BUREAU OF RECLAMATION

2023 Management Agency Agreement Annual Report

Interior Region 10 – California-Great Basin

U.S. Department of the Interior

December 2023

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo: Delta-Mendota Canal/California Aqueduct Intertie Canal with brilliant blue water winding through valley.

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Abbreviations and Acronyms

Action Plan	Actions to Address the Salinity and Boron TMDL Issues for the Lower San Joaquin River November 2008
Basin Plan	Water Quality Control Plan for the Sacramento and San Joaquin River Basins, 5th Edition
BO	Biological Opinion
CALFED	California Bay-Delta Authority
CVO	Central Valley Operations
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CV Water Board	Central Valley Regional Water Quality Control Board
CV-SALTS	Central Valley Salinity Alternatives for Long Term Sustainability Stakeholder Group
CV-SWAT	Central Valley Soil & Water Assessment Tool
D-1641	State Water Resources Control Board Water Right Decision 1641
DF	Base Design Flow
DMC	Delta-Mendota Canal
DWR	California Department of Water Resources
EC	Electrical Conductivity
FY	Fiscal Year
GBP	Grassland Bypass Project
GDA	Grassland Drainage Area
GDF	Goodwin Dam Flow
GUI	Graphical User Interface
GWD	Grassland Water District

LSJR	Lower San Joaquin River
MAA	Management Agency Agreement
MID	Modesto Irrigation District
MOU	Memorandum of Understanding
NOAA	National Oceanic and Atmospheric Administration
mg/L	milligram(s) per liter (parts per million)
µS/cm	micro-Siemens per centimeter
PTMS	Program to Meet Standards
Reclamation	United States Department of the Interior Bureau of Reclamation
RFC	California-Nevada River Forecast Center
RTMP	Real Time Management Program
SJR	San Joaquin River
SJRIP	San Joaquin River Water Quality Improvement Project
SJVDA	San Joaquin Valley Drainage Authority
SLDMWA	San Luis & Delta Mendota Water Authority
State Water Board	State Water Resources Control Board
TAF	Thousand Acre-Feet
TDS	Total Dissolved Solids
TID	Turlock Irrigation District
TMDL	Total Maximum Daily Load
VAMP	Vernalis Adaptive Management Plan
USGS	United States Geological Survey
WARMF	Watershed Analysis Risk Management Framework
WQO	Water Quality Objective

WRDP	Westside Regional Drainage Plan

2023 MAA Summary of Reclamation Activities

Purpose

The Central Valley Regional Water Quality Control Board's (CV Water Board) Control Program for Salt and Boron Discharges into the Lower San Joaquin River (LSJR), also known as the Salt and Boron Total Maximum Daily Load (TMDL), was approved, and placed into effect on September 10, 2004. In response to the Salt and Boron TMDL, the U.S. Bureau of Reclamation (Reclamation) developed the salinity management plan titled "Actions to Address the Salinity and Boron TMDL Issues for the Lower San Joaquin River" (Action Plan) and entered into a Management Agency Agreement (MAA) with the CV Water Board on December 22, 2008. The MAA described Reclamation's actions to meet the obligations allocated to it by the Salt and Boron TMDL for the LSJR. In the MAA, Reclamation agreed to implement the Action Plan. Figure 1 shows seven TMDL subareas for salt load management in the LSJR Basin.

Reclamation and the CV Water Board revised the MAA on December 4, 2015. The revised MAA does not reference the Action Plan. However, Section 2.3d of the revised MAA states that "Reclamation actions will be detailed in an Annual Work Plan and submitted along with a Status of Activities to Date from the previous year."

This report summarizes activities conducted by Reclamation in fiscal year (FY) 2023 in conjunction with the related elements outlined in the revised MAA. The original Action Plan described Reclamation's past practices and procedures to mitigate and manage adverse impacts of salt and boron imported into the San Joaquin Basin via the Delta-Mendota Canal (DMC) to help achieve compliance with the objectives contained in the CV Water Board's *Water Quality Control Plan for the Sacramento River and the San Joaquin River Basins – 5th Edition* (Basin Plan). Reclamation reported the activities in quarterly reports as agreed to in the 2008 MAA. In the 2015 revised MAA (referred to as the MAA from here forward), Reclamation activities are now reported at the end of each calendar year in the Annual Report and activities planned for the next fiscal year are proposed in the Annual Work Plan.

Organization of the Annual Report

The Annual Report provides a synopsis of the various activities performed by Reclamation in accordance with the MAA. Action categories include Providing Flows to the System, Salt Load Reductions, and Phased Program Activities. For each action a brief description and list of activities are provided. The Annual Report includes calculations of salt loads based on DMC deliveries and calculations of assimilative capacity provided through dilution flows. The Compliance Monitoring and Evaluation Plan (Reclamation 2010), outlines the criteria and methodology for determining DMC loads and credits.

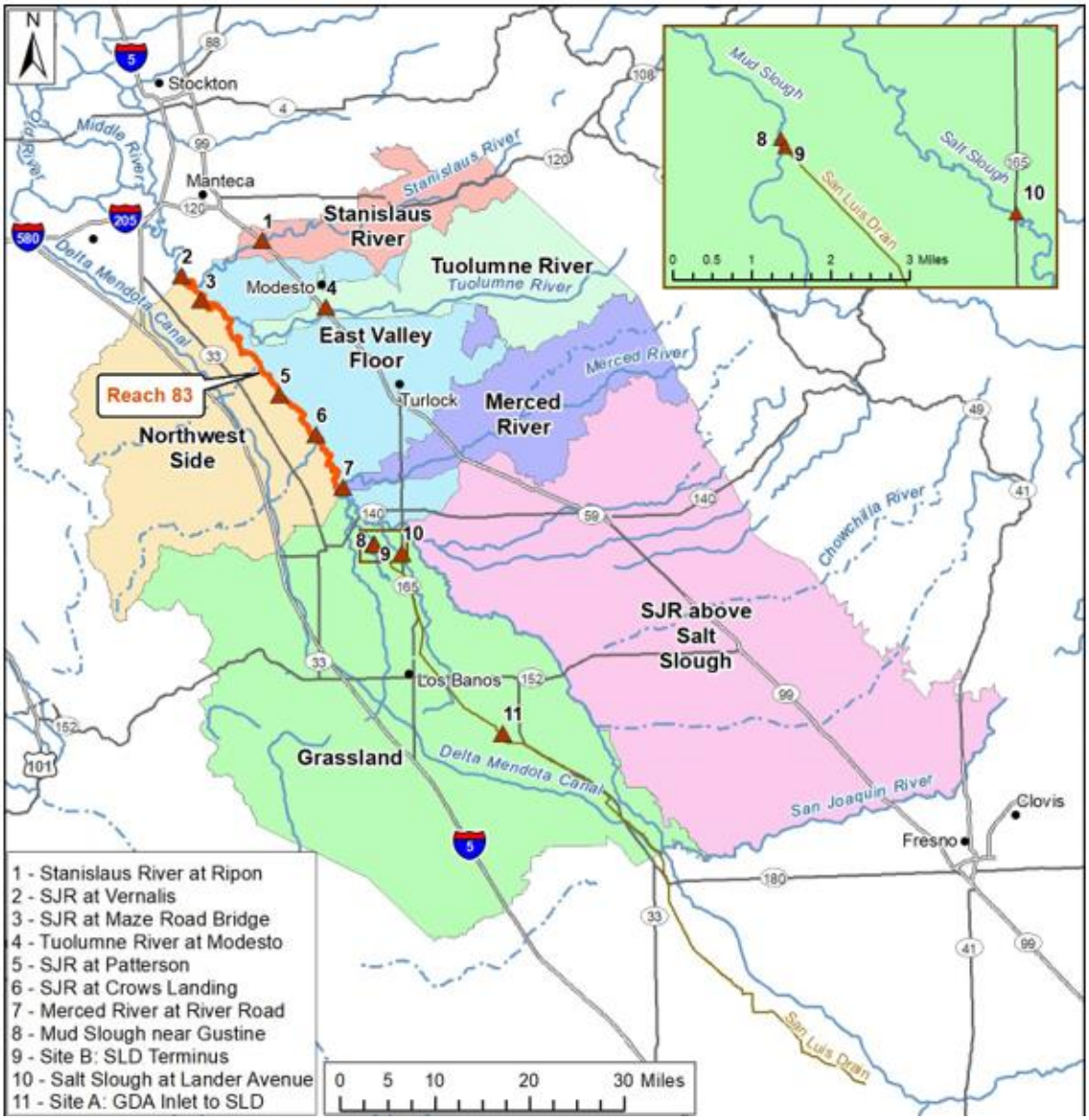

Figure 1. TMDL Subareas for Salt Load Management in the LSJR Basin

Providing Flows to the System

In 2000, Reclamation agreed to the provisions in the State Water Resources Control Board's (State Water Board) revised Decision 1641 (D-1641), which require the release of flows from New Melones Reservoir (Figure 2) to meet the Vernalis salinity objectives. Historically, Reclamation has provided both fishery and water quality dilution flow to the San Joaquin River (SJR) from New Melones Reservoir and through purchases of water supply to satisfy flow objectives established by the Vernalis Adaptive Management Plan (VAMP) and the Central Valley Project Improvement Act (CVPIA). The SJR Agreement, which included provisions to

acquire spring and fall pulse flows for the VAMP, expired on December 31, 2011. Reclamation continued to provide interim spring pulse flows for the SJR through a two-year agreement with Merced Irrigation District, which expired on December 31, 2013. During this timeframe, interested parties within the watershed, including Reclamation, initiated the San Joaquin Tributary Settlement Process to formulate a collaborative solution to present as an alternative to the State Water Board's new proposed SJR flow standard.

New Melones Reservoir Operations – Provision of Dilution Flow

In the Flood Control Act of October 1962, Congress reauthorized and expanded the function of the Melones Reservoir (P.L. 87-874) to become a multipurpose reservoir constructed by the U.S. Army Corps of Engineers and operated by the Secretary of the Interior as part of the Central Valley Project (CVP), thus creating the New Melones Reservoir. Reclamation signed a Memorandum of Understanding (MOU) with the CV Water Board in 1962 to schedule water releases from New Melones Reservoir to maintain a dissolved oxygen level of 5 milligrams per liter (mg/L) in the Stanislaus River at the Ripon monitoring station, downstream of the reservoir. The multipurpose objectives of the reservoir now include flood control, irrigation, municipal and industrial water supply, power generation, fishery enhancement, water quality improvement, and recreation. Since June of 2009, New Melones Reservoir has been operated by Reclamation to meet the National Marine Fisheries Service's Biological Opinion (BO). The BO addresses the effects of the continued operation of the CVP and the California State Water Project on the various runs of Chinook salmon, Central Valley steelhead, and green sturgeon, and their designated critical habitats.

Figure 2. New Melones Reservoir

The Basin Plan was amended in 2004 to include a control program for salt and boron discharges into the LSJR. The control program dictated that through the MAA between Reclamation and the CV Water Board, Reclamation would either (a) meet DMC salinity load allocations, or

(b) provide dilution flows to create additional salt load assimilative capacity in the LSJR equivalent to DMC salt loads in excess of their allocation. Items 12 and 13 in the Salt and Boron Water Quality Control Program include the following statements:

Item 12. Salt loads in water discharged into the LSJR or its tributaries for the express purpose of providing dilution flow are not subject to load limits described in this control program if the discharge:

a. Complies with salinity Water Quality Objectives (WQOs) for the LSJR at the Airport Way Bridge near Vernalis;
b. Is not a discharge from irrigated lands; and
c. Is not provided as a water supply to be consumptively used upstream of the San Joaquin River at the Airport Way Bridge near Vernalis.

Item 13. Entities providing dilution flows, as described in item 12, will obtain an allocation equal to the salt load assimilative capacity provided by this flow. This dilution flow allocation can be used to: 1) Offset salt loads discharged by this entity in excess of any allocation or; 2) trade, as described in item 10. The additional dilution flow allocation provided by dilution flows is calculated as described in Table IV-8 (CV Water Board 2018).

Activities

Reclamation continues to operate the New Melones dam and reservoir to comply with State Water Board D-1641, New Melones Interim Plan of Operations, applicable BOs, and the Stanislaus River at Ripon monitoring station dissolved-oxygen criteria.

Quantification Methodology: Table IV-4.4 (CV Water Board 2017) states that dilution flow allocations should be calculated as follows:

$$A_{dil} = Q_{dil} \times (C_{dil} - WQO) \times 0.8293$$

Where:

A_{dil} = Monthly assimilative capacity provided by a dilution flow (expressed as salt load) in tons per month

Q_{dil} = Dilution flow rate in thousand acre-feet (TAF) per month [above base flows]

C_{dil} = Electrical conductivity (EC) of the dilution flow in micro-Siemens per centimeter (µS/cm)

WQO = Salinity water quality objective for the LSJR at Airport Way Bridge near Vernalis in µS/cm

Table 1 lists data and monthly calculations for the past water year. Data for flow releases from Goodwin Dam, the Stanislaus River, "design flows" and salinity at Orange Blossom Bridge are used to calculate the monthly dilution flow allocations. When Goodwin Dam flows are less than

base design flows, the flows are adjusted to set assimilative capacity for the month to zero. The water-year type is estimated based on the 75% probability of exceedance found in California Department of Water Resources (DWR) Water Supply Index Forecasts (https://cdec.water.ca.gov/reportapp/javareports?name=WSI) for the San Joaquin Valley. The 75% exceedance flow forecast for May 1, 2023, is 6.49, which classifies water year 2023 (October 2022 through September 2023) as a "wet" year. In 2023 the SJR Valley floor received 160% of the average seasonal rainfall[1].

Table 1. Salt Load Assimilative Capacity of Goodwin Dam Releases to the San Joaquin River, Water Year 2023

Date	Goodwin Dam Flow (GDF)a TAF	Base Design Flow (DF)b TAF	Qdil, TAF GDF-DF=Qdil TAF	WQOc, µS/cm	Monthly Average EC at Orange Blossom Bridge (Cdil)d, µS/cm	Monthly Assimilative Capacity, Adil, tons
October 2022	35	8	27	1,000	63	20,980
November 2022	12	12	0	1,000	71	0
December 2022	19	13	6	1,000	79	4,583
January 2023	56	18	38	1,000	89	28,709
February 2023	15	15	0	1,000	114	0
March 2023	70	9	61	1,000	110	45,023
April 2023	82	28	54	700	86	27,496
May 2023	84	28	56	700	75	29,026
June 2023	89	20	69	700	70	36,050
July 2023	75	5	70	700	74	36,340
August 2023	79	18	61	700	78	31,465
September 2023	25	15	10	1000	89	7,555
Total						267,226

a https://www.usbr.gov/mp/cvo/reports.html
b Reclamation 2010 Compliance Monitoring and Evaluation Plan
c State Water Board Decision 1641
d http://cdec.water.ca.gov/dynamicapp/staSearch

[1] https://www.cnrfc.noaa.gov/monthly_precip_2023.php

Water Resources and Water Quality Regulation

The CVPIA, signed into law on October 30, 1992, modified priorities for managing water resources of the CVP. The CVPIA altered the management of the CVP to elevate fish and wildlife protection, restoration, and enhancement as a co-equal priority with water supply for agriculture and municipal and industrial purposes while recognizing other associated benefits such as power generation. To meet water acquisition needs under CVPIA, the U.S. Department of the Interior developed a Water Acquisition Program as a joint effort between Reclamation and the U.S. Fish and Wildlife Service. The program's purpose is to acquire water supplies to meet the habitat restoration and enhancement goals of the CVPIA and to improve the Department of the Interior's ability to meet regulatory water quality requirements.

Activities

Reclamation did not acquire any additional water for water quality purposes in 2023.

Salt Load Reductions

Reclamation is under a court order to provide drainage to the San Luis Unit on the west side of the San Joaquin Valley. As part of this effort, Reclamation historically supported the Westside Regional Drainage Plan (WRDP) through grants and in-kind services. Incidental salt load reduction actions have included the Grassland Bypass Project (GBP), implementation of the WRDP, and the following conservation programs: Water Conservation Field Services Program, WaterSMART Water and Energy Efficiency Grants (formerly Water 2025 Grants Program), and the California Bay-Delta Authority (CALFED) Bay-Delta Water Use Efficiency Program. Although most of these programs were not initiated originally as salt load reduction efforts, their successful implementation has resulted in measurable reduced salt loading to the LSJR. In December of 2019, a new Waste Discharge Requirement for the GBP was adopted by the CV Water Board (Order R5-2019-0077). This order expanded some of the monitoring requirements and implemented a requirement to meet a 5 parts per billion 4-day average selenium WQO at Mud Slough beginning in January 2020.

Grassland Bypass Project (GBP)

The GBP was a multi-agency stakeholder project originally based upon the 1995 Use Agreement[2] between Reclamation and the San Luis and Delta-Mendota Water Authority (SLDWMA) to manage and reduce the volume of agricultural drainage water produced within the Grassland Drainage Area (GDA). As stated above, the Waste Discharge Requirement (Order R5-2019-0077) dictates the current and ongoing monitoring requirements for the GBP. The project continues to use a 28-mile section of the San Luis Drain to convey drainage water to Mud

[2] U.S. Bureau of Reclamation and the San Luis and Delta-Mendota Water Authority, December 22, 2009. Agreement for Continued Use of the San Luis Drain for the Period January 1, 2010, through December 31, 2019. Agreement No. 10- WC-20-3975.

Slough, a tributary of the SJR. All irrigation-induced drainage from the GDA to Mud Slough was curtailed on December 31, 2020 and all irrigation season subsurface drainage discharges are now diverted to the 6,000 acre San Joaquin River Improvement Project (SJRIP) reuse facility. Annual and monthly reductions in allowable selenium load discharge to Mud Slough were part of the original negotiated Use Agreement and have been successfully accomplished over the past 25 years of the project The new Use Agreement and Waste Discharge Order allow storm induced drainage from the Grassland Drainage Area to be conveyed by the San Luis Drain during significant storm events to prevent widespread flooding of the GDA watershed. The GBP has been a highly successful example of agency and stakeholder cooperation to slowly phase out the non-point source environmental pollutant selenium from the water quality impaired SJR.

Activities

- Although the GBP was specifically designed to address selenium non-point source loading to the SJR, the GBP also significantly reduced the drainage discharge loading of salt and boron. The SJRIP has slowly expanded its footprint to accommodate all subsurface drainage from the selenium impacted watershed. Over time salinity has increased on some of the SJRIP acreage, impacting alfalfa production in particular. Alfalfa fields have been replaced with Jose tall wheatgrass – a more salt tolerant crop that is in high demand from local livestock producers but has lower economic return than alfalfa.

- Prior to Water Year 1996, more than 191,000 tons of salts and 357 tons of boron were discharged annually from the GDA to the LSJR. Figure 3 shows the progressive reduction of salts discharged from the GDA[3] due to agricultural flow diversion to the SJRIP.

- During Water Year 2023, 37,500 tons of salts and 72 tons of boron were discharged from the GDA to Mud Slough through the San Luis Drain as a result of storm-induced discharges During Water Year 2023 water allocation to irrigated agriculture south of the Delta was initially curtailed following three critically dry years in 2020, 2021 and 2022, however, extreme precipitation events in early spring 2023 ended the drought, causing substantial rainfall and runoff in the San Joaquin Basin. By September 30, the state had received 141% of its annual precipitation average, its snowpack was 237% of average, and its reservoirs were storing 129% of their average water levels. Flooding in the San Joaquin Basin caused levee overtopping along reaches of the SJR resulting in impaired drainage of westside agriculture and managed wetlands. Reclamation's deliveries to Westside agriculture were restored in late spring 2023. Reclamation continues to support research in the SJRIP to improve drainage water management and maximize income from forage production activities. The Reclamation-supported selenium treatment facility within the SJRIP was shut down in 2022 owing to a lack of subsurface inflow to support ongoing research and development activities. The plant has not restarted during 2023.

[3] Data Sources: CV Water Board (pre-project), Reclamation, and Summers Engineering.

- During Water Year 2023, approximately 9,188 acre-feet of agricultural drainage was displaced to the SJRIP reuse facility containing roughly 64,000 tons of salts and 134 tons of boron. Absent the collaboration between Grassland Area Farmers and Reclamation, these loads would have been discharged to the LSJR. Figure 4 shows the progressive reduction of boron discharged from the GDA. For Water Year 2023, approximately 169 tons of boron were discharged to the LSJR from the GDA.

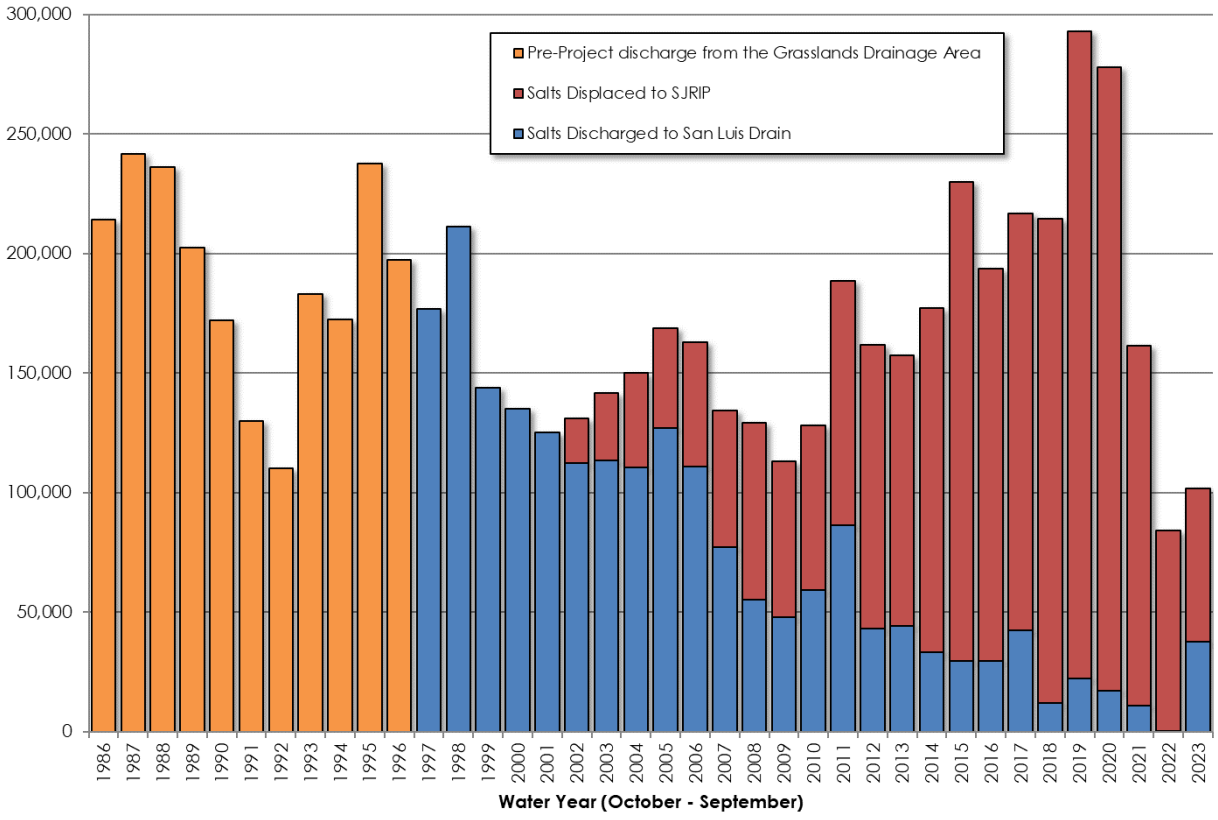

Figure 3. Salts Discharged from the Grassland Drainage Area (tons)

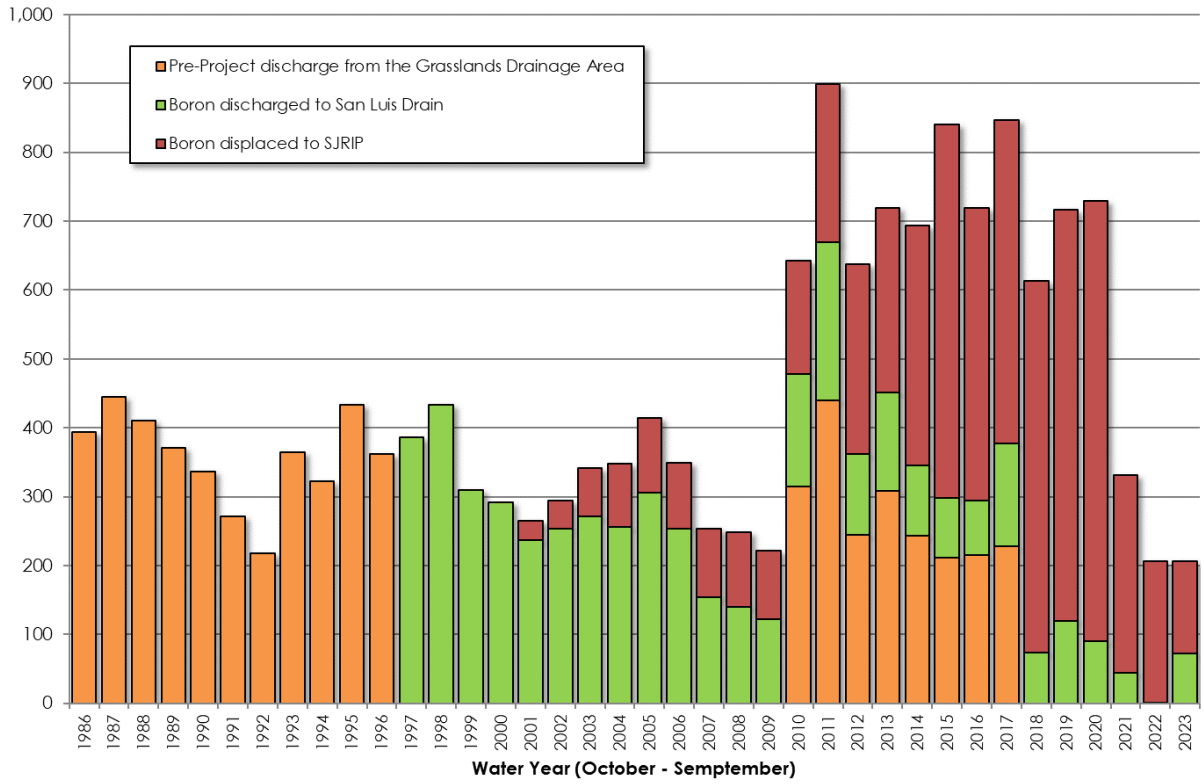

Figure 4. Boron Discharged from the Grassland Drainage Area (tons)

- The current GBP management plan retains provision for the SJRIP facility to provide some storm water management benefits under the CV Water Board Order R5-2019-0077. As before, storm-induced drainage generated in the GDA can be conveyed through the San Luis Drain to Mud Slough and the SJR during these extreme weather events to avoid flooding within the Basin. The plan update provides details of the circumstances when this discharge is allowable and the reporting requirements.

- Reclamation continues to collect and analyze water samples from nine sites for selenium, boron, salts, nutrients, and molybdenum, and continues to operate auto-samplers in the San Luis Drain and in the river at Crows Landing as listed in Order R5-2019-0077.

Westside Regional Drainage Plan

The WRDP is a local drainage management program developed by government and local agencies and private partnerships. The original efforts of the WRDP focused on reducing selenium discharges to the SJR. The initial goals of the WRDP have been met, demonstrating the importance of real-time monitoring and management in the success of this initiative.

Additional Activities Benefiting Salt Management

- The GDA continues to implement activities associated with the WRDP and SJRIP. The SJRIP currently reuses subsurface agricultural drain water from the GDA to irrigate salt-tolerant crops such as Jose tall wheatgrass, alfalfa, and pistachio trees. Income from the sale of forage hay and pistachios has been used to offset costs associated with management of the SJRIP facility.

- The San Luis Demonstration Treatment Facility remained shut down for renovations during FY 2023. Reclamation posted a solicitation to retrofit the feed pumps and other aspects of the solids waste handling system at the demonstration plant. A plan to resume operation of the Treatment Facility during 2022 was shelved due to the lack of drainage return flows from fields with underlying tile drains. The Treatment Facility requires a minimum flow volume to keep the biological treatment and reverse osmosis units for selenium and salt removal operational.

- Reclamation has provided approximately $45 million in past funding to the SJRIP and continues to support research activities at the facility that relate to optimization of the unit processes and improvements in system reliability.

- Reclamation will continue to fund activities in the western San Joaquin Valley through the WaterSMART Program. The competitive grant program has been expanded beyond the drought resiliency and water and energy efficiency themes to include watershed management, which now better aligns with the goals and cyberinfrastructure themes of real-time water quality management.

Water Conservation Efforts Benefiting Salt Management

The water use efficiency program oversees several grant programs, most of which fund actions to assure efficient use of existing and new water supplies. Activities to improve water use efficiency can alter the magnitude and scheduling of water diversions from Reclamation canals potentially resulting in reduced discharge of agricultural drainage and associated pollutants, improving water quality in receiving waters such as the SJR. Although Reclamation is not always able to quantify the benefits of the various funded projects with respect to salt load reduction, these projects all contribute to the agency's water conservation efforts in the basin. Funding for approximately 100 projects in the San Joaquin Valley has been provided through programs such as WaterSMART, the Reclamation/Natural Resources Conservation Service partnership, and the various state bond measures. The funding Reclamation provided in FY 2023 is listed in Table 2.

Table 2. Fiscal Year 2023 Reclamation Funding

Funding Program	FY 2023 Allocation
Program to Meet Standards • Provided financial assistance to Grassland Water District for the real-time management program to provide public access to their sensor network and wetland drainage data critical to calibrating Reclamation's Watershed Analysis Risk Management Framework (WARMF) forecasting model. • Systech Water Resources Inc. released the latest version of the WARMF model. WARMF version 7 has a new ArcGIS-compliant graphical user interface built using the Visual C# development platform. Watershed boundaries have been updated as shapefiles in the ArcGIS interface. • Systech Water Resources Inc. developed a WARMF model self-calibrator to improve the forecasting accuracy using real time data retrieved on the day of forecasting. The self-calibrator was incorporated into the graphical user interface of WARMF 7. The self-calibrator is still being tested and enhanced for a range of hydrological conditions and system operation regimes. • Systech Water Resources Inc. substituted the diffusive wave equation to improve the reliability of WARMF model channel routing in the SJR. • Monitoring system technical support that was previously provided through a cooperative agreement with UC Merced has been extended via a multi-year agreement through Grassland Water District. This new arrangement will better support stakeholder communication and coordination with interested parties. • Reclamation staff continues to provide technical support for WARMF model based SJR water quality forecasting and salt load assimilative capacity and data dissemination.	$750,000

Phased Program Activities

The MAA lists several actions that are intended to improve management of salt and boron loads in the SJR. These actions have been phased in coordination with interested parties in the SJR Basin and associated with primary goals. These phases and goals were recognized in the most recent Annual Work Plans developed jointly with the San Joaquin Real-Time Management Program (RTMP) Steering Committee (Reclamation 2018, 2019, 2020, 2021, 2022, 2023). The RTMP Steering Committee meets quarterly and includes both east- and west-side San Joaquin Basin organizations, agency personnel, and consultants.

Phases 1 and 2 of the RTMP were focused on initiation (Phase 1) and early development (Phase 2) that tackled the following goals: (Goal 1) monitoring station design, installation, and operation, (Goal 2) engaging participation from interested parties, (Goal 3) multi-organizational

cooperation to seek grants and other external funding and (Goal 4) initial development of a watershed-level water quality simulation and forecasting tool that would provide essential decision support for salt load assimilative capacity determination and salt load management. Phase 2 of the San Joaquin RTMP occurred from March 31, 2015, to March 31, 2016. Some goal elements from Phase 2 have been carried forward into Phases 3 and 4.

Phase 3 of the RTMP was the early implementation phase, which concluded in March 2018. Goals under this phase included (Goal 1) programmatic weekly forecasting of assimilative capacity in the SJR by one or more cooperating RTMP parties, (Goal 2) initiation of data-sharing activities between and among RTMP parties and information technology innovations to facilitate secure reliable data flows, (Goal 3) periodic analysis of additional infrastructure and funding needs through feedback from the MOU Steering Committee, (Goal 4) development and recommendation of specific additional management practices needed to better coordinate the real-time operation of discharges to the SJR, and (Goal 5) proactive outreach to current and prospective interested parties in the basin, specifically those who have not participated in the RTMP to date.

Phase 4 of the RTMP is the current implementation phase, in which Phase 2 and 3 activities become fully realized and are formalized as part of an ongoing program. There are technical and institutional components to Phase 4 of the RTMP. Under Phase 4, RTMP participants continue to implement and upgrade monitoring sites, improve real-time data access and dissemination, and encourage innovative salt management practices. Current Phase 4 activities include a technical review of the Central Valley Salinity Alternatives for Long Term Sustainability (CV-SALTS) Coalition's model selection and development for the San Joaquin Basin to use in its salt control program's ongoing characterization study. CV-SALTS consultants have made extensive use of WARMF model data in development of their Central Valley Soil & Water Assessment Tool (CV-SWAT) model that will be used to identify salinity management zones and best management practices in the San Joaquin Basin (and the rest of the Central Valley). The WARMF model will continue to provide utility given that real-time management will likely be one of the best management practices recommended for achieving CV-SALTS salinity management goals.

The WARMF model is capable of forecasting salt load assimilative capacity within a watershed and was developed for use by interested parties to coordinate the timing of drainage discharges to the river with adequate available salt load assimilative capacity (Goal 1 of RTMP Phase 4). Additional goals of Phase 4 of the RTMP include: (Goal 2) participants continue to address long-term funding and project needs, (Goal 3) the current RTMP membership may expand to include all regulated parties, including both direct and indirect dischargers of salt to the SJR, and (Goal 4) continue making technical improvements to data processing, quality assurance, and the SJR assimilative capacity forecast modeling.

Ongoing Phase 3 Activity Summary (April 2016 – September 2023)

Goal 1: Model-Based Forecasting of Salt Assimilative Capacity

Reclamation has actively supported the development of SJR salinity forecasting models, including the WARMF model, to estimate daily river salt assimilative capacity and to provide decision support for real-time salinity management at the watershed level. The WARMF model simulates watershed hydrology and irrigation return flow to the river and allows substitution of real-time, continuous data of flow and salt loads from monitored tributaries and water district diversions. The accuracy of salt load assimilative capacity forecasts is increased with the provision of recent observed flow and salinity data and advance information on anticipated management actions that could impact flow and salinity over the two-week forecast period. The accuracy of these forecasts can be enhanced with stakeholder willingness to share information in a timely manner and take interest in the disseminated forecasts.

As previously reported – starting in FY 2018 and continuing through FY 2023 – Reclamation has also used a simple, data-driven regression model for estimating EC at all three compliance monitoring stations (Vernalis, Maze Road Bridge, and Crows Landing) on the SJR. This alternate approach was developed to allow greater automation of forecasts and reduce the effort involved, which in the case of the WARMF model involves assembling both hydrological and meteorological data sets. The compliance monitoring station at Maze Road Bridge specifically recognizes the reach upstream of Vernalis to protect riparian diverters along Reach 83. The data-driven regression approach focuses just on salinity at the three compliance locations along the main stem of the SJR. The inverse gradient regression model has provided good forecast accuracy, as was described in the journal article in *Water* that summarized the use of both forecasting models during Water Year 2021 (Quinn, Tansey, and Lu, 2021). The comparison analysis of the two forecasting methods is an ongoing effort and helps benchmark model accuracy over time. The more physically based WARMF model has performed more reliably than the regression-based approach both in 2022 and 2023 for daily flow and EC forecasts on the LSJR given the unusual dry basin hydrology during 2022 and the extreme rainfall runoff events in early 2023.

The CV-SALTS Prioritization and Optimization Study has been developed around the concept of crafted salinity management zones that would help corral resources needed to maintain compliance with WQOs in the Basin Plan. Although the CV-SWAT model was recommended by the technical committee overseeing the Prioritization and Optimization Study modeling approach, the committee recognized that the WARMF model would continue to have utility in current and ongoing calibration of the CV-SWAT tool. CV-SWAT was previously used as a modeling tool within the CV Water Board's Irrigated Lands Program and has a level of acceptance from interested parties – the main reason for its selection for the study.

Reclamation will continue to support Systech Water Resources, Inc.'s development of the WARMF model during Water Year 2024 given its utility as a water quality forecasting tool. The current WARMF model has this capability that cannot be emulated by the CV-SWAT model. The Systech Water Resources, Inc. released WARMF 7 for testing by Reclamation. WARMF 7 has a completely new graphical user interface (GUI), which was built on Visual C# development

platform. WARMF 7 has additional capabilities: 1) GIS linkage capabilities via a shapefile-based map, 2) macros run internal and external processes, 3) a self-calibrator to calibrate simulated flow and EC with real time observed data on forecasting days. The self-calibrator is still being tested and enhanced for a range of hydrological conditions and system operation regimes. Figures 5 shows the new WARMF 7 GUI and its additional capabilities.

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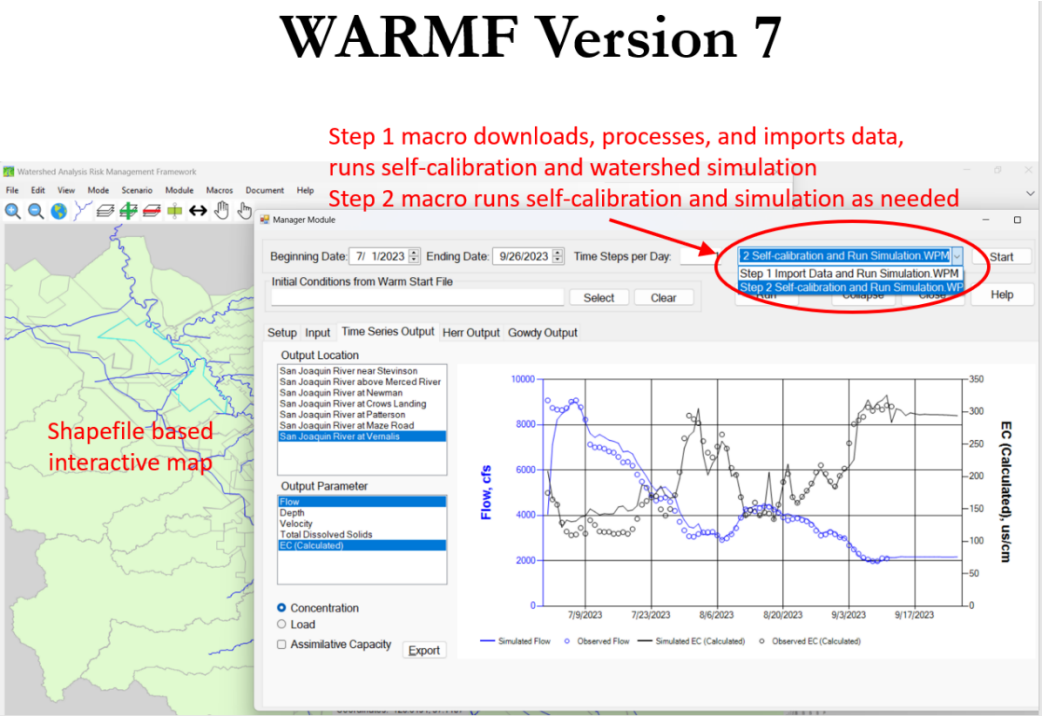

Figure 5. GUI of WARMF version 7 shows additional capabilities vs WARMF 6

Goal 2: Data Assimilation Automation and Centralization

Continued development work was undertaken in FY 2023 to improve data assimilation from state, federal, and private water and water quality data web portals.

Goal 3: Identification of Necessary Funding for Additional Infrastructure

Reclamation continues to participate in work on two funded Proposition 84 grants led by Grassland Water District (GWD) and the SJVDA entitled: (a) “Optimizing Real-Time Management of Combined Surface and Subsurface Drainage Return Flows from Seasonally Managed Wetlands in the San Joaquin River Basin” and (b) “Real-Time Management of Surface and Subsurface Drainage Return Flows to Benefit Sustainable San Joaquin River Flow and Water Quality.” The SJVDA Proposition 84 grant will end on December 31, 2024. The main objective of both grants has been to upgrade the monitoring hardware and cyberinfrastructure needed to move the RTMP into the implementation phase. These upgrades were completed both in the GWD and the agricultural service area. Diversion monitoring sensor installations have

been operating in both Patterson and West Stanislaus Irrigation Districts that provide both continuous flow and EC data for use in the WARMF forecasting model. Diversion flow and EC data are reported weekly from the District's supervisory control and data acquisition system and provided on each District's public access website.

Reports are e-mailed to Reclamation from Patterson and West Stanislaus Irrigation District that compute daily salt loading using the flow and EC data at their river pump intake facilities. Drainage monitoring installations that measure flow and EC sites in both districts have been reporting for most of 2023 and report 15-minute flow, EC, and calculated salt load data to the SJVDA HydroMetCloud web portal. Sonde data provision was interrupted for short periods during 2023 due to an undisclosed manufacturing defect that the vendor eventually acknowledged. This led to leakage of water through the sensor manifold of each sonde causing data acquisition errors. Most sondes have been repaired under extended warranty and have been returned to the monitoring sites. Monitoring equipment issues have also occurred with one of the acoustic doppler transducers that is currently undergoing warranty repair.

Goal 4: Development and Recommendation of Specific Additional Management Practices to Better Coordinate the Real-Time Operation of Discharges to the SJR

The RTMP is described in the TMDL documentation as an interested party driven effort to use real-time water quality and flow data to support water salinity management decisions to maximize the use of assimilative capacity in the SJR. Reclamation has been working with SJR interested parties and participants in the CV-SALTS initiative, as described earlier, to support the development of a water user-driven RTMP. GWD uses real-time sensor technology to reduce wetland drainage export to the SJR and reuse wetland return flows that can help extend the wetland irrigation period post drawdown. Drainage monitoring sites at Spanish Land Grant Drain and Marshall Road Drain in Patterson Irrigation District and have allowed the district access to reduce DMC diversions and make water available for export to adjacent water districts and landowners in unincorporated areas of the basin. Flow information allows Patterson Irrigation District to decide whether to incept these flows for conveyance to the Marshall Road reservoir for within-District reuse. These real-time salinity management activities are more advanced than the planning activities currently underway within CV-SALTS and provide an example of the real-time salinity management concept.

A multimillion-dollar drainage reuse system in GWD, that was partially funded by Reclamation, has been fully operational since 2021. The real-time monitoring network monitors the EC of the intercepted drainage water and pumps the water upslope to a pond where it is blended with surface water deliveries. The EC concentrations of the diverted wetland drainage is continuously monitored to ensure the blended water doesn't exceed salinity influent guidelines. Elevated salinity in applied water can negatively impact the maintenance and function of wetland moist-soil plant habitat. Reclamation is documenting other examples of interested party initiated real-time salinity management activities as we are made aware of them. The GWD wetland drainage recirculation system may be replicated in the state and federal refuges if sufficient funding is made available and water supply allocations continue to be suboptimal.

Goal 5: Continued Outreach for Additional interested parties

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) were required to obtain full compliance with the RTMP in accordance with the Basin Plan's Salt and Boron Control Program in 2018 and MID is routinely reporting operational spill and drainage return flow volumes and EC for eight discharge locations into the SJR and its major tributaries, the Stanislaus and Tuolumne Rivers. These are being provided on a quarterly schedule. These return flows can add significant salt load assimilative capacity to the SJR and are critical for the development of accurate forecasts, especially during certain times of the year when the flow-EC regression relationship is less reliable. In the past the quarterly flow and EC data from both districts were used to update WARMF model input files.

Reclamation continues to retrieve daily flow forecasts at Vernalis, Crows Landing, and Maze Road Bridge from the California-Nevada River Forecast Center (RFC) operated by the National Oceanic and Atmospheric Administration (NOAA). NOAA analysts in the RFC receive daily updates on reservoir release schedules from east-side reservoir operators and maintain a simple flow model for estimating reliable tributary outflow to the SJR. Although the RFC model does not include EC forecasts, the RFC flow forecasts significantly improve the reliability of 14-day projections made with both the Regression and WARMF models. Interaction with the RFC has also informed both Central Valley Operations (CVO) staff and NOAA analysts on the MAA water quality forecasting activities. This coordination led CVO to continue support for several important long-term San Joaquin Basin monitoring stations, including those at Mud Slough, Salt Slough, Crows Landing, and Fremont Ford. Reclamation CVO funds are being used to upgrade the monitoring at Mud and Salt Slough stations to include acoustic doppler flow measurements. These stations are often in backwater conditions during periods of high flow in the LSJR and lead to potential loss of data and increased work for the United States Geological Survey (USGS) that has been operating these stations for the past 30 years. The sensor monitoring upgrade at Mud Slough was completed in September 2023. The USGS continues to work on deployment sedimentation issues that are impacting data reliability as of December 5, 2023. The Salt Slough installation has yet to be initiated.

Reclamation attends monthly meetings of the CV-SALTS Executive Committee as a participating agency. Reclamation staff continue to participate in CV-SALTS subcommittees providing technical guidance on model selection, data availability and model calibration protocols for the P&O Study and policy feedback on Basin Plan implementation.

Phase 4 Activity Summary (April 2018 to Present)

Phase 4 activities include actions initiated during Phase 3 of the program that will lead to more widespread adoption of RTMP practices and better cooperation and coordination among interested parties. Phase 4 also involves an institutional component to secure long-term funding and technical expertise to ensure continued success of the RTMP. As previously noted, the RTMP is seen as a potential example by CV-SALTS for other salinity management areas in the Central Valley which share some of the characteristics of the SJR Basin.

Goal 1: Continue to implement/upgrade monitoring and data networks and to support real-time management practices. Use salt load assimilative capacity forecasting to coordinate the timing of discharges to the river.

A successful RTMP requires telemetered networks of flow and salinity sensors along the main stem of the SJR and in watersheds draining to the SJR. The networks allow easy access to data, promote data sharing, and provide knowledge of scheduled releases from reservoirs that discharge into tributaries to the SJR. Real-time quality assurance is essential to avoid posting erroneous data and to encourage data sharing.

- Reclamation has continued to provide funding and technical support to GWD for the continued development of its RTMP. GWD operates approximately 25 real-time web-based flow and water quality monitoring stations. With the help of additional grant funding through Proposition 84, GWD has been able to restore and upgrade monitoring with state-of-the-industry instrumentation. GWD and the SJVDA use HydroMetCloud Data Services for data telemetry and real-time data access available through Sutron Corporation. Real-time data access has proven useful to both entities for checking sensor readings prior to regular data quality assurance site visit and efficiently scheduling site troubleshooting.
- Real-time data for GWD and the SJVDA projects can be accessed on the HydroMetCloud web portal that lists both project sites:
    - For GWD: http://hydrometcloud.com/ User: RTWQ@gwdwater Password: Grassland
    - For the SJVDA: http://hydrometcloud.com/ User: sjvda-RTM Password: Realtime2020
- Reclamation continues to support its own website where river flow and EC forecasts can be accessed. The site was redesigned to allow easy access from a smartphone by entering "Reclamation PTMS" in a search engine such as Google.com. This web application is discussed during ongoing quarterly meetings.

Goal 2: Continue to address long-term funding and project needs.

The UC Merced project, entitled "Integrated Science and Management of Nutrient, Salt, and Mercury Export from San Joaquin River Wetland Tributaries to the Delta," which focused on salt and mercury loading from two wetland impoundments in the Los Banos Wildlife Management Area submitted a final report in August 2022. The project simulated potential management strategies to optimize control of both pollutants discharged to the SJR using the WARMF model. Results of the three-year project are applicable to all wetlands within the Grassland Ecological Area. Several stations in the GWD monitoring network were used in the project and the sonde at the San Luis Canal site (SL-1) were supplemented with additional water quality sensors, provided by the university.

Goal 3: Expand real-time management program membership to include all regulated parties, including both direct and indirect dischargers of salt to the San Joaquin River.

The RTMP has, to date, focused on those subareas of the SJR Basin that directly discharge salt loads to the SJR. Grant funding over the past decade has supported flow and salinity loading monitoring several agricultural drainage monitoring stations on the west-side of the basin and from seasonally managed wetlands. The California Department of Fish and Wildlife and the Grassland Resource Conservation District utilize best management practices to reduce the salt loads in discharges from managed wetlands into the SJR. Reclamation has provided resources to support the development of the real-time monitoring networks in GWD and is hopeful that similar sensor networks can be developed in the state and federal refuges during FY 2024 and beyond through wetland stakeholder outreach efforts.

- Reclamation continues to support the network of real-time flow and water quality monitoring stations that provide flow and EC data at major GWD inlets and outlets as well as along the water distribution network.
- Reclamation funding for the GBP was $760,000 in FY 2023,[4] including $200,000 to the USGS to monitor five stations on the LSJR and tributary sloughs.
- Reclamation has provided funding for flow monitoring upgrades to the Mud and Salt Slough stations with the installation of SONTEK acoustic doppler sensors. The use of these instruments will help to eliminate flow estimation errors associated with occasional backwater conditions where high river stage impedes tributary inflow and leads to unrealistic elevated flows. Reclamation has worked with DWR (Fresno) to improve flow and water quality monitoring at the Maze Road Bridge site. Monitoring issues recognized during 2022 have been largely resolved and the site is now reporting both flow and EC data. A telemetry error was recognized in late September 2023, whereby EC data were being reported in the pH column on CDEC and the CDEC EC data column contained temperature data in degrees Fahrenheit. This error has been resolved on the CDEC web portal.

Goal 4: Continue technical improvements to data processing, quality assurance, and the SJR assimilative capacity forecast modeling.

Reclamation has continued to investigate further automation of data acquisition to reduce the data processing steps needed for WARMF model forecasts and simplifying the WARMF GUI to reduce the model's learning curve while retaining model performance. The WARMF model relies on a very large array of both publicly accessible and more restricted data to reliably perform weekly forecasts of flow and EC. For the westside drainage stations Reclamation and the SJVDA have worked closely with Patterson and West Stanislaus Irrigation Districts to automate data collection to allow migration of these data to the WARMF model from telemetered monitoring site to a web portal hosted by HostGator.com. This initiative was

[4] The funding allocation is not specifically a part of the MAA RTMP but yields salinity benefits in the LSJR.

intended to demonstrate to interested parties the direct use of real-time data while helping to build confidence in the performance of the WARMF model. This additional routine was eliminated in 2023 owing to the preference for HydroMetCloud for data access and the cost of maintaining the HostGator web portal.

Data quality assurance has always been a major constraint to implementation of the RTMP. Participants are reluctant to share erroneous data for potential liability reasons. Poor data quality assurance also has potential to diminish public trust in the data and their willingness to utilize the data and the forecast model results for decision support The U.S. Army Corps of Engineers HEC-DSSVue platform was used as a development platform to address project real-time data quality assurance issues. The HEC-DSSVue software is in the public domain and well documented and accommodates customized Python scripts developed to process raw data, correct errors, and fill data gaps to produce reliable daily mean flow and EC data files for direct import to the WARMF model. At present the most recent data from the SJVDA westside drainage stations and two years of data from GWD have been loaded into the HEC-DSSVue database. Online user manual videos have been created to provide essential information to other potential users of this readily accessible real-time data quality assurance software routine.

Central Valley Project Deliveries Load Calculation

The CVP delivers water to both the Grassland and Northwest subareas, as described in the Basin Plan, through the DMC, the San Luis Canal, and the San Joaquin River/Mendota Pool. Most CVP water is pumped from the Delta into the DMC through the Jones Pumping Plant located near Tracy, California. CVP water is conveyed south to DMC Check 13 near Santa Nella, California, where water is either mixed with the State Water Project in O'Neill Forebay and then either pumped into San Luis Reservoir for later delivery, or conveyed further south to the DMC terminus at the Mendota Pool. During periods of drought, groundwater and river water are pumped into the DMC at several locations. The calculation methods used in this report are provisional, and some elements in this report do not include estimations of benefits at this time. Reclamation submitted the *Compliance Monitoring and Evaluation Plan* (Reclamation 2010), which outlines the criteria and methodology for determining DMC loads and credits, to the CV Water Board.

Quantification Methodology: The monthly amount of CVP water supply delivered to each district is prorated according to the area of each district within either the Grassland subarea, Northwest subarea, or outside of these subareas. The monthly mean salinity of CVP water is calculated from average daily measurements taken at three locations along the DMC. The salinity of CVP water delivered to each district is associated with the salinity monitoring site closest to the district's turnout along the DMC.

The Basin Plan allocates a salt load to Reclamation for water delivered to the Grassland and Northwest subareas. This background load allocation is calculated according to Table IV-8 as shown in the following equation:

$$LA_{DMC} = Q_{DMC} \times 52 \text{ mg/L} \times 0.00136$$

Where:

LA_{DMC} = load allocation of salts, in tons

Q_{DMC} = monthly amount of CVP water delivered to Grassland and Northwest subareas, in acre-feet

52 mg/L = "background" salinity of water in the San Joaquin River released at Friant Dam (per the Basin Plan) measured as total dissolved solids (TDS)

0.00136 = factor for converting units into tons

Actual DMC salt loads are calculated by the following equation:

$$L_{DMC} = Q_{DMC} \times C_{DMC} \times 0.00136$$

Where:

L_{DMC} = actual DMC load, in tons

Q_{DMC} = monthly amount of water delivered to Grassland and Northwest Subareas, in acre-feet

C_{DMC} = monthly average of salinity of the water delivered to Grassland and Northwest subareas, in mg/L TDS

0.00136 = factor for converting units into tons

Each subarea's QDMC is calculated and then paired with the associated monthly average TDS for that reach, so the equation becomes:

$$L_{DMC} = 0.00136 * \Sigma(Q_{DMC} * C_{DMC}) \text{ Subareas}$$

This equation is then broken into calculations for each subarea based on the source of CVP water. Table 3 lists the salt loads of CVP water delivered to the Grassland and Northwest subareas and an estimate of the salts delivered in excess of the monthly load allocation.

Table 3. Calculation of DMC Allocations and Loads

Water Year	Water Year Type	Grasslands Subarea – San Joaquin River and Mendota Pool Salt Load from CVP (Thousand Tons)	Grasslands Subarea – Delta-Mendota Canal Salt Load from CVP (Thousand Tons)	Grasslands Subarea – San Luis and Cross Valley Canal Salt Load from CVP (Thousand Tons)	Grasslands Subarea – Total Flow (Thousand Acre-Feet)	Grasslands Subarea – Load Allocation (Thousand Tons)	Grasslands Subarea – Actual Load – Load Allocation (Thousand Tons)	Northwest Subarea – San Joaquin River and Mendota Pool Salt Load from CVP (Thousand Tons)	Northwest Subarea – Delta-Mendota Canal Salt Load from CVP (Thousand Tons)	Northwest Subarea - Total Flow (Thousand Acre-Feet)	Northwest Subarea – Load Allocation (Thousand Tons)	Northwest Subarea – Actual Load - Load Allocation (Thousand Tons)	Total – Total Excess Load from CVP Deliveries (Thousand Tons)
2016	Dry	275.4	89.9	36.2	873.4	61.7	339.8	20.5	15.5	92.8	6.6	29.5	369.2
2017	Wet	147.5	57.8	20.1	1,031.4	72.9	152.6	9.3	11.0	122.8	8.7	11.6	164.1
2018	Below Normal	219.7	117.6	41.6	1,112.1	78.6	300.4	16.9	18.5	114.9	8.1	27.3	327.7
2019	Wet	167.2	75.7	27.7	1,023.0	72.3	198.3	12.1	11.8	109.6	7.7	16.2	214.5
2020	Dry	225.0	99.7	40.0	1,006.3	71.1	293.6	17.9	20.4	110.9	7.8	30.4	324.1
2021	Critical	266.4	104.8	43.7	777.8	55.0	361.4	19.5	29.1	95.6	6.8	41.7	403.1
2022	Critical	269.4	89.7	44.7	892.3	63.1	342.8	21.8	19.6	97.0	6.9	34.4	377.2
2023	Wet	145.3	69.8	20.9	909.1	64.2	173.3	11.4	57.6	305.8	21.6	47.6	220.9

Report of Annual Work Plan Activity Performance

Reclamation has met schedule milestones for the MAA and performance of actions for assisting interested parties in managing salt loads and offsetting the DMC salt load into the SJR. New Melones Reservoir continues to be operated in accordance with D-1641.

During 2023, Reclamation continued to support the development and use of the WARMF-based 14-day forecasts for EC and discharge. The following three tasks were planned for FY 2023 and FY 2024:

1. Complete the WARMF model self-calibrating feature. WARMF self-calibration and automation to closely match the model simulation to observations of flow and EC by using the most recent real-time data from the same day. The calibration using the most recent real-time data will significantly improve the model's forecasting accuracy. There are several time series inputs to the WARMF model for which observation data is not available but are important parts of the flow and salt balances on the SJR. These include seepage losses from the San Joaquin and Stanislaus Rivers, unknown saline inflow to the SJR, and operational spills from the TID and MID. Systech has developed utility programs which compare the WARMF model SJR simulations and field observations make required adjustments to bring these values into alignment. Under most conditions, this will result in a better match between the model simulated flow and EC and observed data on the day before forecasts are made.

2. Upgrade of WARMF Hydrologic Simulation Algorithm. One of the limitations of the WARMF model is its use of the kinematic wave approximation of the one-dimensional Saint-Venant equation to route flow through the watershed. The kinematic wave approximation assumes that the slope of the water surface is parallel to the river bottom slope and the depth of the river at a given point is independent of the depth further downstream. These assumptions are not accurate during rapidly changing flow in the LJSR, however, because of the river's low slope and extensive backwater effects. As a result, simulated flow peaks occur earlier and tend to be higher than is observed and simulated recession from high flow is faster than observed. This error can propagate to simulated EC because the model does not simulate the correct proportions of flow from fresh versus saline. The WARMF simulation engine is being modified to allow hydrologic routing using the diffusive wave approximation. The diffusive wave approximation accounts for backwater effects and is accurate for subcritical flow conditions found on the SJR. A technical memorandum will be prepared describing the changes to model code and the substitution this adjustment makes to modeling results.

3. Utilities to Enhance Flow Forecasts. To simulate flow and salinity during the forecast period, WARMF uses a combination of flow forecasts from the RFC and meteorology forecasts. Other model inputs are assigned based on their most recent measured value or with typical values for the time of year.

a. **Mud Slough near Gustine**. Other than flow forecasts provided by the RFC, the preprocessing routines which prepare real-time inputs to the WARMF model assume that the most recent measured flow at each of the WARMF boundary inflow points will continue through the forecast period. This is generally a good strategy, but there are cases where the model's forecast can be improved. The spring draw down of wetlands in the Mud Slough watershed is a key event since the salinity of the SJR is often near its water quality criterion at that time of year. The assumption of continued constant flow can be improved upon by referencing historical data as shown in Figure 2 below. Each year flow predictably increases starting about March 10 for 1-2 weeks before decreasing through the end of April. A utility will be developed to estimate flow in Mud Slough during the forecast period based on current flow and historical data.

b. **Seepage Loss Forecasts**. Seepage loss from different reaches of the SJR and the Stanislaus River are an important part of the river's flow and salt balance. By default, seepage losses are currently set to typical values for the time of year during the forecast period. Seepage loss depends on river depth (and therefore flow) so losses during the forecast period can be better estimated from forecast flow. A utility will be created which analyzes the current flow, forecast flow, and current seepage loss to estimate seepage loss for the forecast period and modify the corresponding WARMF input files.

c. **Precipitation Forecast at Stations with Missing Data**. Precipitation is set at each of the meteorology stations used as WARMF inputs from measured CIMIS data or 6-day forecasts issued by the RFC. Any time there isn't data or forecast available, the data must be filled with reasonable values to have complete input for the WARMF simulation engine. Currently, if there is no measured data at a station with a precipitation forecast, the forecast is used as data when it becomes the past. If there is no measured data and no forecast, typical values for the time of year are used. These methods are not very accurate and required making frequent manual adjustments to WARMF meteorology files during the winter of 2021-2022. A better method would be to use measured data from a nearby station with data and scale the precipitation amount based on the average ratio of precipitation between the stations. The import processing procedure will be modified to automatically use the improved method of filling missing data.

Systech will integrate the utilities developed in this task into the automated preprocessing of input data currently under development. The deliverable of this task will be the updated WARMF GUI and supporting utility programs in an install set.

The WARMF model's capability to perform reliable flow, EC and salt load forecasts has been tested during the unusual 2022 and 2023 hydrologic years. Conditions, such as those experienced

during 2022 and 2023, were dissimilar from most of the historic data in the WARMF model database –and provide good bookends for improving future forecasts.

The Salt and Boron Control Program states that "Participation in a Regional Water Board approved real-time management program and attainment of salinity and boron water quality objectives will constitute compliance with this control program." Figure 6 shows that Reclamation has maintained annual compliance with the salinity WQO at Vernalis during Water Year 2023.

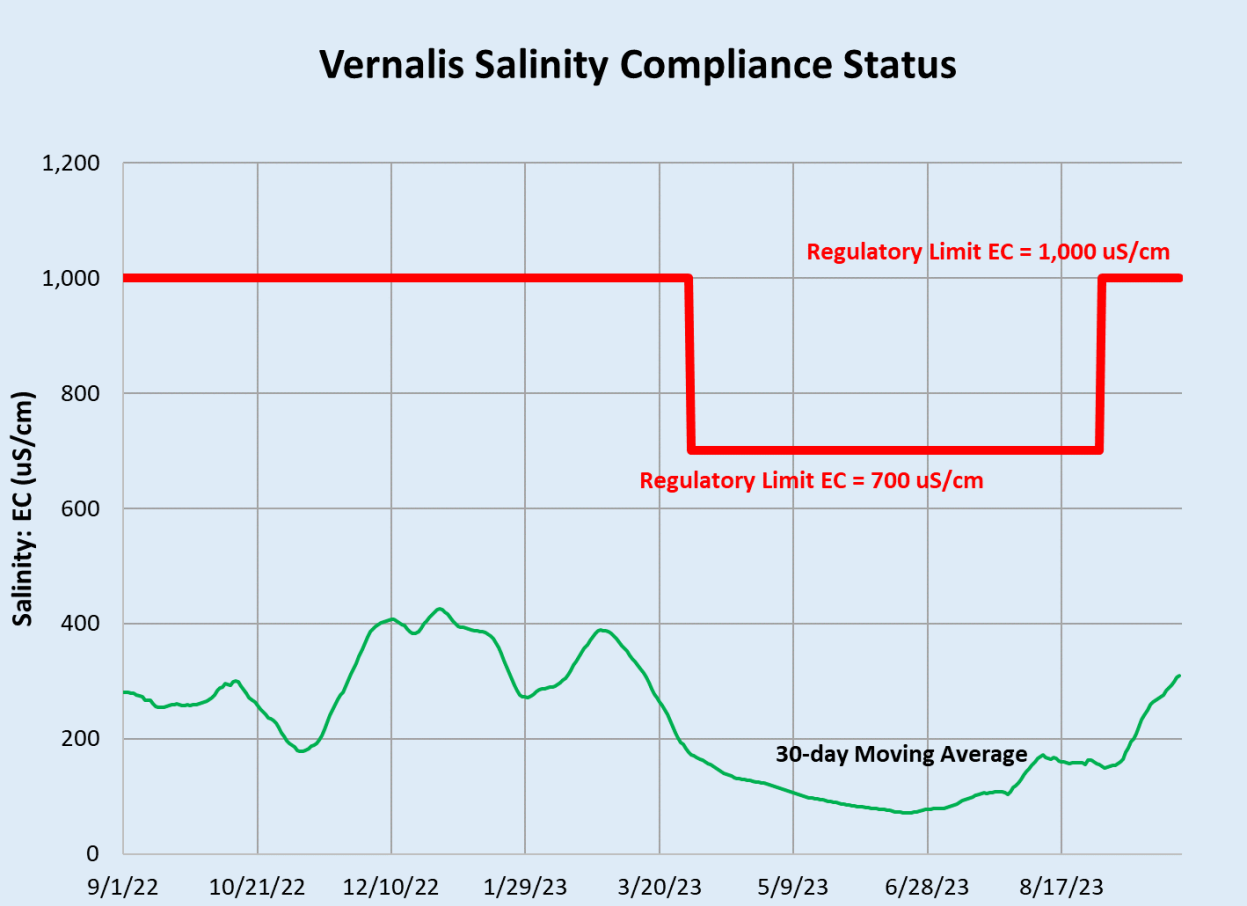

Figure 6. Water Year 2023 Compliance with the Salinity WQO at Vernalis

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