Appendix C
TUFLOW Model Results and CEQA Impacts Analysis

TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT

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Prepared for
California Department of Water Resources

September 2020

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TABLE OF CONTENTS

Tisdale Weir Rehabilitation and Fish Passage Project, TUFLOW Model Results and CEQA Impacts Analysis

Page

Attachments

List of Figures

List of Tables

Acronyms and Other Abbreviations

1D	one-dimensional
2D	two-dimensional
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CropScape Data	CropScape–Cropland Data Layer
CVFED	Central Valley Floodplain Evaluation and Delineation
DEM	digital elevation model
DWR	California Department of Water Resources
ESA	Environmental Science Associates
Farmland	Prime Farmland, Unique Farmland, and Farmland of Statewide Importance
HEC-RAS	Hydrologic Engineering Center River Analysis System
LiDAR	Light Detection and Ranging
model	coupled one-dimensional/two-dimensional hydrodynamic model
NAVD 88	North American Vertical Datum of 1988
NDWI	Normalized Difference Water Index
NOP	Notice of Preparation
Project	Tisdale Weir Rehabilitation and Fish Passage Project
SNWR	Sutter National Wildlife Refuge
TUFLOW	TUFLOW HPC commercial software package
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
WY	water year
Yolo EIR	Yolo Bypass and Salmonid Habitat Restoration and Fish Passage Project Environmental Impact Report

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TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT

TUFLOW Model Results and CEQA Impacts Analysis

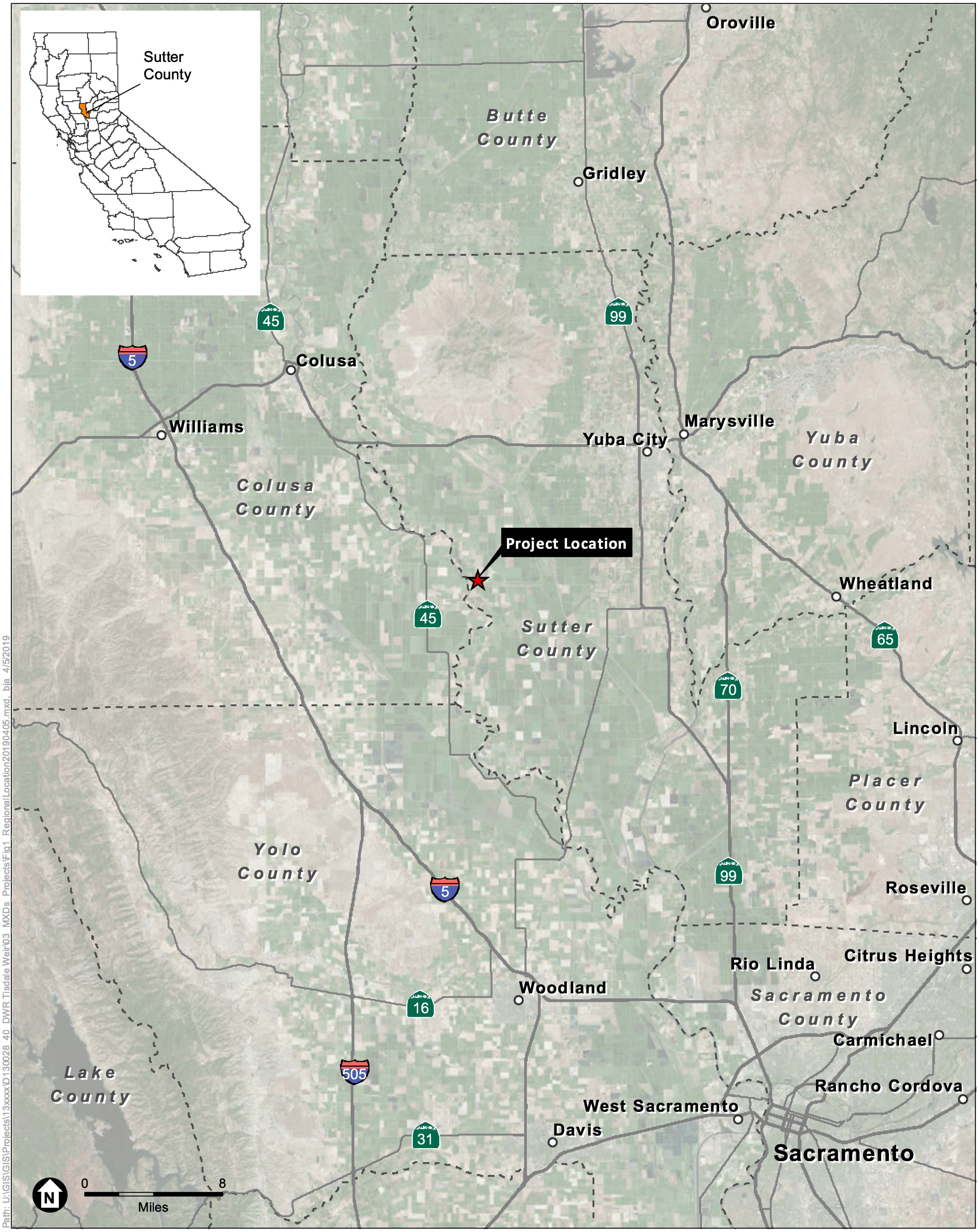
1 Introduction and Purpose

Tisdale Weir is a critical, State-owned flood risk reduction facility located along the left bank of the Sacramento River about 10 miles southeast of the town of Meridian and 56 miles north of Sacramento (**Figure 1**). The weir was originally constructed by local interests and was improved by the U.S. Army Corps of Engineers in 1932 as part of the Sacramento River Flood Control Project (USACE 1955). Tisdale Weir currently needs structural rehabilitation to extend its design life, and during certain flow conditions it can prevent up-migrating fish from passing to the Sacramento River.

The proposed multi-benefit Tisdale Weir Rehabilitation and Fish Passage Project (Project) would construct needed structural repairs to the weir, and would modify the weir to add new fish passage facilities. If approved, the Project would improve public safety by rehabilitating the weir to provide ongoing conveyance of excess floodwaters. It would also reduce historical fish stranding at the weir as floodwaters recede and flows from the Sacramento River to the Tisdale Bypass cease. Of concern are potential losses of Chinook salmon (*Oncorhynchus tshawytscha*), North American green sturgeon (*Acipenser medirostris*), and other anadromous fishes.

To improve fish passage and prevent stranding, the Project proposes to construct a connection channel between the river and Tisdale Weir, create a notch in the weir, and install an operable gate in the notch. The gate would be operated to connect the river to the Tisdale Bypass during and after a weir overtopping event, with the objective of providing an opportunity for fish to pass through the notch and back into the Sacramento River. With operation of the Project, flows to the Tisdale Bypass and the downstream portion of the Sutter Bypass would increase during certain periods, potentially increasing the depth, extent, and duration of inundation on agricultural fields and in other areas (e.g., waterfowl hunting areas).

For purposes of Project review under the California Environmental Quality Act (CEQA), Environmental Science Associates (ESA) analyzed existing- and Project-condition hydrology and hydraulics to understand and quantify any downstream changes in inundation. For this analysis, ESA developed a coupled one-dimensional/two-dimensional (1D/2D) hydrodynamic model (model) of the Tisdale and Sutter Bypasses, and an approach and methodology for assessing the modeling results in the context of CEQA impact criteria.



SOURCE: Esri, 2015; ESA, 2019

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 1
Regional Location

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This report summarizes the results of the modeling and provides the information necessary to support preparation of the Project's draft environmental impact report for compliance with CEQA. The modeling analysis and results focus on the potential operational impacts of the Proposed Project with respect to agricultural resources, recreation, and biological resources.

2 Hydrology and Hydraulics

Operation of the Project would increase downstream flow into the Tisdale Bypass when the gate is open and the Sacramento River is above the topographic hinge point[1] of the Tisdale Bypass (elevation 37 feet, North American Vertical Datum of 1988 [NAVD 88]). This new Project condition may often coincide with antecedent flooding in the Sutter Bypass created by upstream flow inputs from the Butte Basin (Butte Creek and Cherokee Canal drainages; any Sacramento River overflow into the Butte Basin) and the Wadsworth Canal, or attributable to backwatering from the Sacramento and Feather River systems. However, flow through the notch may also occur when these antecedent flows from the Butte Basin are receding. Thus, the modeling for this analysis needed to be capable of representing lower flow conditions than the flood flows that existing available models were intended to represent (e.g., CH2M Hill 2013).

This section summarizes the input and hydrologic boundary conditions for the model, and the development, parameterization, calibration, and validation of the model.

2.1 Hydrology

The Sutter Bypass serves primarily as an overflow flood conveyance channel, but it also serves as a sink for drainage of floodwaters and agricultural return flows, and as a conduit for conveyance and distribution of irrigation water. For major surface water inputs, hydrologic boundary condition time series for flow and/or stage were developed based on the best available data (e.g., DWR California Water Data Library, U.S. Geological Survey gages). As appropriate, these were augmented with previously modeled flows (e.g., CalSim 3, Central Valley Hydrology Study) or other means to fill gaps in the data record (e.g., regression with nearby gages). The largest hydrology inputs for the Sutter Bypass are overflows from the Sacramento River at the Tisdale Weir, Butte Basin inputs via Butte Creek/Slough, and overflows from the Feather River. However, as described below, backwater conditions from the Sacramento River and Feather River at the downstream end of the Sutter Bypass also have a large influence over the extent of upstream flooding within the bypass. In general, the extent of flooding and inundation within the Sutter Bypass depends on the interaction of the variable flow inputs and timing as well as the water surface elevation of the Sacramento River in the vicinity of the Fremont Weir (the downstream terminus of the Sutter Bypass). Specific hydrology inputs and other boundary conditions are described further in Section 2.2, *Hydraulic Model*).

1 The hinge point is an area in the Tisdale Bypass approximately 1,500 feet downstream of the weir where the topography is slightly higher than the areas to the east (downstream in the bypass) and higher than the proposed notch in the weir (elevation 33 feet, NAVD 88) located to the west of the hinge point; thus, it would control flow through the Tisdale Bypass when the notch is open and Sacramento River stage is lower than the hinge point.

2.1.1 Flow During Flood Season

The Sutter Bypass serves primarily as an overflow channel for conveying Butte Basin and Sacramento River floodwaters in the winter. Flood season is November 1 through April 15 (California Code of Regulations Title 23, Section 112), though based on historic observations the Sutter Bypass can flood anytime from October through June. The Sutter Bypass receives direct floodwater input primarily from three sources: Butte Slough, the Tisdale Bypass, and the Feather River, which is also fed by the Yuba and Bear Rivers. Butte Slough always maintains flow into the Sutter Bypass, the Tisdale Bypass flows approximately 12 percent of the time in a given year (on average), and the Feather River spills directly into the Sutter Bypass only during extreme, larger floods (e.g., 1986, 1997). Flood flows in Butte Slough are generated by inputs to the Butte Basin, dominantly by Butte Creek and other inputs like Cherokee Canal (Dry Creek); however, sometimes significant inputs to the Butte Basin come from the Sacramento River. This occurs when Sacramento River flood flows spills over the Moulton or Colusa weirs, or the M&T Flood Relief Structure, the Goose Lake Flood Relief Structure, or the Three B's Natural Overflow Area. Sacramento River flood flows may also enter the Sutter Bypass downstream via the Tisdale Weir and Bypass.

2.1.2 Variability of Inundated Extent

In a typical flood season, backwater conditions exist throughout most of the lower Sutter Bypass (i.e., at the north, from the vicinity of the Feather River confluence downstream to the terminus of the Sutter Bypass), while the upstream portion of the Sutter Bypass is functionally a conveyance channel governed by open channel flow dynamics (i.e., gradient and roughness). The point of transition from flow conveyance to flow impoundment (i.e., backwater) can shift to some degree throughout the flood season, and this transition point often ends up somewhere between the Tisdale Bypass and the Feather River. The degree of backwatering is a function of flow through the bypass and the magnitude of flows in the Sacramento and Feather Rivers at the terminus of the bypass. In general, much of the lower Sutter Bypass is inundated for extended periods of time during a typical winter.

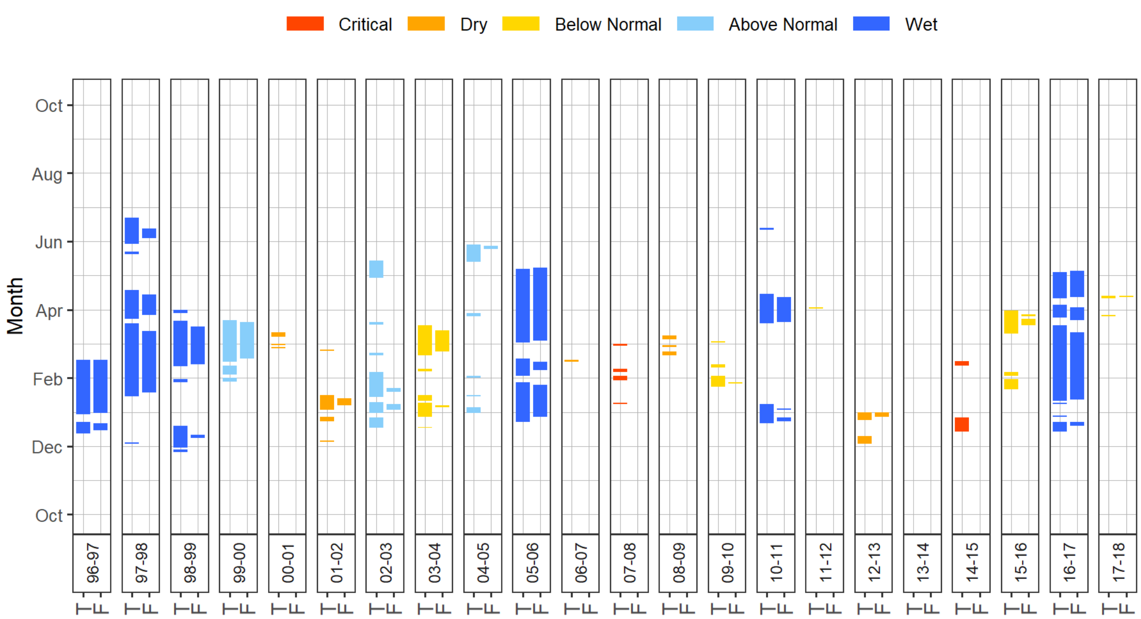
2.1.3 Flow During Irrigation Season and Related Operations

Operationally, aside from flood conveyance, the Sutter Bypass serves as a key source of irrigation water for Sutter County farmers during the late spring, summer, and early fall, as a point of drainage for runoff and irrigation return flow from primarily agricultural lands adjacent to the bypass, and as a source of habitat water for the Sutter National Wildlife Refuge (SNWR) and waterfowl wetlands in fall. During the dry season, all flows moving downstream through the Sutter Bypass are typically contained in the East and West Borrow Canals. Dry-season input is from Butte Slough, Wadsworth Canal and irrigation return flows from lands adjacent to the bypass.

2.1.4 Seasonal and Annual Flow Variability

Rainfall and flooding in California exhibit substantial variability from year to year, a characteristic aspect of California's hydrology. However, even in moderately wet years, the Sacramento River would historically overtop its banks and flood the surrounding territory. Season-to-season hydrologic variability has a strong influence on conveyance, impoundment, and drainage timing of floodwaters in the Tisdale and Sutter Bypasses. To aid in water supply DWR has developed a water year typology based on the Sacramento Valley Water Year Index (State Water Board 1995). Water year types are classified Wet, Above Normal, Below Normal, Dry, and Critical. **Figure 2** shows the frequency and duration of Tisdale and Fremont Weir overtopping events and illustrates both the seasonal and year-to-year variation in flow.

The hydraulic analysis (discussed further below) adopted a simulation period of water years (WYs) 1997 to 2018, which optimizes the period of observed data and reflects a wide range of WY types. A water year spans from October 1 of the prior calendar through September 30 of the given WY. However, to account for all seasons of interest (discussed further below) and eliminate unnecessary computational time, a truncated WY period spanning from September 28 through June 30 was used for the model simulations. Thus, herein, all calculations and results reported by WY are for this truncated period, unless otherwise indicated.



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 2
Spill Duration at Tisdale Weir (T) and Fremont Weir (F) for Water Years 1997 to 2018, Color Coded by Water Year Type

2.2 Hydraulic Model

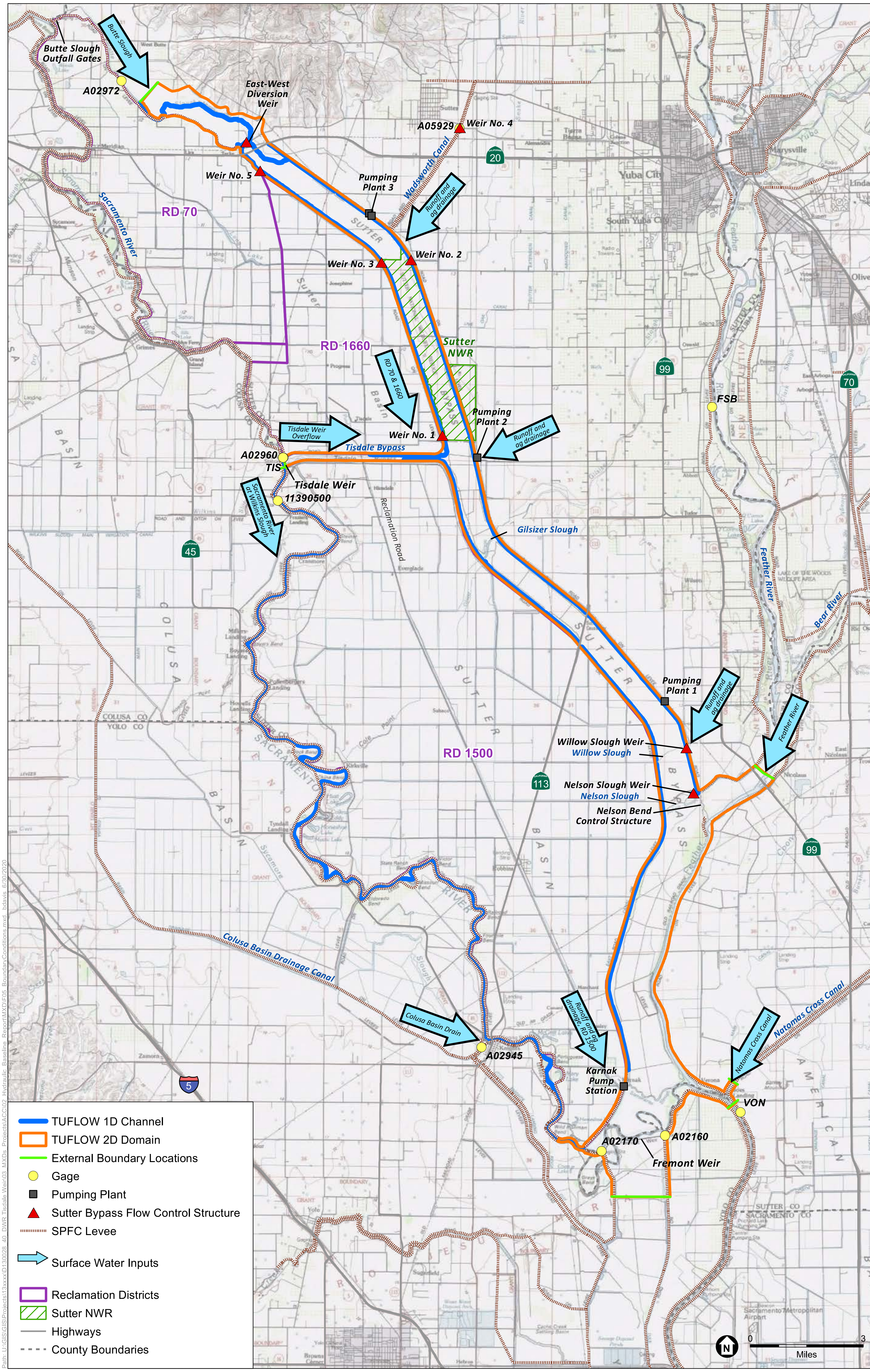
A detailed hydraulic analysis was performed using a high-resolution 1D/2D coupled hydrodynamic model built using the TUFLOW HPC commercial software package. TUFLOW HPC simulates depth-averaged, 1D and 2D unsteady-state free-surface flow such as occurs from downstream flowing water and tides, using a 2D finite volume solution occurring over a regular grid of square elements. As described above, inundation over the study area was simulated for the period between September 28 through June 30 for all water years from 1997 to 2018 for without- and with-Project conditions.

For purposes of calibrating, validating, and establishing a baseline to assess the effects of the Proposed Project, the without-Project condition was defined using the following general assumptions:

- Topography in the area of interest is assumed to be constant across all water years, using the 2008 Central Valley Floodplain Evaluation and Delineation (CVFED) Program Light Detection and Ranging (LiDAR) data collection effort as a baseline. (Note: Changes in topography since 2008, such as field leveling for agricultural objectives, can affect drainage patterns.) Although transport of sediment within the Tisdale Bypass is dynamic and sediment accumulation over time is documented, the assumption to use 2008 topography is not deemed to have a significant influence on flood routing or timing related to managed lands downstream of the Project. This representation of the terrain is consistent with conditions following the 2007 sediment removal maintenance action, and is considered reasonable (and conservative) for purposes of evaluating the Project's effects.
- Similarly, land use is considered consistent across all water years. Although some land uses within the bypass system have changed since WY 1997 (such as conversion from agriculture to duck clubs), vegetation conditions during the fall through spring periods on the managed lands in the bypass system are assumed to be relatively consistent from year to year.
- The flow over Tisdale Weir is represented across all water years using a rating curve based on the post–Garmire Road improvements that were implemented in 2009. Although not a precise representation of the historic hydrology for the pre-2009 era, this simplifying assumption is suitable to represent the hydrologic variability of the system when comparing without- and with-Project conditions (see Attachment A).
- Fremont Weir is represented in the model as it exists today, consistent with the historic hydrology data that were used to define the model boundary conditions. Improvements to the weir to improve fish passage, which are currently being designed, may influence the backwater relationship at the downstream end of the Sutter Bypass, potentially allowing lands at the bottom of the Sutter Bypass to drain more quickly than they do today. Thus, representing the Fremont Weir as it exists today provides a more conservative representation of any potential Project impacts.
- Levees and other water control features are assumed to function as intended, and are not represented as failing or otherwise malfunctioning during the simulations. This assumption is intended to maximize flow deliveries to the area of interest, providing a conservative representation of baseline flooding conditions in the bypass system.

2.2.1 Geographic Extents

The extent of the model domain is shown on **Figure 3** and includes the Tisdale Bypass and the Sutter Bypass upstream of the Fremont Weir Complex. The model domain has been defined sufficiently upstream to represent the distribution of flows between the east and west borrow canals of the Sutter Bypass, which is critical for mapping floodplain extents during low flow periods, particularly towards the end of the flood season. However, modeling results showed no impacts on areas north of State Route 20; thus, these areas are generally eliminated from further discussion herein, as they are not relevant. The model domain has been defined sufficiently downstream to ensure the model is bounded by well-defined hydraulic controls (Fremont Weir and stage records from the Sacramento River at Verona stream gage) to capture tailwater effects



SOURCE: USDA, 2016; Esri, 2018; DWR, 2019; USGS, 2019, ESA, 2020

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 3
Tisdale/Sutter Bypass TUFLOW Model Boundary Conditions

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governing inundation in the lower Sutter Bypass. The model domain captures all lands within the Sutter Bypass that might potentially be impacted by operation of the Project.

2.2.2 Boundary Conditions

Model boundary conditions consisted primarily of flow and stage data, with some additional spatially distributed boundaries.

Flow and Stage Boundaries

Except for the Tisdale Bypass and the Sacramento River downstream of Tisdale Weir, most model boundary conditions are based on observed flow and stage time series measured at stream gages. In a few cases, observed time series data were supplemented with or derived from a synthetic time series based on observed or previously modeled hydrographs (e.g., from CalSim 3 in the case of some agricultural return flows).

To represent the distribution of flow between Tisdale Weir and the Sacramento River, a rating curve was developed using a 1D Hydrologic Engineering Center River Analysis System (HEC-RAS) model, adapted from DWR's CVFED HEC-RAS model of the Sacramento River and its tributaries. This rating curve was then used to translate measured river stages in the Sacramento River at Tisdale Weir and Wilkins Slough into corresponding flow time-series data. Flows derived using this approach were used to represent the without-Project condition, and for model calibration and validation.

The flow and stage model boundaries are shown in Figure 3 and can be generally summarized as follows:

- Flow at Butte Slough
- Flow at the Wadsworth Canal
- Flow into the Tisdale Bypass at Tisdale Weir
- Flow at the Sacramento River below Wilkins Slough
- Flow at DWR pump stations and other major agricultural return flow locations
- Flow at the Feather River
- Flow at the Colusa Basin Drain at Knights Landing
- Flow at the Natomas Cross Canal
- Sacramento River stage at Verona

Flow leaving the model domain at the Yolo Bypass downstream of Fremont Weir is assumed to flow at normal depth.

Spatially Distributed Boundaries

Additional hydrologic inputs such as precipitation, infiltration, and evaporation were also accounted for using historic information and best available data from the California Irrigation Management Information System, the U.S. Natural Resources Conservation Service, and other sources.

2.2.3 Topographic and Bathymetric Survey Data

Terrain data for this Project are based on the following data sources, which are layered in the model input to build a composite bathymetric and terrain surface:

- LiDAR data collected by DWR in 2008 as part of the CVFED Program (DWR 2010a). The LiDAR data were the primary source of terrain data, representing the existing terrain for the majority of the model domain. For preparation of the model input, the elevation data were re projected to California State Plane II FIPS 0402 (U.S. feet) for consistency with the Project datum, and clipped to a smaller extent to reduce the data footprint and terrain processing overhead.
- Yolo Bypass 2-meter digital elevation model (DEM) (Wang et al. 2018) covering the Fremont Weir complex and the Yolo Bypass.
- Single-beam bathymetric surveys of the Feather River and Sacramento River collected as part of DWR's CVFED Program in 2010.
- Single-beam bathymetric surveys of the low-flow borrow ditches and channels (e.g., Sacramento Slough, Willow Slough) collected by ESA in 2019 and 2020.

Although more recent Tisdale Bypass surveys have been conducted by DWR as part of ongoing maintenance activities, data from the CVFED LiDAR survey were used to represent conditions in the bypass. As noted previously, although transport and deposition of sediment in the Tisdale Bypass is dynamic, this assumption is not deemed to have a significant influence on flood routing or timing relative to managed lands downstream of the Project. This representation of the terrain is consistent with conditions after the 2007 sediment removal maintenance action, and is considered a close approximation of as-built conditions following maintenance activities.

The 1D model components of the TUFLOW model are based on the single-beam survey sources noted above. The TUFLOW topographic layering hierarchy for the 2D model components was input as follows (layers listed in order from the "top" of the stack to the "bottom"):

1. CVFED LiDAR (Photo Science, Inc. 2009; Fugro EarthData, Inc. 2010)
2. Yolo Bypass 2-meter DEM

Terrain Enforcement

Using the three-dimensional breaklines prepared previously as part of DWR's CVFED LiDAR surveying efforts and the data in the DWR California Levee Database (DWR 2010b) as a base, a comprehensive breakline data set was developed to enforce the tops of levees and embankments in the domain area. Breaklines representing small agricultural berms were delineated by ESA and assigned elevations, using DWR's CVFED LiDAR and Yolo Bypass 2-meter DEM data.

2.2.4 Floodplain Roughness

Although land use and crop types change from year to year, the simulation periods of interest are primarily during and shortly after large flow events (i.e., when the Tisdale Weir would spill), and these are typically periods when agricultural fields are idle or otherwise not yet sowed and planted. Because this analysis is comparative between without- and with-Project conditions, land cover was assumed to be static and not change between water years (or between without- and with-Project conditions) in order to establish more simplified comparisons.

Land use classifications within the model domain were adapted primarily from model input data from the CVFPB RMA2 model of the Sutter Bypass (CH2M Hill 2013). To address gaps in land use coverage, ESA adapted DWR land use surveys (DWR 2006, 2011) and updated their classifications based on an inspection of aerial imagery. A final composite land use data set was used to assign floodplain roughness coefficients in the 2D model domain. TUFLOW allows the use of depth-variable roughness curves, yielding a more realistic relationship between flow depth and roughness elements on the floodplain surface. Depth-variable roughness was applied in the model according to previously developed rules (DWR 2013).

2.2.5 One-Dimensional Channel Roughness

Channel roughness coefficients in the Sacramento River were based on the values from the calibrated CVFED HEC-RAS model and were not adjusted. Roughness coefficients for Butte Slough and the various borrow canals were estimated using standard roughness values for a vegetated canal (USGS 1989).

2.2.6 One-Dimensional Channel Geometry

Linear features in the model including the Sacramento River, the East and West Borrow Canals, Butte Slough, and several other canals were represented as 1D model elements (Figure 3) to minimize complexity and model computation time. In 2019 and 2020, ESA surveyed the borrow canals and Sacramento Slough both through ground-based surveys and by boat, using a single-beam echosounder to capture the geometry of the low-flow features. Because previous studies in the bypasses have focused on high-flow conditions, this is believed to be the first time that this type of information has been collected within the Tisdale/Sutter Bypass system.

Extensive quality assurance and quality control was required to identify and classify aquatic primrose and other submerged vegetation, to ensure that the model was properly representing the channel geometry. In locations where ground-based surveys were available, such as the north end of the West Borrow Canal of the Sutter Bypass, the elevations for the cross section were estimated from the closest survey data downstream and the slope of the water surface, using LiDAR. The boat-based survey consisted of a zigzag traverse along the canals. One-dimensional cross sections were derived from the zigzag survey data, using the approach described by Wang et al. (2018). In some cases, the zigzag survey data were insufficient to develop cross sections, so data from nearby cross sections and the LiDAR were used to interpolate the bathymetry. Channel cross sections and attributes for the 1D components of the Sacramento River were converted to TUFLOW file format from the CVFED HEC-RAS 1D model geometry.

2.2.7 Hydraulic Structures

A variety of hydraulic structures, including operable and non-operable weirs, bridges, road crossings, and outfalls are distributed throughout the Sutter Bypass. Hydraulically-significant structures were modeled explicitly using 1D elements in the model. Where reliable elevation information was available for the hydraulic structures from existing as-built drawing or reference material, it was used. A field topographic survey of 28 hydraulically significant structures was necessary to acquire reliable elevations for structures for which no data were already available, and to field-verify elevations shown in recorded document drawings. The primary flow control structures reflected in the model are the East-West Diversion Weir, and Weir 5, Weir 3, and Weir 1 along the West Borrow Channel, and Weir 2 and Willow Slough Weir along the East Borrow Channel. Annual or seasonal weir operations, based on the best available information, were also incorporated into the model.

2.2.8 Model Calibration and Validation

Prior to the Project analysis, the model was calibrated. The objective of the calibration effort was to test and refine the model's simplified geometric elements and empirical parameters so that the model reproduces the behavior of the system during an observed event as faithfully and reasonably as possible. The quality of the calibration can be significantly influenced by the quality of its data inputs and observations, particularly with respect to the hydrology that drives the model boundary conditions. For this calibration exercise, four parameters were used to evaluate model performance, listed below in descending order of importance and reliability:

1. Stream stage observations (2006 high flow, 2019 low flow, 2017 validation)
2. Streamflow observations (2006 high flow, 2019 low flow, 2017 validation)
3. Borrow canal flow split (2019 low flow)
4. Surveyed high-water marks (2006 high flow)
5. Remotely sensed area of inundation (2019 low flow and 2017 validation)

Stage gage observations are considered the most reliable values for comparison to model output, because stage is measured directly. In general, stage gage measurements are considered reliable to within 1 foot (Brunner 2008). Potential sources of error in stage measurements include mechanical problems with the gage, human error (e.g., data entry problems), and systematic errors (e.g., incorrect datum). Streamflow measurements are the next most reliable value for comparison against modeled output, because they are derived values that are computed based on rating curves. Generally, calibrated maximum streamflow that is within ± 10 percent is acceptable (Brunner 2008). High-water marks are best used to evaluate trends in water surface elevation, rather than absolute values at any one location; absolute values are subject to measurement error, and hydraulic factors (e.g., super-elevation, wave run-up, debris snags, surveyor experience) affect the actual water surface elevation relative to stream discharge (Brunner 2008). Remotely sensed data and derived products (i.e., the area of inundation) are subject to a variety of sources of error. For satellite imagery, the most common source of error is poor image resolution caused by clouds and other atmospheric conditions. For this Project, ESA prepared maps of the area of inundation during late periods of WY 2017 and WY 2019 by processing multispectral satellite imagery using a Normalized Difference Water Index (NDWI) processing routine. The NDWI method requires iterative adjustment to arrive at a final estimate of the wetted area that represents a compromise between sensitivity and overestimation; hence the estimates of wetted area also have some degree of error.

Model Uncertainty

To assess uncertainty in the modeling study a sensitivity analysis was performed. Sensitivity analyses were executed to evaluate how variation in channel and floodplain roughness, minor fluxes (i.e., precipitation, evapotranspiration, and infiltration), gate operations, and variation in inflow from Wadsworth Slough affected predicted stages in the calibrated model.

Summary

The Tisdale/Sutter Bypass TUFLOW model was developed and calibrated with the WY 2006 high-flow event and the 2019 low-flow event. Initial simulations identified areas where adjustments to the model geometry and parameters were necessary to improve the correlation with observed data. The model was then validated with the WY 2017 hydrology. Errors in water level predictions were generally less than 0.5 feet, and were less than 1 foot in all cases for the high-flow model runs, while flow at Verona was off by 12 percent. The latter difference was deemed acceptable given the hydraulic complexity of that locale. For the low-flow model, all calibrated stage differences were less than 1 foot, except Willow Slough, which was 1.5 feet higher than the observed water surface elevation, but stage differences at and above the elevation of the adjacent floodplain were quite small.

Willow Slough is challenging to model as a coupled 1D reach because the channel flows perpendicular to the dominant trend of flood flows in the Sutter Bypass. During model development and testing, this location performed poorly in 1D for the range of flows during which the floodplain is activated, resulting in numerical instabilities and poor representation of the hydraulic grade line in the Sutter Bypass. For the model to perform satisfactorily for the range of flows of interest, it was necessary to simplify this reach and represent its geometry in the 2D grid. Under very low flow conditions, this results in an overestimate of the channel's water level, but does not significantly affect the quality of the results during periods when the floodplain is activated. While the fit of stage in the low-flow calibration was not ideal, the fit for stage near the elevation of the adjacent floodplain berms, when Willow Slough connects to the floodplain, was under 0.5 feet. Hence, the calibration for Willow Slough was determined to be acceptable.

Modeled flow for the low-flow calibration period generally agrees with the observed data within ±10 percent, except for Verona. Flow at Verona was deemed acceptable using the same rationale as for high flow. In addition, the 2017 validation run shows a difference of 4.4 percent at this location, well under the calibration threshold of 10 percent. Nonetheless, the error was relatively low, especially when considered with the overall good fit of stage and flow throughout the low-flow model domain. The validation model run had fitted stage differences of less than 1 foot in all cases, and flow difference of less than 10 percent in all cases.

In addition, an analysis of the model's capability to reproduce the pattern and extent of late-season drying for WY 2017 and WY 2019, by comparing the model output with satellite imagery, indicates that the model reasonably reproduces late-season floodplain dynamics in the Sutter Bypass. A sensitivity analysis of channel roughness coefficients indicates that the water surface elevation through the borrow canals during low-flow conditions in the late spring is governed primarily by the network of gated flow control structures.

The model's sensitivity to minor flow fluxes such as infiltration was quantified, and deemed significant for reflecting the drying of fields during the late spring. Finally, a sensitivity analysis illustrates that minor flow inputs during the late season—such as from the Wadsworth Canal and pumped agricultural drainage—can influence the timing of late-season drying, either increasing or decreasing the date of Last Day Wet on some fields by up to 2 weeks.

The model is considered suitably calibrated and validated for estimating the downstream effects of Project operations. In general, the model provides a conservative but reasonable estimate of flooding and drying on lands downstream of the Project and is suitable for use in quantifying the changes that would result from Project operation. Application of the model to analyze without- and with-Project conditions is considered robust and defensible for supporting the analysis of Project impacts under CEQA.

3 Agricultural Resources (Farmland)

Long-term operation of the Proposed Project could affect land use and agricultural resources in the Sutter Bypass through the addition of water (flowing through the notch) and subsequent potential increase in the extent and/or duration of inundation in some areas. Increased inundation may prevent or conflict with existing land uses and agricultural practices, potentially leading to the conversion of land to some other purpose or practice. Relevant to this analysis, an impact resulting from implementing the Proposed Project would be considered significant if it would convert Prime Farmland, Unique Farmland, Farmland of Statewide Importance (collectively, Farmland), or other designated farmlands, including grazing lands, to nonagricultural or incompatible uses. Further, an impact would be considered significant if it would convert Williamson Act lands to nonagricultural or incompatible uses or otherwise conflict with an existing Williamson Act contract.

This analysis is primarily based on assessing the potential effects of the Proposed Project on individual agricultural fields currently in production (see Section 3.1.2, *Field Mapping*), all of which are also Farmland and thus relevant for this CEQA analysis. Other relevant areas not in active agricultural production, such as grazing lands and Williamson Act lands, are addressed separately (see Section 4, *Other Agricultural Resources and Recreation*).

3.1 Methods

The permanent conversion of agricultural land to nonagricultural uses was evaluated by assessing whether, due to Project implementation, additional annual fallowing would occur and, if so, whether that would potentially lead to the conversion of land. The driving variable behind the analysis is the incremental difference in location, duration, and frequency of additional wetted area in the Sutter Bypass between existing and Project conditions during the assumed agricultural preparation and planting period (March 1 through June 30). The assumption is that if a field is wet for too long, it would not be planted in time and is instead fallowed for that year. It follows that the Proposed Project would cause a change when it results in sufficient additional inundation during the standard preparation and planting period to make fallow a field that would have otherwise been planted. Further, if an increase in fallowing is predicted, the analysis presents a basis for determining whether that increase in fallowing could reasonably be expected to result in permanent conversion of land.

3.1.1 Farmland Mapping

Prime Farmland, Unique Farmland, and Farmland of Statewide Importance (Farmland), as well as Williamson Act lands and other types of farmland (e.g., grazing lands), have been previously mapped by the California Department of Conservation (DOC 2018) (**Figure 4**). The California Department of Conservation administers the Farmland Mapping and Monitoring Program, California's statewide agricultural land inventory. Ownership information and parcel boundaries were acquired from Sutter County (2018, 2019) and Yolo County (2018).

3.1.2 Field Mapping

Lands within the Sutter Bypass were further delineated into active agricultural fields based upon (1) fields that appeared to be in active production based on aerial imagery from 2018 and (2) fields that appear to be discrete areas in terms of water management based on field berms explicitly represented in the CVFED LiDAR data (Fugro Earth Data, Inc., 2010) (there were no active agricultural fields within the Tisdale Bypass). The agricultural field delineations are shown in **Figure 5a** and **Figure 5b**. Mapped fields represent discrete areas that are assumed to be viable for individual management. For example, within or across a parcel it is assumed that individual fields can be fallowed or placed into production. All mapped fields are generally coincident with previously mapped Farmland (see Figures 5a and 5b); any areas of Farmland outside of mapped fields are very small and are associated with differences in spatial resolution.

3.1.3 Last-Day Wet and Fallowing Thresholds

Timing of inundation on agricultural lands within the Sutter Bypass can significantly influence the ability for growers to manage their operations. For example, although many factors influence crop yield for the production of rice, extended late season flooding can result in delaying planting which results in yield losses and potentially the choice to fallow certain fields for a given year. With regard to actual or predicted fallowing, there is some practical threshold date or range of dates beyond which, if a given field is still inundated or saturated, planting is unlikely to occur. During the growing season (spring to fall), much of the land within the Sutter Bypass is used primarily to cultivate rice, although some row crops (e.g., beans, tomatoes, safflower, sunflowers) may also be grown, particularly in the downstream end of the bypass. The planting of these row crops is generally less dependent on inundation timing than rice (e.g., planting of beans generally occurs in June).

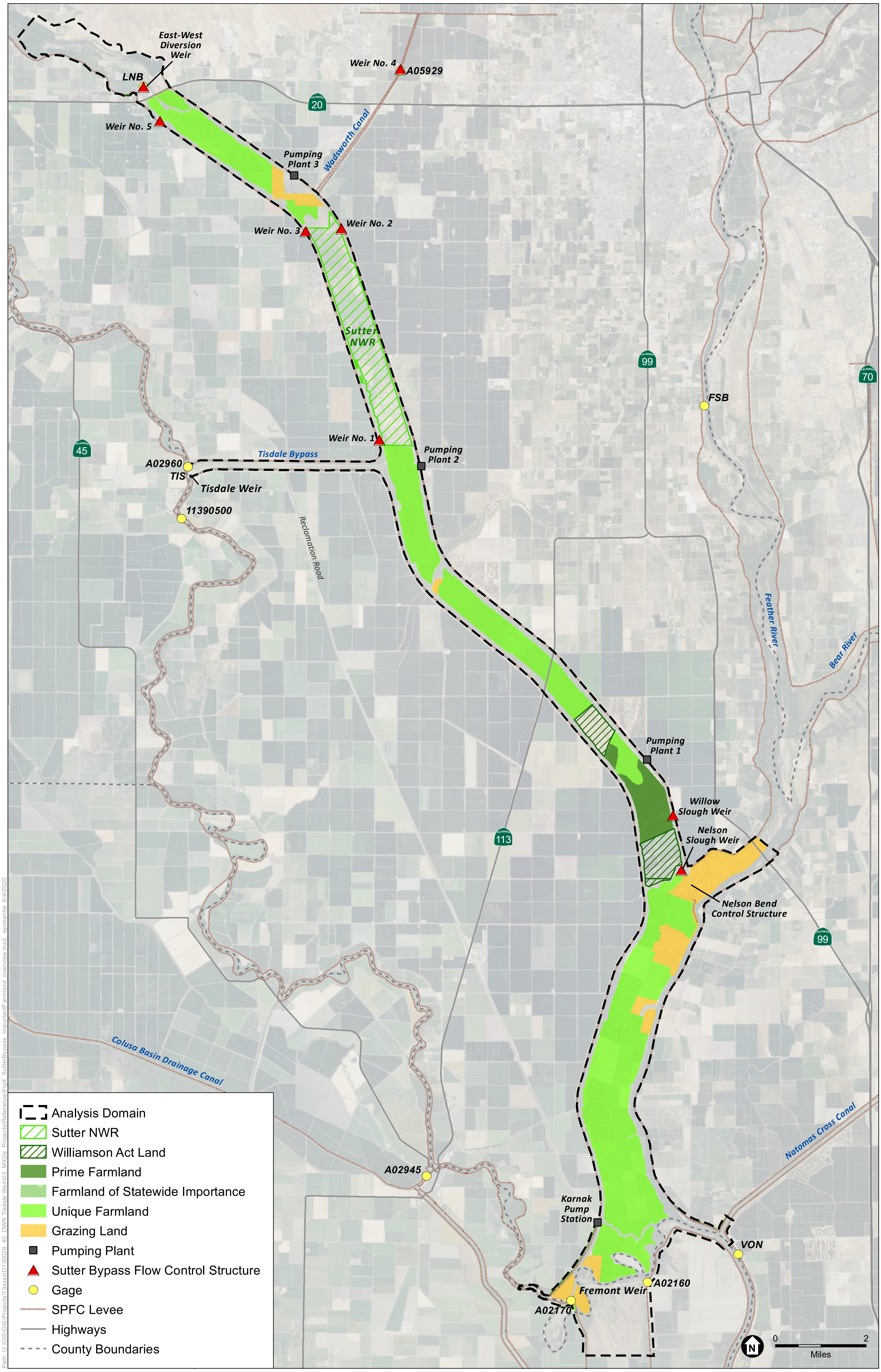
Because rice cultivation is the predominant agricultural practice in the Sutter Bypass, a general summary of typical seasonal rice cultivation practices is relevant for the analysis and assumptions. It is important to note that the dates and activities are generalized and that individual agriculturalists may make different choices on the timing and extent of various activities—ultimately influencing yields and perhaps even choices to fallow certain ground. Beginning in the fall, rice fields may be flooded to facilitate the decomposition of rice straw after harvest is completed. During the winter period, active field flooding for waterfowl habitat may be maintained for both conservation and recreational hunting. Under current practice, sometime early in the new year (optimally by early February to allow for drainage and drying), fields are drained. As conditions permit, field tillage then takes place to prepare the ground for planting. Typically, seed bed preparation begins in late March and is completed by the end of April. Once fields have been prepared, they are flooded in April and May and presoaked rice seeds are broadcast, typically via aircraft. May through October is the period of active growth. Harvest occurs in the fall, with the timing driven by crop maturation and harvest conditions (wind, rain, field conditions). After harvest, rice straw may be chopped and/or incorporated into the ground before any flood-up, after which the cycle begins again.

Based on an understanding of current agricultural practices within the Sutter Bypass, the following variables were calculated and the following assumptions adopted in the modeling analysis of potential Project impacts on Farmland:

- Last Day Wet—defined as the date the ground is considered to be dry enough for tractors to chisel fields. This is assumed to occur when 70 percent or more of the field is dry (Reclamation and DWR 2019), as computed by the TUFLOW model at the end of a given day.
- Drying and Preparation Period—defined as the sum of additional days to reflect (1) the necessary assumed drying time before field preparation begins, and (2) an assumed field preparation period.
- Planting Date—defined as the Last Day Wet plus the Drying and Preparation Period. The later the planting date, the greater potential for decreases in agricultural yield.
- Agricultural Field Preparation and Sowing Period—defined as March 1 through June 30 (based on Reclamation and DWR 2019).

In reality, field drying and preparation times and subsequent target planting dates vary to some degree both spatially within the Sutter Bypass and from year to year; thus, a range of reasonable assumptions was considered in the analysis. A similar analysis presented in the Yolo Bypass and Salmonid Habitat Restoration and Fish Passage Project Environmental Impact Report (Yolo EIR) (Reclamation and DWR 2019) assumed that June 1 was the end date of the standard planting window for crops in the Sutter Bypass (assumed to be rice) and that 34 days of field drying (6 days) and preparation (28 days) would be required before that. In addition, comments submitted in response to the Notice of Preparation (NOP) for this Project's environmental impact report by Somach, Simmons, and Dunn (2019) suggested that it takes at least 45 days to drain the land from the last day of inundation and an additional 30 days to allow for groundwork (i.e., 75 days of total drying and field preparation time). Further, the comments stated that the last possible date for planting is approximately June 10. The largest variation in the available information concerns the amount of time it takes to drain and dry out a given agricultural field, before working the ground in preparation for planting. For the initial processing of model results and assessing sensitivity, the analysis assumed field drying and preparation times of, collectively, 34 and 75 days, and a last viable planting date range of June 1 to June 10 of a given year.

For the field preparation and sowing season, the Last Day Wet computed by the model was used to identify the date that ground is considered dry enough for tractors to begin disking the fields. A planting date was then calculated by adding the assumed number of days for field drying and preparation to the Last Day Wet; if the calculated planting date exceeded the target planting date (or "plant by" date), then the field was assumed to be fallowed for that year.



SOURCE: Esri, 2018; CDC, 2018; Sutter County, 2019; ESA, 2020

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 4
Sutter Bypass Land Use

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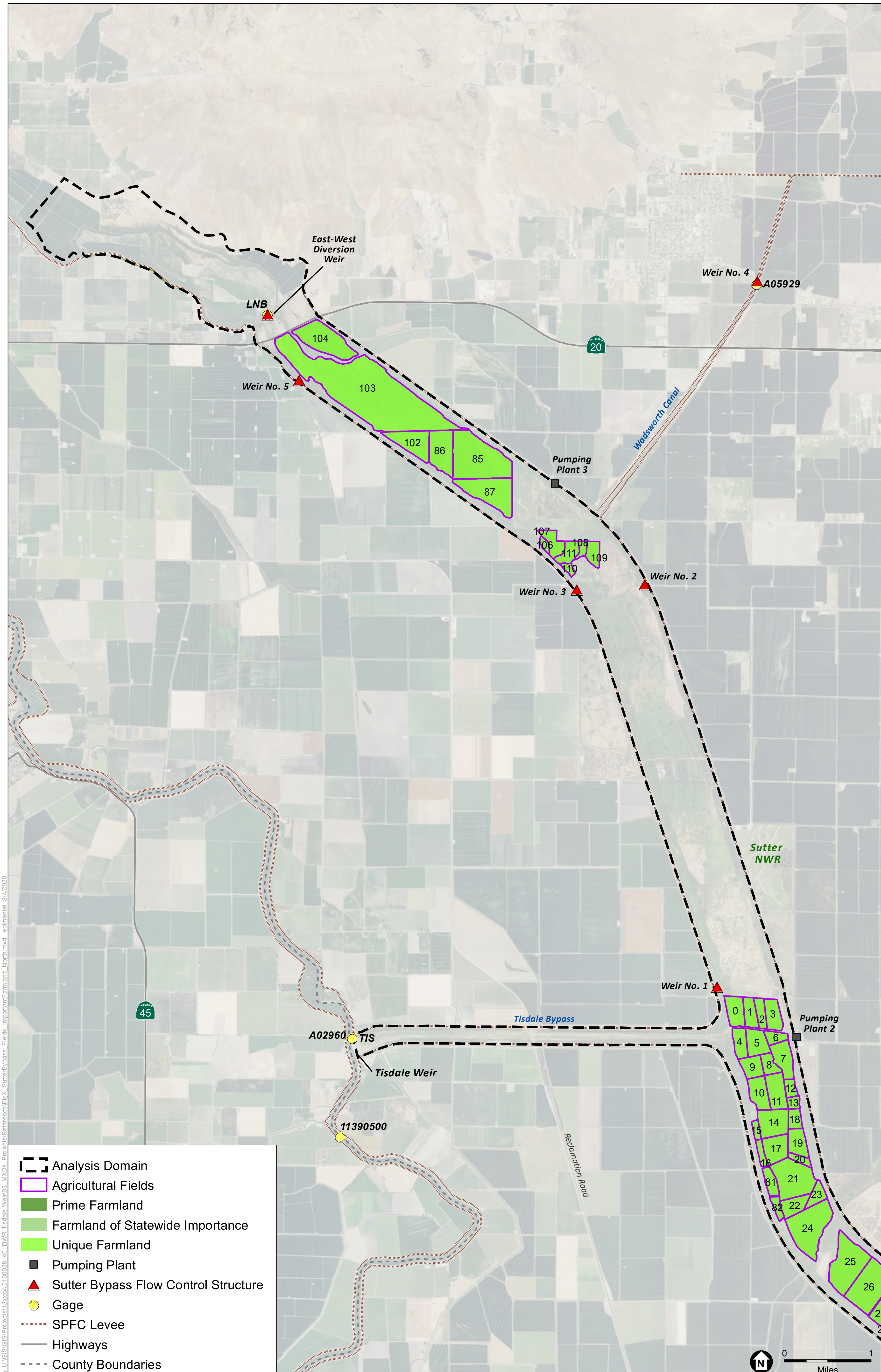
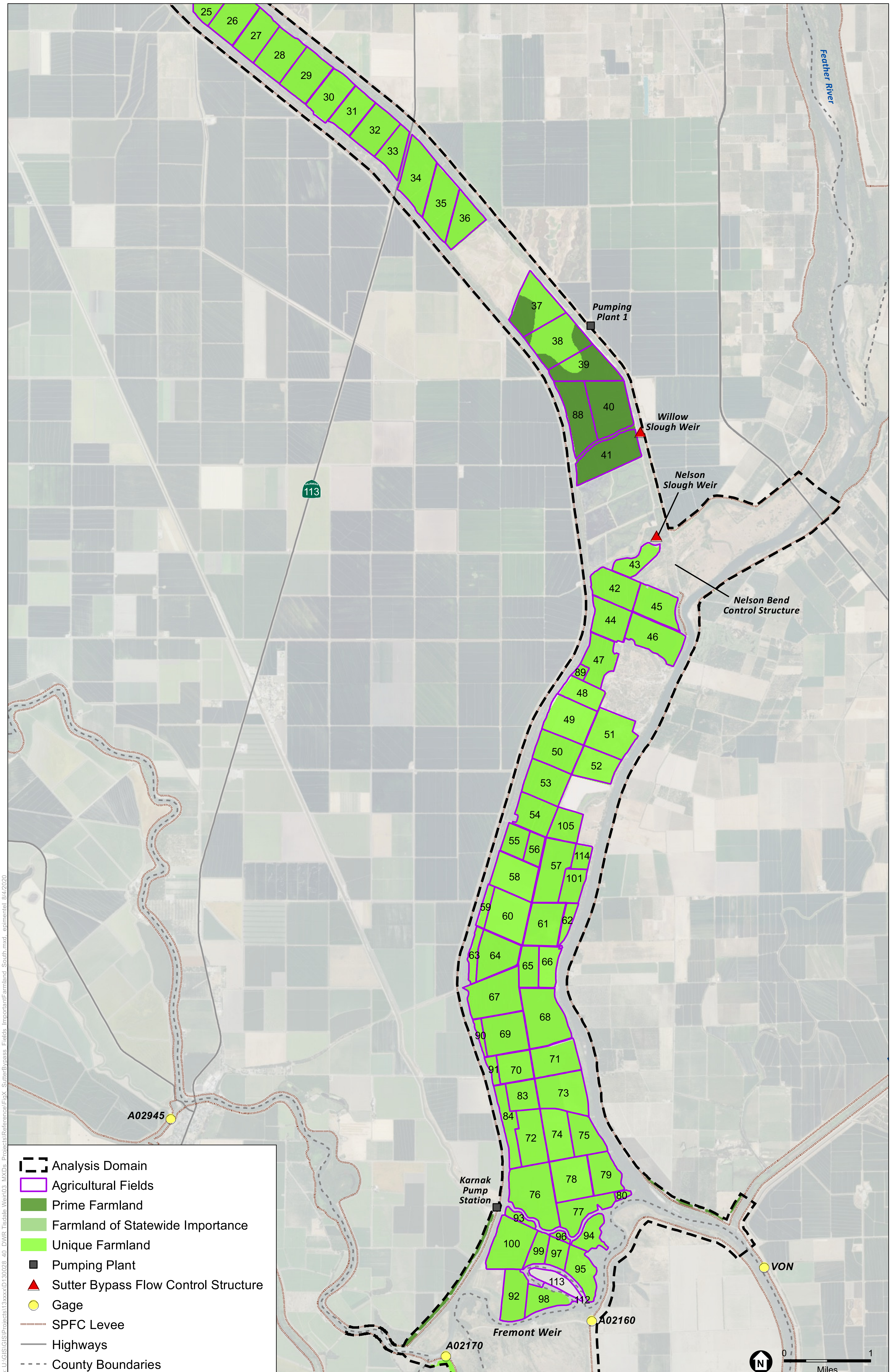


SOURCE: Esri, 2018; CDC, 2018; ESA, 2020

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 5a
Sutter Bypass North Agricultural Fields and Land Use



SOURCE: Esri, 2018; CDC, 2018; ESA, 2020

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 5b
Sutter Bypass South Agricultural Fields and Land use

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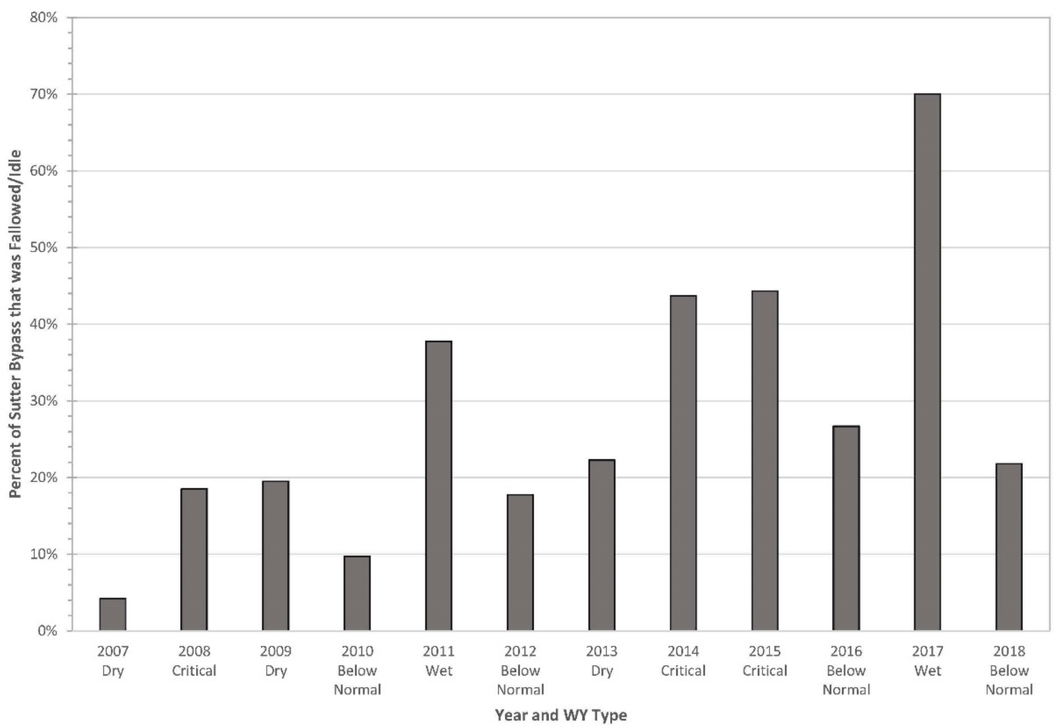
3.1.4 Fallowing and Conversion

Fallowing of some agricultural fields within the Sutter Bypass occurs to some degree almost every year and may happen for a variety of reasons: A producer is resting the ground; market conditions drive a producer to decide to fallow a field; a producer may not have sufficient irrigation water in a drier water year and may choose to fallow a field; and (related to this analysis) ground conditions may be wet too late in the season for planting to occur in time for an expected yield to be realized. It is important to note that annual fallowing reflects temporary cropland idling, and not permanent land conversion.

The U.S. Department of Agriculture (USDA), National Agricultural Statistics Service has mapped crop types and land use in the Project area dating back to 2007, including fallow/idle cropland, and has published these data as part of the national CropScape–Cropland Data Layer (CropScape Data) (Attachment B) (USDA NASS 2020). **Figure 6** summarizes the estimated percentage of land fallowed annually within the Sutter Bypass according to the CropScape Data. The percent of fallowed land generally ranges from 5 percent (in WY 2007) to 70 percent (in WY 2017) of mapped croplands within the Sutter Bypass. Relatively large sections of the Sutter Bypass may be fallowed in a given year, and the spatial distribution of the fallowing may shift depending on the driver. For more details on the CropScape Data and analysis, see Attachment B.



SOURCE: Derived from USDA NASS 2020

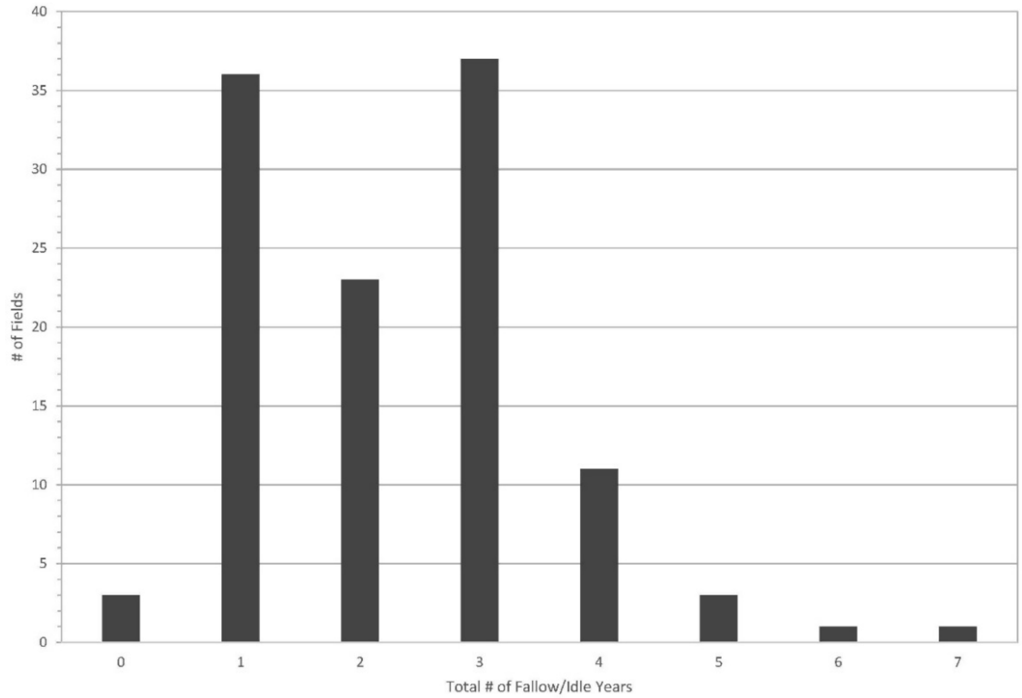
Tisdale Weir Rehabilitation and Fish Passage Project

Figure 6
USDA CropScape - Cropland Data Layer, California (2007-2018)

To assess whether any annual fallowing that could be caused by the Proposed Project may lead to permanent land conversion, the analysis assumes that some number of total and/or consecutive years of fallowing of a field (for any reason) may ultimately result in a loss of economic viability for that field, which would then be cause for potential permanent land conversion (from agricultural use). Optimally, a documented threshold for the number of consecutive or total years of fallowing that would result in permanent land conversion would be the best way to assess whether any fallowing caused by the Proposed Project could incrementally lead to permanent land conversion; however, no documentation is available.

The CropScape Data generally represent the best estimate of the contemporary extent and frequency of fallowing within the entire Sutter Bypass, and based on these data, almost every active agricultural field in the Sutter Bypass has been temporarily fallowed at one time or another. Yet, as stated above, all of the agricultural fields delineated herein (see Figures 5a and 5b) are currently in active use and production (as of 2018), and thus represent agricultural lands that have not been subjected to permanent land conversion. Thus, as a proxy for a conversion threshold, this analysis used the CropScape Data to estimate both the total years and the maximum number of consecutive years of fallowing that did *not* result in permanent land conversion for a given agricultural field.

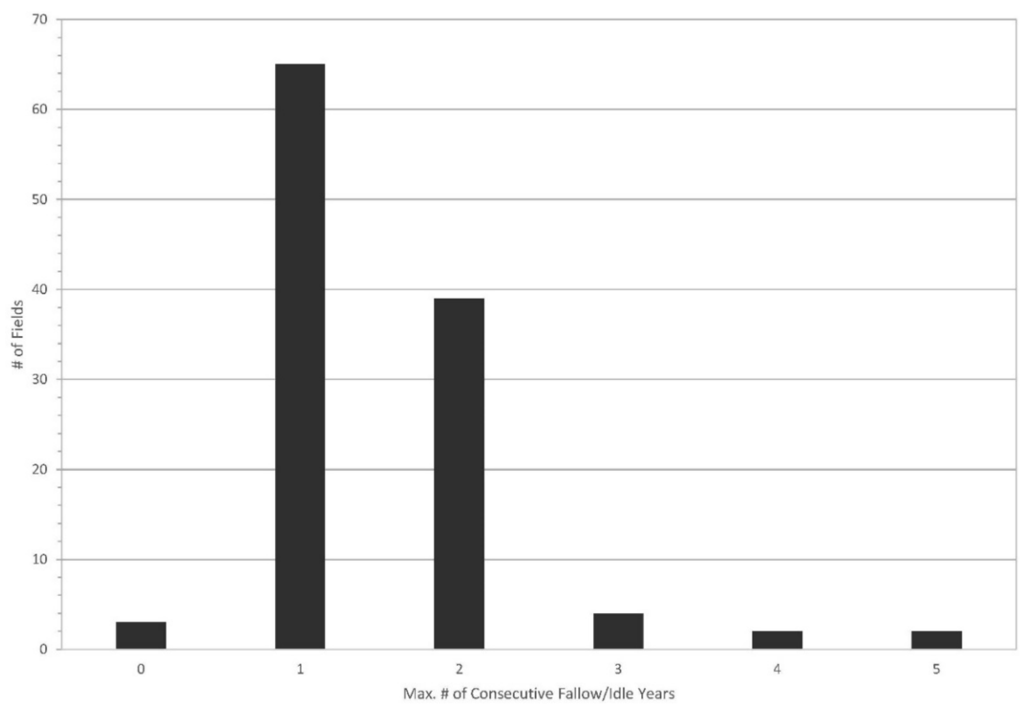
Figure 7 and **Figure 8** summarize the number of agricultural fields that had a given total number of fallowed years and a given maximum number of consecutively fallowed years, based on the CropScape Data, from 2007 to 2018. Generally, according to the CropScape Data, most of the agricultural fields in the Sutter Bypass have experienced 1 to 4 years of fallowing over approximately the last decade, with the observed range between 0 and 7 years. Further, with regards to maximum consecutive fallowed years, most of the agricultural fields in the Sutter Bypass have experienced up to 1 to 2 years, with a range of 0 to 5. Using this proxy, the analysis examines the total and maximum consecutive years of fallowing for existing conditions and for the Proposed Project. If the Proposed Project is predicted to cause an increase in the frequency of fallowing, beyond the range of fallowing currently observed, then it is assumed that the given field(s) may potentially be a candidate for conversion and would be further considered in the CEQA analysis. Further details of how historical annual fallowing data were analyzed are provided in Attachment B.



SOURCE: Derived from USDA NASS 2020

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 7
Total Fallow Years, USDA CropScape Data Layer, Sutter Bypass (2007-2018)



SOURCE: Derived from USDA NASS 2020

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 8
Max. Consecutive Fallow Years, USDA CropScape Data Layer, Sutter Bypass (2007-2018)

3.2 Results

The results derived from the June 1 planting date and 34-day field drying and preparation time assumptions were most consistent with the observed CropScape Data on fallowing. Also, the June 1 planting date is consistent with prior work (Reclamation and DWR 2019) as well as contemporary crop insurance criteria related to fallowing.[2] Therefore, these were the target planting date and field drying and preparation time assumptions used for the analysis of the Project and the results presented below.

Figure 9 and **Figure 10** present the results of the analysis. (Note: The modeled existing condition is shown in the left panel; the modeled Project condition is shown in the center panel; the difference between the modeled Project and existing conditions is shown in the right panel.) Over the 22-year simulation period, the Project is predicted to result in one additional year of fallowing for 15 fields (out of 115 total fields) and two additional years of fallowing for 3 fields. In other words, for these fields, the modeled additional flow that would result from Project implementation extends the duration of inundation beyond the assumed target plant date, as compared to the existing condition. The number of fields potentially affected by the Project is small; of those fields, the potential increase in the number of total fallowed years is likewise relatively small, such that the predicted range of fallowing under the Project remains within the observed range of fallowing under existing conditions over approximately the last decade (see Figure 7). For example, the model does not exactly match the observed CropScape Data (which is expected, as discussed above). However, if one just considers the additional fallow years predicted by the model (i.e., the Project condition minus the existing condition) for the 18 affected fields, and adds these to the CropScape values shown in Figure 7 for these same fields, the increase would result in, at most, six total years of fallowing in the context of the CropScape Data. (Again, this would be within the range observed under existing conditions, which is 0 to 7 total years of fallowing.)

Similar to total fallowed years, the analysis of maximum consecutive fallowed years shows a relatively small change as a result of Project implementation. In this case, for two fields in the Sutter Bypass, the Project would add one additional year to the maximum number of consecutively fallowed years over the 22-year simulation period. For the affected fields, the predicted range in maximum number of consecutively fallowed years is 1 to 2 years under the existing condition and 2 to 3 years under the Project condition. Thus, as in the case above, the predicted range of fallowing under the Project remains within the observed range of fallowing under existing conditions (see Figure 8).

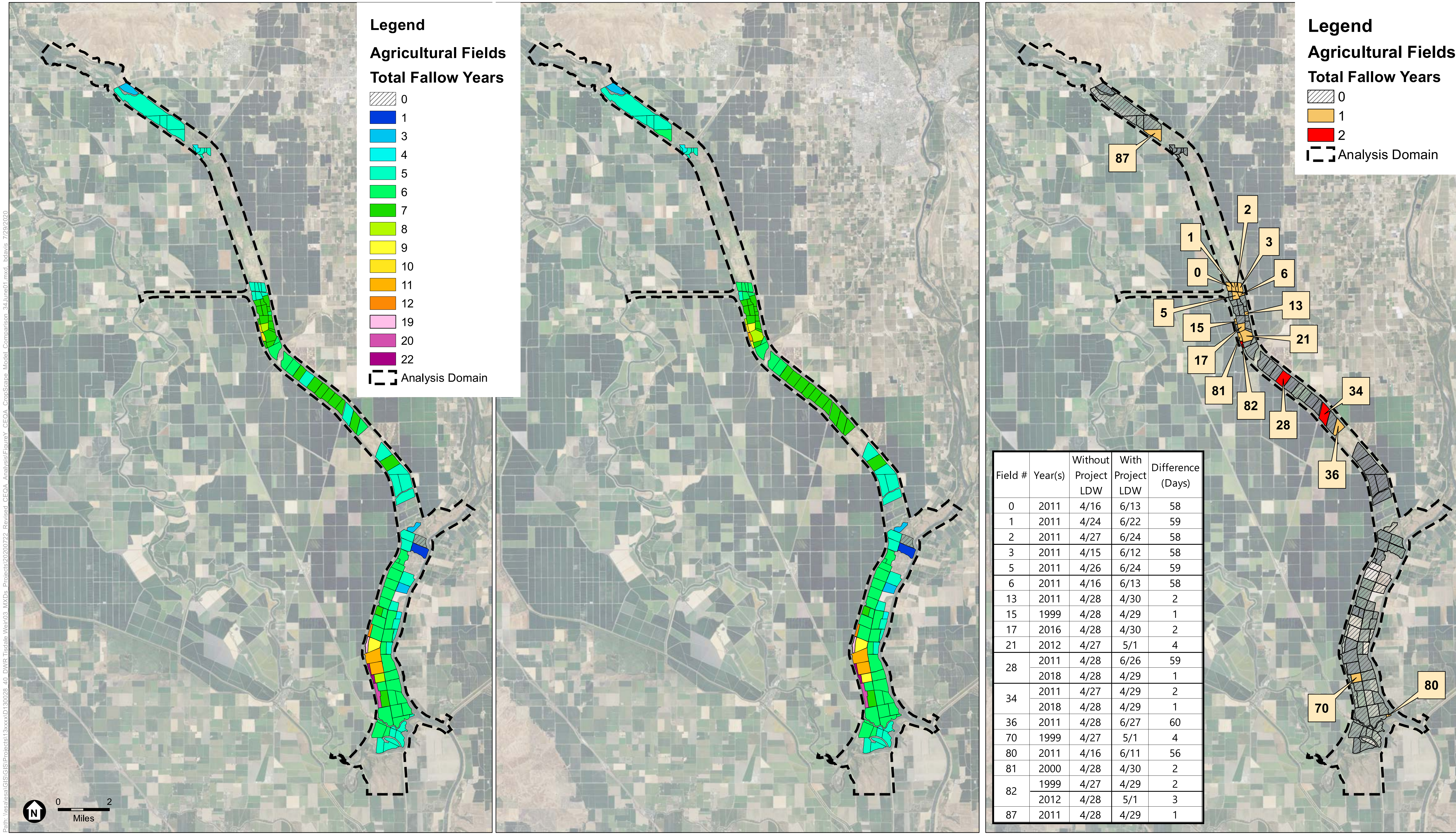
Also, the table presented in the right panel of Figure 7 shows the difference between the Last Day Wet for each field in which the Project is predicted to result in an additional year or two of fallowing. For many affected fields, the Project is predicted to extend the Last Day Wet by only 1 to 5 days, suggesting that even under existing conditions these fields, for the given years, would be very close to the assumed planting date threshold without the Project; the only exception to this is for 2011, where recorded spill data at Tisdale Weir show that the weir during this year spilled briefly in early June, which is not common, and prior to that the last spill was in the early part of April.

[2] https://www.dailydemocrat.com/2019/05/07/rice-planting-is-underway-despite-a-late-start/

Without Project Total Fallow Years (1997-2018, 34 Day Prep Period, Plant by June 1)

With Project Total Fallow Years (1997-2018, 34 Day Prep Period, Plant by June 1)

Difference in Total Fallow Years With Project minus Without Project



Field #	Year(s)	Without Project LDW	With Project LDW	Difference (Days)
0	2011	4/16	6/13	58
1	2011	4/24	6/22	59
2	2011	4/27	6/24	58
3	2011	4/15	6/12	58
5	2011	4/26	6/24	59
6	2011	4/16	6/13	58
13	2011	4/28	4/30	2
15	1999	4/28	4/29	1
17	2016	4/28	4/30	2
21	2012	4/27	5/1	4
28	2011	4/28	6/26	59
	2018	4/28	4/29	1
34	2011	4/27	4/29	2
	2018	4/28	4/29	1
36	2011	4/28	6/27	60
70	1999	4/27	5/1	4
80	2011	4/16	6/11	56
81	2000	4/28	4/30	2
82	1999	4/27	4/29	2
	2012	4/28	5/1	3
87	2011	4/28	4/29	1

Tisdale Weir Rehabilitation and Fish Passage Project

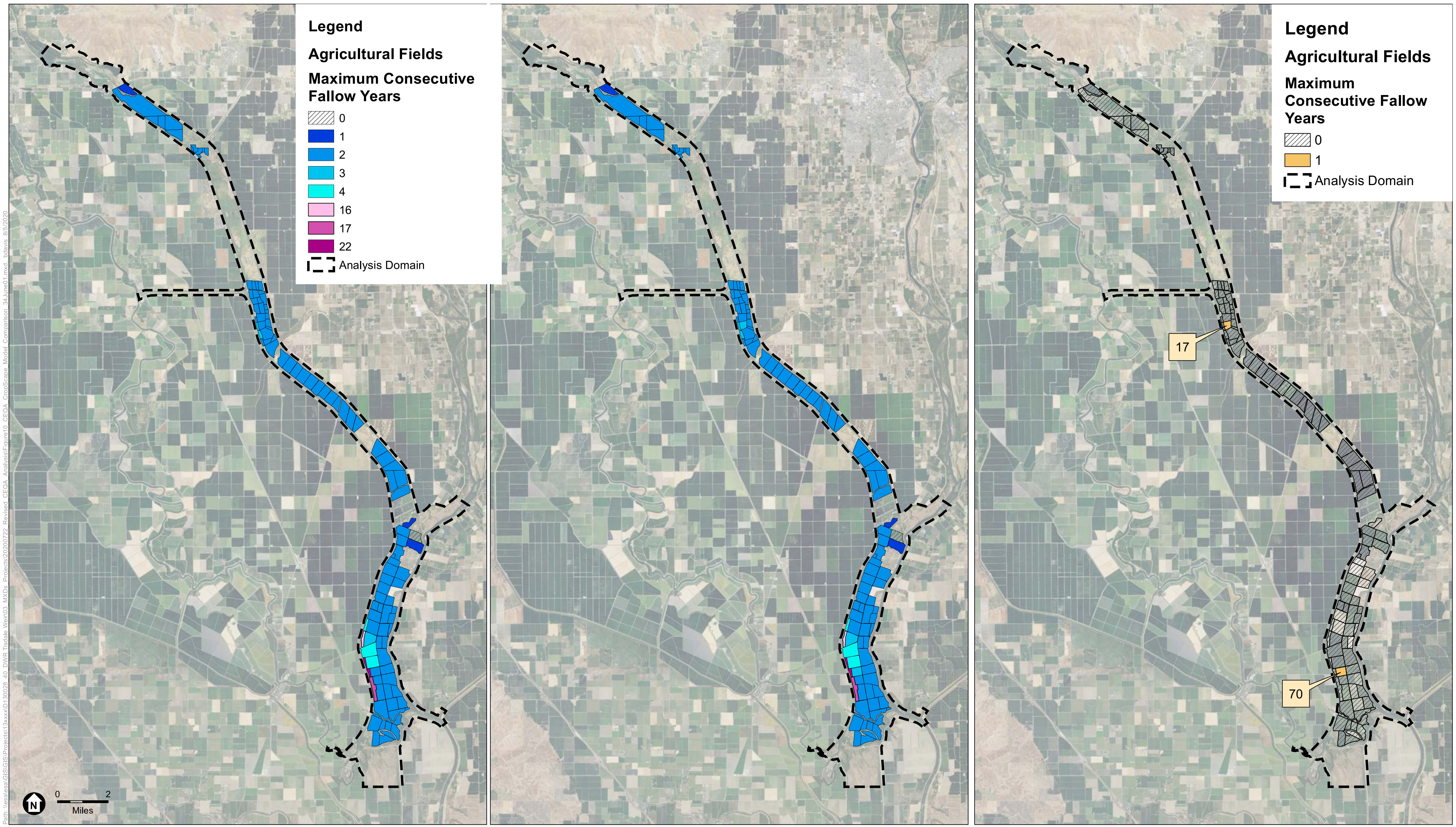
Figure 9
Results – Total Fallow Years, Tisdale/Sutter Bypass TUFLOW Model (WY 1997-2018)

ESA

Without Project Maximum Consecutive Fallow Years (1997-2018, 34 Day Prep Period, Plant by June 1)

With Project Maximum Consecutive Fallow Years (1997-2018, 34 Day Prep Period, Plant by June 1)

Difference in Maximum Consective Fallow Years With Project minus Without Project



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 10

Results – Maximum Consecutive Fallow Years, Tisdale/Sutter Bypass TUFLOW Model (WY 1997-2018)

ESA

The predicted impact of Project implementation on the fallowing of agricultural fields within the Sutter Bypass is relatively small, at both the scale of individual fields and the scale of the entire bypass. For a small set of fields within the Sutter Bypass, the Project is predicted to slightly increase the frequency with which these fields may be fallowed (i.e., adding one or two additional fallow years over approximately two decades of modeled conditions). However, based on available information, the predicted frequency of annual fallowing under the Project, in terms of both total years and consecutive years, would remain within the range of fallowing currently observed and practiced within the Sutter Bypass. Thus, while implementation of the Project could temporarily affect up to approximately 10 percent of Sutter Bypass Farmland fields (shown on Figures 5a and 5b) because of increased periods of inundation, there is no evidence to suggest that the relatively small predicted change would cause these fields to be permanently taken out of production or otherwise converted to other nonagricultural uses.

3.3 Uncertainties and Limitations

Implicitly, this analysis uses a proxy for an assumed fallowing "tolerance." The analysis confirms (through 2018 aerial imagery) agricultural fields in the Sutter Bypass that are active (i.e., have not been permanently retired or converted to a non-agricultural use). For these fields, the analysis assesses the total and maximum consecutive years fallow across a 12-year period, as reported in the CropScape Data. Thus, this recorded frequency and extent of fallowing is assumed to be within a range that does not necessitate or result in the permanent conversion of land. The same CropScape data were used to assess and roughly validate key assumptions in the analysis (e.g., drying and preparation time, and plant-by date) by comparing modeled results for fields fallowed, by year, against observed planting decisions by bypass farmers via the CropScape data. However, the model is only predicting fallowing related to prolonged inundation and, as discussed above, other cropping decisions are reflected in the actual fields fallowed (as illustrated by CropScape results). However, the fallowing predictions based on the model results compared reasonably well to the CropScape Data when considering all the factors that somewhat confound this validation.

Ultimately, fallowing is a decision made by the landowner based on a number of factors, including economic health and feasibility as well as risk tolerance. The analysis does not explicitly address these factors. These factors are assumed to be implicitly reflected in the fallowing data available for the 2007 to 2018 period, and this period is assumed to be reasonably reflective of existing conditions.

4 Other Agricultural Resources and Recreation

Other than Farmlands, which coincide with the active agricultural fields (above), the other land uses within the Sutter Bypass comprise the following: Williamson Act lands, grazing lands, and the SNWR (Figure 4). The former two are considered farmland or agricultural land uses in this case as it applies to CEQA; the latter is a wildlife refuge owned and operated by the U.S. Fish and Wildlife Service (USFWS). The Williamson Act contracts for the two relevant areas in the Sutter Bypass state that the subject property shall not be used other than commercial agricultural uses and agricultural compatible uses specified in the contract.[3] However, currently, the relevant Williamson Act parcels in the Sutter Bypass are not in active agricultural production or otherwise being used for commercial agriculture, rather they are being used as waterfowl hunting clubs (which is an agricultural compatible use). Likewise, USFWS allows for public hunting on parts of the SNWR following certain refuge-specific guidelines and criteria. Thus, the Williamson Act lands and the SNWR are addressed here primarily in the context of recreation as it relates to CEQA, as this would reflect the existing land uses. At some point, the Williamson Act lands could be transitioned to commercial agriculture or another agricultural compatible use; however, the analysis does not explicitly address such scenarios, as they are hypothetical. The following addresses potential Project impacts on farmlands (other than Prime Farmland, Unique Farmland, and Farmland of Statewide Importance) and recreation.

4.1 Methods

Ownership and parcel information was compiled for all areas within the Sutter Bypass analysis domain (as described above in Section 3.1.1, *Farmland Mapping*). The grazing lands, Williamson Act lands, and the SNWR are generally large areas that, in large part, coincide with or are on a similar scale as mapped parcel boundaries (e.g., the field scale is generally no longer relevant to these land use designations). Therefore, the assessment detailed below was carried out at the parcel scale.

4.1.1 Grazing Lands

There are a number of areas designated as grazing lands within the Sutter Bypass (Figure 4). Relevant to this analysis, an impact resulting from implementing the Proposed Project would be significant under CEQA if it would result in changes in the existing environment which could result in conversion of farmland (in this case, grazing lands) to non-agricultural use.

This analysis assumes that the mechanism for a potential flow-related impact would be from a change in the extent, depth, and/or duration of inundation on parcels used for grazing; these changes could affect the extent of available grazing area. However, unlike the assessment of active agricultural fields and fallowing (above), there are no specific metrics with regards to grazing (e.g., a planting date or a “season”), and thus there is uncertainty with regards to the degree of change in inundation that would preclude this type of land use. It is important to note that these grazing areas are inside the Sutter Bypass, a floodway that conveys floodwater and frequently inundates these locations to considerable depths under existing conditions. As such, the practice of grazing is likely somewhat opportunistic and cyclical, though without any defined season, and it would likely require a considerable change in inundation frequency to prohibit or convert this type of land use. To assess any potential flow-related impacts of the Proposed Project, a comparative assessment of any additional “wet days” resulting from increased flows from the Proposed Project was used as a proxy for days when grazing may be precluded. A wet day was determined as a day during the WY simulation period (September 28 through June 30) when the TUFLOW model results indicate that 30 percent or greater of a parcel is at least 0.1 feet deep.

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[3] As described above (Section 2.2.1, *Geographic Extents*), the modeling (or analysis) domain (shown in Figure 3) extends north of State Route 20. This was done for model accuracy purposes at the upstream boundary. However, modeling results showed no impacts on areas north of State Route 20 and, thus, these areas are not discussed.

4.1.2 Williamson Act Lands and Recreation

This analysis assumes that potential flow-related impacts from the Proposed Project would be to waterfowl hunting areas. Based on aerial imagery from 2018, there are two hunting clubs located downstream of the Tisdale Bypass inside the Sutter Bypass, both on Williamson Act lands (Figure 4). These two areas (comprising a total of 3 parcels) have been converted from agricultural use and are configured and planted to enable waterfowl use and hunting; they are not designated as Farmland, but they are enrolled in Williamson Act contracts (as mentioned above). Further, USFWS allows for public hunting on parts of the SNWR following certain refuge-specific guidelines and criteria. Hunting season for waterfowl (ducks and geese) within the Sutter Bypass is open between September 28 and February 12 (CDFW 2020), and operation of the Project may result in increased flows during these periods.[4] As many of the duck blinds in the Sutter Bypass are already accessed by boat, impacts on operations of these facilities are anticipated to be minimal. Nonetheless, relevant to this analysis, an impact resulting from implementing the Proposed Project would be significant under CEQA if it would cause a substantial loss of recreational opportunities that would require the construction or expansion of recreational facilities that might have an adverse physical effect on the environment.

This analysis assumes that the mechanism for a potential flow-related impact would be from a change in the extent, depth, and/or duration of inundation on parcels used for hunting waterfowl; these changes could affect the extent of recreational area (e.g., change in available waterfowl habitat) or preclude access along roads that may be newly inundated compared to the existing condition. Similar to that stated above, it is important to note that these hunting areas are inside the Sutter Bypass, a floodway that conveys floodwater and frequently inundates these hunting sites at depths considerably greater than a few feet and closes access roads. Further, when the sites are not inundated by floodwaters, some areas are actively managed (via diversion/pumping) to generate the desired, shallow-flooded habitat (i.e., less than 18 inches in depth). The exact timing of when these sites are actively managed is unknown and, therefore, the interaction of natural floodwaters and any supplement flow or water movement is complex and not readily assessed. To assess any potential flow-related impacts of the Proposed Project, a comparative assessment of the additional wet days resulting from increased flows from the Proposed Project was used as a proxy for a lack of access/too wet to hunt. A wet day was determined as a day during the waterfowl hunting season (September 28 through February 12 [CDFW 2020]) when the TUFLOW model results indicate that 30 percent or greater of the parcel is at least 0.1 feet deep.

4.1.3 Number of Wet Days

The following variables and assumptions were used in the analysis to identify potential impacts on Williamson Act lands, grazing lands, and the SNWR:

- Number of Wet Days—the number of days in a given season that the geographic unit (parcel, field, or continuous ownership) is more than 30 percent inundated at the end of the given day(s), as computed by the TUFLOW model.

4 Hunting within the SNWR may be limited to discrete periods within the hunting season.

Further, the analysis summarizes the model output for both the entire Water Year Simulation Period (September 28 through June 30), as well as for waterfowl season (September 28 through February 12), coincident with the legal hunting season, to account for potential impacts on duck club operations.

4.2 Results

Figure 11, **Figure 12**, and **Table 1** present the results of the above analysis of potential agricultural resources and recreation impacts on Williamson Act lands, grazing lands, and the SNWR. The figures and tables present results with respect to the predicted average annual change in the number of wet days, by parcel, as a result of Project implementation. For the Williamson Act lands and the SNWR the range of additional wet days (based on annual average) is 0 to 3.9 days for the water year and 0 to 1.9 days for just the waterfowl season (i.e., from September 28 through February 12). These values comprise, at most, less than approximately 1.4 percent of the water year (simulation period) and waterfowl hunting season, respectively. Specifically, for the Williamson Act lands, which are currently used as private waterfowl hunting clubs, the predicted increase in the number of wet days, on average, is at most one day. For grazing lands, the predicted change over the water year ranges from 0 to 3.1 days which, again, is relatively small.

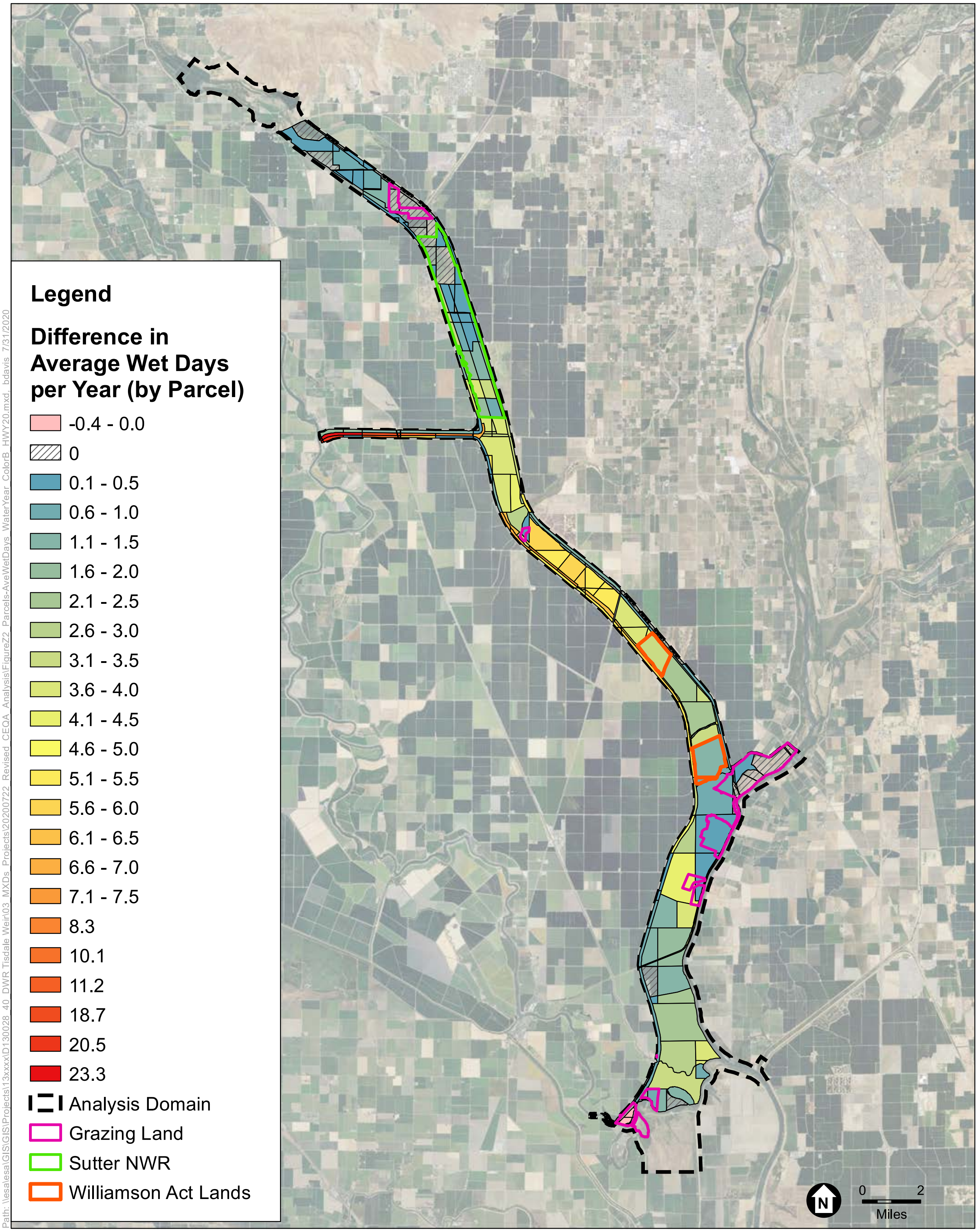
TABLE 1
ADDITIONAL NUMBER OF WET DAYS, ANNUAL AVERAGE BY PARCEL(S) (PROJECT CONDITION MODEL RESULTS, WY 1997-2018)

	Season	
Land Use	**WY (simulation period, Sep 28-Jun 30)**	**Waterfowl Season (Sept 28-Feb 12)**
Grazing lands	0.0 to 3.1 days	NA
SNWR	0.0 to 3.9 days	0.0 to 1.9 days
Williamson Act lands (1)	0.9 to 3.0 days	0.5 to 1.0 days

(1) Current agricultural compatible use = duck/hunting club

More broadly, the average annual change in the number of wet days, by parcel, does not exceed approximately seven days (or one week) throughout the modeled domain of the Sutter Bypass. The largest changes, which are outside of this range, are all within the Tisdale Bypass (as expected); lands within the Tisdale Bypass are generally perennially idle, and none of the land use designations related to agricultural resources are relevant.

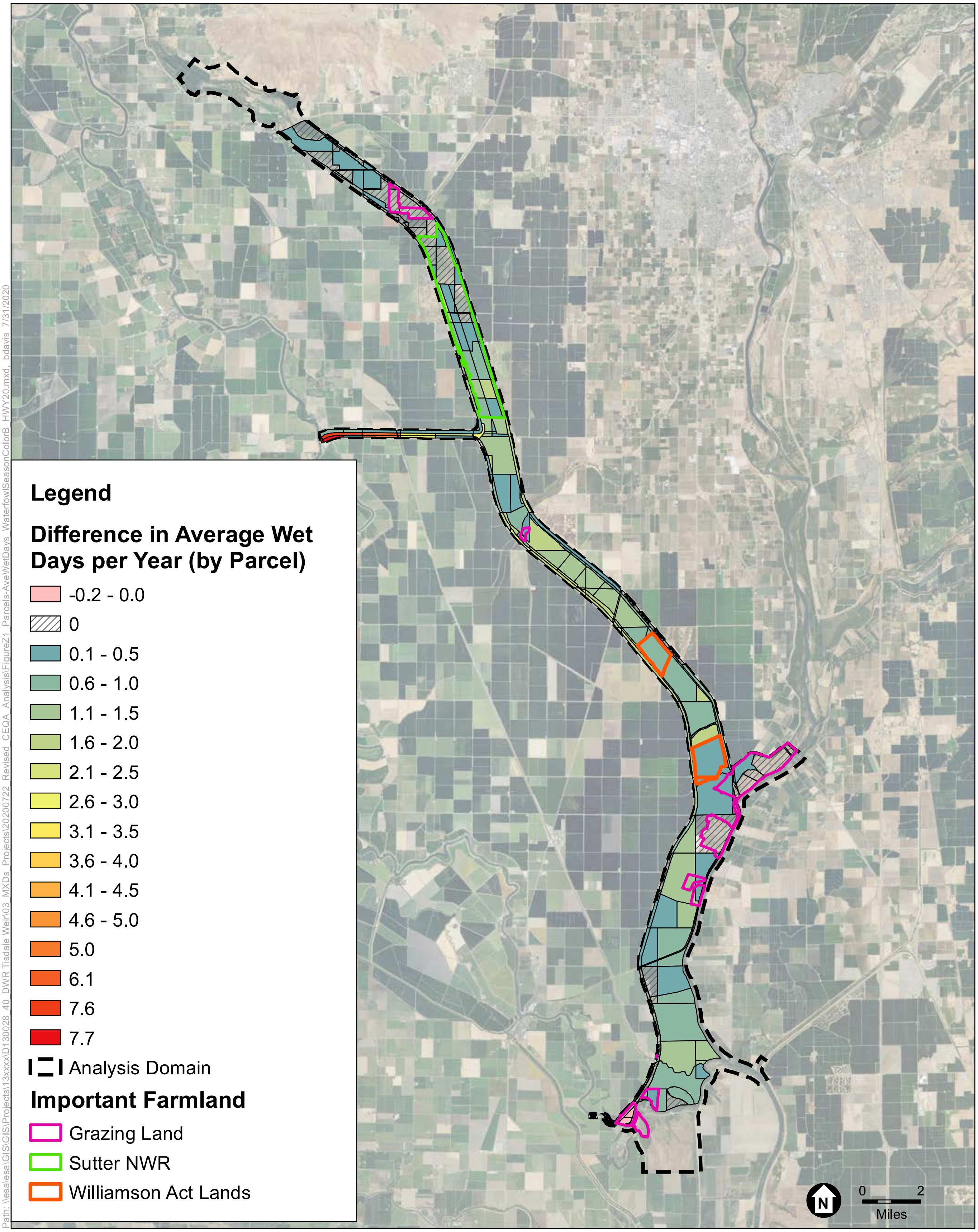
Based on the modeling results, implementation of the Proposed Project would result in very little to no increase in the average annual number of wet days on grazing lands, Williamson Act lands, and SNWR parcels. Given the seasonal and year-to-year variation in inundation within the Sutter Bypass under existing conditions, there is nothing to suggest that this small, predicted change would result in farmland conversion to non-agricultural uses or cause any substantial loss of recreational opportunities with regards to waterfowl hunting. To the contrary, the small increase in the duration of wet conditions may be beneficial to areas that are used for waterfowl hunting (e.g., it may provide additional habitat or maintain existing habitat for longer). In this case, implementation of the Project would not conflict with any Williamson Act contracts.



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 11
Difference in Average Wet Days per Year by Parcel for September 28 - June 30
Tidale/Sutter Bypass TUFLOW Model (1997-2018)

ESA



Path: \\esa\esa\GIS\GIS\Projects\13xxxx\D130028_40_DWR Tisdale Weir\03_MXDs_Projects\20200722_Revised_CEQA_Analysis\FigureZ1_Parcels-AveWetDays_WaterfowlSeasonColorB_HWY20.mxd, bdavis 7/31/2020

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 12
Difference in Average Wet Days per Year by Parcel
for Waterfowl Season September 28 - February 12
Tidale/Sutter Bypass TUFLOW Model (1997-2018)

ESA

5 Biological Resources

Much of the Sutter Bypass downstream of the Tisdale Bypass is actively farmed, and of the approximately 10,000 acres of land within this footprint, most is annually planted in rice and much of the remaining in various field crops or otherwise fallow/idle (USDA NRCS 2016; USDA NASS 2018; LandIQ 2017). Agricultural areas provide habitat for a variety of wildlife species, including bats, amphibians, reptiles, and birds. The Proposed Project would result in additional flow of water to the Sutter Bypass which, as analyzed above (Section 3, *Agricultural Resources [Farmland]*), may slightly increase the frequency of annual fallowing for a small set of agricultural fields. The following analysis assesses the potential consequences of this increase in fallowing of agricultural lands on special-status species known to occur within or in the vicinity of the Sutter Bypass; these species include giant garter snake (*Thamnophis gigas*), Swainson's hawk (*Buteo swainsoni*), and sandhill crane (*Antigone canadensis*).

Depending on the extent or frequency of any land fallowing in Sutter Bypass agricultural areas, these three species may be directly influenced by changing habitat conditions. Giant garter snakes have become increasingly reliant on inundated rice fields for foraging habitat due to the conversion of historical natural wetland habitat in the Central Valley. While the snake's access and presence in the bypass is uncertain, the species is known to be present around large areas of rice, the predominant crop type grown in the Sutter Bypass. A significant increase in fallowed fields associated with rice crops could potentially impact this species. On the other hand, Swainson's hawk could potentially benefit from additional fallowing of cropland, since fallowed land is considered higher quality foraging habitat for this species compared to land in active production. Significant additional land fallowing of rice cropland could potentially reduce the overall quality of suitable foraging habitat for overwintering sandhill cranes, which have grown accustomed to feeding on excess grain left in fields after harvest. Relevant to this analysis, a significant impact under CEQA resulting from implementing the Proposed Project would be an increase in land fallowing such that there is a subsequent, significant reduction in habitat for these special-status species.

5.1 Giant Garter Snake

Giant garter snake is federally listed and State listed as threatened. During the colder months of the year, giant garter snakes spend their time in a lethargic state. During their inactive season (October 1 to May 1), giant garter snakes over-winter in locations such as mammal burrows along canal banks and marsh locations, or riprap (Halstead et al. 2015). Giant garter snakes have not been previously documented within the Sutter Bypass (Sites and Reclamation 2017), likely in part because giant garter snakes typically do not overwinter where flooding occurs in channels with rapidly moving water. Access to upland refuges that are safe from flooding is important for this species (USFWS 2017). Individuals can travel as much as 600 feet from water to reach the high water line to avoid flooding during their inactive period (Halstead et al. 2015).

Suitable habitat for giant garter snakes may be closely associated with rice agriculture and natural wetlands located in close proximity to a high density of canals and low density of streams (Halstead et al. 2010). Rice is a flood-irrigated crop of seed-producing annual grasses. It is maintained in a flooded state until it is nearly mature (University of California Cooperative Extension 2015). Rice is commonly grown in areas that previously supported natural wetlands, and species such as giant garter snake have adapted to rice fields in response to large-scale decline of natural wetlands within the Central Valley (USFWS 2016a). During the active season, individuals are typically found with 30 feet of aquatic habitat. Giant garter snakes are known to occur in areas immediately adjacent to the Sutter Bypass (Sites and Reclamation 2017), and it cannot be ruled out this species traverses into the Sutter Bypass during their active season to access naturally inundated areas, rice fields, and agricultural canals and drainages to forage.

During periods when rice cropland is fallowed, though these areas may still provide connectivity between suitable habitat patches if irrigation canals or drainage ditches remain full (USFWS 2017), the field areas would not be irrigated and thus not provide wetted habitat during the snake's active season. Thus, a significant increase in the frequency of rice field fallowing and/or extent of permanent fallowing or land conversion could contribute to a net reduction in suitable giant garter snake foraging habitat, resulting in increased competition for remaining resources, reduced reproductive rates, and increased mortality from predation (USFWS 2016b). However, as summarized above, based on available information the predicted frequency of annual fallowing under the Project, both in terms of total years and consecutive years, would remain within the range of fallowing currently observed and practiced within the Sutter Bypass. Therefore, the Proposed Project is not projected to result in changes to habitat conditions for giant garter snake within Sutter Bypass outside the range of existing conditions.

5.2 Swainson's Hawk

Swainson's hawk is State listed as threatened. Swainson's hawk typically nest in scattered trees or along riparian systems adjacent to agricultural fields or pastures (CDFG 1994a). Major prey items for Central Valley birds include: California voles (*Microtus californicus*), valley pocket gophers (*Thomomys bottae*), deer mice (*Peromyscus maniculatus*), California ground squirrels (*Spermophilus beecheyi*), mourning doves (*Zenaida macroura*), grasshoppers, crickets, and beetles (Estep 1989). Swainson's hawk foraging habitat includes native grasslands, lightly grazed pastures, and certain agricultural croplands (CDFG 1994a). The types of agricultural land which are considered suitable foraging habitat for Swainson's hawk include the following:

- Alfalfa
- Fallow fields
- Beet, tomato, and other low-growing row or field crops
- Dryland and irrigated pasture
- Rice lands (when drained)
- Cereal grain crops (including corn after harvest)

Within agricultural croplands, research in the Central Valley identified preferences in foraging habitat of Swainson's hawk (Estep 1989), which are presented as follows:[5]

1. Alfalfa: Provides a relatively low abundance of prey at a steady rate of accessibility throughout the breeding season (March to September).
2. Fallow fields: Provide a high abundance of accessible prey if such fields are not dominated by dense stands of thistle and other weedy vegetation.
3. Beet and tomato fields: Provide the largest prey populations, but dense cover reduces accessibility of prey to foraging Swainson's hawk, except during harvesting operations when Swainson's hawk has been observed foraging almost exclusively in these fields (late July to early September).
4. Dry-land pasture: May provide primary foraging habitat for some individuals.
5. Irrigated pasture: Provides suitable foraging habitat, especially during flooding.

Based on the latest CropScape data, alfalfa, which is the agricultural crop type with the highest quality foraging habitat conditions for Swainson's hawk, is known to be grown in the Sutter Bypass downstream of the confluence with the Tisdale Bypass. Fallow fields provide the next highest value of foraging habitat conditions for Swainson's hawk. For a small set of fields within the Sutter Bypass, the Project is predicted to slightly increase the frequency with which these fields may be fallowed (i.e., adding one or two additional fallow years over approximately two decades), and therefore the Project may provide Swainson's hawk with improved foraging conditions within the Sutter Bypass. Though these same fields would also experience increased inundation as a result of the Project (i.e., thus triggering fallowing), a condition which is not conducive to Swainson's hawk foraging, they would still generally be fully drained during the vast majority of the period when Swainson's hawk are present in the Central Valley. Nonetheless, the analysis shows that any additional fallowing of fields that may occur as a result of the Project would be within the range of fallowing currently observed within the bypass, and so no change is expected as a result of Project implementation.

5.3 Sandhill Crane

There are two subspecies of sandhill crane found in the Central Valley: greater sandhill crane and lesser sandhill crane. Greater sandhill crane is State listed as threatened and is a California Department of Fish and Wildlife fully protected species. The lesser sandhill crane is the more common subspecies in the Central Valley and a California species of special concern. The two subspecies of cranes migrate to different areas of North America to breed during the summer. On average greater sandhill cranes are taller and larger in mass than their lesser sandhill crane counterparts. While overwintering in the Central Valley, these two subspecies utilize similar habitat. The Central Valley is the most important sandhill crane wintering area in the Pacific Flyway (Ivey et al. 2016).

[5] Habitats unsuitable for foraging include any crop where prey are not available due to the high density of vegetation, or have low abundance of prey (i.e., flooded rice fields, mature corn, orchards, and cotton fields).

In the Central Valley, sandhill cranes winter almost entirely in agricultural fields and edges. Wintering habitat consists of three primary elements: foraging habitat, loafing habitat, and roosting habitat. Winter foraging habitat consists of annual and perennial grasslands, moist croplands (corn, sorghum, barley, and rice), or emergent wetlands (Mayer and Laudenslayer 1988). Sandhill cranes are omnivores that consume invertebrates, amphibians, reptiles, small mammals and birds, and a variety of plant parts (Shuford and Gardali 2008). Waste grains and other seeds are dominant foods in winter. Waste grains consumed include milo, corn, wheat, rice, barley, and oats (Littlefield 2002). Sandhill cranes use pastures, moist grasslands, alfalfa fields, and shallow wetlands for loafing sites (Shuford and Gardali 2008). Irrigated pastures are used extensively as loafing sites in some wintering areas (CDFG 1994b). Nighttime roost sites are typically located 2 to 3 miles from foraging and loafing areas, usually in shallowly flooded, open fields of variable size (1 to 300 acres) or wetlands interspersed with uplands.

Sandhill crane numbers have increased in the Sacramento Valley in recent decades, hypothesized to be in part due to the limitation in burning of rice stubble and the greatly increased practice of flooding to decompose stubble (Ivey et al. 2014). Although there are many areas of flooded rice fields for cranes to choose from, most flooded rice fields are subject to disturbance from waterfowl hunting or are too deep to serve as ideal roost sites (Ivey et al. 2014).

Long-term fallowing of rice fields or other grain crops is likely to contribute to a net reduction in foraging habitat. Given that nighttime roosting habitat must occur in fairly close proximity to available forging habitat, major reductions in foraging habitat quality in a given area could prompt sandhill crane usage of the area to decline. Reductions in favorable agricultural crops for cranes has previously been associated with a decline in sandhill crane utilization of an area. For example, in some areas east of the Sacramento River where former pastures and rice fields formerly used by sandhill cranes were converted to more natural wetland habitat types, sandhill crane usage decreased (Ivey et al. 2016). However, based on available information the predicted frequency of annual fallowing under the Proposed Project, both in terms of total years and consecutive years, would remain within the range of fallowing currently observed and practiced within the Sutter Bypass. Therefore, the Proposed Project is not projected to alter habitat conditions for sandhill crane within Sutter Bypass beyond the range of existing conditions.

5.4 Results and Discussion

As described above (Section 3, *Agricultural Resources [Farmland]*), annual fallowing is driven by a variety of factors and occurs throughout the Sutter Bypass under existing conditions, though the extent varies from year to year. Flooding regularly occurs in the Sutter Bypass during the wet season from inflows from Butte Slough (Butte Creek and the Butte Basin), the Tisdale Bypass, the Feather River, and local Sutter Basin drainage flows entering the Bypass. Farmers have adapted to these conditions and the associated risk to their operations from this flood regime. Flooding events can delay planting times and in turn reduce crop yields—or even prevent planting if inundation events persist later in the spring. Further, fallowing could also occur due to, for example, lack of irrigation water or in response to commodity market conditions. Thus, the practice of fallowing currently occurs within the Sutter Bypass, and the current extent and frequency, based on published data from 2007 to 2018, is summarized above (Section 3.1.4, *Fallowing and Conversion*).

Based on the modeling results, the Project is expected to have minimal effects on the extent of fallowing of rice fields (Section 3.2, *Results*). The modeling indicates that for a small number of fields within the Sutter Bypass, the Project may slightly increase the frequency with which these fields are fallowed (i.e., adding one or two additional fallow years over approximately two decades). However, overall, the modeling suggests that any change in the extent and frequency of fallowing would remain within the range of fallowing currently observed and practiced within the Sutter Bypass. Therefore, the change to fallowing of fields due to the Project would have minimal effects on overall habitat conditions within the bypass for Swainson's hawk, sandhill crane, and the giant garter snake. Based on the analysis, any additional land fallowing as a result of the Proposed Project would not lead to a subsequent, significant reduction in habitat for special-status species.

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Attachment A

Tisdale Weir 1D HEC-RAS Modeling

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esassoc.com

memorandum

date August 21, 2020

to John Pritchard, P.E. and Eric Ginney

cc Project file

from Michael Strom and Justin Gragg

subject Tisdale Weir One-dimensional HEC-RAS Modeling

1. Background

The California Department of Water Resources (DWR) Tisdale Weir Rehabilitation and Fish Passage Project (Project) would include installation of fish passage facilities at the weir to reduce stranding of salmon and sturgeon and improve passage from the Tisdale Bypass to the Sacramento River. The proposed fish passage facilities would consist of a reconstructed energy dissipation and fish passage basin on the downstream side of the weir, installation of a notch and operable gate at the north end of the weir, and construction of a channel connecting the notch in the weir to the Sacramento River.

Compared to existing conditions, with operation of the Project, flows to the Tisdale Bypass and subsequently the Sutter Bypass would increase during certain periods, potentially increasing the depth, extent, and duration of inundation on agricultural fields and in other areas (e.g., waterfowl hunting areas). Consequently, an analysis of existing- and Project-condition hydrology and hydraulics was needed to understand and quantify any downstream changes in inundation. For this analysis, Environmental Science Associates (ESA), using the TUFLOW HPC commercial software package, developed a coupled one- and two-dimensional (1D/2D) hydrodynamic model of the Tisdale and Sutter Bypasses (Tisdale/Sutter Bypass TUFLOW model). The simulation period for the model is WY 1997-2018. To drive this model, revised hydrology for Tisdale Weir spill (and through-notch flow) for with-project conditions was necessary. Similarly, for the with-project condition, the weir modifications would result in changes in flow in the Sacramento River that needed to be quantified to address other analyses, such as the potential impacts of the Project on flood conveyance.

2. Purpose and Need

Most flow boundary conditions for the Tisdale/Sutter Bypass TUFLOW model were based on observed or previously simulated data; however, a different approach was required for the Sacramento River flow split at the Tisdale Weir (i.e., the boundary condition time series defining the amount of flow overtopping the weir and flowing into the Tisdale Bypass and the amount of flow remaining in the Sacramento River). The reason for an alternate approach in this case was the presence of the old Garmire Road bridge (built in 1935), which ran directly across the top of the Tisdale Weir (along the crest) up until 2008 when it was removed. Because of the tendency for the old bridge to accumulate and retain floating debris (mostly large wood) between and on its many piers, it notably reduced the amount of Sacramento River flow conveyed over Tisdale Weir and into the Tisdale Bypass during high flow conditions.

For example, **Figure 1** shows the relationship between flow in the Sacramento River and flow in the Tisdale Bypass going back to 1989. The Sacramento River values shown are the instantaneous data reported for the USGS Sacramento River below Wilkins Slough gage (USGS Wilkins Slough gage) (located just downstream of Tisdale Weir),[1] and the Tisdale Bypass flow values are those measured in the field by the California Department of Water Resources (DWR).[2] The data prior to the old bridge being removed (the 1989-1996 and 1997-2008 data series) clearly indicate less flow being conveyed over the weir for a given Sacramento River flow compared to the data after the old bridge was removed (2009-2018 data series).[3]

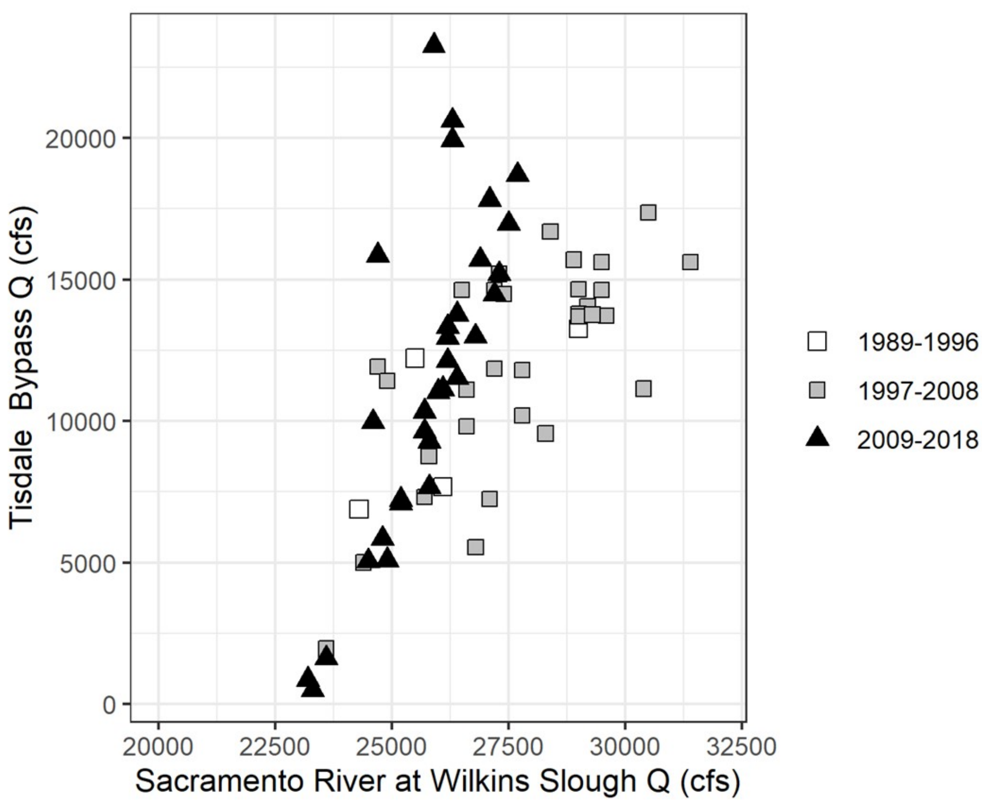

Figure 1. Sacramento River at Wilkins Slough flow (15-min reported data) versus measured Tisdale Bypass flow.

1 USGS 11390500 SACRAMENTO R BL WILKINS SLOUGH NR GRIMES CA, data: https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=11390500.

2 DWR staff, personal email communication (October 2018).

3 The 1997-2008 data series spans up to January of 2008, which was when the only 2008 field measurement of weir flow was made by DWR. The old Garmire Road bridge was removed later that year, in the fall of 2008.

Periodic sediment maintenance performed by DWR (e.g., generally on the order of every decade or so) may also have some influence on the conveyance capacity of the Tisdale Bypass, but it does not seem to influence weir and bypass conveyance as much as the presence of the old Garmire Road bridge. For example, approximately 1.7 million cubic yards of sediment was removed from the Tisdale Bypass during the latter half of 2007, and so the 2009-2018 data includes the influence of this maintenance event as well as the absence of the old bridge. However, cumulatively between 1984 and 1987, DWR removed approximately 2.0 million cubic yards of sediment from the Tisdale Bypass, yet the data for the period immediately after still seem to indicate a reduced amount of conveyance over the weir compared to the contemporary (post-bridge move) period (2009-2018). Under existing conditions, large wood debris still consistently accumulates on or upstream near the weir during large spill events and influences flow hydraulics at the weir. Yet, the subsequent effects on overall weir conveyance are not (yet[4]) obvious and certainly not as pronounced compared to the period when the old Garmire Road bridge was still in place. Thus, though flow data are available for the Tisdale Weir spanning the entire simulation period (WY 1997-2018), the data from 2008 and prior are not representative of contemporary conditions with regards to the flow split at this location and were deemed inappropriate for direct usage as inputs for the Tisdale/Sutter Bypass TUFLOW model.

For this reason, a one-dimensional (1D) HECRAS model of the flow split at the Tisdale Weir (Tisdale Weir HECRAS model), reflecting existing “clean” weir conditions (i.e., no bridge), was developed to generate the flow input at this location for use in the Tisdale/Sutter Bypass TUFLOW model. The 1D HECRAS model was used to generate the time series of Tisdale Weir flow and downstream Sacramento River flow (i.e., the flow remaining in the river) over the entire Tisdale/Sutter Bypass TUFLOW Model simulation period of WY 1997-2018. Even though flow data are available for the time period after the bridge was removed from the top of the weir (2009-2018), we modeled flows for the entire simulation period in order to make the comparison of existing- and Project-condition results consistent (e.g., as mentioned, debris accumulation still influences hydraulic conditions at the weir). The development and calibration of the Tisdale Weir HECRAS model is described below.

3. Model Setup

The Tisdale Weir HECRAS model was derived from the previously developed DWR Central Valley Floodplain Evaluation and Delineation (CVFED) HEC-RAS model of the Sacramento River Basin (Wood Rodgers 2015), and updated to include 2015 LiDAR data (primarily for the levees) and 2017 (Tisdale Bypass bed) and 2018 (Tisdale Weir geometry) topographic ground survey data. The portion of the Sacramento River in the CVFED model relevant to this exercise spans from just upstream of the Tisdale Weir downstream to the USGS Wilkins Slough gage as well as the Tisdale Bypass downstream to its confluence with the Sutter Bypass (**Figure 2**). A model was generated for existing conditions (i.e., the existing weir crest and geometry) and Project conditions (i.e., including a notch and gate in the lateral weir). A lateral structure representing the existing Tisdale Weir geometry connects the Sacramento River and Tisdale Bypass reaches of the model. For Project conditions a notch was added to the existing weir geometry, and all other model parameters remained the same. For the Project condition model geometry, a broad-crested overflow gate was added to the notch in the weir with a height of 11.1 feet, width of 33 feet, and an invert elevation of 33 feet NAVD88.[5]

4 Through time, additional data may allow for a refined understanding of how debris on the weir influences conveyance.

5 Herein, all elevations are referenced to the NAVD88 vertical datum, unless otherwise indicated.

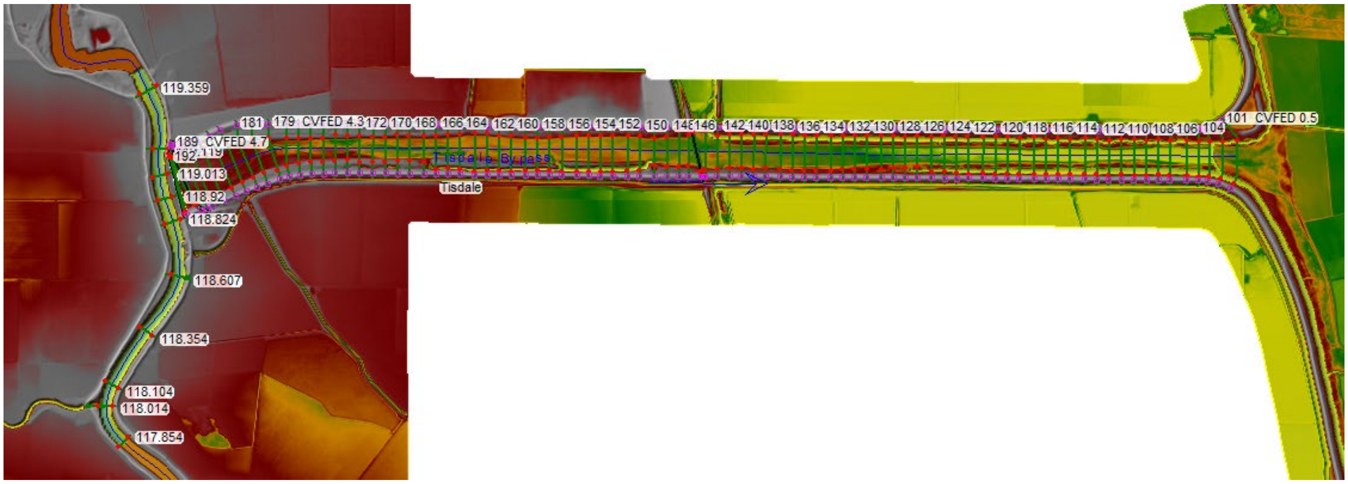

Figure 2. **Model domain**

Operation of the notch gate would likely involve opening the gate upon Sacramento River stage overtopping the weir crest (44.1 feet) and keeping the gate open, allowing fish to return to the river, until Sacramento River stage drops below the invert of the notch and basin (33 feet). A river stage of 36.5 to 37 feet roughly corresponds to the cessation of eastward flow through the Tisdale Bypass as a result of a topographic high point (or "hinge" point). In other words, with an open notch, the river would not flow into the bypass if the river's water surface were below an elevation of approximately 36.5 to 37 feet. Stages at and below this elevation range (and above the notch invert of 33 feet) would be associated with placid conditions behind the weir in the basin, with water receding back into the Sacramento River commensurate with the decline in stage of the river.

Therefore, within the model rules were assigned to open the gate when Sacramento River stage overtopped the weir crest (44.1 feet) and to close the gate when river stage dropped below a bypass hinge point of 36.5 feet. In reality, the gate would close once river stage dropped below the basin and notch invert (33 feet), but due to model instability the gate needed to close at 36.5 feet; this was because the bypass needed to maintain a small baseflow to avoid going dry and creating instability in the model, and setting the gate closure threshold to 33 feet resulted in a head gradient that drained the baseflow into the river instead of flowing beyond the hinge to keep the bypass wet and stable. However, as mentioned above, in reality no bypass flow would occur below a Sacramento River stage of approximately 36.5 feet, so this simulation approach still reflects proposed operations and processes. Additional gate logic was added to reopen the gate to address instances when, after weir overtopping (stage exceeded 44.1 feet), river stage rose back above 36.5 feet prior to dropping below 33 feet. While ensuring computational stability, this accounted for the potential situation in which the river stage overtops the weir crest, the gate opens, stage recedes below the hinge point, stage doesn't recede below the notch invert, and then stage rises again above the hinge point. Under existing- and Project-conditions, the bypass baseflow for stability purposes was 1 cubic foot per second (cfs) and 10 cfs, respectively (and these baseflows were found to have a negligible effect on the variation in existing- and Project-conditions hydrology and hydraulics).

Other boundary conditions included a 15-minute time series of flow entering the Sacramento River upstream of the weir for WY 1997 through WY 2018. This was developed by summing the flow recorded at the USGS Wilkins Slough gage and the DWR Tisdale Weir gage.[6] Stage-discharge rating curves at the downstream ends of

[6] Tisdale Weir Spill to Sutter Bypass near Grimes gage, data: https://wdl.water.ca.gov/ContinuousData.aspx?site2=A02960&source=map

the Sacramento River and Tisdale Bypass were obtained for the USGS Wilkins Slough gage and derived from the DWR Tisdale Weir and SB2 gages (ESA 2019),[7] respectively (the DWR SB2 gage is located in the East Borrow Canal of the Sutter Bypass opposite the confluence of the Tisdale Bypass) (**Figure 3** and **Figure 4**). The USGS Wilkins Slough gage rating curve was used as the Sacramento River downstream boundary condition instead of the stage time series in part because of the change in the weir geometry in 2008 (e.g., the pre-2009 stage series would reflect the pre-2009 flow split at the weir, which is no longer valid). The SB2 gage data do not span the entire simulation period, and hence a rating curve derived from the observed data was used for this boundary condition as well; this rating curve was developed previously as part of the Fish Passage Analysis (ESA 2019) for the Project.

Lastly, the existing- and Project-conditions scenarios were also run using a synthetic hydrograph ramping up to 66,000 cfs in the river upstream of the weir, which is associated with the USACE (1955) design flow split between the bypass and river. These synthetic hydrographs were run because no observed event within the simulation period reached this design flow value; however, the results for these simulations were for QA/QC and informational purposes (e.g., to develop more complete weir rating curves for existing- and Project-conditions) and were not used in the Tisdale/Sutter Bypass TUFLOW Model simulation.

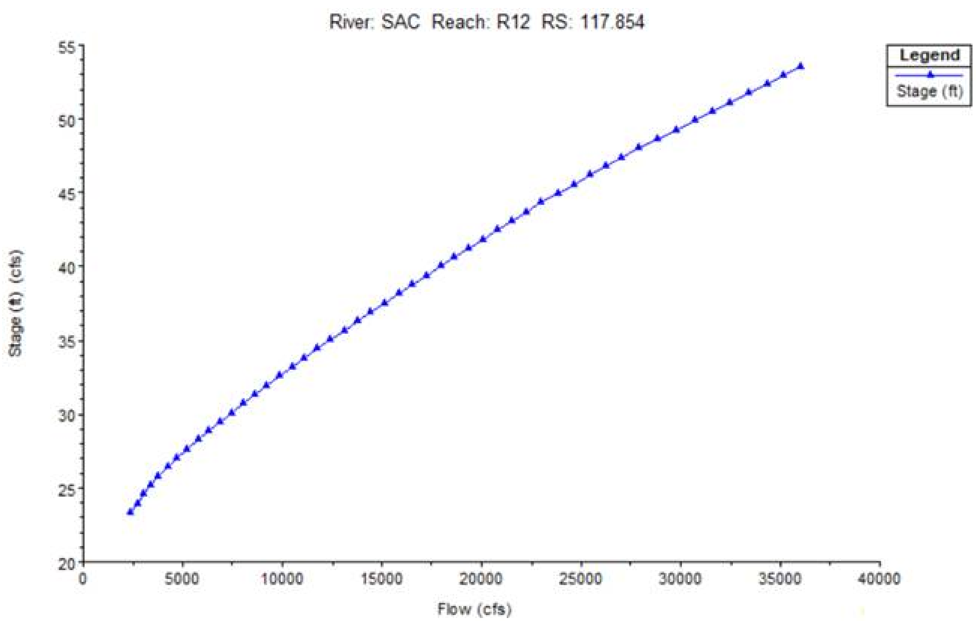

Figure 3. 1D HECRAS model Sacramento River downstream boundary rating curve (from USGS Wilkins Slough gage).

7 Sutter Bypass at DWR Pumping Plant #2 gage, data: https://wdl.water.ca.gov/ContinuousData.aspx?site2=A05920&source=map.

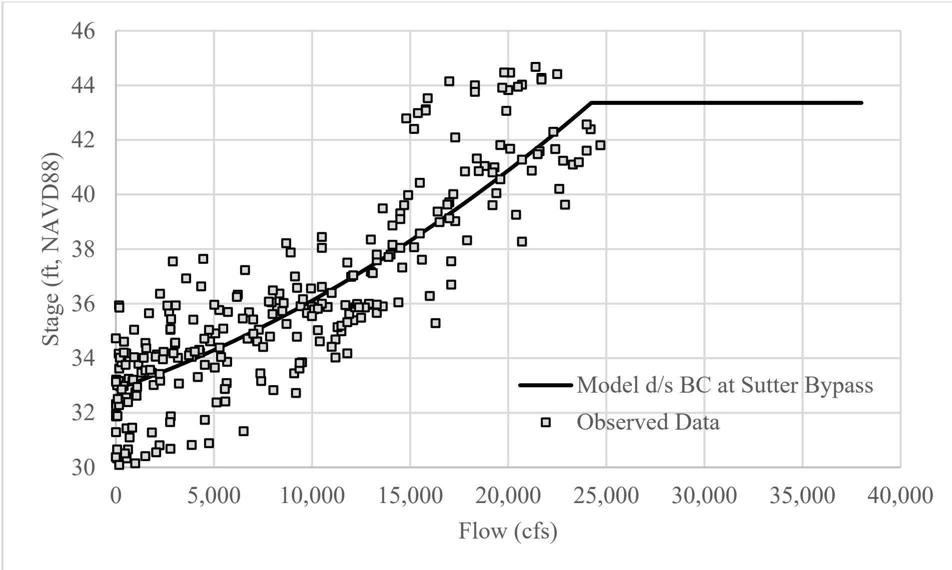

Figure 4. 1D HECRAS model Tisdale Bypass downstream boundary rating curve (derived from DWR 2019a, 2019b data, WY 2008-2017) (ESA 2019).

4. Calibration

The weir coefficient for Tisdale Weir was used to calibrate modeled spill over the weir to observed spill at the DWR Tisdale Weir gage. The HECRAS manual (USACE 2016) includes the below table for guidance on selecting an appropriate weir coefficient for lateral structures. A value of 2.8 was selected following calibration runs (**Figure 5**), which is at the high end in the table, but the existing weir is a relatively high and smooth feature, so this value was reasonable.

What is being modeled with the Lateral Structure	Description	Range of Weir Coefficients
Levee/Roadway – 3ft or higher above natural ground	Broad crested weir shape, flow over levee/road acts like weir flow	**1.5** to **2.6** (2.0 default) SI Units: 0.83 to 1.43
Levee/Roadway – 1 to 3 ft elevated above ground	Broad crested weir shape, flow over levee/road acts like weir flow, but becomes submerged easily.	**1.0** to **2.0** SI Units: 0.55 to 1.1
Natural high ground barrier – 1 to 3 ft high	Does not really act like a weir, but water must flow over high ground to get into 2D flow area.	**0.5** to **1.0** SI Units: 0.28 to 0.55
Non elevated overbank terrain. Lat Structure not elevated above ground	Overland flow escaping the main river.	**0.2** to **0.5** SI Units: 0.11 to 0.28

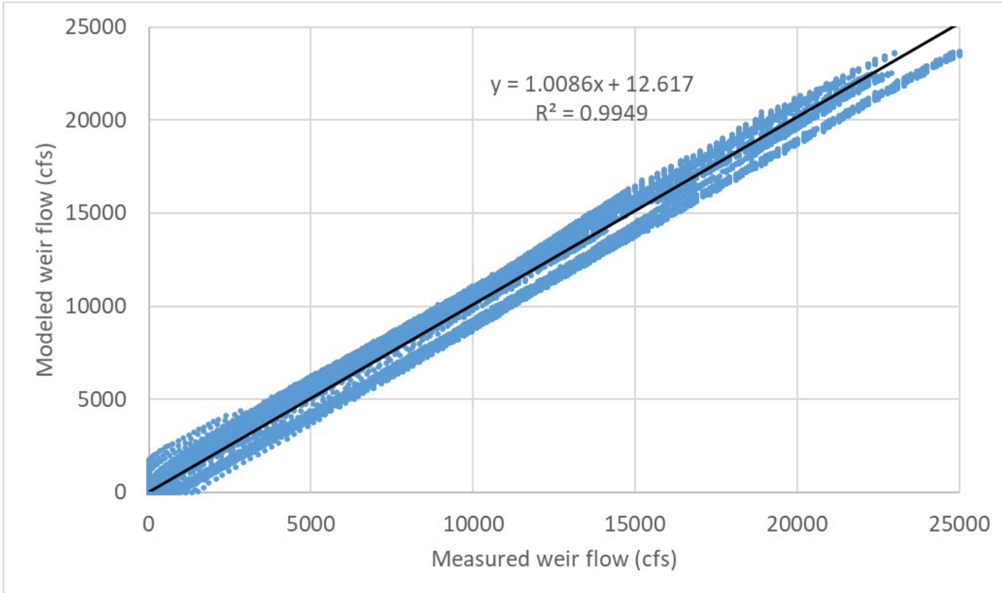

Figure 5. Modeled vs. measured flow over the existing Tisdale Weir (WY 2009-2018).

Clearly, no observed data exists at the site to calibrate the weir coefficient of the open notch under Project conditions, but flow through the notch was not assumed to be represented by the same weir coefficient as flow over the weir crest. The 2D HECRAS model developed by ESA (2019) to evaluate fish passage conditions through the notch was used to refine the gate weir coefficient. While the notch hydraulics predicted with the 2D model are not validated, the more robust solution of the governing flow equations in the 2D model was deemed useful to reference in refining the weir coefficient. A value of 2.0 was selected, and **Figure 6** shows that using the same value as the weir crest would produce significantly more weir flow compared to the 2D model for a given Sacramento River stage.[8]

8 The 2D simulation was run over the rising and falling limbs of a hydrograph, hence the two curves shown for the 2D model.

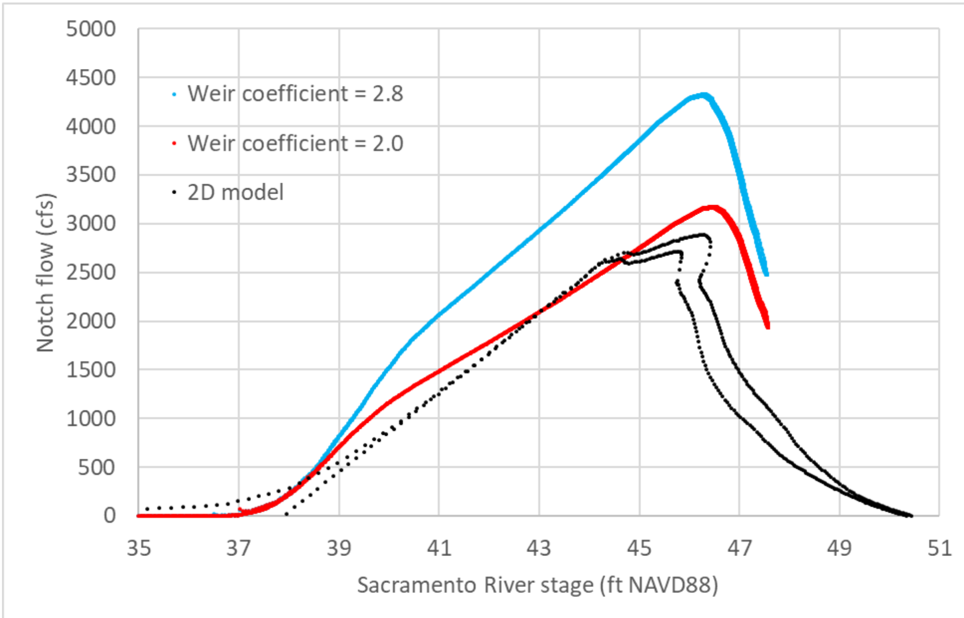

Figure 6. Notch flow vs. Sacramento River stage for the 2D model and two notch weir coefficients in the 1D HECRAS model.

5. Results

Figure 7 presents rating curves of modeled bypass flow versus Sacramento River stage for existing- and Project-conditions over the WY 1997 through 2018 period plus, above the range of this data set, the hypothetical ramp up to 66,000 cfs for the Sacramento River. Bypass flow under existing conditions begins once the weir crest is overtopped, while the with-notch (Project condition) scenario shows flow into the bypass for stages above the bypass hinge point. Notch-only flow peaks at approximately 2,500 cfs. The rate of increase in bypass flow under Project conditions is greater once the weir crest begins spilling, and the two scenarios converge at the highest stages once the influence of the notch becomes less relevant to the total bypass flow (i.e., when tailwater conditions in the Bypass begin to reduce conveyance through the notch). These two rating curves were used to represent the flow-split at the weir in the Tisdale/Sutter Bypass TUFLOW model.

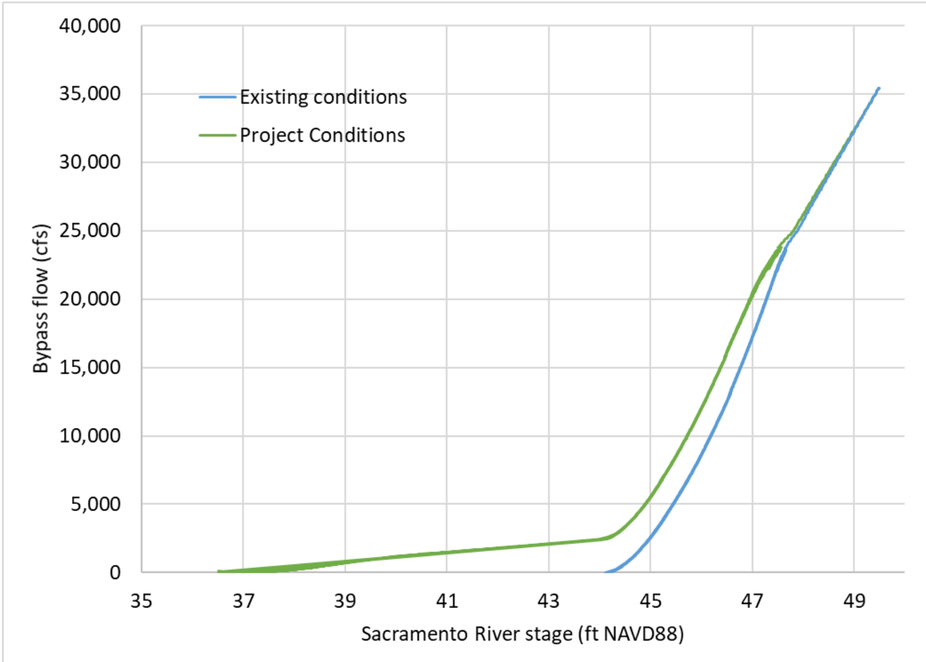

Figure 7. 1D HECRAS Modeled Rating Curves, Tisdale Bypass flow vs. Sacramento River stage.

6. References

DWR (California Department of Water Resources). 2019a. Water Data Library, Tisdale Weir Spill to Sutter Bypass near Grimes, Station A02960. http://wdl.water.ca.gov/waterdatalibrary/docs/Hydstra/index.cfm?site=A02960&source=map.

———. 2019b. Water Data Library, Sutter Bypass at DWR Pumping Plant #2, Station A05920. http://wdl.water.ca.gov/waterdatalibrary/docs/Hydstra/index.cfm?site=A05920&source=map.

ESA (Environmental Science Associates). 2019. Tisdale Weir Rehabilitation and Fish Passage Project Fish Passage Analysis Technical Memorandum. September 2019.

USACE (U.S. Army Corps of Engineers). 1955. Supplement to Standard Operation and Maintenance Manual, Sacramento River Flood Control Project Unit No. 156—Tisdale Weir and Bypass, Sacramento River, California. Sacramento District, Sacramento, CA.

———. 2016. HEC-RAS River Analysis System, 2D Modeling User's Manual, Version 5.0. Institute for Water Resources, Hydrologic Engineering Center (HEC), February 2016.

Wood Rodgers, Inc. 2015. Refine/Calibrate Combined Sacramento River and San Joaquin River Systems - Sacramento River System Study Area Report. Prepared on behalf of the California Department of Water Resources.

Attachment B
USDA CropScape Data Analysis

The U.S Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) has mapped crop types and land use in the Project area dating back to 2007, including fallow/idle cropland, and has published these data as part of the national CropScape–Cropland Data Layer (CropScape Data). The Cropland Data Layer is a raster, geo-referenced, crop-specific land cover data layer that typically has a ground resolution of 30 meters. The Cropland Data Layer is produced using satellite imagery (e.g., from the Landsat 8 OLI/TIRS sensor and the European Space Agency SENTINEL-2 sensors) collected during the growing season. Agricultural training and validation data are derived from the Farm Service Agency (FSA) Common Land Unit (CLU) Program. The strength and emphasis of the Cropland Data Layer is agricultural land cover. It should be noted that no farmer reported data are derivable from the Cropland Data Layer.

Figures B1 through **B4** show the Cropland Data Layer fallow/idle classification for the Sutter Bypass from 2007 to 2018. The agricultural field delineations are also shown, as well as the WY type.

Relatively large sections of the Sutter Bypass may be fallowed in a given year, and the spatial distribution of the fallowing may shift depending on the driver. For example, in Wet years the fallowing may be concentrated in the lower Sutter Bypass, south of the Feather River; in Dry or Critically Dry years, the fallowing may be concentrated in bypass areas north of the Feather River. In really wet years, as in 2017 for example, fallowing may be widely distributed throughout all areas of the bypass, as the extended duration of flooded or wet conditions likely precluded planting crops in time (e.g., by late spring).

Figures B5 and **B6** summarize the CropScape Data fallowing/idle classifications by field and by consecutive and total years fallowed from 2007 to 2018. If 70 percent or more of a particular field was classified as fallow/idle according to the CropScape Data, then it was considered fallow in the analysis, otherwise it was considered not fallow. Generally, according to the CropScape Data, most of the agricultural fields in the Sutter Bypass have experienced up to 1 or 2 consecutive years of fallowing over approximately the last decade, with a very limited number of fields in the 3 to 5 year range as well as the zero range. Further, with regards to total fallowed years based on the CropScape Data, most of the agricultural fields in the Sutter Bypass have experienced from to 1 or 4 total years of fallowing over a twelve-year period. The most frequently fallowed land in the Sutter Bypass, according to the CropScape Data, is located in the section between the Tisdale Bypass and the Feather River.

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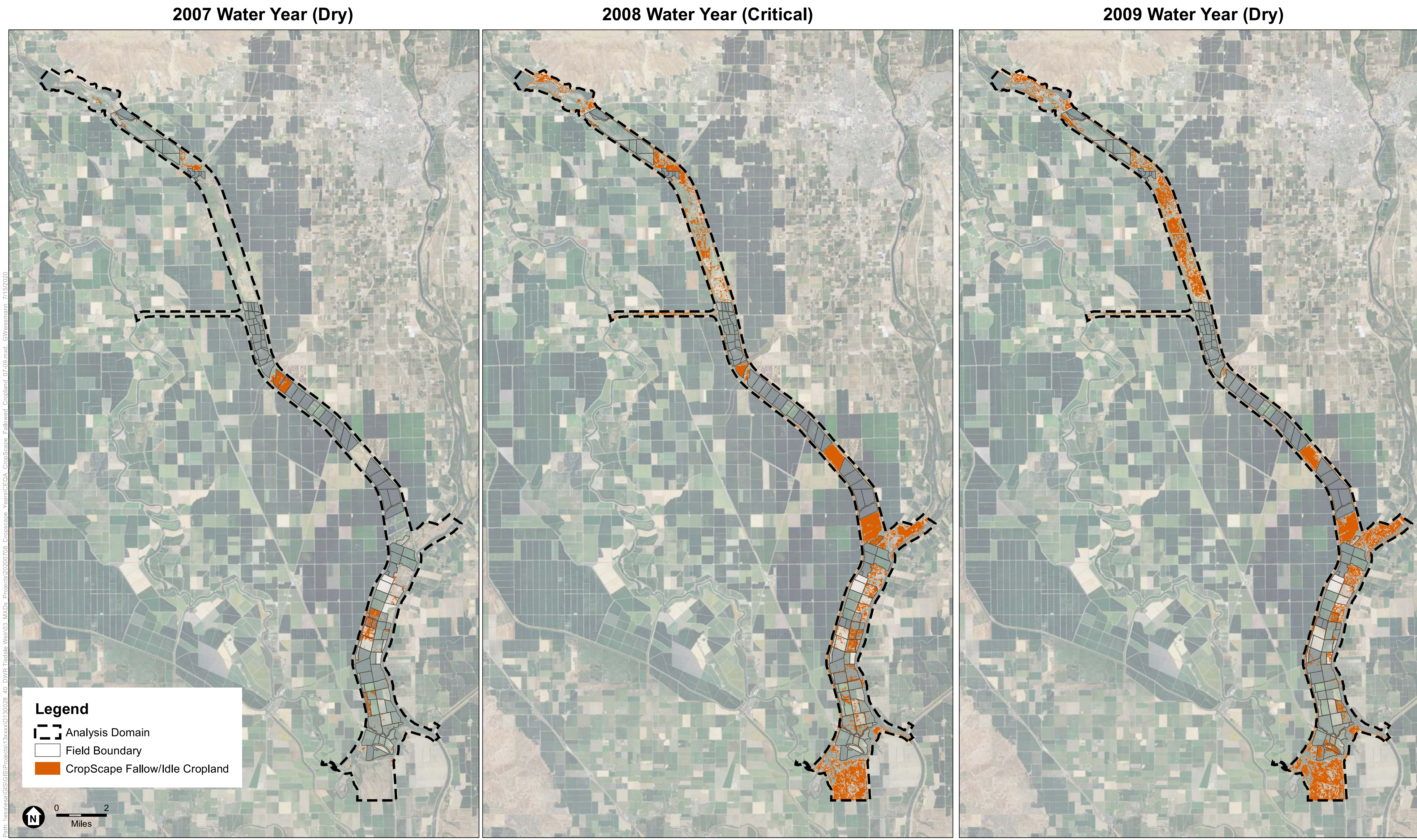
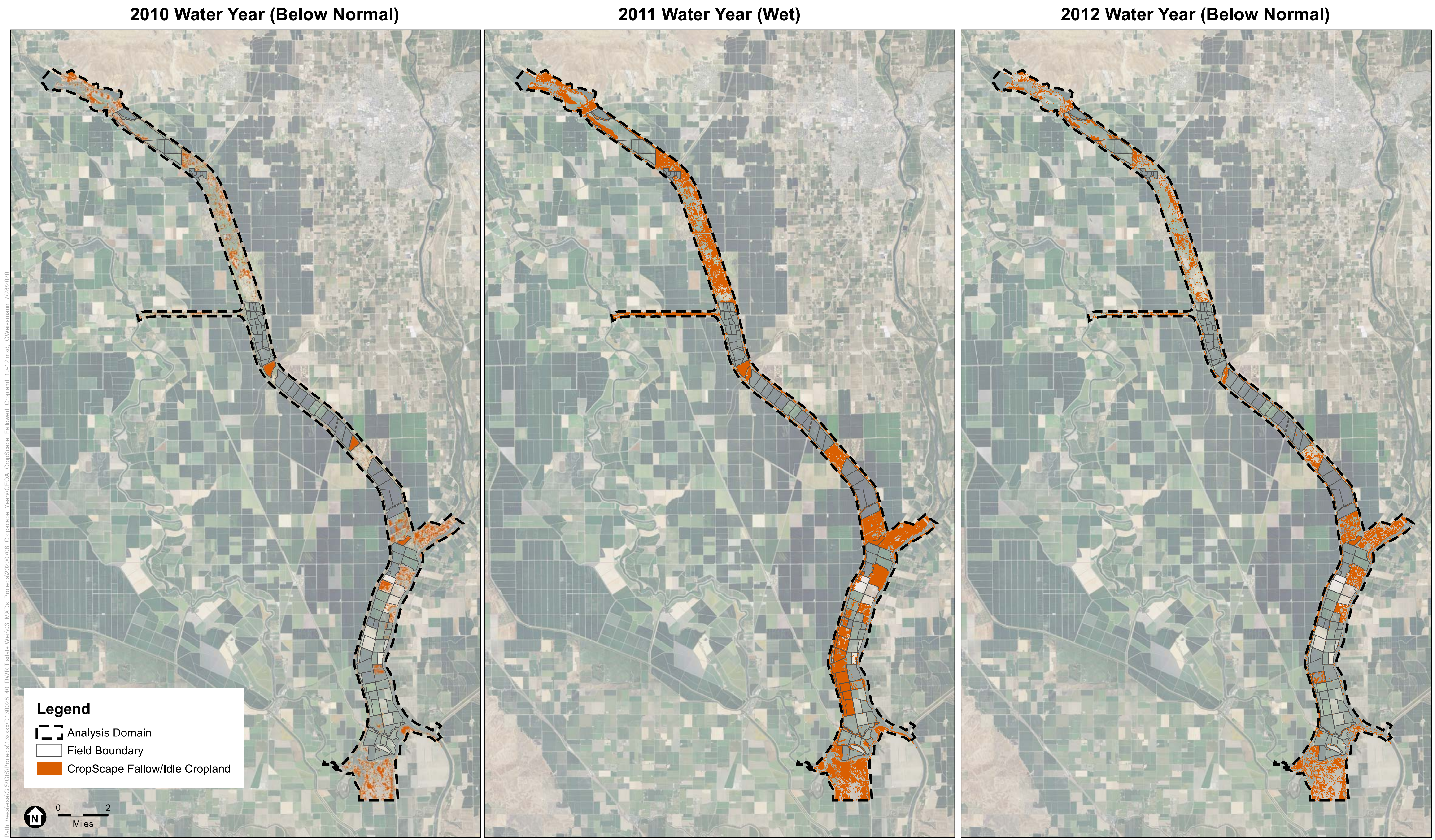


SOURCE: USDA National Agricultural Statistics Service CropScape Cropland Data Layer (2020)

Tisdale Weir Rehabilitation and Fish Passage Project

Figure B-1
CropScape Fallowed Cropland (2007-2009)

ESA

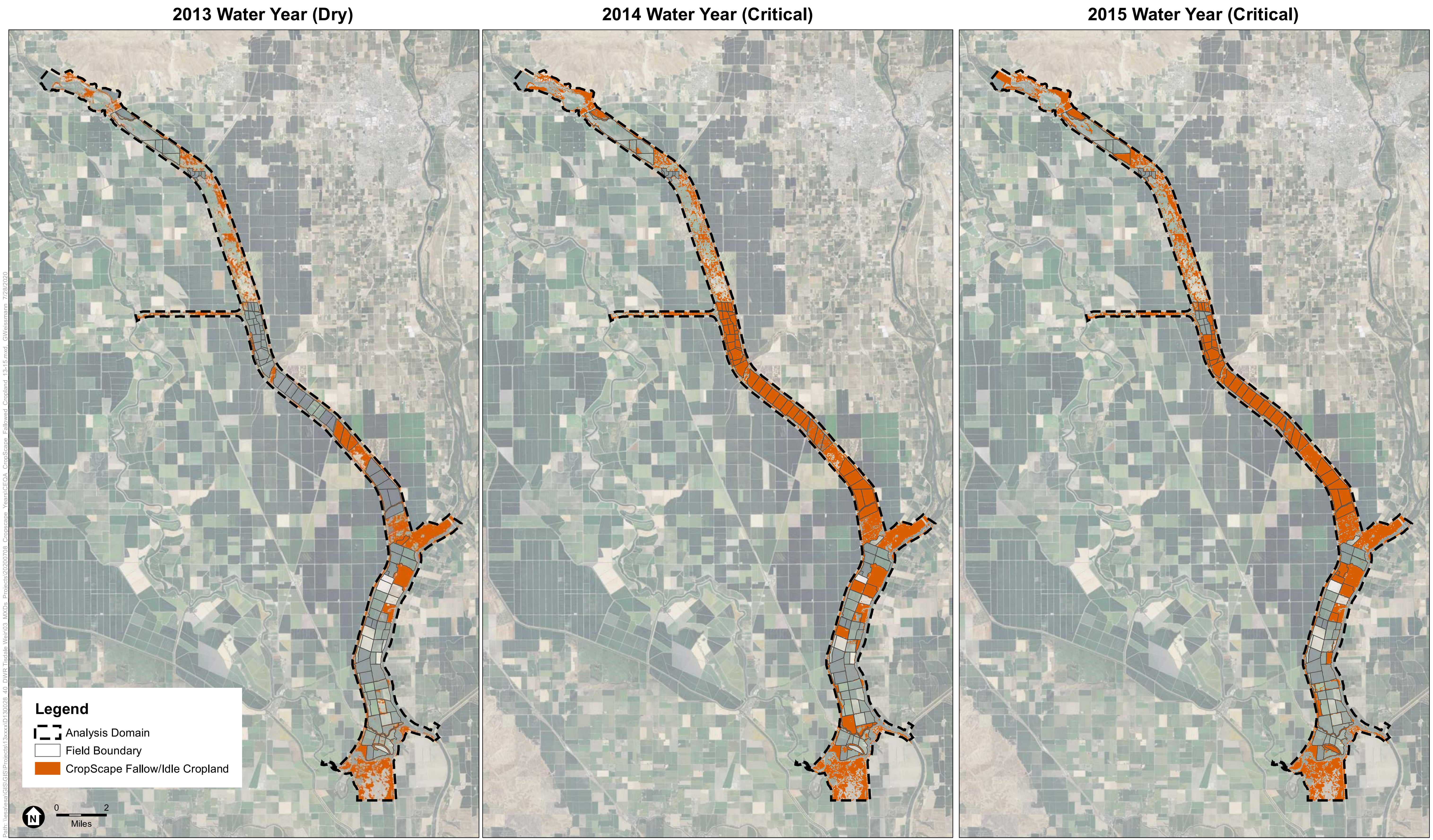


SOURCE: USDA National Agricultural Statistics Service CropScape Cropland Data Layer (2020)

Tisdale Weir Rehabilitation and Fish Passage Project

Figure B-2
CropScape Fallowed Cropland (2010-2012)

ESA



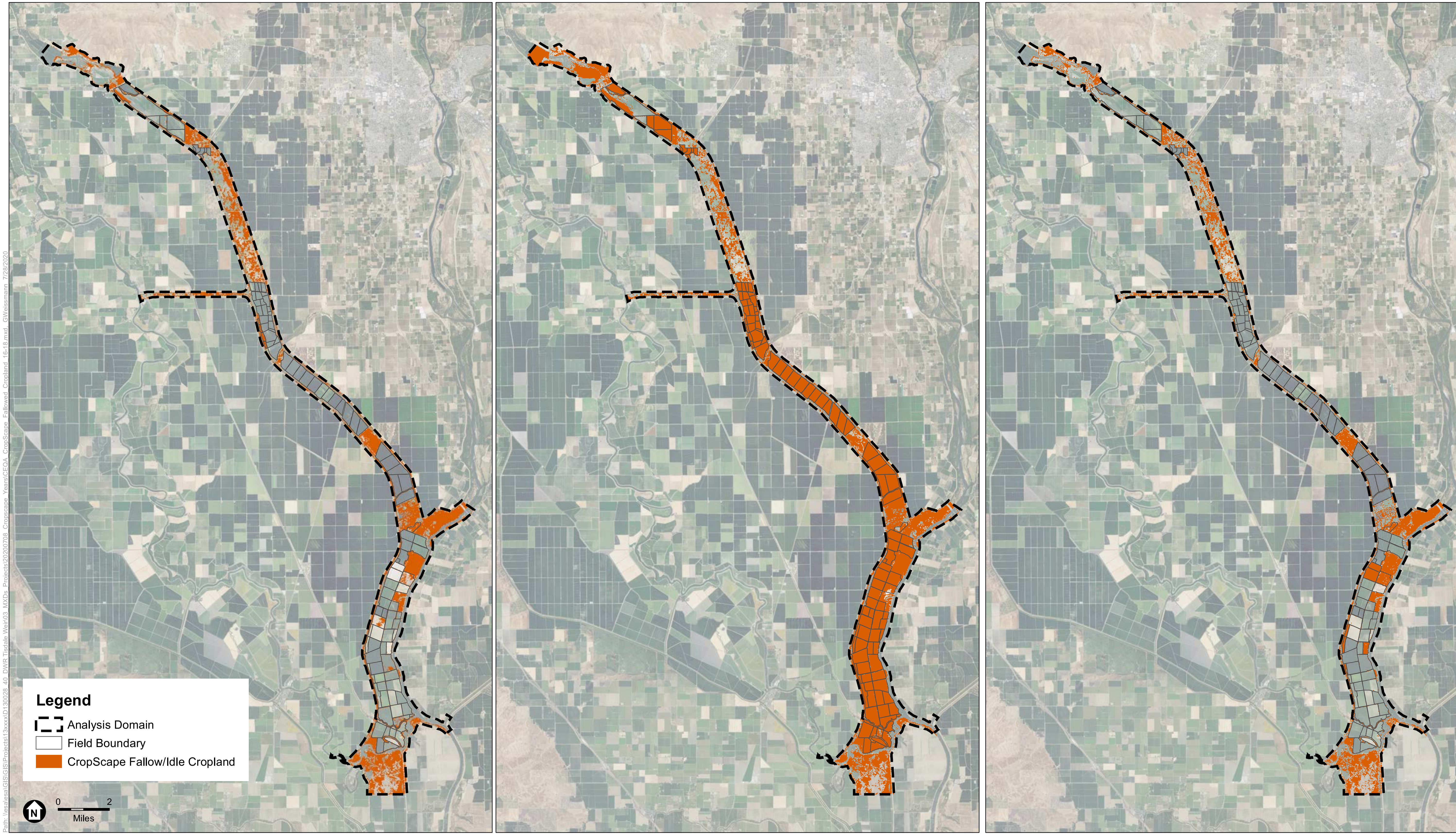
SOURCE: USDA National Agricultural Statistics Service CropScape Cropland Data Layer (2020)

Tisdale Weir Rehabilitation and Fish Passage Project

Figure B-3
CropScape Fallowed Cropland (2013-2015)

ESA

2016 Water Year (Below Normal) **2017 Water Year (Wet)** **2018 Water Year (Below Normal)**

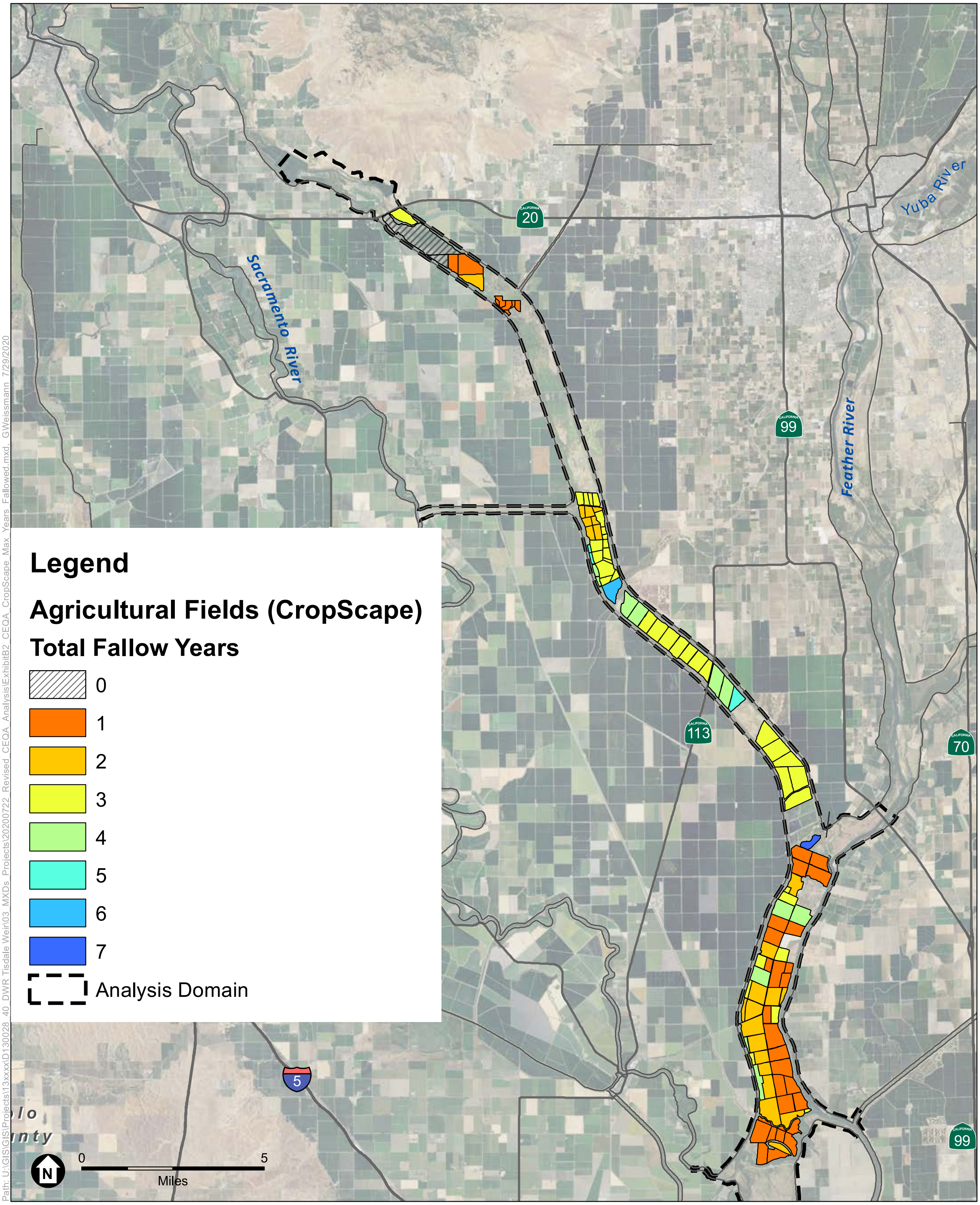


SOURCE: USDA National Agricultural Statistics Service CropScape Cropland Data Layer (2020)

Tisdale Weir Rehabilitation and Fish Passage Project

Figure B-4
CropScape Fallowed Cropland (2016-2018)

ESA

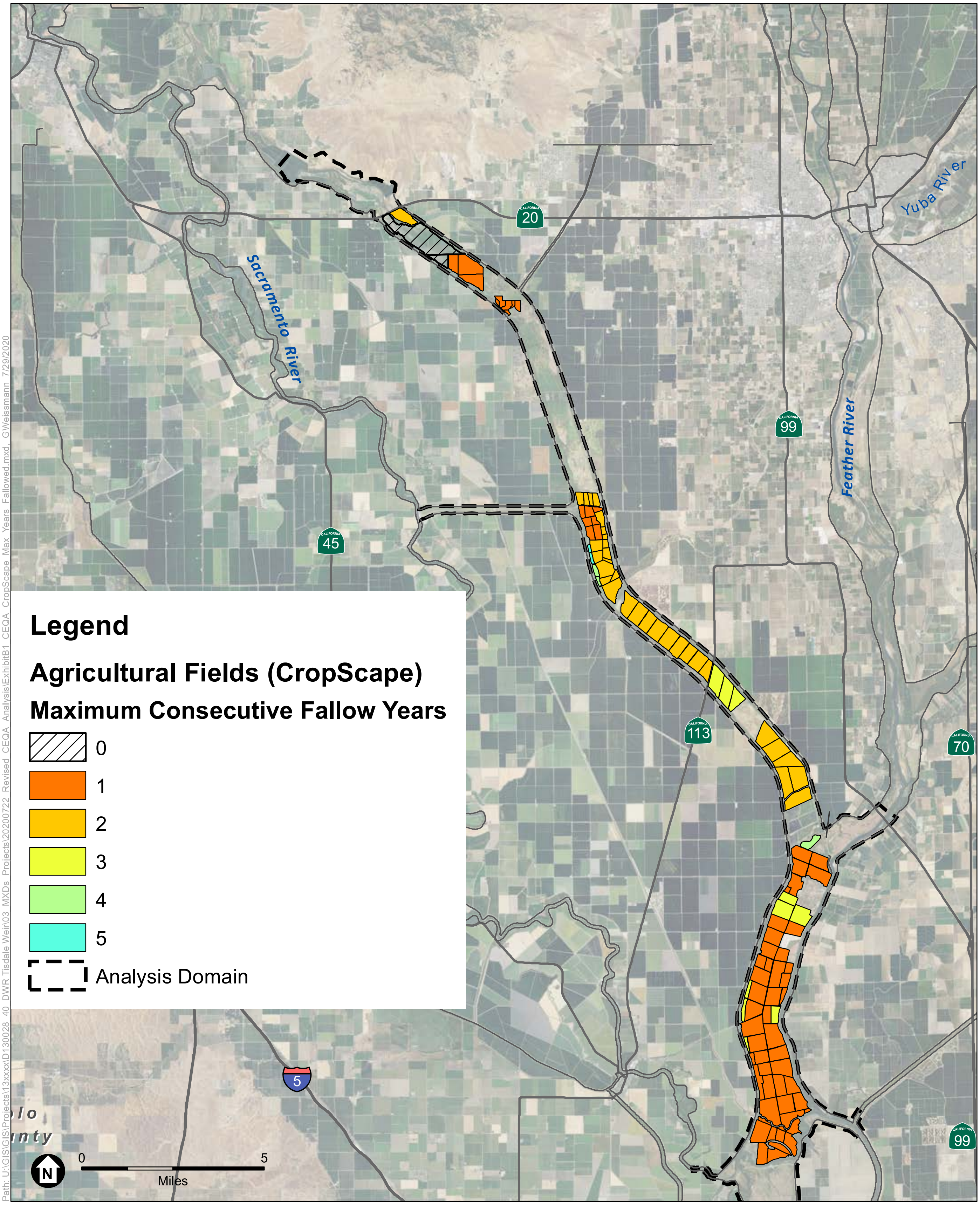


SOURCE: Derived from USDA National Agricultural Statistics Service CropScape Cropland Data Layer (2020)

Tisdale Weir Rehabilitation and Fish Passage Project

Figure B-5
CropScape Total Years Fallow, By Field (2007-2018)

ESA



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SOURCE: Derived from USDA National Agricultural Statistics Service CropScape Cropland Data Layer (2020)

Tisdale Weir Rehabilitation and Fish Passage Project

Figure B-6
CropScape Max Consecutive Years Fallow, By Field (2007-2018)

ESA