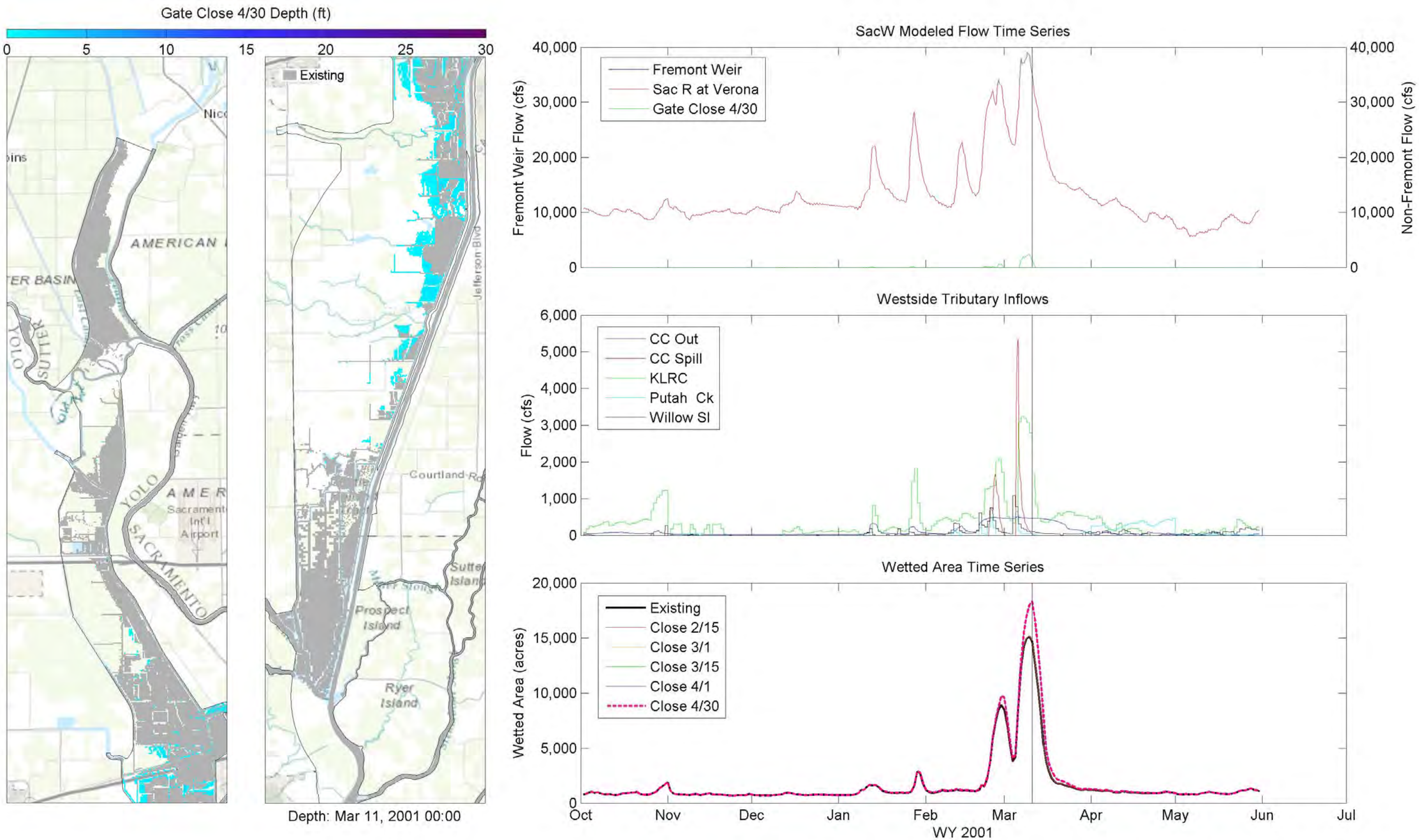


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2000 for SacW

Prepared for DWR | Created By: SJB | **Figure E52**

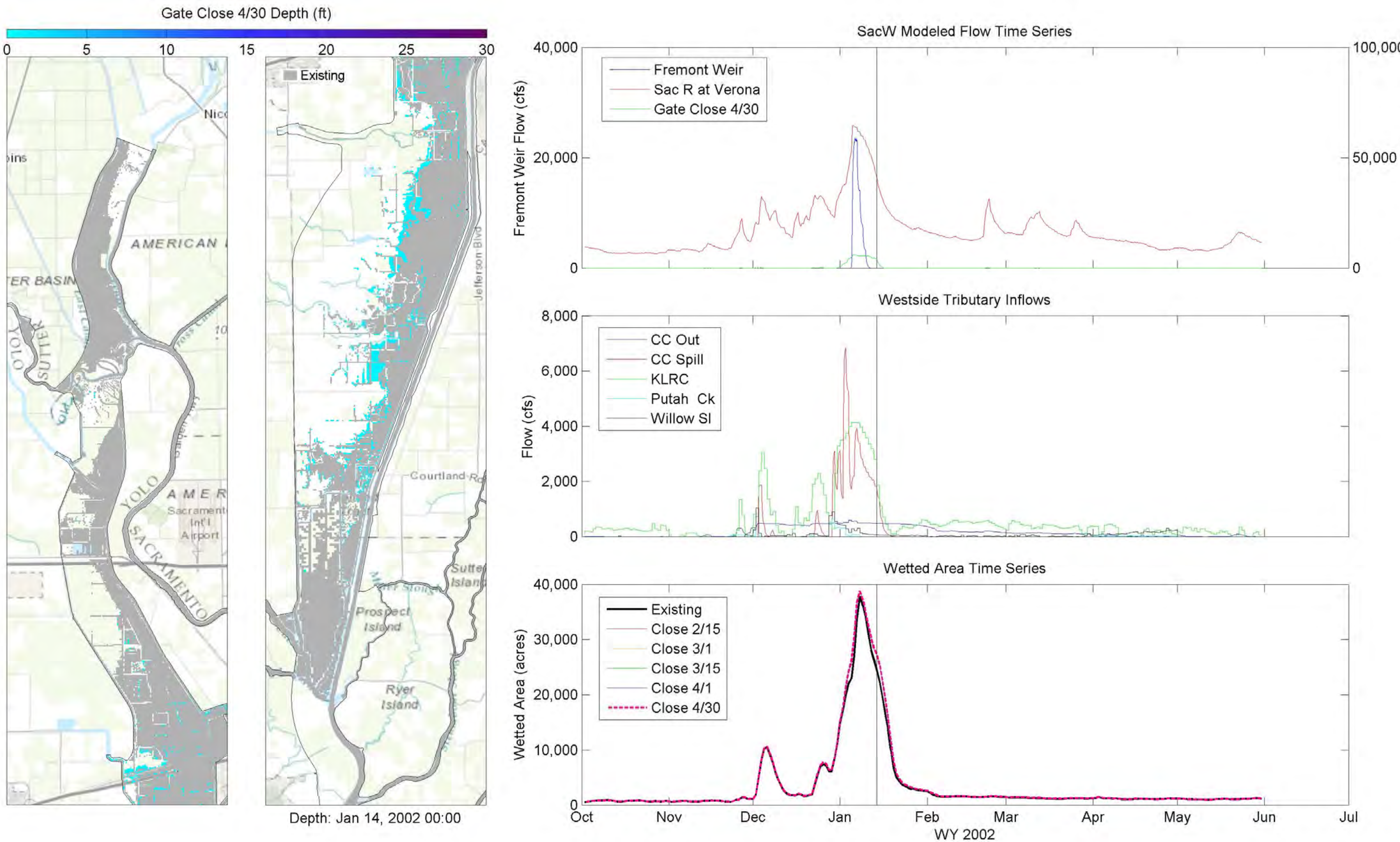


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2001 for SacW

Prepared for DWR | Created By: SJB | **Figure E53**

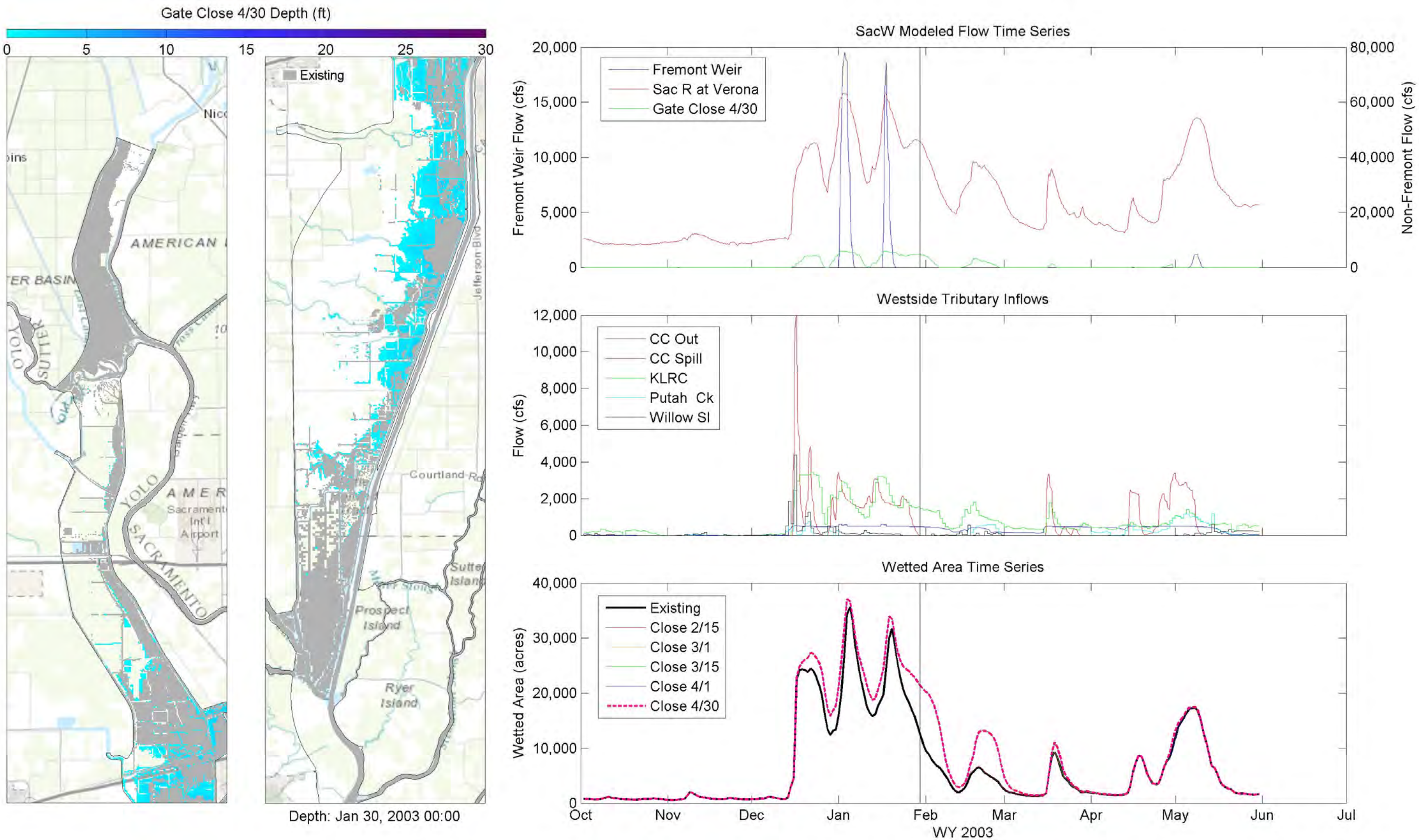


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2002 for SacW

Prepared for DWR | Created By: SJB | **Figure E54**

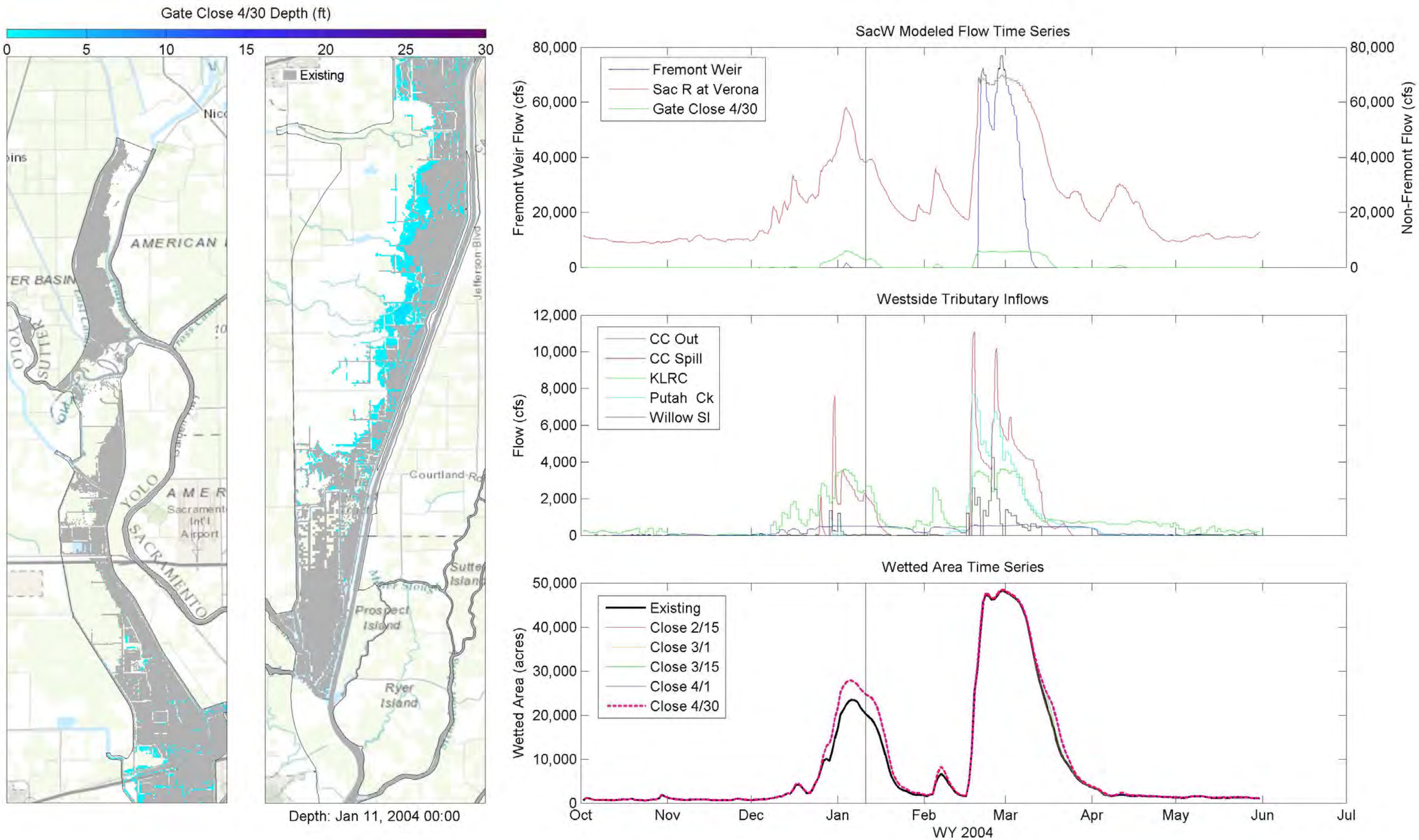


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2003 for SacW

Prepared for DWR | Created By: SJB | **Figure E55**

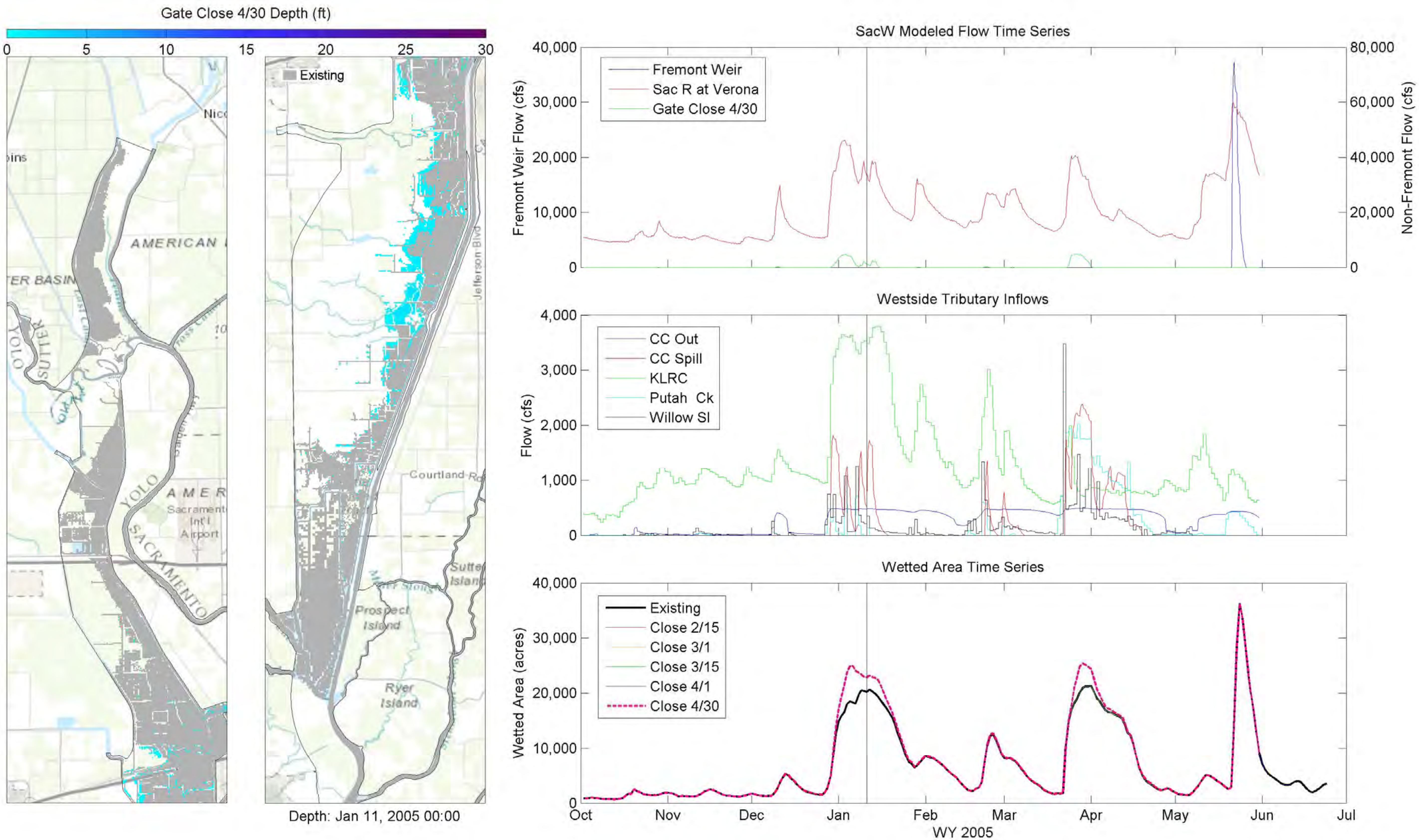


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2004 for SacW

Prepared for DWR | Created By: SJB | **Figure E56**

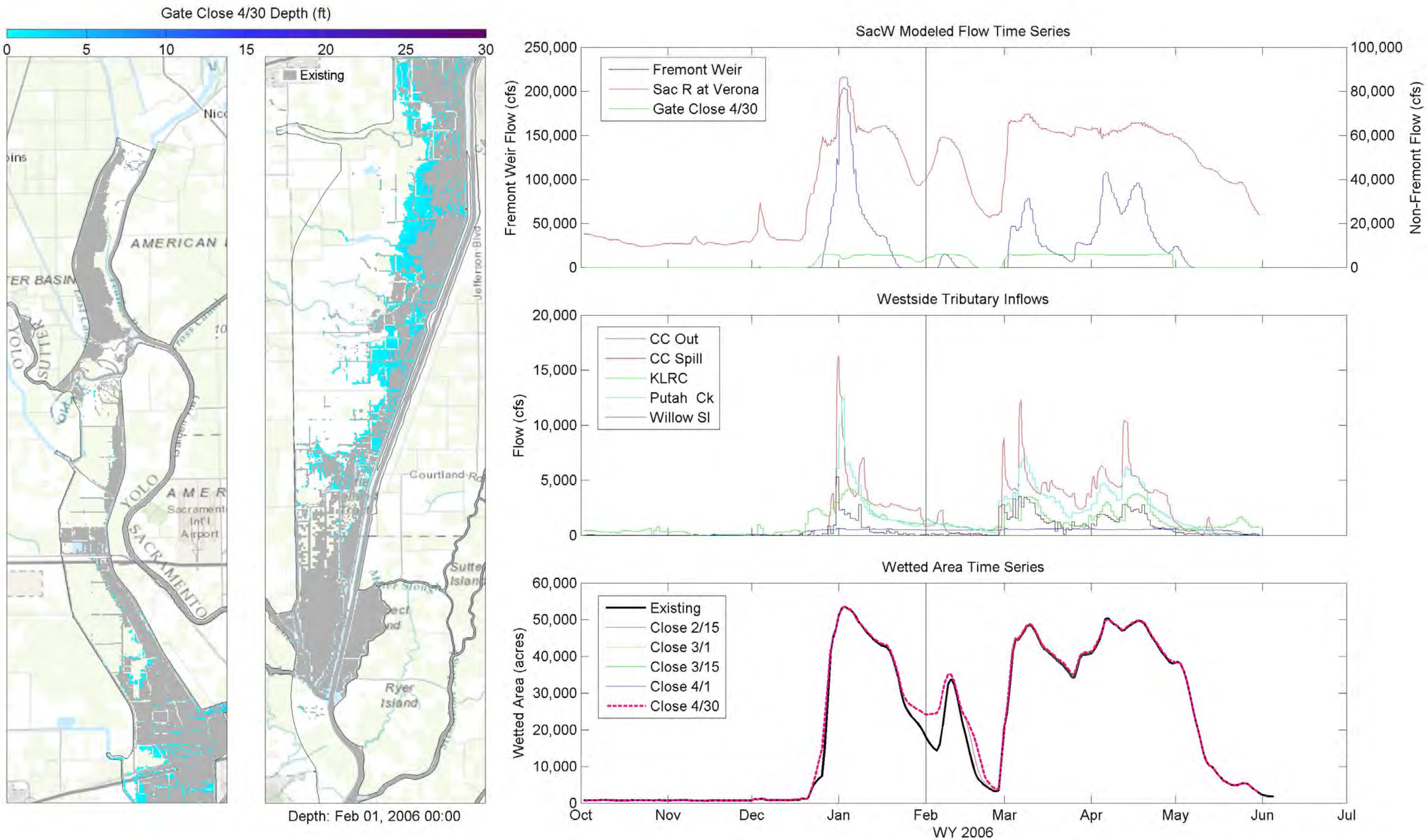


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2005 for SacW

Prepared for DWR | Created By: SJB | **Figure E57**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

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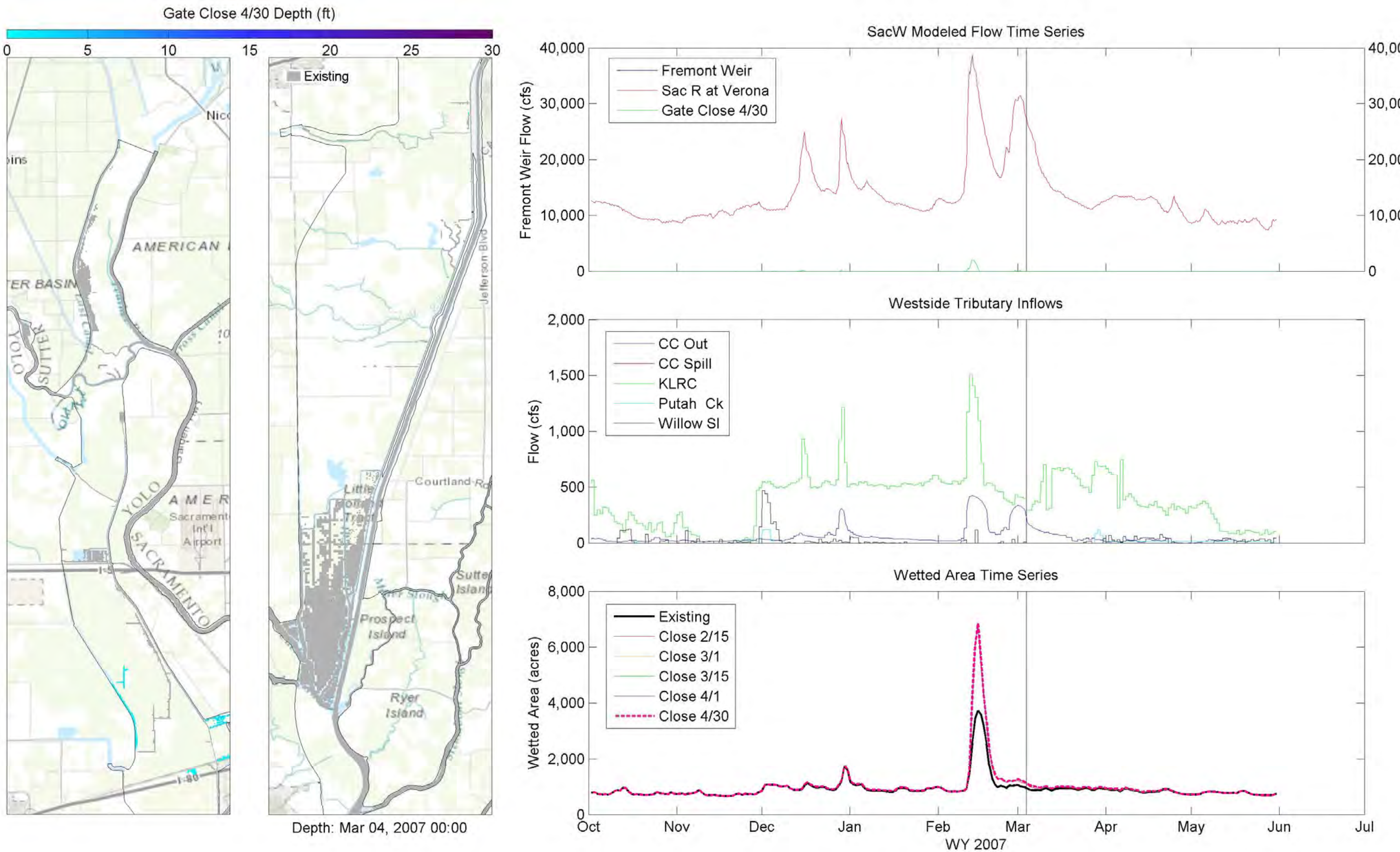
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2006 for SacW

Prepared for DWR	Created By: SJB	**Figure E58**

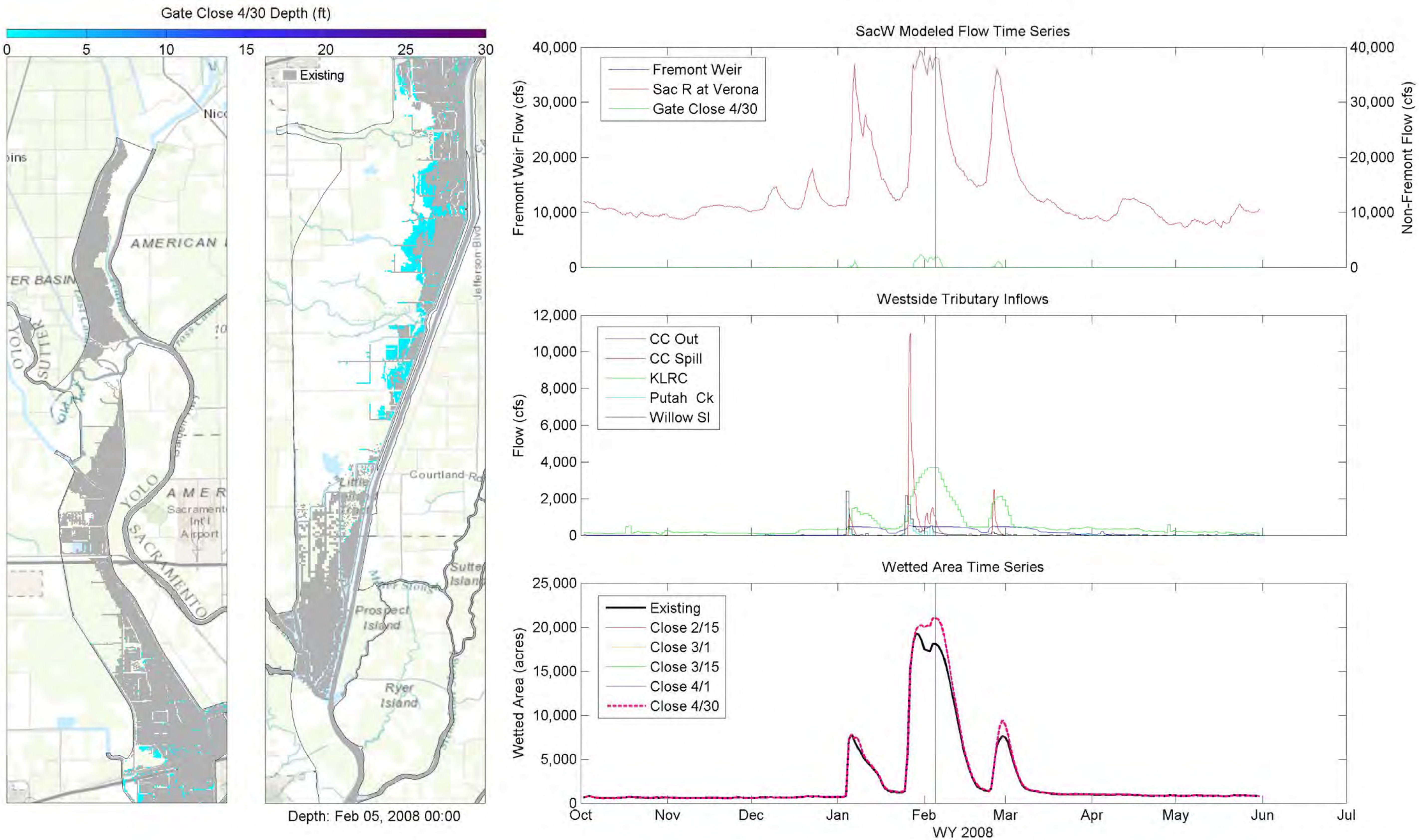


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2007 for SacW

Prepared for DWR | Created By: SJB | **Figure E59**



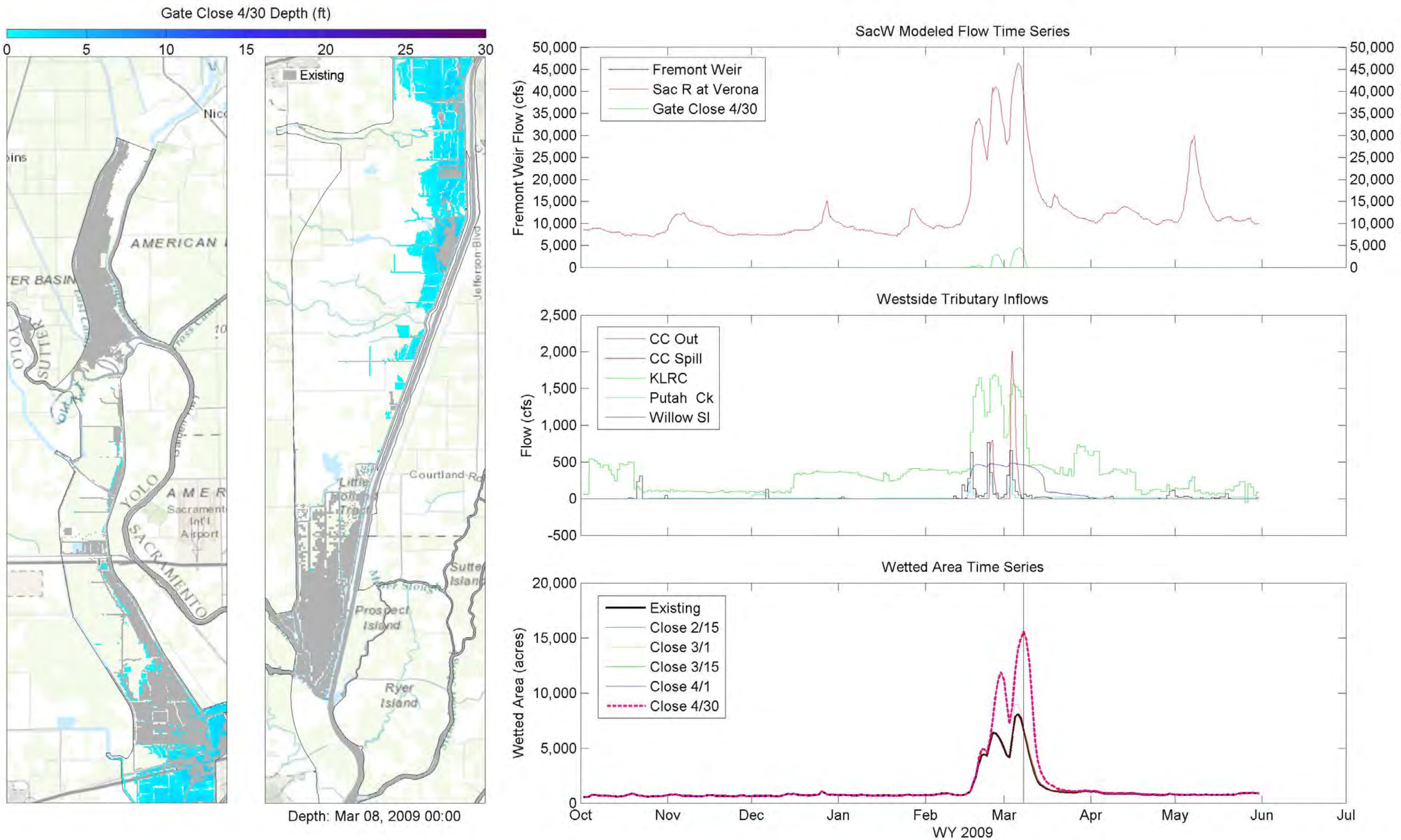
Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2008 for SacW

Prepared for DWR | Created By: SJB | **Figure E60**



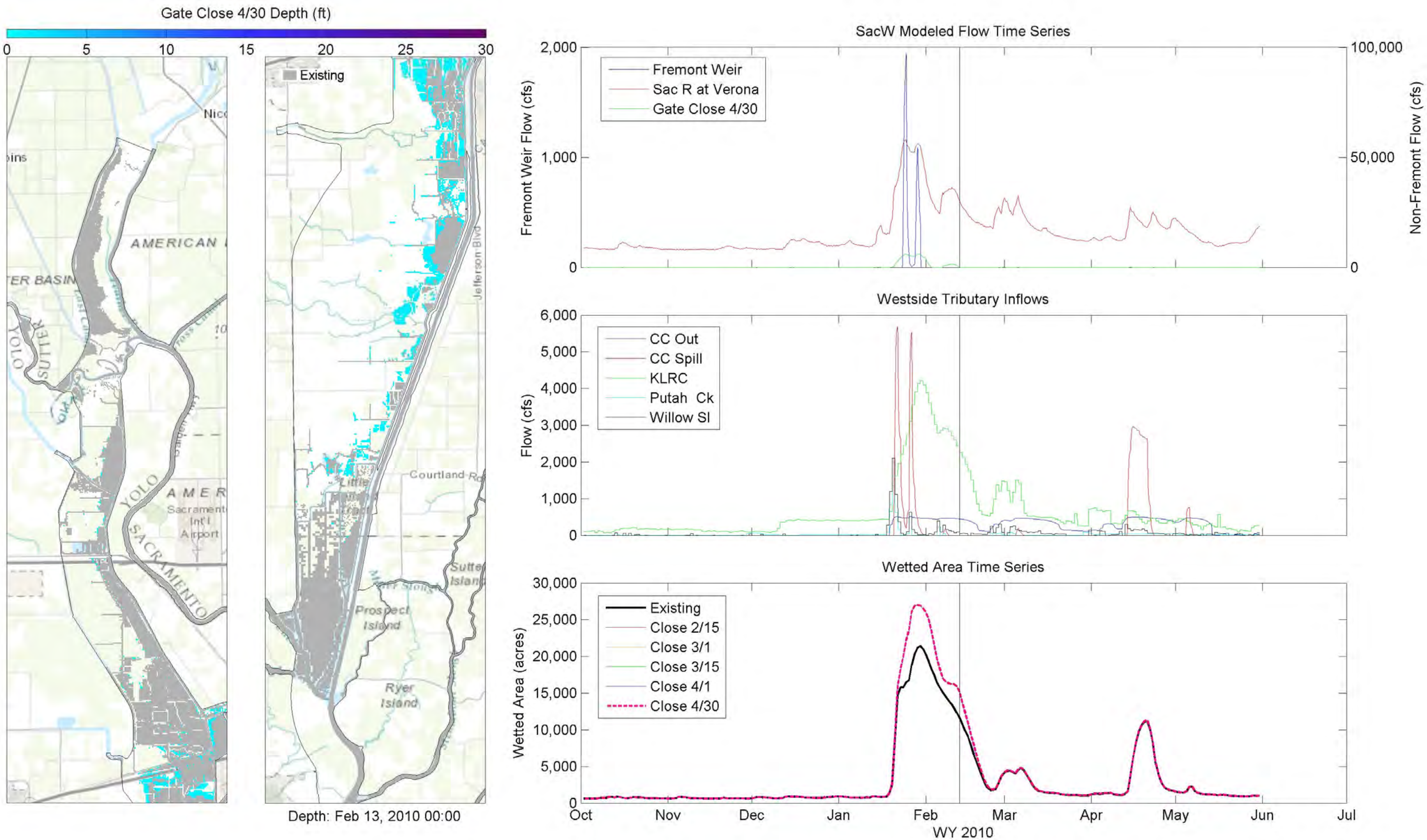
Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2009 for SacW

Prepared for DWR | Created By: SJB | **Figure E61**

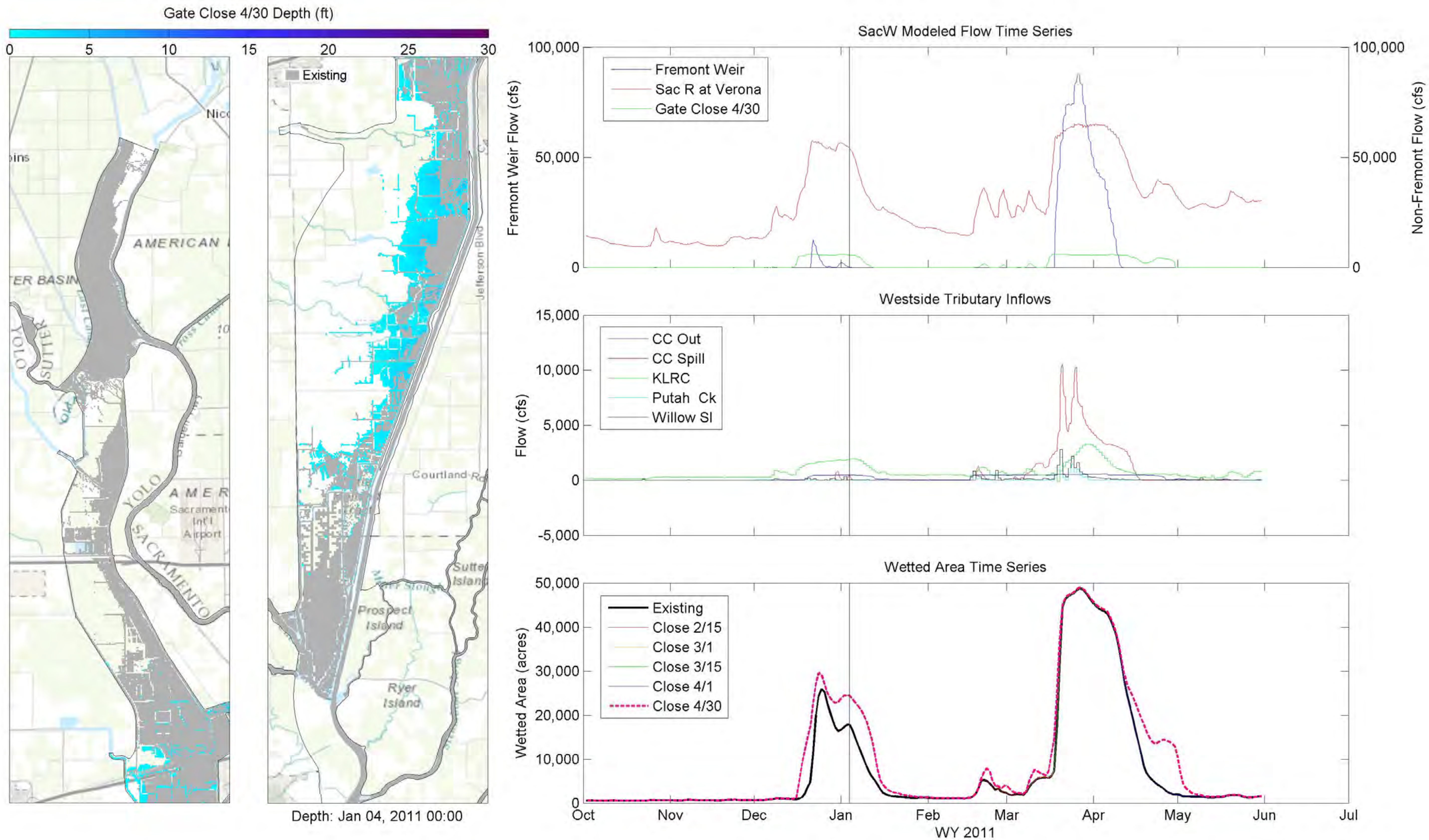


Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2010 for SacW

Prepared for DWR | Created By: SJB | **Figure E62**



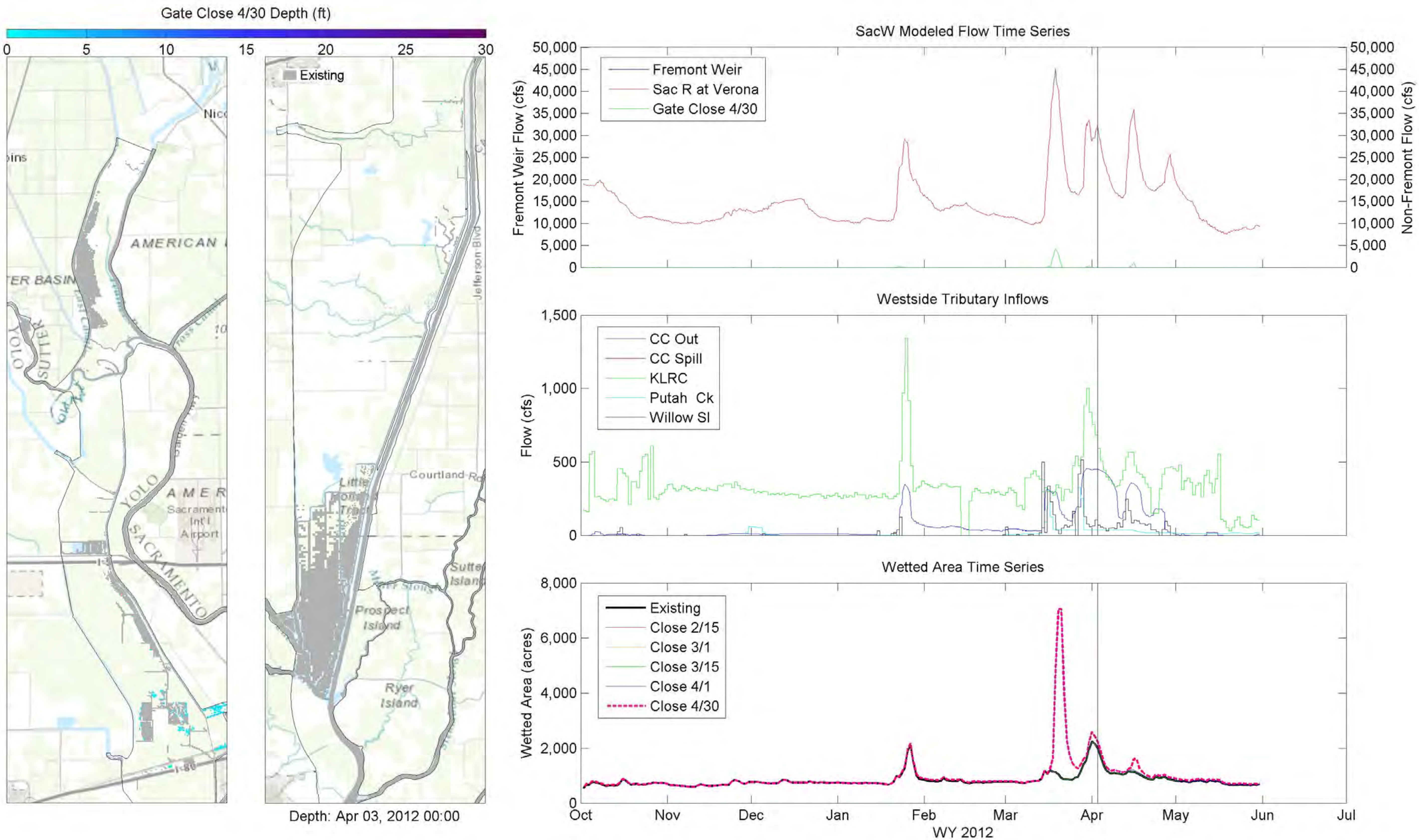
Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2011 for SacW

Prepared for DWR	Created By: SJB	**Figure E63**



Notes: TUFLOW model results showing 2D inundation patterns (at specified time stamp) for existing and 4/30 gate closure (left panes), Yolo Bypass inflows (upper right panes), and wetted area for all five gate closures (lower right pane). The vertical bar in the right panes corresponds to the time stamp below the left panes, whereby the blue hatching represents 4/30 gate closure conditions as overlain by the grey hatching representing existing conditions.

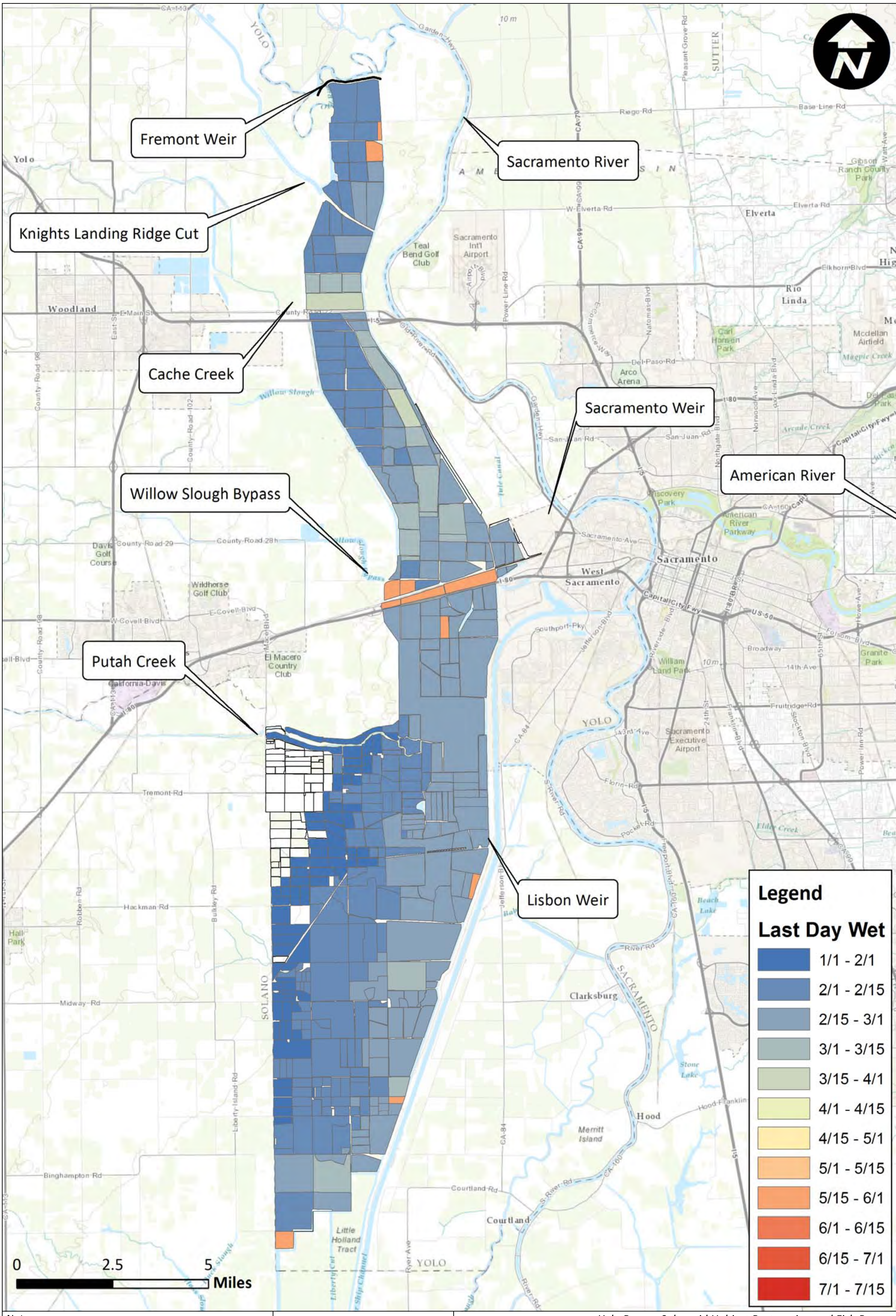
Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Wetted Area Comparison for WY 2012 for SacW

Prepared for DWR | Created By: SJB | **Figure E64**

Appendix F

Complete Last Day Wet (LDW) Results



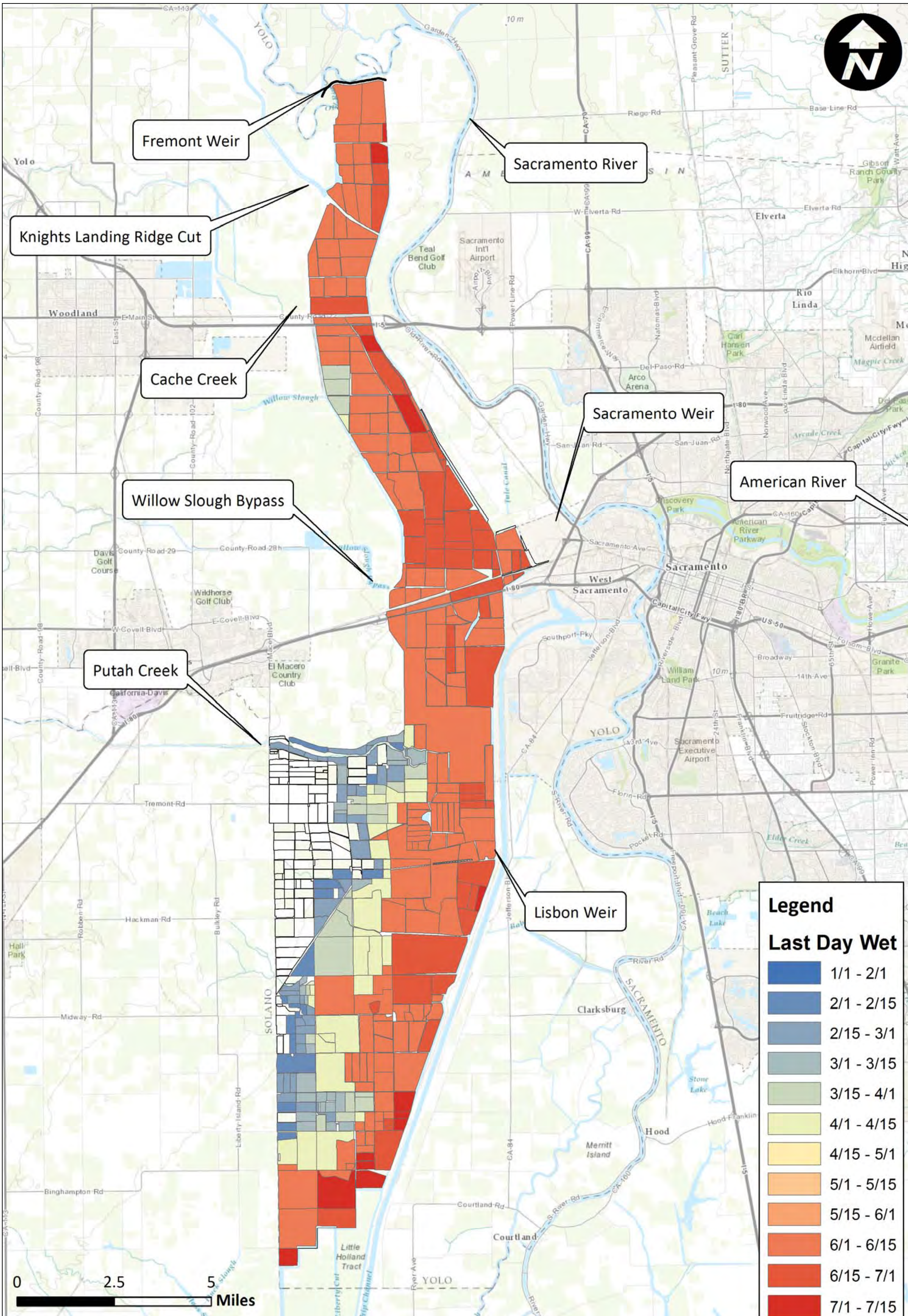
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

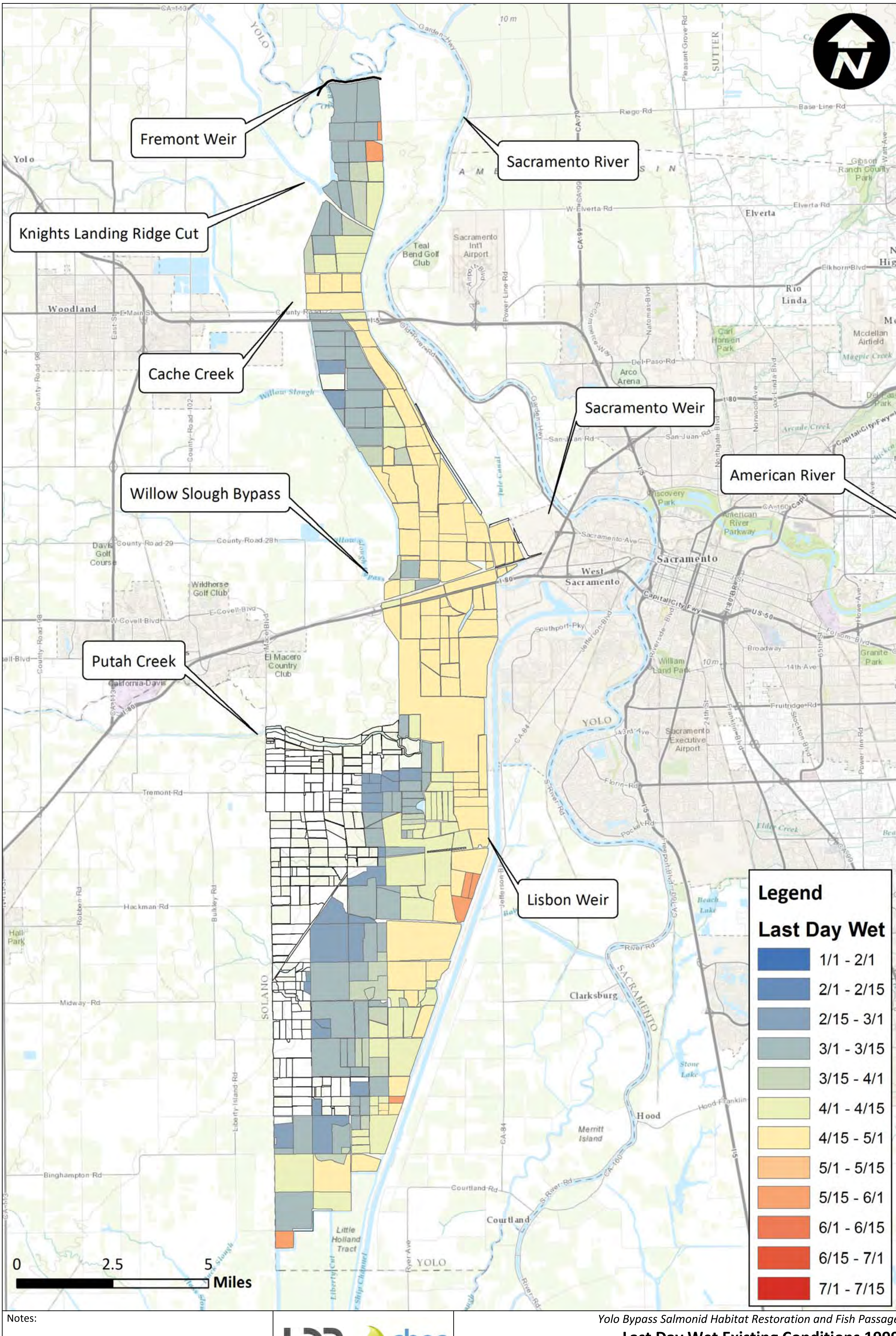
Last Day Wet Existing Conditions 1997

Prepared for DWR | Created By: RDJ

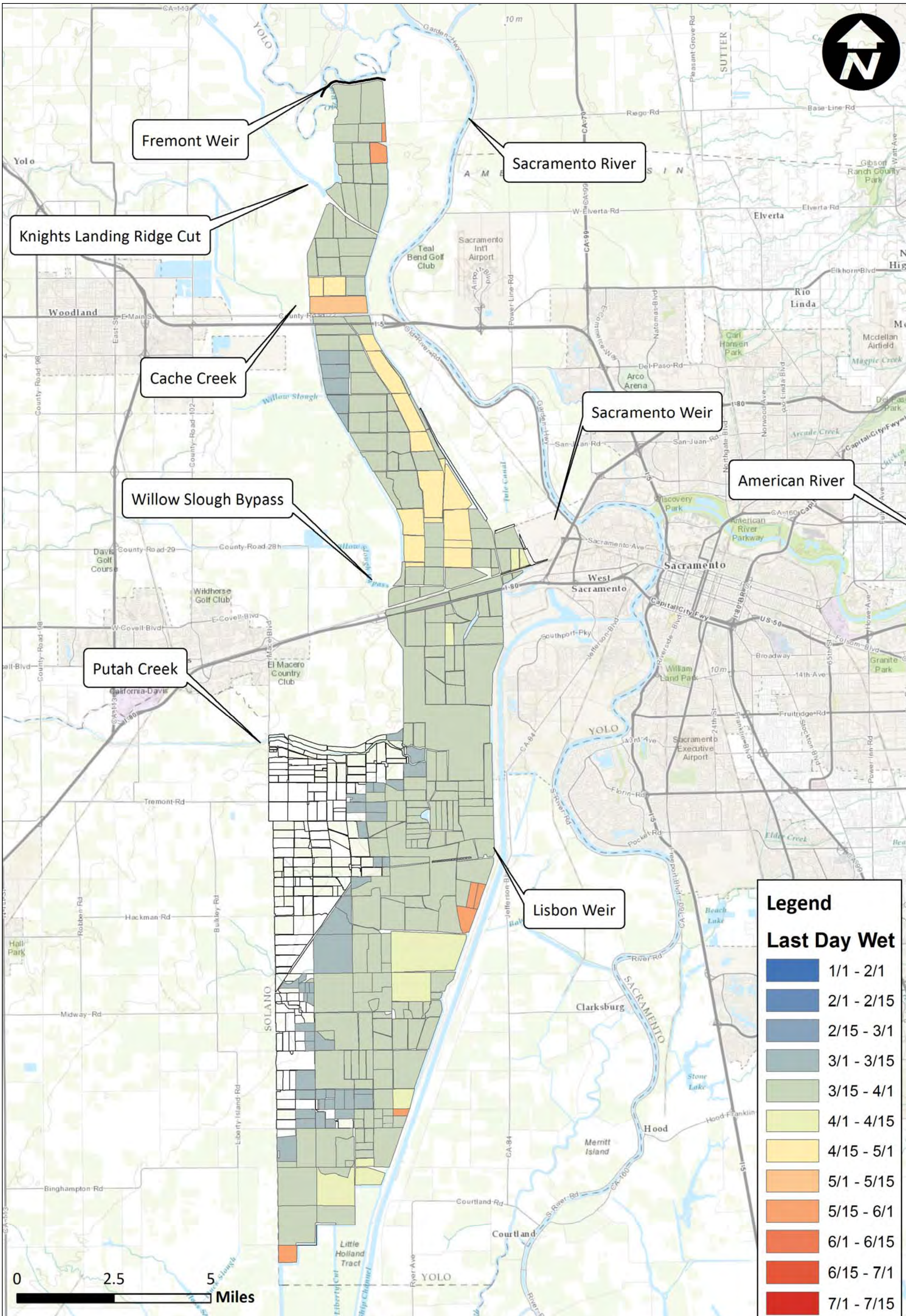
Figure F1



Notes:	HDR cbec	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Last Day Wet Existing Conditions 1998**
		Prepared for DWR · Created By: RDJ · **Figure F2**



Notes:	HDR cbec	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Last Day Wet Existing Conditions 1999**		
		Prepared for DWR	Created By: RDJ	**Figure F3**



Notes:

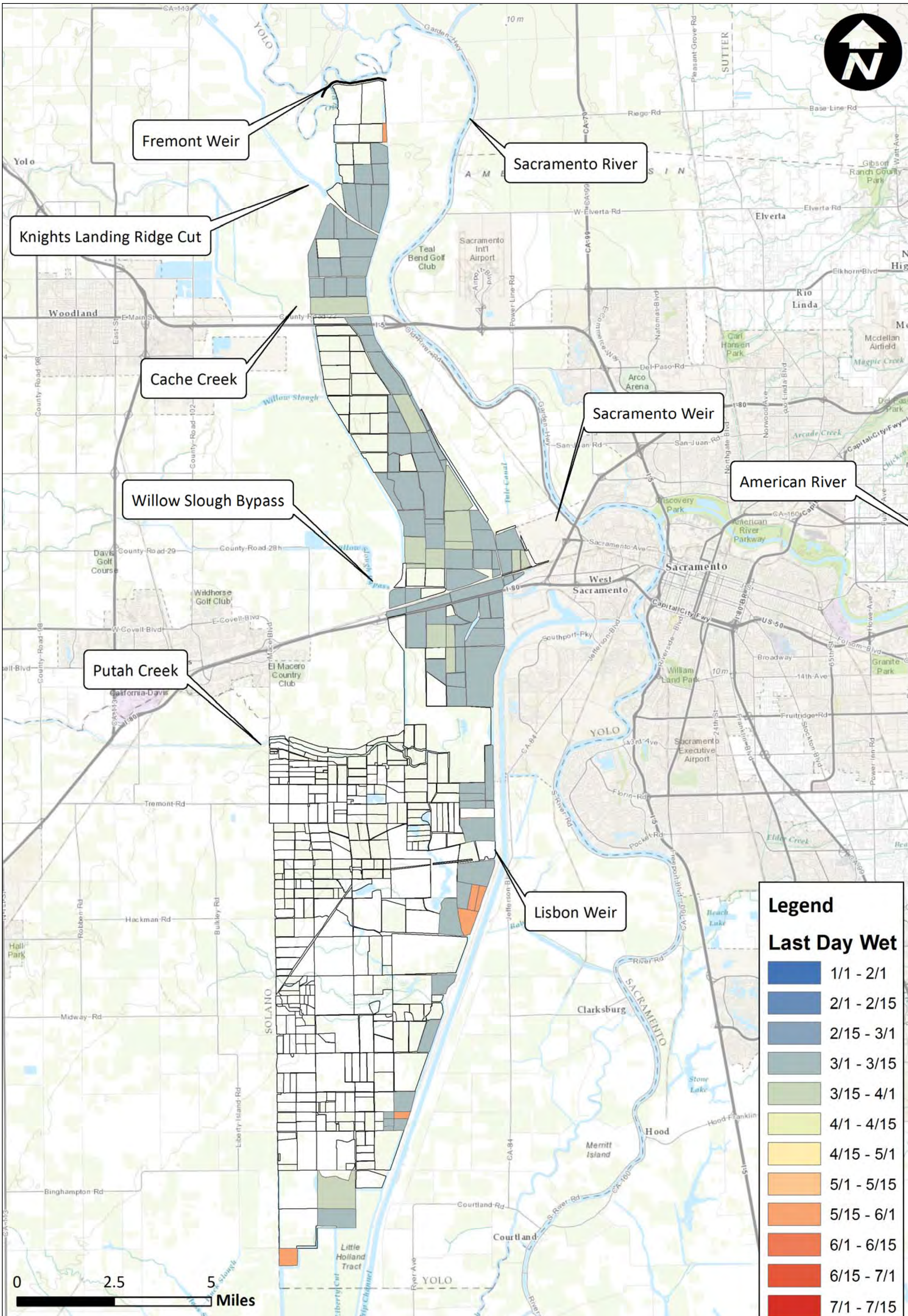
HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2000

Prepared for DWR | Created By: RDJ

Figure F4



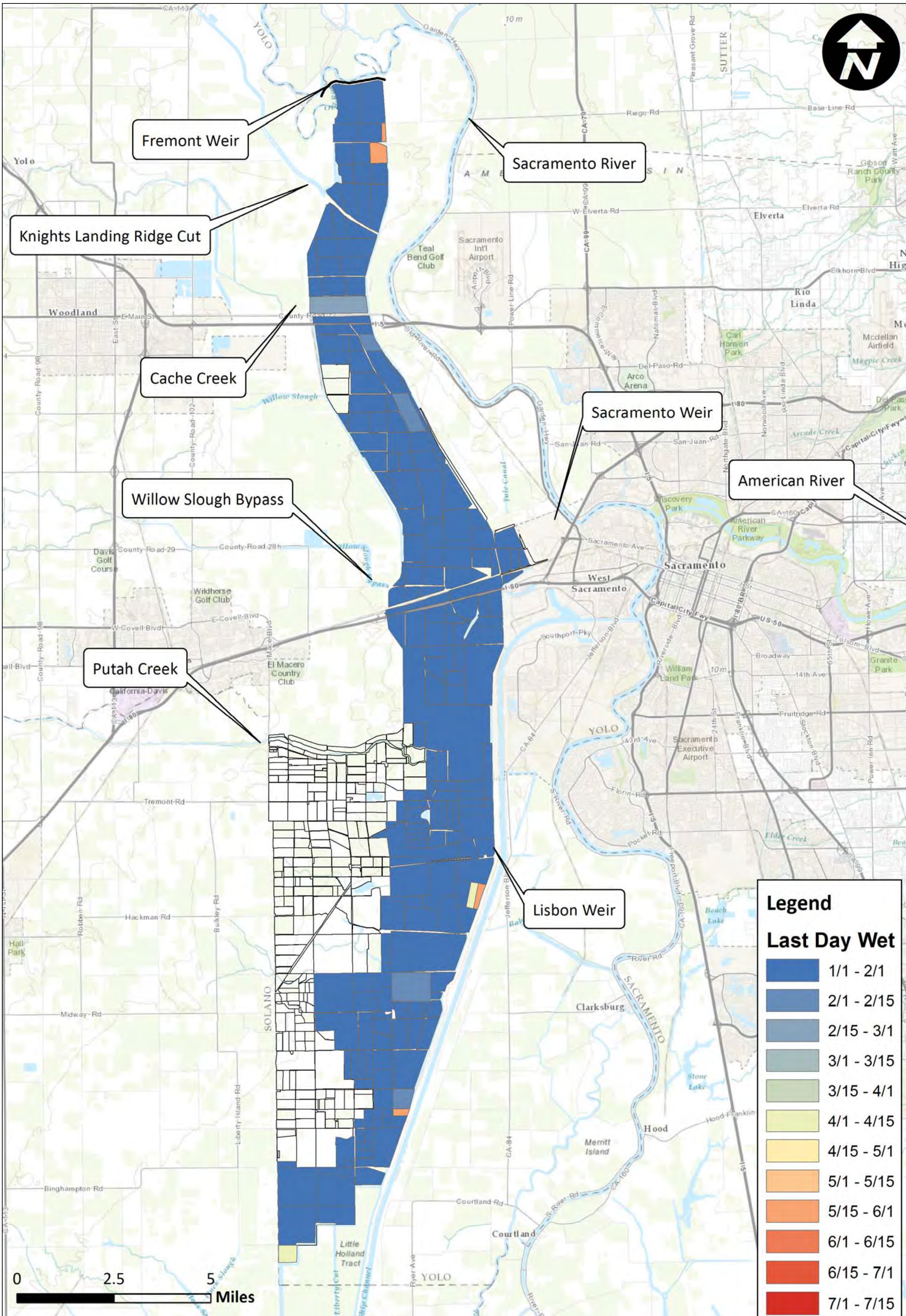
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2001

Prepared for DWR | Created By: RDJ

Figure F5



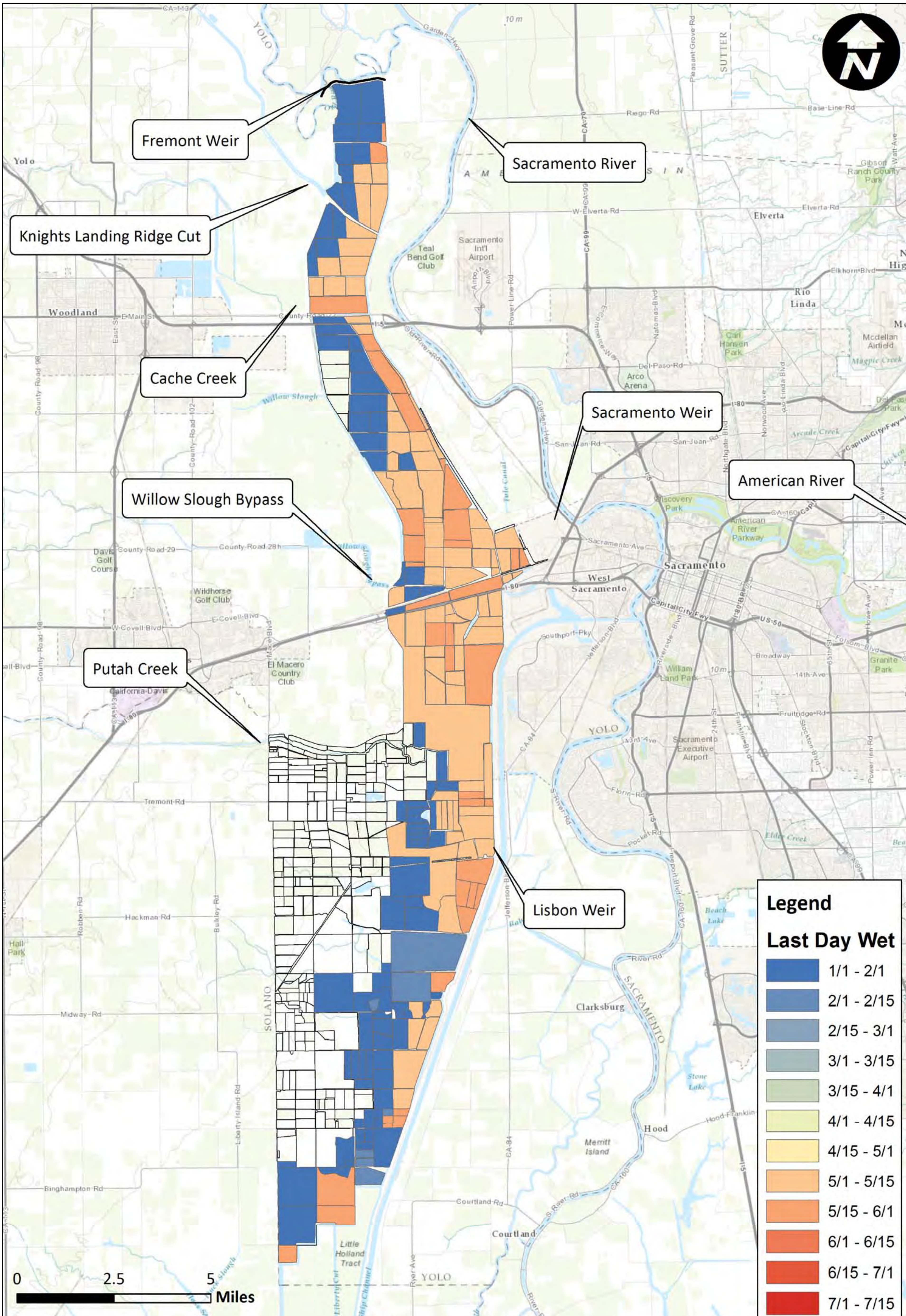
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2002

Prepared for DWR | Created By: RDJ

Figure F6



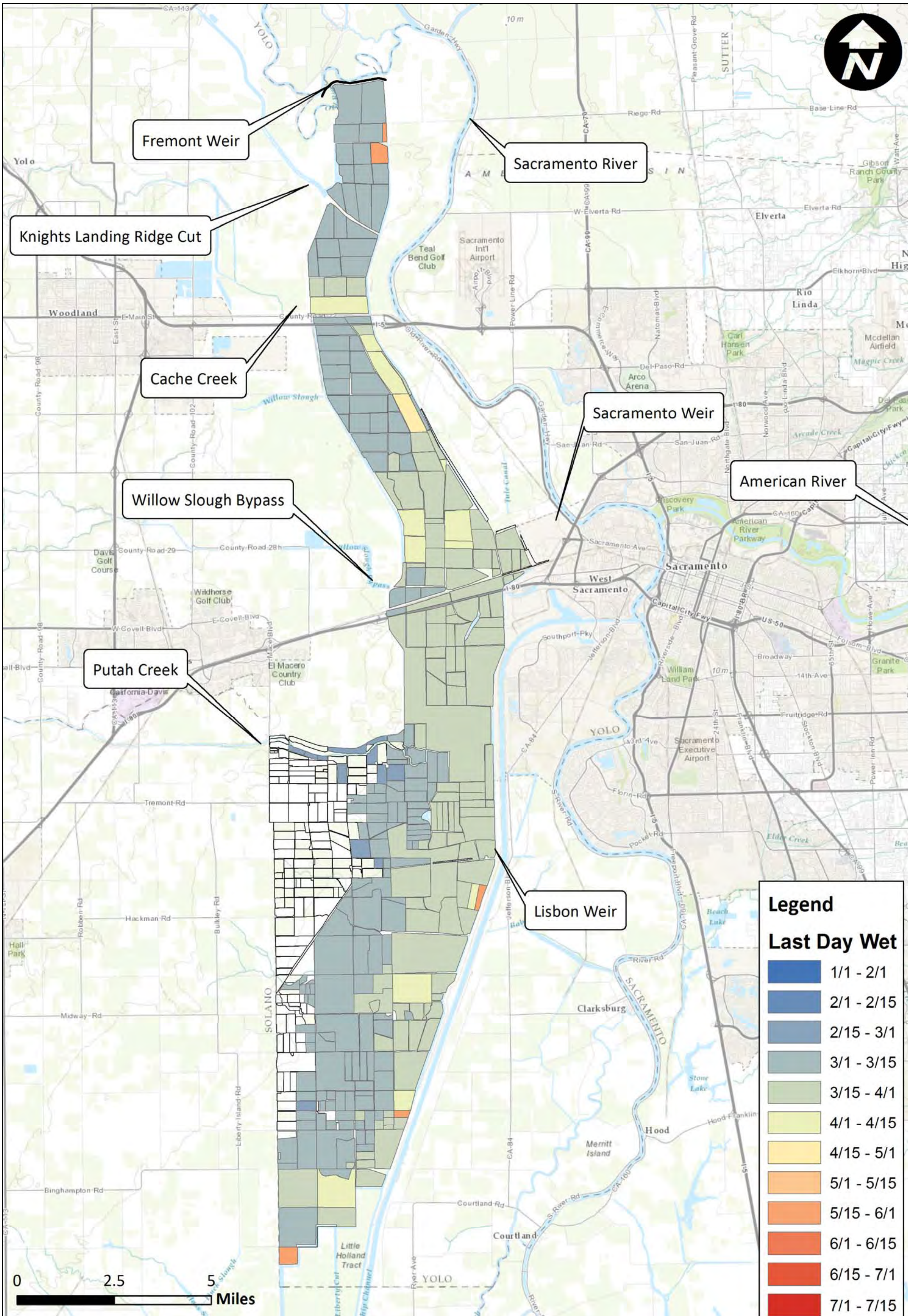
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2003

Prepared for DWR | Created By: RDJ

Figure F7



Notes:

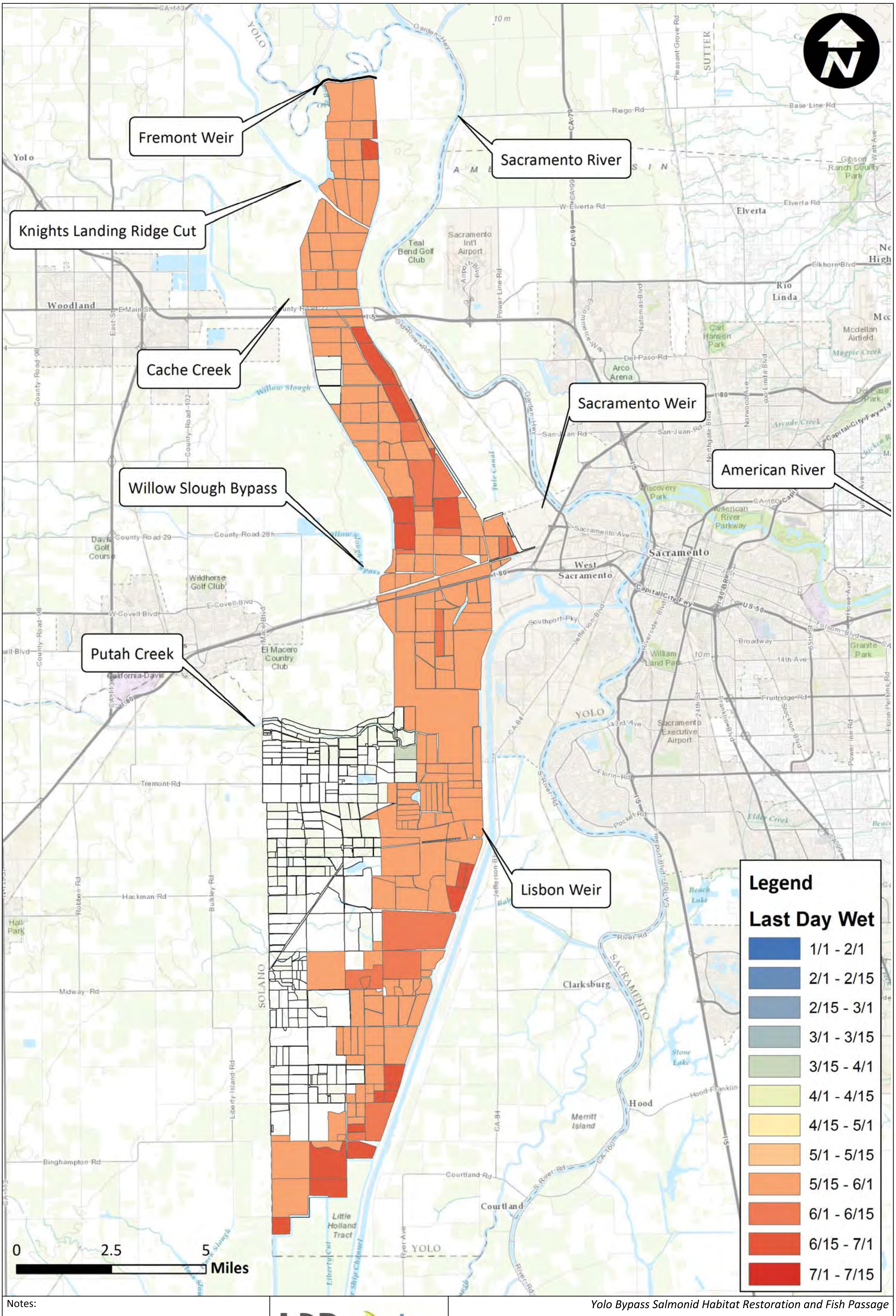
HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2004

Prepared for DWR | Created By: RDJ

Figure F8



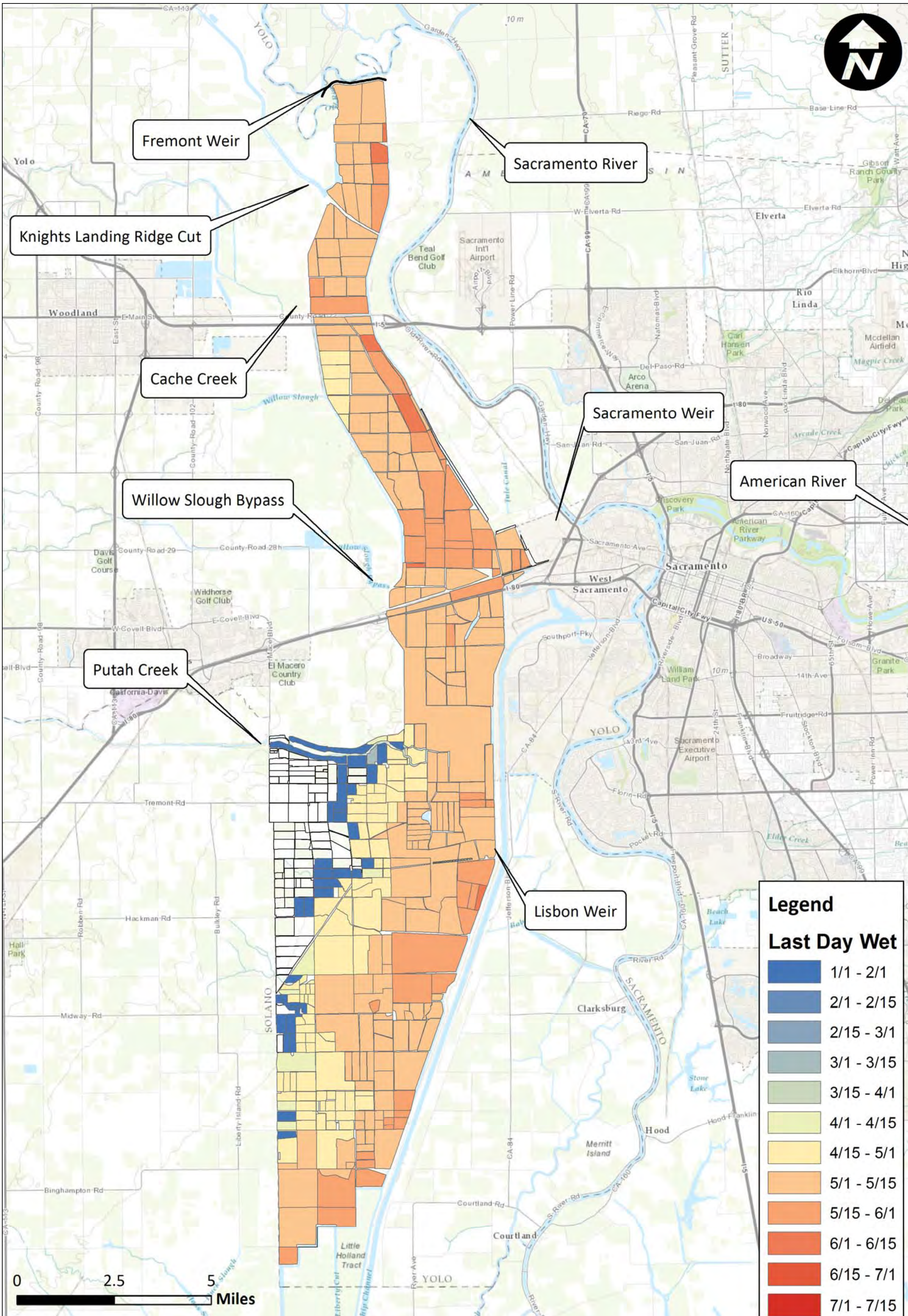
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

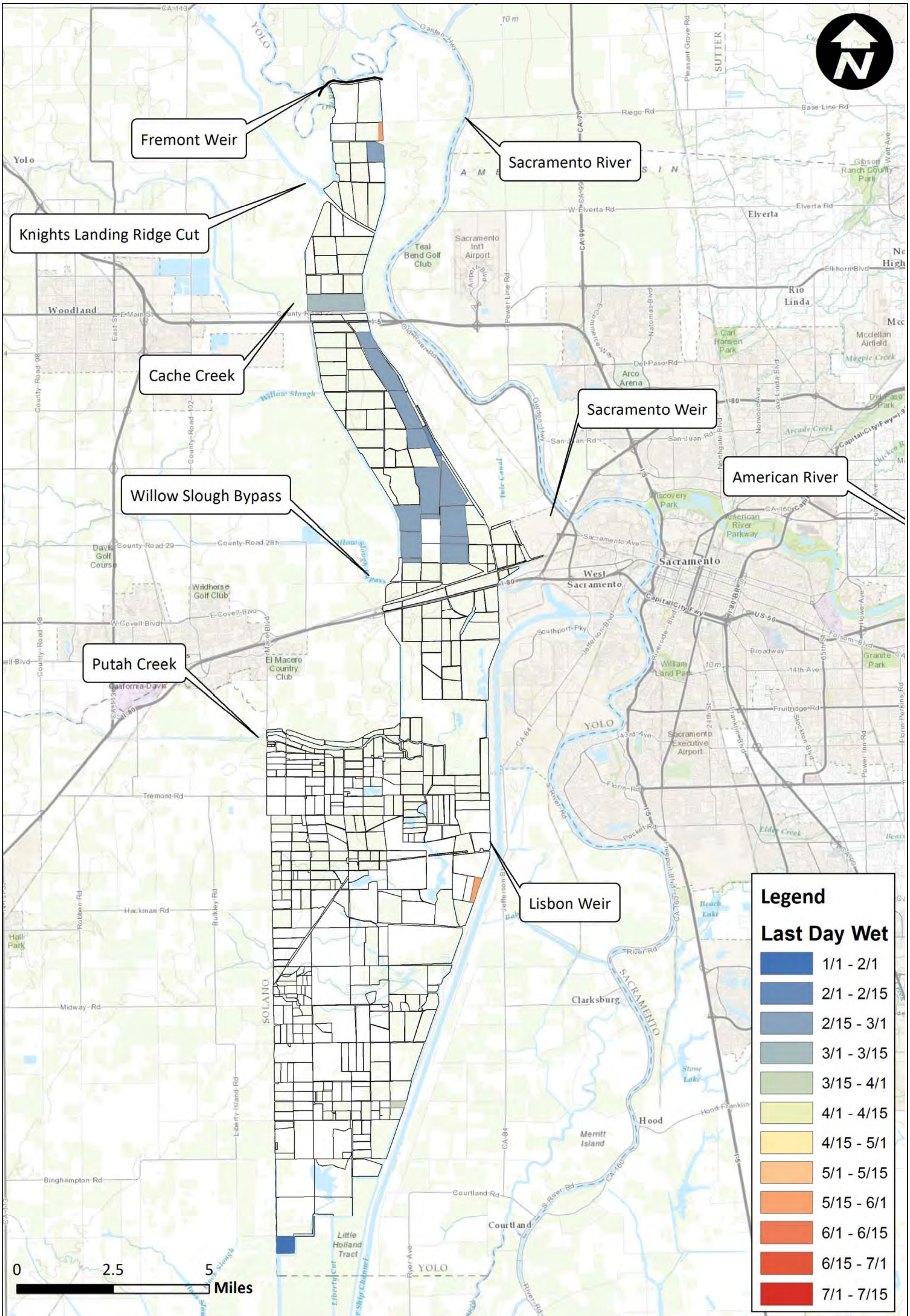
Last Day Wet Existing Conditions 2005

Prepared for DWR | Created By: RDJ

Figure F9



Notes:	HDR cbec	*Yolo Bypass Salmonid Habitat Restoration and Fish Passage* **Last Day Wet Existing Conditions 2006**		
		Prepared for DWR	Created By: RDJ	**Figure F10**



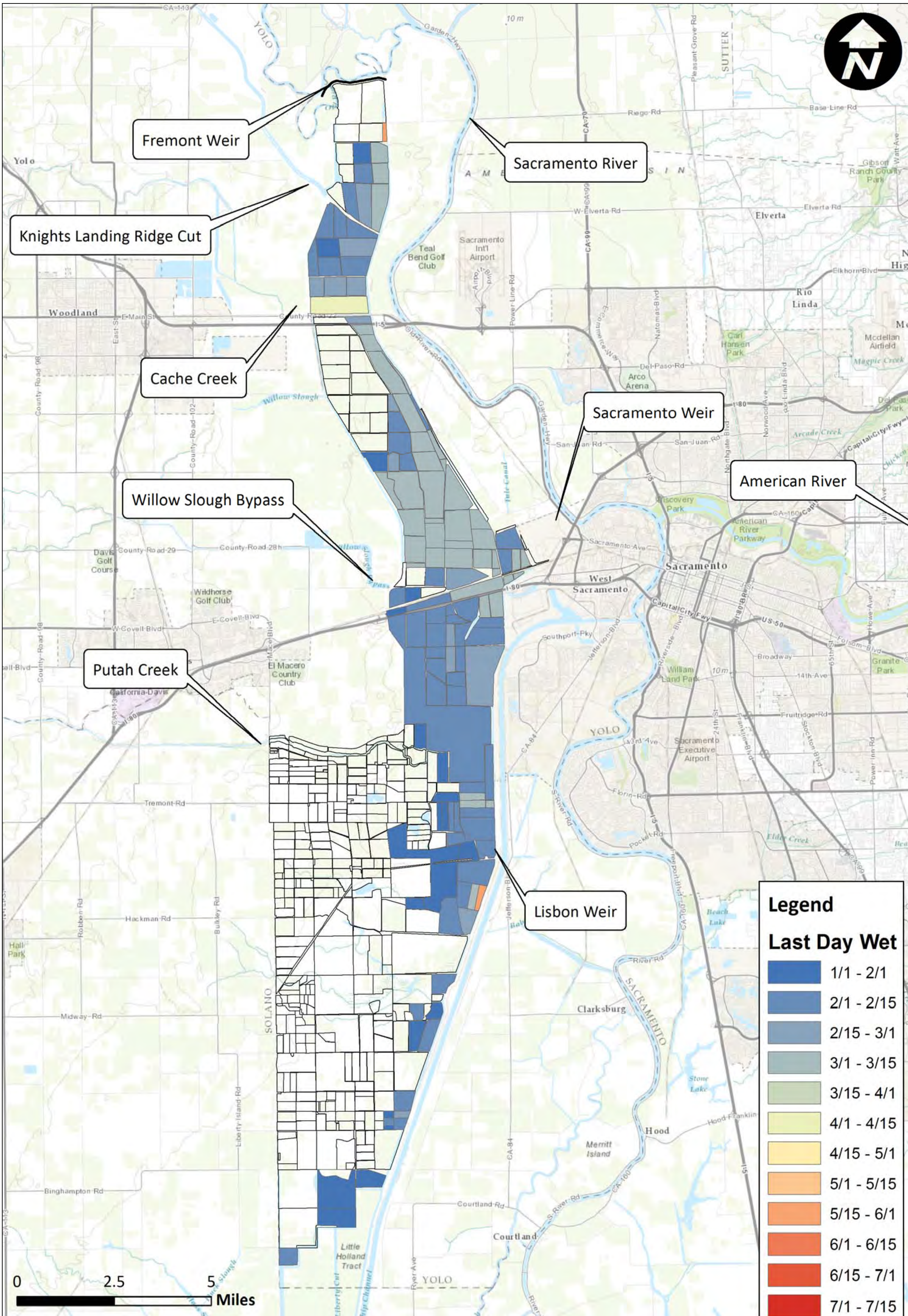
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2007

Prepared for DWR | Created By: RDJ

Figure F11



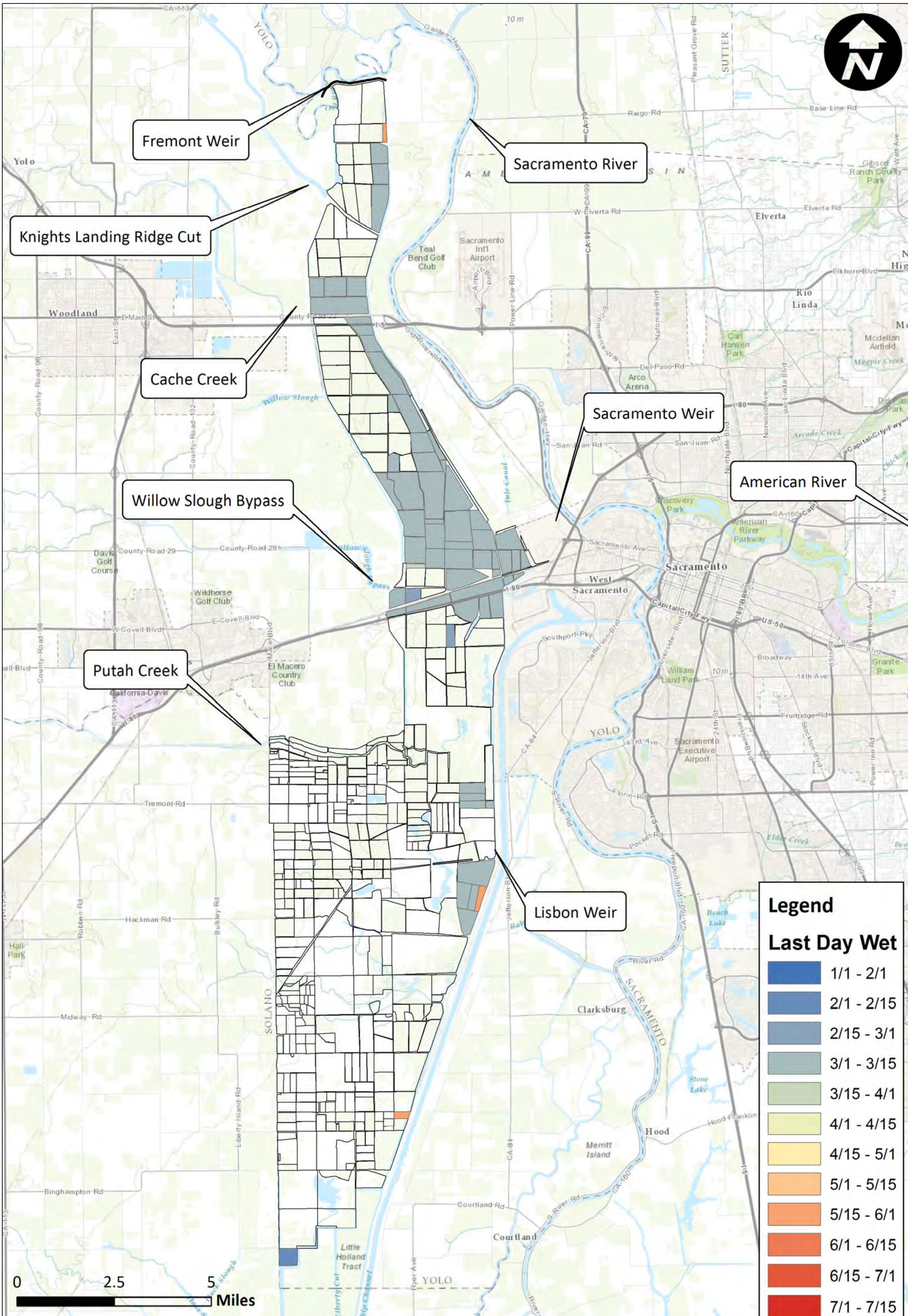
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2008

Prepared for DWR | Created By: RDJ

Figure F12



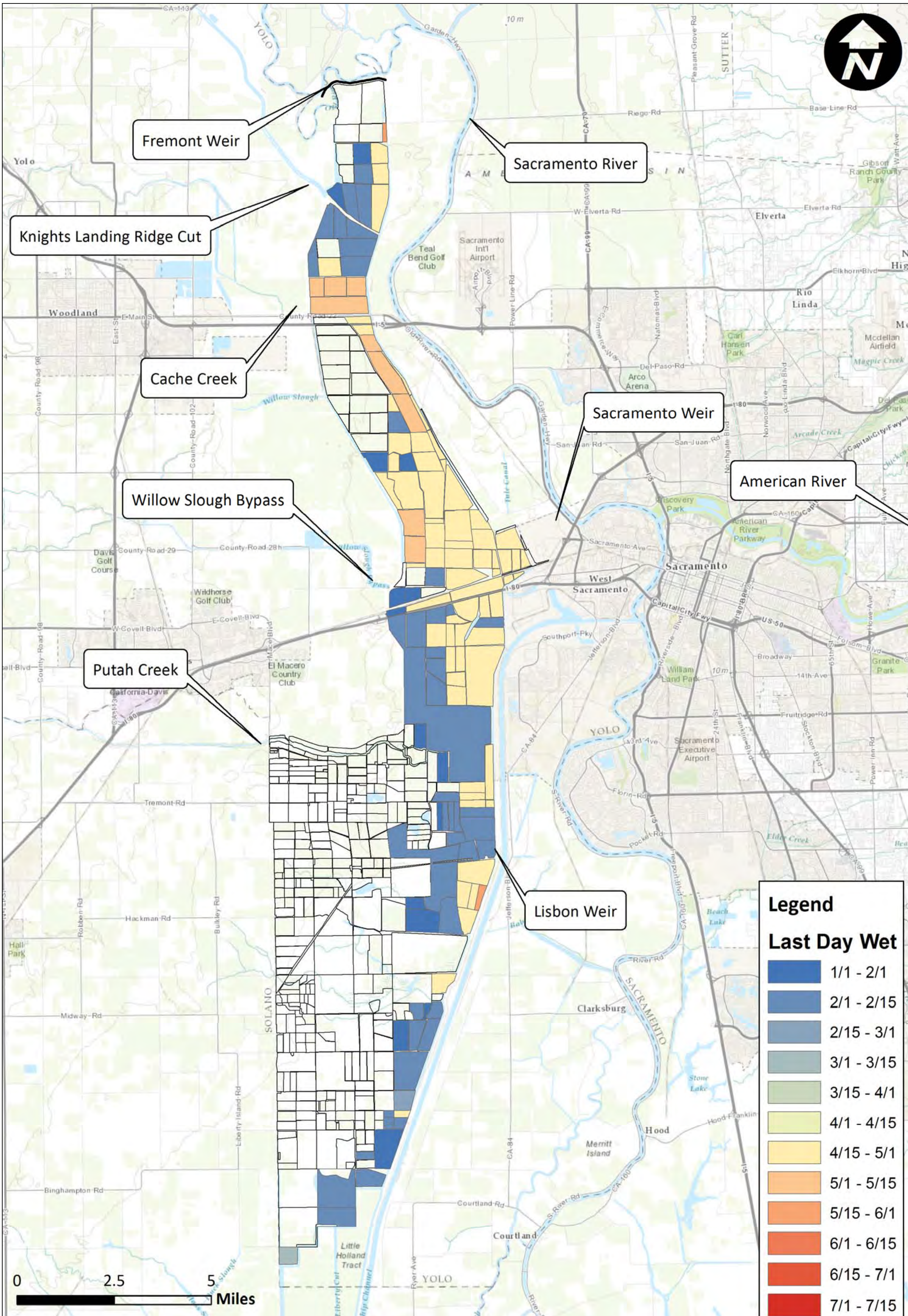
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2009

Prepared for DWR | Created By: RDJ

Figure F13



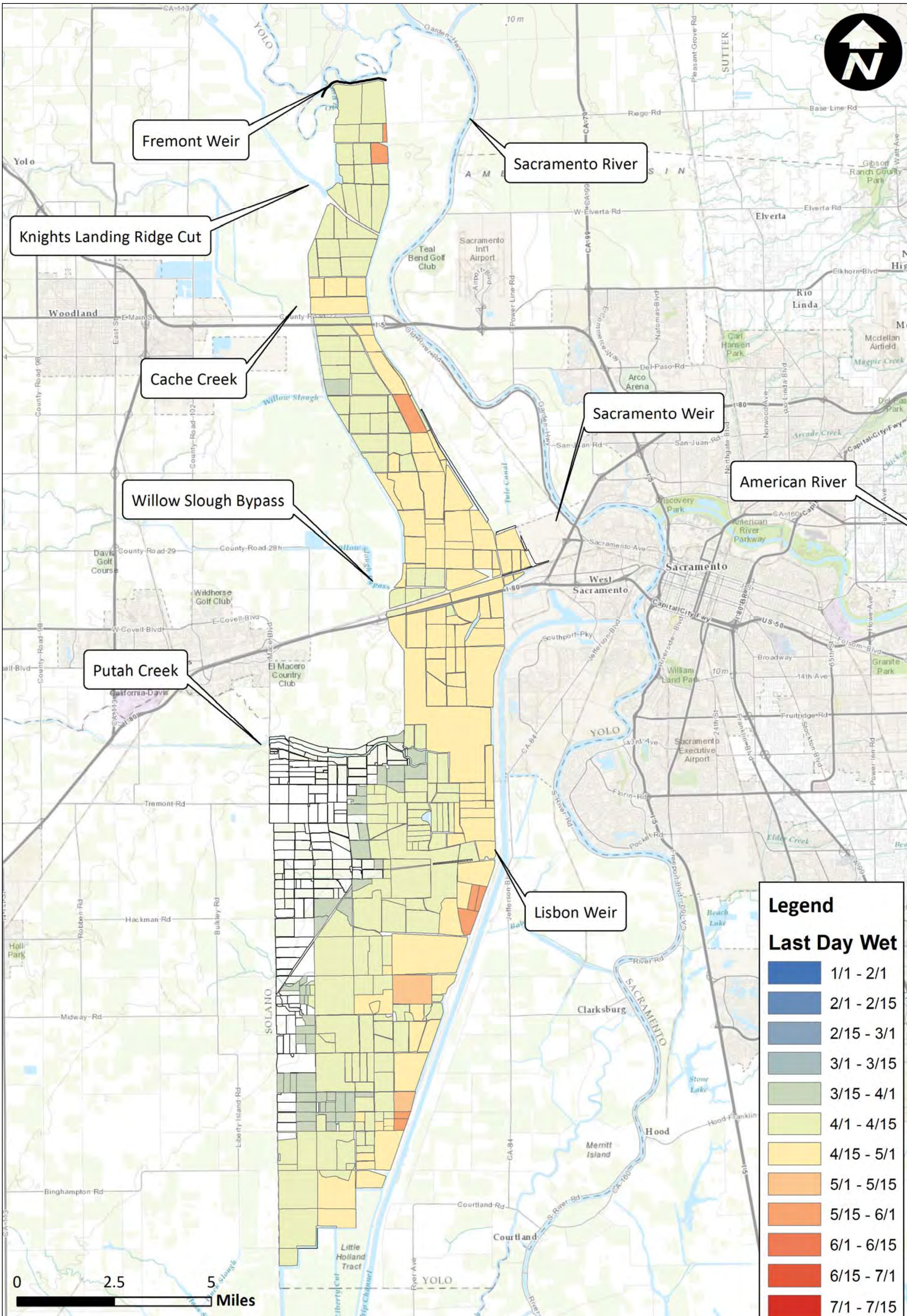
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2010

Prepared for DWR | Created By: RDJ

Figure F14



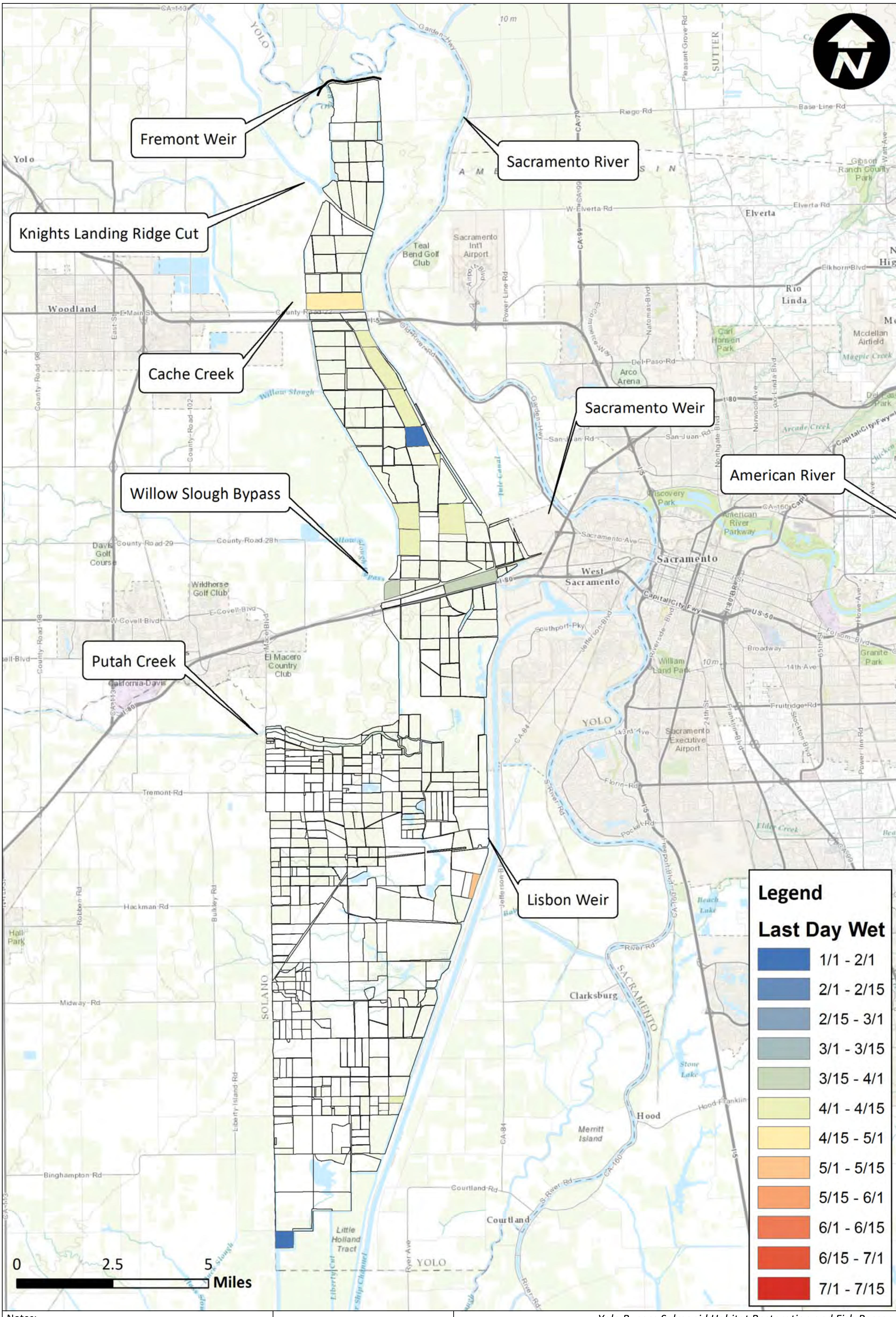
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2011

Prepared for DWR | Created By: RDJ

Figure F15



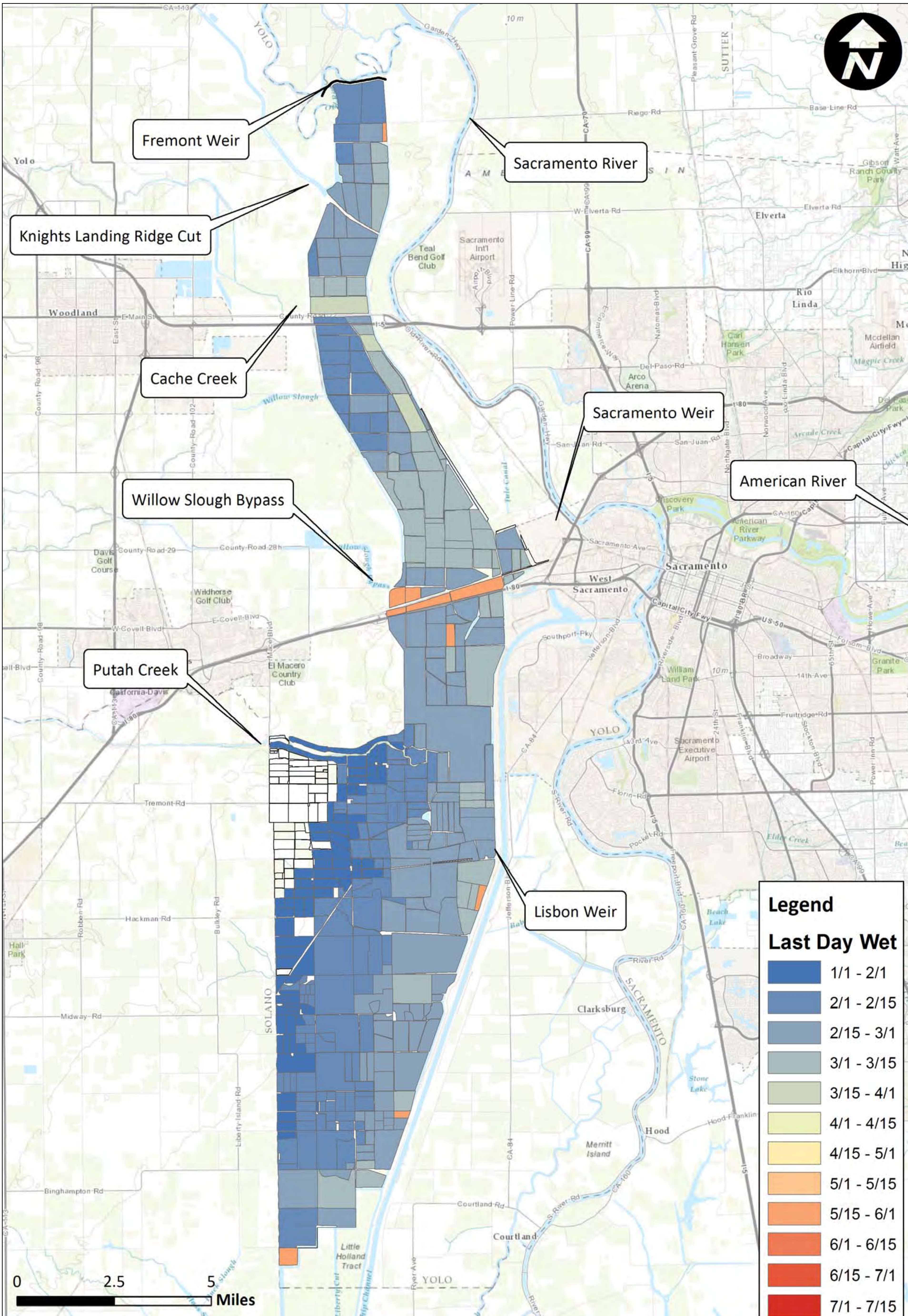
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Existing Conditions 2012

Prepared for DWR | Created By: RDJ

Figure F16



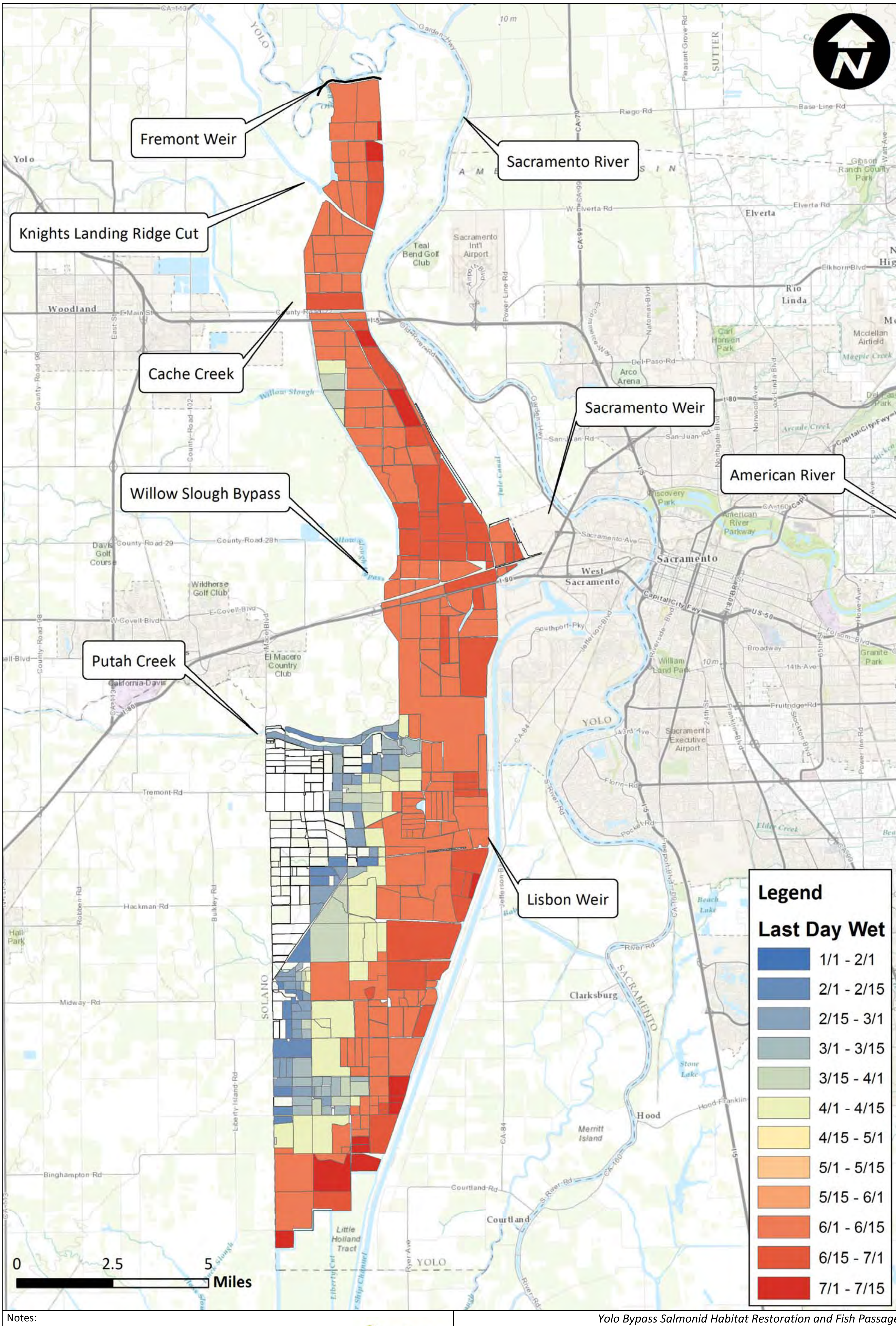
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 1997

Prepared for DWR | Created By: RDJ

Figure F17

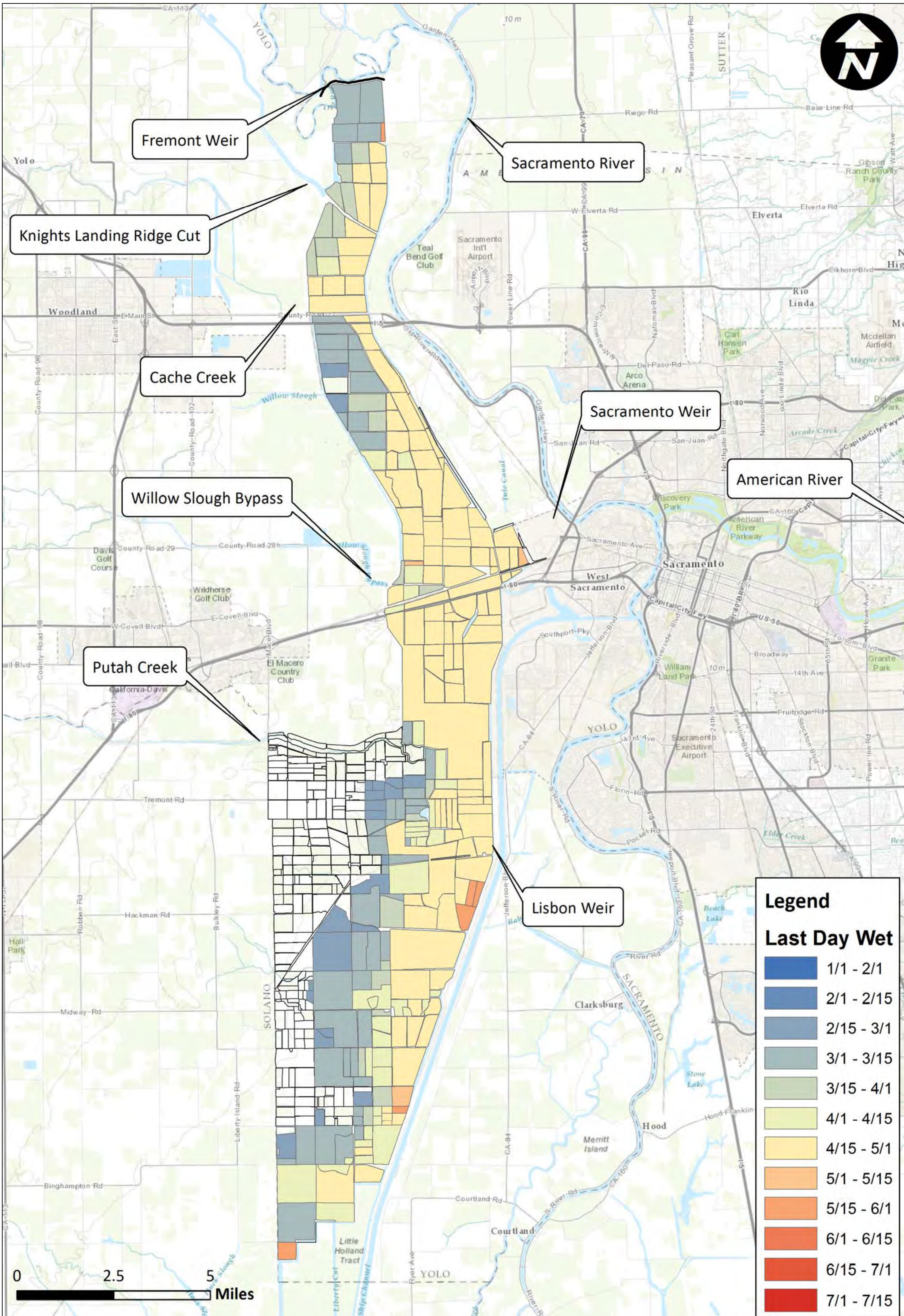


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 1998

Prepared for DWR	Created By: RDJ	**Figure F18**



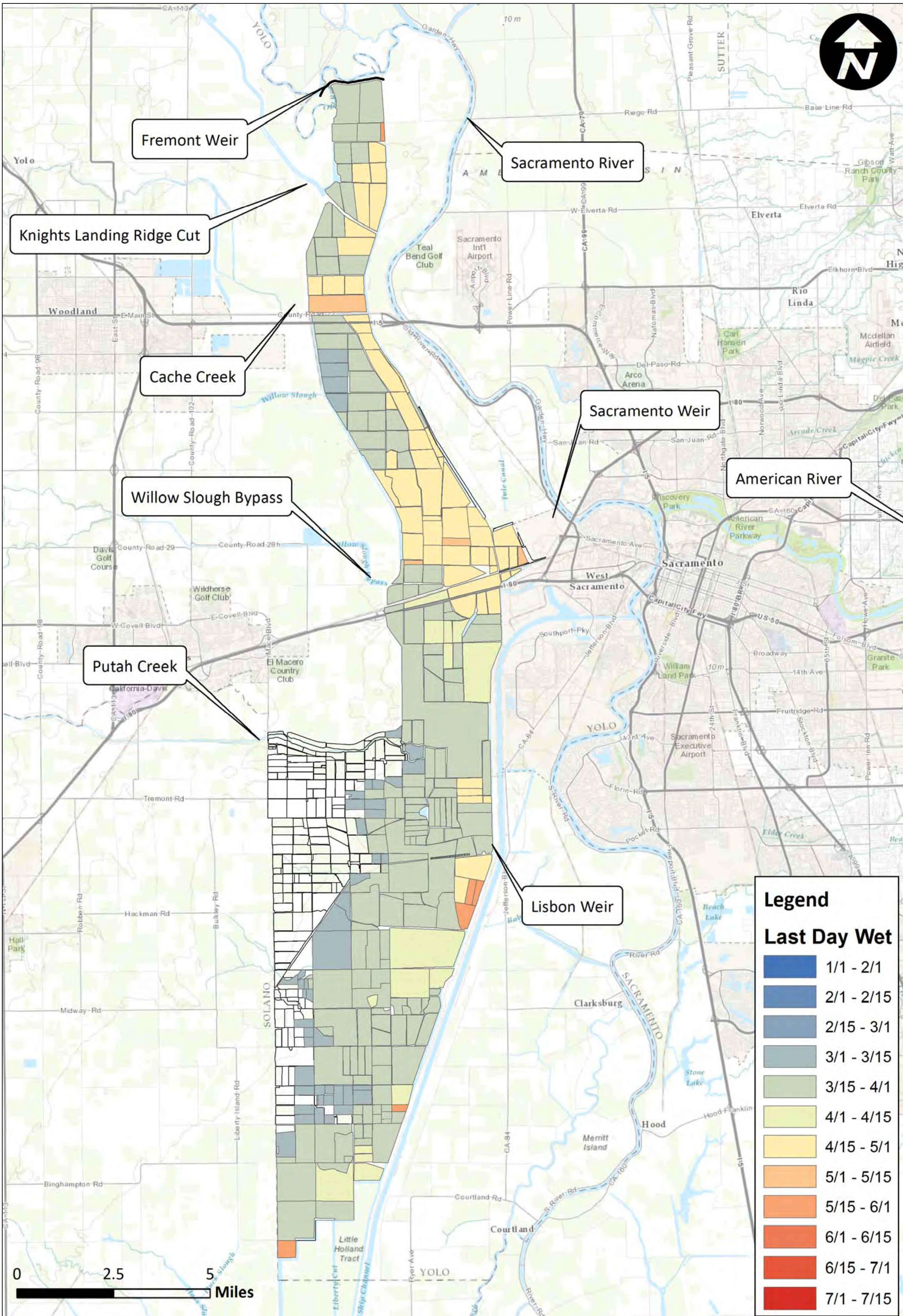
Notes:

HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 1999

Prepared for DWR | Created By: RDJ | **Figure F19**



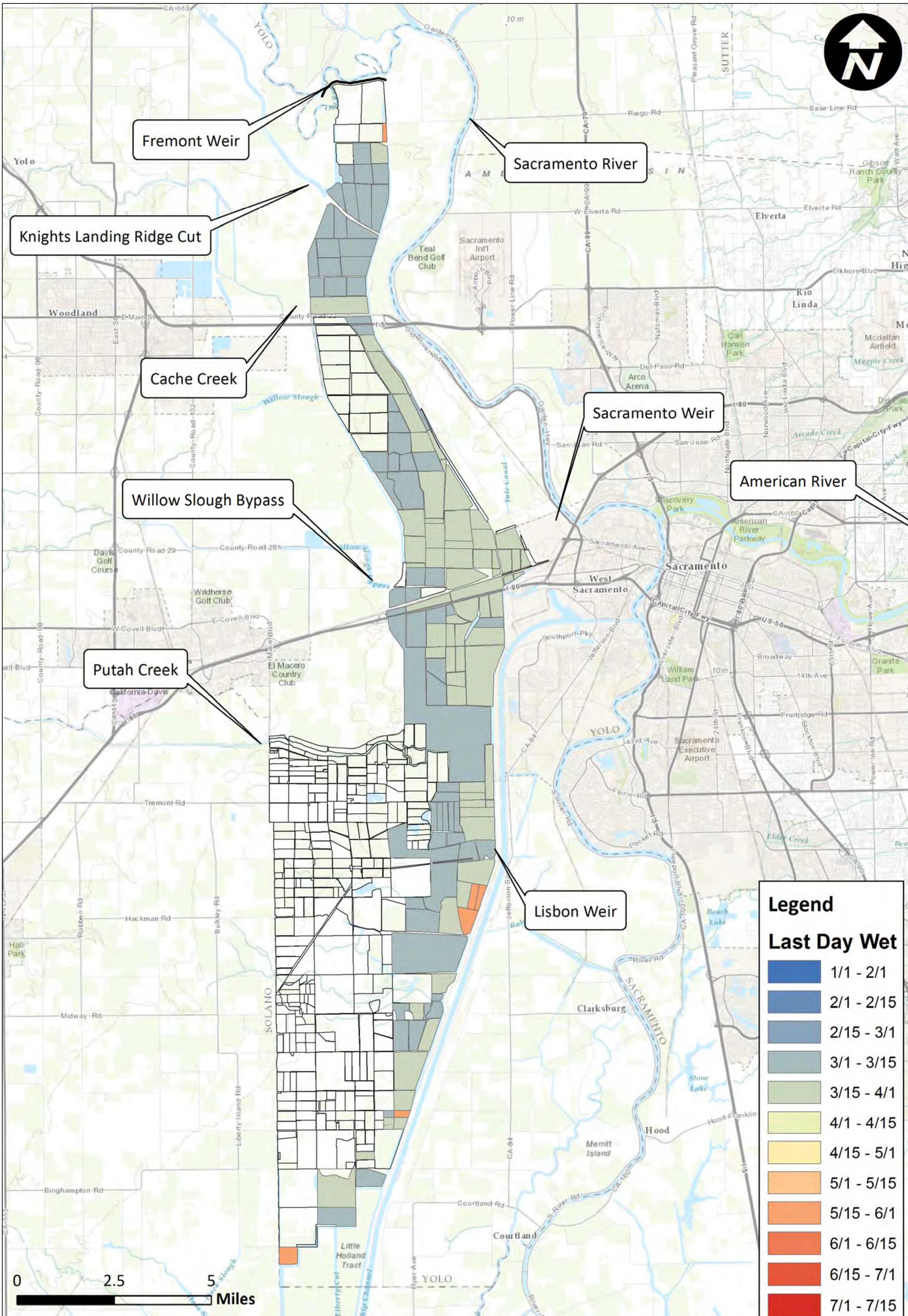
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2000

Prepared for DWR | Created By: RDJ

Figure F20



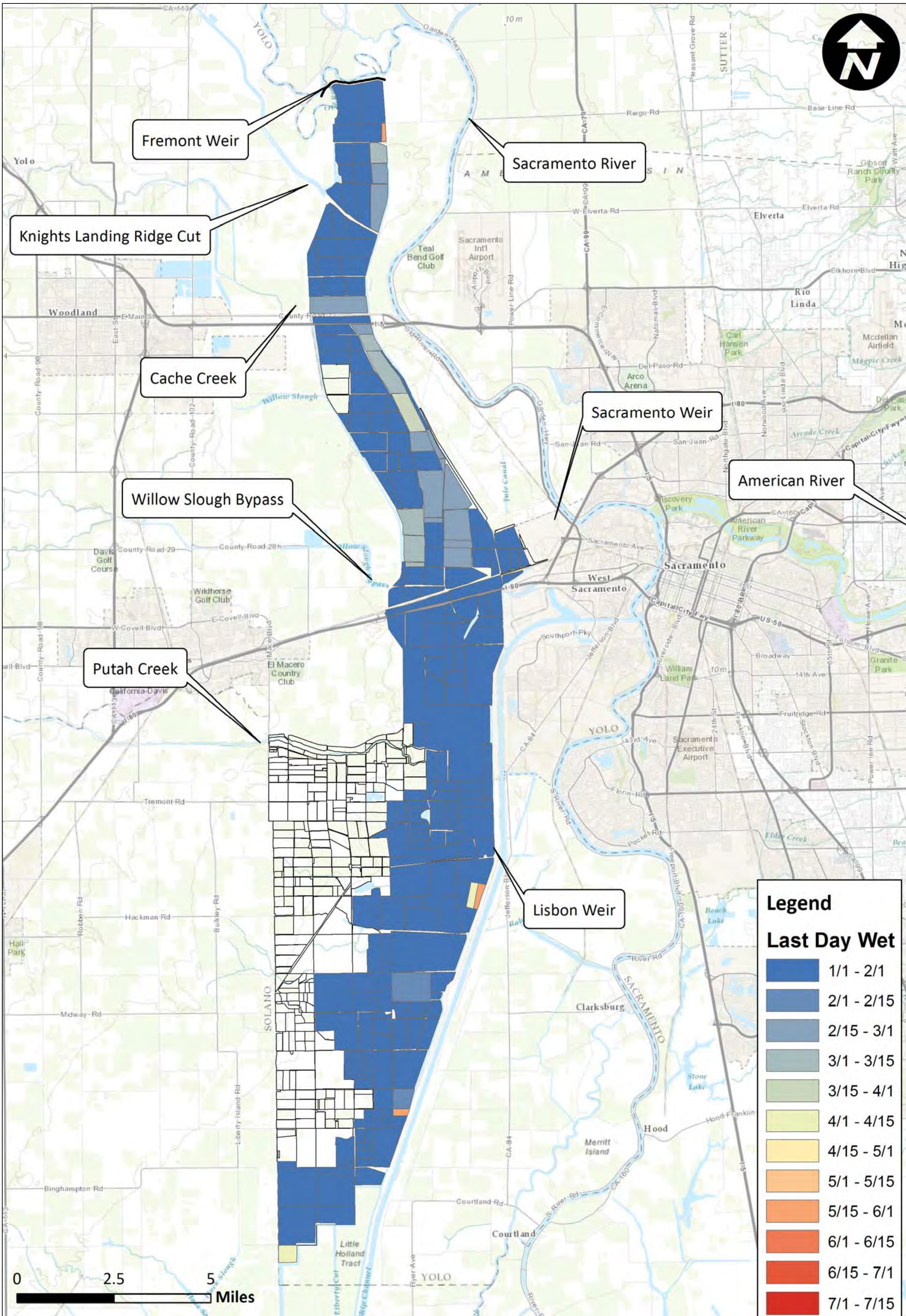
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2001

Prepared for DWR | Created By: RDJ

Figure F21



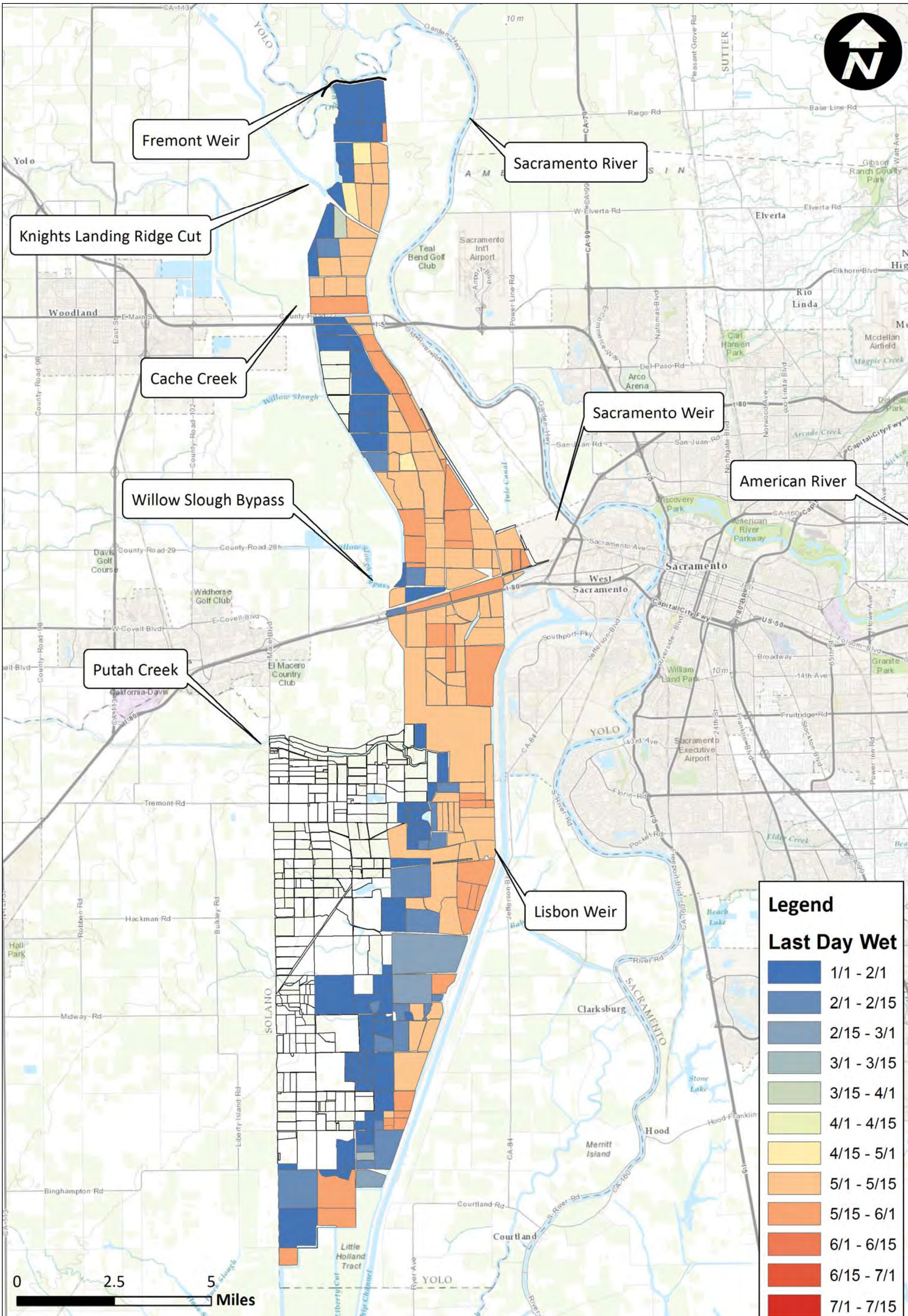
Notes:

HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2002

Prepared for DWR | Created By: RDJ | **Figure F22**



Notes:

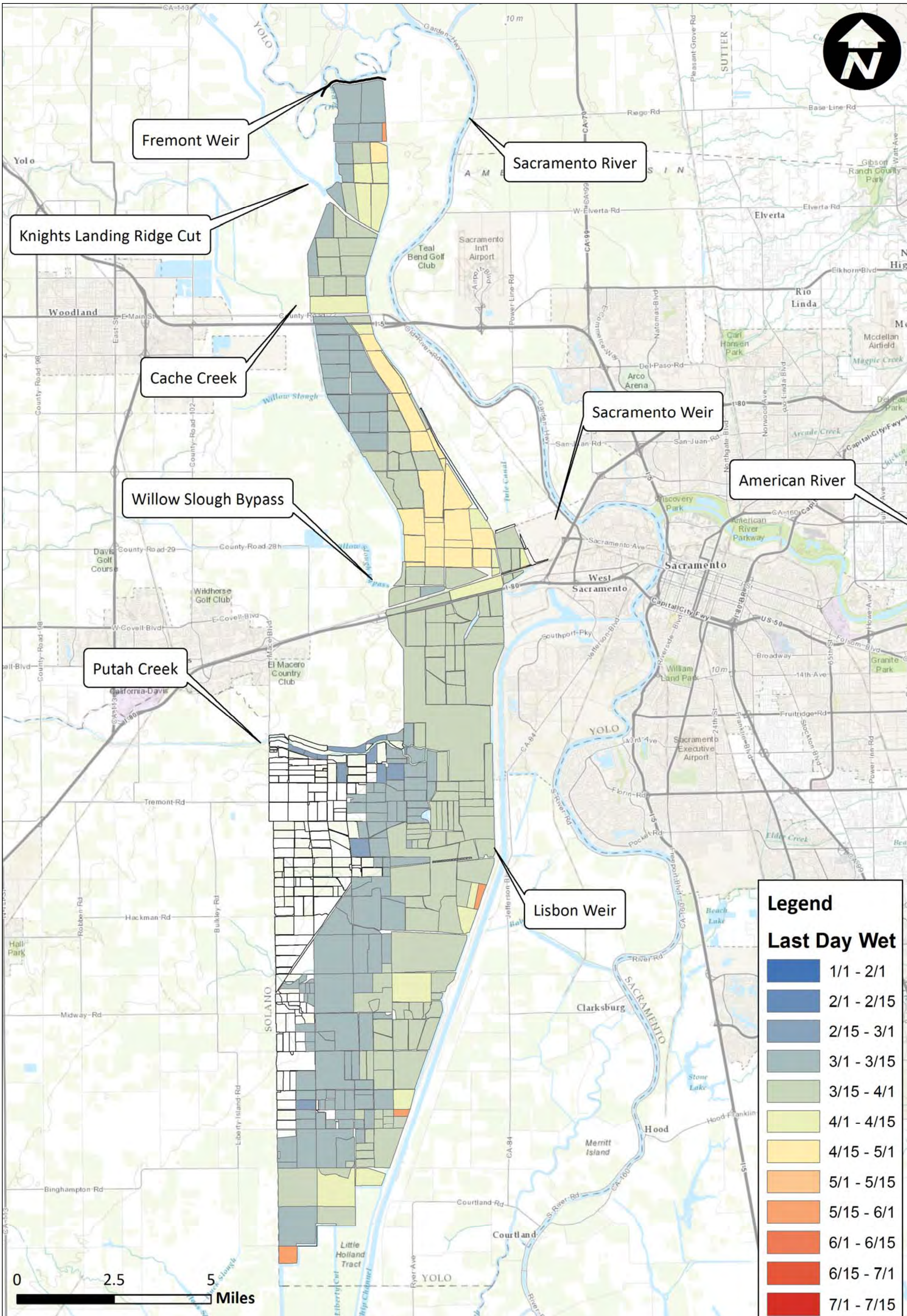
HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2003

Prepared for DWR | Created By: RDJ

Figure F23

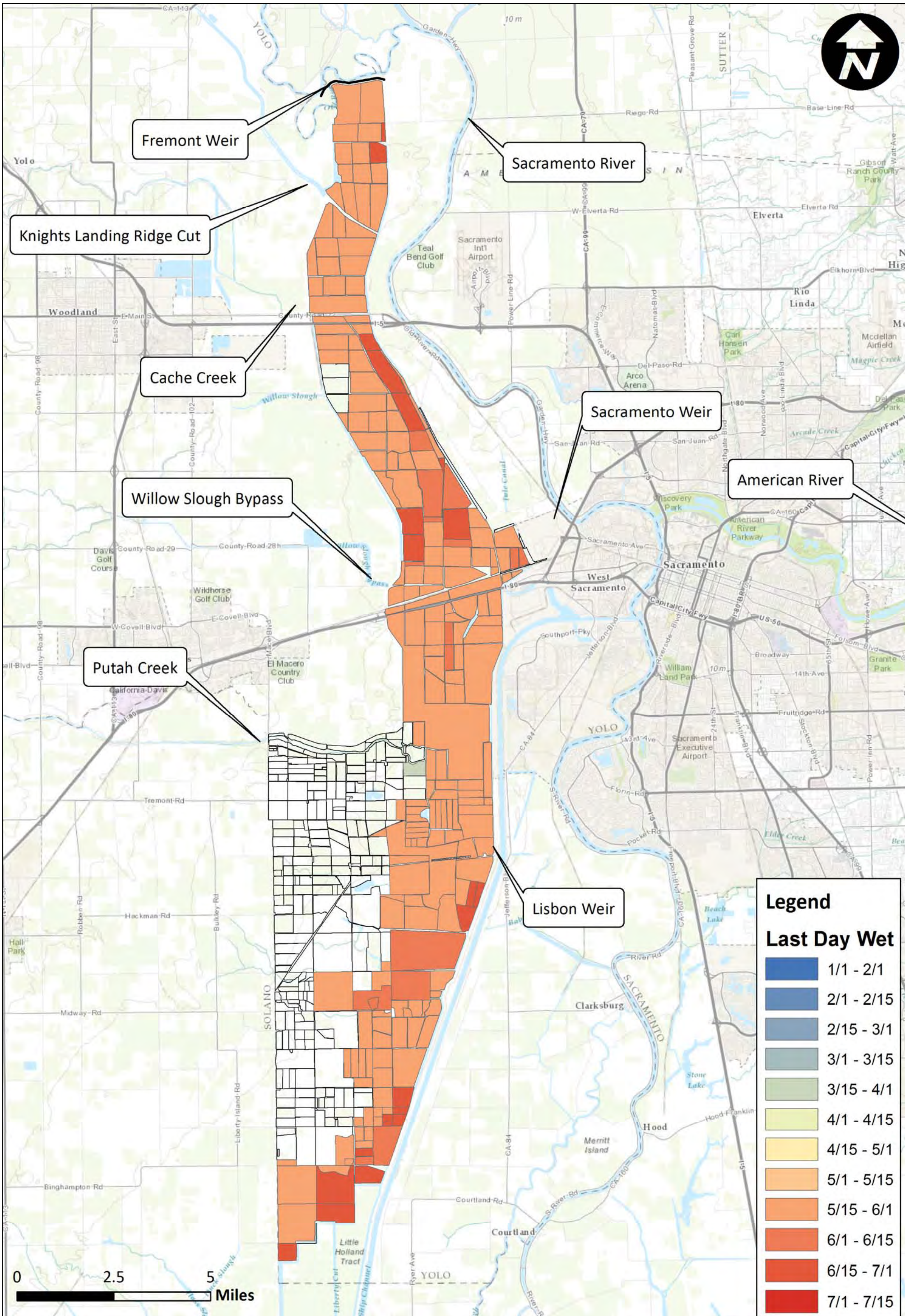


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2004

Prepared for DWR | Created By: RDJ | **Figure F24**



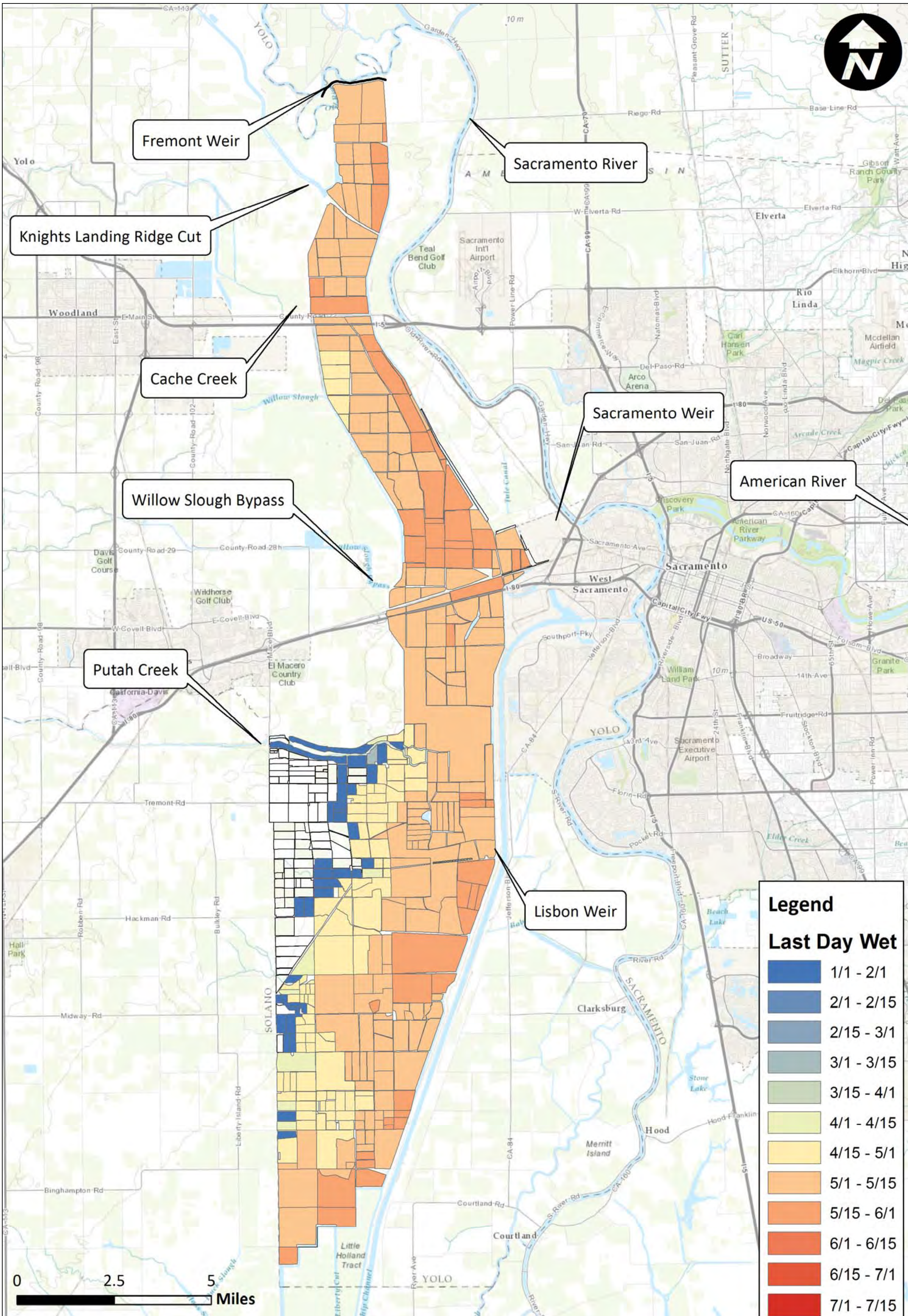
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2005

Prepared for DWR | Created By: RDJ

Figure F25

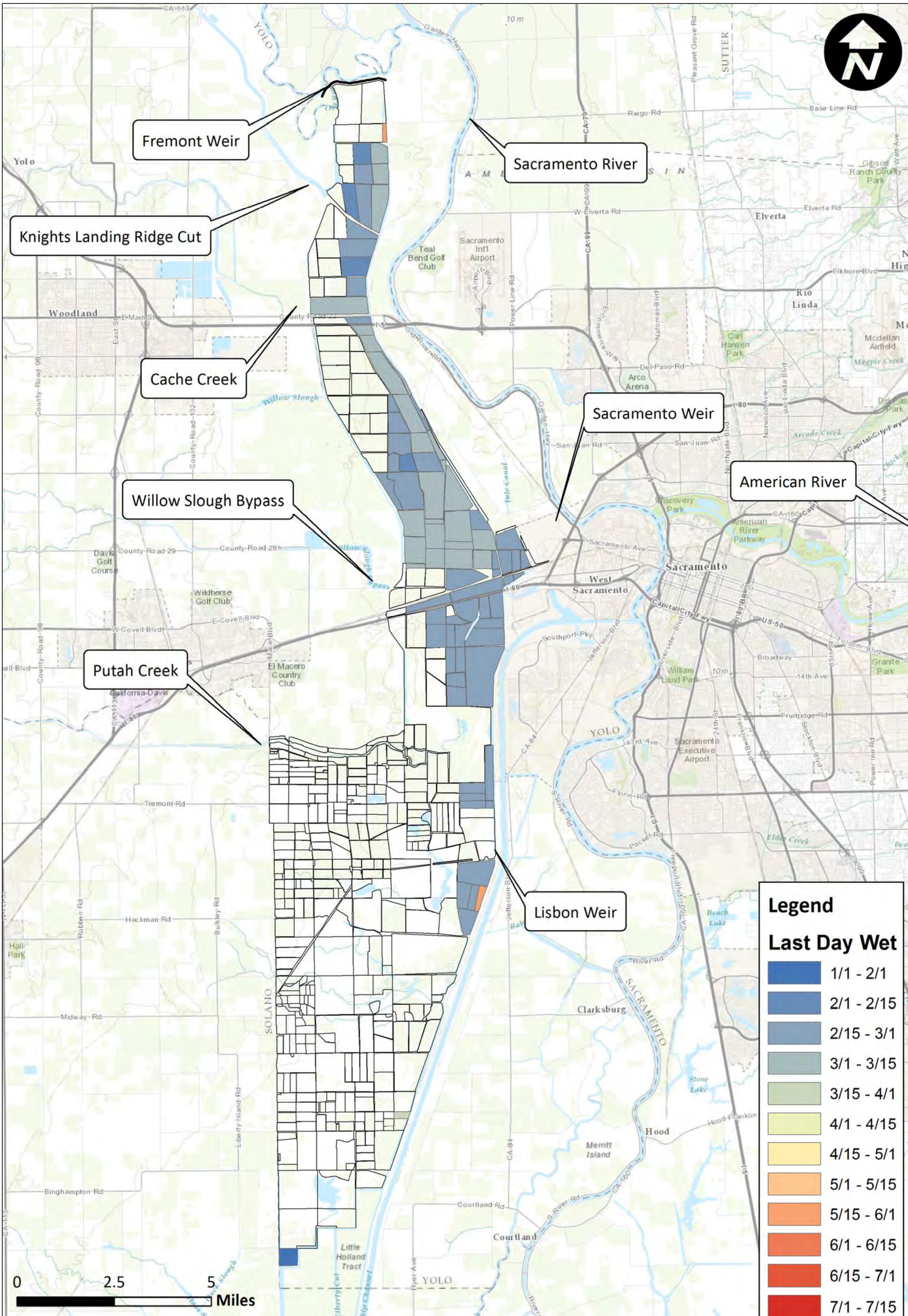


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2006

Prepared for DWR | Created By: RDJ | **Figure F26**



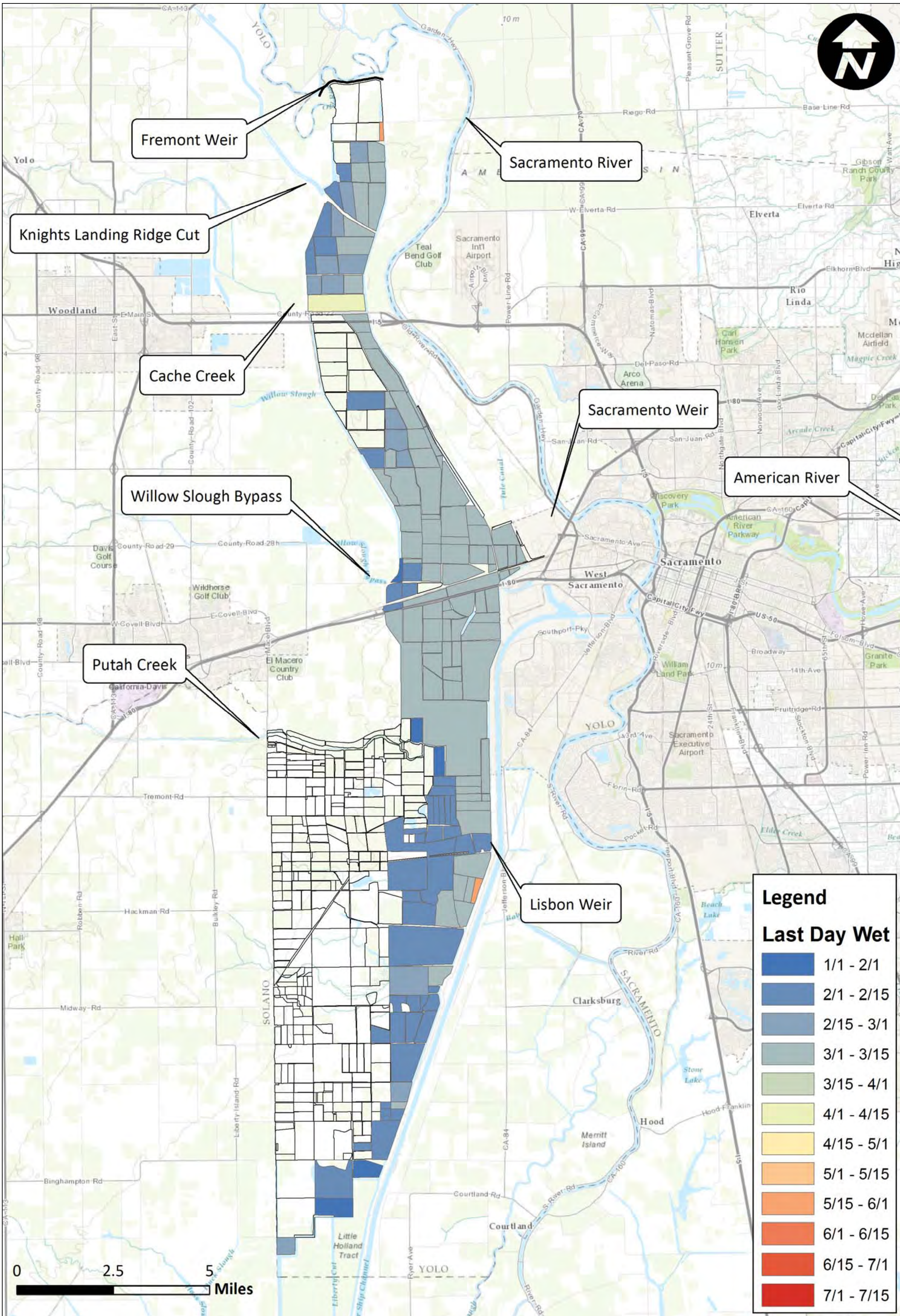
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2007

Prepared for DWR | Created By: RDJ

Figure F27



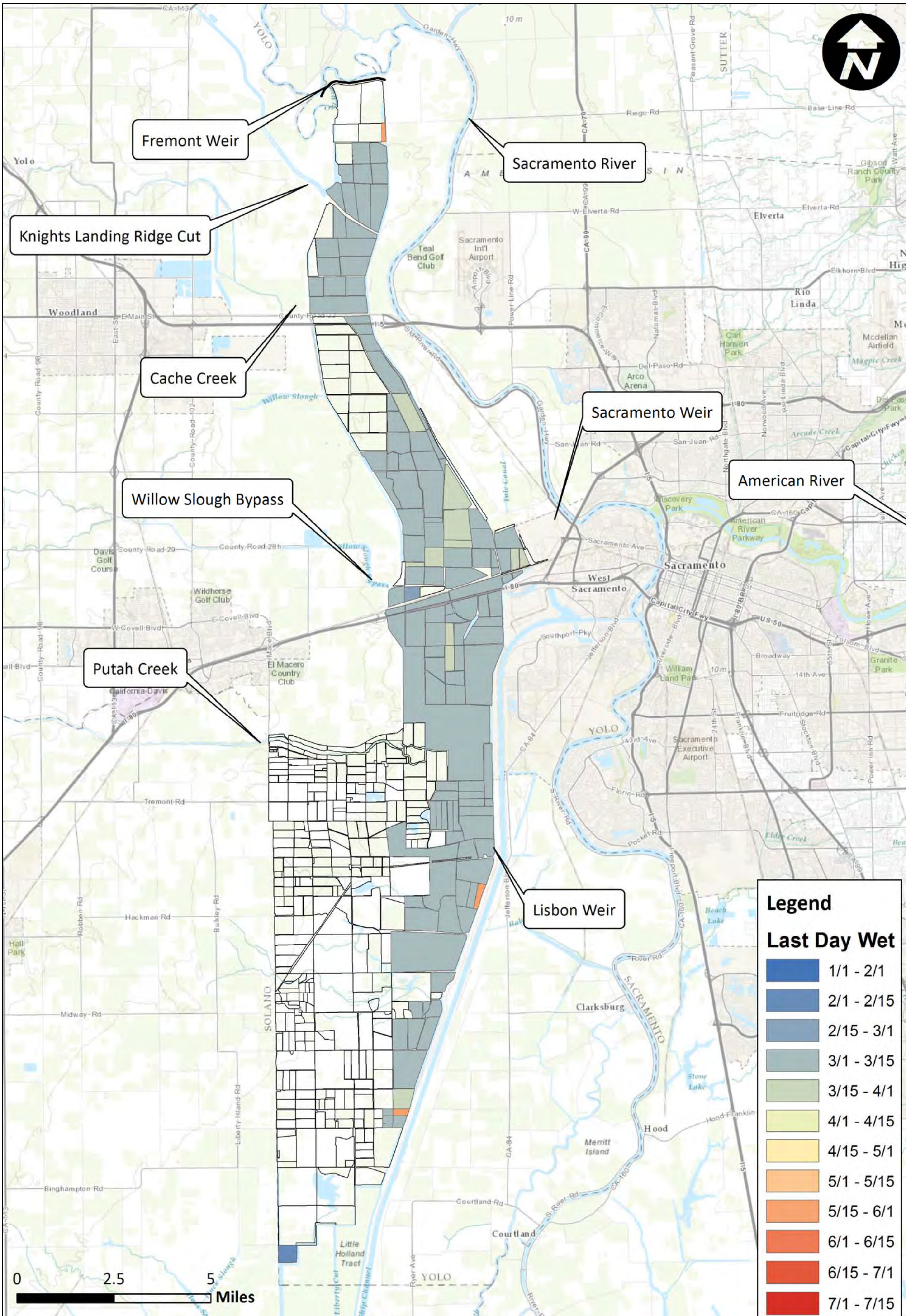
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2008

Prepared for DWR | Created By: RDJ

Figure F28

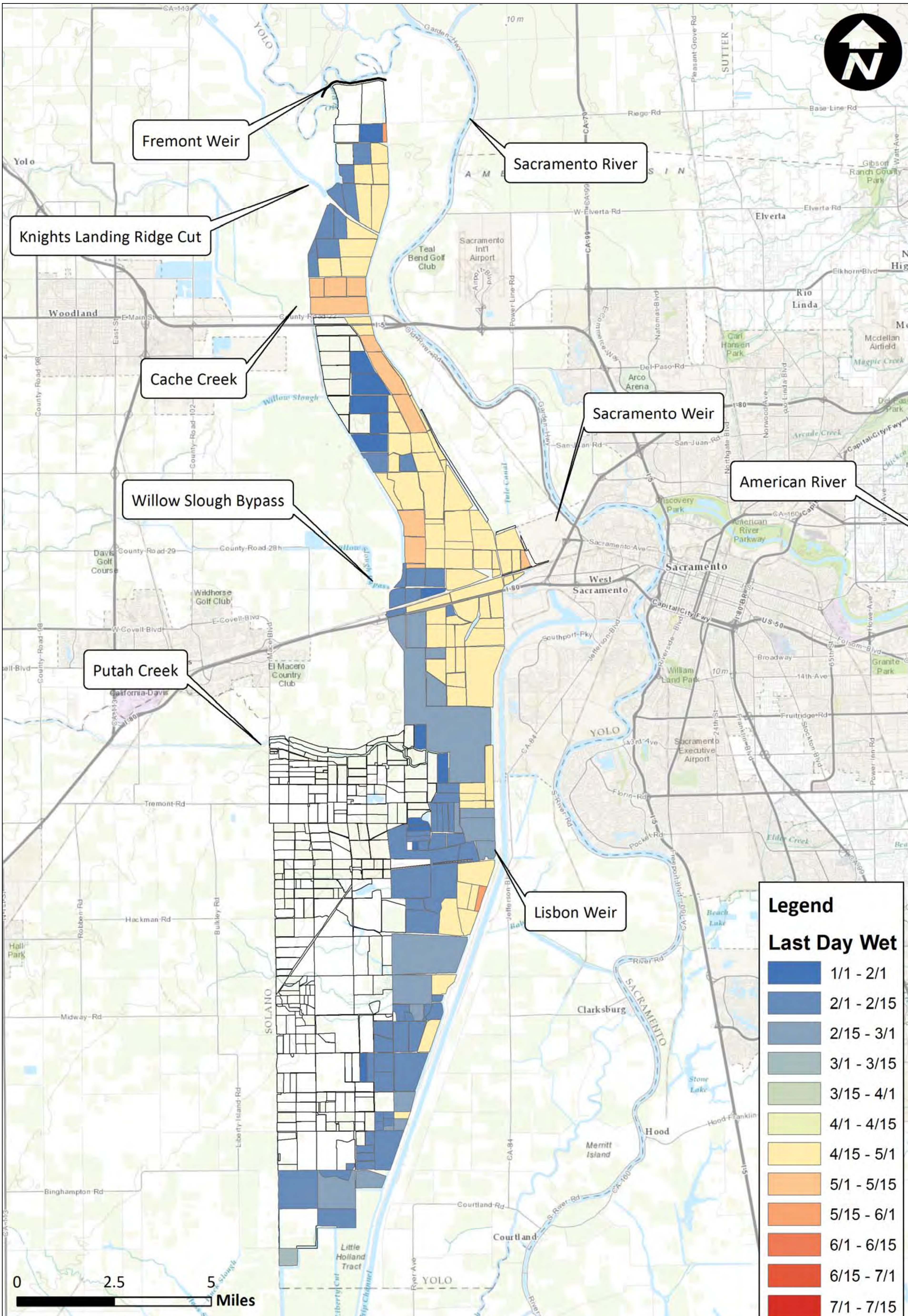


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2009

Prepared for DWR | Created By: RDJ | **Figure F29**



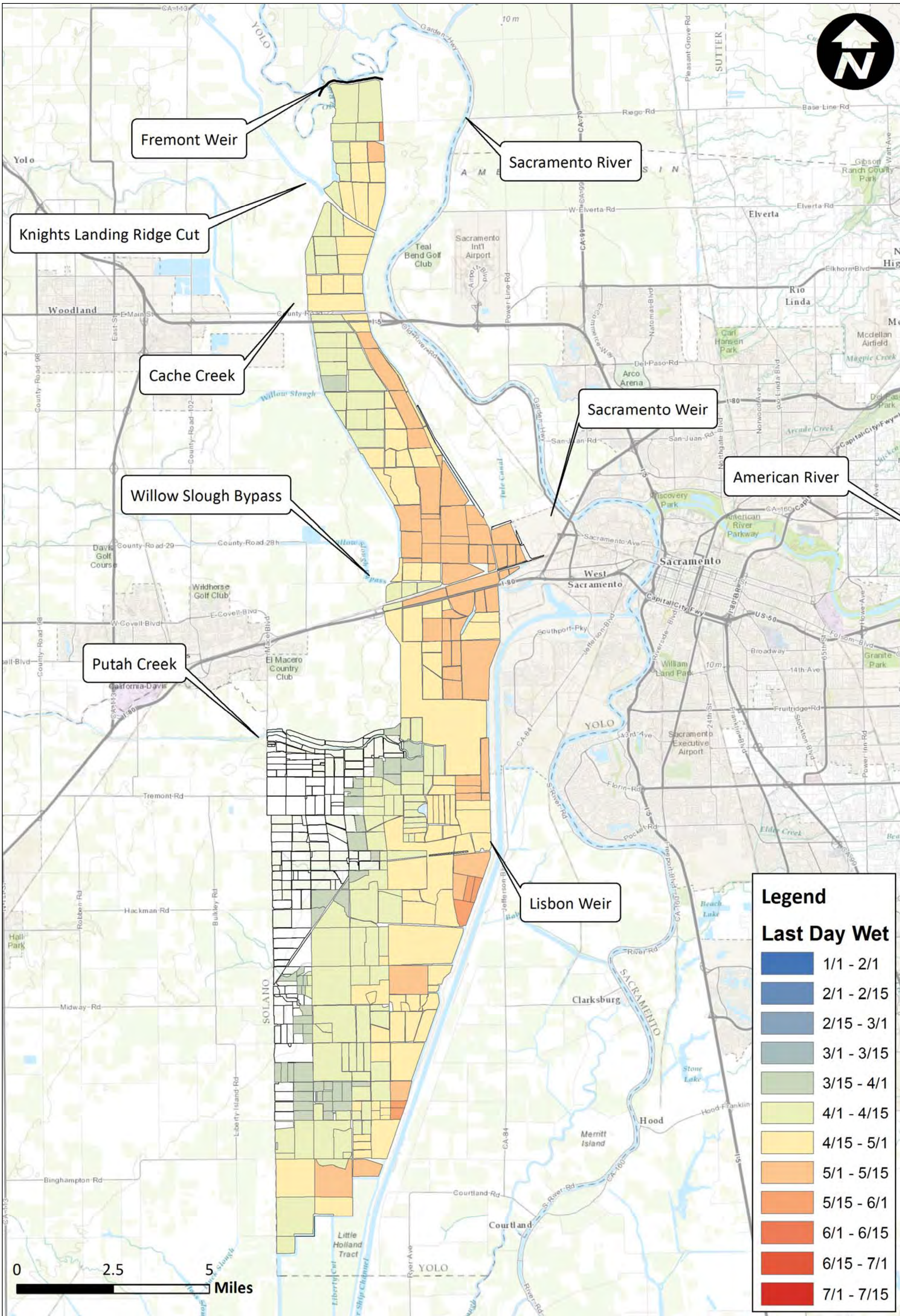
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2010

Prepared for DWR | Created By: RDJ

Figure F30



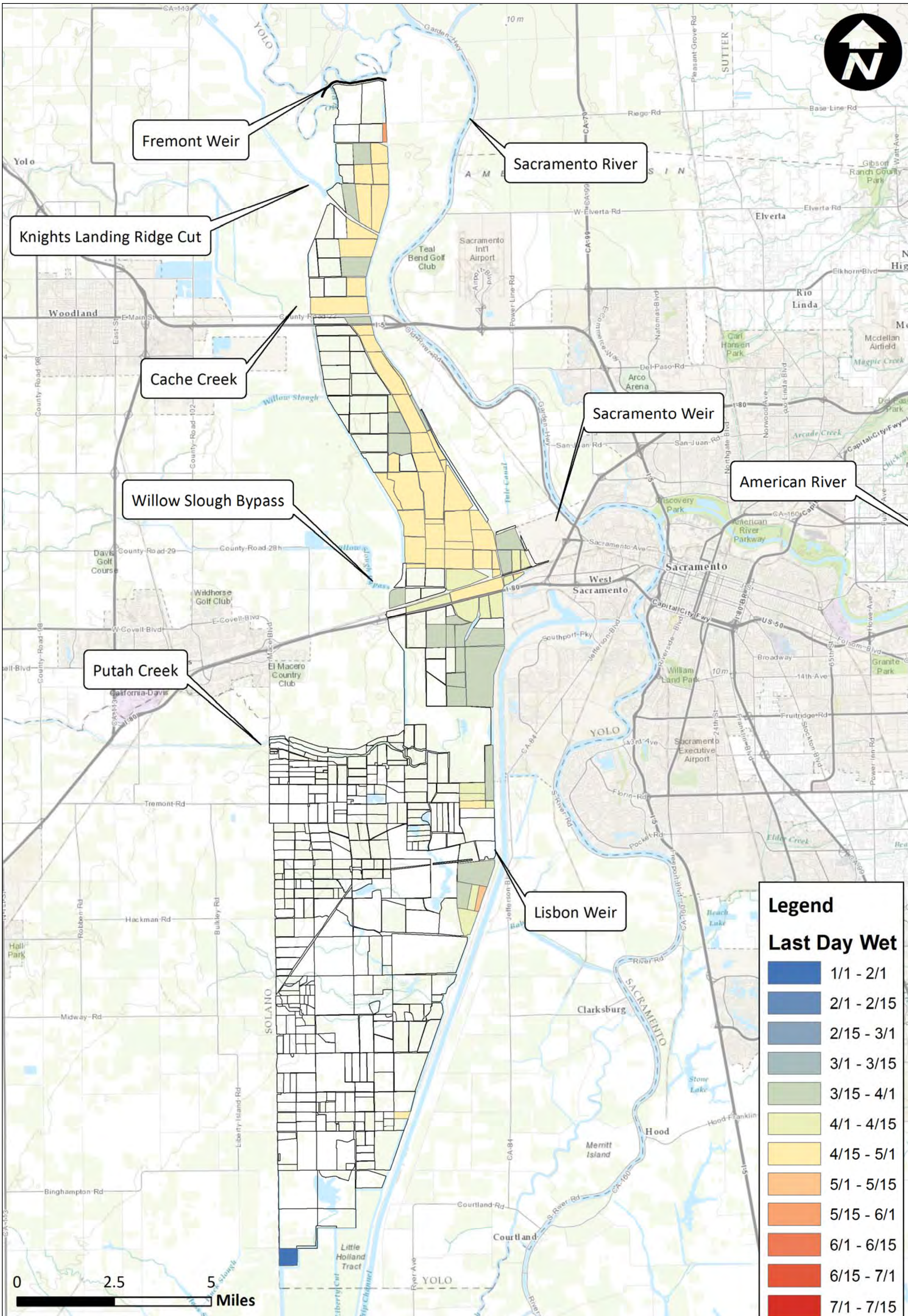
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2011

Prepared for DWR | Created By: RDJ

Figure F31

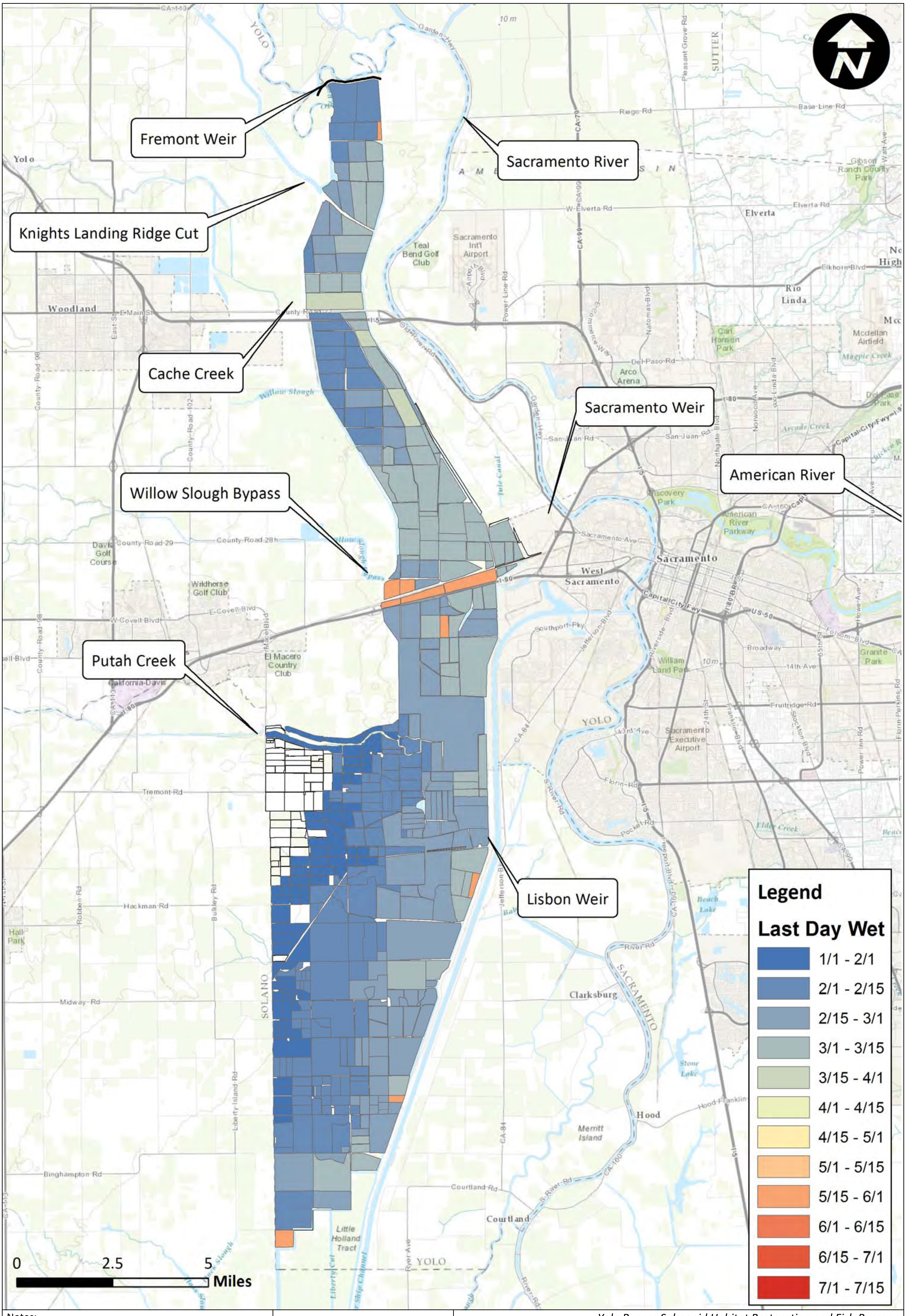


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Small Channel 2012

Prepared for DWR | Created By: RDJ | **Figure F32**



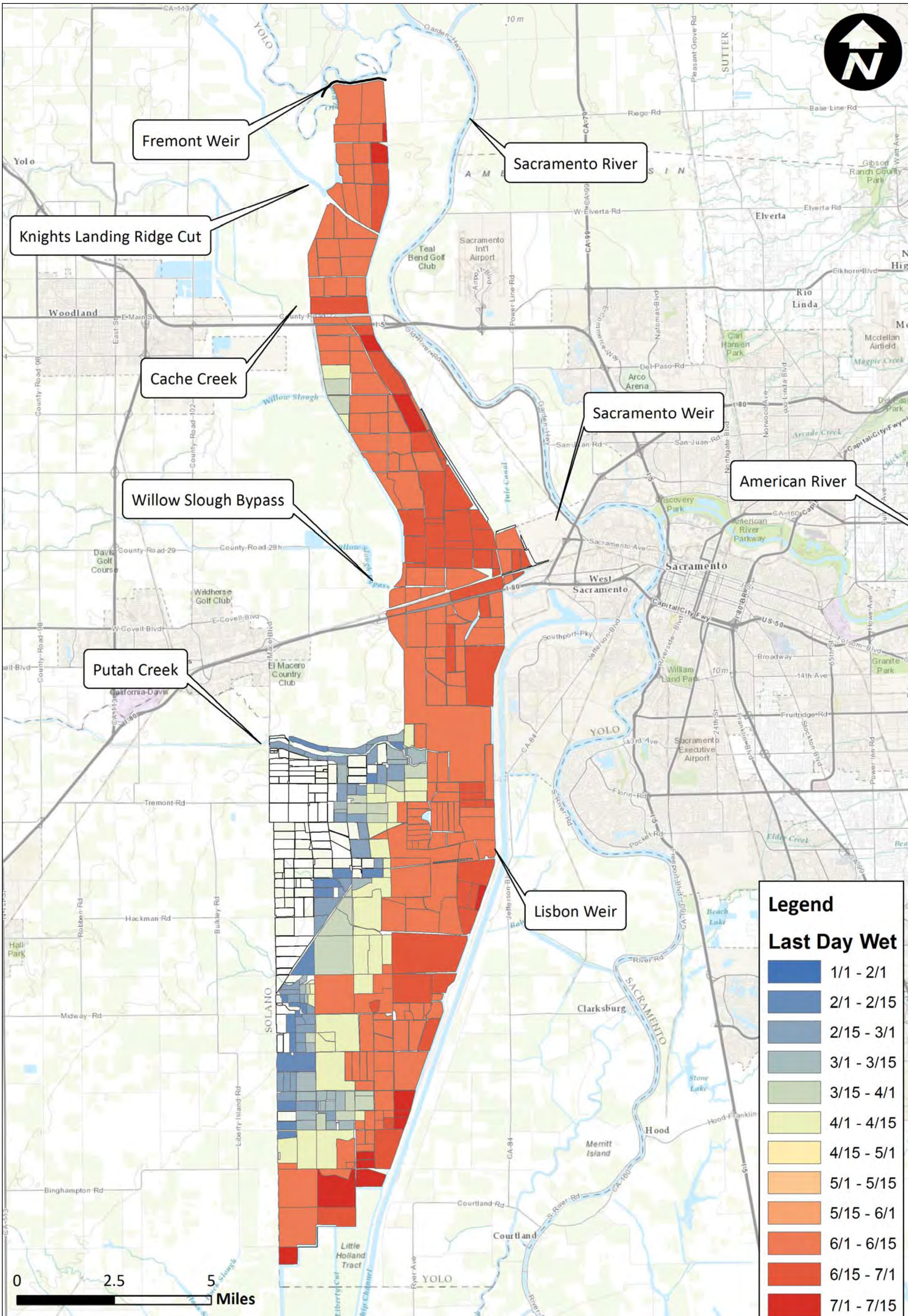
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 1997

Prepared for DWR | Created By: RDJ

Figure F33



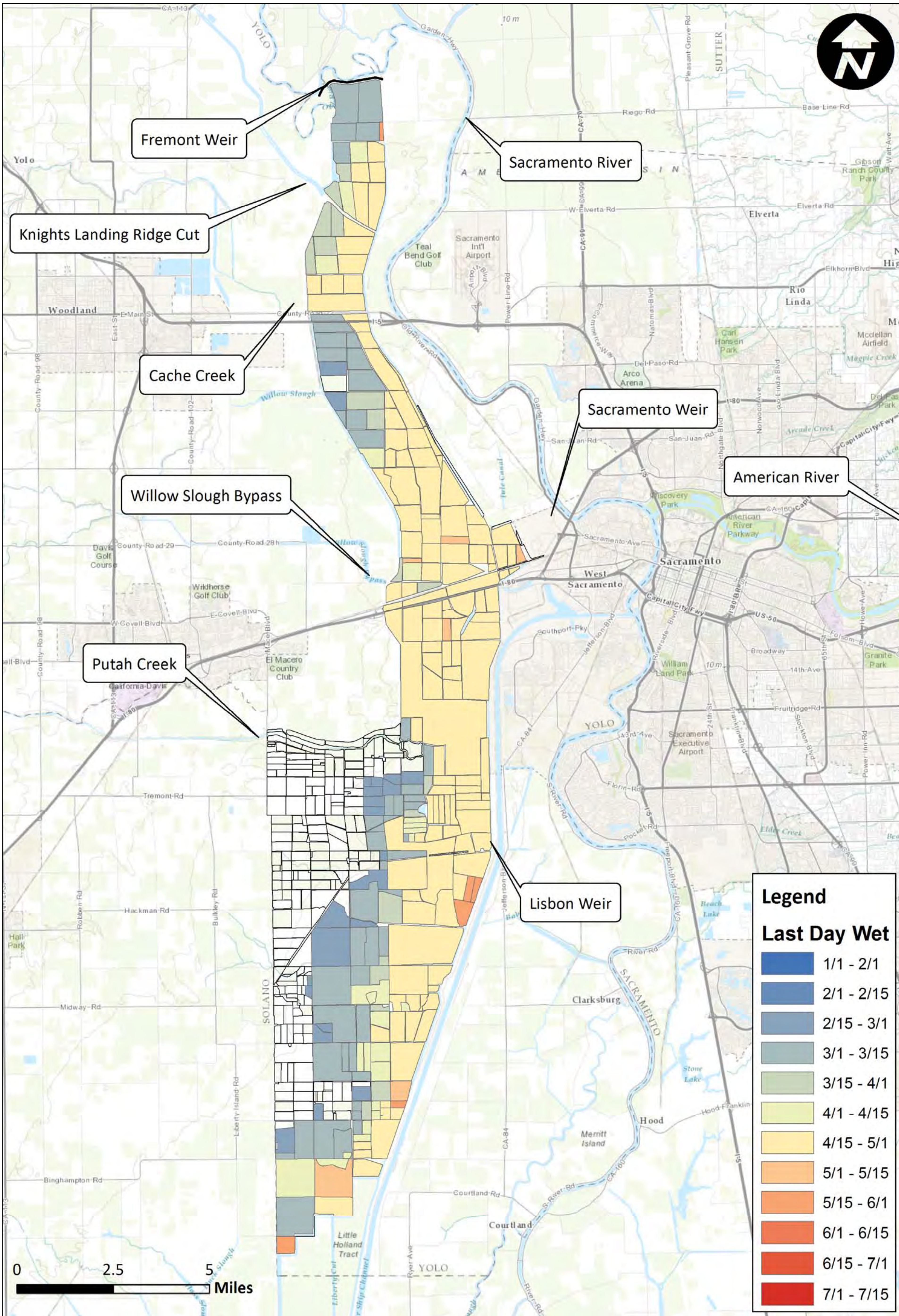
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 1998

Prepared for DWR | Created By: RDJ

Figure F34



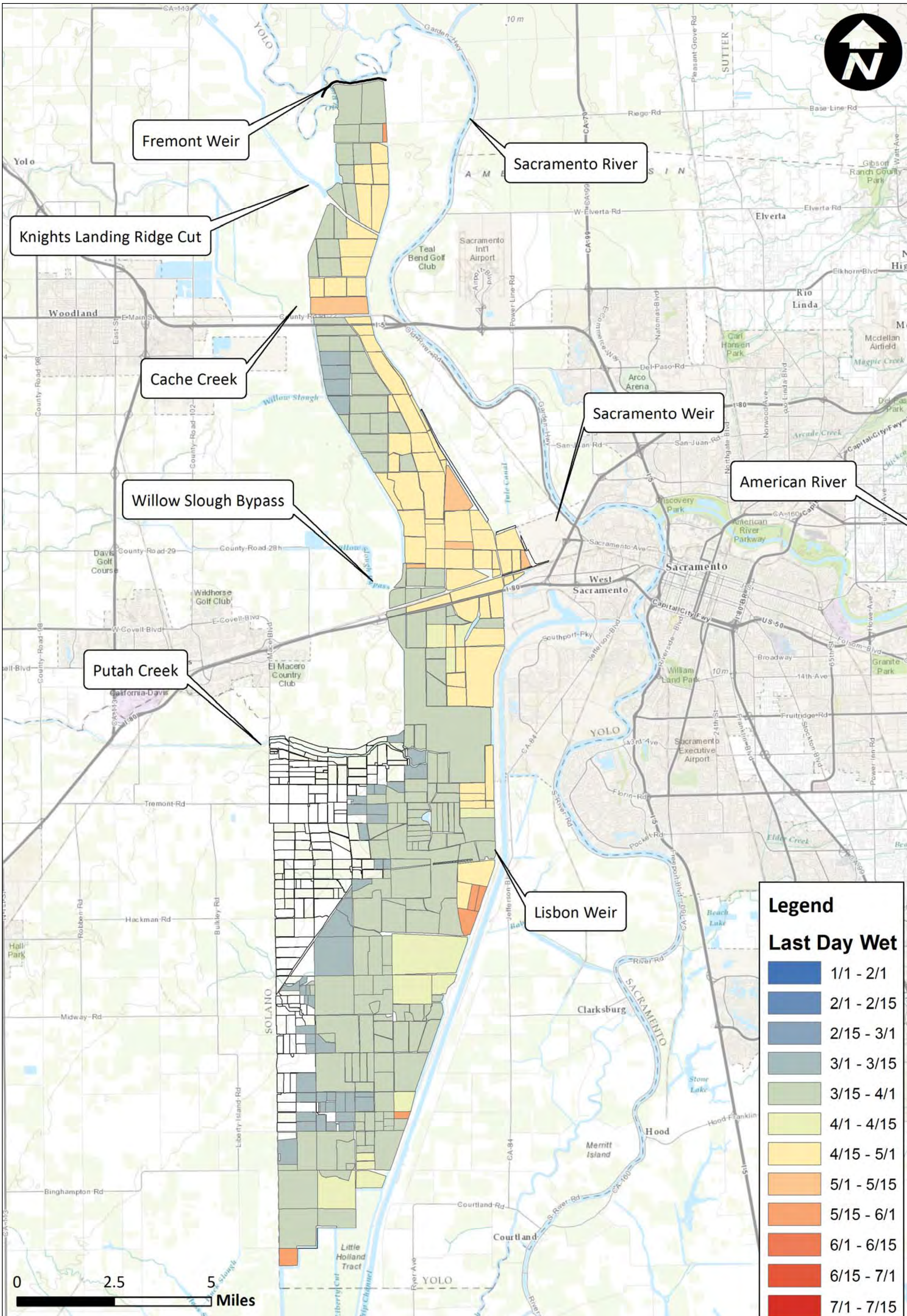
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 1999

Prepared for DWR | Created By: RDJ

Figure F35

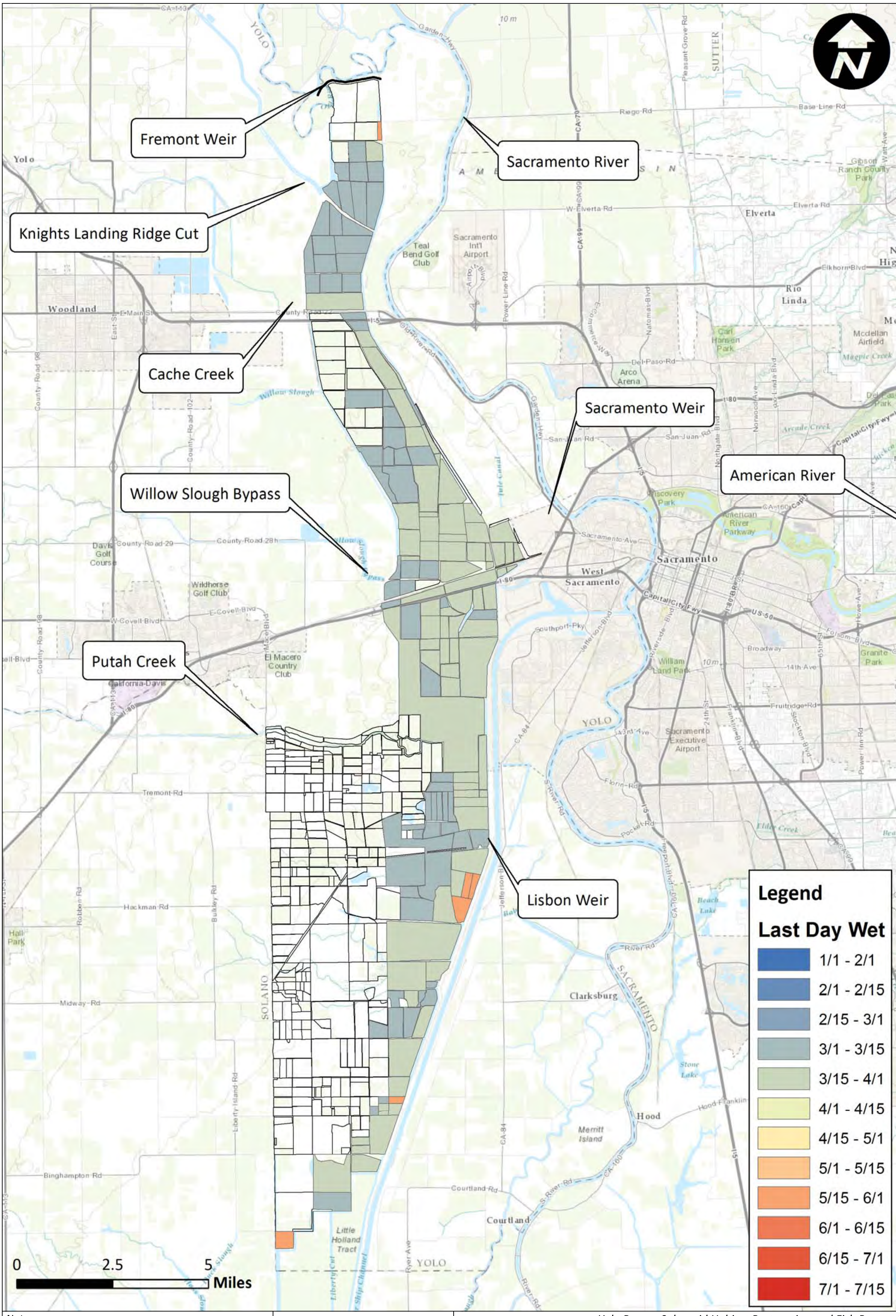


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2000

Prepared for DWR	Created By: RDJ	**Figure F36**



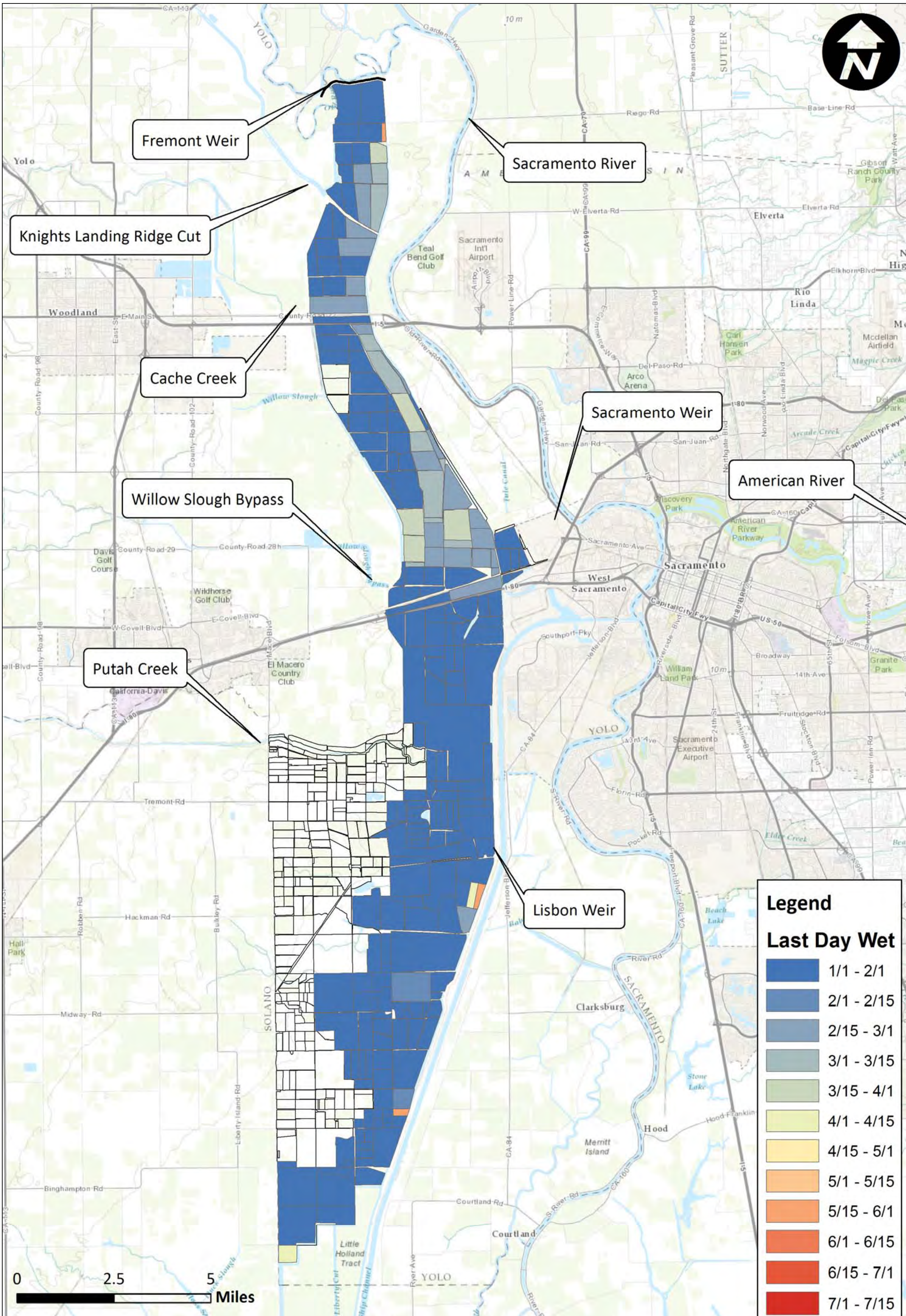
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2001

Prepared for DWR | Created By: RDJ

Figure F37



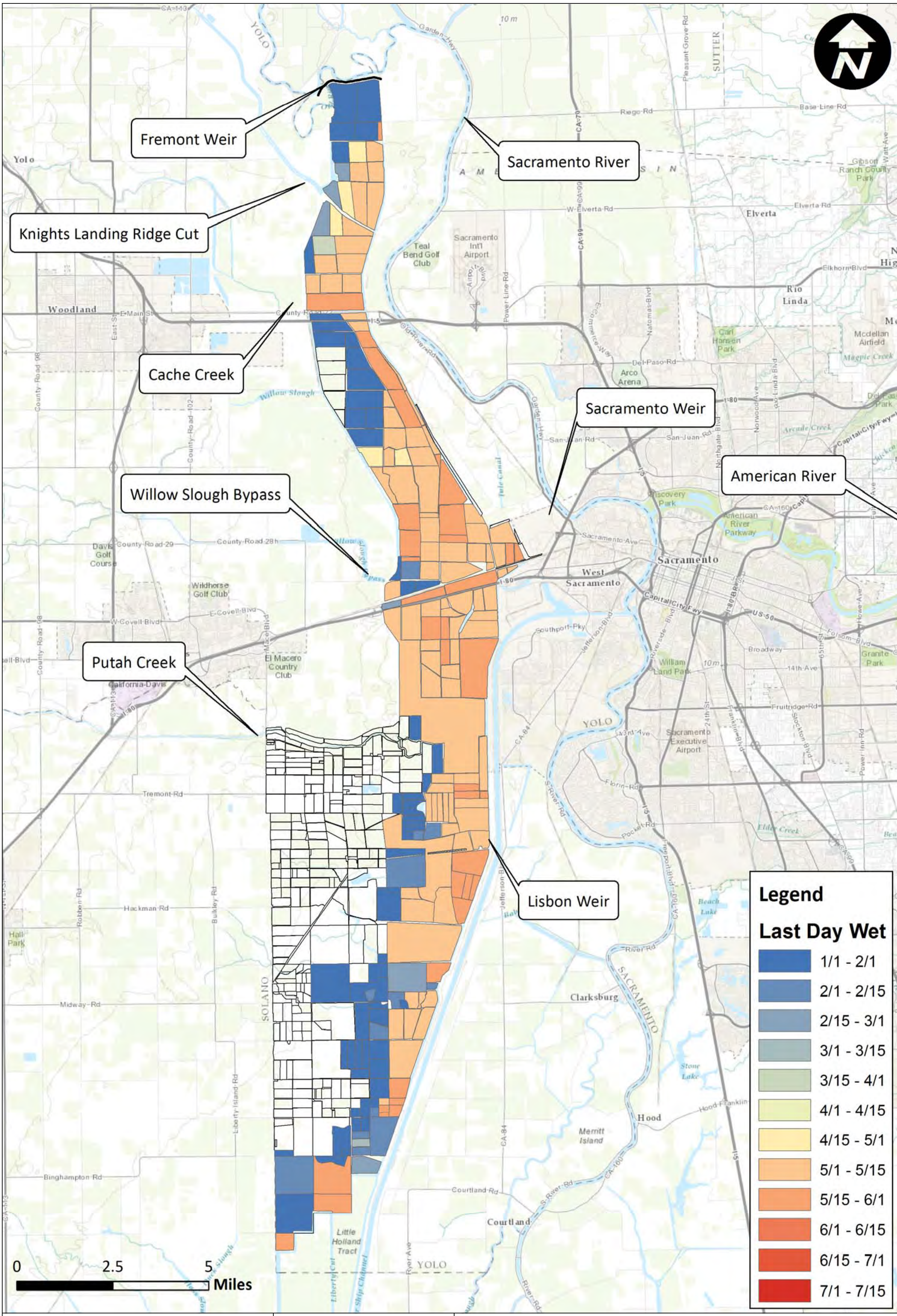
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2002

Prepared for DWR | Created By: RDJ

Figure F38



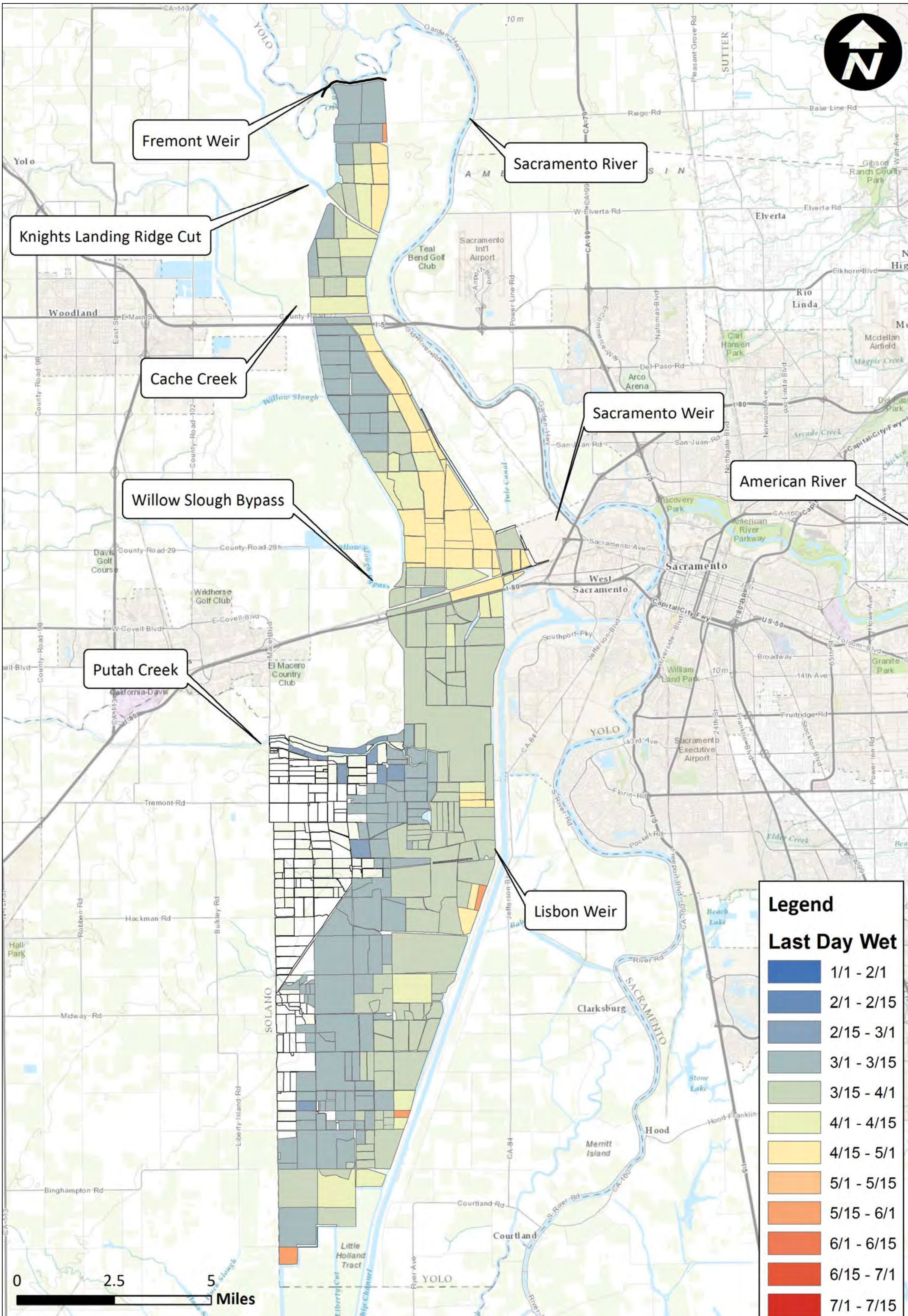
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2003

Prepared for DWR | Created By: RDJ

Figure F39



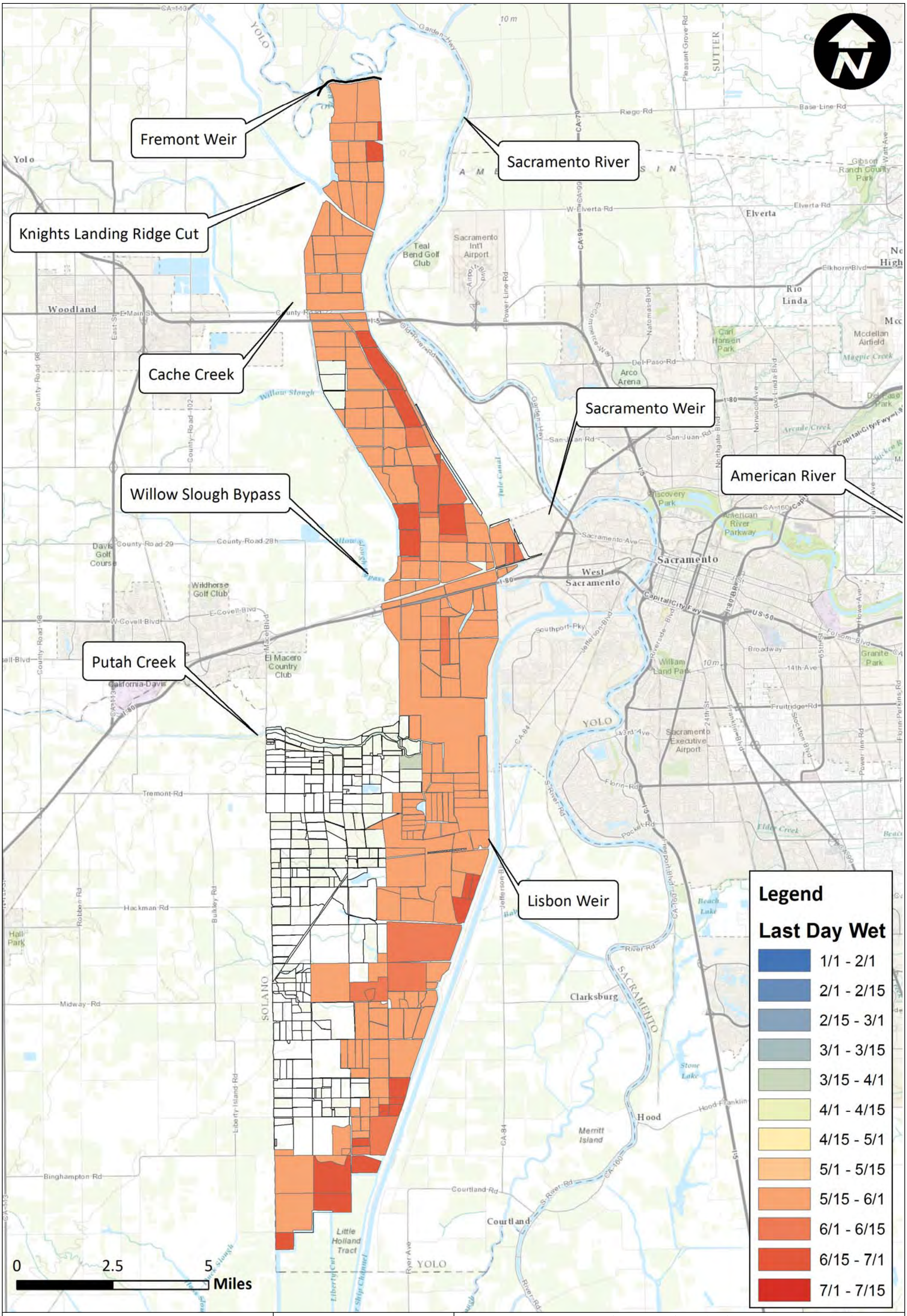
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2004

Prepared for DWR | Created By: RDJ

Figure F40



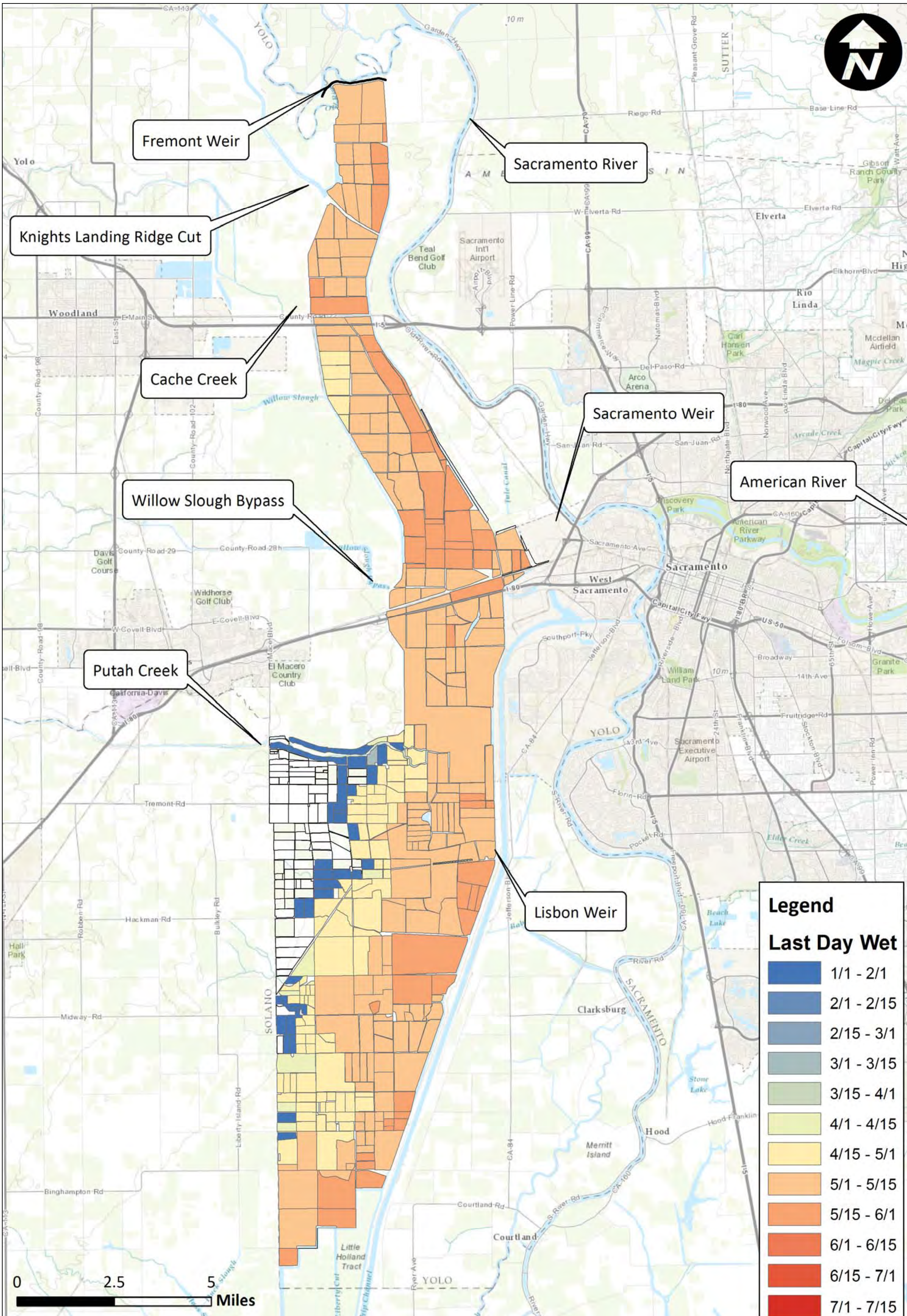
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2005

Prepared for DWR | Created By: RDJ

Figure F41



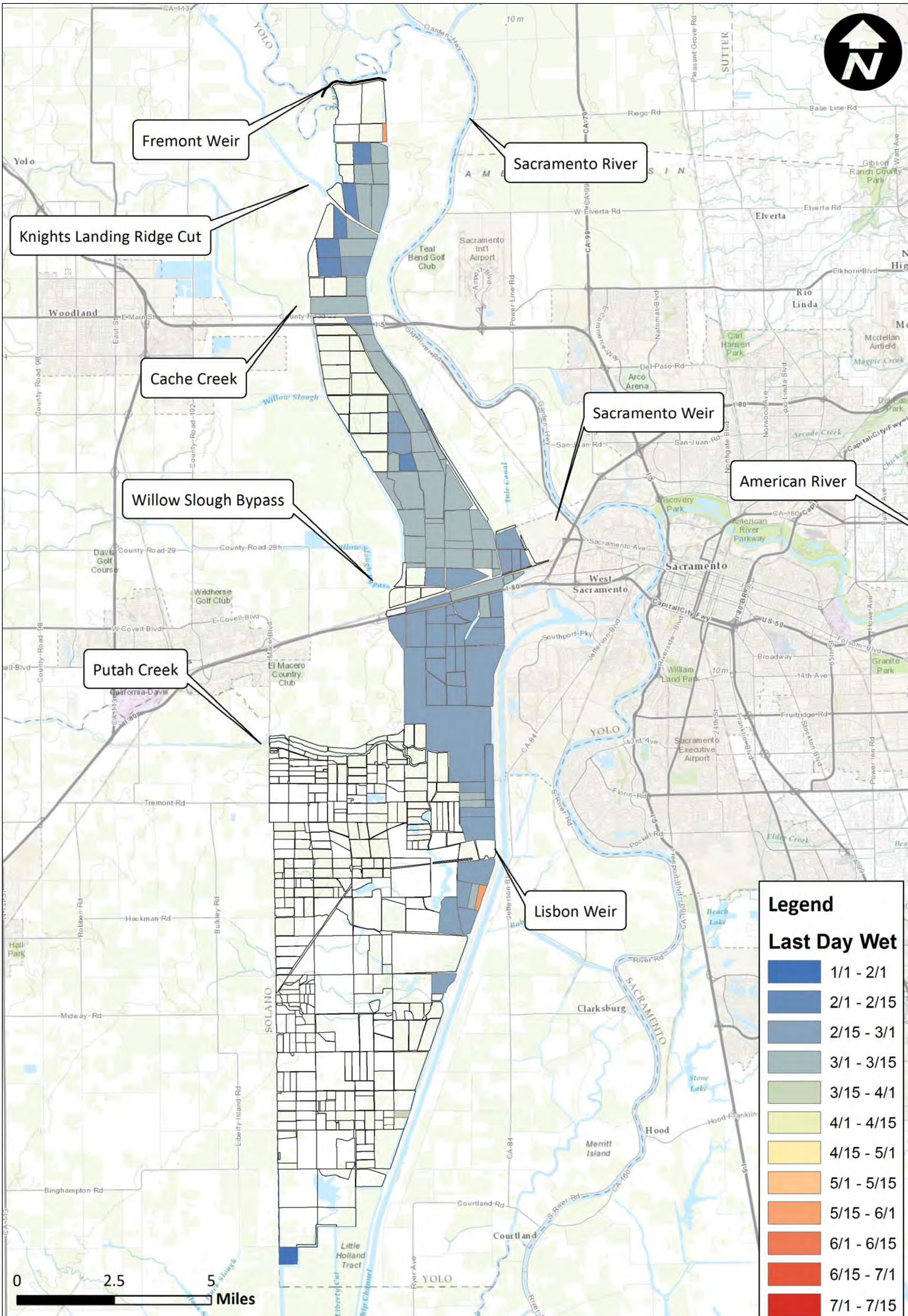
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2006

Prepared for DWR | Created By: RDJ

Figure F42



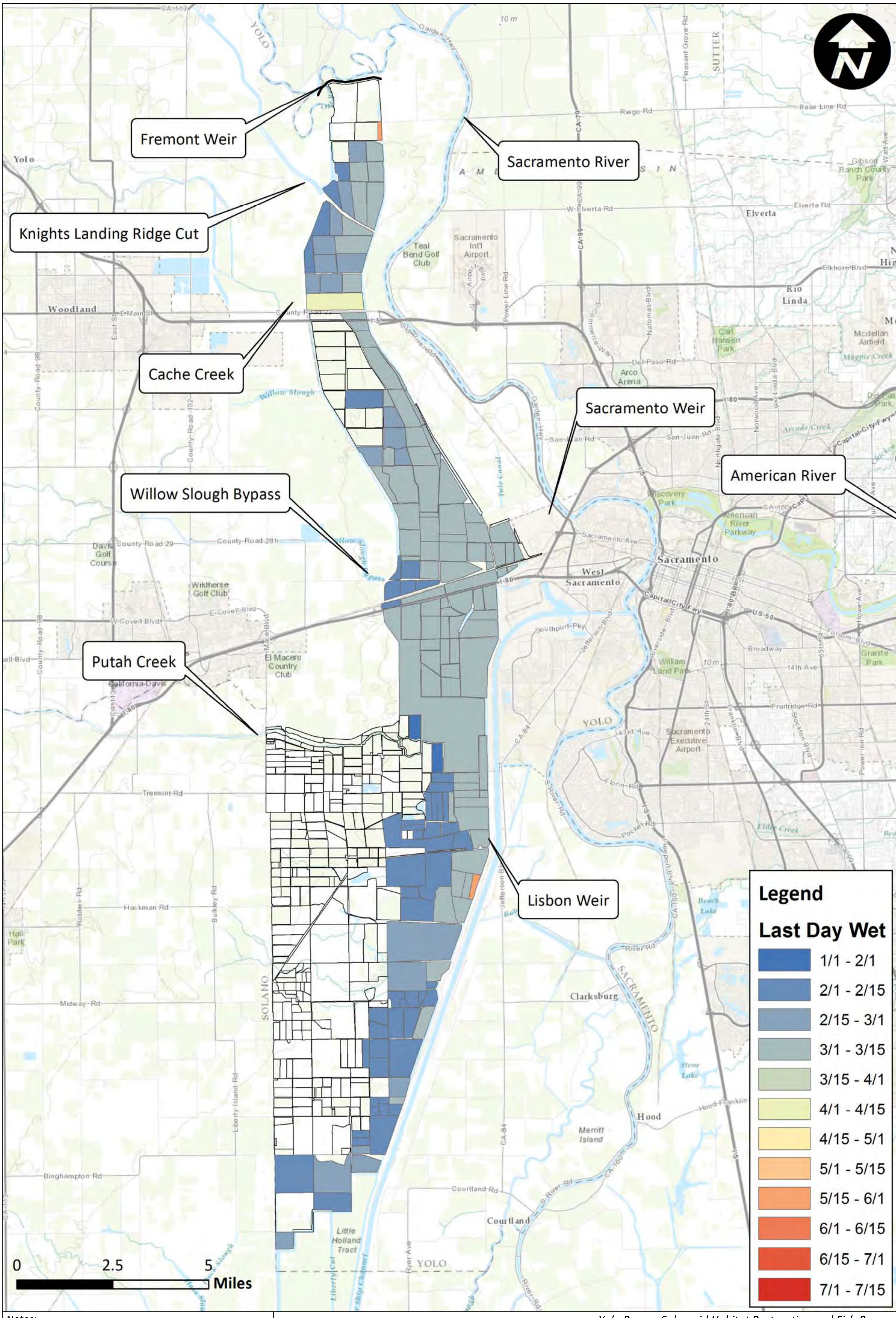
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2007

Prepared for DWR | Created By: RDJ

Figure F43



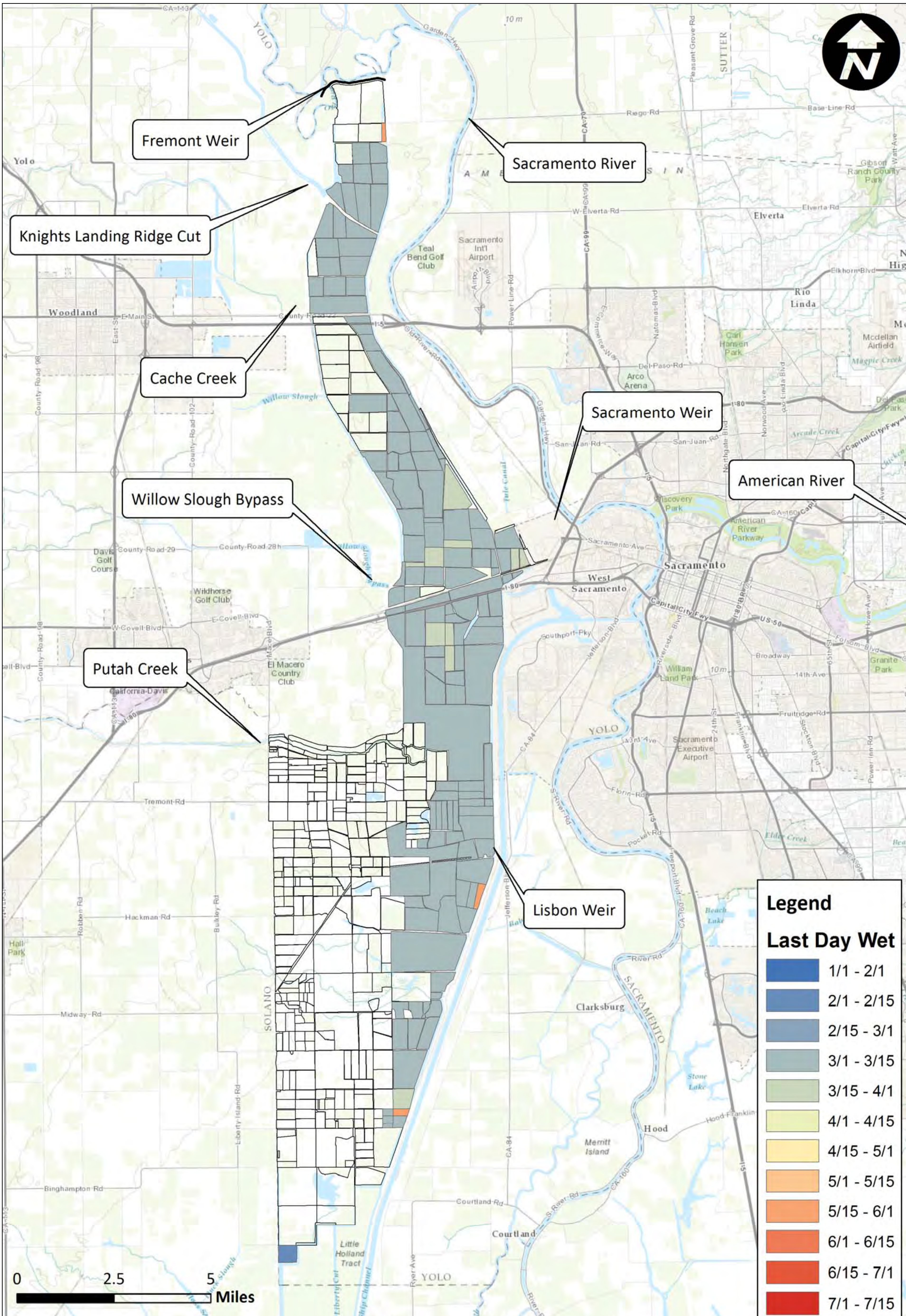
Notes:

HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2008

Prepared for DWR	Created By: RDJ	**Figure F44**

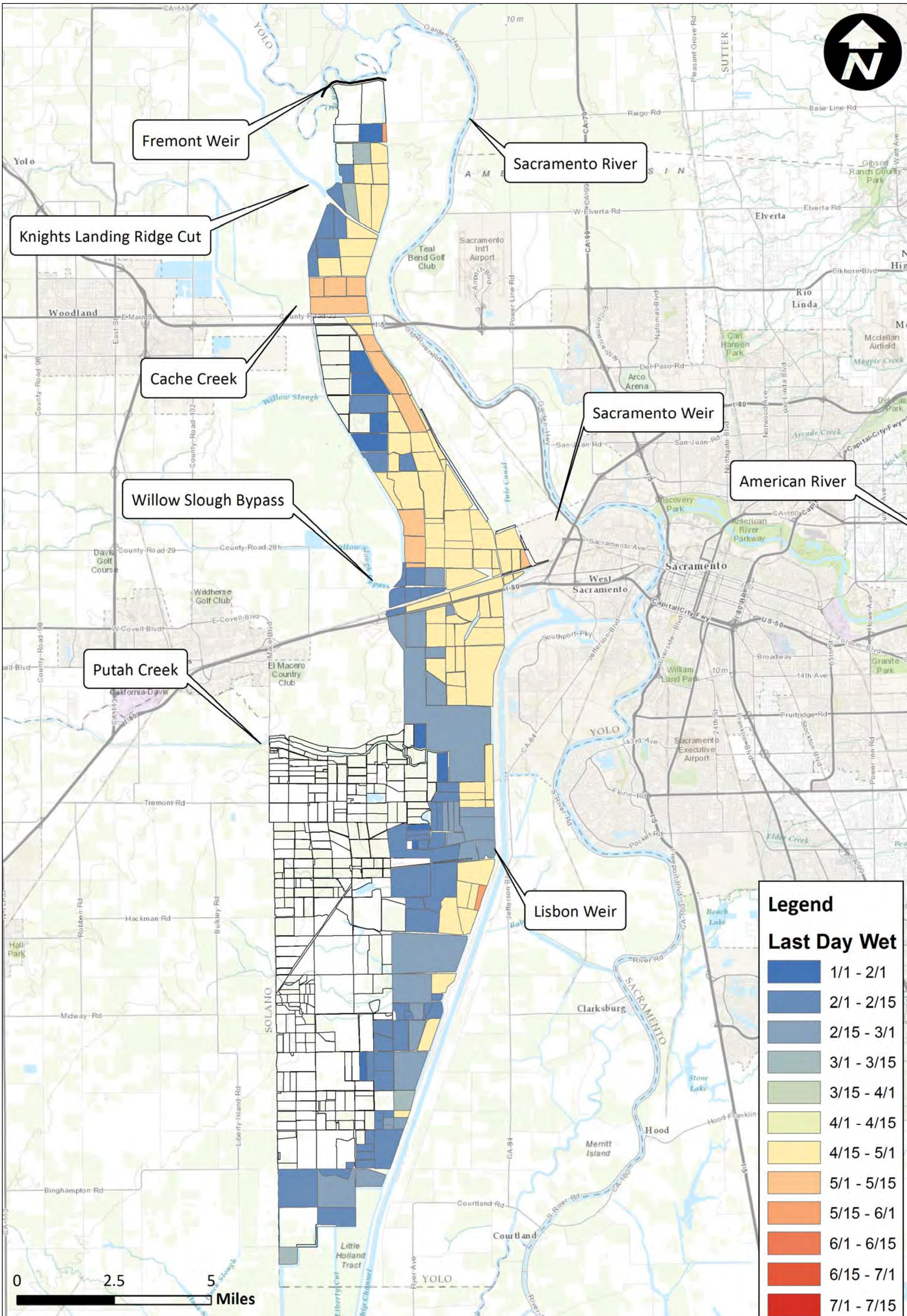


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2009

Prepared for DWR | Created By: RDJ | **Figure F45**



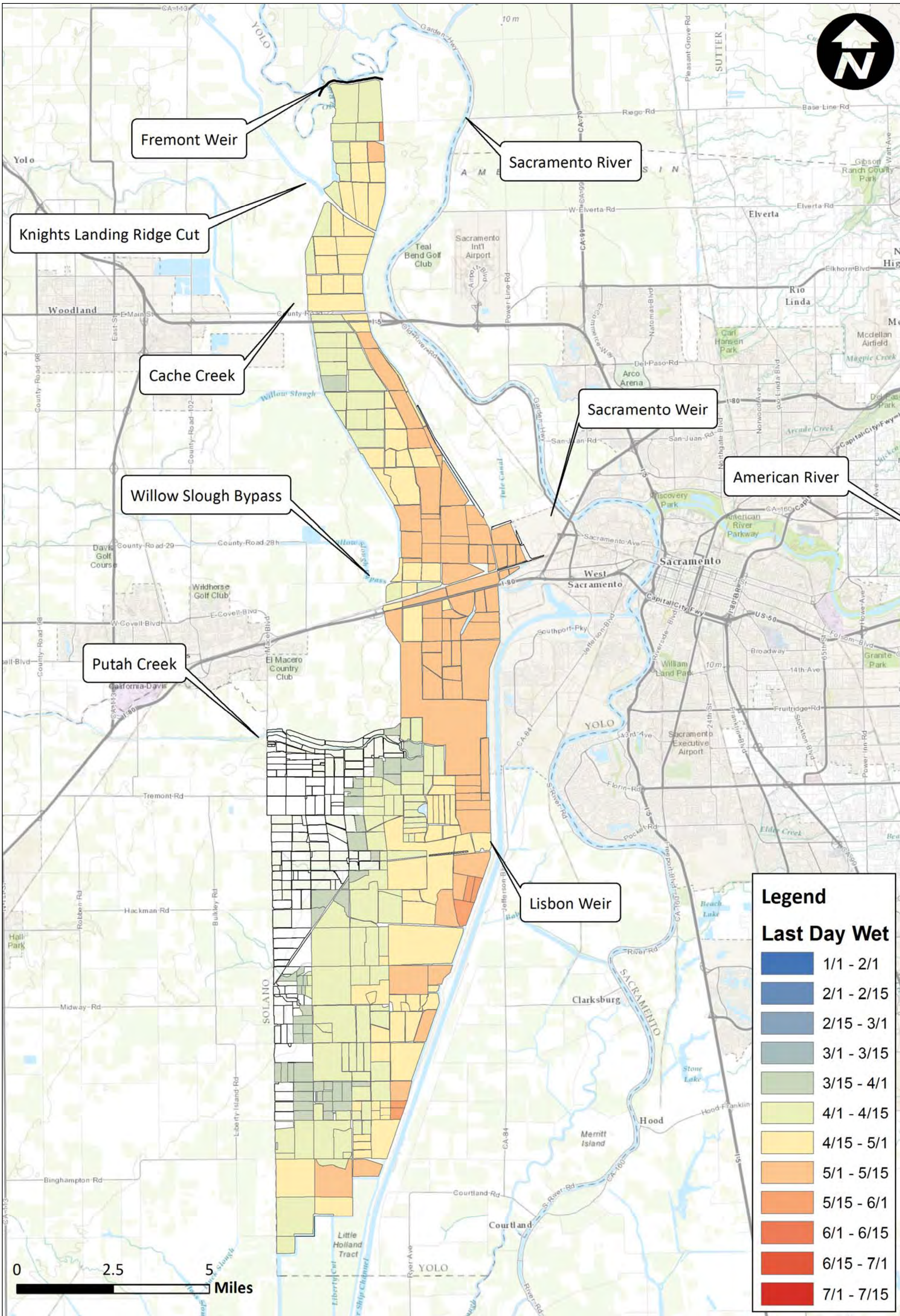
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2010

Prepared for DWR | Created By: RDJ

Figure F46

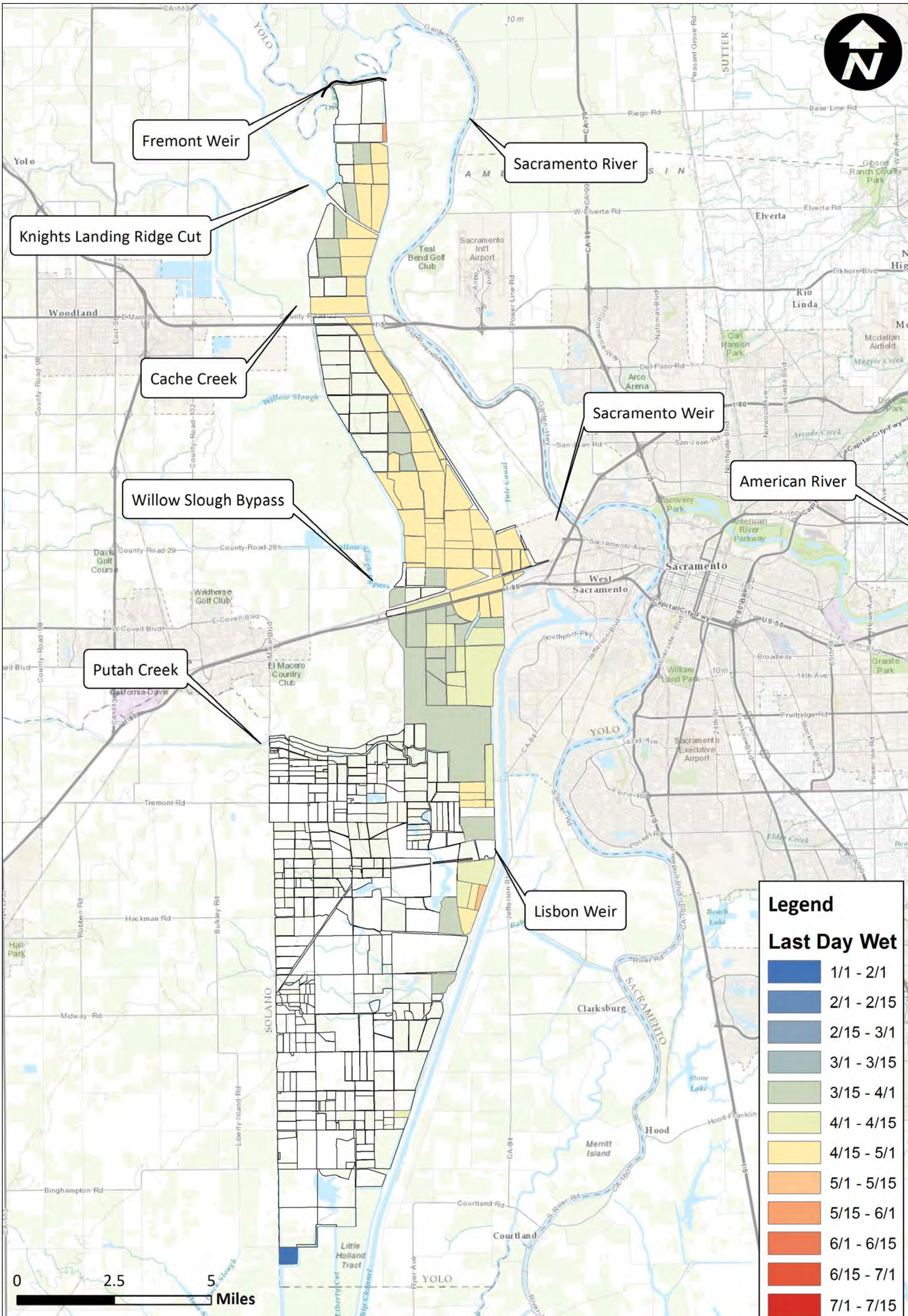


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2011

Prepared for DWR	Created By: RDJ	**Figure F47**

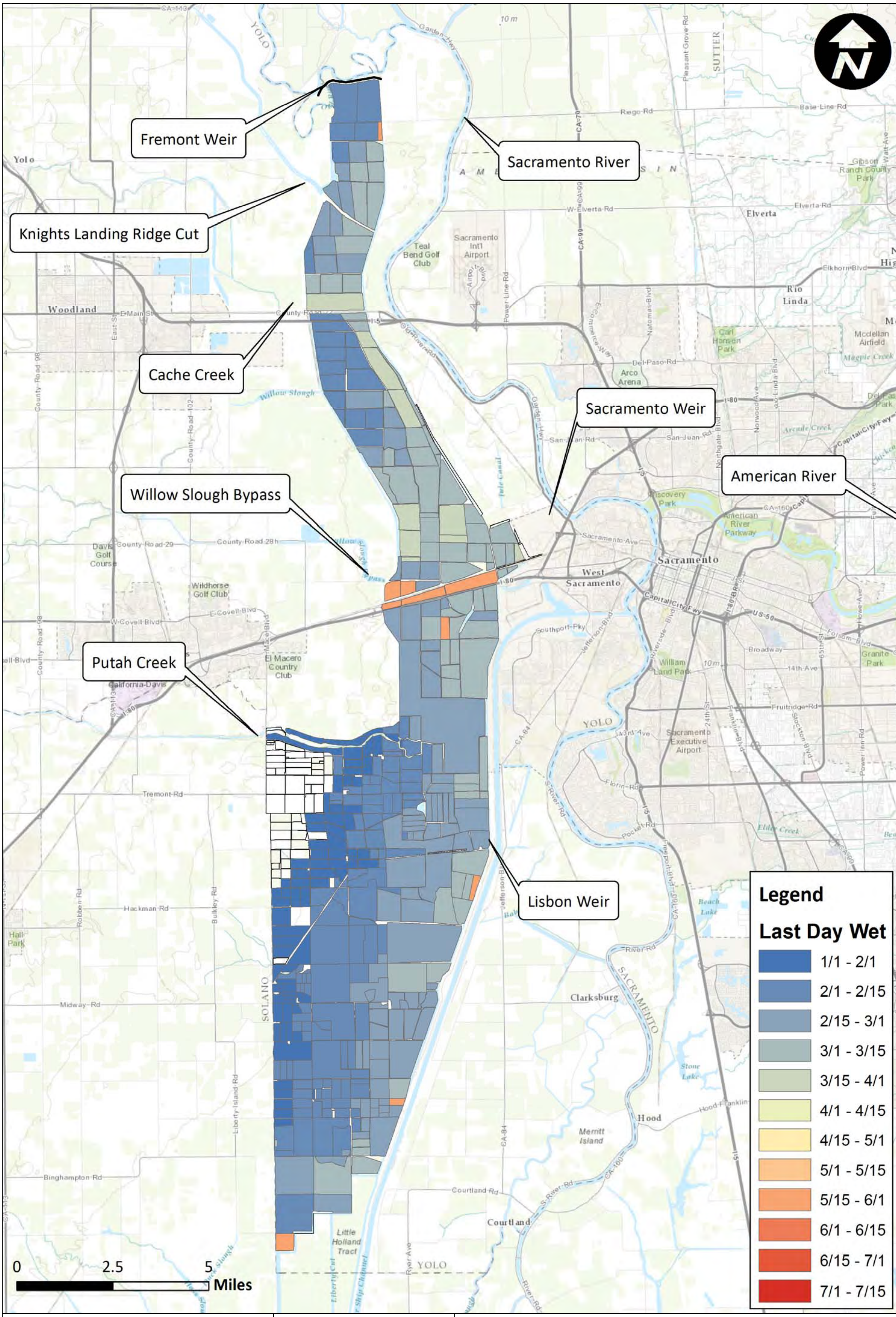


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Medium Channel 2012

Prepared for DWR	Created By: RDJ	**Figure F48**



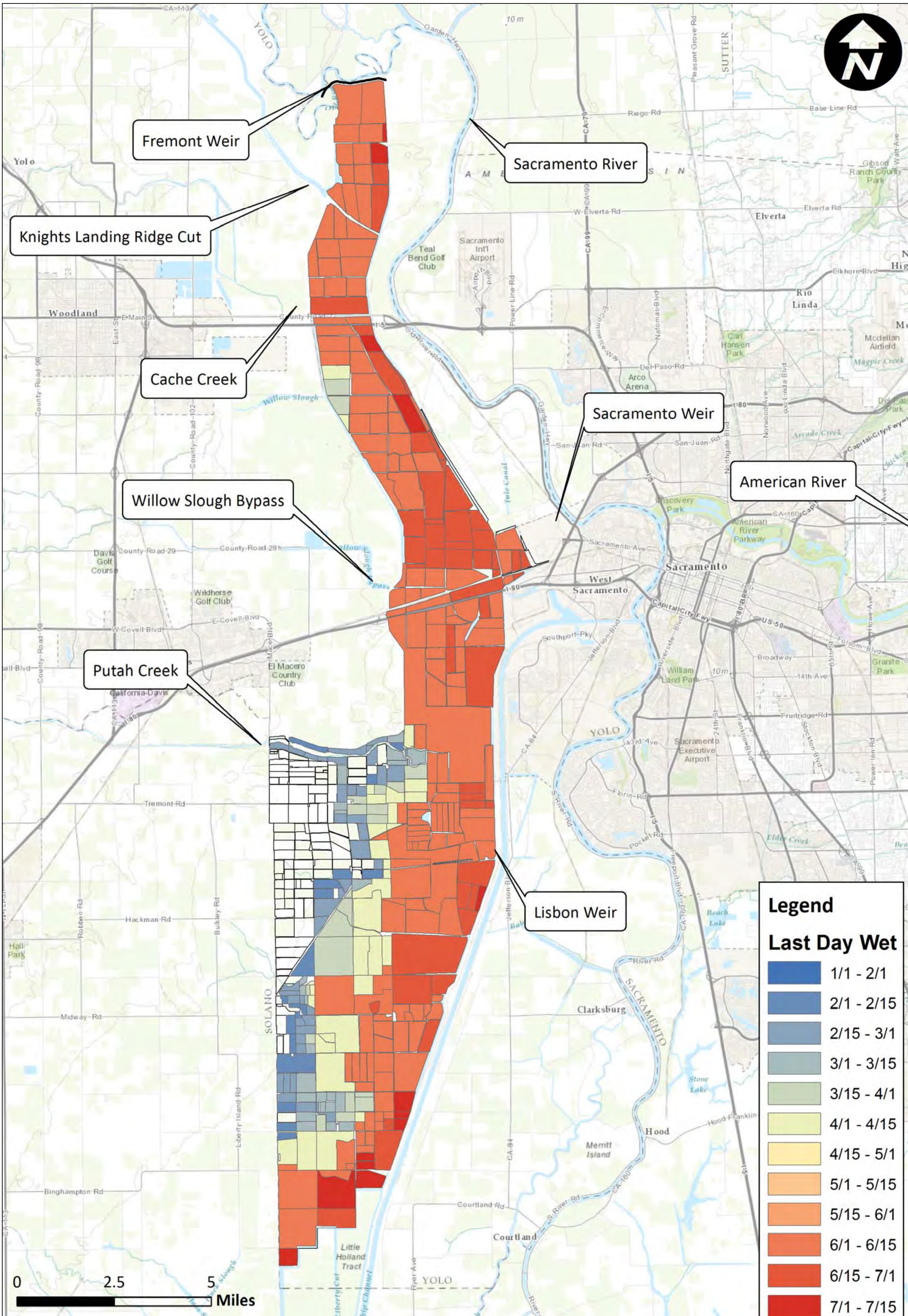
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 1997

Prepared for DWR | Created By: RDJ

Figure F49



Notes:

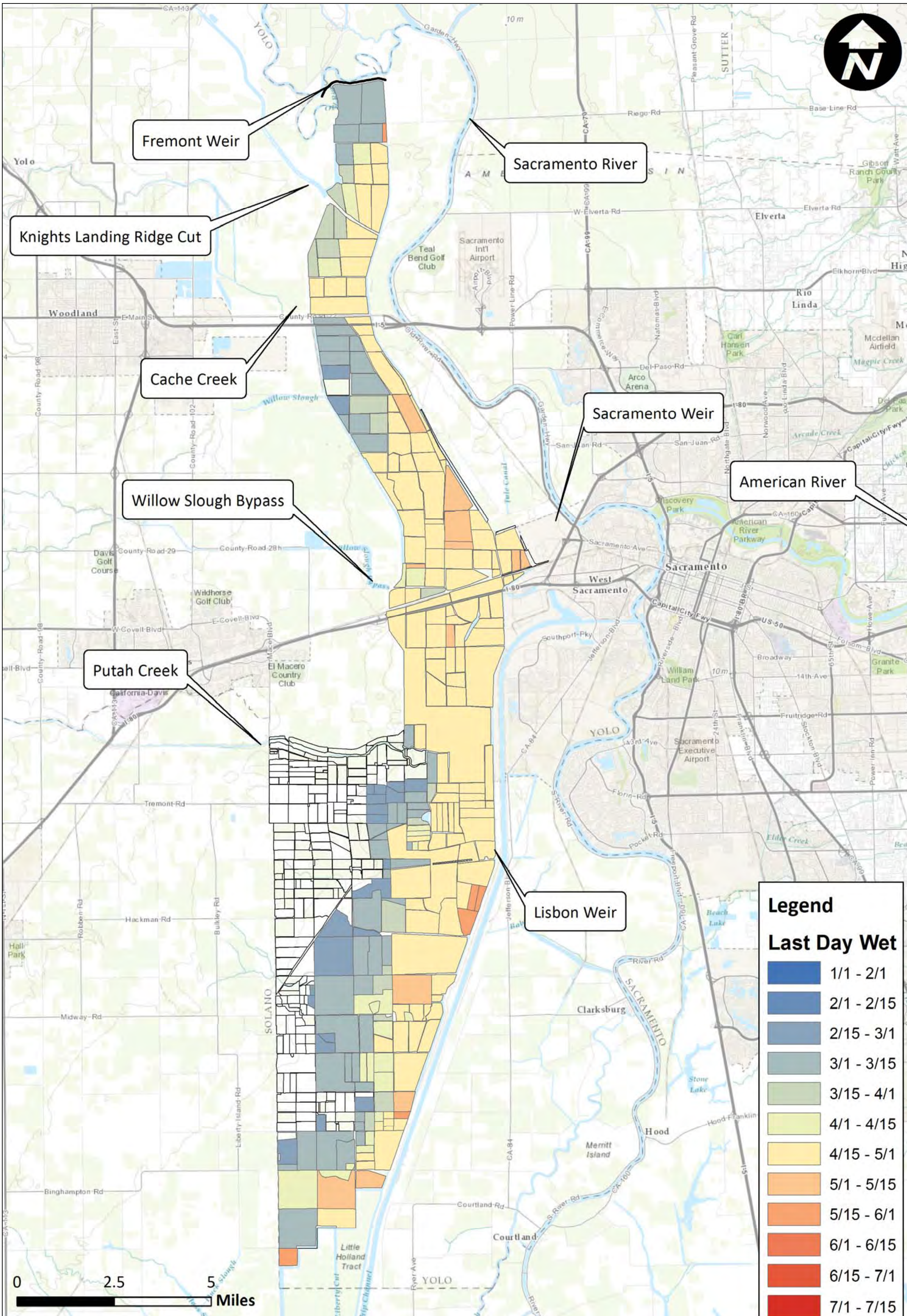
HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 1998

Prepared for DWR | Created By: RDJ

Figure F50

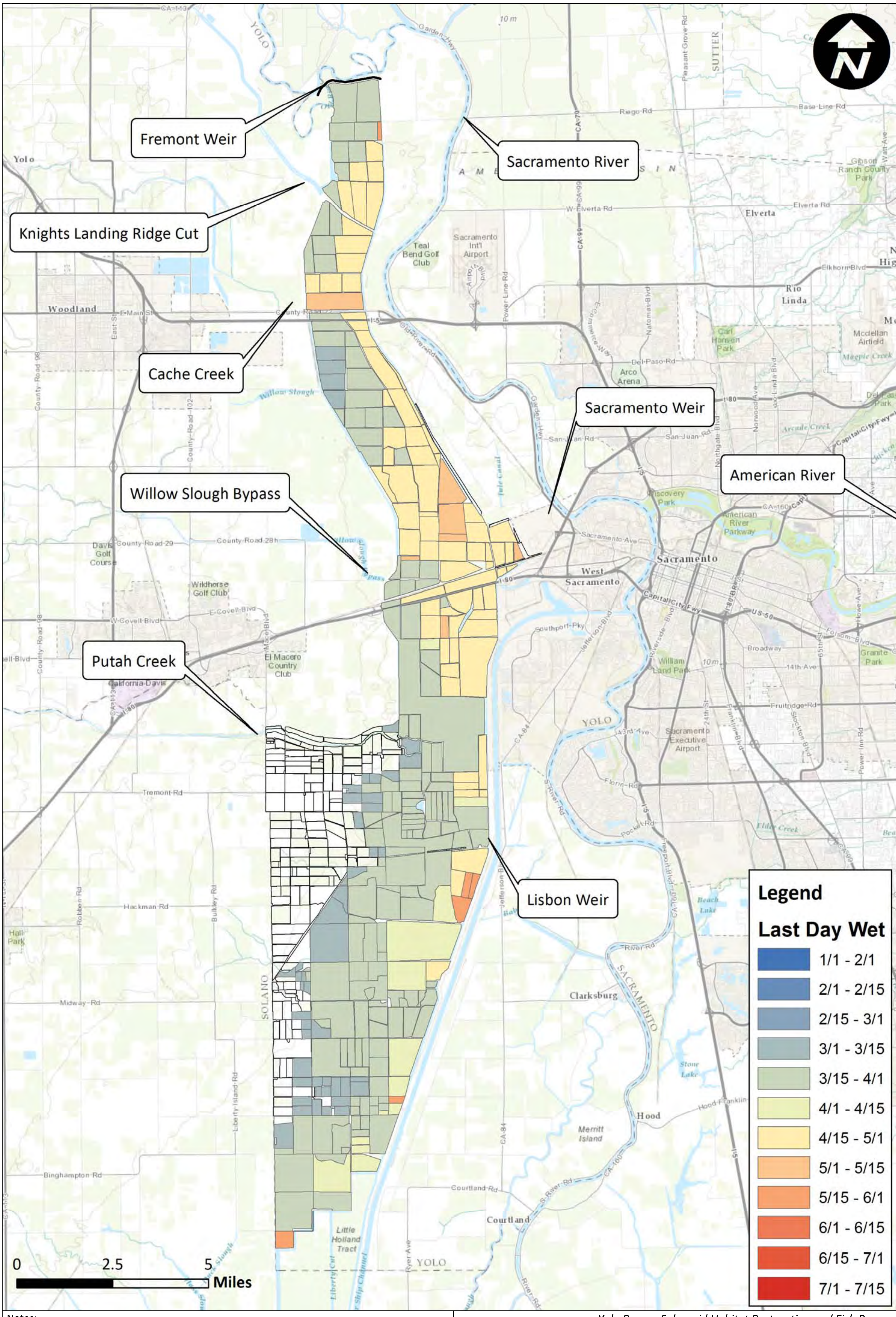


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 1999

Prepared for DWR | Created By: RDJ | **Figure F51**

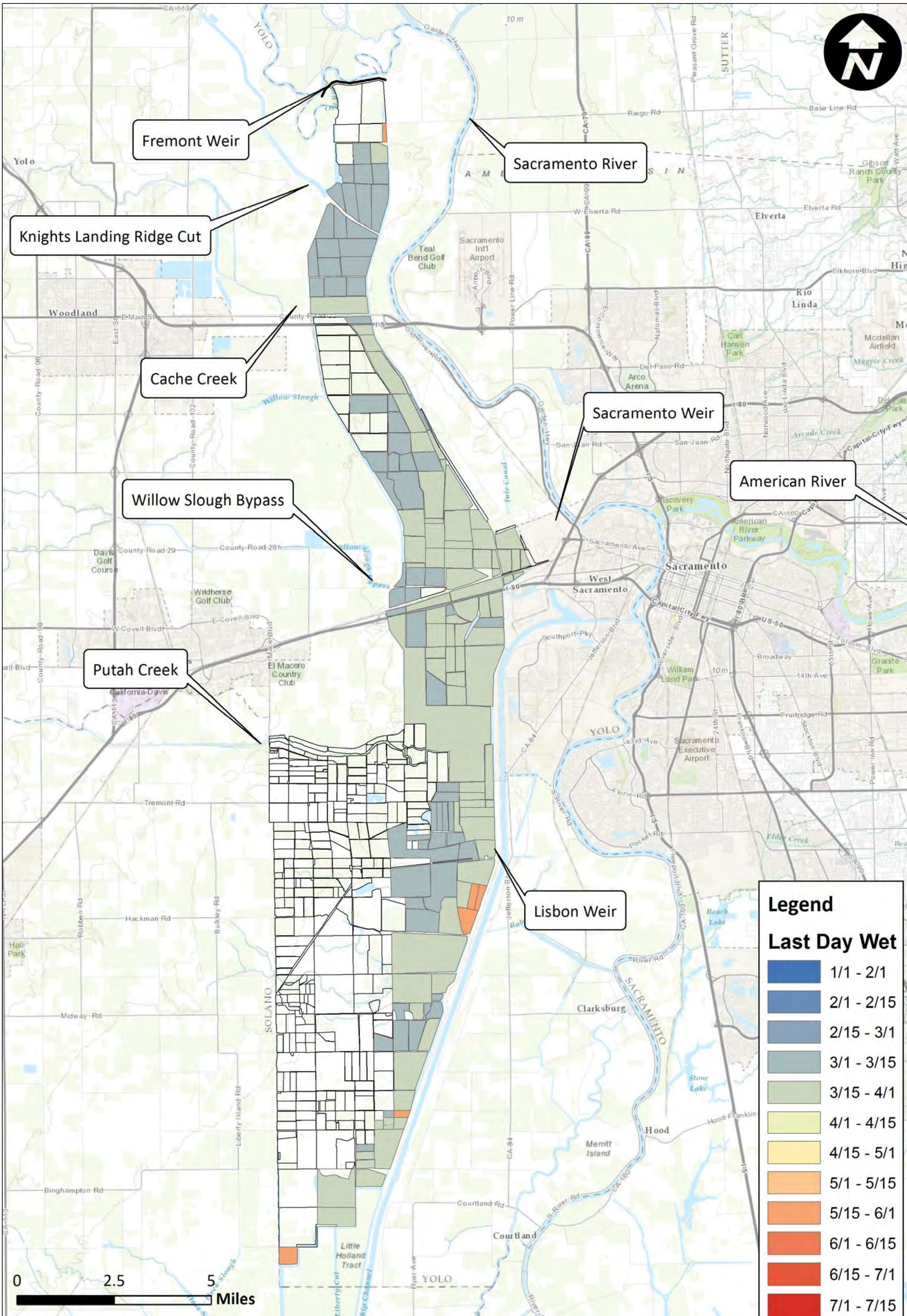


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2000

Prepared for DWR | Created By: RDJ | **Figure F52**



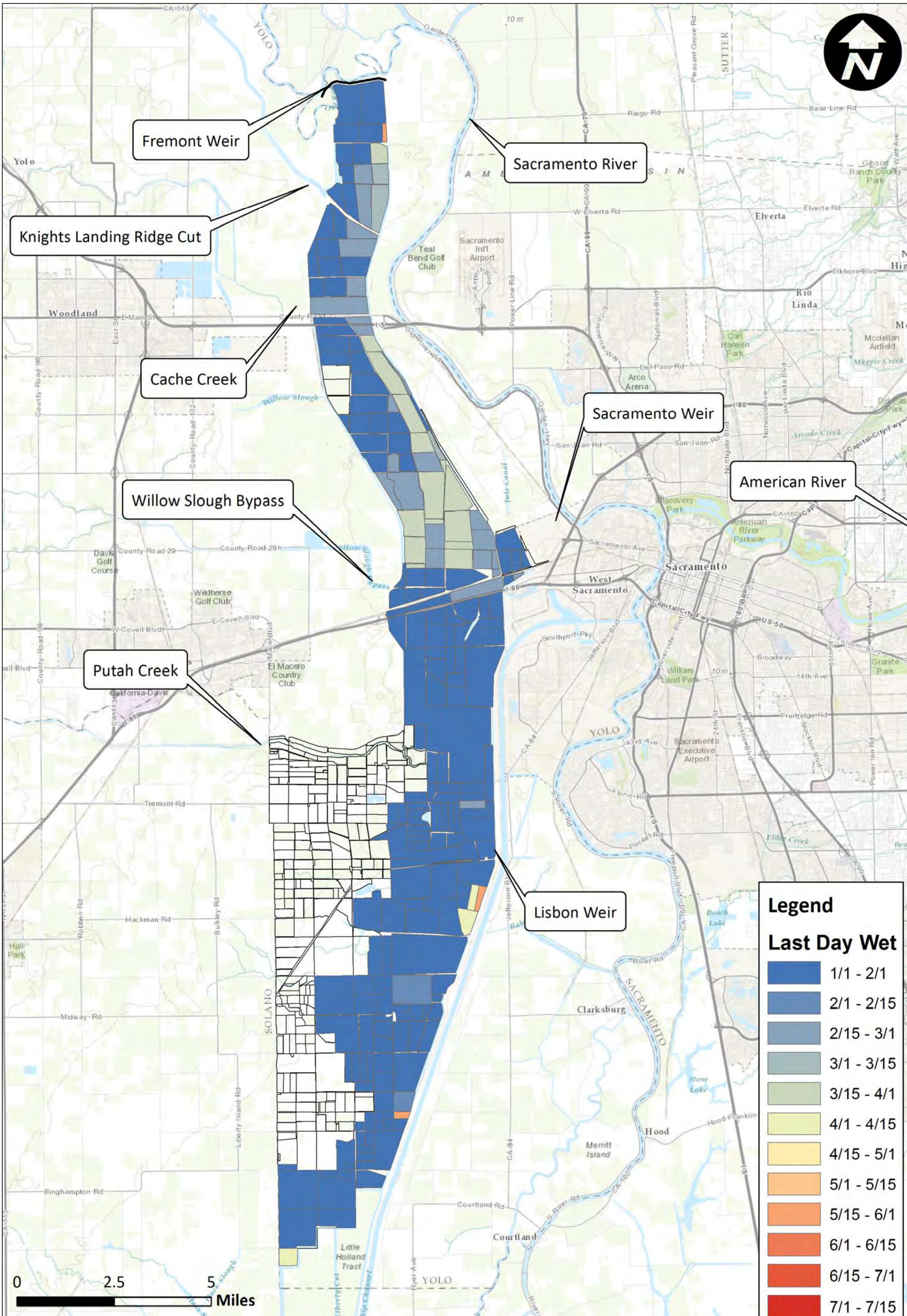
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2001

Prepared for DWR | Created By: RDJ

Figure F53

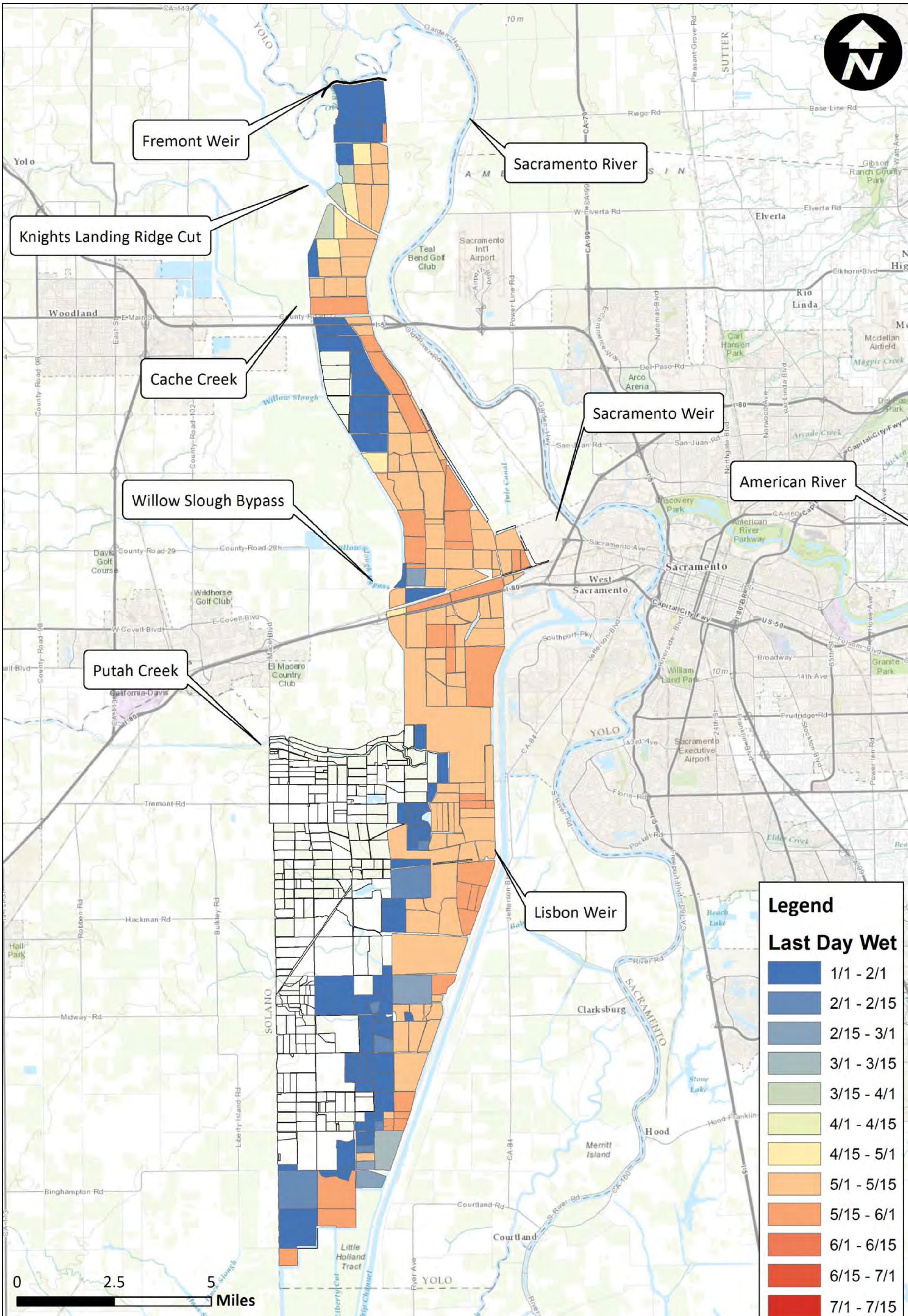


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2002

Prepared for DWR | Created By: RDJ | **Figure F54**



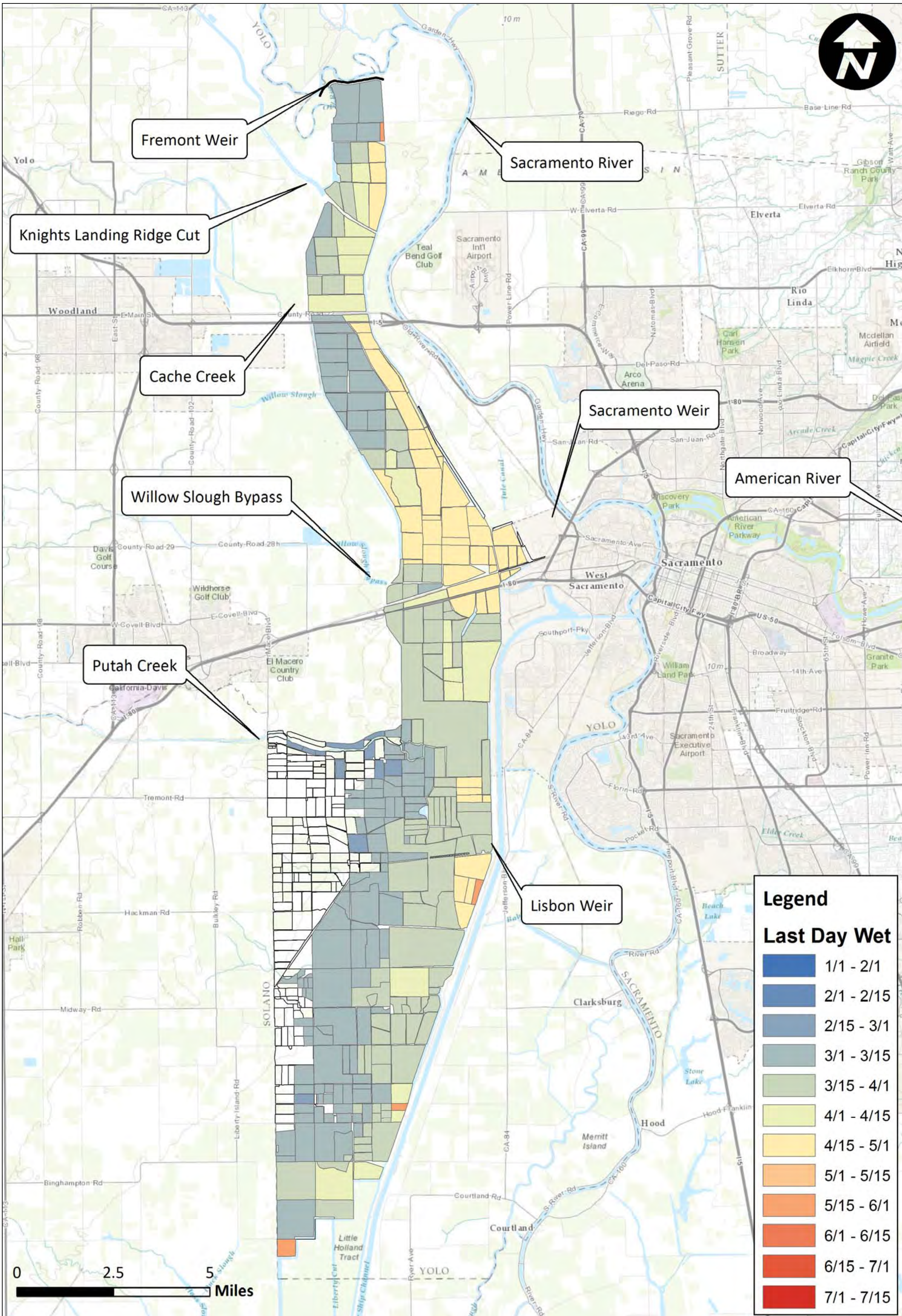
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2003

Prepared for DWR | Created By: RDJ

Figure F55



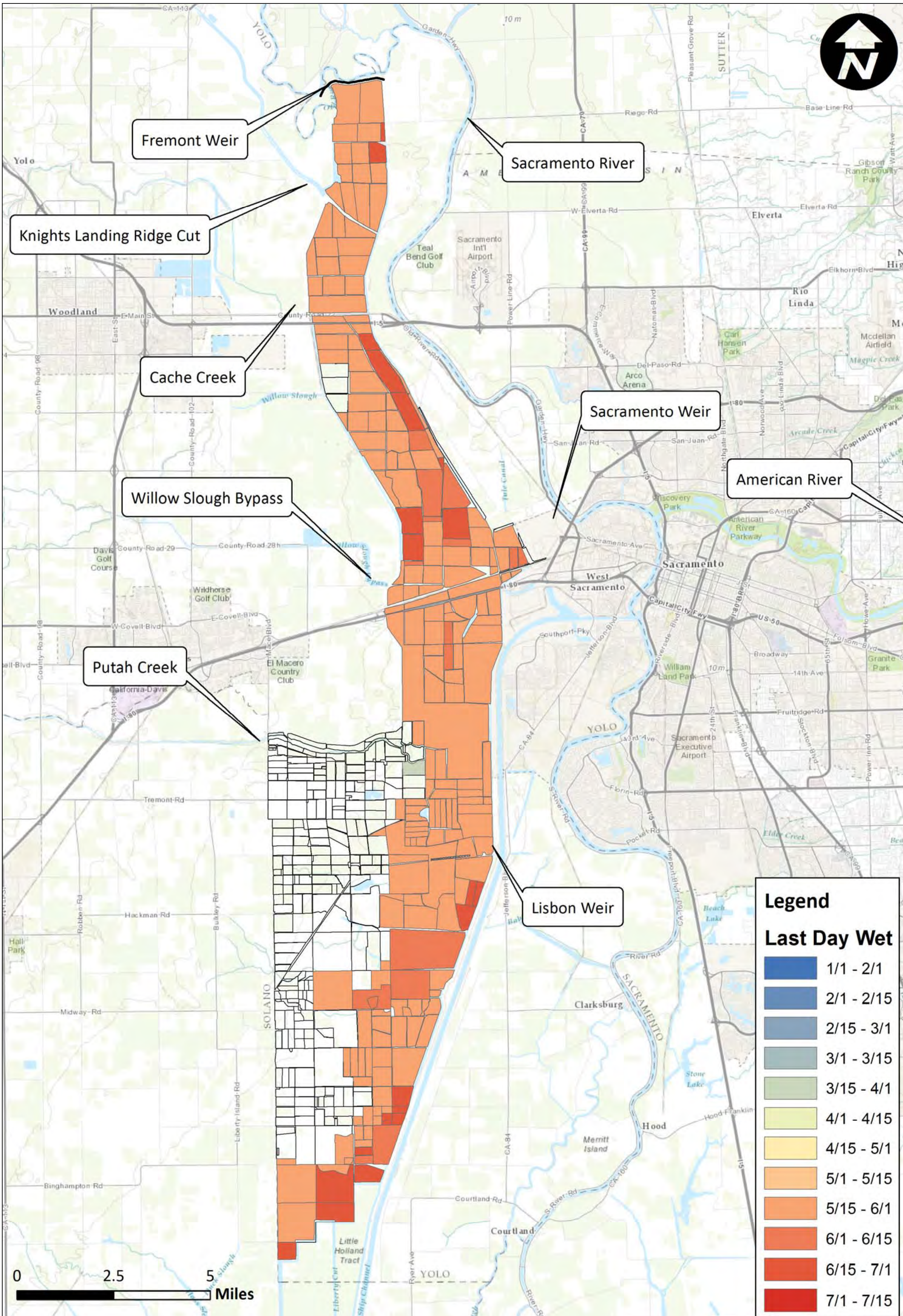
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2004

Prepared for DWR | Created By: RDJ

Figure F56



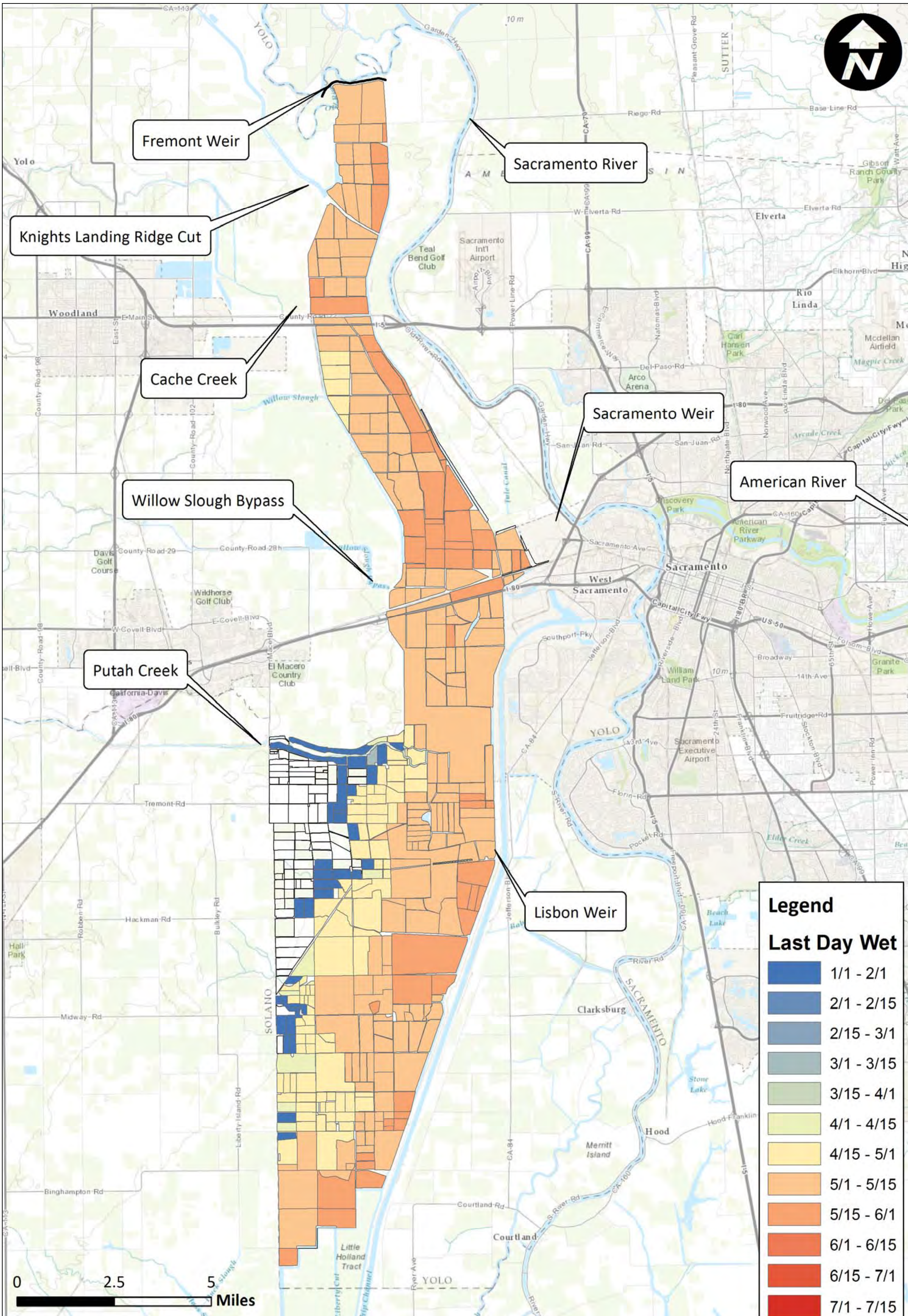
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2005

Prepared for DWR | Created By: RDJ

Figure F57



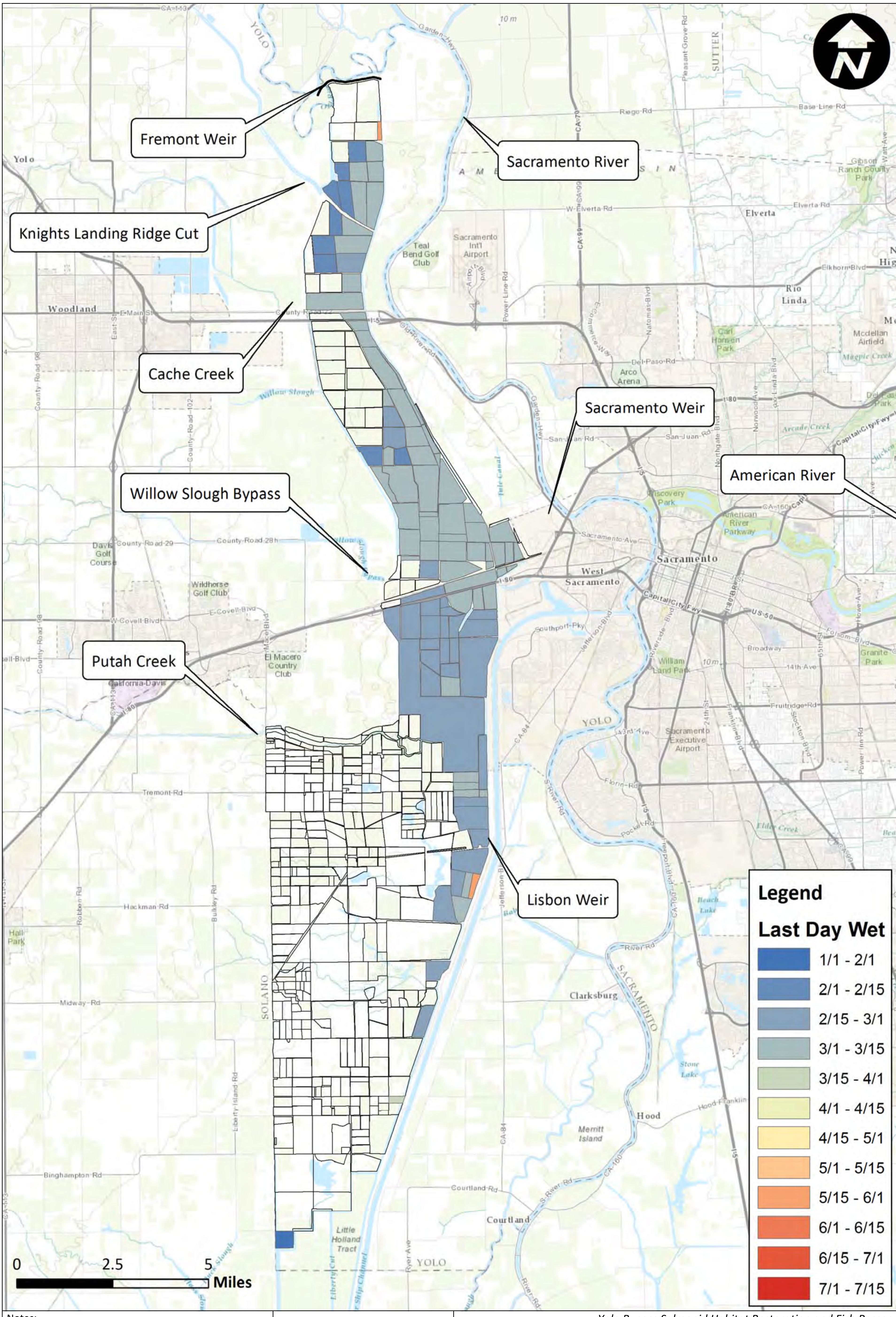
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2006

Prepared for DWR | Created By: RDJ

Figure F58

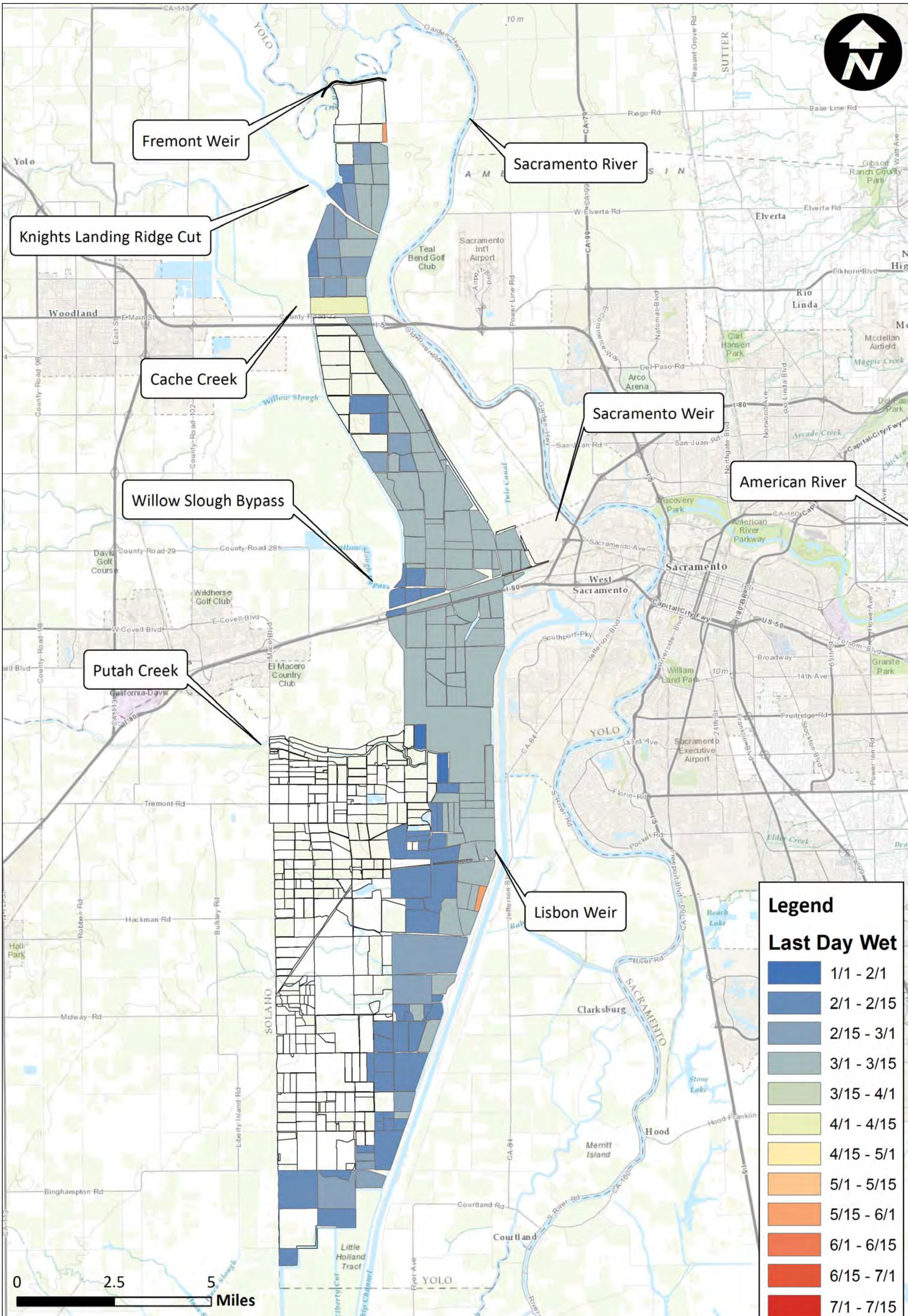


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2007

Prepared for DWR | Created By: RDJ | **Figure F59**



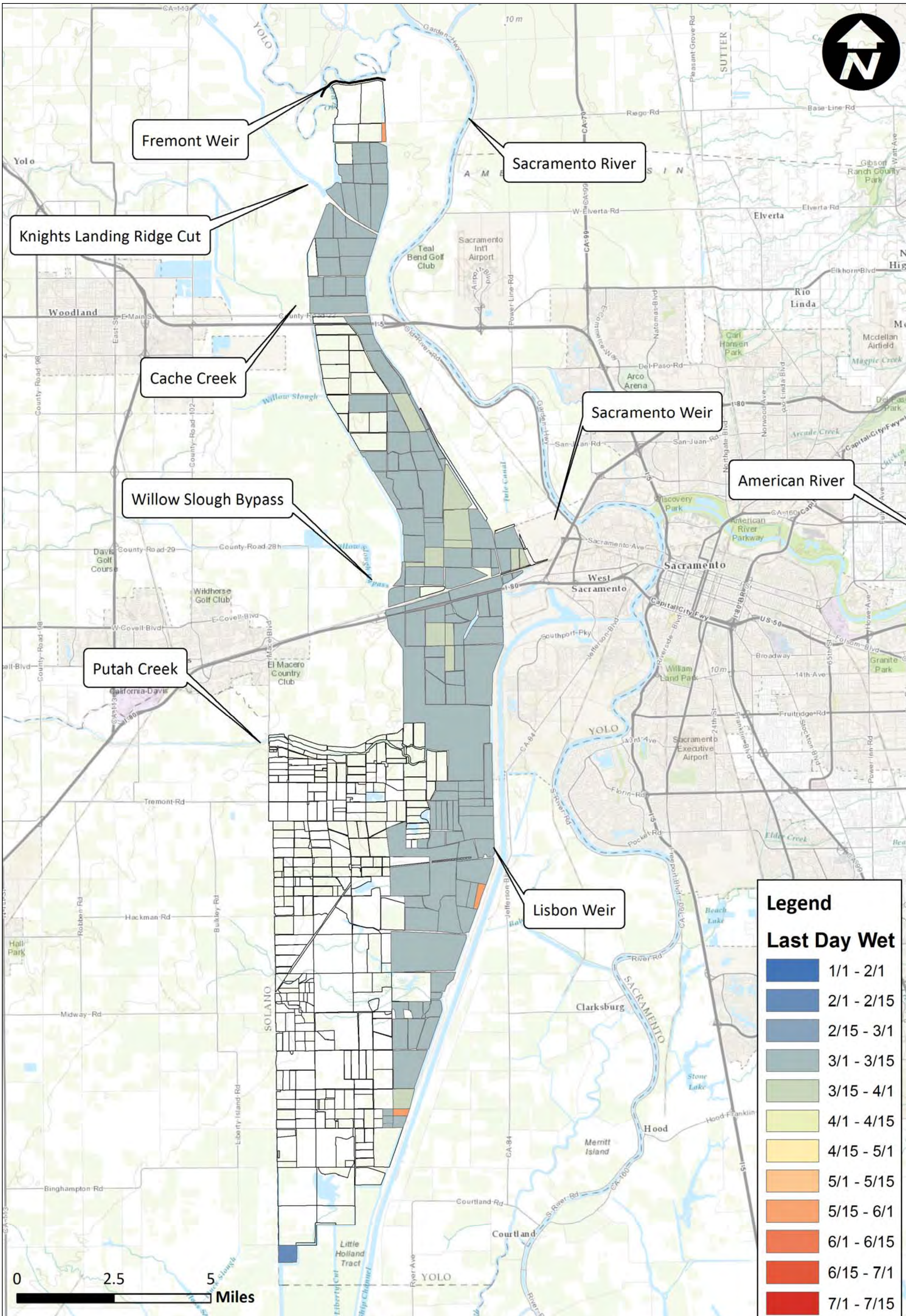
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2008

Prepared for DWR | Created By: RDJ

Figure F60

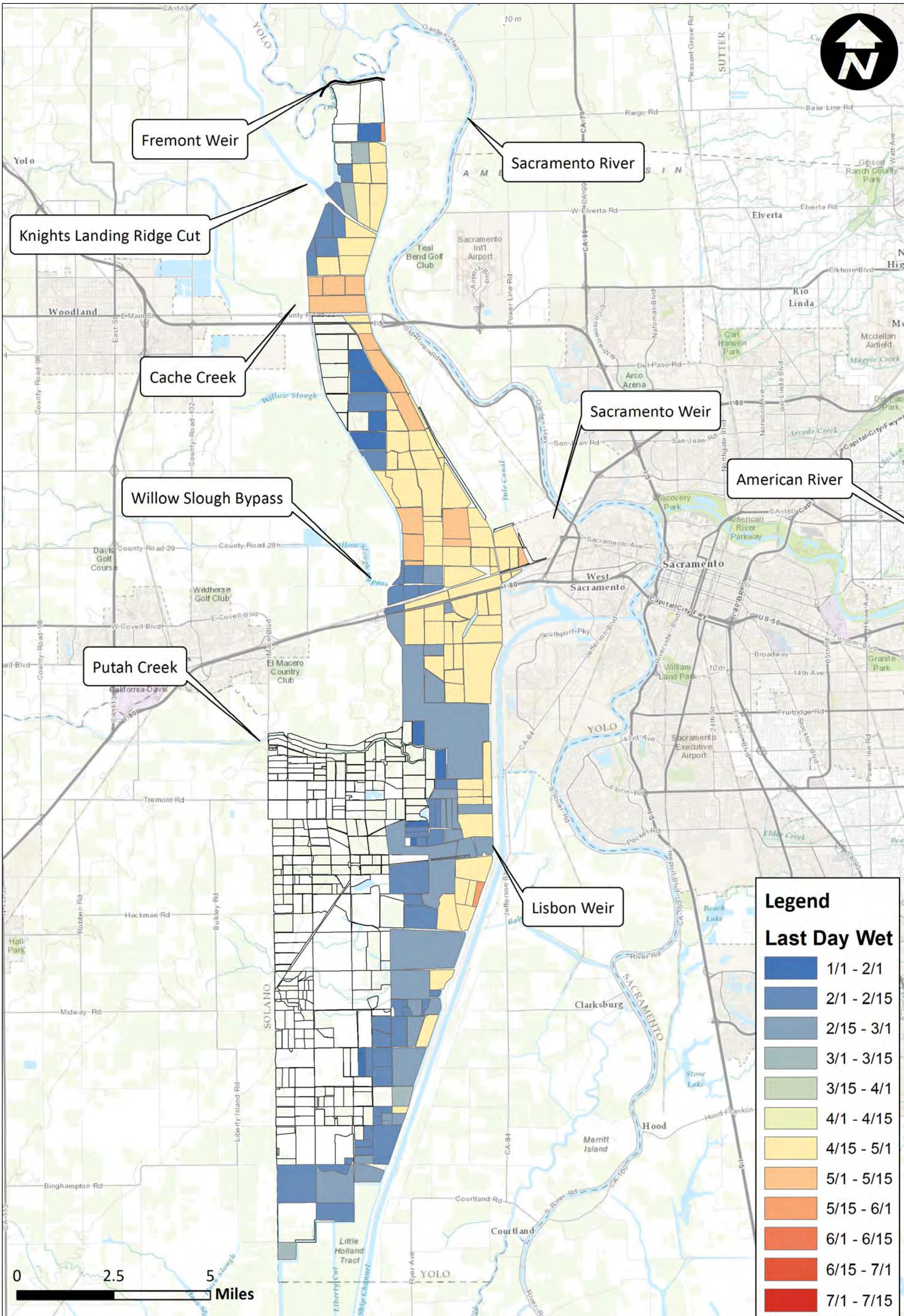


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2009

Prepared for DWR | Created By: RDJ | **Figure F61**



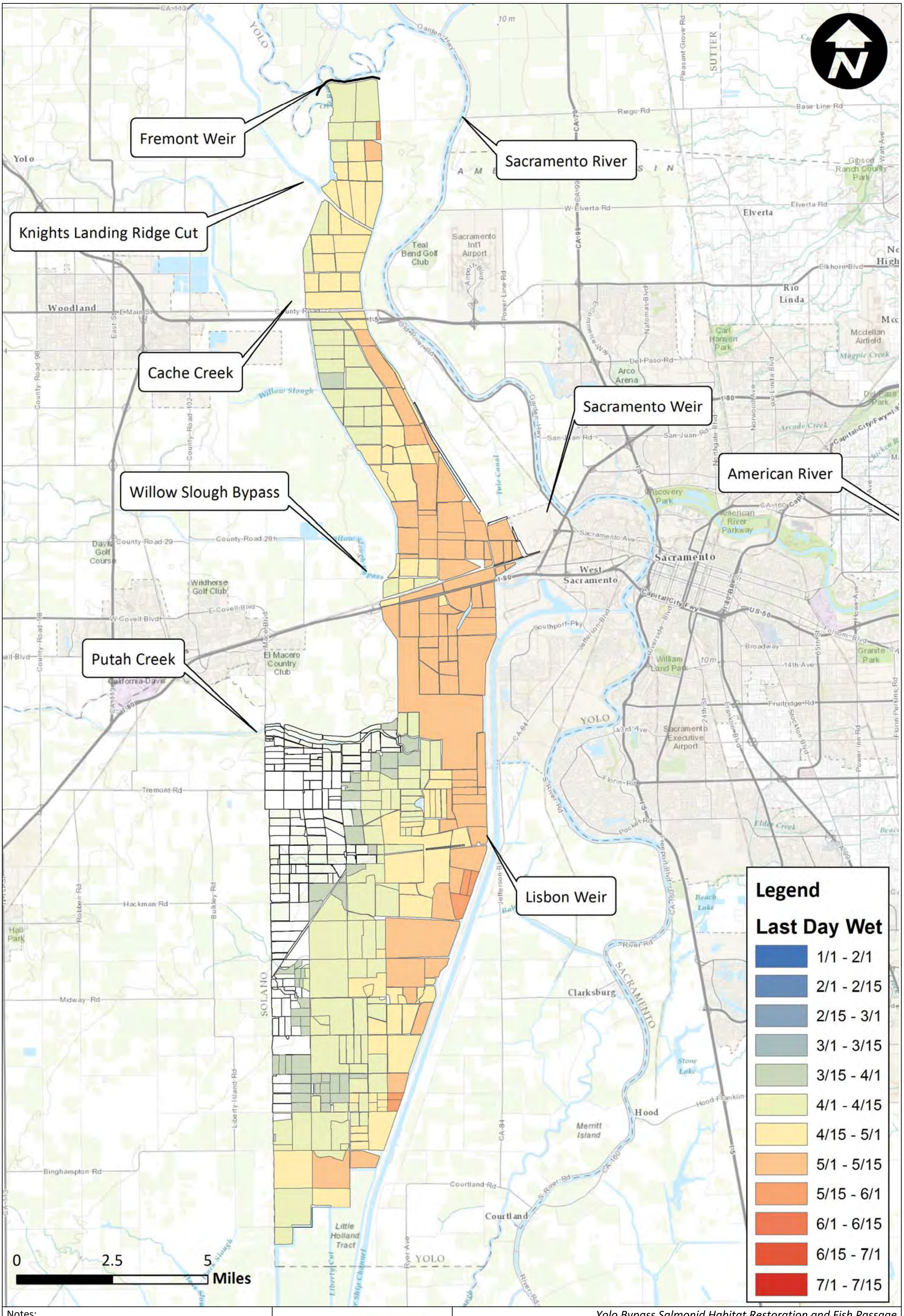
Notes:

HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2010

Prepared for DWR	Created By: RDJ	**Figure F62**

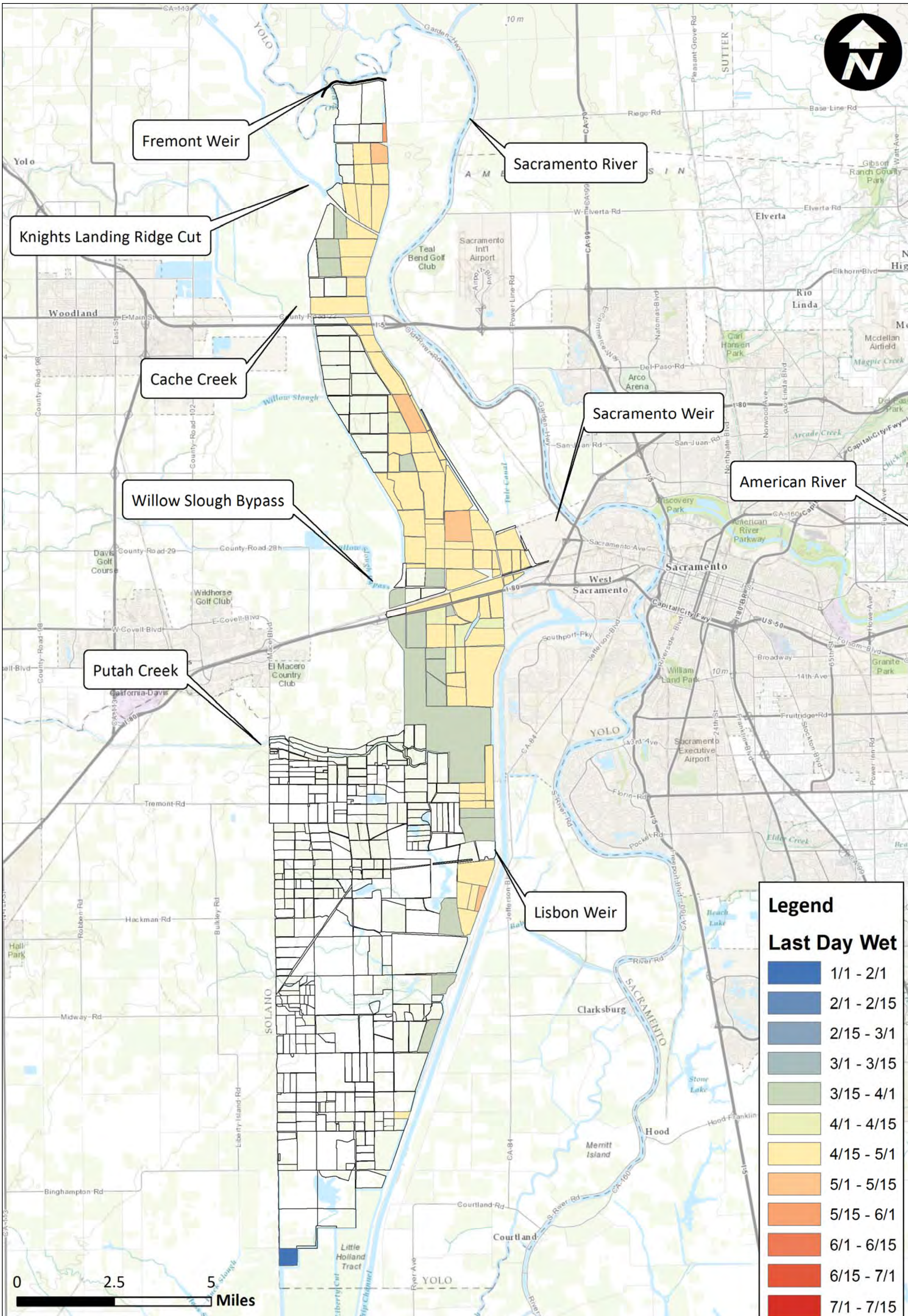


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2011

Prepared for DWR | Created By: RDJ | **Figure F63**

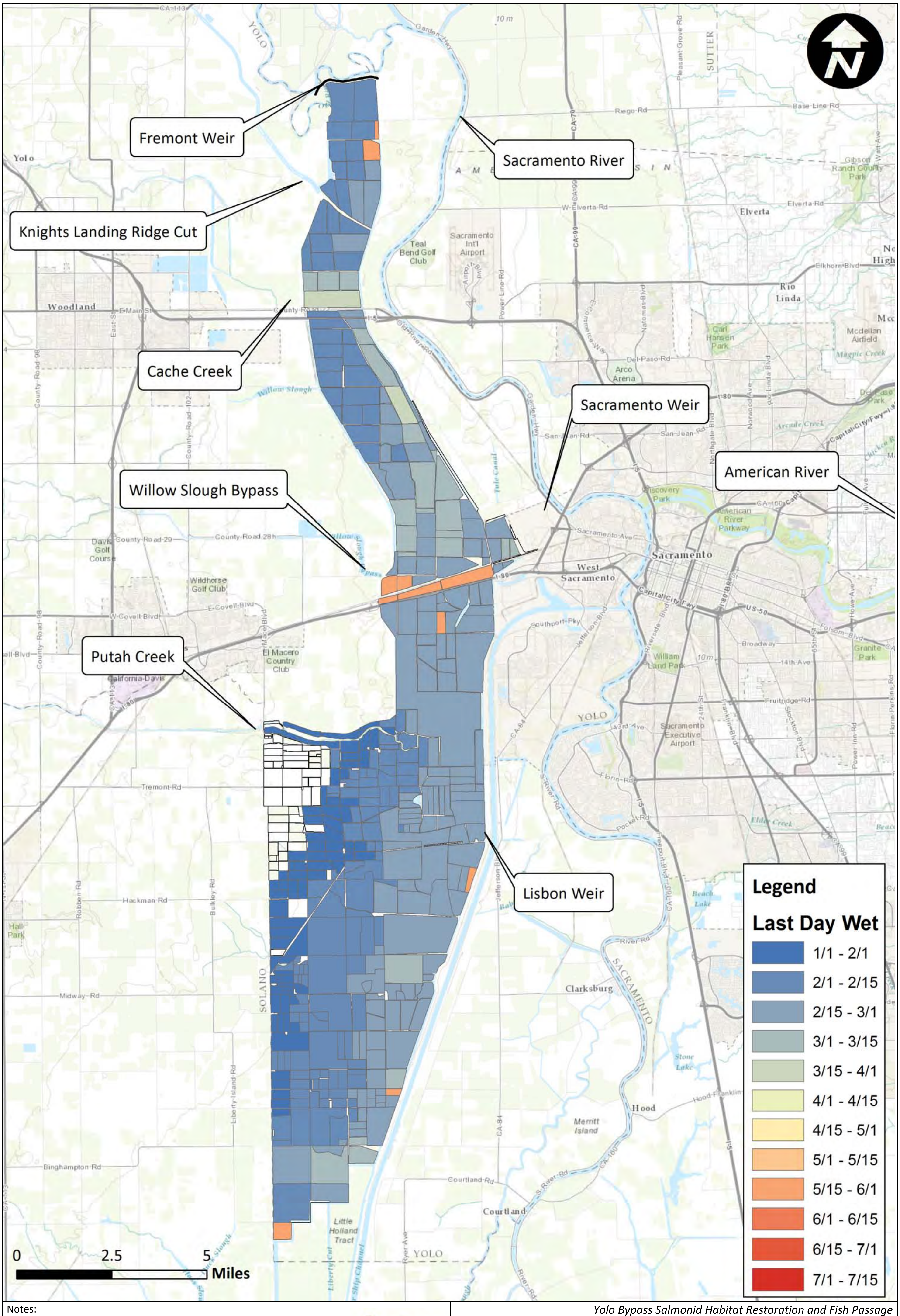


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Fremont Large Channel 2012

Prepared for DWR | Created By: RDJ | **Figure F64**



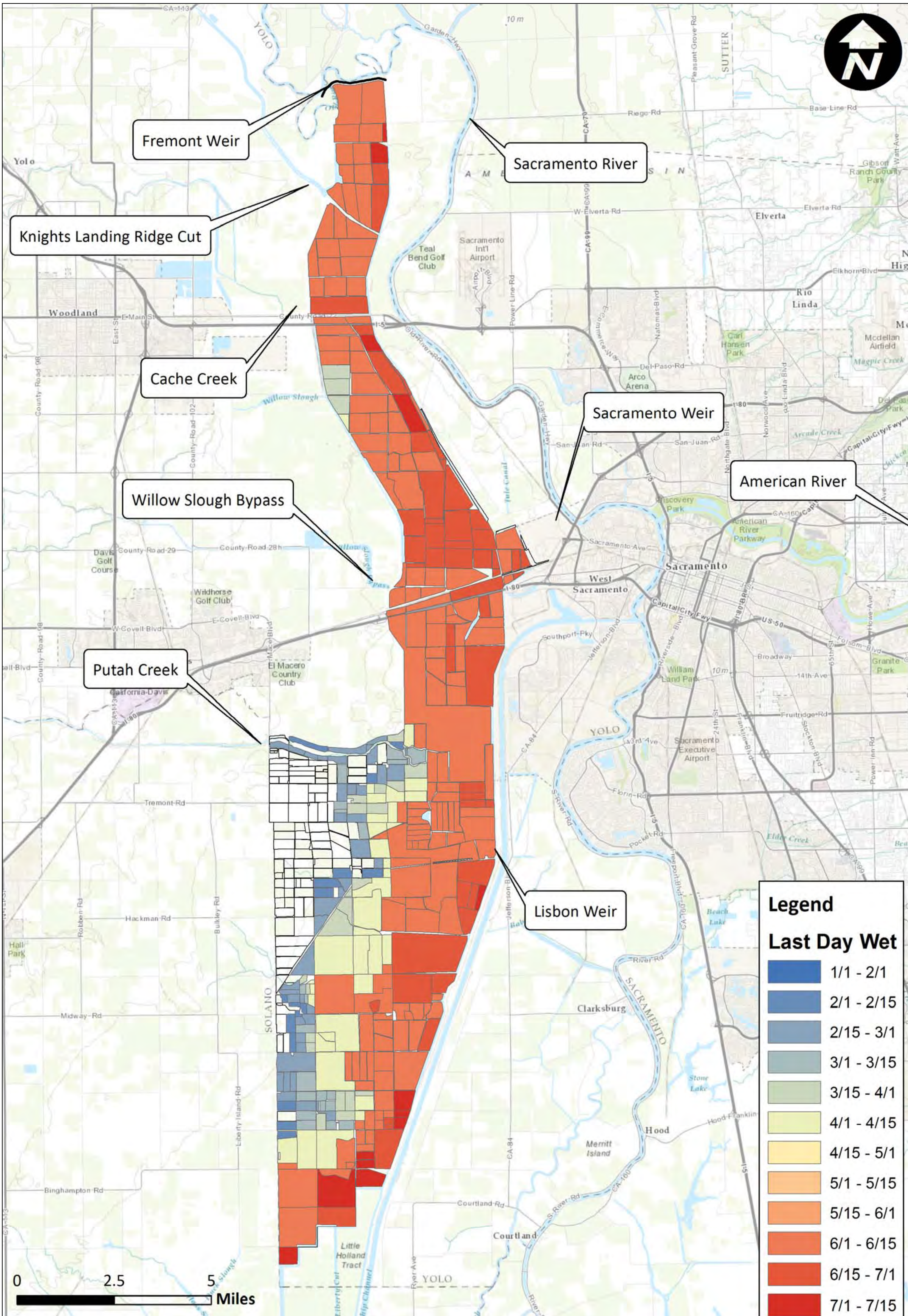
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 1997

Prepared for DWR | Created By: RDJ

Figure F65



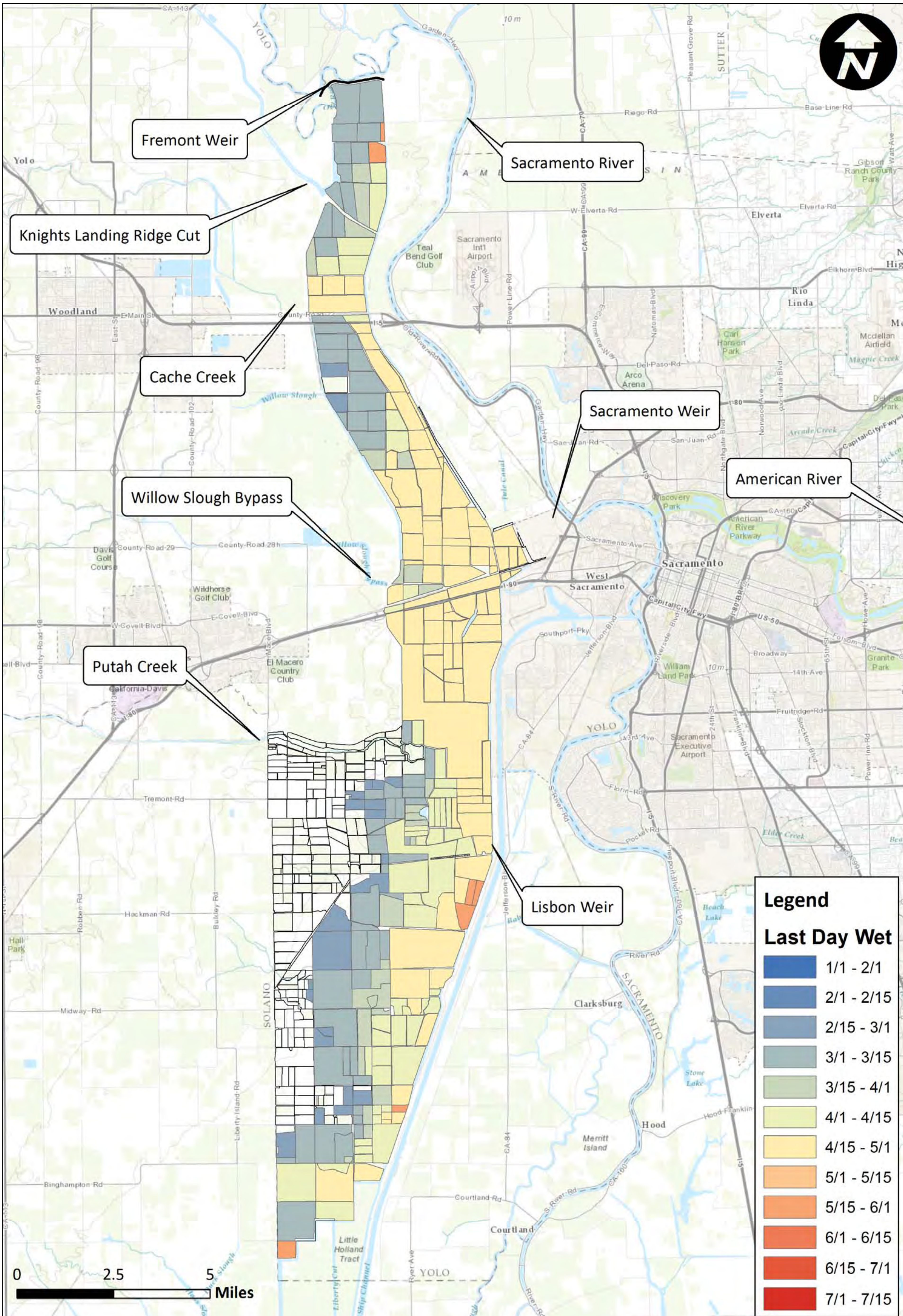
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 1998

Prepared for DWR | Created By: RDJ

Figure F66



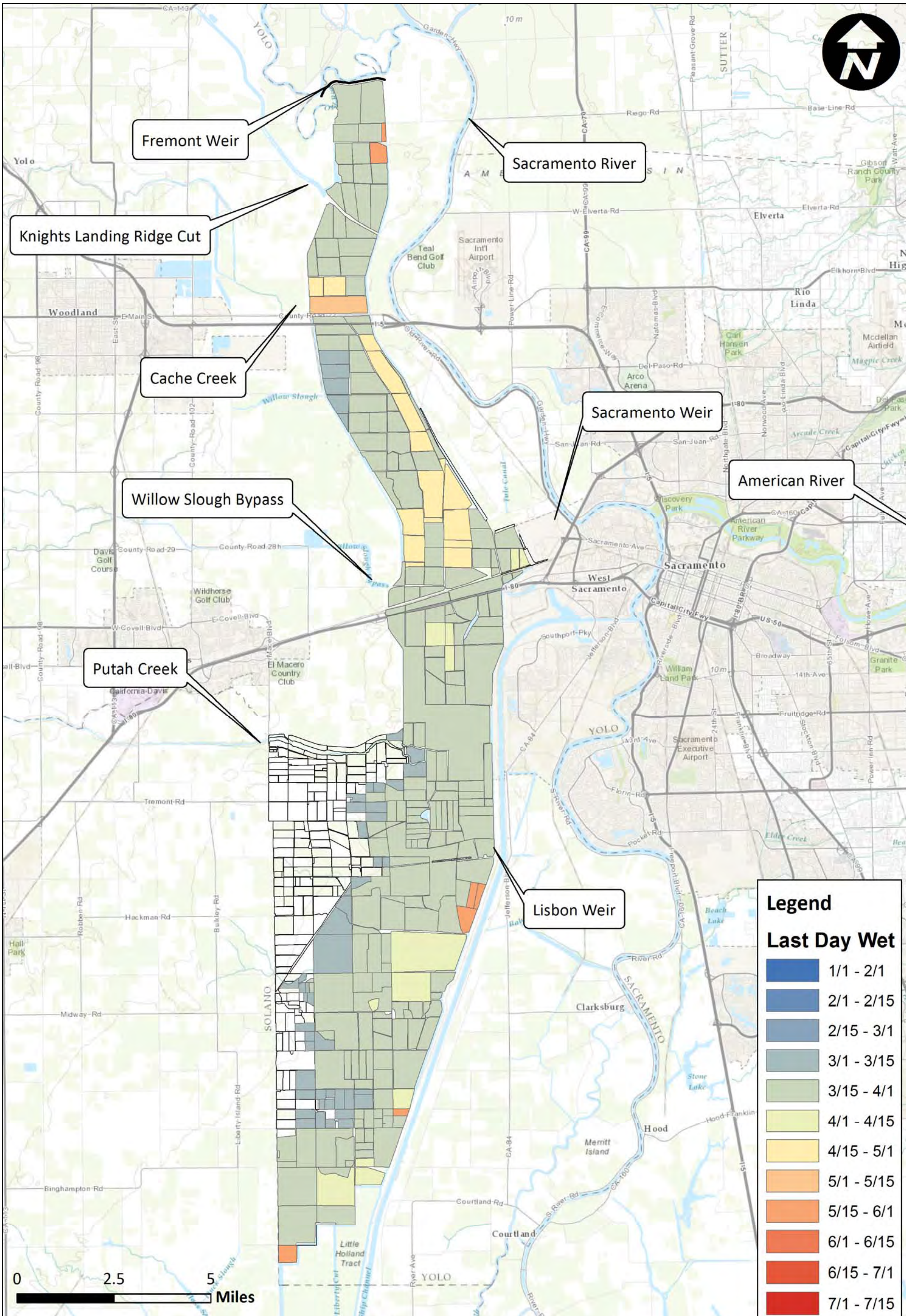
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 1999

Prepared for DWR | Created By: RDJ

Figure F67



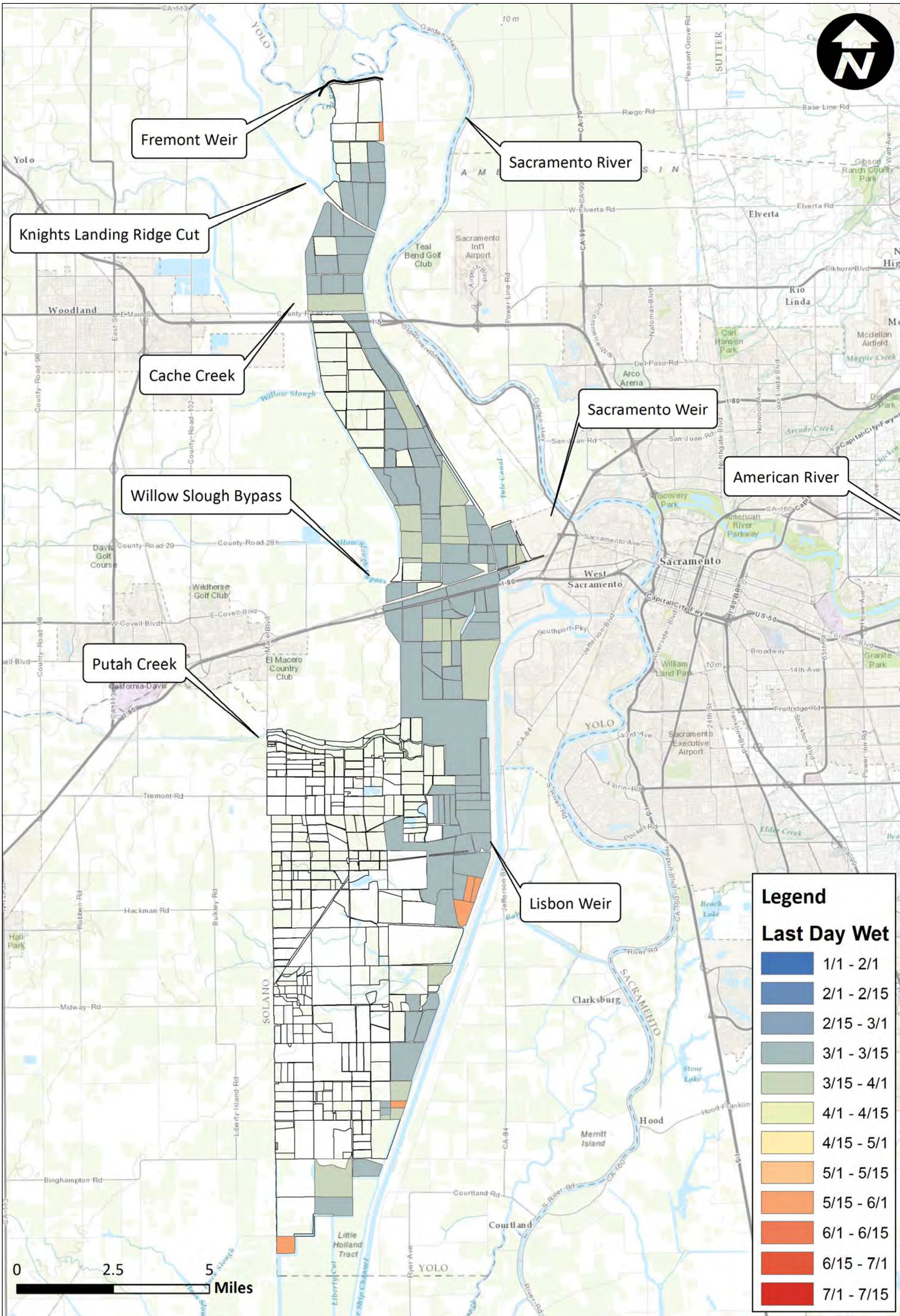
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2000

Prepared for DWR | Created By: RDJ

Figure F68

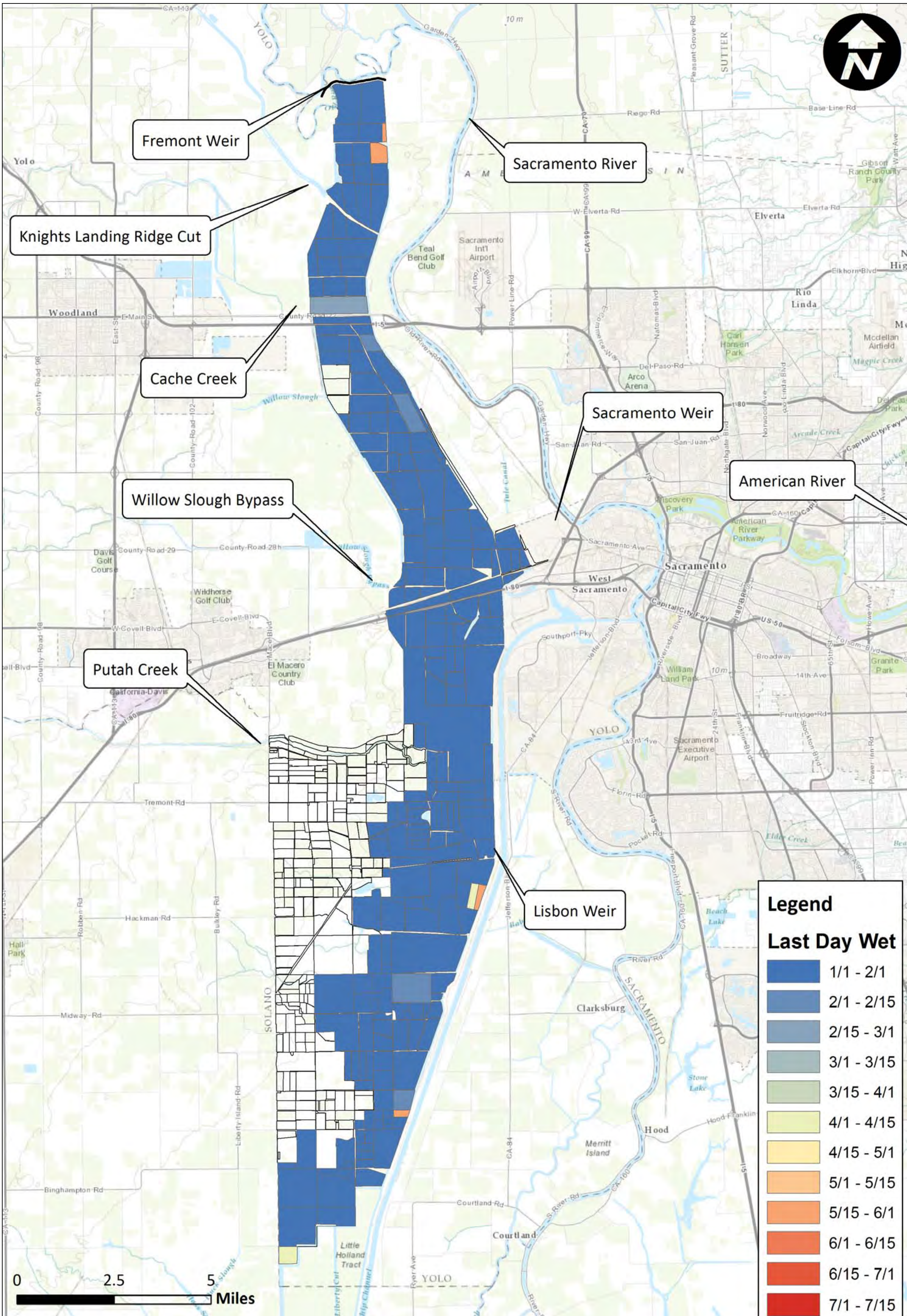


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2001

Prepared for DWR | Created By: RDJ | **Figure F69**



Notes:

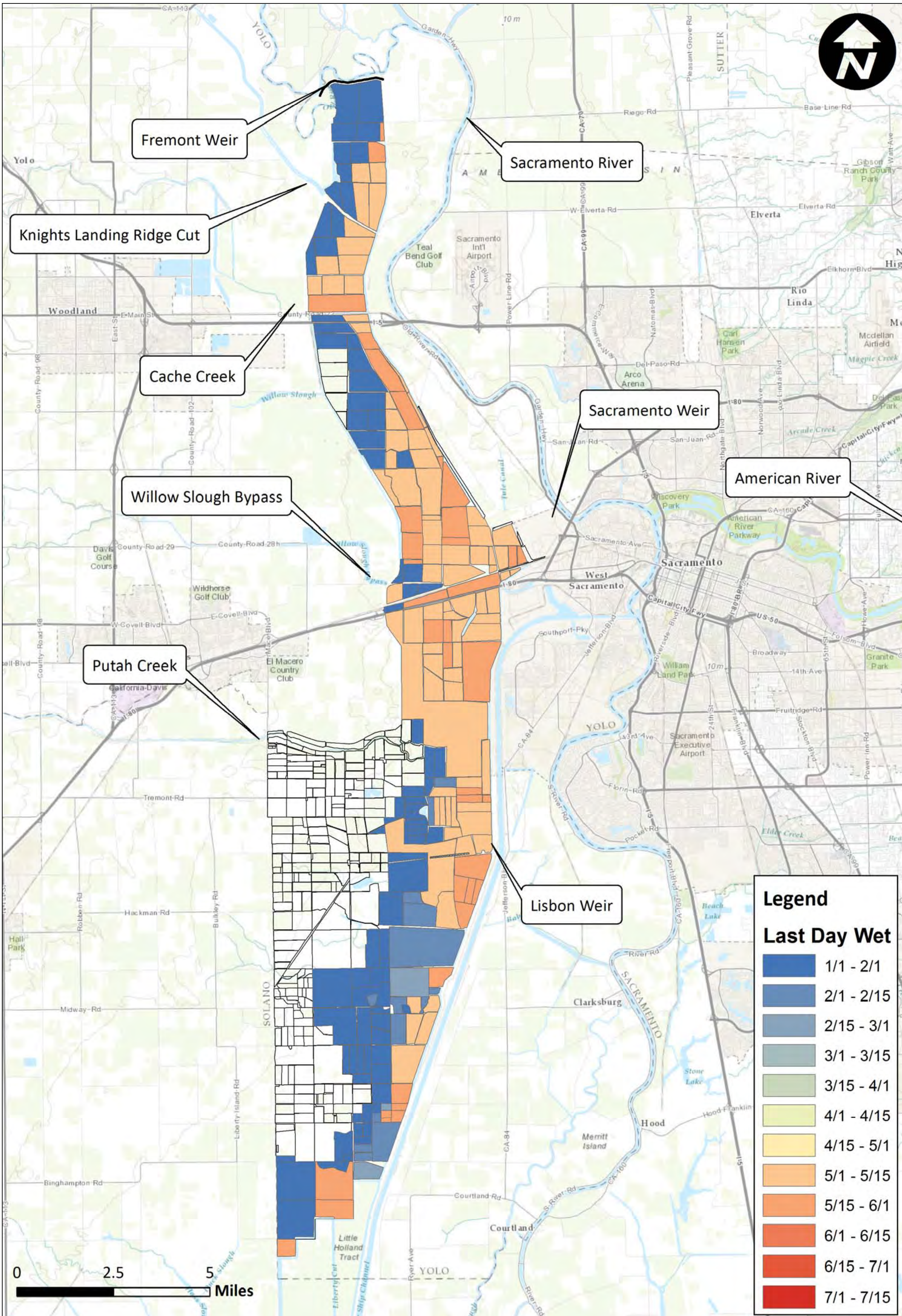
HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2002

Prepared for DWR | Created By: RDJ

Figure F70



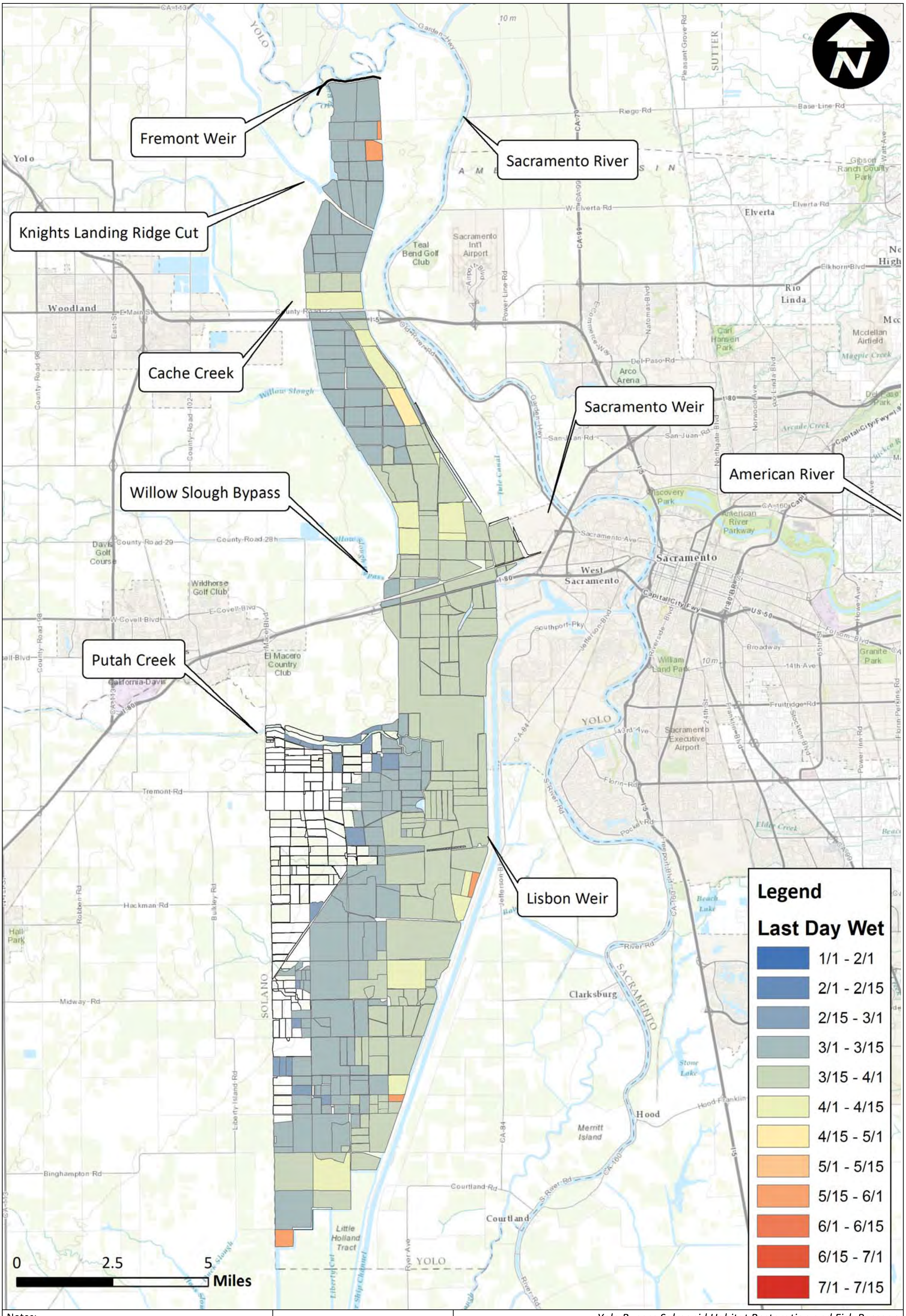
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2003

Prepared for DWR | Created By: RDJ

Figure F71



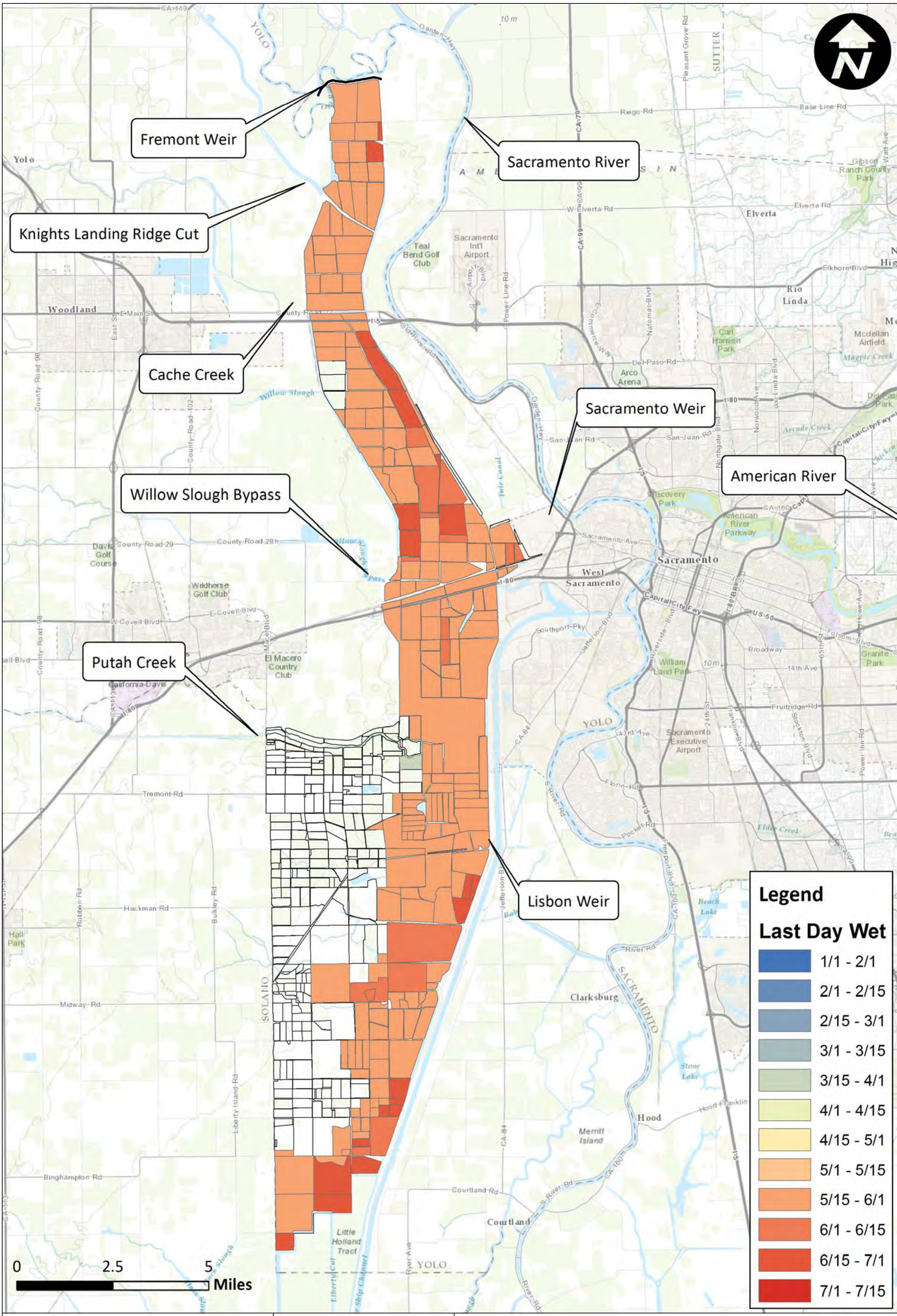
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2004

Prepared for DWR | Created By: RDJ

Figure F72



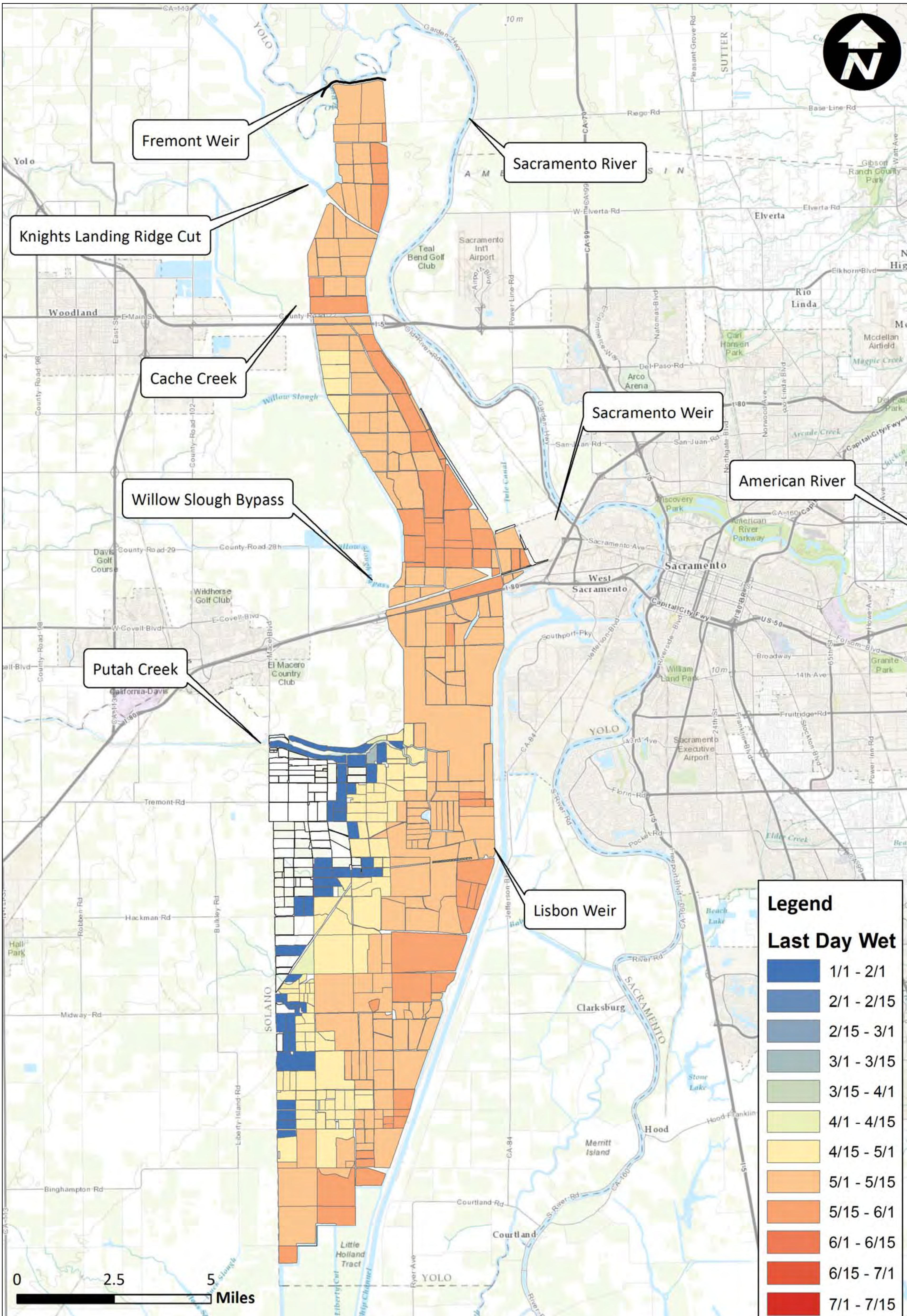
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2005

Prepared for DWR | Created By: RDJ

Figure F73



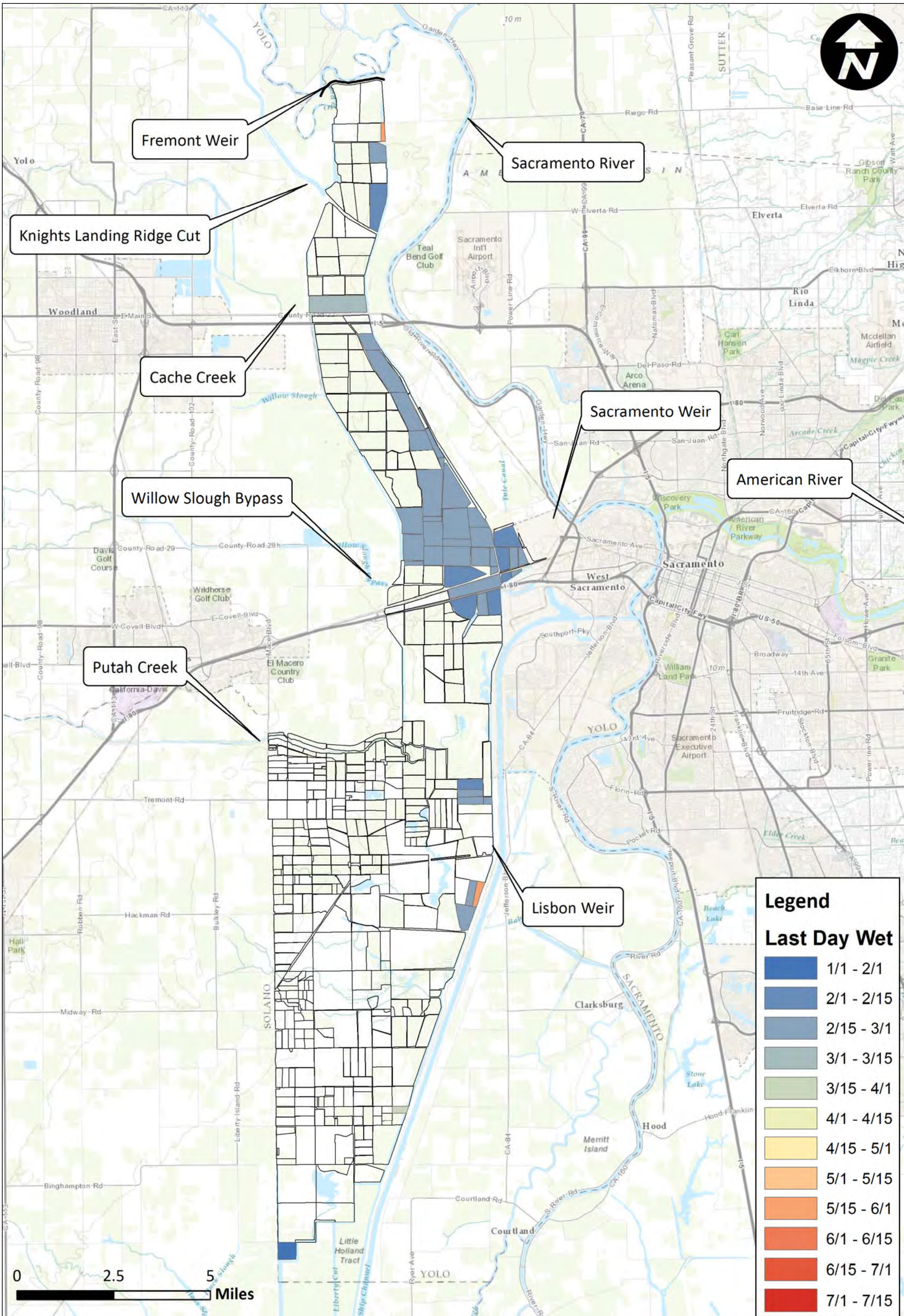
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2006

Prepared for DWR | Created By: RDJ

Figure F74



Notes:

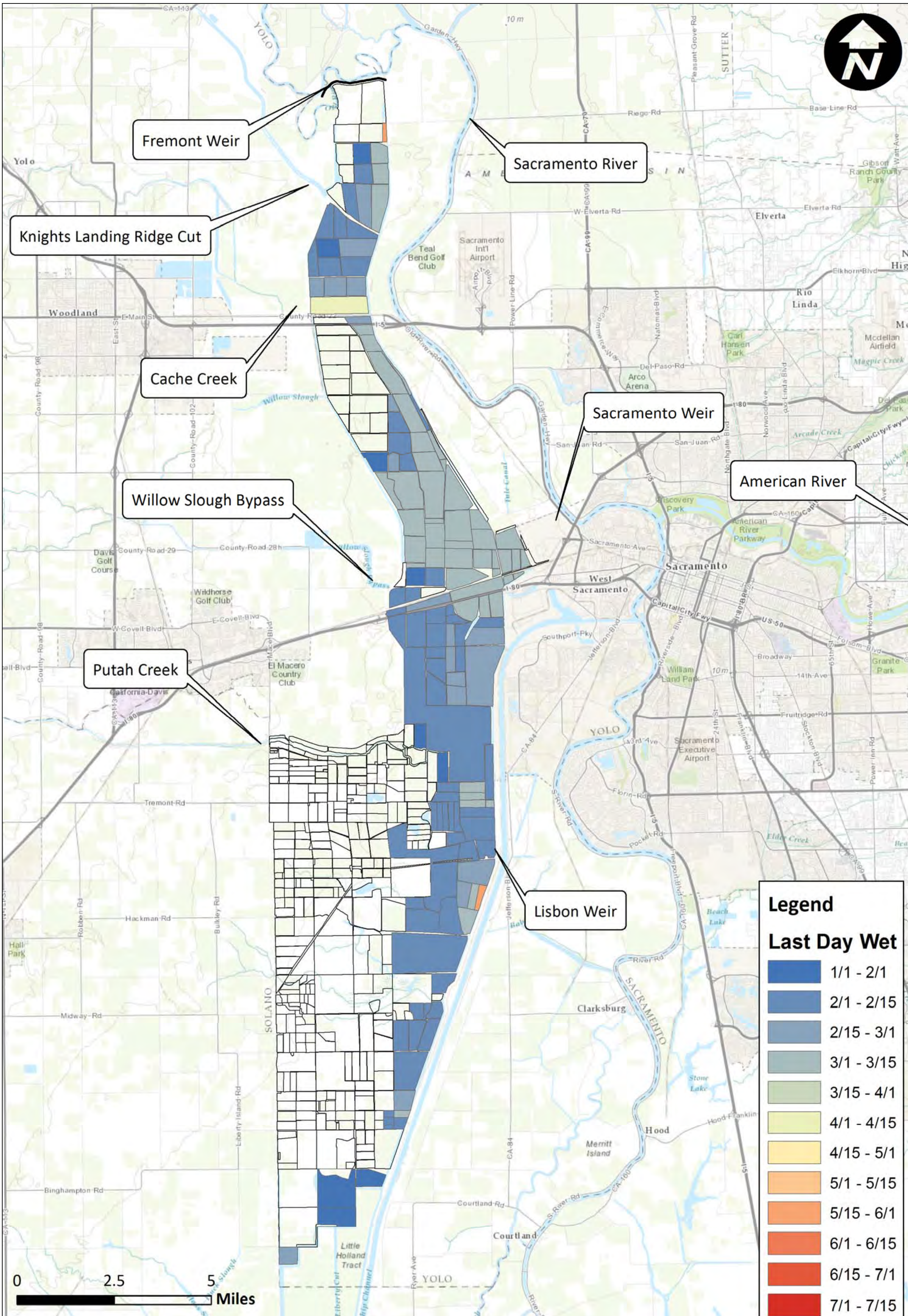
HDR cbec

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2007

Prepared for DWR | Created By: RDJ

Figure F75

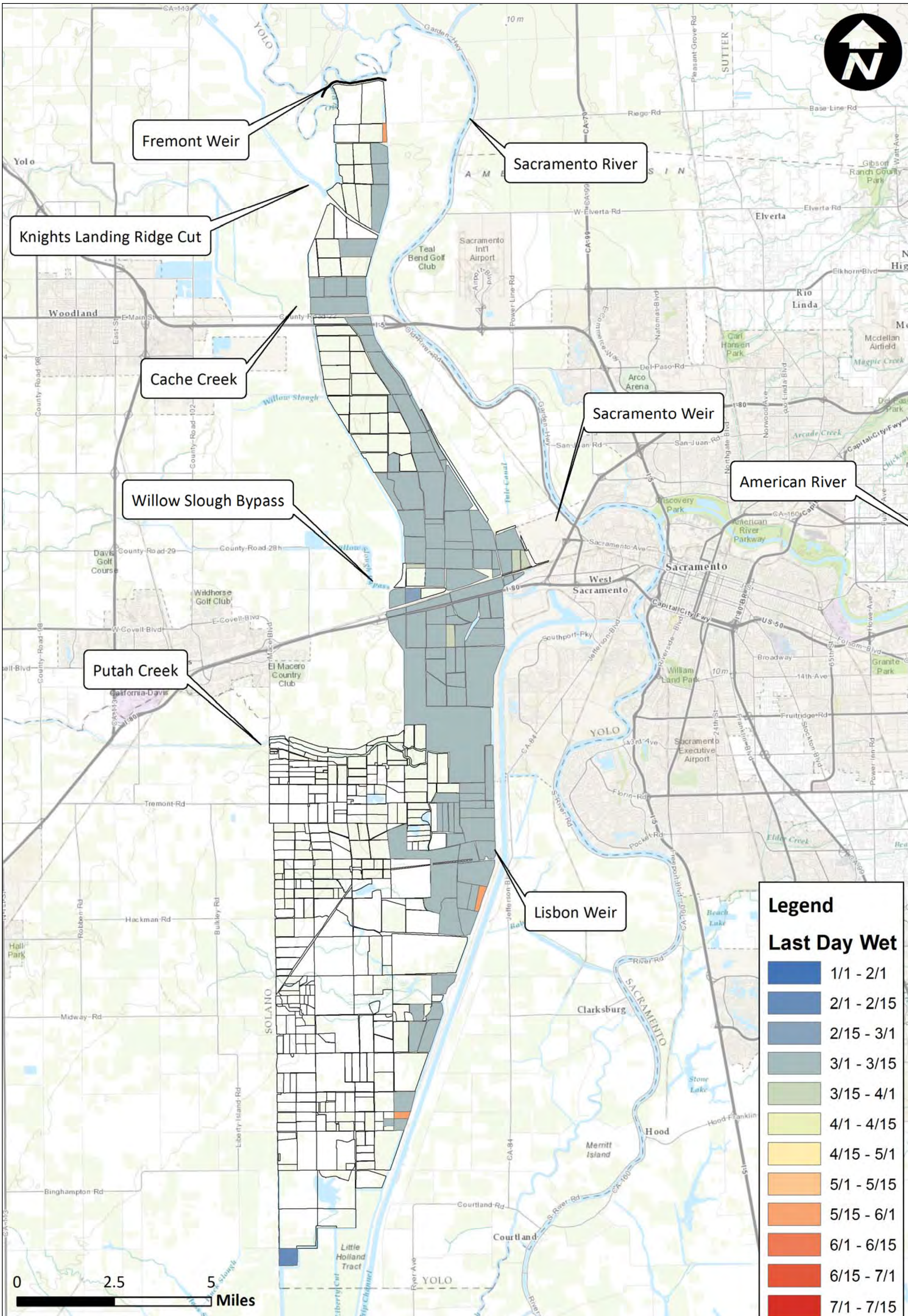


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2008

Prepared for DWR | Created By: RDJ | **Figure F76**



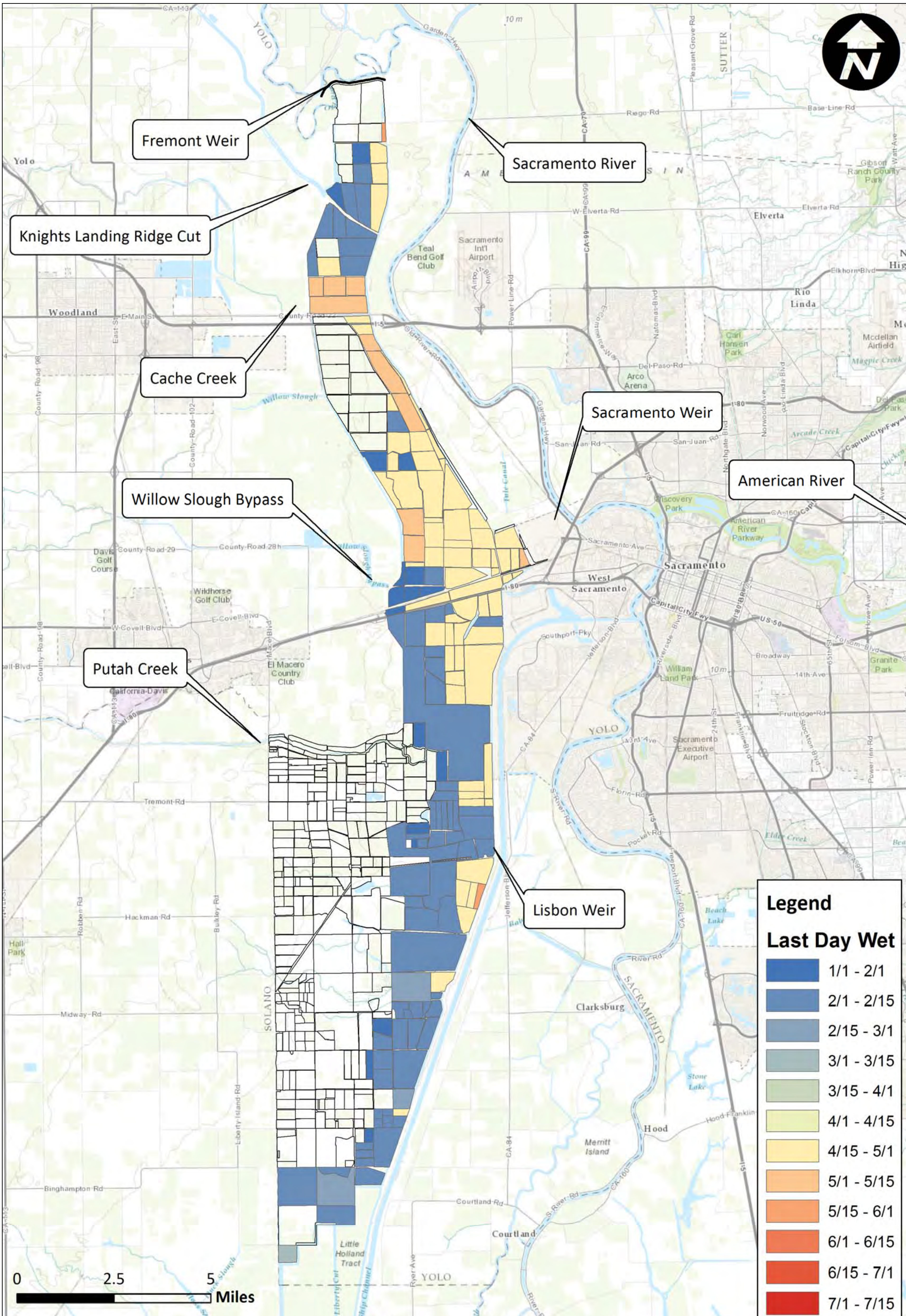
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2009

Prepared for DWR | Created By: RDJ

Figure F77



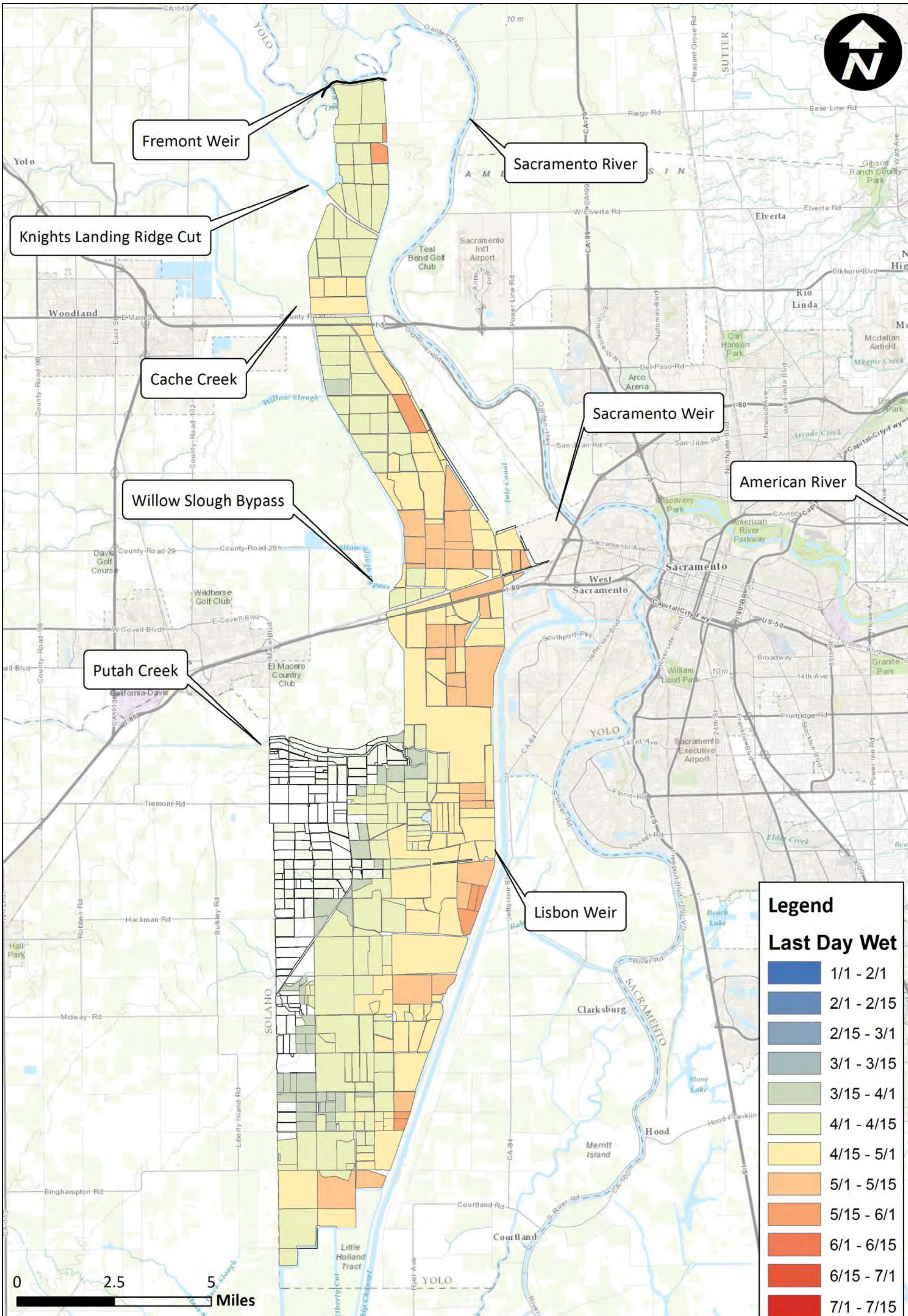
Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2010

Prepared for DWR | Created By: RDJ

Figure F78

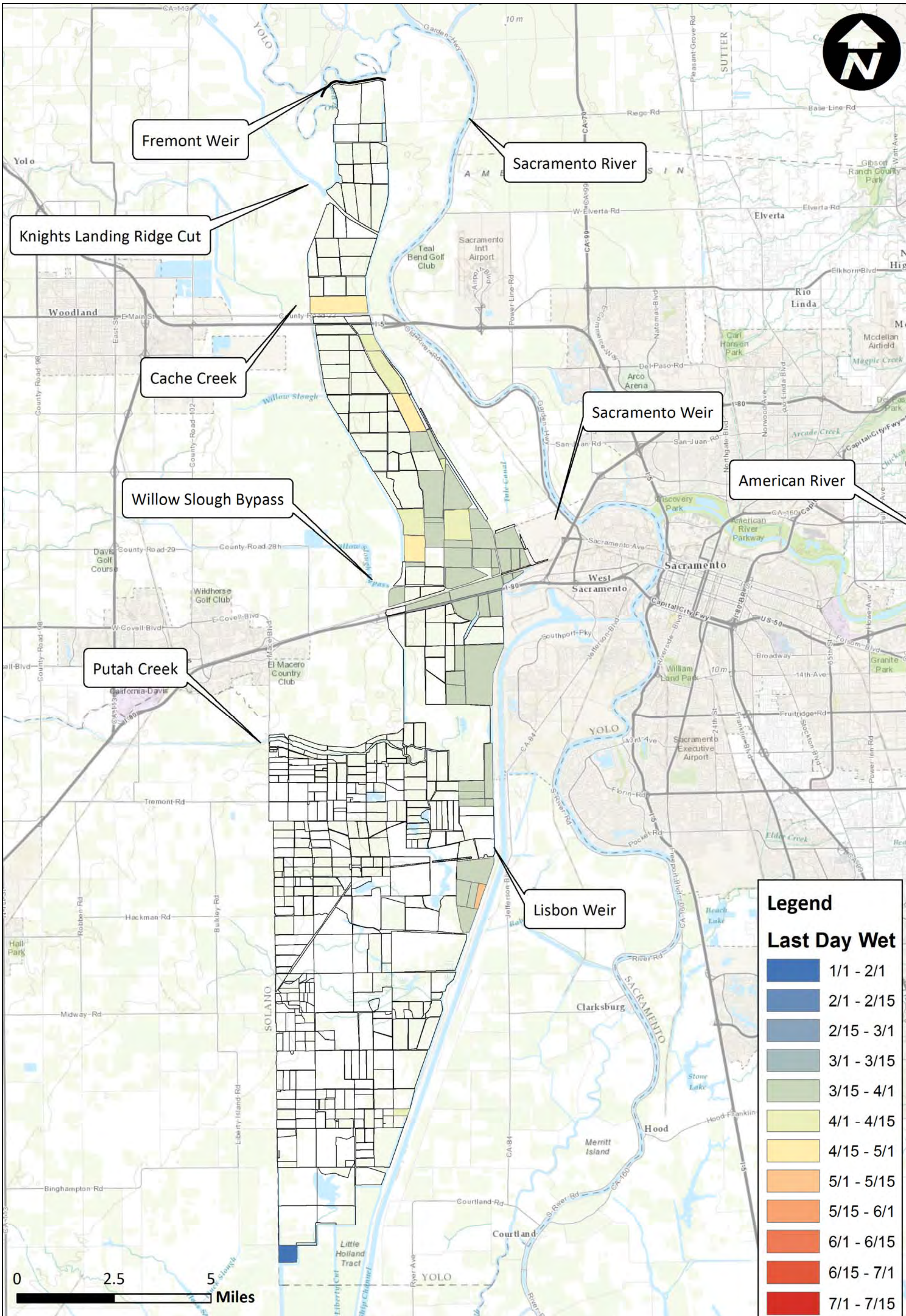


Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2011

Prepared for DWR | Created By: RDJ | **Figure F79**



Notes:

Yolo Bypass Salmonid Habitat Restoration and Fish Passage

Last Day Wet Sacramento Weir Channel 2012

Prepared for DWR | Created By: RDJ | **Figure F80**

Appendix G

FEMA Requirements and FEMA FIRM Panels

FEMA Requirements

Fremont Weir is located in Yolo and Sutter Counties, California. The weir is primarily located in Yolo County but a small portion on the west side lies between the Sacramento River and the Old River cutoff. Since the county boundaries generally follow the old Sacramento River in this area, this portion of the weir resides in Sutter County. Since both of these communities participate in the National Flood Insurance Program (NFIP), they are required to follow the NFIP regulations related to floodplain development found in Chapter 44 of the Code of Federal Regulations (44 CFR).

The NFIP regulations are keyed to “development” in the floodplain. “Development” is defined as “any man-made change to improved or unimproved real estate.” The NFIP regulations identify the minimum requirements that communities must follow. The communities may establish more stringent requirements. The minimum requirements set forth in the CFR depend on the flood hazard and level of detail of the data FEMA provides to the community. For Sutter County and Yolo County in the area of the Fremont Weir, FEMA has provided flood insurance rate maps (FIRMs) showing special flood hazard areas (SFHA) Zone A and Zone AE. FEMA SFHA Zone A indicates areas subject to inundation by the 1-percent-annual-chance flood event. Because detailed hydrodynamic analyses have not been performed, no Base Flood Elevations (BFEs) or flood depths are shown on the flood hazard maps. FEMA SFHA Zone AE indicates areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods. BFEs are shown within these zones. The flood maps in the area of Fremont Weir do not include a regulatory floodway. The current FIRM panels available from FEMA’s website (see also Appendix G) in the area of Fremont Weir are:

- Sutter County – Map No. 0603940795E, effective December 2, 2008
- Yolo County – Map No. 06113C0320G, effective June 18, 2010

In both counties, the Fremont Weir is located in an AE Zone with base flood elevations and no floodway designated. The specific regulation that applies to development in this case is 44 CFR 60.3(c)(10): [Communities must] Require until a regulatory floodway is designated, that no new construction, substantial improvements, or other development (including fill) shall be permitted within Zones A1-30 and AE on the community's FIRM, unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the WSE of the base flood more than one foot at any point within the community.

In order to comply with this requirement, the effective flood insurance study hydrodynamic models must be obtained from FEMA. Specific procedures outlined by FEMA are then followed to develop the existing conditions and project conditions hydrodynamic models for comparison. Unless the individual communities have more stringent requirements, this would be the minimum analysis necessary to provide to the floodplain administrators of each jurisdiction where the project is located.

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' National Geodetic Vertical Datum of 1929 (NGVD 29). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 10. The **horizontal datum** was NAD83, GRS1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the National Geodetic Vertical Datum of 1929. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov/ or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, MD 20910-3282

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242**, or visit its website at http://www.ngs.noaa.gov/.

Base map information shown on this FIRM was provided in digital format by the USDA National Agriculture Imagery Program (NAIP). This information was photogrammetrically compiled at a scale of 1:24,000 from aerial photography dated 2005.

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

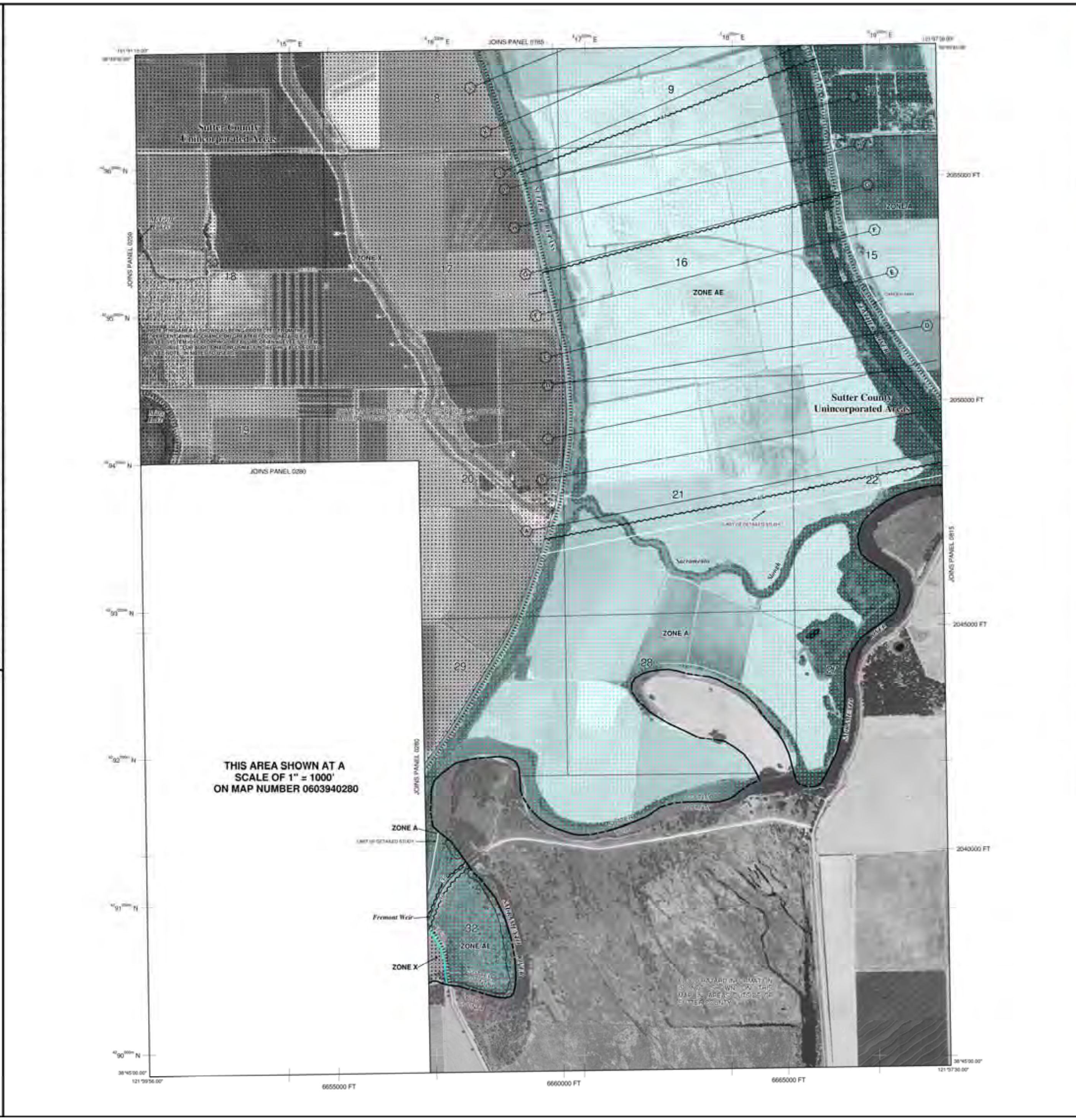
Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map showing the layout of map panels for this jurisdiction.

Contact the **FEMA Map Service Center** at 1-800-358-9616 for information on available products associated with this FIRM. Available products may include previously issued Letters of Map Change, a *Flood Insurance Study* report, and/or digital versions of this map. The FEMA Map Service Center may also be reached by Fax at 1-800-358-9620 and its website at http://www.msc.fema.gov/.

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1-877-FEMA MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/.

Accredited Levee Notes to Users: Check with your local community to obtain more information, such as the estimated level of protection provided (which may exceed the 1-percent-annual-chance level) and Emergency Action Plan, on the levee system(s) shown as providing protection for areas on this panel. To mitigate flood risk in residual risk areas, property owners and residents are encouraged to consider flood insurance and floodproofing or other protective measures. For more information on flood insurance, interested parties should visit the FEMA Website at http://www.fema.gov/business/nfip/index.shtm.



LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

1% annual chance floodplain boundary
0.2% annual chance floodplain boundary
Floodway boundary
Zone D boundary
CBRS and OPA boundary
Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29)

(A)—(A)	Cross section line
(23)- - -(23)	Transect line
	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
	1000-meter Universal Transverse Mercator grid ticks, zone 10
6000000 FT	5000-foot grid ticks: California State Plane coordinate system, II zone (FIPSZONE 0402), Lambert Conformal Conic
DX5510	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

MAP REPOSITORY

INITIAL NFIP MAP DATE
June 7, 1977
FLOOD HAZARD BOUNDARY MAP REVISIONS

FLOOD INSURANCE RATE MAP EFFECTIVE
April 5, 1988
FLOOD INSURANCE RATE MAP REVISIONS
November 15, 1988 - July 6, 1998
December 2, 2008 - to change base flood elevations, to reflect updated topographic information, to update map format, to add base flood elevations, to change zone designations, and to add roads and road names.

MAP SCALE 1" = 1000'
500 0 1000 2000 FEET
300 0 300 600 METERS

NATIONAL FLOOD INSURANCE PROGRAM

NFIP

PANEL 0795E

FIRM
FLOOD INSURANCE RATE MAP

SUTTER COUNTY, CALIFORNIA
(UNINCORPORATED AREAS)

PANEL 795 OF 880
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
SUTTER COUNTY	[illegible]	[illegible]	E

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
0603940795E

MAP REVISED
DECEMBER 2, 2008

Federal Emergency Management Agency

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations tables in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations tables should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

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The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) Zone 10N. The **horizontal datum** was NAD 83, GRS80 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

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NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
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Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242**, or visit its website at http://www.ngs.noaa.gov.

Base map transportation information shown on this FIRM was provided in digital format from Sacramento Area Council of Governments (SACOG). These data were developed in conjunction with the tax assessor's parcel base map and published by SACOG in June 2005. The road centerlines follow the computed centers of the parcel right-of-ways.

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to confirm to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study Report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

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Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

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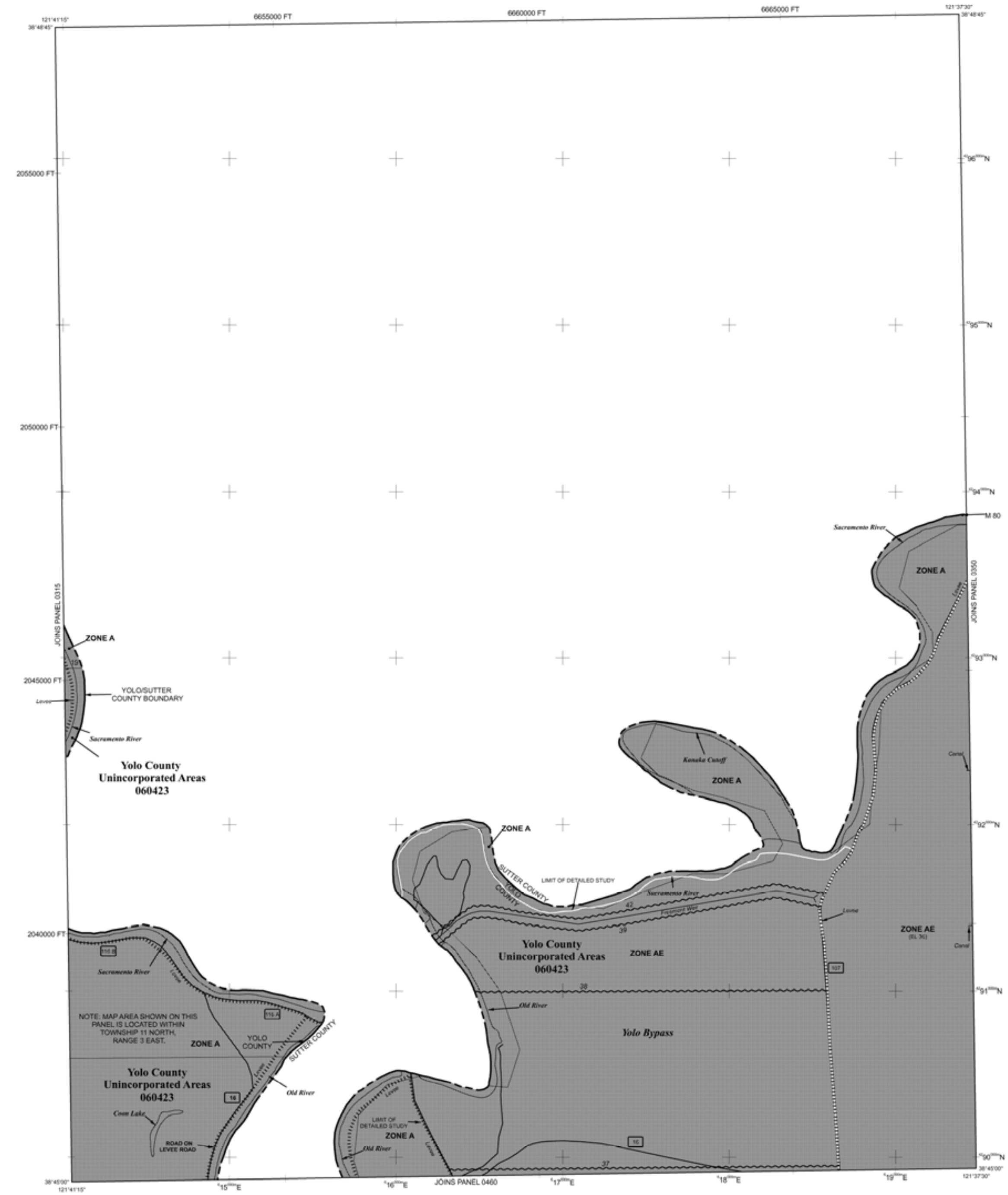

LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

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ZONE A	No Base Flood Elevations determined.
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FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

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OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

	Floodplain boundary
	Floodway boundary
	Zone D boundary
	CBRS and OPA boundary
	Boundary dividing Special Flood Hazard Area zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the North American Vertical Datum of 1988

(A)—(A)	Cross section Line
(23)- - - -(23)	Transect line
87°07'45", 32°22'30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
76N	1000-meter Universal Transverse Mercator grid values, zone NAD 1983 UTM Zone 10N
600000 FT	5000-foot grid values: California State Plane coordinate system, zone II (FIPSZONE 0402), Lambert Conformal Conic projection
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
●M1.5	River Mile

MAP REPOSITORY
Refer to listing of Map Repositories on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
June 18, 2010

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your Insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 1000'

500 0 1000 2000 FEET

300 0 300 600 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0320G

FIRM
FLOOD INSURANCE RATE MAP

YOLO COUNTY, CALIFORNIA
AND INCORPORATED AREAS

PANEL 320 OF 785

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
YOLO COUNTY	060423	0320	G

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
06113C0320G

EFFECTIVE DATE
JUNE 18, 2010

Federal Emergency Management Agency