Draft Technical Memorandum

Procedures for the Measurement, Monitoring, and Reporting of Restoration Flows

SAN JOAQUIN RIVER RESTORATION PROGRAM

December 17, 2007

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List of Abbreviations and Acronyms

ADCP	acoustic Doppler current profiler
CDEC	California Data Exchange Center
CDFG	California Department of Fish and Game
cfs	cubic feet per second
CVO	Central Valley Operations
CVP	Central Valley Project
DO	dissolved oxygen
DWR	California Department of Water Resources
EC	electrical conductivity
FWUA	Friant Water Users Authority
GIS	geographic information system
GOES	geostationary orbit environmental satellite
HAR	hydrologic assessment report
IIMS	Integrated Information Management System
IWRIS	Integrated Water Resources Information System
kW	kilowatt
m	meter
M&I	municipal and industrial
msl	mean sea level
NRDC	Natural Resources Defense Council
NWIS	National Water Information System
PEIS/R	Program Environmental Impact Statement/Report
QC	Quality Control
Reclamation	United States Department of the Interior, Bureau of Reclamation
RM	river mile
SJRRP	San Joaquin River Restoration Program
TM	Technical Memorandum
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service
WPIE	Water Planning Information Exchange

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This Draft Technical Memorandum (TM) was prepared by the San Joaquin River Restoration Program (SJRRP) Team as a draft document in support of preparing a Program Environmental Impact Statement/Report (PEIS/R). The purpose for circulating this document at this time is to facilitate early coordination regarding initial concepts and approaches currently under consideration by the Program Team with the Settling Parties, Third Parties, other stakeholders, and interested members of the public. Therefore, the content of this document may not necessarily be included in the PEIS/R.

This Draft TM does not present findings, decisions, or policy statements of any of the Implementing Agencies. Additionally, all information presented in this document is intended to be consistent with the Settlement. To the extent inconsistencies exist, the Settlement should be the controlling document, and the information in this document will be revised before its inclusion in future documents. While the Program Team is not requesting formal comments on this document, all comments received will be considered in refining the concepts and approaches described herein to the greatest extent possible. Responses to comments will not be provided and this document will not be finalized; however, refinements will likely be reflected in subsequent program documents.

1.0 Introduction

This Draft Technical Memorandum (TM) describes procedures for measuring, monitoring, and reporting Interim Flows and Restoration Flows that are required by the Settlement Agreement for restoration of the San Joaquin River, California. Publicly available, high-quality, continuous stream flow data are critical for demonstrating compliance with the provisions of the Settlement Agreement. Accurate stream flow data will be essential for computing a water balance for the Interim Flows and Restoration Flows; verifying assumptions made regarding hydrographs contained in the Exhibit B of the Settlement Agreement; and planning and evaluating a wide variety of restoration projects. The San Joaquin River Restoration Program (SJRRP) will have limited success in predicting, implementing, and evaluating the effects of restoration actions on the fish, wildlife, and water resources of the San Joaquin River without reliable, high-quality stream flow data.

1.1 Background

In 1988, a coalition of environmental groups, led by the Natural Resources Defense Council (NRDC), filed a lawsuit challenging renewal of long-term water service contracts between the United States and Central Valley Project (CVP) Friant Division contractors. After more than 18 years of litigation of this lawsuit, known as *NRDC et al. v. Kirk Rodgers et al.*, a Settlement Agreement was reached. On September 13, 2006, the "Settling Parties" reached consensus on the terms and conditions of the Settlement Agreement, which was subsequently approved by the Court on October 23, 2006. The "Settling Parties" include NRDC, Friant Water Users Authority (FWUA), and the United States Departments of the Interior and Commerce.

The SJRRP will implement the San Joaquin River litigation Settlement Agreement. The "Implementing Agencies" responsible for management of the SJRRP include the United States Department of the Interior, through the Bureau of Reclamation (Reclamation) and the Fish and Wildlife Service (USFWS), the United States Department of Commerce through the National Marine Fisheries Service, and the State of California through the Department of Water Resources (DWR) and Department of Fish and Game (CDFG).

1.2 Purpose

The purpose of this Draft TM is to document interim methods that will be used for measuring, monitoring, and reporting daily releases of the Interim Flows and Restoration Flows in compliance with the San Joaquin River Settlement Agreement. This TM will be used for planning purposes, and to facilitate discussion of monitoring the Interim Flows and Restoration Flows with the Implementing Agencies, Settling Parties, and stakeholders in the restoration effort. This document is a first step in developing a comprehensive monitoring plan for the SJRRP that is scheduled to be completed in spring 2008.

2.0 Objectives and Definitions

This section describes objectives of the stream gaging program and measurement needs in the Settlement Agreement, and defines key terms used in the TM.

2.1 Objectives

The primary objective of the stream gaging program will be to obtain publicly available, high-quality, continuous stream flow data to support the river restoration effort. A secondary objective of the stream gaging program will be to obtain publicly available, accurate water quality data to support the river restoration program.

A continuous record of the flow in the San Joaquin River will be made at the primary monitoring stations using standard stream gaging techniques, as described in the United States Geological Survey (USGS) publication series Techniques of Water Resource Investigations (Buchanan and Somers, 1968, 1969; Carter and Davidson, 1968).

2.2 Descriptions of Measurement Needs in the Settlement Agreement

Paragraph 13 of the San Joaquin River Settlement Agreement contains relevant language regarding measuring, monitoring, and reporting Interim Flows and Restoration Flows.

Paragraph 13(j) of the Settlement Agreement states the following:

> *Prior to the commencement of the Restoration Flows as provided in this Paragraph 13, the Secretary, in consultation with the Plaintiffs and Friant Parties, shall develop guidelines, which shall include, but not be limited to:*
>
> *Procedures for the measurement, monitoring and reporting of the daily releases of the Restoration Flows and the rate of flow at the locations listed in Paragraph 13(g) to assess compliance with the hydrographs (Exhibit B) and any other applicable releases (e.g., Buffer Flows);*

Paragraph 13(g) of the Settlement Agreement states the following:

> *The Restoration Flows will be measured at not less than the following six locations between Friant Dam and the confluence of the Merced River, and the measurements will be monitored to ensure compliance with the hydrograph releases (Exhibit B) and any other applicable flow releases (e.g., Buffer Flows):*

> *(i) at or immediately below Friant Dam (designated as "Friant Release" on the applicable hydrograph;*
>
> *(ii) Gravelly Ford (designated as "Reach 2" on the applicable hydrograph);*
>
> *(iii) immediately below the Chowchilla Bifurcation Structure (designated as "Reach 3" on the applicable hydrograph);*
>
> *(iv) below Sack Dam (designated as "Reach 4" on the applicable hydrograph);*
>
> *(v) top of Reach 4B (designated as "Reach 5" on the applicable hydrograph);*
>
> *and (vi) at the confluence of the Merced River (designated as "Confluence" on the applicable hydrograph).*

2.3 Definitions of Key Terms

Key terms defined in the Settlement Agreement include the following:

- Restoration Flows – Base flows + buffer flows.
- Interim flows – Releases of additional water commencing no later than October 1, 2009, for the purpose of collecting relevant data concerning flows, temperatures, fish needs, seepage losses, recirculation, recapture, and reuse.
- Base flows – A function of water year type.
- Buffer flows – Up to 10 percent augmentation of base flows.
- Water year type – The Settlement Agreement identifies six water year types based on October-to-September unimpaired runoff (inflow) at Friant Dam. These are (in order of increasing "wetness") as follows: Critical – Low, Critical – High, Dry, Normal – Dry, Normal – Wet, and Wet. Except the lowest volume water year type (Critical – Low), water years are defined as falling in a defined range on an exceedence curve of the unimpaired runoff (Table 2-1). Year type volumes were established by analyzing water years 1922 through 2004. This is not to change as new data (years) are added to the record.

Table 2-1.
Water Year Types and Associated Exceedence Probabilities Defined in the San Joaquin River Settlement Agreement

Exceedence Level	Water Year Type
Wettest 20%	Wet
Next 30% (20 to 50%)	Normal-Wet
Next 30% (50 to 80%)	Normal-Dry
Next 15% (80 to 95%)	Dry
Remaining 5% (95 to 100%)	Critical-High and Critical-Low

- Hydrographs – A chronological graphic record of stream discharge or water level (stage) at a given point on a stream (a graph of discharge or stage vs. time). Hydrographs for various reaches of the San Joaquin River for a given water year type are contained in Exhibit B of the Settlement Agreement.

Key terms not explicitly defined in the Settlement Agreement, but integral to implementation of releases of Interim Flows and Restoration Flows in accordance with the Settlement Agreement, include the following:

- Unimpaired runoff – Unimpaired runoff represents the natural water production of a river basin, unaltered by upstream diversions, storage, or export or import of water to or from other watersheds.

- DWR Bulletin 120, Water Conditions in California – A publication issued four times a year, in the second week of February, March, April, and May, by DWR. It contains forecasts of the volume of seasonal runoff from the State's major watersheds, including the San Joaquin River at Friant Dam. Bulletin 120 contains summaries of precipitation, snowpack, reservoir storage, and runoff in various regions of the State.

- Water year – Time convention used for compiling and reporting stream flow data. A water year is from October 1 to September 30.

- Exceedence probability – The probability that a specified discharge will be exceeded.

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3.0 Measuring Locations

The Settlement Agreement requires that Interim Flows and Restoration Flows be measured at six locations between Friant Dam and the Merced River. This section presents the analysis of and recommendation for location selection.

3.1 Summary of Selected Locations

The locations identified in the settlement are summarized in Table 3-1 and shown in Figure 3-1. Interim Flows and Restoration Flows will be measured using existing stream gages, where possible. Where existing gages are not available, or are inadequate to measure Interim Flows and Restoration Flows, new gages will be installed or, in some cases, formerly used gages will be retrofitted to measure the Interim Flows and Restoration Flows. The monitoring locations listed in Table 3-1 are referred to as the primary monitoring stations for purposes of this TM.

Table 3-1.
Interim Flow and Restoration Flow Monitoring Locations Specified in San Joaquin River Settlement Agreement

Location	Existing Station/ Station Identifier [1]	Agency	Parameters	Remarks
Friant Dam	Yes/MIL	Reclamation	Flow, EC, temperature, others	Flows will be measured at Friant Dam outlets.
Gravelly Ford	Yes/GRF	Reclamation	Flow, EC, temperature, others	Existing gage adequate to measure Interim Flows and Restoration Flows.
Below Chowchilla Bifurcation Structure	Yes/CBP	Reclamation	Flow, EC, temperature, others	Existing gage will be retrofitted to measure Interim Flows and Restoration Flows.
Below Sack Dam	No	DWR	Flow, EC, temperature, others	Abandoned (Dos Palos) stream gage will be retrofitted.
Top of Reach 4B	No	DWR	Flow, EC, temperature, others	A new stream gage will be established.
Merced River Confluence	Yes/ FFB, MSG, MST, & NEW	USGS/ DWR	Flow, EC, temperature, others	Multiple existing gages will be evaluated. A new gage may be required.

Note:
[1] California Data Exchange Center identifiers.
Key:
CBP = Chowchilla Bifurcation Structure
DWR = California Department of Water Resources
EC = electrical conductivity
FFB = Fremont Ford Bridge
GRF = Gravelly Ford gaging station
MIL = Millerton Lake
MSG = Mud Slough near Gustine
MST = Merced River near Stevinson
NEW = Newman
Reclamation = United States Department of the Interior, Bureau of Reclamation
USGS = United States Geological Survey

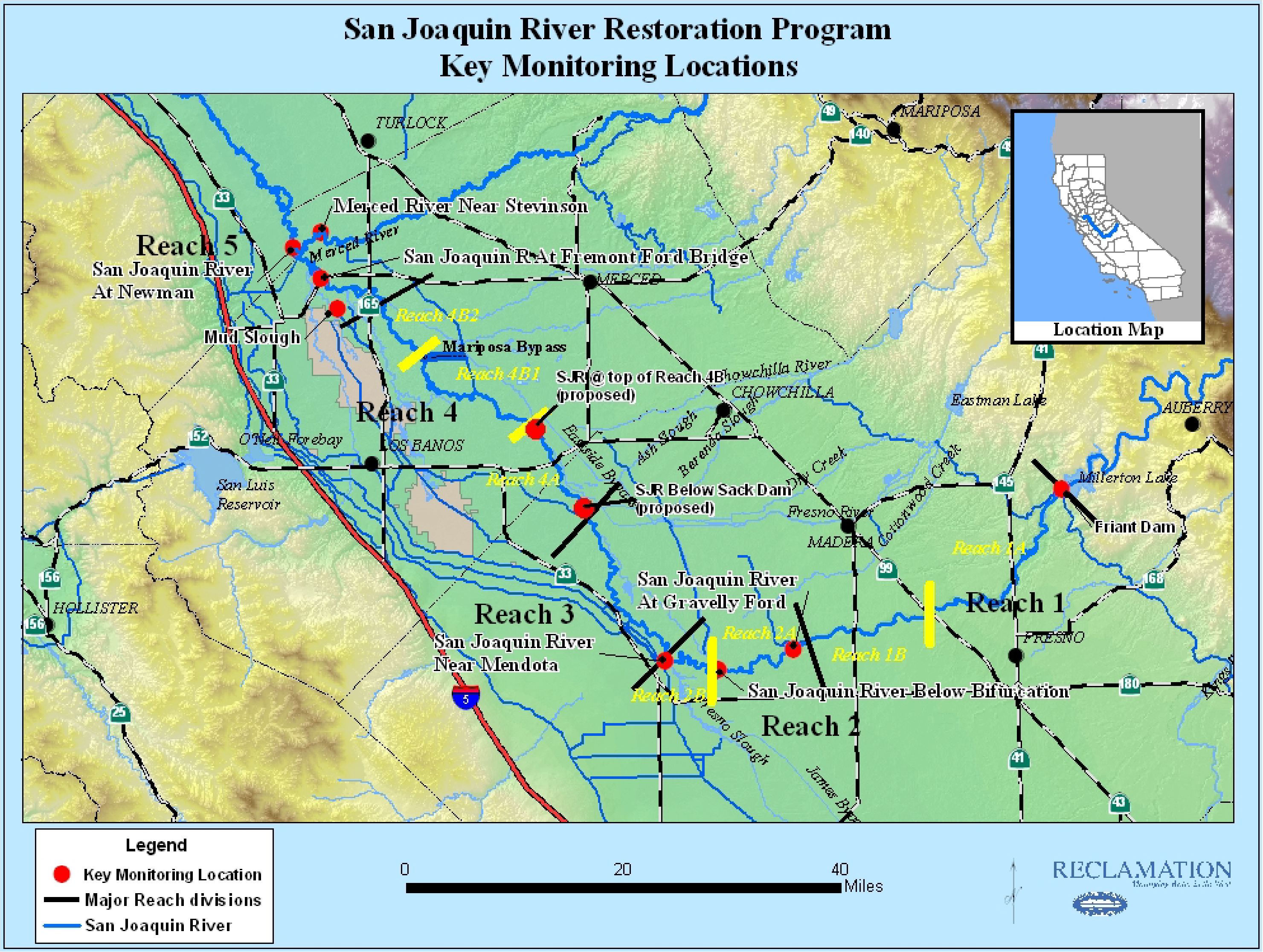

Figure 3-1.
Key Flow Monitoring Locations for Implementation of the San Joaquin River Settlement Agreement

3.2 Monitoring Station Descriptions

A detailed description of the primary monitoring stations required by the Settlement Agreement follows.

3.2.1 Release to the San Joaquin River from Friant Dam

The Settlement Agreement for restoration of the San Joaquin River requires that Interim Flows and Restoration Flows be measured “at or immediately below Friant Dam” (designated as “Friant Release” on the hydrograph in Exhibit B of the Settlement Agreement document). The purpose of this section is to describe how Interim Flow and Restoration Flow releases to the San Joaquin River from Friant Dam will be measured, monitored, and reported in compliance with the Settlement Agreement.

Friant Dam is located on the San Joaquin River at river mile (RM) 267.5, approximately 25 miles northeast of Fresno, California (Figure 3-1). The dam is an integral part of the Friant Division of the CVP and is operated by Reclamation for the purposes of water supply, flood control, and recreation. Facilities of the Friant Division provide deliveries of irrigation and municipal and industrial (M&I) water supplies through the Friant-Kern Canal and Madera Canal from Millerton Lake; downstream releases to meet demand from diversions in the San Joaquin River above Mendota Pool; and flood control for the San Joaquin River.

Under normal operating conditions, water is released to the San Joaquin River through the river outlet works at Friant Dam. The river outlet works consists of four 110-inch-diameter (2.79-meter [m]) steel pipes (R1, R2, R3, and R4), each controlled by a 96-inch-diameter (2.43 m) hollow-jet valve. Smaller volume releases to the river can be made through two 24-inch-diameter (0.60 m) steel pipes that branch from outlet pipes R3 and R4, and are controlled by two 18-inch-diameter (0.45 m) needle valves. Smaller volume releases can also be made through a 48-inch-diameter (1.21 m) steel pipe, which branches from outlet pipe R1 and delivers water to the Friant Power Authority 2,000-kilowatt (kW) powerplant located adjacent to the outlet works stilling basin. Total capacity of the river outlet works is 16,400 cubic feet per second (cfs) at a gross pool elevation of 580.6 feet above mean sea level (msl). The flows released to the San Joaquin River through the outlet works are controlled by adjusting the percent opening on each valve. To achieve the desired flow rate for a river outlet valve, a percent opening is manually calculated for a given reservoir elevation using the appropriate rating table for each valve. The reservoir elevation is measured continuously to the nearest .01 foot in a stilling well on the upstream face of the dam, and determines the net hydraulic head on the valves. Under normal operating conditions, the valve openings are calculated and adjusted by operations staff according to demand for water in the San Joaquin River on a daily basis.

Releases to the San Joaquin River can also be made over the spillway at Friant Dam. The spillway consists of an ogee overflow section, chute, and stilling basin in the center of the dam. The spillway has a discharge capacity of 83,160 cfs at a gate height of 18.0 feet. Spillway releases are controlled by one 18-foot-high by 100-foot-wide drum gate in the center of the dam, and two comparably sized Obermeyer gates, which are located on both sides of the drum gate. Spillway releases to the San Joaquin River are computed using a stage-discharge relation for each gate. To achieve the desired flow rate for a spillway gate, a gate opening is manually calculated for a given reservoir elevation using the appropriate rating table for each gate.

Releases of water to the San Joaquin River are reported by Friant operations staff on a daily basis as part of the Millerton Lake Daily Operations Report. The report contains a summary of a daily water balance for Millerton Lake that includes reservoir elevation, reservoir storage, 24-hour change in reservoir storage, and 24-hour average inflow and outflows to the San Joaquin River and the canal systems. Operations data are first manually input into a Friant Operations Log spreadsheet. The spreadsheet performs a quality control (QC) check on the input parameters using lookup tables. The data are then manually input into a Hydrologic Assessment Report (HAR), and an additional QC check is performed before the HAR database is updated. The Millerton Lake Daily Operations Report is posted by Friant operations staff on the HAR database by 0900 each day (7 days a week). Provisional daily operations data for Friant Dam are available to the public on the California Data Exchange Center (CDEC) Web site at http://cdec.water.ca.gov under the daily station identifier code of “MIL.”

3.2.2 San Joaquin River at Gravelly Ford

The Settlement Agreement for restoration of the San Joaquin River requires that Interim Flows and Restoration Flows be measured at Gravelly Ford (designated as Reach 2 on the applicable hydrograph). Gravelly Ford is the boundary between Reaches 1 and 2 on the San Joaquin River (Figure 3-1). Reclamation currently operates a stream gage at RM 229 on the San Joaquin River at Gravelly Ford that is adequate to satisfy the requirement for measuring, monitoring, and reporting Interim Flows and Restoration Flows. Under current operations, the primary purpose of the gage is to measure compliance with contractual commitments to supply water to riparian water right holders in Reach 1.

The gage consists of a stilling well and gage house on the left bank of the river. River stage is measured continuously to the nearest 0.01 foot using a mechanical float and a Stevens recorder unit. The system is equipped with a shaft encoder that translates the mechanical stage measurements into an electronic signal recorded by a data logger. The station is also equipped with a water quality sonde that measures water temperature and electrical conductivity (EC). Stage and water quality data are telemetered periodically via a geostationary orbit environmental satellite (GOES) system, and are available to the public on a provisional basis on the CDEC Web site at http://cdec.water.ca.gov under the daily station identifier code of “GRF.” Flow measurements are made at the station at least twice a month by Reclamation staff. A record of discharge is made in the field, and QC-checked and verified by Reclamation operations staff. A corrected monthly flow record consisting of mean daily flows for the station is produced that incorporates any required shift corrections. The corrected flow data are currently stored on the local network at the South Central California Area Office of Reclamation. Several existing data archives are under consideration for storing and retrieving SJRRP flow data (see Section 4.4). The corrected flow data will be archived in the system that is selected to store and retrieve flow data for the SJRRP.

3.2.3 San Joaquin River Below Chowchilla Bypass

The Settlement Agreement for restoration of the San Joaquin River requires that Interim Flows and Restoration Flows be measured immediately below the Chowchilla Bifurcation Structure (designated as Reach 3 on the applicable hydrograph). The Chowchilla Bifurcation Structure is located at RM 216, and controls the flow split between the mainstem San Joaquin River and the Chowchilla Bypass (Figure 3-1). This portion of the San Joaquin River is typically dry under presettlement operating conditions unless flood releases are being made from Friant Dam. An existing stream gage is located approximately 250 feet downstream from the structure on the right bank of the San Joaquin River. This gaging station was installed by FWUA and is currently operated by the San Luis and Delta-Mendota Water Authority under an agreement with Reclamation. This station is primarily used to monitor flood flows that are being routed through the structure and into Mendota Pool, and is not adequate for measuring the full range of Interim Flows and Restoration Flows anticipated at the site. The gage consists of a 4-foot-diameter corrugated metal stilling well structure with a 4-inch-diameter galvanized intake pipe (communication line) anchored to the stream channel. To measure the lower range of anticipated Interim Flows and Restoration Flows in the San Joaquin River channel downstream from the bifurcation structure, the stilling well will need to be deepened by approximately 10 feet, and the communication line would need to be extended approximately 30 feet into the deepest part of the stream channel. Reclamation will be the lead agency for retrofitting, operating, and maintaining the stream gage.

River stage will be measured continuously to the nearest 0.01 foot using a mechanical float and a Stevens recorder unit. The system will be equipped with a shaft encoder that translates the mechanical stage measurements into an electronic signal recorded by a data logger. The station will also be equipped with a water quality sonde that measures water temperature, EC, pH, dissolved oxygen (DO), and turbidity. Stage and water quality data will be telemetered periodically via the GOES system, and will be available to the public on a provisional basis on the CDEC Web site at http://cdec.water.ca.gov under the daily station identifier code of “SJB.” Flow measurements will be made at the station at least twice a month by Reclamation staff. Discharge records made in the field will be QC-checked and verified by operations staff. A corrected monthly flow record consisting of mean daily flows for the station will be produced that incorporates any required shift corrections. Several existing data archives are under consideration for storing and retrieving SJRRP flow data (see Section 4.4). The corrected flow data will be archived in the system selected to store and retrieve flow data for the SJRRP.

3.2.4 San Joaquin River Below Sack Dam

The Settlement Agreement for restoration of the San Joaquin River requires that Interim Flows and Restoration Flows be measured below Sack Dam (Figure 3-1, designated as Reach 4 on the applicable hydrograph). An abandoned stream gage present at the site is known as the San Joaquin River at Dos Palos gage (USGS Station 11256000). The stream gage is located on the left bank of the San Joaquin River approximately 3,800 feet downstream from Sack Dam, and approximately 7 miles east of the town of Dos Palos. The gage is currently not operational and has only been operated intermittently since 1954, when USGS ceased using it as a monitoring station. Reclamation used the station for monitoring stream flow in 1986, 1987, and 1995. The station consists of a corrugated metal stilling well housing with a single 2-inch-diameter galvanized intake pipe at the base of the stilling well.

The station will be retrofitted, operated, and maintained by DWR. DWR proposes to equip the San Joaquin River near the Sack Dam station with a WaterLog H350XL/H355 gas bubbler/data logger system, as well as a GOES transmitter (H-222DASE). The gas bubbler system is reliable and requires little maintenance. The gas bubbler system measures the amount of pressure exerted by the water column on the orifice at the end of plastic tubing attached to the bubbler. The data logger translates the pressure measurement as stage, from which stream flow can be estimated. The station will also be equipped with a water quality sonde that measures water temperature, EC, pH, DO, and turbidity. Stage and water quality data will be telemetered periodically via the GOES system, and will be available to the public on a provisional basis on the California CDEC Web site at http://cdec.water.ca.gov. The daily station identifier code for the station is to be determined. Flow measurements will be made at the station at least twice a month by DWR staff. A corrected monthly flow record consisting of mean daily flows for the station will be produced annually and will incorporate any required shift corrections. Several existing data archives are under consideration for storing and retrieving SJRRP flow data (see Section 4.4). The corrected flow data will be archived in the system selected to store and retrieve flow data for the SJRRP.

3.2.5 San Joaquin River at the Top of Reach 4B

The Settlement Agreement for restoration of the San Joaquin River requires that Interim Flows and Restoration Flows be measured at the top of Reach 4B (Figure 3-1, designated as Reach 5 on the applicable hydrograph). The San Joaquin River channel at this site currently conveys significant amounts of water only during periods of heavy runoff, such as in 2005 and 2006. Most of the time, the channel conveys only small quantities of drain water or local runoff. During periods of low flow, water in the San Joaquin River channel flows over a Parshall flume, located just upstream from the Washington Avenue Bridge, and into the Eastside Bypass. The flow capacity of the flume is not known; however, it is not large enough to measure the entire range of Interim Flows and Restoration Flows anticipated in the Settlement Agreement for this reach. It is also not known if the flume presents an obstacle to fish passage for the range of Interim Flows and Restoration Flows expected at this site. During times of high flows in the bypass, such as in 2005 and 2006, water backs into the river channel from the bypass channel, and can completely submerge the Parshall flume. Head gates at the top of Reach 4B currently prevent any water from flowing down the San Joaquin River into the Reach 4B channel. The head gates consist of four slide gates that are approximately 4 feet by 5 feet each. It is not known when the gates were last operated, but it appears to have been years or decades since this occurred. The flow capacity of the structure is also unknown. The Reach 4B channel downstream of the head gate structure is choked with vegetation. An abandoned stilling well, constructed for the purpose of measuring river stage, is located upstream from the head gate structure on the left bank, on the outside of a sharp bend in the river. USGS formerly measured at two stations in the general area: SJR, near El Nido 11260000, and SJR plus Chamberlain Slough, near El Nido 11260001. Both stations were used from 1939 to 1949. The abandoned stilling well is probably the former stream gage operated by USGS from 1939 through 1949, referred to as San Joaquin River near El Nido gage 11260000.

It has not been decided which channel will be used as the restored San Joaquin River at this site. Alternatives under consideration by the SJRRP include constructing the restored channel in the Eastside Bypass or in the Reach 4B channel, or using the Reach 4B channel as a low flow channel. For purposes of measuring Interim Flows and Restoration Flows at this site, beginning in October 2009, it is assumed that stream gages must be operational in both channels.

Two new stream gages will be constructed and operated by DWR at the top of Reach 4B. The monitoring station for the Reach 4B channel will be located on the right bank of the San Joaquin River, approximately 800 feet downstream from the Reach 4B head gates on the Old River channel (RM 168.3, Lat. 37 deg. 6 min. 47.96 sec N, Long. 120 deg. 35 min. 32.44 sec W). The monitoring station for the connector channel will be located on the left bank, approximately 200 feet downstream from the Parshall flume on the connector channel leading to the Eastside Bypass (RM 168.4, Lat. 37 deg. 6 min. 46.70 sec N, Long. 120 deg. 35 min. 18.51 sec W).

Stage and water quality sensors will be installed at the stations to monitor stream flow, as well as EC, pH, temperature, chlorophyll, turbidity, and DO. All stations will be equipped with a WaterLog H350XL/H355 gas bubbler/data logger combination, and a GOES H-222DASE transmitter. The gas bubbler system is reliable and requires little maintenance. The gas bubbler system measures the amount of pressure exerted by the water column on the orifice at the end of plastic tubing attached to the bubbler. The data logger translates the pressure measurement as stage, from which stream flow can be estimated. The gas bubbler system has a self-maintaining purging option to prevent sediment accumulation and system failure. Water quality measuring equipment will consist of a YSI 6600 V2-4 sonde water quality sensor for measuring the aforementioned quality parameters.

In addition to the electronic data collection and transmitting equipment, the following will also be installed: an air dessicator, a nonspillable 12-volt battery, and a solar panel/controller. Also, a new graduated staff gage will be placed at each site to visually note the stage of the river during field visits. Furthermore, concrete anchors 18 inches in diameter, 12 to15 inches deep, and cured for a minimum of 30 days, will be used to keep pipes that contain the bubbler tubing and sonde electrical lines stable while stream flow measurements and water quality parameters are recorded.

The stage and water quality data will be telemetered periodically via the GOES system, and will be available to the public on a provisional basis on the CDEC Web site at http://cdec.water.ca.gov. The daily station identifier code for the station is to be determined. Flow measurements will be made at the station at least twice a month by DWR staff. A corrected monthly flow record consisting of mean daily flows for the station will be produced annually that incorporates any required shift corrections. Several existing data archives are under consideration for storing and retrieving SJRRP flow data (see Section 4.4). The corrected flow data will be archived in the system selected to store and retrieve flow data for the SJRRP.

3.2.6 San Joaquin River at Merced River Confluence

The Settlement Agreement for restoration of the San Joaquin River requires that Interim Flows and Restoration Flows be measured at the confluence of the Merced River (designated as "confluence" on the applicable hydrograph). The term "confluence" refers to the junction of two streams. Four existing stream gages currently in operation near the junction of the San Joaquin and Merced rivers will be evaluated for the purpose of measuring the Interim Flows and Restoration Flows (Table 3-2, Figure 3-2).

Table 3-2.
Summary of Existing Monitoring Stations near the Merced River Confluence

Station	Agency	Parameters	Remarks
San Joaquin River at Fremont Ford Bridge (Station 11261500)	USGS	Flow, EC, temperature, pH, DO, Se, others	San Joaquin River water quality upstream of Grasslands discharge
San Joaquin River near Newman (Station 11274000)	USGS	Flow	Measures flow of San Joaquin and Merced rivers
Mud Slough near Gustine (Station 11262900)	USGS	Flow, EC, temperature, pH, DO, Se, others	Water quality of Grasslands drainage discharge
Merced River near Stevinson (Station 11272500)	USGS/DWR	Flow, EC, temperature, pH, DO, Se, others	Measures Merced River water quality upstream from the confluence with San Joaquin River
Salt Slough near Stevinson (Station 11261100)	USGS	Flow, EC, temperature	Measures Salt Slough water quality

Key:
DO = dissolved oxygen
DWR = California Department of Water Resources
EC = electrical conductivity
Se = selenium
USGS = United States Geological Survey

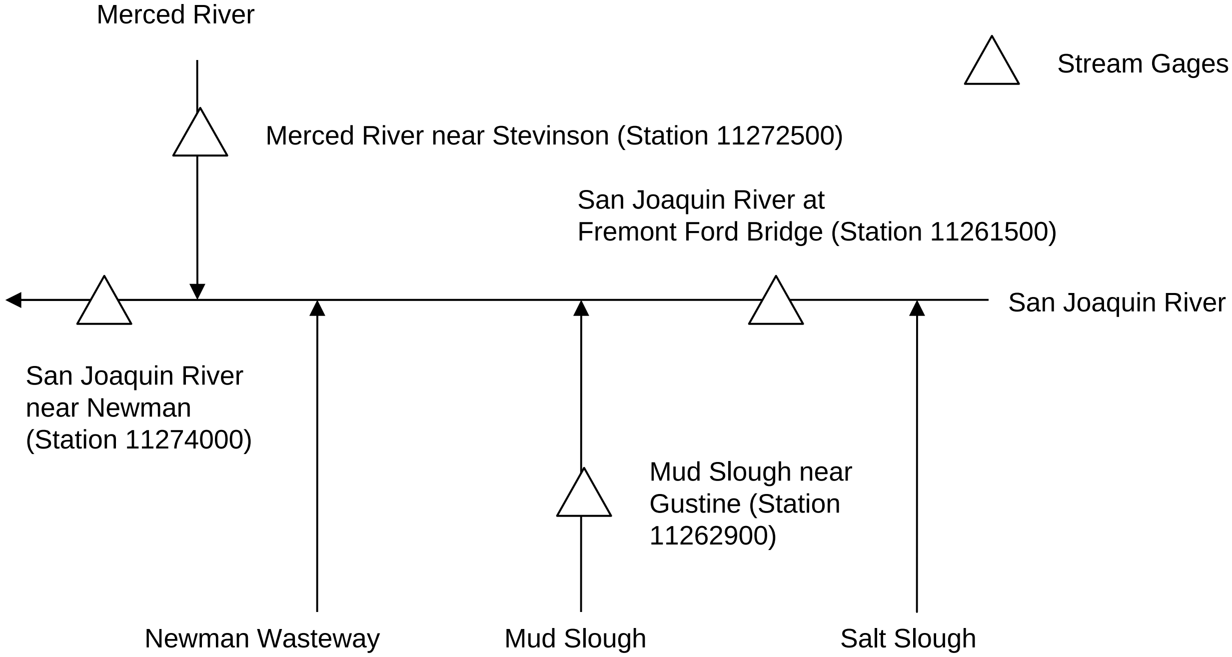

Figure 3-2.
Schematic Showing Existing Stream Gages near the Confluence of the San Joaquin and Merced Rivers (not to scale)

Three alternatives are under consideration for determining the flow of the San Joaquin River at the Merced River confluence. The first alternative consists of using the San Joaquin River at Newman gage in combination with the Merced River near Stevinson gage to determine the flow. The second alternative consists of using the gage on the San Joaquin River at Fremont Ford Bridge (California Highway 140 crossing) in combination with the Mud Slough near Gustine gage to determine the flow at the confluence. The third alternative is to establish a new stream gage on the San Joaquin River just upstream from the junction with the Merced River.

Alternative 1

USGS operates the San Joaquin River near Newman gage (Station 11274000), located approximately 3 miles northeast of the town of Newman in Stanislaus County. The gaging station is on the left bank of the San Joaquin River 650 feet downstream from the confluence with the Merced River, and measures the combined flows of both the San Joaquin and Merced rivers. The gage has been in operation since 1912, and corrected flow data are published annually and input into the National Water Information System (NWIS) database, which is available to the public. Flow at the Newman gage could be used in combination with flow measured on the Merced River near Stevinson gage (Station 11272500) to estimate flow of the San Joaquin River at the confluence. The Stevinson gage is located on the right bank of the Merced River, 4.4 miles upstream from the confluence with the San Joaquin River (Figure 3-2). DWR operates the Stevinson gage on the Merced River. The Stevinson gage has been in operation intermittently since 1940, and corrected flow data are published annually and input into the NWIS database, which is available to the public. Merced River flow measured at the Stevinson gage could be subtracted from the combined flow of the Merced and San Joaquin rivers measured at the Newman gage to estimate flow on the San Joaquin River at the confluence of the two rivers.

Alternative 2

USGS operates a stream gage on the San Joaquin River at the Fremont Ford Bridge (Highway 140 crossing, Station 11261500), located approximately 2 miles downstream from Salt Slough in Merced County (Figure 3-2). The gaging station is on the left bank of the San Joaquin River, 6.7 miles upstream from the confluence with the Merced River. The gage has been in operation intermittently since 1937, and corrected flow data are published annually and input into the NWIS database, which is available to the public. Flow at the Fremont Ford Bridge gage could be used in combination with flow measured at Mud Slough (the last major tributary to the San Joaquin River upstream from the confluence with the Merced River) to estimate flow at the confluence with the Merced River. The Mud Slough gage is operated by USGS, and is located on the right bank of Mud Slough at the terminus of the San Luis Drain, approximately 6 miles upstream from the confluence with the San Joaquin River (Figure 3-2). The Mud Slough gage has been in operation since 1985, and corrected flow data are published annually and input into the NWIS database, which is available to the public. Flow measured at the Mud Slough gage could be added to flow measured at the Fremont Ford Bridge gage to estimate flow on the San Joaquin River at the confluence of the Merced River.

Alternative 3

A new stream gage could be installed on the San Joaquin River just upstream from the confluence of the Merced River. Considerations for siting a new station include measurement of flows from the Newman Wasteway; backwater effects from the Merced River at high flow; potential flow in bypass channels at high flow; the mobile nature of the streambed in Reach 5; and accessibility to a new stream gage site. If Alternatives 1 or 2 discussed above will provide estimates of the Interim Flows and Restoration Flows at the Merced River confluence that are as good or better than those of a new stream gage, a new gage would not be necessary to fulfill the requirements of the Settlement Agreement. The decision to use existing gages will be made based on consultation with the Implementing Agencies and Settling Parties after an analysis of the existing monitoring network is completed.

4.0 Measuring Methods and Reporting

This section describes procedures for measuring river state and discharge, and disseminating, reporting, and archiving flow data.

4.1 Measurement Procedures

Much of the language in the following paragraphs describing the measurement of stage and discharge, and dissemination of data is excerpted from the USGS publication Stream-Gaging Program of the U.S. Geological Survey – U.S. Geological Survey Circular 1123 (Wahl, Thomas, and Hirsch, 1995).

The basic measurement made at each stream gaging station is the river stage, which is the height of the water surface above a reference elevation. Stream discharge (flow) is derived from stage data through use of a relation between stage and discharge. The stage-discharge relation for a specific stream location is defined from periodic discharge measurements made at known stages.

The most common method of measuring the stage of a river is through use of a stilling well. Stilling wells are located on the bank of a stream or on a bridge pier and are topped by a shelter that holds recorders and other instruments associated with the station. The well is connected to the stream by several intakes such that when the water level changes in the stream, the level simultaneously changes in the well. Thus, the water surface in the well is maintained at the same level (stage) as the water surface of the stream. The well damps out momentary fluctuations in the water surface in the stream because of waves and surging action that may be present in the river. An outside reference gage, typically a graduated staff gage, is read periodically to verify that the water level in the well is indeed the same as the water level in the stream, and that the intakes are not plugged. As the water level in the well rises or falls, a float in the well also rises or falls. A graduated tape or beaded cable attached to the float, and with a counterweight on the other end, is hung over a pulley. This pulley drives a recording device. Historically, the recording device would have used a pen that recorded a graph of the river stage as it changed with time. The gaging stations at Friant Dam, Gravelly Ford, and the Chowchilla Bifurcation Structure are equipped with stilling wells.

In some cases, stilling wells are impractical because of difficulties either in installation or operation. Stations that use a bubbler system are an alternative because the shelter and recorders can be located hundreds of feet from the stream. In a bubbler system, an orifice is attached securely below the water surface and connected to the instrumentation by a length of tubing. Pressurized gas (usually nitrogen or air) is forced through the tubing and out through the orifice. Because the pressure in the tubing is a function of the depth of water over the orifice, a change in the stage of the river produces a corresponding change in pressure in the tubing. Changes in the pressure in the tubing are recorded and are converted to a record of the river stage. The gaging stations below Sack Dam and at the top of Reach 4B will be equipped with gas bubbler systems.

4.2 Measuring Discharge

The most practical method of measuring the discharge of a stream is through the velocity-area method. This method requires the physical measurement of the cross-sectional area and the velocity of the flowing water. Discharge is determined as the product of the area times the velocity. Velocity is measured by using a current meter. The meter consists of a propeller rotated by the action of flowing water. The rotation depends on the velocity of the water passing by the propeller. With each complete rotation, an electrical circuit is completed and recorded in some fashion. Given the number of revolutions in a given time interval, velocity can be determined for the location of the current meter.

Measuring the average velocity of an entire cross section is impractical; therefore, an incremental method is used. The width of the stream is divided into a number of increments; the size of the increments depends on the depth and velocity of the stream. The purpose is to divide the section into about 25 increments with approximately equal discharges. For each incremental width, the stream depth and average velocity of flow are measured. For each incremental width, the meter is placed at a depth where average velocity is expected to occur. That depth has been determined to be about 0.6 of the distance from the water surface to the streambed when depths are shallow. At greater depths, the average velocity is best represented by averaging velocity readings at 0.2 and 0.8 of the distance from the water surface to the streambed. The product of the width, depth, and velocity of the section is the discharge through that increment of the cross section. The total of the incremental section discharges equals the discharge of the river.

When the stage is low, and the stream can be waded, measurements are made by wading with the current meter mounted on a wading rod. The meter is positioned at the appropriate depth on the wading rod, which also is used to measure the water depth. If the water is too deep for wading, the measurement is made either from a boat, bridge, or cableway across the stream. If the measurement is made from a boat, bridge, or cableway, the meter is suspended on a thin cable wound on a reel. A torpedo-shaped weight is attached below the meter to permit it to be lowered into the water and to hold it in position once submerged. If measuring from a bridge, the reel is mounted on a wheeled frame (or crane) that permits the lowering of the meter assembly over the bridge rail; from a cableway, the reel is mounted in a cable car suspended from the cableway that crosses the river.

4.2.1 Acoustic Doppler Current Profiler

The acoustic Doppler current profiler (ADCP) is an acoustic instrument used to measure water velocities, boat velocities, and water depths. Water-velocity measurements are made by transmitting sound at a known frequency into the water and measuring the Doppler shift, or change in sound frequency, from signals reflected off particles in the water. ADCPs also can measure water depths and, when deployed from a moving boat, can measure velocity of the boat. The capability of ADCPs to measure water velocity, depth, and boat velocity enables them to measure discharge in rivers. United States Department of the Interior agencies have used the ADCP to measure discharges in rivers and streams since the mid-1980s, and an ADCP was used during hydrographic surveys on the San Joaquin River in 2005. The primary advantages of making discharge measurements using the ADCP, compared with point velocity meters such as the Price AA current meter, are that in most situations (1) the time required to complete a measurement is reduced, which is an advantage for personnel safety and for making measurements in unsteady-flow conditions, (2) the ADCP allows data to be collected throughout most of the water column and cross section rather than at discrete points, (3) the ADCP is deployed at the water surface, thus appreciably reducing the chance of snagging by debris, another safety advantage, (4) the instrument can be boat-mounted, thus eliminating the installation, maintenance, and liability of costly manned cableways, (5) complex flow regimes, such as vertical bidirectional flow, can be accurately identified and measured, and (6) many parameters are available for analyzing measurement quality. Where it is appropriate, the ADCP will be used to supplement discharge measurements made on the San Joaquin River using point velocity meters. Discharge measurements made with the ADCP will follow quality assurance guidelines established by USGS (Oberg, Morlock, and Caldwell, 2005).

4.2.2 Determining a Continuous Record of Discharge

Rating curves will be used to derive stream flow from stage data at each stream gage. The stage-discharge relation is used to relate river stage to an associated stream flow. The rating curve for each gage site will be developed by making successive stream flow measurements at many different stream stages to define and maintain a stage-discharge relation. These stream flow measurements, and their corresponding stages, are then plotted on a graph. Continuous stream flow throughout the year can be determined from the rating curve and the record of river stage. The rating curve is important because it allows the use of river stage, which is easily measured, to estimate the corresponding stream flow at virtually any stream stage.

The stage-discharge relationship for the stream gages located in the sand-bedded reaches of the San Joaquin River (i.e., Reaches 2 through 5) are not expected to be permanent. Scour and deposition, as well as the growth of riparian vegetation, can alter the channel cross section and roughness, thus changing the stage-discharge relation at the gage site. Discharge measurements will be made at least twice a month, and more frequently, if feasible, during and immediately following high-flow events (i.e., spring and fall pulse flows and flood flows) to assess the stage-discharge relationship at the gage. Shift corrections (adjustments in stage) will be applied to the base stage-discharge rating in computing the final discharge record for the gage.

Real-time data provided by USGS are shift-corrected, incorporating mathematical adjustments for ease of use. The shift adjustments will be applied to individual ratings, as measured data become available, resulting in an adjusted rating. Some ratings may change as often as weekly; others may not change for months or years.

Because the relationship between stage and discharge may vary with time, discharge is known only with certainty at the time of discharge measurements. If the relationship is changing, then judgement must be used to determine the most probable status of the stage-discharge relationship for times between discharge measurements. In fact, changes in the stage-discharge relationship may not be evident until a whole series of measurements is available for analysis. Therefore, the computational process usually has the following steps:

1. Following a measurement, a preliminary evaluation is made of the degree to which the stage-discharge relationship has changed on the basis of measurements made to that time. Provisional discharges are determined, assuming that the most recent measurements define the channel condition.

2. This process is repeated following each measurement. However, with each measurement, more measurements are available to evaluate the stage-discharge relationship. This may lead to changes in the provisional discharges that were computed for previous months.

3. At the end of the year, all measurements are available for review. The entire set of measurements is used to reevaluate rating conditions for the year. Final decisions are made about the stage-discharge relationships in effect during the year, and the record is refined or recomputed, as necessary. This record is then passed through a rigorous review process and, once approved, the data are considered final and are placed in the archives and published.

4.3 Disseminating Provisional Data

Primary gaging stations for the SJRRP will be equipped with satellite telemetry and electronic data loggers that use a 12-volt battery power supply with a solar panel recharging system. The data loggers will monitor and record gage heights at 15-minute intervals. The data will be periodically transmitted to a GOES using a radio transmitter. The stations will typically transmit data every 4 hours. The data are relayed via the satellite to a ground station and, in turn, via landline to a computer system operated by DWR or USGS. Computer software decodes the data, which often (but not always) arrive in binary format, and places the data in a format that hydrologic data processing software can recognize. Gage-height data are stored and manipulated to provide stream flow in cfs. Software continuously accesses the various data files (site information, gage height, and discharge) and portrays the information graphically. Provisional real-time stream flow and water quality data for the primary monitoring stations will be made available on the Internet via the CDEC Web site, at http://cdec.water.ca.gov, or USGS Web site, at http://www.usgs.gov.

Automated telemetry provides water data users with provisional stage and discharge information in a time frame that meets water-management needs. This technology will permit field offices to monitor operation of the hydrologic stations continuously, time visits to stations to coincide with times of maximum need for data (such as during floods), and service equipment at the stations.

4.4 Reporting and Archiving Flow Data

Reporting and archiving of flow data are discussed in this section.

4.4.1 Reporting Flow Data

Daily discharge data (mean daily flows) will be published on a water-year basis for each primary monitoring station for the SJRRP. A water year is the 12-month period from October 1 through September 30, and is designated by the calendar year in which it ends. Because of the need for review of the completed computations, these reports will be published from 3 to 6 months after the end of the water year.

4.4.2 Archiving Flow Data

Daily flow data for the existing primary monitoring stations on the San Joaquin River are currently stored in several data archives. One or more of these existing data archives will be adequate to serve the needs of the SJRRP for storing and retrieving the flow data. A brief description of the alternatives under consideration for archiving the flow data follows:

- CDEC – California Data Exchange Center (State of California)

  http://cdec.water.ca.gov/

  CDEC provides a centralized location to store and process real-time hydrologic information gathered by various cooperators throughout the State. The focus of CDEC is solely to distribute provisional real-time data. Therefore, it is important to note that none of the data available from CDEC are quality controlled.

- CVO – Central Valley Operations (Reclamation)

  http://www.usbr.gov/mp/cvo/

  The CVO maintains an internal database with a variety of reservoir- and operations-related data. Some of the data are publicly available in the form of automated daily and monthly reports posted to the Web site. Some of the data are also posted to CDEC, such as flows released to the San Joaquin River from Friant Dam.

- IIMS – Integrated Information Management System (Reclamation)

  http://www.trrp.net/science/IIMS.htm

  IIMS is a local data repository with some built-in data visualization tools, and is currently under development by Reclamation. IIMS will contain a variety of multidisciplinary spatial and tabular data. IIMS is being developed with a generalized database architecture to facilitate easy deployment across multiple Reclamation offices; data sharing; and standardization of data formats.

- IWRIS – Integrated Water Resources Information System (State of California)

http://gis.wrime.com/iwris/

IWRIS is a pilot project currently under development by the Conjunctive Water Management Branch of DWR. IWRIS is being designed to serve as a central data portal for a variety of conjunctive water-management-related data in a network of distributed local databases. Data are accessed from one integrated, geographic information system (GIS) based graphical user interface. IWRIS provides the capability to integrate data and model/analysis results with GIS map layers for decision support purposes.

DWR is considering using Proposition 84 funding to expand the IWRIS effort to cover a much wider array of data in an effort to facilitate local water planning efforts and development of Bulletin 160. The proposed expansion is called Water Planning Information Exchange (WPIE).

- NWIS – National Water Information System (USGS)

http://waterdata.usgs.gov/nwis

NWIS is a large public online central database that stores water resources data (surface water, groundwater, water quality) for approximately 1.5 million sites across the United States. Published, quality-controlled data are available as well as provisional real-time and provisional recent daily data.

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