Executive Summary

Background

The Sacramento River Settlement Contractors and U.S. Bureau of Reclamation are currently completing the Sacramento River Basinwide Water Management Plan. Among the numerous water management improvement options evaluated in the Basinwide Water Management Plan, water measurement was identified as an area requiring additional investigation to promote continued reuse and optimal management of water supplies. To assess the potential for improved water measurement, this Sub-basin-level Water Measurement Study (Measurement Study) was undertaken. Because the Measurement Study, as originally proposed, was not fully funded, the scope of work was refined to focus on evaluating sub-basin outflow. An improved understanding of sub-basin outflow, in terms of quantity and timing, would help support regional water management in the Sacramento Valley.

Measurement Study Objectives

The objectives of the Measurement Study are as follows:

- Investigate and document the existing sub-basin outflow water measurement facilities.
- Evaluate and recommend facility improvements to achieve higher levels of accuracy and/or data collection if deemed appropriate.
- Provide cost estimates for recommended measurement facility improvements.
- Identify potential issues of implementing a regional approach to water measurement operations, data collection, and use.
- Identify the potential benefits of improved sub-basin-level water measurement.

Relationship to CALFED Objectives and Other Regional Efforts

Consistent with the Basinwide Water Management Plan, this Measurement Study recommends the implementation of an ongoing Sub-basin-level Water Measurement Program (Measurement Program). The proposed Measurement Program would contribute to the goals of the CALFED Bay-Delta Program. Implementation of a coordinated Measurement Program would be consistent with CALFED's Water Use Efficiency Program by assisting with water use efficiency evaluation at the sub-basin level. The proposed Measurement Program would also have benefits that support overall Sacramento Valley water management and goals of the CALFED Watershed Management Program. In addition, this Measurement Program is complementary to the Sacramento Valley Water Management Agreement, which is a cooperative basin-wide approach to providing supplies to help meet water quality standards in the Delta while providing supply to water-short regions of the Sacramento Valley and for transfer to Central Valley Project and State Water Project users.

Recommendations for Outflow Measurement Improvement

The Measurement Study evaluated existing facilities and methods of outflow measurement in the following four Sacramento Valley sub-basins: the Colusa Sub-basin, the American Sub-basin, the Butte Sub-basin, and the American Sub-basin. Due to limited funding and the complexity of the Redding Sub-basin, it was excluded from this Measurement Study. The Measurement Study focused on areas served mostly by Sacramento River Settlement Contractors; therefore, the Measurement Study addresses only portions of the outflow from the Colusa, American, Butte, and Sutter Sub-basins. Details of the areas covered by the Measurement Study and the existing measurement methods and facilities are provided in this technical memorandum.

Based on this Measurement Study, changes are suggested to existing measurement facilities and methods to improve the understanding of the quantity and timing of sub-basin outflow. The total estimated cost to implement all of the measurement improvements recommended in this Measurement Study is approximately $155,000. The annual operations and maintenance costs associated with data collection and processing, calibration, and general upkeep of the measuring and logging equipment are estimated to be approximately $60,000. It is recommended that funding on the order of approximately $275,000 be sought to implement an initial 2-year phase of the Measurement Program. These funds would be used to purchase and install equipment where needed and calibrate new and existing measuring devices to improve or ensure the accuracy of outflow measurement within the four Sacramento Valley sub-basins identified above. In addition, these funds would provide for the operation and maintenance of the measuring devices for the first 2 years of the proposed Measurement Program. Longer-term implementation would require $60,000 annually (in today's dollars) for operation and maintenance.

Implementation Benefits

Implementation of the Measurement Program would provide an improved understanding of sub-basin outflow, which, in turn, would assist in water balance analyses. In addition, the outflow information would lead to the following potential benefits, which are consistent with CALFED Quantifiable Objectives:

- Improved understanding of sub-basin outflow to evaluate opportunities for improved management
- Coordinated management of sub-basin outflow
- Maximized benefits from other regional actions
- Possible integration with future sub-basin-level water quality monitoring program
- Confirmation or revision of CALFED Quantifiable Objectives

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section 1 Introduction and Background

Measurement of agricultural water supplies is essential to water management, particularly in a climate of increasing water demands from growing urban areas and environmental purposes. Changing demands on finite and highly variable water supplies in the Sacramento Valley have led to the need for a greater understanding of the water balance.

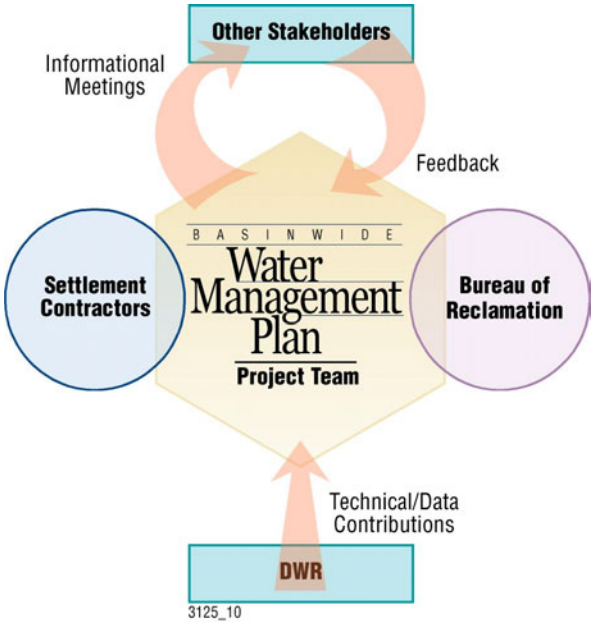
Although the majority of total water demands in the Sacramento Basin continue to come from agriculture, other factors continue to complicate water use management, including increasing water demands from urban areas, more focused attention to environmental uses, and improved hydrologic understanding of the Sacramento Valley region and the Sacramento-San Joaquin River Bay-Delta system (the Delta or Bay-Delta).

The Sacramento River Settlement Contractors (SRSC) and U.S. Bureau of Reclamation (Reclamation) are currently completing the Sacramento River Basinwide Water Management Plan (BWMP). The primary objectives of the BWMP include the following:

1. Provide a common set of data to serve as the basis of contract renewal negotiations
2. Document district, sub-basin, and basin-wide water requirements and supplies
3. Identify management tools and potential approaches to match water supply and requirements while identifying opportunities for environmental enhancement

Among the numerous water management improvement options evaluated in the BWMP, water measurement was identified as an area requiring additional investigation. Given the relatively high degree of water reuse both within and between districts, the BWMP recommended that water management and associated measurement at a sub-basin level should be further evaluated to promote continued reuse and optimal management of inter-district water use. To assess the potential for improved water management and, accordingly, measurement at a sub-basin level in the Sacramento Valley, this Sub-basin-level Water Measurement Study (Measurement Study) was initiated. This Measurement Study is a step toward implementing the Sub-basin-level Water Measurement Program (or Measurement Program) that focuses on increasing the accuracy of the accounting of sub-basin inflow and outflow.

This technical memorandum summarizes the findings of the Measurement Study, which was funded by a CALFED Water Use Efficiency (WUE) Program grant. This



technical memorandum also summarizes a preliminary investigation of potential measurement locations, facilities, and associated implementation issues, which would allow for water measurement for up to five Sacramento Valley sub-basins that are addressed in the Sacramento Valley BWMP. Reclamation District (RD) 108 received a $100,000 grant from the CALFED WUE Program on behalf of the BWMP participants in response to a proposal to evaluate the implementation of a Sub-basin-level Water Measurement Program. The original Measurement Study proposal included an extensive evaluation, design, permitting, and construction program totaling approximately $7.5 million. Included within the proposal was a feasibility study to identify potential locations, appropriate structures and devices, permitting requirements, implementation issues, and related estimated costs.

Because the full program and related feasibility study were not fully funded, the scope of work was refined to maximize the available funds toward gaining the greatest understanding of a potential Measurement Program. In general, the major diversions from the Sacramento River into the sub-basins are measured by the SRSCs and Reclamation. Other inflows in many cases have not been quantified, but are thought to represent a smaller fraction of the overall water supply. Because outflow data are much less available and generally considered the largest uncertainty in sub-basin water balances, this Measurement Study focuses on evaluating sub-basin outflow during the irrigation season.

Measurement Study Objectives

Development of the Measurement Study objectives grew out of an understanding of Sacramento River Valley hydrology. The majority of the irrigated lands are part of a hydraulic system where agricultural return flows run downstream to other water users or return to the river for subsequent diversion.

Hydrologic Characteristics of the Sacramento Basin

Generally, the Sacramento Basin may be characterized as a "flow-through" system, in that the vast majority of the water that is not consumptively used eventually returns to the river. Water used for irrigation is returned to the river via drains that carry surface runoff away from fields. Water may also percolate into the ground, where it recharges groundwater supplies. Groundwater levels remain high in the Sacramento Valley. In some areas, groundwater is tributary or adds to the river flows during normal or wet years. Excess groundwater may also enter nearby drains and return to the river system as drainwater.

All of the water returned to the river system is reused by downstream water users or is used to meet Delta outflow requirements. Therefore, the actions of upstream users can have a considerable effect on agricultural users and other entities located downstream. Although water from the river is used efficiently, the timing of diversions and return flows may affect water availability at other locations in the system, necessitating effective water management.

Agricultural water requirements are met through both surface water and groundwater supplies, as well as reused or recirculated drainwater. Each sub-basin may meet its specific requirements using the optimal combination of sources, depending on basin-specific needs and characteristics. The Sacramento River and its tributaries are the primary sources of surface water for users in the Sacramento Valley. All sources must be recharged by precipitation, which can vary significantly from year to year. Flows within

the Sacramento River are also influenced by the operation of the Shasta, Keswick, and Oroville Dams, and other climatic and infrastructure requirements. Water rights and contractual allocations also dictate the use of surface water.

Although SRSCs primarily rely on surface water, groundwater is also used to augment surface supplies, particularly during dry periods. Major aquifers in the Sacramento Basin include the Redding Groundwater Basin and the Sacramento Valley Groundwater Basin. In general, groundwater is a minor source of supply because of relatively higher pumping and equipment costs. Areas with less senior and less reliable water rights rely on groundwater more extensively. Groundwater is also a significant domestic supply source for individual farmsteads and small towns. The American Sub-basin is the most groundwater-dependent sub-basin within the Sacramento Basin mostly due to urban groundwater use in the Sacramento metropolitan area (Reclamation, 2001).

Drainwater is another important source of water and is provided by runoff from fields and groundwater seepage into the drains. The source of this water is mainly diverted water from the Sacramento River upstream of the drainwater user. Although not a new source of water, reuse of drainwater allows water users to manage the timing and quantity of water delivered, providing flexibility and maximizing water use efficiency in a region. Because of extensive water reuse within and between districts, water use efficiencies in the Sacramento Basin sub-basins have been estimated to be as high as 90 percent. Conservation programs have been developed by several SRSCs. Many of these conservation programs rely on recirculation and reuse of drainwater and reduced river diversions. However, these practices can substantially impact downstream users and are limited by leaching and associated crop salinity tolerances. Therefore, good communication across sub-basins is necessary to avoid conflicts. Water quality concerns resulting from drainwater reuse also impacts management practices.

Water measurement practices vary widely within sub-basins in terms of mechanical operation, target accuracy, and level of distribution system. Measurement techniques depend on several factors, including the type of delivery, scheduling, presence of channel lining, component of recycled water, irrigation method, available funding, and site-specific constraints.

Study Objectives

This Measurement Study builds on the BWMP investigations to improve water measurement as one means of improving water management in the Sacramento Valley. The objectives of the Measurement Study are as follows:

- Investigate and document the existing sub-basin outflow water measurement facilities
- Evaluate and recommend facility improvements to achieve higher levels of accuracy and/or data collection if deemed appropriate
- Provide cost estimates for recommended measurement facility improvements

- Identify potential issues of implementing a regional approach to water measurement operations, data collection, and use
- Identify the potential benefits of improved sub-basin-level water measurement

Scope of Measurement Study

The scope of this Measurement Study includes preliminary steps toward the implementation of a Measurement Program in the Sacramento Valley. Work on this project was funded by a grant received by RD 108 from the CALFED WUE Program on behalf of the BWMP participants to conduct a preliminary investigation of potential measurement locations, facilities, and associated implementation issues on a sub-basin level. Consistent with the BWMP, the sub-basins included in this Measurement Study are as follows (see Figure 1-1):

- Colusa Sub-basin
- American Sub-basin
- Butte Sub-basin
- Sutter Sub-basin
- Redding Sub-basin

The Redding Sub-basin was excluded from this first phase of Measurement Study due to its complexity and the limited budget. It is recommended that future efforts evaluate the Redding Sub-basin with respect to the potential for measuring outflows and internal sub-basin water management in concert with the ongoing Redding Area Water Council/Shasta County investigations.

Currently, the majority of the surface water supply available to each of the sub-basins is derived from the Sacramento River. Water diverted by the SRSCs is measured by the SRSCs and Reclamation. In many cases, other inflows have not been quantified, but in general are thought to represent a small fraction of the overall water supply. Outflow data are much less available and generally are considered the largest uncertainty in estimating a sub-basin-level water balance in the Valley.

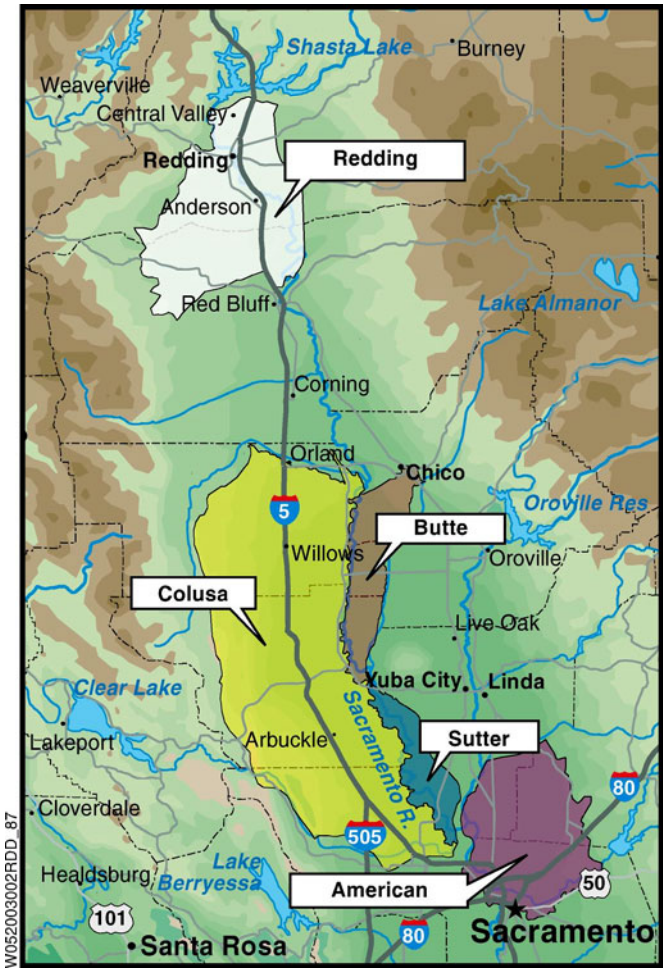


Figure 1-1
Sub-basins

Accordingly, outflow measurement sites were the focus of the investigation with respect to potential locations and facilities. Existing measurement locations and the entity responsible for their operation were documented. This Measurement Study also recommends improvements to increase the accuracy of sub-basin outflow measurement. In addition, issues were identified for implementing a Sub-basin-level Water Measurement Program related to funding,

operation and maintenance (O&M), sub-basin coordination, and data sharing.

Data Collection Approach

Sub-basin coordinators (SRSC district/ company managers) were identified as part of this Measurement Study to bring in local expertise and to review study findings. The coordinators also facilitated data collection and field visits to each of the sites.

First, sub-basin coordinators provided existing data on existing and potential measurement locations. Examples of data collected include existing facility locations, maps, and historical flow data. Sources of data also included SRSCs, reclamation districts, California Department of Water Resources (DWR), and other sources, as appropriate. Additional information was collected from several sources regarding potential implementation issues relating to the installation and operation of sub-basin-level water measurement facilities.

Next, locations were visited and reviewed, and potential measurement sites and facilities were identified and prioritized. These sites were chosen because they are considered critical points for outflow measurement, and increased accuracy of such measurement would afford water management benefits to SRSCs and water users throughout the Sacramento Valley. The outflow measurement site locations in this preliminary study are listed below (individual sub-basin maps showing the outflow measurement site locations are presented later in this section):

- Colusa Sub-basin
  - Knights Landing Outfall Gates
  - Knights Landing Ridge Cut
- American Sub-basin
  - RD 1000 Outflow
- Butte Sub-basin
  - RD 1004 Outflow
- Sutter Sub-basin
  - RD 1500 Outflow
- Redding Sub-basin
  - Measurement sites were not identified for the Redding Sub-basin in this preliminary study

Reconnaissance-level preliminary costs were developed for the facilities determined to be most appropriate for a given outflow location. Appropriate facilities may consist of new facilities, modification of existing facilities, or both. A potential time frame for implementation at each point was identified, noting any anticipated implementation issues that could arise at each site.

Relationship to CALFED Objectives and Other Regional Efforts

CALFED Bay-Delta Program

The proposed Measurement Program would contribute to the goals of the CALFED Bay-Delta Program. CALFED aims to restore ecological health and improve water management for beneficial uses of the Bay-Delta, which includes the entire Sacramento River watershed. Implementation of a coordinated Sub-basin-level Water Measurement Program would be consistent with the goals of CALFED's WUE Program and the Watershed Management Program.

The goal of the WUE Program is to make the best use of existing water supplies by defining appropriate water measurement techniques, certifying best management practices, and refining quantifiable objectives for agricultural water use efficiency. This program would assist in evaluating water use efficiency at the sub-basin level and

would contribute to quantifiable improvements in water management by studying the feasibility of implementing more accurate water measurement at the sub-basin level.

The proposed coordinated Measurement Program, which is a component of the ongoing BWMP activities, would have benefits that support overall Sacramento Valley water management and goals of the CALFED Watershed Management Program. This Measurement Program aims to improve water measurement and make the data available for water operations and long-term planning. Improved sub-basin-level data may support improved use of existing water supplies, operational flexibility, and coordinated management.

Sacramento Valley Water Management Agreement

This Measurement Study is also complementary to the Sacramento Valley Water Management Agreement (SVWMA), which was signed in 2002 to avoid litigation related to Phase 8 Hearings of the State Water Resources Control Board for the Bay-Delta Water Quality Control Plan. The SVWMA is a cooperative basinwide approach to providing supplies to help meet water quality standards in the Delta, while providing supply to water-short regions of the Sacramento Valley, and for transfer to Central Valley Project and State Water Project users.

This Measurement Study also has been proposed as a short-term and long-term component of the SVWMA. Implementation of a coordinated Sub-basin-level Water Measurement Program will not provide direct water supply yield, but may assist in evaluating overall water use efficiency in the Valley and provide re-routed flows to help meet CALFED's quantifiable objectives. A sub-basin approach to water measurement may also facilitate cooperative management of Sacramento Valley water resources.

Other Local and Regional Management Plans

Within the Colusa Sub-basin, water users began coordinated sub-basin management through the transfer of water among users and the continued evaluation of the conjunctive use of surface water and groundwater. These efforts have resulted in improved communication among the water users within the sub-basin. Improved management will assist in sustaining long-term production agriculture and is based on the collective knowledge of historical flows and water needs within the sub-basin, together with a mutual desire to optimize water management. This Measurement Program would assist these water users in optimizing water management and ensuring sustainable agriculture within the sub-basin.

Within the American Sub-basin, management efforts have begun through the Sacramento Area Water Forum, of which Natomas Central Mutual Water Company (NCMWC) is a member. Various potential groundwater and conjunctive use projects are being investigated by the Sacramento Groundwater Authority and the American River Basin Cooperating Agencies. This project complements these efforts.

Sub-basin Descriptions

The scope of the BWMP and this Measurement Study includes 3,500 square miles in the Sacramento Basin from Shasta Dam to the confluence of the Sacramento and American Rivers. The American and Feather Rivers are included to the extent that they contribute as major tributaries to the Sacramento River. The BWMP identified five hydrologic sub-basins that included the service areas of the SRSCs who participated in the BWMP. The boundaries of each of the sub-basins were developed based on existing DWR data and hydrologic boundaries.

The sub-basins, shown on Figure 1-1, are as follows:

- Colusa Sub-basin
- American Sub-basin
- Butte Sub-basin
- Sutter Sub-basin
- Redding Sub-basin (included in the BWMP, but not investigated as part of this Measurement Study)

For the purpose of the BWMP and this Measurement Study, water management and strategy development are recommended to be conducted on a sub-basin level for several reasons.

First, this approach allows relationships between users to be maximized within each sub-basin. Managing on this scale allows greater opportunity for accurately matching supplies and demands and is consistent with actual water management practices in the Sacramento Valley. However, the approach is encompassing enough to allow management variations within sub-basins for the most optimal use of resources and best opportunity to meet regulatory requirements. This management level also encourages stakeholder participation and creativity in developing solutions to supply-and-demand discrepancies. The sub-basins defined in the BWMP and used in the Measurement Study are detailed below.

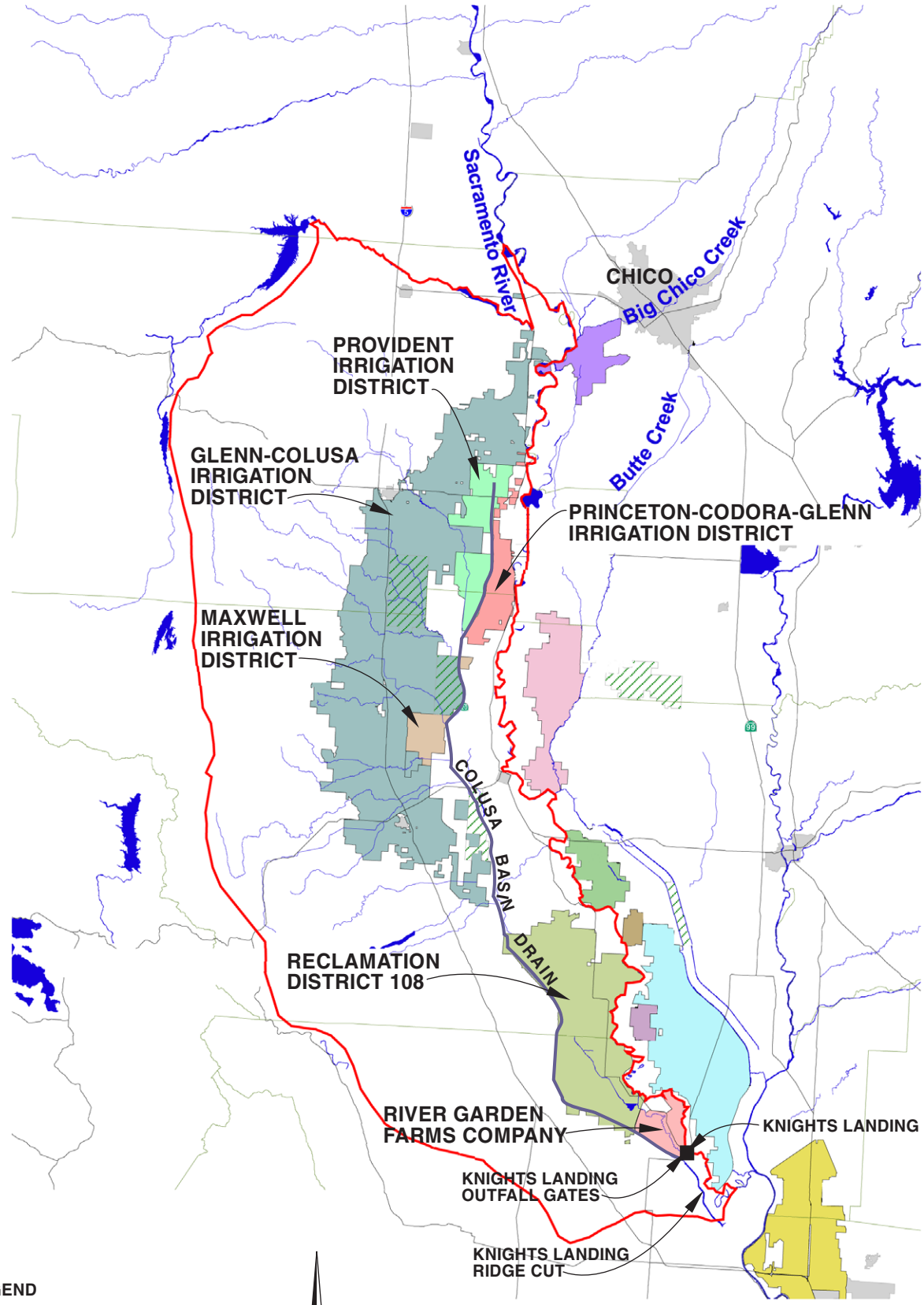
Colusa Sub-basin

The Colusa Sub-basin represents the west side of the Sacramento Valley and is bounded on the east by the Sacramento River and by the coastal mountain range to the west. Stony Creek is the northern boundary, and Cache Creek is the southern boundary. Figure 1-2 shows the extent of the Colusa Sub-basin.

Surface water accounts for approximately 60 to 65 percent of the water used in Colusa Sub-basin. (Contractually, SRSCs account for 50 to 55 percent of total water supply, and water service contractors contribute 5 to 10 percent.) Additionally, 20 percent of the water need is supplied by groundwater, and 17 percent by drainwater. Drainwater reuse is extensive, and drainwater from upstream districts makes up a significant fraction of the drainwater used to contribute to total supply (Reclamation, 2001).

The Colusa Basin Drain is the main drainage channel for the Colusa Sub-basin. On average, about 250,000 acre-feet (ac-ft) is discharged through the Knights Landing Outfall Gates each year. A wet year could see discharges of up to 700,000 ac-ft. Average daily flows typically range from 600 cubic feet per second (cfs) for flood flow to 15 cfs during dry months. However, during rice drainage operations, 1,000 cfs is typical; and flows over 2,000 cfs have been recorded.

The Knights Landing Ridge Cut channel extends from the Colusa Basin Drain (approximately 0.5 mile upstream from the outfall structure) to the Yolo Bypass. The channel provides flood relief for the drain canal in winter (20,000 cfs design capacity) and also conveys irrigation water in the summer. Several irrigation pumps divert water from the Ridge Cut channel. The channel is wide with little slope, and the



LEGEND

- CITY
- COUNTY BOUNDARY
- SUB-BASIN BOUNDARY
- WILDLIFE REFUGE

N

0 6 12 MILES

SCALE IS APPROXIMATE

FIGURE 1-2
COLUSA SUB-BASIN
SACRAMENTO RIVER BASINWIDE WATER MANAGEMENT PLAN
SUB-BASIN-LEVEL WATER MEASUREMENT STUDY

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flow is split into two distinct channels at lower flows. Flow into or out of the Knights Landing Ridge Cut is not currently measured.

The SRSCs within the Colusa Sub-basin are Glenn-Colusa Irrigation District, Provident Irrigation District, Maxwell Irrigation District, Princeton-Codora-Glenn Irrigation District, River Garden Farms Company, and RD 108. The major non-SRSC users are within the Tehama-Colusa Canal Authority region, which also drains into the Colusa Basin Drain and the Colusa Basin Drain Mutual Water Company. Although it has a supplemental water supply contract with Reclamation, the Colusa Basin Drain Mutual Water Company relies entirely on drainage from upstream water users for its surface water supplies.

American Sub-basin

The American Sub-basin, as defined by the BWMP, is bounded on the west by the Sacramento and Feather Rivers, on the north by the Bear River, and on the south and southeast by the American River. The eastern boundary is the Valley floor. A large proportion of the area encompasses urban areas including parts of the City of Sacramento and Sacramento County. Figure 1-3 shows the extent of the American Sub-basin.

Groundwater accounts for a significant proportion of water supplied to the sub-basin at 40 percent with the majority of groundwater use attributable to municipal and industrial (M&I) users in the Sacramento metropolitan area. Surface water supplies make up 54 percent of the total supply. (SCRCs contribute 20 to 25 percent of total water supply, and water service contractors make up less than 10 percent of total water supply.) Although drainwater contributes to only a small fraction of supply, it amounts to nearly 60,000 ac-ft per year, or 6 percent of sub-basin water supply. In most sub-basins, water demand is primarily from agricultural users, but in the American Sub-basin, the demand is split nearly equally between agricultural and M&I water requirements (Reclamation, 2001). Agricultural water demands in the American Sub-basin are met mostly with surface water.

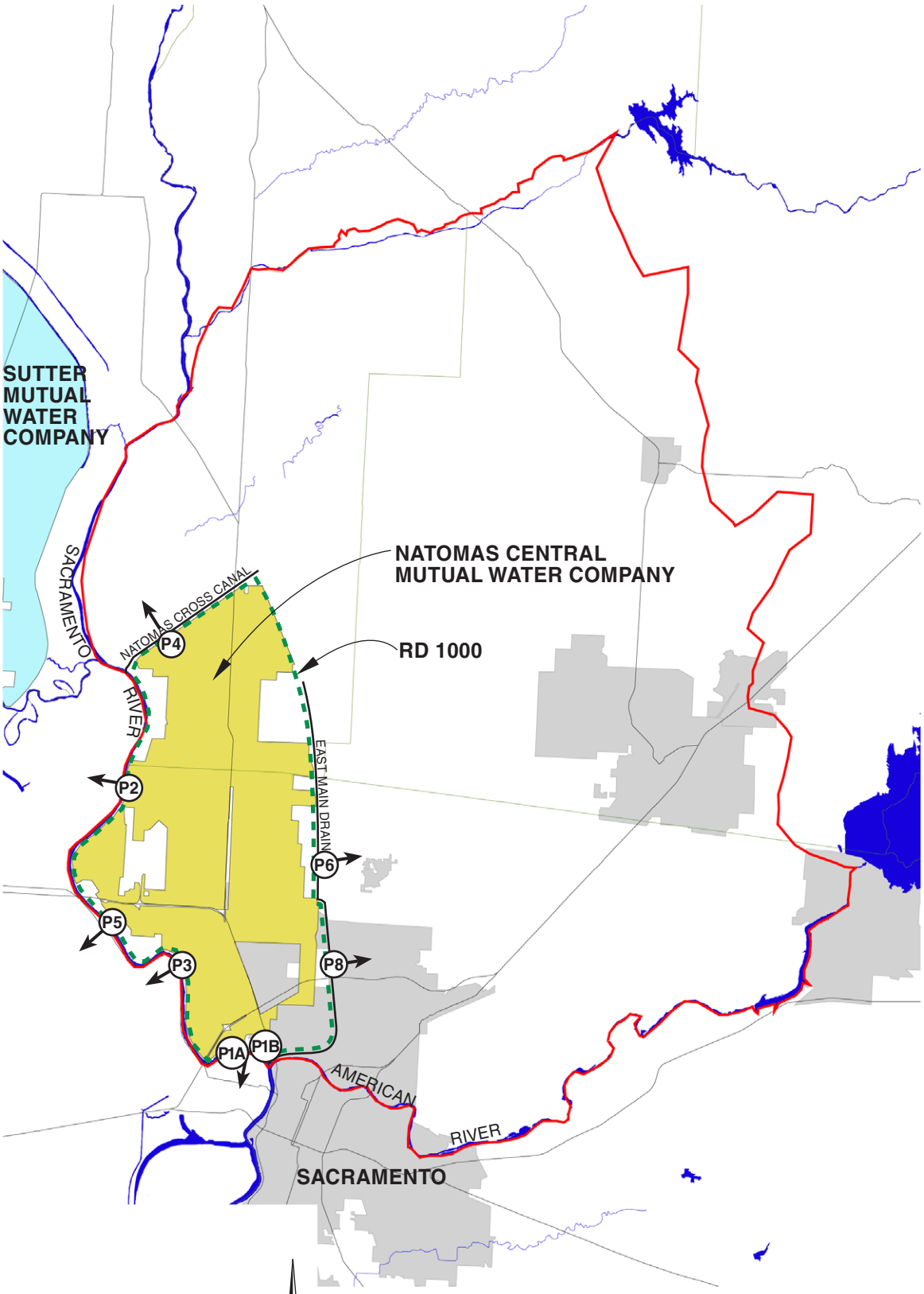
The Measurement Study narrowed down the geographic scope of the American Sub-basin to include only the Natomas Basin. The SRSCs in the Natomas Basin include the NCMWC and several smaller (short-form) contractors. The NCMWC provides water supplies mostly to agricultural users. Drainage out of the Natomas Basin is the responsibility of RD 1000.

Butte Sub-basin

The Butte Sub-basin is on the east side of the Valley and bounded by the Sacramento River on the west, by Big Chico Creek on the north, by Butte Creek and Butte Slough on the east, and by the Sacramento River and Butte Slough on the south. Figure 1-4 shows the extent of the Butte Sub-basin.

Agricultural water requirements make up 98 percent of the sub-basin water demand. Surface water supplies make up 48 percent of the total water supply, drainwater supplies 17 percent, and groundwater supplies 35 percent. No water service contractors are in the sub-basin, and SCRCs contribute to less than 15 percent of the total water supply (Reclamation, 2001). Drainwater return flows and diversions, particularly along the lower Butte Creek and Butte Slough, are significant to the hydrology of Butte Sub-basin and flow management. Improved management may benefit drainwater users by increasing supply reliability.

Due to the limited budget of this Measurement Study, the scope of the Butte Sub-basin investigations was restricted to the southern region, within the service area of RD 1004.



LEGEND

- CITY
- COUNTY BOUNDARY
- SUB-BASIN BOUNDARY
- WILDLIFE REFUGE
- STUDY AREA
- (P3) RD 1000 PUMPING PLANT

N

0 2.5 5 MILES

SCALE IS APPROXIMATE

FIGURE 1-3
AMERICAN SUB-BASIN
SACRAMENTO RIVER BASINWIDE WATER MANAGEMENT PLAN
SUB-BASIN-LEVEL WATER MEASUREMENT STUDY

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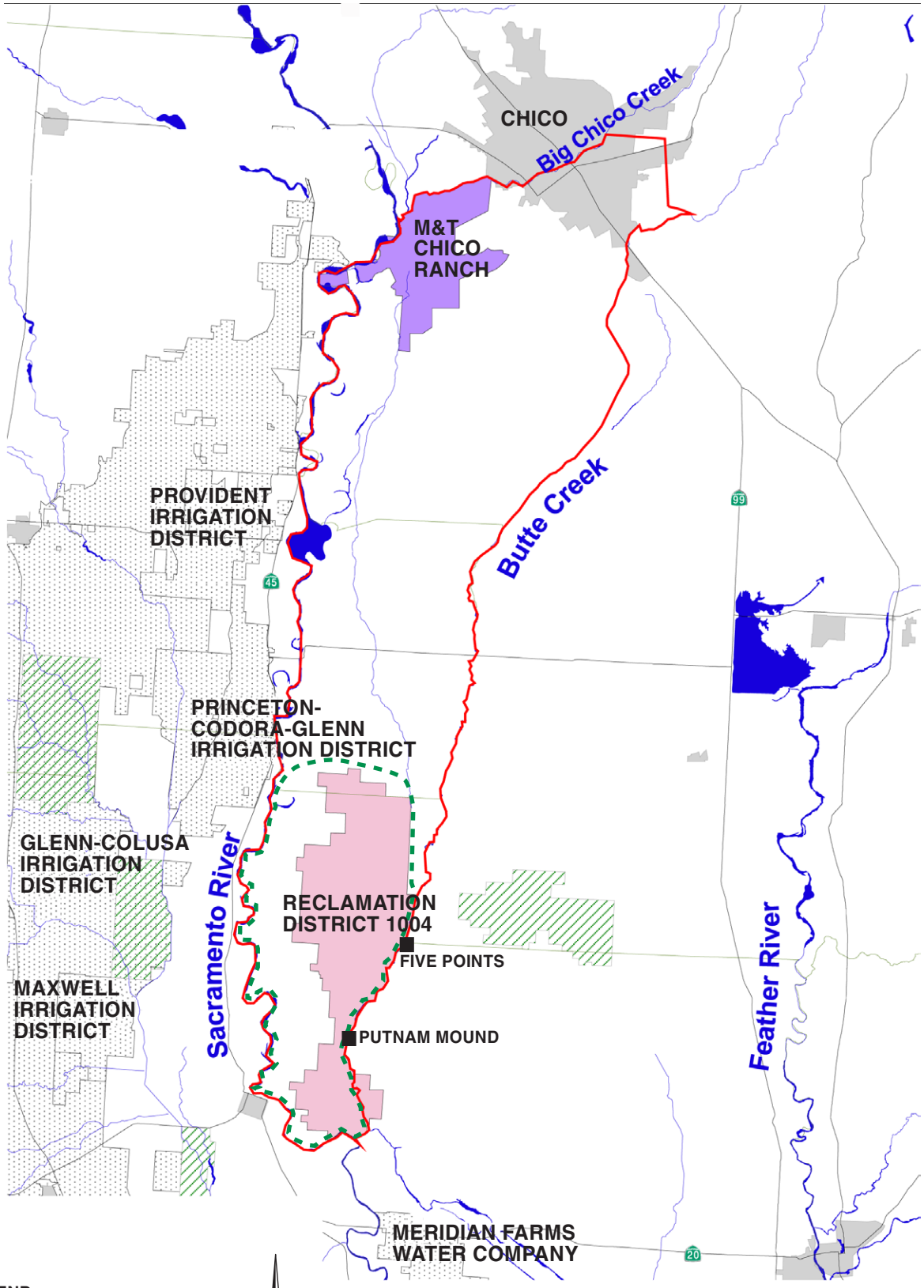

LEGEND

- CITY
- COUNTY BOUNDARY
- SUB-BASIN BOUNDARY
- WILDLIFE REFUGE
- STUDY AREA

N

0 3 6 MILES

SCALE IS APPROXIMATE

FIGURE 1-4
BUTTE SUB-BASIN
SACRAMENTO RIVER BASINWIDE WATER MANAGEMENT PLAN
SUB-BASIN-LEVEL WATER MEASUREMENT STUDY

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Sutter Sub-basin

The Sutter Sub-basin, as defined in the BWMP, includes the drainage area on the east side of the Valley floor and is bounded by the Sacramento River on the western and southern boundary. The eastern boundary is the west levee of the Sutter Bypass. The northern boundary is Butte Creek and Butte Slough, as shown on Figure 1-5.

Surface water accounts for 83 percent of the water supply for the southern Sutter Sub-basin, and drainwater accounts for the remaining 17 percent. Agricultural water requirements account for 99 percent of the demand in the sub-basin (Reclamation, 2001).

RD 1500 is responsible for providing drainage facilities and management in the southern portion of the Sutter Sub-basin and operation of the pumping plant at Karnak. The Main Drainage Canal in the Sutter Sub-basin flows generally from north to south. Water within the Sutter Mutual Water Company (SMWC) system is distributed from the Main Canal to a series of secondary canals, laterals, and fields, separated by flashboard checks. Drainage occurs from fields, several of which may drain into one lateral. Laterals flow into the secondary canal and finally into the Main Drainage Canal.

Water recycling is restricted within SMWC due to water quality concerns, but it remains a key component of the water supply. Nearly 15,000 ac-ft of water is recycled in a favorable crop year, depending on the crop pattern. The cost of "new" water generally drives the recycled water market. Recycling is also used to supplement the water supply at times of the year when water demand is unusually high, such as during the rice flood-up season.

Due to the limited budget for this Measurement Study and because the area north of the Tisdale Bypass is small compared to the area south of the bypass, this Measurement Study is restricted to the southern portion of the Sutter Sub-basin, which is the region south of the Tisdale Bypass. Although there are other small SRSCs in the southern Sutter Sub-basin, SMWC is the SRSC responsible for the delivery of water to most agricultural areas in this portion of the sub-basin.

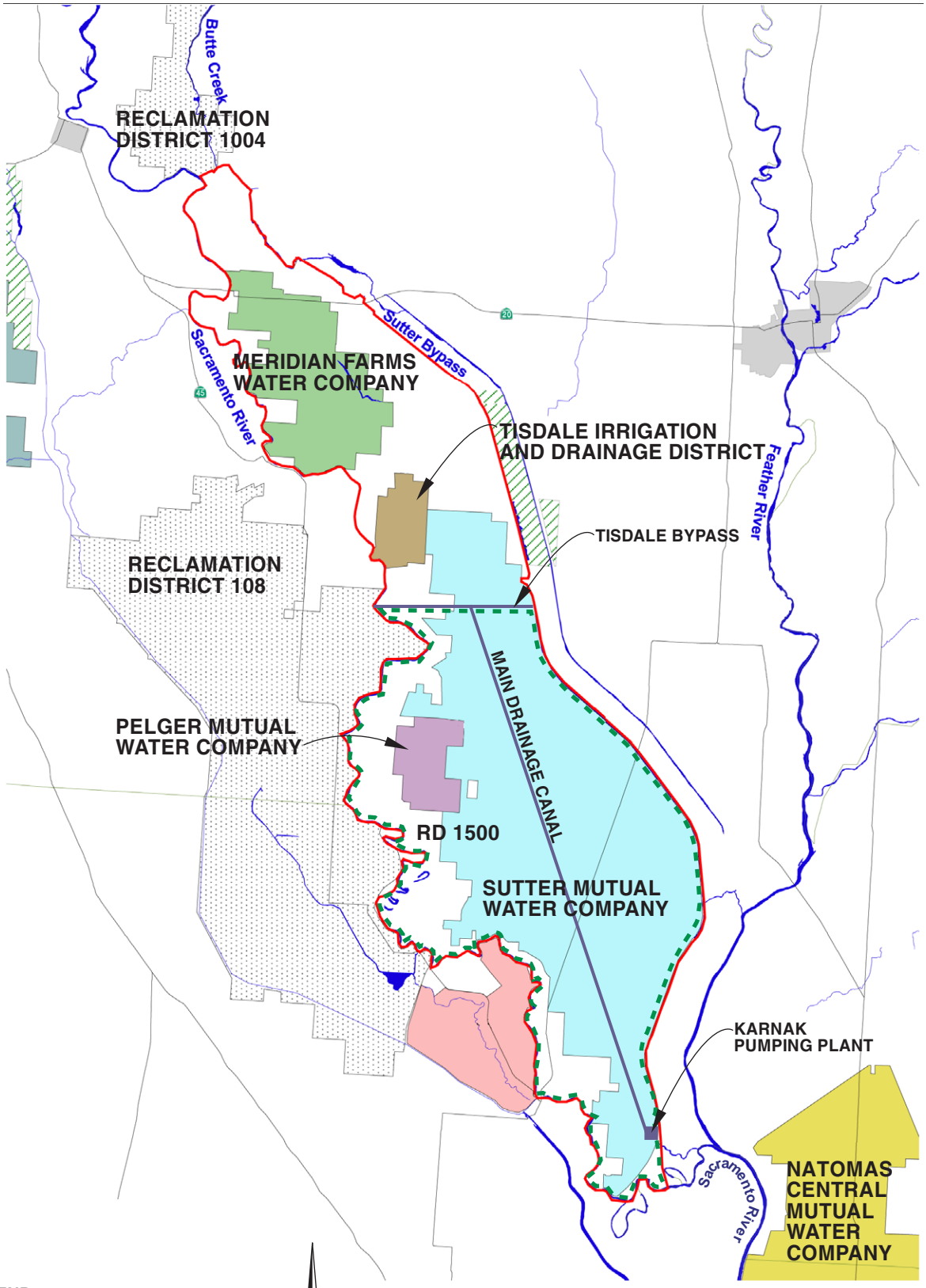
Redding Sub-basin

The Redding Sub-basin covers the northern part of the Sacramento Valley floor. The area spans from Shasta Dam to just above Red Bluff on the western side of the Valley up to the coastal mountain range. See Figure 1-6 for the area encompassed by the Redding Sub-basin.

A substantial fraction of the water requirement in the Redding Sub-basin comes from M&I uses in the Redding metropolitan area. One-third of the water requirement is from M&I, and two-thirds of the water requirement is from agricultural needs. SRSCs account for 55 to 60 percent of the water supply, and water service contractors account for 15 percent. Drainwater supplies less than 2 percent. Finally, groundwater makes up 15 to 20 percent of water supply (Reclamation, 2001).

DWR has reported that the Redding Groundwater Basin is of quality and availability adequate for storage. Drainwater, conversely, is rarely available. Anderson-Cottonwood Irrigation District, the only significant irrigation district within the sub-basin, has crop and irrigation types not conducive to drainwater use.

Due to its complexity and the limited budget of this Measurement Study, the Redding Sub-basin has been excluded from this initial phase of investigation with respect to sub-basin water measurement.



LEGEND

- CITY
- COUNTY BOUNDARY
- SUB-BASIN BOUNDARY
- WILDLIFE REFUGE
- STUDY AREA

N

0 2.5 5 MILES

SCALE IS APPROXIMATE

FIGURE 1-5
SUTTER SUB-BASIN
SACRAMENTO RIVER BASINWIDE WATER MANAGEMENT PLAN
SUB-BASIN-LEVEL WATER MEASUREMENT STUDY

W052003002RDD_56 (7/1/03)

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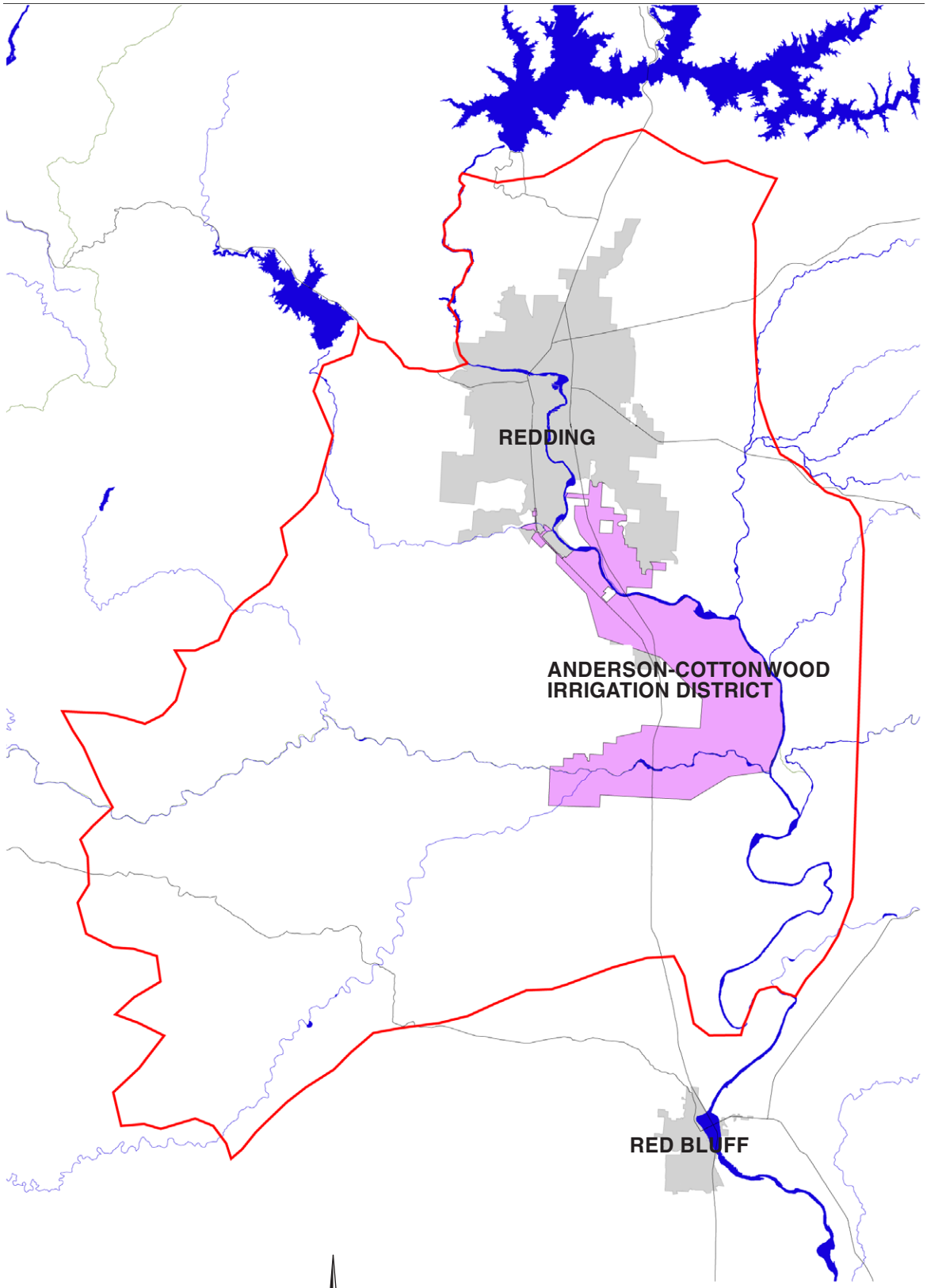

LEGEND

- CITY
- COUNTY BOUNDARY
- SUB-BASIN BOUNDARY
- WILDLIFE REFUGE

N

0 3 6 MILES

SCALE IS APPROXIMATE

FIGURE 1-6
REDDING SUB-BASIN
SACRAMENTO RIVER BASINWIDE WATER MANAGEMENT PLAN
SUB-BASIN-LEVEL WATER MEASUREMENT STUDY

W052003002RDD_55 (6/27/03)

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section 2 Existing Outflow Water Measurement Facilities and Operations

For each of the sub-basins investigated in this Measurement Study, management of the measurement facilities, measurement procedures, and data collection efforts were documented. Water quality monitoring, if any, that occurs at the sub-basin outflow sites was also identified.

Colusa Sub-basin

Management

The Colusa Basin Drain and the Knights Landing Outfall Gates structure on the Sacramento River facilitate removal of drainwater from the Colusa Sub-basin. The Colusa Basin Drain begins about 9 miles northeast of the City of Willows and flows southerly to its outfall at the Sacramento River near the Town of Knights Landing. The Knights Landing Outfall Gates are located 0.3 mile northwest of the town at Sacramento River Mile 34.15. The outfall structure consists of eight 66-inch-diameter automated gates and two 42-inch-diameter hand-operated gates. Flap gates installed on the downstream or Sacramento River side of the structure permit flow only in the direction of the drain to the river.

Colusa Basin Drain Outfall Structure

All of the gates were rebuilt in 1985. The two hand-operated gates are only opened during flood conditions. The outfall gates are operated to maintain the water level upstream of the structure to certain target levels, depending on agricultural operations and flood conditions.

Typical Ridge Cut Channel Conditions

The Knights Landing Ridge Cut is an additional point of outflow from the Colusa Sub-basin and provides flood relief during high water events. The Ridge Cut functions as an extension of the Colusa Basin Drain from Knights Landing to the Yolo Bypass allowing drainage water to flow into the bypass when the Sacramento River level is high. Farmers use a small amount of water from the Ridge Cut for irrigation. During the irrigation season, the water level in the Colusa Basin Drain is maintained at the outfall gates to ensure that water can be diverted from the Colusa Basin Drain by upstream users. The flow into and through

the Ridge Cut is not measured during the irrigation season or flooding season.

Measurement

Measurements were first recorded at the Knights Landing Outfall Gates in the 1940s. The O&M of the outfall structure is primarily the responsibility of the Sacramento Maintenance Yard of the DWR Central District, and the Northern District's Sutter Yard maintains the water measurement facilities.

Colusa Basin Drain Immediately Upstream of the Outfall

DWR has classified this gauge as an "Atypical Station," which means that the flow is determined by a rating curve based on gauge height and not actual flow measurements. Flow is calculated from theoretical equations that take into account flow regime, gate opening, and an estimate of the headloss through the gates.

The following four flow regimes may exist through the gates:

- Submerged orifice flow
- Freeflow orifice flow
- Submerged weir flow
- Freeflow weir flow

These flow regimes are used to determine the method used to calculate the discharge. Typical flow conditions through the outfall structure are usually characterized as "submerged." Potentiometers (Celesco, 0 to 5 volts) are calibrated to the gate opening. A linear relationship exists between voltage and the gate opening. The potentiometers are tied into the telemetry system at the Sacramento Maintenance Yard.

Both upstream and downstream water levels are needed to compute the discharge through the Outfall Gates. The upstream gauging station is located immediately upstream of the outfall structure, and the downstream station is located at the Sacramento River at Knights Landing Station, approximately 0.25 mile downstream of the Knights Landing bridge. The head difference between these stations is used to estimate the headloss between the drain and the river (DWR, 1998).

Discharge through the outfall gates is calculated using a computer program developed by DWR. The calculation is dependent on the flow regime at the time data were recorded and whether the water elevation in the Colusa Basin Drain is above or below the height of the gate opening. If submerged weir conditions exist, the coefficient of submergence is equal to one. If other conditions are present, the percentage of submergence is calculated based on a ratio between the Sacramento River stage and Colusa Basin Drain stage. Each gate has a discharge coefficient. Orifice flow is calculated for each gate by multiplying the coefficient of submergence, discharge coefficient, and the depth of flow. Stage and gate opening are used to calculate depth of flow when the Colusa Basin Drain is above the height of the gate opening. An adjustment is made to account for closed flap gates, if necessary (DWR, 1998). Historically, the discharge coefficient was calibrated with discharge measurements taken with flow meters, but no calibration has taken place for at least 8 years.

Measurement of discharge at the gates is difficult because highly turbulent conditions usually exist when measurements are most often needed. Turbulence is a problem for obtaining an accurate measurement on the downstream side. Upstream flow is deep and slow-moving, which presents other measurement challenges. Additionally, water can rise faster than the gates can adjust to keep the water level at target depth. Although water levels are measured and recorded each hour and the gates adjusted accordingly, water levels may rise significantly between measurements as a result of changes upstream.

Data Collection

A DOS-based computerized data logger tracks gate position and upstream gauge height measured by a shaft encoder. The data is logged at 15-minute intervals. This upstream data is not telemetered; DWR employees download the data by hand and return to the office to calculate flow through the outfall structure. DWR employees rely on handwritten notes taken by the Sacramento Maintenance Yard to fill in any missing or questionable data points. Data have been certified in this manner through 2001.

Certified data are available upon request from DWR; however, the data are not posted on the California Data Exchange Center website.

Water Quality Measurement

DWR Sutter Yard employees do not take water quality measurements at the outfall structure. DWR collects periodic grab samples for testing water quality in the Colusa Basin Drain at Highway 20. In addition, Glenn-Colusa Irrigation District takes periodic drainwater electrical conductivity readings of its outflow.

American Sub-basin

Management

The focus of the Measurement Study relating to the American Sub-basin is outflow from the Natomas Basin, which is within the American Sub-basin and includes the service area of NCMWC, an SRSC and a BWMP participant, and several smaller short-form contractors along the Sacramento River. RD 1000 is responsible for the drainwater outflow of NCMWC and the Natomas Basin.

RD 1000 Pumping Plant 4

Although several individuals with small pumps divert water from the Sacramento River into the Natomas Basin, NCMWC is responsible for the majority of the Natomas Basin surface water supply. The NCMWC's surface water supplies are supplemented by recycled water operations at Pumping Plants 2 and 4 and numerous internal lift pumps. Plant 4, located in the northern part of NCMWC's service area, pumps water out of the Natomas Cross Canal and into the supply canal. The Natomas Cross Canal generally flows into the Sacramento River during the winter. In some years, during the irrigation season, the flow in the Sacramento River drops to a level that restricts NCMWC's ability to divert water from the Natomas Cross Canal. When these conditions occur, NCMWC constructs a temporary dam in the canal just upstream of the

Sacramento River confluence, and water is pumped from the Sacramento River into the Cross Canal and flows easterly toward the companies Bennett and Northern Pumping Plants.

Due to rising water costs and holding time requirements for pesticides and herbicides, the Natomas Basin has been operated as a "closed system" since about 1986. This designation changed some of the pumping operations and limited the outflow of drainage water. A minimum of 28 days is now required between certain pesticide/herbicide application and discharge of water to the Sacramento River. The typical water holding time for drainage water is 30 to 45 days after the last application in RD 1000. During the irrigation season, water levels in the drainage canals may fluctuate between 12 and 18 inches due to recirculation in the system.

RD 1000 Pumping Plant 3

The NCMWC and RD 1000 have agreements regarding outflow operations. From April 1 to October 1, RD 1000 does not discharge unless NCMWC requests the discharge. RD 1000 operates the pumps, but does not release water unless the county agricultural commissioner agrees with NCMWC pumping requests.

RD 1000 operates eight pumping plants to manage basin outflow. All pumps are considered to be high-head pumps (20+ feet of head), and are not as efficient when pumping larger heads (when river is low). None of the RD 1000 pumps have variable-frequency motors. Some pumps have been reconditioned in recent years, which involved either building up, grinding, and refinishing the impellers to original specifications, or installing new impellers and replacing the bell and dome if necessary. Table 2-1 lists some general notes on the pumps.

RD 1000 Pumping Plant 4 Discharge to the Natomas Cross Canal

Measurement

The NCMWC has recorded measurements of all inflows into NCMWC, totaling about 92,000 ac-ft annually in recent years. These measurements do not include inflows from some private diverters and groundwater pumped for irrigation (approximately 5,000 acres).

None of the RD 1000 pump discharges are directly metered. All measurements of drainwater discharge are estimates based on original pump curves, unless more recent pump curves are available from pump testing. Although the last testing of the drain pumps was conducted in 1991 to 1992, not all pumps were tested at that time. Generally, RD 1000 focuses on removing the water from the Natomas Basin without focusing on the exact quantity of water removed.

TABLE 2-1
RD 1000 Pumping Plants – Summary Details

Plant	Description	Measurement	Other Notes
1A	4 x 600 hp centrifugal pumps. Strictly used for winter flows currently.	Flow estimates based on pump tests from 1992. The pumps were tested after being refurbished in 1990. Outflow discharges into box culverts and cannot be measured at that point. When pumps were tested in 1992, the exposed suction pipes were metered.	Constructed 1911 to 1914.
1B	RD 1000 is demolishing and rebuilding the original Plant 1B in summer of 2003. The existing two pumps will be replaced with six new pumps with 48-inch-diameter discharge pipes. Planned continued use for rice drainage operations in the fall and for winter drainage outflow.	Meters are not included in the new plant construction. The discharge pipes will be exposed in a meter vault, which could facilitate installation of meters.	
2	1 x 200 hp pump: Drain canal water can be pumped into an irrigation lateral (Highland Ditch) or into the river. Re-circulation of drainwater into the irrigation lateral occurs all summer. 1 x 300 hp pump: Used almost exclusively for winter outflows.	1 x 200 hp pump: The flow into irrigation lateral is not currently metered. 1 x 300 hp pump: Not currently metered.	Pumps constructed in the 1960s. 300-hp pump used occasionally for rice drainage due to maintenance at other plants.
3	1 x 300 hp; 2 x 200 hp pumps; 1 x 250 hp pump: Used almost exclusively for winter outflow.	An access vault exists for testing discharge. Potentially, the vault could be outfitted with meters.	1 x 300 hp and 2 x 200 hp pumps constructed in late 1960s and reconditioned in 2001. 1 x 250 hp pump constructed in 2001.
4	2 x 400 hp and 1 x 300 hp pumps each with 48-inch-diameter discharge pipes. Operation occurs in winter and summer. Normally drains rice acreage in the northern part of RD 1000. The 2 x 400 hp pumps are typically used for winter drainage. All pumps are equipped with 36-inch-diameter discharge pipes.	There is no access to discharge pipes because a stability berm between the levee and pumping plant buried the area. Metering would require construction of an access vault. "Recycled" water is not metered. Flow estimates are made with RD 1000 pump rating table[a].	Original 300-hp pump constructed in late 1950s. All reconditioned in 2001. If siphoning action is present, the pumps noticeably discharge more flow.
5	3 x 100 hp pumps. Used all winter for normal airport drainage.	There is no access vault to the discharge pipes that could facilitate metering the pump outflow.	Plant was constructed as part of Sacramento Airport in 1970s.
6	1 x 125 hp; 1 x 200 hp; 1 x 250 hp; 1 x 300 hp. Under normal operations, strictly used for flood control.	Exposed section of pipe might not meet minimum required for testing. For metering, construction of a vault would be required.	Pumps constructed in 1970s.
8	4 x 700 hp: Exclusively used for winter drainage. 2 x 300 hp: Used for fall rice drainage. 1 x 200 hp: Used for fall rice drainage. 2 x 500 hp: Added in 2001 as a city project for new development.	No pump testing since construction.	Constructed in early 1980s.

[a] Recycle operations: If water is flowing from the river into the Natomas Cross Canal (and not the reverse), NCMWC gets "credit" from Reclamation for pumping water from the single 300-hp pump into the Natomas Cross Canal. Because water is not flowing to the river, NCMWC remains a closed system.

Note:

hp = horsepower

To estimate the monthly discharge of water from all plants, the operators estimate pumping volumes strictly based on the pump rating table. This table has a discharge rating (ac-ft per hour) that was derived from the most recent pump test or, in some cases, the original pump curve. These ratings are based on typical operating condition hydraulic head differentials. No adjustments are made to the ratings to account for actual pumping head, siphoning action, or impeller age, even if there is a noticeable increase or decrease in flow.

Data Collection

One time per month, RD 1000 operators record the hour meter reading for every pump in the Natomas Basin. From the hour totals, the operator uses ac-ft per hour ratings on the pump rating table to calculate volume pumped (ac-ft per month).

RD 1000 does not have a database for pumping records, and therefore, all pumping volume data are recorded on paper records. RD 1000 staff are responsible for entering monthly pumping volumes in the monthly Superintendent's Report, which has been reported to the RD 1000 Board of Directors since 1911. The outflow data are not made readily available for use outside of RD 1000 without authorization from the District Engineer.

Water Quality Measurement

The only water quality testing performed by RD 1000 occurs during herbicide operations each fall. RD 1000 applies Glyphocate (for water primrose, Johnson grass, and nut grass) and copper (for coontail). A National Pollutant Discharge Elimination System permit requires RD 1000 to test prior to, during, and after every herbicide application.

The City of Sacramento completed a baseline water quality study in the Natomas Basin prior to the 2001 irrigation season. The City of Sacramento regularly tests drainwater throughout the summer.

Butte Sub-basin

Management

RD 1004 encompasses approximately 15,000 acres of irrigated land. Rice is the predominant crop. Both groundwater and surface water are used for irrigation. RD 1004 has one 7-cfs groundwater well that runs most of the irrigation season. Two additional groundwater wells are being considered in the northern part of RD 1004. Numerous private groundwater wells are located throughout the system, but generally they are only used during droughts or when curtailments are imposed on Sacramento Valley water users. RD 1004 also has three pumps on Butte Creek, known as the "Behring Pumps," that provide a critical secondary source of surface water.

RD 1004 generally takes water into the system year-round, except when maintenance is performed on the conveyance system and during weed spraying. This occurs for approximately 2 weeks before and 2 weeks after the rice growing season. In the fall and winter, RD 1004 floods fields for rice decomposition and for wildlife habitat. Although drainwater can exit the sub-basin from RD 1004 via gravity flow into Butte Creek, RD 1004 operates a closed system with an extensive recirculation system.

Several factors have led to the development of a recirculating system, including inadequate drainwater retention capacity and the increasing cost of Central Valley Project water. Water is reused approximately three times, and there is minimal outflow through most of the irrigation season. Recirculated water is blended with

surface water sources and a small amount of groundwater sources. Water from the farthest low point in RD 1004 can be recirculated by a series of pumps throughout two-thirds of RD 1004. After harvest, RD 1004 slowly releases drainwater into Butte Creek.

Because RD 1004 operates as a closed system, outflow during the irrigation season is minimal. During this time, the only outflow is from seepage and weir-board leaks. All weirs at outflow points are intentionally blocked during this season.

Drainage can exit RD 1004 by gravity into Butte Creek at the following three locations:

- **Five Points –** Drainwater in most of RD 1004 generally flows into Drumheller Slough, which ends at Putnam Road. The "cut-off channel" conveys drainwater to Five Points. Water can be routed into the borrow pit to be used for recirculation or discharged to Butte Creek. The gate at Five Points is closed throughout the irrigation season. The discharge pipe is 48 inches in diameter. In 2002, no water drained from Five Points until flood runoff resulted from heavy rains. During these situations, water flows over the weir boards.
- **Putnam Mound –** This outflow point is located at the lowest end of the system, south of the California Levee, at the end of the Flyway Ditch, Boat Canal, and East Canal. Most of the RD 1004 outflow is discharged at Putnam Mound through a 48-inch-diameter pipe.
- **Baber Land along Butte Creek –** There are several points along Butte Creek where small amounts of drainage can exit to Butte Creek via check structures, but they are rarely used for that purpose.

Measurement

Inflow to RD 1004 is metered at the main pumping plant near Princeton. Estimates of water diverted from Butte Creek can be made based on power records and pump tests. RD 1004 meters deliveries to all fields within its boundaries. RD 1004 does not measure discharge from the district at Five Points, Putnam Mound, or from the Baber Lands along Butte Creek.

Data Collection

RD 1004 does not collect any outflow data.

Water Quality Measurement

Currently, a regular water quality monitoring program is not in place within RD 1004.

Sutter Sub-basin

Management

The SMWC is responsible for initial conveyance into SMWC and delivery of the water. RD 1500 manages the outflow of water from the southern portion of Sutter Sub-basin. The SMWC delivers irrigation water to approximately 50,000 acres. An additional 20,000 acres are provided drainage service by RD 1500, but are outside SMWC's boundaries. Those within this acreage, "Rim Landers," have their own riparian rights to the water or short-form contracts, but still require drainage of the water by RD 1500.

The most significant outflow facility in SMWC is the main pumping station for RD 1500, located at Karnak at the end of the Main Drainage Canal. The RD 1500 pumping station at Karnak consists of three pumping plants. The plants discharge into the lower end of the Sutter Bypass where the channel becomes Sacramento Slough. Pumping Plant No. 1, constructed in 1914,

consists of six 800-hp units, each rated at 78,500 gallons per minute. Each has been recently renovated with new impellers. The renovated pumps have not been re-rated, but, according to RD 1500, are likely close to the original specifications. These pumps are only operated during times of high water (never during irrigation season) because they are inefficient at low flows.

Constructed in 1952, Pumping Plant No. 3 consists of four 700-hp vertical turbine pumps. The outlet to Plant No. 3 consists of three box culverts, each approximately 7 feet wide by 6 feet tall. The pumps may run every day during irrigation season. They may also be used in the winter to manage drainwater if flood flows are present. When in use, the pumps run for 12 hours each night, or they may alternate turning off at off-peak hours to ensure power costs are minimal. Plant No. 3 is much more efficient than Plant No. 1 when water in the river is low.

Pumping Plant No. 2 is currently inoperative. Between the two operational plants, Plant Nos. 1 and 3, capacity is reached at 1,900 cfs. However, these plants do not run concurrently. If possible, pumps are only run at off-peak hours to minimize cost. Outflow at Plant No. 3 can occur by gravity flow when the water level in the Sutter Bypass is lower than that in the Main Drainage Canal. If the water level in Sutter Bypass is higher, excess water must be pumped from the forebay.

Measurement

The critical outflow measurement site for the Sutter Sub-basin is at the Karnak pumping station. DWR classified this measurement site as "Atypical" and has created a computer program to perform the flow calculations for both gravity flow and pumping flow. For gravity flow, velocity coefficients (C-values) have been calibrated using a series of curves generated for velocity coefficient versus head. The velocity coefficients are multiplied by the flow area to calculate discharge.

For pumping flow at both Pumping Plant Nos. 1 and 3, a series of curves for rate of discharge versus head have been generated to best fit the rating curve for the rate of discharge. In both plants, the rate of discharge is multiplied by the number of pumps in operation to calculate the total discharge rate. Outflow from Pumping Plant No. 3 can occur by gravity if the water level in the drain is greater than the water level in the bypass. If the water surface in

Karnak Pumping Plant Forebay

the bypass is high and gates at Pumping Plant No. 3 are open, water may flow from the bypass into the Main Drainage Canal. Backflow from the bypass into the plant forebay is not measured.

Sutter Bypass at Karnak Pumping Plant Discharge and Beginning of the Sacramento Slough

Data Collection

Power use (recorded in hours), Sutter Bypass water-level elevations, and the pumping plant forebay elevations are recorded at the pumping facility. Sutter Bypass water levels are measured at a stilling well located on the levee near the discharge from Pumping Plant No. 1. Changes in water level are recorded from a readout on the side of Plant No. 2 in the forebay. Data are recorded at 15-minute intervals for both the water levels in the forebay and the Sutter Bypass. The data recorder consists of a tape with encoder and data logger, which records water levels and gate elevations. The data are manually downloaded and sent to DWR for calculation of mean daily flows for the facility. Calculated flow data are available from DWR; however, the data are not posted on the California Data Exchange Center website.

Water Quality Measurement

Electrical conductivity, a salinity indicator, is measured weekly by RD 1500 staff, and water samples are sent to University of California at Davis for analysis. Electrical conductivity monitoring is fairly inexpensive, and adding total dissolved solids or temperature testing to the existing electrical conductivity monitoring program has been considered for a future expansion of the water quality monitoring program.

Discharge of Pumping Plant No. 3 into the Sutter Bypass

section 3 Recommended Facilities and Operational Improvements

Recommendations for potential outflow measurement improvements in each sub-basin are discussed below.

Colusa Sub-basin

As noted in Section 2, the flow conditions downstream of the Knights Landing Outfall Gates are turbulent during a large portion of the year and not ideal for water measurement. Upstream of the structure, the water in the Colusa Basin Drain is extremely slow and deep with silt buildup and surface debris, presenting other challenges to developing a permanent station. The recommendations below are to refine, if possible, the existing measurement methods used by DWR. Also presented is an alternative option that would develop a new measurement station on the Colusa Basin Drain.

Measurement Facility Improvements

The following measurement improvements are suggested for the Knights Landing Outfall Gates station.

Option 1: Calibration Effort

- Verify and/or refine the hydraulic coefficients for theoretical flow calculations for all flow regimes. Develop loss coefficients as a function of gate opening, if warranted.
- Recalibrate the potentiometers that measure outfall gate openings for the 10 gates. Accurate gate opening measurements are critical to the hydraulic calculations used to determine flow.

Option 2: New Measurement Site

An alternative to Option 1 would be to line a section of the Colusa Basin Drain upstream of the outfall and upstream of the overflow into the Ridge Cut channel. In the lined section of the canal, a Doppler flow meter to measure flow would be installed. This alternative measurement option would allow for the measurement of both the Outfall and the Ridge Cut, which could provide a more complete data set of sub-basin outflow.

Environmental Study and Permitting Requirements

Environmental study and permitting requirements have been identified for the implementation of Option 2. Because of the minor extent of modifications to the Colusa Basin Drain, it is anticipated that the project would be exempt from the California Environmental Quality Act (CEQA) as a minor alteration to an existing facility (Class 1, as described in Section 15301 of the CEQA Guidelines). This determination would need to be made by the Lead Agency, which for this project is assumed to be DWR. In general, nothing other than minor administrative action is required for a Categorical Exemption.

The Lead Agency could choose to prepare an Initial Study/Negative Declaration to satisfy CEQA requirements. If an Initial Study is prepared, effort would be required to characterize the affected environment and potential impacts for key resources of concern (e.g., vegetation and associated wildlife, and groundwater). It is assumed that the limited extent of the proposed improvements, and associated limited potential impacts to the environment, would not

warrant the inclusion of mitigation measures or result in impacts that are potentially significant (i.e., that warrant preparation of an Environmental Impact Statement).

Table 3-1 provides a list of permits, including a brief description, and agency approvals that likely would be required to implement Option 2.

Operational and Maintenance Improvements

The following O&M improvements are suggested for the Knights Landing Outfall Gates station:

- Provide funding mechanism to keep this measurement site operable.
- Modernize the data collection equipment.

Estimated Costs

Additional funding would be required to improve measurement at the Colusa Basin Drain Outfall. The poor channel conditions for measurement currently present in the Colusa Basin Drain upstream of the Knights Landing Outfall Gates do not facilitate the use of Doppler or other type of velocity-measuring equipment. Due to the expense required to improve these channel conditions, two options are suggested for measurement improvement. First, it is suggested that the rating for the existing facilities be checked and refined to improve the existing level of outflow measurement for the Colusa Sub-basin. An alternative recommended improvement option requiring further investigation would be to develop a new measurement site on a lined section of the Colusa Basin Drain upstream from the Knights Landing Ridge Cut. The estimated costs for these efforts are identified below.

Option 1: Calibration Effort

The calibration effort would involve making a series of flow measurements under various conditions to validate and/or refine the existing equations used by DWR to estimate outflow. Because the flow reaching the Knights Landing Outfall Gates is unregulated, this effort would need to be conducted at various times during an irrigation season to assure testing is conducted under all possible flow conditions. It is recommended that one set of measurements be conducted

TABLE 3-1
Permit Summary for Option 2 – Colusa Sub-basin

Permit/Approval	Responsible Agency	Intent/Description
Streambed Alteration Agreement/ California Endangered Species Act	California Department of Fish and Game	Required for changes to a "streambed" pursuant to Section 1601 of the Fish and Game Code. Triggers Responsible Agency requirements under CEQA.
Encroachment Permit	Reclamation Board	The Reclamation Board, a division of DWR, maintains jurisdiction over nonfederal levees, and requires a permit for work along levees under their jurisdiction.
National Pollution Discharge Elimination System – Stormwater Management during Construction	State Water Resources Control Board/Central Valley Regional Water Quality Control Board	The State Water Resources Control Board's General Permit requires that projects that disturb greater than 1 acre develop a plan to minimize potential erosion and sedimentation associated with stormwater releases.

at each of the four flow regimes identified in Section 2 under Colusa Sub-basin Measurement. Each set of measurements would consist of two to three discharge measurements made with different gate configurations. The cost for each set of measurements, including the associated office work required to check the existing ratings or develop new ratings, is estimated to be approximately $5,000. The total cost for four sets of measurements would be approximately $20,000. This cost estimate assumes existing equipment is used to log and record gate openings and water levels. The estimate does not include O&M costs. As with the current measurement practice at the Knights Landing Outfall Gates, this alternative would not capture the flow out of the Colusa Sub-basin to the Knights Landing Ridge Cut.

Option 2: New Measurement Site

Table 3-2 shows the estimated cost to shape and concrete line a 100-foot section of the Colusa Basin Drain. A Doppler or other ultrasonic-type flow meter would be installed in the control section to monitor velocity, flow direction, and water depth. Flow rates and volume would be calculated based on the data collected.

Annual Operations and Maintenance

If the only measurement improvement at Knights Landing Outfall Gates is a calibration effort, no new equipment would be installed; thus, no additional annual O&M costs would be incurred. If DWR drops the Knights Landing Outfall Gates station from its measurement program, funding would need to be obtained to collect, tabulate, review, and report outflow data.

If Option 2 is developed, costs for O&M would be incurred in addition to the cost of the measurement equipment and its installation. These estimated costs include the periodic inspection of the equipment to ensure it is operating correctly, periodic calibration of the measurement device(s), replacing or charging batteries, and downloading and processing the recorded data. These additional annual O&M costs for the Colusa Sub-basin are estimated to be approximately $10,000 to $15,000. This estimate is based on the following assumptions:

- Site is inspected once prior to the irrigation season and once per month after the irrigation season begins (six visits).
- Site is inspected, and only minor maintenance is required such as replacing batteries, clearing minor obstructions, and cleaning sensors.
- Calibration is checked once per year.
- Collected data are reviewed and processed, and a table of mean daily and monthly discharge is prepared for each site.

TABLE 3-2
Colusa Basin Drain Equipment Cost Estimate for Alternative Measurement Site

Location	Equipment	Description	Estimated Cost
Colusa Basin Drain	Side-looking Doppler flow meter	Sontek Argonaut or similar	$16,000
		Installation, calibration, and testing	$10,000
	Canal lining	Concrete line up to 100 feet of canal	$190,000
		Engineering	$38,000
		Environmental and permitting (assume Initial Study/Negative Declaration)	$16,000
Total			**$270,000**

American Sub-basin

Measurement Facility Improvements

Measurement investigations of the American Sub-basin were focused on outflow at RD 1000, since that is the outflow directly related to NCMWC, an SRSC and participant of the BWMP. Pumping data from 1990 to 2002 were used to determine the average contribution of each plant to the total volume of water pumped from NCMWC during the irrigation season (April to September) and during rice drainage (September to October). As shown on Figure 3-1, Pumping Plants 1B, 8, and 4 have historically accounted for the highest total volume of water pumped from NCMWC by RD 1000 during each season.

Within Plants 1B, 8, and 4, individual pumps have contributed to plant outflow to various degrees. In Plant 1B, Pumps 1 and 2 have been responsible for 80 to 90 percent of the flow during both the irrigation season and rice drainage period. Although Plant 8 is important during both the irrigation and rice drainage period, only Pumps 3, 4, and 5 (of seven total pumps) are used during September through October. These pumps would be critical to NCMWC's outflow measurement during the rice drainage season. Finally, Pump 3 is most significant to the performance of Plant 4, accounting for over 50 percent of the flow through the plant during both seasons. However, Pumps 1 and 2 in combination are also equally important during these seasons.

Installing ultrasonic flow meters on discharge pipes is recommended to improve flow measurement accuracy and water management. Plants 1B, 8, and 4 typically account for the majority of NCMWC's outflow during the irrigation and rice drainage seasons and are therefore considered a priority for any outflow measurement program.

The following pumps within each plant are recommended for metering priority:

- Plant 1B: All six pumps in the new plant (48-inch-diameter discharge pipe)
- Plant 4: Pumps 1, 2, and 3 (48-inch-diameter discharge pipe)
- Plant 8: Pumps 3, 4, and 5 (36-inch-diameter discharge pipe)

Plant 4 would also require the construction of an access vault to add meters. The other plants have exposed discharge pipes.

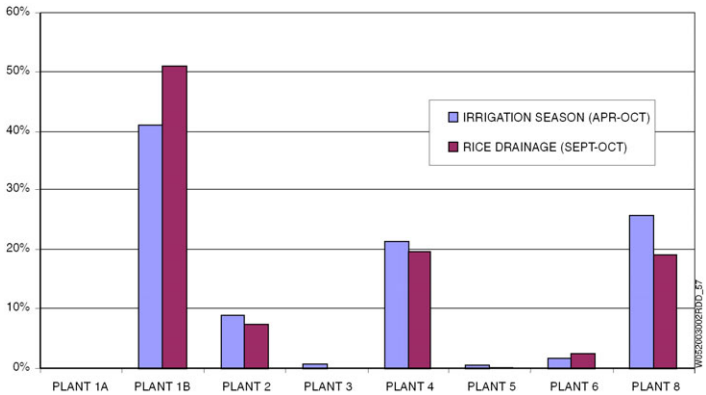


Figure 3-1
RD 1000 Pumping Plants Percentage of Total Outflow by Plant

Operational and Maintenance Improvements

Currently, operations staff at RD 1000 record data reliably on a monthly basis using pump curve estimates. The proposed measurement devices would collect data continuously and more accurately for most of the irrigation season outflow. The proposed data collection would also allow data storage in a database rather than the current practice of paper records.

Estimated Costs

As identified above, Pumping Plant 1B Pumps 1 through 6, Pumping Plant 4 Pumps 1 through 3, and Pumping Plant 8 Pumps 3 through 5 are considered critical for measurement of irrigation-season outflow

from the American Sub-basin. The accuracy of the outflow measurements at these facilities would be greatly increased through the installation and use of ultrasonic flow meters. The cost estimates identified in Table 3-3 are based on a recent project conducted by RD 108 at its Rough and Ready Pumping Plant and information obtained from various manufactures of water measurement equipment. Additional costs would be incurred if all pumps at each of the three pumping plants were outfitted with flow meters or if nonirrigation-season outflow measurement is required at the other pumping plants.

The Panametrics ultrasonic flow transmitters identified above provide totalized flow readings. This information can be sent via a 4-20 mA signal to a data logger to monitor the timing and the quantity of flow or directly to a supervisory control and data acquisition system for remote monitoring.

The cost to purchase and install data loggers capable of recording outflow data at the three pumping plants identified above is estimated to be $2,000 per site, or a total of $6,000 for the three pumping plants.

Based on Table 3-3, the total cost to purchase, install, and calibrate equipment capable of accurately measuring the majority of the outflow from the Natomas Basin is estimated to be approximately $70,000. These costs do not include annual O&M costs or data processing costs.

Annual Operations and Maintenance

In addition to the cost of the measurement equipment and its installation, costs for O&M would be incurred. These costs include the periodic inspection of the equipment to ensure it is operating correctly, periodic calibration of the measurement device(s), replacing or charging batteries, and downloading and processing the recorded data.

TABLE 3-3
Equipment Cost Estimates for RD 1000 Pumping Plants

Pumping Plant	Equipment	Description	Estimated Cost
1B	2-Channel Panametrics Model AT 868 ultrasonic flow transmitter	3-AT 868 dual-channel transmitters, with transducers, couplings, and wiring	$22,000
	(2-channel model allows one transmitter to monitor and record flow in two pipes)	Installation and calibration	$6,000
	Data logger	Purchase and install	$2,000
4	2-Channel Panametrics Model AT 868 ultrasonic flow transmitter	2-AT 868 dual-channel transmitters, with transducers, couplings, and wiring	$15,000
	(2-channel model allows one transmitter to monitor and record flow in two pipes)	Installation and calibration	$3,000
	Data logger	Purchase and install	$2,000
8	2-Channel Panametrics Model AT 868 ultrasonic flow transmitter	2-AT 868 dual-channel transmitters, with transducers, couplings, and wiring	$15,000
	(2-channel model allows one transmitter to monitor and record flow in two pipes)	Installation and calibration	$3,000
	Data logger	Purchase and install	$2,000
Total			**$70,000**

Notes:

Cost for a single-channel AT 868 is approximately $5,000. Installation costs are the same as the dual-channel units. The dual-channel AT 868 transmitters at Pumping Plants 4 and 8 would allow for one additional pump to be equipped with an accurate measuring device and could serve as a backup if one of the primary pumps was not able to be used.

The cost of installing an access vault for Plant 4 is not included at this time.

Annual O&M costs for the Natomas Basin are estimated to be approximately $20,000. This estimate is based on the following assumptions:

- Site is inspected once prior to the irrigation season and once per month after the irrigation season begins (six visits).
- Site is inspected, and only minor maintenance is required such as replacing batteries, clearing minor obstructions, and cleaning sensors.
- Calibration is checked once per year.
- Collected data are reviewed and processed, and a table of mean daily and monthly discharge is prepared for each site.

Butte Sub-basin

Measurement Facility Improvements

As noted in Section 2, RD 1004 currently operates a closed system and makes extensive use of tailwater occurring within is boundaries. As a result, in most years, there is very little outflow from RD 1004 during the irrigation season. In addition, where possible, preharvest drainwater from rice fields is recirculated and reused for rice straw decomposition and wetlands habitat. As also noted in Section 2, although RD 1004 measures its diversions from the Sacramento River and all deliveries within RD 1004 are metered, RD 1004 currently does not measure its outflow. Therefore, to better understand the actual quantity and timing of outflow from RD 1004, the following facility improvements are suggested for Butte Sub-basin:

- Retrofit Five Points and Putnam Mound with measurement devices in discharge pipes. Outflow points along Butte Creek are rarely used and, thus, not recommended at this time for measurement improvement.
- Install data collection devices.

Operational and Maintenance Improvements

Under current operations, there is very little outflow from RD 1004. However, because RD 1004 does not monitor the outflow that is discharged, it is recommended that the equipment be installed at the two existing points where the majority of the outflow does occur, Five Points and Putnam Mound.

Estimated Costs

Table 3-4 shows the estimated cost for the purchase and installation of equipment capable of measuring outflow at RD 1004's two main discharge locations, Five Points and Putnam Mound. Because the pipes may

TABLE 3-4
RD 1004 Equipment Cost Estimates

Pumping Plant	Equipment	Description	Estimated Cost
Five Points	Ultrasonic flow meter with water-level sensor installed in 48-inch-diameter pipe	Unidata Starflow or similar	$6,000
Putnam Mound	Ultrasonic flow meter with water level sensor installed in 48-inch-diameter pipe	Unidata Starflow or similar	$6,000
Total			**$12,000**

Note:

Estimated cost includes approximately $3,500 for equipment and approximately $2,500 for installation.

not always run full and because debris can be an issue in the drains, it is proposed that ultrasonic flow meters with water-level sensors be installed in the 48-inch-diameter discharge pipes at both locations. Collecting water-level data in the pipes together with velocity data would allow the flow volumes to be calculated. These installations may require that the existing discharge pipes be extended with sections of smooth-wall pipe to accurately measure velocities

Annual Operations and Maintenance

In addition to the cost of the measurement equipment and its installation, costs for O&M would be incurred. These costs include the periodic inspection of the equipment to ensure it is operating correctly, replacing or charging batteries, and downloading and processing the recorded data. Annual O&M costs for the Butte Sub-basin are estimated to be approximately $7,500 to $10,000. This estimate is based on the following assumptions:

- Each site is inspected once prior to the irrigation season and once per month after the irrigation season begins (six visits).
- Both sites are visited on the same day.
- The site is inspected, and only minor maintenance is required such as replacing batteries, clearing minor obstructions, and cleaning sensors.
- Collected data are reviewed and processed, and a table of mean daily and monthly discharge is prepared for each site.

Sutter Sub-basin

Measurement Facility Improvements

Measurement of outflow from the Sutter Sub-basin is based on ratings developed by DWR. The rating for Pumping Plant No. 1 is based on the number of hours the pumps are in operation. Each pump is assumed to pump at the same rate, and there is no adjustment for pumping head. As stated previously, Pumping Plant No. 1 is not used for irrigation-season outflow.

Irrigation-season outflow occurs by both gravity and pumping at Pumping Plant No. 3. Outflow is calculated based on head differential between the RD 1500 Drain and Sacramento Slough, gate openings, and, for pumped flow, the hours and number of pumps in operation.

Pumping Plant No. 2 is not currently used for either irrigation-season or winter outflow.

DWR field staff have indicated that the data currently being collected at the Karnak Pumping Plant, regarding water levels and time of operation, may be within 10 percent of actual. The accuracy of the ratings being used to calculate the flow through the pumping plant is uncertain. To improve the accuracy of the measurement of the outflow from SMWC, two possible options have been identified.

Option 1: Flow-meter Installation

Option 1 would install ultrasonic flow meters in each of the four concrete box culverts leading from the pumps to the Sacramento Slough. This option would allow for continuous measurement of the irrigation-season outflow but would not capture outflow pumped through Pumping Plant No. 1. To capture the nonirrigation-season outflow, smaller flow meters also would need to be installed on the Pumping Plant No. 1 discharge pipes.

Option 2: New Measurement Site

Option 2 would line a section of the Main Drainage Canal upstream from the pumping plant forebay and install a Doppler-type

flow meter to measure flow in the canal. Option 2 would allow for the measurement of both irrigation-season and nonirrigation-season outflow without the need to install equipment on the Pumping Plant No. 1 discharge pipes.

Environmental Study and Permitting Requirements

Environmental study and permitting requirements have been identified for the implementation of Option 2. Because of the minor extent of modifications to the RD 1500 Main Drainage Canal, it is anticipated that the project would be exempt from CEQA as a minor alteration to an existing facility (Class 1, as described in Section 15301 of the CEQA Guidelines). This determination would need to be made by the Lead Agency, which for this project is assumed to be RD 1500. In general, nothing other than minor administrative action is required for a Categorical Exemption.

The Lead Agency could choose to prepare an Initial Study/Negative Declaration to satisfy CEQA requirements. If an Initial Study is prepared, effort would be required to characterize the affected environment and potential impacts for key resources of concern (e.g., vegetation and associated wildlife, and groundwater). It is assumed that the limited extent of the proposed improvements, and associated limited potential impacts to the environment, would not warrant the inclusion of mitigation measures or result in impacts that are potentially significant (i.e., that warrant preparation of an Environmental Impact Statement).

Table 3-5 provides a list of permits, including a brief description, and agency approvals that likely would be required to implement Option 2.

Operational and Maintenance Improvements

Cooperative efforts between RD 1500 and DWR have been successful in maintaining the current methods of measurement at the Karnak Pumping Plant. This Measurement Study is recommending improvements to the measurement methods by adding meters that would allow for continuous recording of flow data. It is assumed that the current level

TABLE 3-5
Permit Summary for Option 2 – Sutter Sub-basin

Permit/Approval	Responsible Agency	Intent/Description
Streambed Alteration Agreement/ California Endangered Species Act	California Department of Fish and Game	Required for changes to a "streambed" pursuant to Section 1601 of the Fish and Game Code. Triggers Responsible Agency requirements under CEQA.
Encroachment Permit	Reclamation Board	The Reclamation Board, a division of DWR, maintains jurisdiction over nonfederal levees, and requires a permit for work along levees under their jurisdiction.
National Pollution Discharge Elimination System – Stormwater Management during Construction	State Water Resources Control Board/Central Valley Regional Water Quality Control Board	The State Water Resources Control Board's General Permit requires that projects that disturb greater than 1 acre develop a plan to minimize potential erosion and sedimentation associated with stormwater releases.

of cooperation between these entities would continue.

Estimated Costs

The amount of funding required to improve outflow measurement from the Sutter Sub-basin is dependent upon the option chosen and the level of environmental review required. Because the focus of the Measurement Study is on irrigation-season outflow and because of the uncertainly at this time regarding the permitting and environmental review requirements, Option 1 is recommended as the preferred course of action. The Option 1 improvements recommended are limited to installing continuously recording flow meters at Pumping Plant No. 3.

For comparison purposes, costs for improvements to Pumping Plant No. 1 under Option 1 and the estimated cost to implement Option 2 are also provided below.

Option 1: Flow-meter Installation

Table 3-6 shows the estimated cost for the purchase and installation of equipment for Option 1. To compare the costs to collect the same level of information under the two options, Table 3-6 includes costs associated with installing measuring equipment on both Pumping Plant Nos. 1 and 3.

Option 2: New Measurement Site

Table 3-7 shows the estimated cost to shape and concrete line a 100-foot section of the RD 1500 Main Drainage Canal. A Doppler or other ultrasonic-type flow meter would be installed in the control section to monitor velocity, flow direction, and water depth. Flow rates and volume would be calculated based on the data collected.

TABLE 3-6
SMWC Equipment Cost Estimates – ***Option 1***

Pumping Plant	Equipment	Description	Estimated Cost
Pumping Plant No. 3	Sontek Argonaut – SW or similar	Upward-looking Doppler-type flow meter (includes one unit for each of the four box culverts at approximately $10,000 each)	$40,000
		Installation and calibration for all four units	$13,000
Total for Pumping Plant No. 3			**$53,000**
Pumping Plant No. 1	2-Channel Panametrics Model AT 868 ultrasonic flow transmitter (2-channel model allows one transmitter to monitor and record flow in two pipes)	3-AT 868 dual-channel transmitters, with transducers, couplings, and wiring	$22,000
		Installation and calibration	6,000
	Data logger[a]	4-20mA data logger to record flow data at 15-minute intervals	1,600
Total for Pumping Plant No. 1			**$29,600**

[a]The Panametrics ultrasonic flow transmitters identified above provide totalized flow readings. This information can be sent via a 4-20 mA signal to a data logger to monitor the timing and the quantity of flow or directly to a supervisory control and data acquisition system for remote monitoring. The cost to purchase and install data loggers capable of recording outflow data is estimated to be $1,600 per site.

TABLE 3-7
SMWC Equipment Cost Estimates – ***Option 2***

Location	Equipment	Description	Estimated Cost
RD 1500 Drain Canal	Side-looking Doppler flow meter	Sontek Argonaut or similar	$16,000
		Installation, calibration, and testing	$10,000
	Canal lining if necessary	Concrete line up to 100 feet of canal (concrete lining may not be required)	$175,000
		Engineering	$35,000
		Environmental and permitting (assume Initial Study/Negative Declaration)	$16,000
Total for Option 2			**$252,000**

Annual Operations and Maintenance

In addition to the cost of the measurement equipment and its installation, costs for O&M would be incurred. These costs include the periodic inspection of the equipment to ensure it is operating correctly, periodic calibration of the measurement device(s), replacing or charging batteries, and down-loading and processing the recorded data.

Annual O&M costs for the Sutter Sub-basin are estimated to be approximately $10,000 to $15,000, depending upon the option selected and the number of measuring devices installed. This estimate is based on the following assumptions:

- Site is inspected once prior to the irrigation season and once per month after the irrigation season begins (six visits).
- Site is inspected, and only minor maintenance is required such as replacing batteries, clearing minor obstructions, and cleaning sensors.
- Calibration is checked once per year.
- Collected data are reviewed and processed, and a table of mean daily and monthly discharge is prepared for each site.

section 4 Implementation Benefits and Challenges

The BWMP identified implementation of a Sub-basin-level Water Measurement Program as a necessary step to support the concept of water management at a sub-basin level. Although many have suggested a sub-basin or regional level of management would be beneficial in meeting agricultural, M&I, and environmental water needs, it must be recognized that such an approach would require a substantial degree of coordination with respect to system operations, improvements, data use and management, and funding acquisition. This section identifies the benefits that may be realized with successful implementation, as well as the anticipated challenges associated with such a program.

Sub-basin-level Measurement and Management

Implementation of the proposed Measurement Program would be one of many tools to support the vision for expanded regional cooperation within the Sacramento Valley recommended in the BWMP. As discussed in the BWMP, the relatively high degree of both inter- and intra-district reuse and use of drainwater within the Sacramento Valley suggests the proposed Measurement Program could be particularly beneficial in understanding potential impacts that sub-basin management may have on river flows and timing. Successful implementation would require the establishment of new roles and responsibilities in the areas of program coordination, capital financing, installation, O&M, and data management and reporting.

Benefits of Sub-basin-level Measurement

Water measurement at the sub-basin level would have multiple benefits, including benefits that extend beyond the mere collection and organization of data. Implementation of the proposed Measurement Program may lead to increased coordination among BWMP participants as well as other water management entities within a given sub-basin. Improved measurement would lead to a better understanding of the local water balance, and may provide data that could be used for the real-time management of local, state, and federal water resources. Facilitating information exchange between sub-basins and irrigation districts would be beneficial in that it would enable the exchange of new measurement techniques and provide potential opportunities for measurement improvements through collaboration.

Water measurement at a sub-basin level is recommended in the BWMP as a tool that can assist in improving water supply reliability and water quality, and in providing the information necessary to achieve

maximum environmental benefits and is consistent with CALFED Quantifiable Objectives. Coordinated and improved measurement at the sub-basin level would provide for better understanding of the water balance and may lead to improved water use efficiencies through both short- and long-term management at the sub-basin level. The sites investigated in this Measurement Study were chosen because they are considered initial critical points for sub-basin outflow measurement. Additional sites (as noted in Section 5) are suggested for investigation as an extension of this proposed Measurement Program if funding can be obtained to further evaluate and implement the sub-basin-level approach discussed in this technical memorandum.

The following are among the key benefits of the proposed Measurement Program:

- **Improved Understanding of Sub-basin Outflow/Inflow –** Data collected through the Measurement Program would provide information regarding flow rate, quantity, and timing needed to make basic management decisions and to track implementation of management actions. The data would also help refine estimates of sub-basin-level water use efficiency.
- **Coordinated Management of Sub-basin Outflow/Inflow –** Improved measurement may provide information leading to improved control and coordination of inflows/outflows from sub-basins to ensure adequate supply to in-sub-basin users (as well as down-sub-basin users) and help meet management targets related to timing of return flows into the Sacramento River.
- **Coordinated Management of Drainwater Flow Rates –** Improved measurement may provide information leading to improved control and coordination of inter- and intra-district flows in major regional drains to ensure adequate supply to in-sub-basin users (as well as down-sub-basin users) and help meet management targets related to timing of return flows into the Sacramento River.
- **Maximized Benefits from Other Regional Actions –** Effectively integrating regional drainwater management with other regional actions such as conjunctive use programs and water transfers may maximize regional efficiency in drought periods.
- **In the Future, Facilitation of a Sub-basin-level Water Quality Monitoring Program –** Depending on the implementation of the proposed Measurement Program and emerging water quality regulations, the Measurement Program could potentially facilitate monitoring for water quality purposes.

Improving local water management has a recognized statewide benefit, including benefits consistent with the goals of CALFED's Water Use Efficiency and Watershed Management Programs, which are listed in Tables 4-1 and 4-2.

TABLE 4-1
Relationship with CALFED Water Use Efficiency Program Goals

CALFED Water Use Efficiency Program Goals[a]	Sub-basin-level Water Measurement Program Benefit
Reduce water demand through “real water" conservation	The success of real water conservation is partially determined by an evaluation of actual water diversions and return flows. Improved measurement at the sub-basin level may facilitate evaluation of conservation projects.
Improve water quality by altering volume, concentration, timing, and location of return flows	Improved measurement and the resulting improved understanding of the water balance would provide necessary information on the volume and timing of return flows on the sub-basin level.
Improve ecosystem health by increasing in-stream flows where necessary to achieve targeted benefits	Sub-basin outflow data could assist with water operations decisionmaking that potentially could improve in-stream flows on the Sacramento River.

[a]Source: http://calwater.ca.gov/Programs/WaterUseEfficiency/WaterUseEfficiency.shtml

TABLE 4-2
Relationship with CALFED Watershed Management Program Goals

CALFED Watershed Management Program Goals[a]	Sub-basin-level Water Measurement Program Benefit
Maximize use of available water supplies through conservation, water recycling, and water quality improvements	An improved understanding of the water balance from improved measurement at the sub-basin level may help water districts prioritize conservation and reclamation actions. Improved measurement facilities may facilitate the addition of water quality monitoring equipment.
Increase the flexibility of water systems at the state, federal, and local level through improvements in conveyance, storage, and water project operations	Use of improved data could increase the flexibility of water systems at the sub-basin-level, which could have statewide benefits.
Develop groundwater and surface water storage projects to boost flexibility and provide additional supplies for agriculture, urban, and environmental use	The development of new groundwater and surface water storage projects includes an evaluation of project diversion and release capability. Additional data describing water availability and drainage system capacity would provide increased information for the analysis of new projects.

[a]Source: http://calwater.ca.gov/Programs/WaterManagement/WaterManagement.shtml

Alternative Institutional Frameworks

Successful implementation of the proposed Measurement Program would require some agreed-upon management structure to support coordination in the Sacramento Valley and to define the maintenance and cost-sharing responsibilities among cooperating agencies and SRSCs. It is anticipated that the cooperating entities at a minimum would include the BWMP participants (SRSCs, Reclamation, and DWR). Additional entities would include other agricultural (including reclamation districts), M&I, and environmental users (primarily refuges) within a given sub-basin. It is recommended that initial efforts focus on irrigation districts and companies because of their proportional water needs and to develop momentum and gain acceptance of the concept.

Development of the structure for coordination is being undertaken in the larger context of ongoing BWMP efforts. In support of the BWMP effort, alternative regional partnerships and institutional frameworks are being considered that could support successful implementation of multi-agency or sub-basinwide management options. The SRSCs and Reclamation are currently continuing to explore the development and implementation of regional water management criteria through the BWMP to further support the sub-basin management level. The recently signed SVWMA is an example of another forum that is based on cooperation across districts throughout the Sacramento Valley.

Oversight and cooperative arrangements could take on several forms with varied levels of management authority. For example, institutional frameworks could fall into one of the following categories:

- **Memorandum of Understanding or Agreement:** Existing water districts, water companies, cities, and counties, or some combination of these entities joined through a Memorandum of Understanding or Agreement. Ideally, existing powers granted to current entities under the California Water Code could provide adequate management authority to enable a partnership arrangement to function effectively.
- **Virtual District:** Formation of a new, overarching umbrella-type water district (or "virtual district") that interfaces with existing entities and provides the authority to maintain facilities and coordinate activity involving multiple agencies.
- **Joint Powers Authority:** Formation of a Joint Powers Authority between entities.

Upfront identification of the proposed Measurement Program coordination responsibilities would be necessary to ensure effective implementation and would provide the momentum to move forward and sustain program operation. Under any of the alternative institutional frameworks, agreements regarding the following issues would be required:

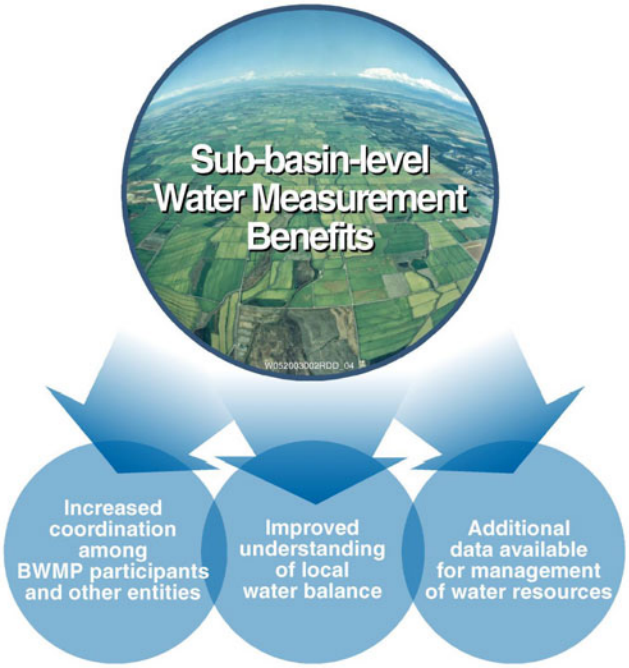
- Membership
- Structure (staff level versus Board level)
- Program scope and goals
- Program administration responsibilities
- Cost-sharing commitments
- Ownership of measurement facilities
- O&M responsibilities
- Data management and reporting
- Interface with other governing bodies such as counties and special districts

Gaining Acceptance

As described above, the potential benefits of regional management at the sub-basin level are large; however, the implementation of such a program (Measurement Program)

would require a significant level of coordination and "re-thinking" of how water is managed. Accordingly, it is suggested that implementation of such a program be taken in manageable steps to ensure buy-in and an understanding of the potential mutual benefits. The focus on a few key outflow points in this technical memorandum (as well as the identification of necessary future actions, including the all-important coordination issue) represents just such an initial, incremental step toward implementing a larger scale program.

At this time and as discussed above, new partnerships are forming in the Sacramento Valley as a result of the BWMP, the SVWMA, and in response to new water quality implementation requirements associated with the agricultural discharge waiver. Each of these ongoing efforts requires an increased level of coordination across district and water user boundaries and suggests a sub-basin-level management approach has merit and could garner support.



Other successful regional programs such as the Redding Area Water Council, coordination among water users in the Colusa Basin, the Sacramento Area Water Forum (in the American Sub-basin), and the American River Basin Cooperating Agencies provide templates and/or existing forums to advance the sub-basin-level concept.

Facility Installation, Operation, and Maintenance

Facility Installation

At this time, the primary implementation issues related to facility installation are funding and agreement among all participating entities as to which facilities should be installed first. This technical memorandum recommends that the initial focus of the proposed Measurement Program be on sub-basin outflow measurement. The actual installation is a relatively simple matter that, if funded, could be implemented by DWR or local participant agencies. For larger-scale construction projects, as identified in Section 3, the use of an independent contractor may be required. Installation and construction would be coordinated with other operational downtime such as pumping plant or outfall gate maintenance to avoid substantial delays.

Operation and Maintenance

O&M responsibilities would need to be specified in a formal agreement. Under a Memorandum of Understanding, an individual water purveyor or drainage district could commit to the O&M of facilities installed on their water conveyance and drainage infrastructure. Alternatively, a Joint Powers Authority or Virtual District could employ staff to carry out the necessary O&M functions. It is recommended that initial efforts, described in Section 5, be focused on facilities that can be operated by either a

participating SRSC, a reclamation district, or DWR because a formal institutional arrangement would not likely be in place immediately.

Cost sharing should take into consideration the value of the data to the individual participants, and an effort should be made to engage other beneficiaries who are not currently party to BWMP efforts. These entities could include CALFED, DWR, the State Water Project contractors, Reclamation, the Central Valley Regional Water Quality Control Board, U.S. Fish and Wildlife Service, and California Department of Fish and Game, all of whom would benefit from the availability of improved flow measurement.

Data Management

The initial Measurement Program, as described in Section 5, would include installation and data collection over a 2-year period. Data management would be performed by cooperating entities such as DWR and SRSCs. Initial data sharing would be among cooperating SRSCs and agencies. Data reports could be made available to other interested entities. Initial data management efforts would involve downloading of data at the sites and making the raw data available to cooperators. After the initial data collection period, the cooperating entities would need to weigh the benefits and costs associated with a centralized database and data management.

In the future, cooperating entities of the fully implemented Measurement Program could consider making the data available on a more widespread basis. Data collected under the Measurement Program could be incorporated into the DWR California Data Exchange Center. The California Data Exchange Center provides a centralized location to store and process real-time and historical hydrologic information gathered by various cooperators throughout the state. The California Data Exchange Center then makes the information accessible to the cooperators, public and private agencies, and any potential stakeholder through the Internet.

Use of Data

This Measurement Study focuses on key sub-basin outflow points, but ultimately, a comprehensive Sub-basin-level Water Measurement Program would include all significant sources of inflow and outflow, which would be of use for all cooperating SRSCs and agencies, as well as numerous other interested entities. Use of real-time and historical data could be used for short-term water operations decisions and longer-term planning purposes to achieve the Measurement Program benefits described previously.

Section 5 outlines a plan to carry out an initial 2-year Measurement Program. After initial outflow measurement locations are improved and data are collected and analyzed, the potential uses of data can be better defined, as well as the extent of data sharing.

section 5 Recommended Next Steps

Immediate action is required to implement the recommendations contained in this technical memorandum as an initial step toward a Sub-basin-level Water Measurement Program. This initial step includes obtaining funding to improve water measurement at key sub-basin outflow locations over a 2-year period to collect data and evaluate the improved water measurement.

During this initial phase, improvements to measurement at existing facilities would be made, data would be collected and analyzed, and refinements to the Measurement Program would be identified. After this initial 2-year period, additional funding would be required for annual O&M at each measurement site. After 2 years, the need for construction at the Colusa Basin Drain for a new measurement site should be evaluated.

It is recommended that SRSCs continue to work toward the development of an inter-district cooperating structure to facilitate the Measurement Program and other operational and planning activities.

Measurement Facility Improvements

The recommendations to improve measurement at key outflow points in the Sacramento Valley were presented in Section 3. These recommendations represent an incremental step toward a comprehensive Sub-basin-level Water Measurement Program that would encompass the major points of inflow and outflow for Sacramento Valley sub-basins. To achieve improved measurement, funding is required to take the reconnaissance-level recommendations contained herein and refine them into detailed final designs. Upon agreement on a final plan, construction or installation of measurement and collection equipment would be required, followed by a calibration process. It is proposed that the initial components of this Measurement Program be implemented over 2 years, with each year followed up with progress reports.

After the initial 2-year phase, structural modification to the Colusa Basin Drain, as described in Section 3, could be constructed, if warranted. The next phase of the Measurement Program would also include continued data collection and study of additional inflow and outflow locations.

The key steps of the initial 2-year phase are described below:

Funding – To implement the recommendations for key outflow sites, funding is required immediately for the program components listed below, including final design, installation, and operation of this initial set of outflow locations. In Section 3, the costs of improving the measurement at outflows locations were estimated. The total cost of the recommended improvements is estimated to be $155,000 for initial capital costs, including design and installation/construction. Annual O&M costs are estimated to be on the order of $60,000. The total estimated cost to implement the proposed initial 2-year phase is $275,000.

These cost estimates do not include larger-scale improvements for a new measurement location on the Colusa Basin Drain. The necessity of this project would be evaluated after the initial improvements were made at

Knights Landing Outfall Gates. Capital costs for engineering, construction, and environmental permitting are estimated to be $270,000.

If additional funding is available beyond the scope of these initial outflow measurement improvements, it is recommended that this Measurement Study be extended to include additional sub-basin outflow and inflow locations to move toward a comprehensive measurement program.

Final Design of Measurement Improvements – The reconnaissance-level recommendations described in Section 3 may require further refinement, including detailed design specifications. Where applicable, a detailed calibration process must be further refined through coordination with DWR and/or other operating agency field staff.

Installation of Measurement and Collection Facilities – Measurement devices and data collection equipment would be installed at all recommended locations. Installation would be coordinated with operations staff of the facility owner. Depending on the sub-basin operations, some sites may be best suited for installation during the irrigation season (during times of minimal outflow) with calibration during the rice drainage period. Other sites that experience sustained drainage outflow during the irrigation season may necessitate installation in the fall season, with calibration during winter rain events.

Measurement Calibration – After installation, the measurement devices would be calibrated to ensure flow measurement accuracy. Where possible, field measurements would be taken to verify data from measurement devices.

Initial Data Collection – Depending on the timing of project funding, data may be collected in the first year as soon as devices are installed and calibrated or other recommended improvements are made. This initial data collection would be useful in determining refinements necessary for ongoing measurement.

Cooperating SRSCs and agencies already operating measurement locations would measure with the recommended improvements under the proposed coordinated program. For this initial 2-year period, a structured agreement may not be in place, and data collection may need to be implemented by a combination of participating district staff and consulting engineers. These costs should be included in any funding requests involving this Measurement Study.

Year 1 Progress Report – The purpose of the progress report after the first year is to document the devices that have been installed or the improvements that have been made, as well as the overall effectiveness of the improvements. This report would document any refinements required for future measurement. Any data that have been collected during Year 1 would be presented in this progress report.

Year 2 Data Collection – It is anticipated that outflow data would be collected for the entire irrigation season in Year 2. The emphasis of this Measurement Program is on water use during the irrigation season. The sites identified and addressed in the Measurement Study do not capture higher outflows from these basins, and therefore, any data collected during high flow events (i.e., in the winter) would have limited, if any, usefulness. Year-round measurement would require additional equipment and/or modifications at every location.

Evaluate Measurement Equipment – The measurement and data collection technologies applied to this initial 2-year phase of the Measurement Program would be evaluated. The evaluation would investigate

measurement accuracy, ease of operation, and reliability of data collection.

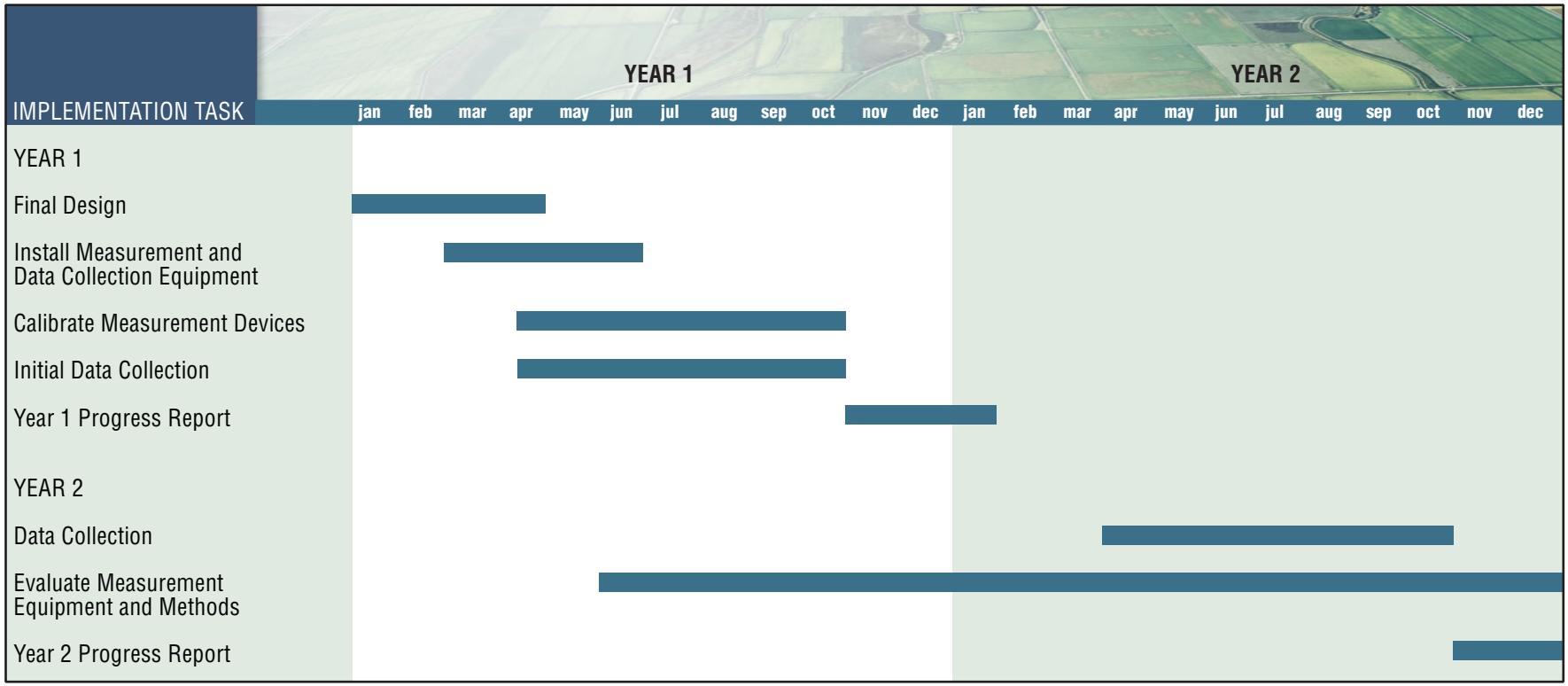
Sub-basin-level Data Analysis – The data collected would be used for sub-basin-level water balance calculations. Other initial uses for the data may include sub-basin outflow discharge timing and quantity analysis. These types of analyses are a potential benefit of the proposed Measurement Program, but not necessarily a component of the program.

Year 2 Progress Report – In the second progress report, all collected data would be summarized. The results of the equipment evaluation and of the measurement improvements would also be presented. The operations costs associated with the improved water measurement could also be documented. A key component of this progress report is an evaluation of how the data could be used in the future for operations and water management purposes.

Figure 5-1 presents a conceptual schedule showing the implementation of the initial 2-year phase of the proposed Measurement Program.

Continued Sub-basin-level Coordination

Improving the water measurement at key sub-basin locations to facilitate improved water operations at the sub-basin level and throughout the Sacramento Valley is one component of the overall BWMP. By improving the confidence in data and making the data available, coordination within sub-basins among districts and among sub-basins should continue to improve. It is recommended that the SRSCs continue to work toward developing the organizational framework required to implement a comprehensive Sub-basin-level Water Measurement Program that would facilitate further coordinated operations throughout the Sacramento Valley.



Note:
Implementation schedule assumes that funding has been secured for a two year initial program including capital costs and O&M.

FIGURE 5-1
INITIAL IMPLEMENTATION SCHEDULE
SACRAMENTO RIVER BASINWIDE WATER MANAGEMENT PLAN
SUB-BASIN-LEVEL WATER MEASUREMENT STUDY

W052003002RDD_05 (6/27/03)

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section 6 References

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