San Joaquin River Real Time Water Quality Management Program
Salinity and Flow Conceptual Model

Introduction

This document describes a conceptual model of the San Joaquin River to help stakeholders understand the real time water quality management process. The conceptual model presents:

- River flows, including in-stream flows, inflows, and diversions;
- Salinity, including in-steam levels and sources; and
- Variations in salinity levels because of water sources, differences in annual precipitation amounts, and seasons.

Overview of San Joaquin River Flows

Flows enter the San Joaquin River from the following sources:

- Upstream releases from Friant Dam;
- Tributaries that originate from the Sierra Nevada mountains and foothills to the east and the Coastal Range to the west;
- Groundwater at points where the river channel is below the water table;
- Water imported for irrigation through the Delta-Mendota and San Luis Canals;
- Agricultural return flows from irrigated fields (surface and subsurface flows);
- Municipal and industrial discharges (treated wastewater and stormwater runoff); and
- Discharges from managed wetlands.

Flows are also diverted from the San Joaquin River for irrigation and municipal purposes. Figure 1 shows the main features on the San Joaquin River. The primary points of flow diversions include:

- Friant Dam – diverted to the Tulare Lake Basin;
- Mendota Pool – diverted for west side irrigation needs; and
- Sack Dam – diverted for west side irrigation needs.

Other diversions occur to supply water for a number of water and irrigation districts, along with managed wetlands and local farms. Over 40 water and

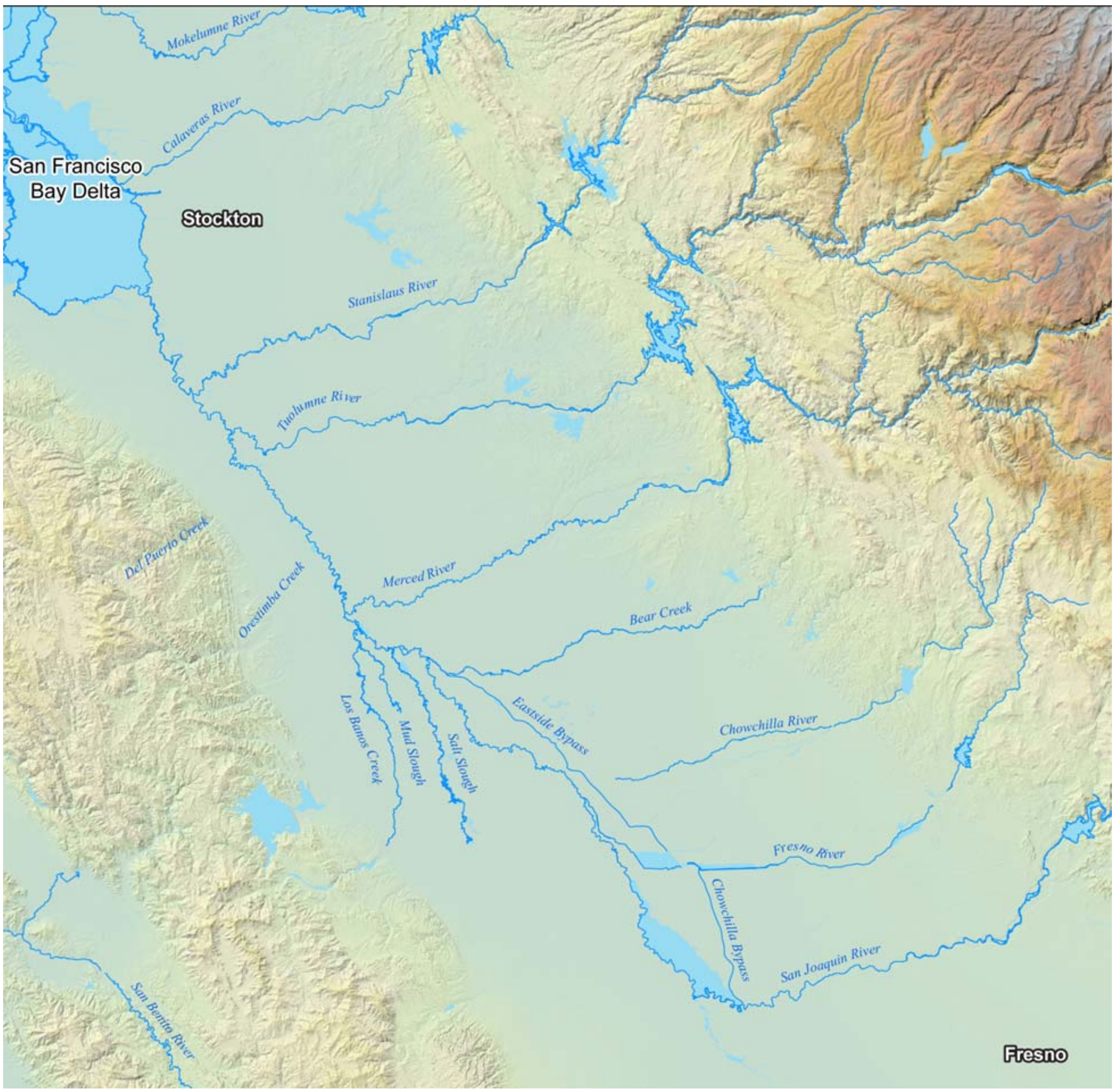


Figure 1. Area Map

irrigation districts are within this portion of the San Joaquin Watershed (CVRWQCB 2004). The three districts with the largest diversions by volume are West Stanislaus Irrigation District, Patterson Water District and El Solyo Water District.

The majority of the flows contained behind the Friant Dam are diverted. An average of 140 cfs is currently released downstream to satisfy riparian water rights (FWUA 2009). Flood flows that exceed storage and delivery capacities are also released on occasion.

As the flows travel downstream of Friant Dam, they are reduced because of infiltration, evaporation, and local diversions. The Bureau of Reclamation is required to release adequate flows to allow 5 cfs to pass each riparian user according to the terms of its water right (McBain and Trush 2002). The furthest downstream user is just above Gravelly Ford; therefore, the Bureau of Reclamation maintains 5 cfs at Gravelly Ford to meet riparian needs. This flow infiltrates into the stream bed before the Chowchilla Bypass, except during periods where the river contains flood flows. During flood periods, the flow is split between the Chowchilla Bypass and the San Joaquin River. The river flows combine with flows entering from the Delta-Mendota Canal and flood flows from the Kings River system at the Mendota Pool.

From the Mendota Pool, water is diverted inland for irrigation or released downstream where it is also diverted for irrigation. After approximately 20 miles of travel, the remaining water collects behind Sack Dam. All the water behind Sack Dam is diverted inland for irrigation during the majority of years, except for flood flows. The San Joaquin River has flow from Sack Dam to the Sand Slough Control Structure only during flood periods. Most of the time, this section of the river contains only a small amount of drainage water. Sand Slough Control Structure diverts any flow into the Eastside Bypass; therefore, the San Joaquin River is dry downstream of the structure year-round except for small amounts of drainage. Some flow from the Eastside Bypass returns to the river through the Mariposa Bypass, but the rest of the water returns at the confluence with Bear Creek.

The San Joaquin River flows year round from Bear Creek to the Delta. Major inflows enter from the east-side tributaries (Merced River, Tuolumne River and Stanislaus River). Other inflows include groundwater, agricultural return flows, and inflows from west-side tributaries (Salt Slough, Mud Slough, Los Banos Creek, Orestimba Creek, Del Puerto Creek, and Hospital/Ingram Creek). Local diversions remove some flows along this section for irrigation.

Flows continue past Vernalis at the San Joaquin and Stanislaus counties border and enter the Delta region at Stockton. Vernalis is the location on the San Joaquin River where salinity limits have been established.

In-stream flows vary by season. Higher flows tend to occur during wet winters, spring snowmelt, February and March when water levels in the managed wetlands are drawn down and pre-irrigation discharges enter the river, and April and May when Vernalis Adaptive Management Plan (VAMP) pulse flows are release to aid salmon smolts on their journey to the ocean. Lower in-stream flows tend to occur during the hot dry summers and falls and non irrigation periods when return flows are reduced.

In-stream flows can vary on an annual basis. In-stream flows will be higher during wet years when substantial precipitation has occurred and lower during dry years with below normal precipitation.

In-stream Salinity Overview

Salinity is the level of dissolved salts in water. In-steam salinity is a concern because elevated levels negatively affect freshwater ecosystems, agricultural productivity, and public health.

Salinity can be measured. Electrical conductivity (EC) is used to express salinity because dissolved salts are a combination of two elements with one having a positive charge and the other a negative charge. Total dissolved solid (TDS) is another common parameter that represents salinity by measuring the mass of dissolved salts in a defined volume of water.

The level of salinity depends on the sources. The sources of salts in the San Joaquin River originate from the soil and water deliveries from the Delta – Mendota and San Luis Canals.

All soils contain salts in various amounts. Soils on the east side of the San Joaquin watershed come primarily from the granitic and volcanic rocks of the Sierra Nevada Mountains and contain relatively low levels of salts. Whereas soils in the west side of the watershed are derived from marine deposits and, as a result, have a high salt content.

Delta diversions provide the water source for the Delta-Mendota and San Luis Canals. Delta water has a relatively high salt content because of inflows from the San Joaquin River, Sacramento River, and San Francisco Bay.

Upstream and east-side tributary flows are low in salinity because the soils in this portion of the San Joaquin watershed have a low salt content. These inflows do not increase salinity concentrations in the San Joaquin and often lower the concentrations through dilution.

Groundwater from the east side has relatively low salinity concentrations because of the low salt content in the soils while groundwater from the west side has high salinity concentrations because it comes in contact with the marine-derived soils. Groundwater from the west increases in-stream salinity levels during periods of low flow.

The majority of flows from the west side are agricultural return flows. A small portion is natural flows but only during wet periods. All flows from the west side have high salinity concentrations. The primary sources of the water used for irrigation are the Delta-Mendota and San Luis Canals and local groundwater. All three sources have high salinity concentrations (CVRWQCB 2004). The water then comes in contact with soils that have a high salt content. The west-side agricultural return and natural flows increase in-stream salinity concentrations during periods of low flow.

Managed wetlands are primarily on the west side. They receive water from the Delta-Mendota Canal, groundwater, and agricultural return flows (Chilcott 2000).   All three sources have high salinity concentrations. The uses on the wetlands increase concentrations slightly because of exposure to marine-derived soils. The water that is discharged from the wetlands in February and March has a high salinity concentration. These discharges can increase in-stream salinity concentrations when upstream flows are low.

Municipal and industrial discharges are sources of salinity. Salt concentrations are relatively high. However, their impact on in-stream salinity concentrations is relatively minor because of their low flow volumes (CVRWQCB 2004).

In-stream salinity varies by season. Concentrations are low when the San Joaquin River is dominated by flows from the east-side tributaries or upstream releases from Friant Dam. This occurs during spring runoff, VAMP pulse flow in April and May, and substantial wet weather events. Salinity concentrations are high in the river when flows are dominated by groundwater accretions and agricultural return flows. These conditions occur during the summer and early fall growing season. Salinity concentrations may be low during wet winters but higher if the winters are dry especially during February and March when the wetlands are drawn down and pre-irrigation begins.

The table below summarizes the magnitude of salt loads and flows estimated for each source. The groundwater, agricultural returns, and east-side tributaries contribute the highest salt loads. Upstream and east-side tributary flows contribute a major portion of the total load in the San Joaquin watershed because of the large volume of flood flows that occur during spring snowmelt and wet years even though the concentrations are relatively low (CVRWQCB 2004).

Salt Contributions from Major Sources for 1977-1997

Source	Salt Load	Salinity (TDS)	Discharge
Upstream and East-side Tributaries	20%	52 mg/L	81%
Groundwater	28%	1600 mg/L	4%
Agricultural returns	41%	960 mg/L	9%
Wetlands	9%	380 mg/L	5%
Municipal and Industrial	2%	680 mg/L	1%

Source: CVRWQCB (2004)

Evaluation of In-stream Salinity Levels

Figures 2 though 7 graphically depict the salinity concentrations and flows throughout the San Joaquin River system. The evaluation considered in-stream salinity concentrations for different water year types and different periods during the year. A dry year and a wet year were selected based on the San Joaquin River index (DWR 2008). Water year 2005 represents wet year conditions and water year 2004 represents dry year conditions. Both years are relatively recent and have the maximum data available for flow and water quality.

Specific periods of interest that were selected include:

1. Wetland drawdown and pre-irrigation: February-March
2. VAMP pulse flows: April 15 – May 15
3. Late summer irrigation season: August-September

The parameter selected to represent in-stream salinity concentrations was electrical conductivity because it had the most data available.

Figures 8 and 9 include salt loads for the San Joaquin River and its tributaries. These figures only include a dry and wet year during the VAMP period to provide information about how loads change during different year types. TDS was the parameter selected to represent salt loads because of its availability.

Figure Development

Flow and the water quality data were compiled at individual monitoring stations that exist on the San Joaquin River and its tributaries. Seven stations located directly on the San Joaquin River represent in-stream flows and quality between Friant Dam and the Delta. Another 11 stations represent in-stream flows and quality from tributaries. The database developed for the WARMF Model of the San Joaquin River provided the majority of the data (Herr and Chen 2006). Additional data were compiled for the Delta-Mendota Canal (USBR 2004 and 2005).

Six scenarios were evaluated: one for each combination of water year type (2004 and 2005) and seasonal period of interest (wetland drawdown, VAMP pulse flow, and late summer irrigation). Figures 2 through 7 present average values for flow rate and EC concentrations at each station for each period of interest. The colors represent the salinity concentrations, and the line thickness represents flow. The dark green color represents a concentration of 700 µs/cm, which is the water quality standard at Vernalis from April through August, and the dark yellow color represents a concentration of 1000 µs/cm, which is the water quality standard at Vernalis from September through March.

TDS loads were calculated from the flow and the water quality data that had been compiled for the WARMF Model of the San Joaquin River (Herr and Chen 2006) and the DMC (USBR 2004 and 2005). For the period of interest, average TDS concentrations were multiplied by the average flow rate to generate a daily load. The daily load is expressed in tons per day. If TDS data were not available for the selected period, a conversion factor between EC and TDS was applied to the average EC value. This conversion factor was calculated for each station based on available paired EC and TDS data that were collected at the same time.

Two TDS load scenarios were evaluated during the VAMP pulse flow period: one for water year 2004 (Dry) and 2005 (Wet). Figures 8 and 9 present TDS loads at each station for both water years. The colors represent the daily loading.

Findings

Water released from Friant Dam is low in salinity (average EC is <65 µs/cm) during all periods analyzed. Flow rates are also consistent except during flood conditions when flows are higher, such as April-May during the 2005 wet year. Salinity concentrations remain low as the flow travels downstream toward the Mendota Pool but flow rates decrease.

Salinity concentrations increase ten-fold after the Delta-Mendota Canal based on the compiled data from 2004 and 2005. Average EC concentrations in the DMC are relatively consistent between wet and dry years and seem to improve marginally as the year progresses. The salinity concentrations vary between 350 and 900 µs/cm. Flow deliveries to the Mendota Pool increase during the irrigation season and wet years.

The highest salinity concentrations on the San Joaquin River are between Bear Creek and the Merced River at the Fremont Ford monitoring station. Average EC concentrations ranged from 1000 to 1800 µs/cm. Even though water in Bear Creek is low in salinity throughout the year, this monitoring station is just downstream from Salt Slough and Mud Slough. It also receives water that has high salinity concentrations from groundwater accretion and local agricultural return flows. Mud Slough has average EC concentrations as high as 4000 µs/cm. Additionally, this monitoring station is upstream from some of the major east-side tributaries that provide larger flows with relatively low salinity concentrations (Merced River, Tuolumne River, and Stanislaus River).

The data indicates salinity concentrations in this portion of the San Joaquin River are higher during dry years. This increase is most likely caused by the in-stream flows dominated by groundwater and agricultural returns from the west side. Average flow rates in this portion of the San Joaquin were lower during the 2004 dry year compared to rates during the 2005 wet year.

Salinity concentrations in the San Joaquin River are lower after the Merced River enters based on the compiled data from 2004 and 2005. The water from the Merced has low salinity concentrations and dilutes the upstream salinity. However, salts received from west-side sources, including Orestimba and Del Puerto creeks, groundwater accretion, local agricultural returns, and discharges from managed wetlands, also contribute to the in-steam salinity concentrations in this portion of the San Joaquin River between the Merced and Tuolumne Rivers. During dry years, the reduction in salinity is not substantial except when VAMP pulse flows are released from the east-side tributaries from April 15 through May 15. During wet years, the reduction can be substantial due to higher flow rates coming from the east-side tributaries. The exception is when the managed wetlands are drawn down in February and March.

In-stream flows increase and salinity concentrations decrease after the Tuolumne and Stanislaus Rivers enter the San Joaquin based on the compiled data from 2004 and 2005. Both rivers represent sizeable flows with low salinity concentrations (average EC concentrations are <100 µs/cm). Salinity concentrations at the Vernalis station are lower during wet years (average values range from 250 to 600 µs/cm) compared to dry years (average values range from 400 to 600 µs/cm).

The lowest salinity concentrations occur during the VAMP pulse flow period in April and May when additional flows are released from the east-side tributaries with their low salinity concentrations. The highest concentrations occur in February and March, the period when pre-irrigation discharge begins and managed wetlands are being drawn down. Salinity concentrations are also higher in August and September when the east-side tributaries are at their lowest flow rates and agricultural returns with their high salinity are at their highest flow rates. These same patterns are found during both dry and wet years.

Figures 8 and 9 examine loads during the VAMP period instead of concentrations. Comparing the load figures to concentration figures during the same period indicates some differences. In the concentration figure, the east-side tributaries seem to be a large supply of fairly clean water; however, the load figure indicates that the load from these tributaries (such as the Merced River) can be significant during wet years. While the concentrations are low, the higher flow results in a higher overall load. Additionally, the loads are generally higher throughout the system in a wet year. The load from the Delta-Mendota Canal is much greater because the concentration is similar but the flow is much greater. Also, wetter water years result in more groundwater accretion and agricultural return flow.

References

California Department of Water Resources (DWR) (2008). Chronological Reconstructed Sacramento and San Joaquin Valley Water Year Hydrological Classification Surveys. November 20, 2008.

Central Valley Regional Water Quality Control Board (CVRWQCB) (2004). Appendix 1: Technical TMDL Report, Amendments to the Water Quality Control Plan for the Sacramento River and the San Joaquin River Basins for the Control of Salt and Boron Discharges into the Lower San Joaquin River, Draft Final Staff Report. July 2004.

Chilcott, J.E. 2000, Review of Selenium Concentrations in Wetland Water Supply Channels in the Grassland Watershed. Regional Water Quality Control Board, Central Valley Region. Sacramento, CA.

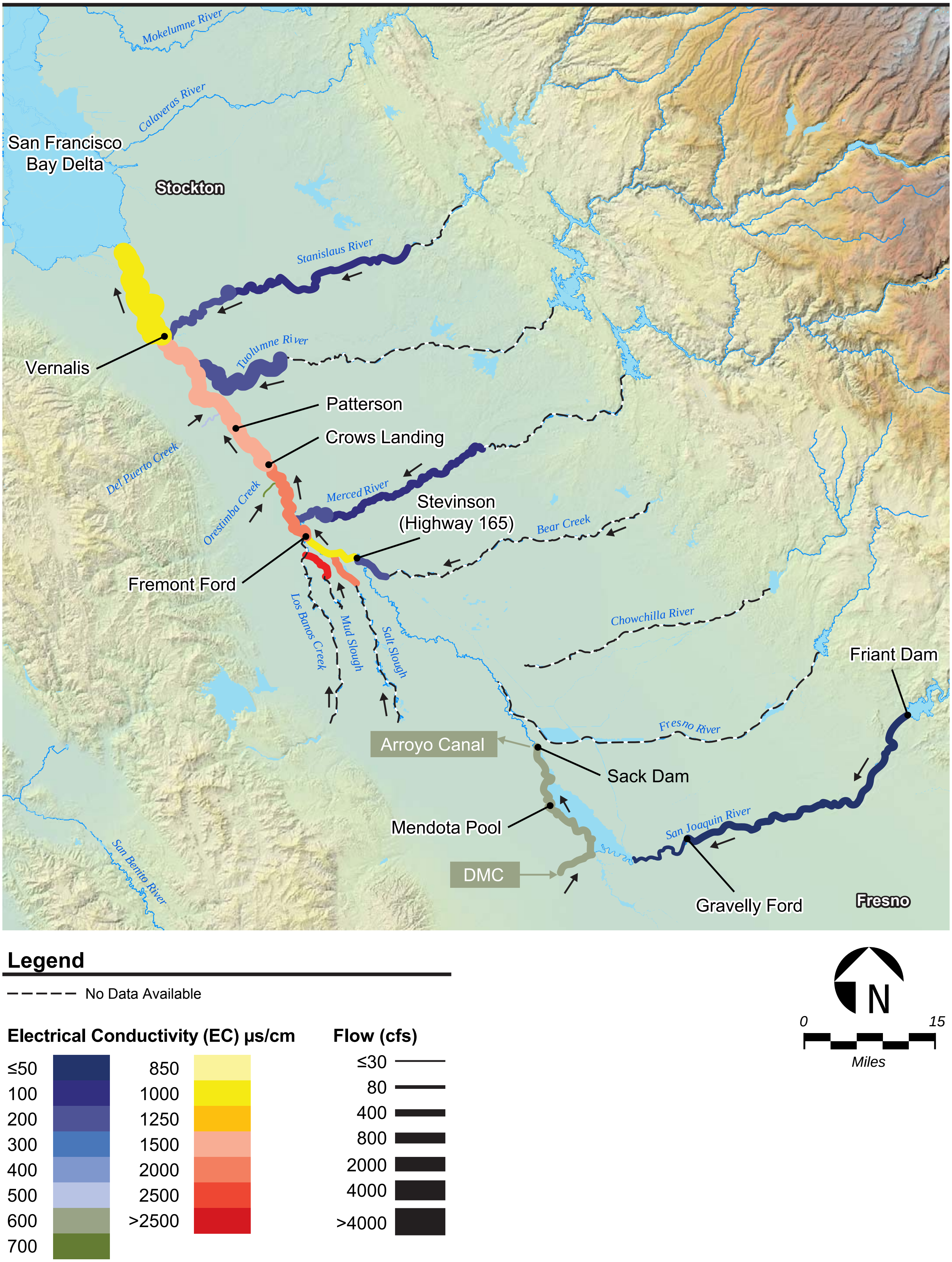
Friant Water Users Authority (FWUA) (2009) About the Friant Division. Web site: http://www.fwua.org/settlement/supplemental/docs/aboutthefriantdivision.pdf. Accessed April 26, 2009.

Herr, J. and C. W. Chen (2006). Annual Report for the Task 6 Modeling of the San Joaquin River Documentation Report. November 17, 2006.

McBain & Trush, Inc. (eds.), 2002. *San Joaquin River Restoration Study Background Report*, prepared for Friant Water Users Authority, Lindsay, CA, and Natural Resources Defense Council, San Francisco, CA. Available from: http://www.restoresjr.net/program_library/05-Pre-Settlement/index.html. Accessed on April 20, 2009.

United States Bureau of Reclamation (USBR) (2005). 2005 Water Quality Reports for DMC Check 21. Web site: http://www.usbr.gov/mp/cvo/wqrpt_05.html. Accessed April 17, 2009.

United States Bureau of Reclamation (USBR) (2004). 2004 Water Quality Reports for DMC Check 21. Web site: http://www.usbr.gov/mp/cvo/wqrpt_04.html. Accessed April 17, 2009.



CDM

Figure 2
Dry 2004 – February to March

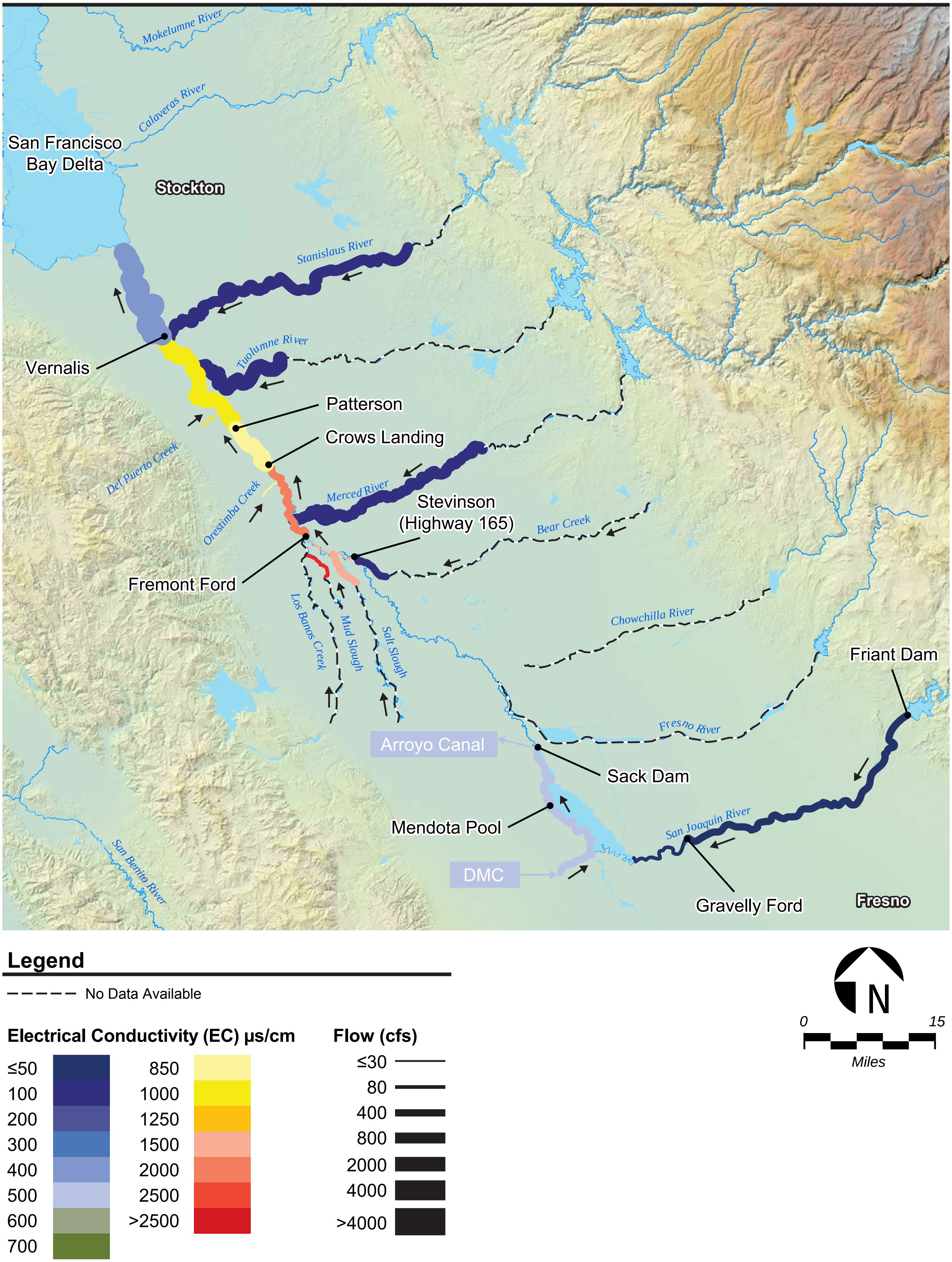


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Figure 3
Dry 2004 – April 15 to May 15

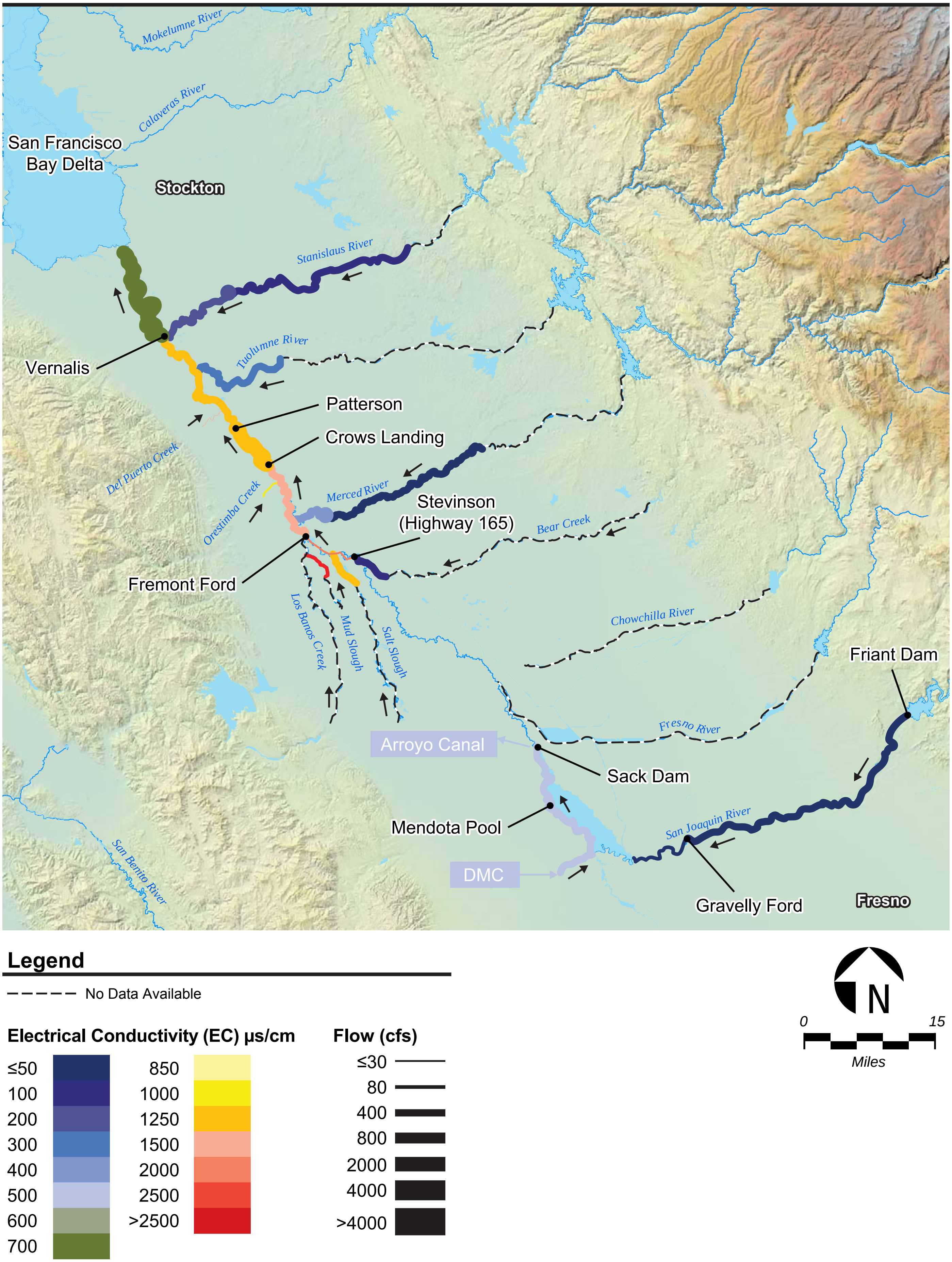

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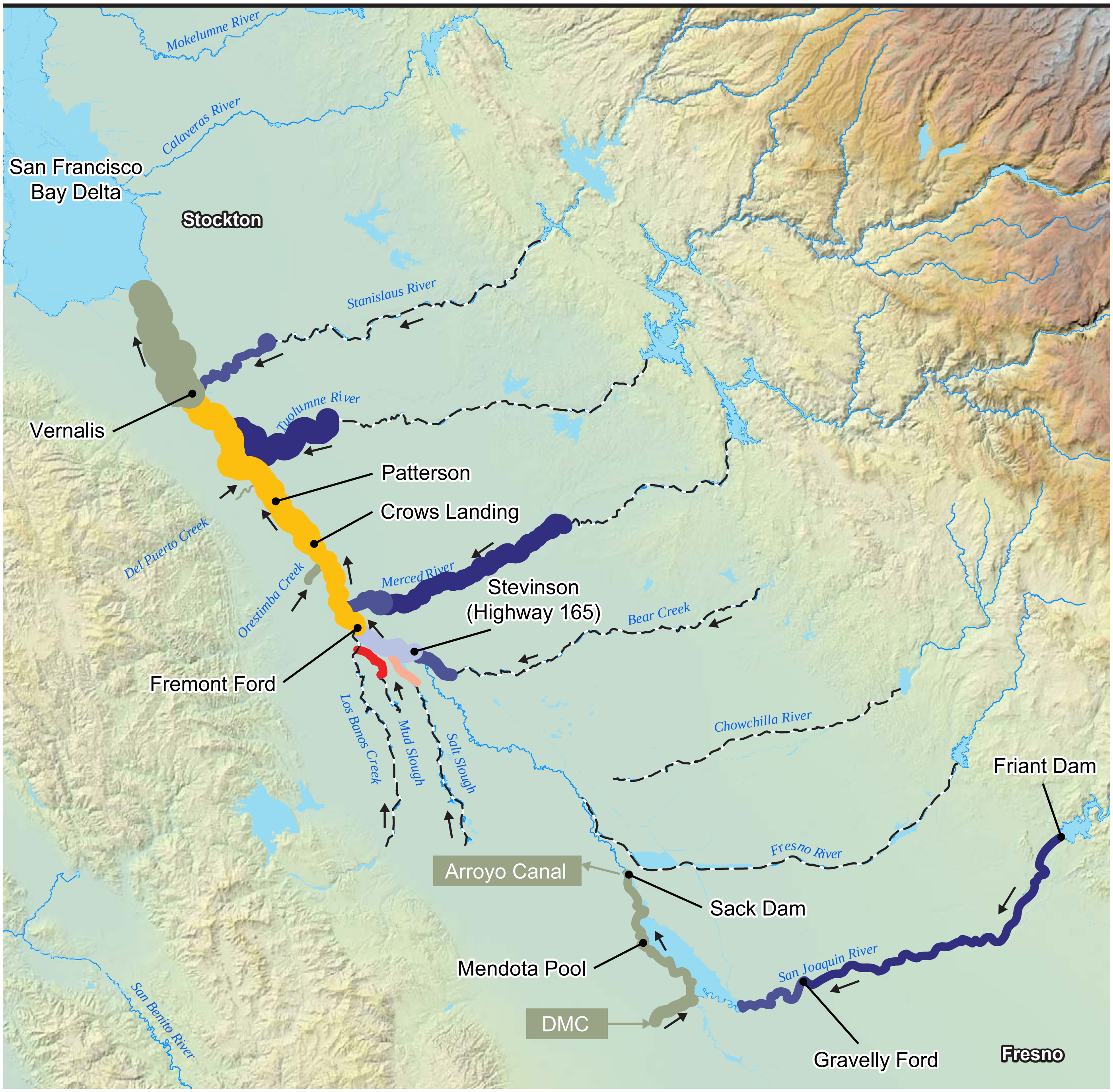
Figure 4
Dry 2004 – August to September



Legend

No Data Available

Electrical Conductivity (EC) µs/cm

EC	EC
≤50	850
100	1000
200	1250
300	1500
400	2000
500	2500
600	>2500
700	

Flow (cfs)

≤30
80
400
800
2000
4000
>4000

0 15
Miles

N

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CDM

Figure 5
Wet 2005 – February to March

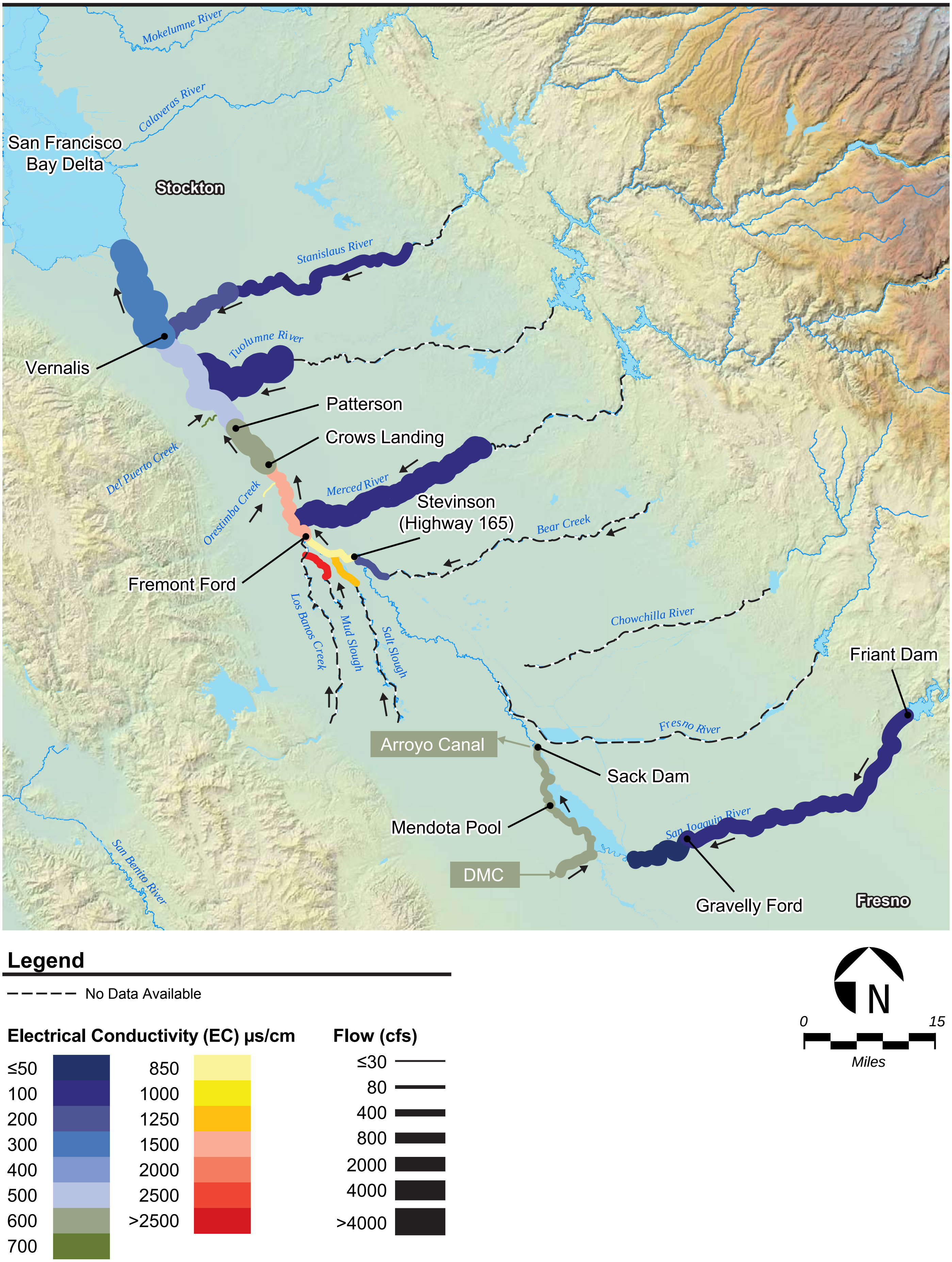

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Figure 6
Wet 2005 – April 15 to May 15

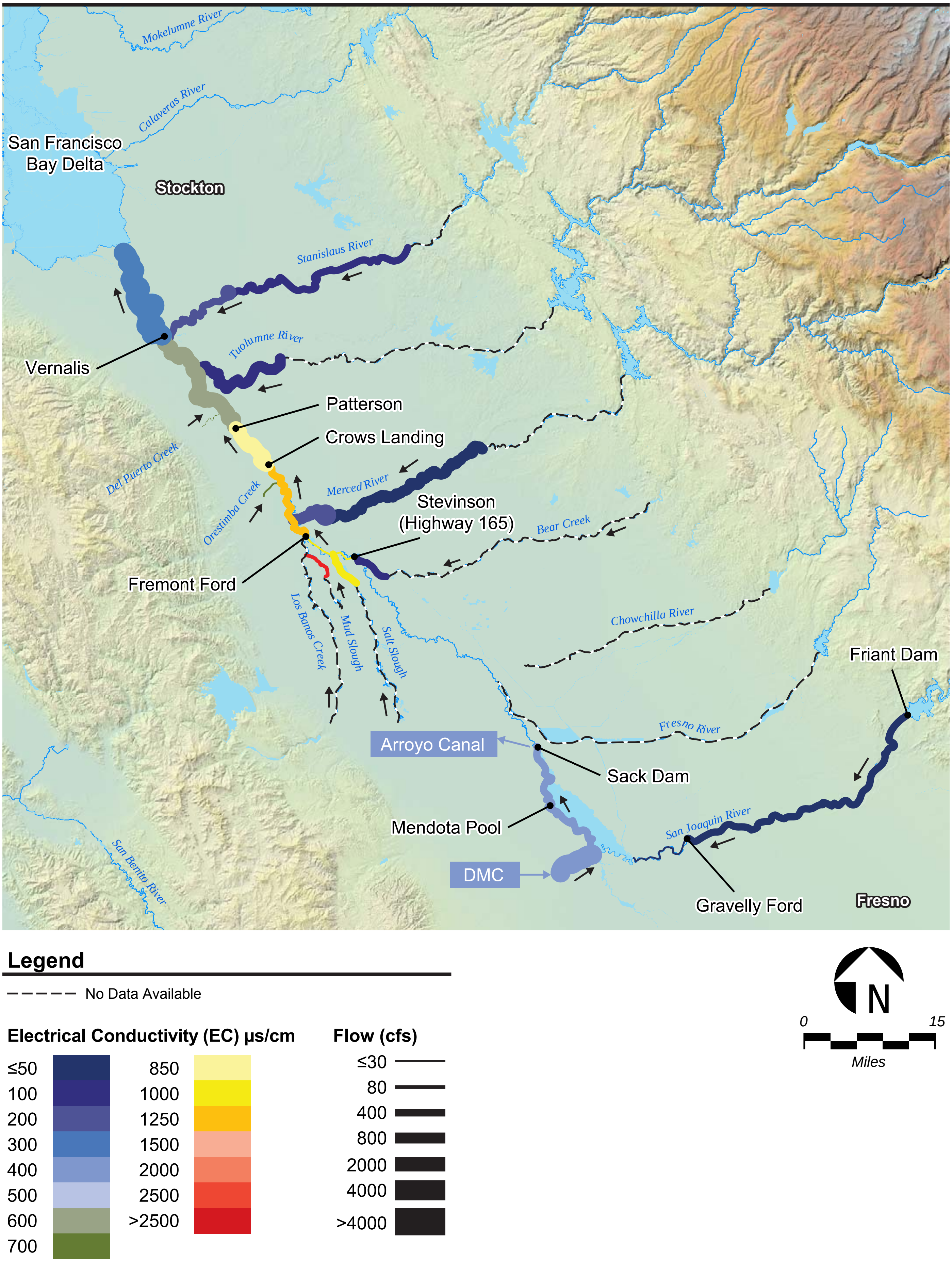

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Figure 7
Wet 2005 – August to September

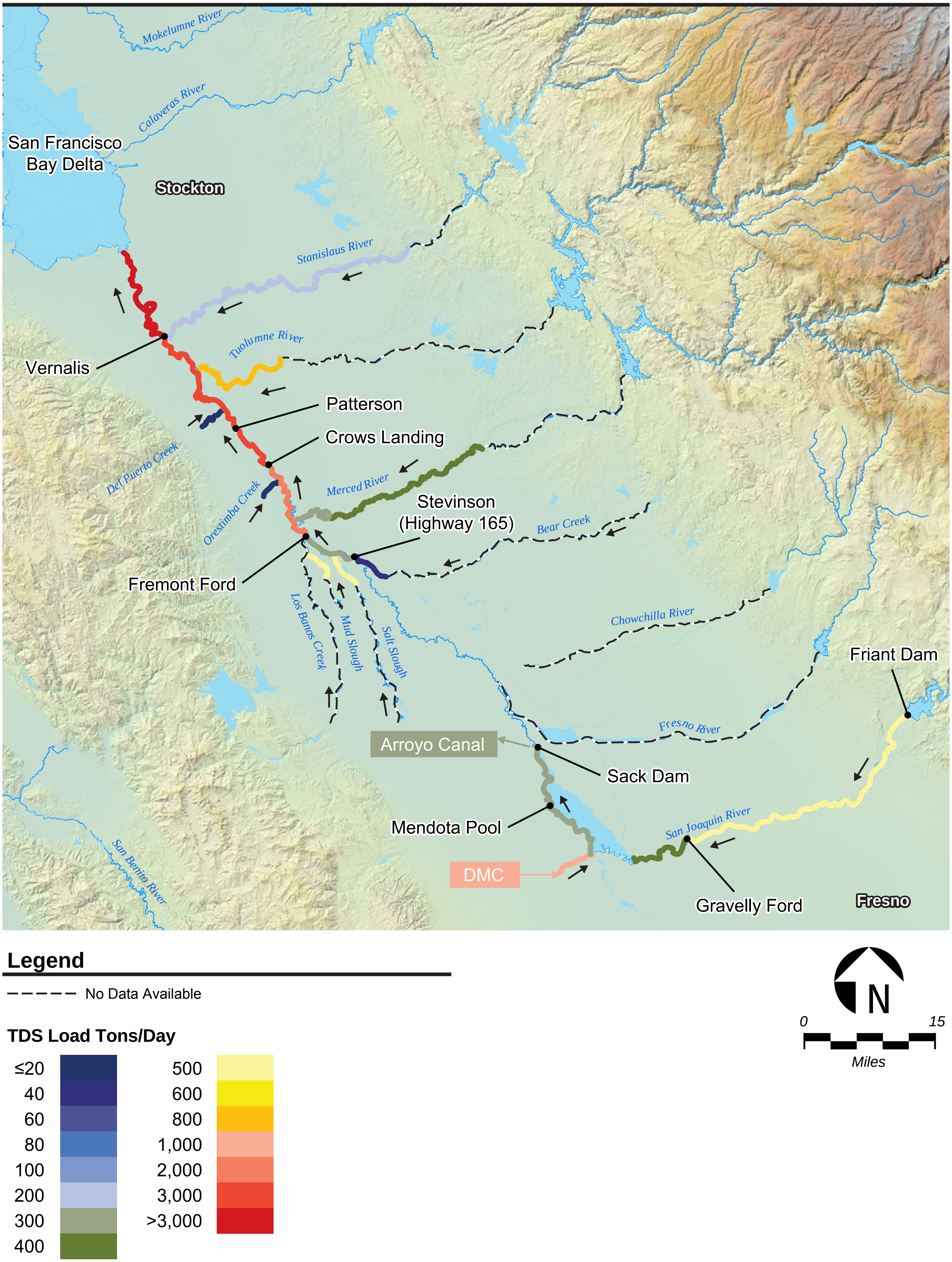

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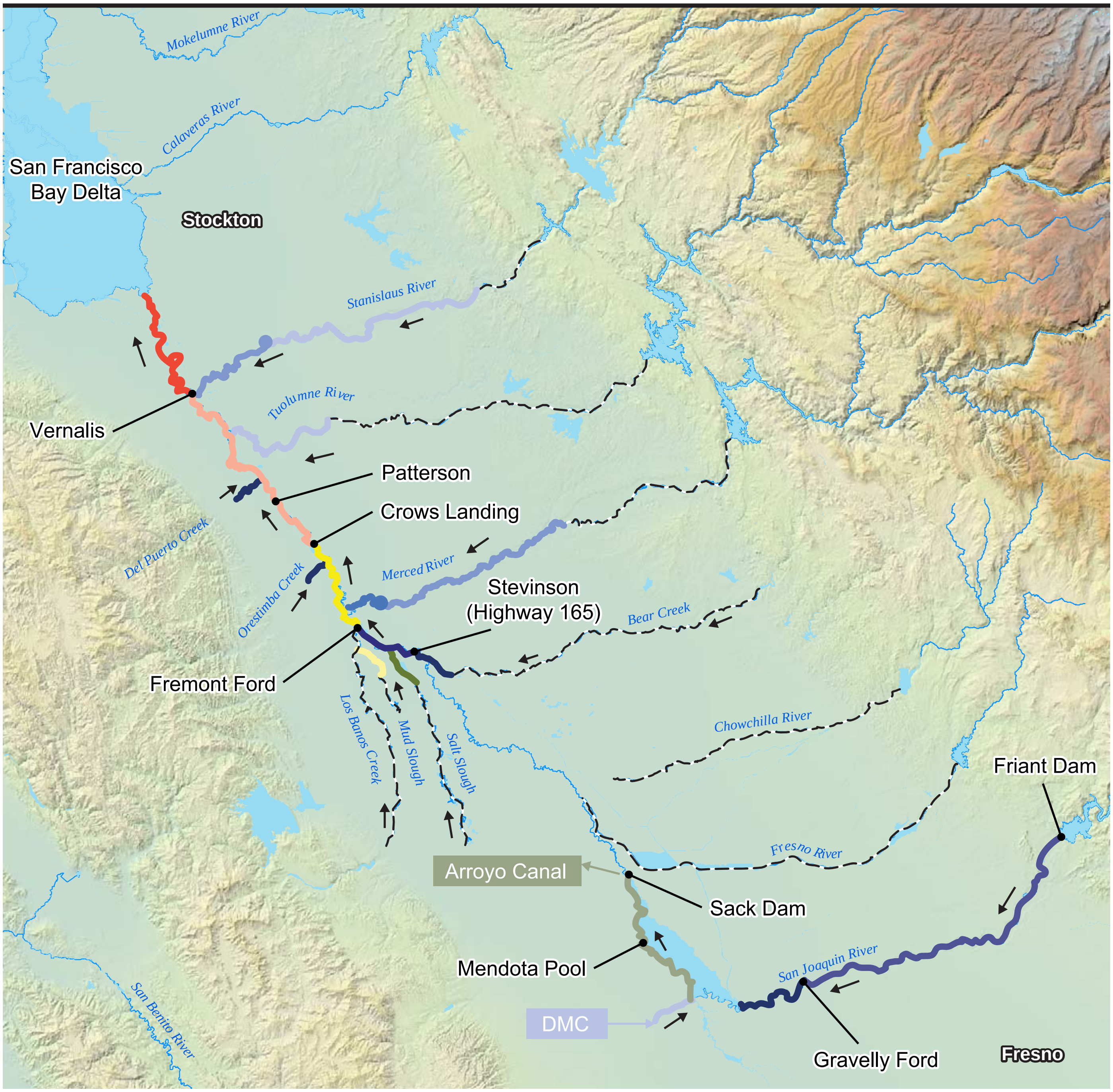
Figure 8
Wet 2005 – April 15 to May 15



Legend

– – – – – No Data Available

TDS Load Tons/Day

≤20	500
40	600
60	800
80	1,000
100	2,000
200	3,000
300	>3,000
400	

N

0 15
Miles

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Figure 9
Dry 2005 – April 15 to May 15