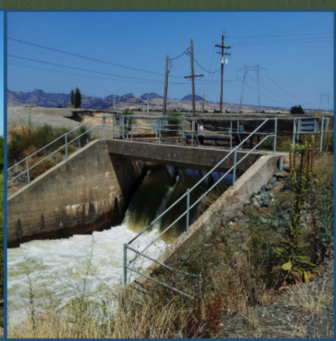
# Feather River Regional
## Agricultural Water Management Plan

## Executive Summary

August 2014





Prepared by

Northern California Water Association and
the Feather River Water Suppliers

Feather Water District  Garden Highway Mutual Water Company  Plumas Mutual Water Company  Tudor Mutual Water Company

## Preface

This Feather River Regional Agricultural Water Management Plan (FRRAWMP) has been prepared by the Northern California Water Association (NCWA) and participating Feather River agricultural water users under a Proposition 204 grant awarded by the California Department of Water Resources (DWR). The plan has been prepared in accordance with the requirements of the Water Conservation Act of 2009 (SBx7-7), which modifies Division 6 of the California Water Code (CWC or Code), adding Part 2.55 (commencing with §10608) and replacing Part 2.8 (commencing with §10800). In particular, SBx7-7 requires all qualifying agricultural water suppliers to prepare and adopt an AWMP as set forth in the CWC and the California Code of Regulations (CCR) by December 31, 2012. Plans must be updated by December 31, 2015 and then every 5 years thereafter (§10820 (a)). Additionally, the CWC requires suppliers to implement certain efficient water management practices (EWMPs).

DWR released a Guidebook to Assist Agricultural Water Suppliers to Prepare a 2012 Agricultural Water Management Plan (Guidebook) on October 24, 2012 (DWR 2012). The Guidebook was relied upon in the preparation of the FRRAWMP to ensure that applicable sections of the CWC were addressed. Some differences in the specific formatting of the FRRAWMP from the template provided in the Guidebook exist due to this plan being a regional AWMP, as compared to an individual supplier AWMP, and in the interest of conciseness and readability.

Development of the plan included coordination among the following Feather River water suppliers and users:

- Joint Water Districts
    - Biggs – West Gridley Water District (BWGWD)
    - Butte Water District (BWD)
    - Richvale Irrigation District (RID)
    - Sutter Extension Water District (SEWD)
- Western Canal Water District (WCWD)
- Lower Feather Water Users
    - Feather Water District (FWD)
    - Garden Highway Mutual Water Company (GHMWC)
    - Plumas Mutual Water Company (PMWC)
    - Tudor Mutual Water Company (TMWC)
    - Sutter Bypass-Butte Slough Water Users Association (SBBSWUA)

Additionally, development of the FRRAWMP included consultation with representatives of the Butte County Department of Water and Resource Conservation, the California Department of Fish and Wildlife (CDFW[1]), the U.S. Fish and Wildlife Service (USFWS), and DWR. These consultations do not necessarily denote endorsement of the plan.

The FRRAWMP is structured in two volumes. Volume I includes regional AWMP components, and Volume II includes individual supplier AWMP components. Sections in the second volume of the regional AWMP for agricultural water suppliers serving over 10,000 acres include a cross-reference identifying the location(s) in the AWMP within which each of the applicable requirements of SBx7-7 and the corresponding sections of the CWC are addressed. This cross-reference is intended to support efficient review of the AWMP to verify compliance with the CWC.

This document represents the first AWMP for the Feather River region and the first regional AWMP prepared to satisfy the requirements of SBx7-7. It is anticipated that this AWMP will be updated every five years, as required by the CWC with the first update in 2015. Due to this plan being completed in 2014, major changes are not expected for the 2015 update. The next update will occur in 2020 and is expected to include updated descriptions of hydrology and water management within the region, additional detail describing regional water management objectives and opportunities, and updated descriptions of projects with the potential to further enhance water management capabilities for individual suppliers and for the region collectively.

[1] Formerly the California Department of Fish and Game (CDFG).

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## Introduction

This Feather River Regional Agricultural Water Management Plan (FRRAWMP) has been funded by a Department of Water Resources (DWR) Proposition 204 grant awarded to the Northern California Water Association (NCWA). The plan has been developed for the irrigation water suppliers along the Feather River, including those receiving water from Thermalito Afterbay. The region relies on substantial amounts of surface water and groundwater, yet water supplies, consumptive uses, and water management have generally not been comprehensively documented historically. The region has been evaluated for its potential to expand conjunctive water management practices through groundwater management planning and other efforts; however, there remains interest in better understanding groundwater–surface water interactions in the region.

To address these needs, this regional AWMP includes an inventory of surface water and groundwater supplies and uses and through water balance analyses characterizes the interaction between irrigated lands, underlying groundwater systems, and the surrounding environment. Additionally, the AWMP provides an evaluation of opportunities to enhance water management and monitoring in the region to meet local, regional, and statewide water management objectives. The plan identifies and characterizes interdependencies between agricultural water suppliers and other water uses, including other agriculture in the region and important wetlands and aquatic ecosystems. Water use in the region can be described as “flow through” or “cascading” where water diverted and applied to an individual farm or within an individual supplier service area that is not consumed to produce crops or provide habitat flows through the system where it is available for other beneficial uses.

## Water Use Efficiency in the Feather River Region

Indicators of water use efficiency in the region are described as part of regional and supplier water balance analyses. As described by NCWA (2011), analysis of efficiency in interconnected systems such as the Feather River region should not focus on individual uses or water users without also considering consequential effects of water management actions related to upstream and downstream water uses. By developing a detailed understanding of the hydrology of and water management within the region as part of the Feather River Regional AWMP, the groundwork has been laid for further development of specific actions to meet water management objectives. By accounting for the relationships between water users within the region, potentially undesirable consequential effects have been identified that can be collaboratively avoided or minimized while still achieving desired benefits. Although there is negligible opportunity to increase water supplies by reducing irrecoverable losses of water, there are opportunities to increase local, regional, and statewide water supply and water supply reliability by better managing *when* and *where* (1) available water supplies are used and (2) water returns to the system.

## Plan Area

The plan area, herein referred to as the Feather River Region, is located on the east side of the Sacramento Valley in northern California and includes approximately 324,000 acres of some of the Sacramento Valley's most productive agricultural land; several natural waterways, including Butte Creek, an important waterway for salmon and steelhead; and approximately 76,000 acres of important riparian habitat, managed wetlands, and wildlife areas and refuges, including Sutter National Wildlife Refuge, Gray Lodge Wildlife Area, Upper Butte Basin Wildlife Area, North Central Valley Wildlife Management Area, and Butte Sink Wildlife Management Area. It is bounded on the east by Thermalito Afterbay and the Feather River and on the west by the Sacramento River, Butte Slough, and the west levee of the Sutter Bypass. It is bounded in the north by the northern boundary of WCWD and Rancho Llano Seco and by the confluence of the Feather River and Sacramento River in the south. A map of the region is provided in Figure ES-1.

The primary industry in the region is agriculture, with over 180,000 acres of rice, approximately 90,000 acres of orchards, and 34,000 acres of other crops grown in recent years. Water for irrigation is the lifeblood of the region's economic engine. In 2012, the estimated gross value of crops grown in the region was over $700 million with a total contribution to the regional economy of between $1.5 and $1.9 billion.

## Plan Components

The individual components of the plan are driven by the objectives of the plan and by the requirements of the California Water Code (CWC) Sections 10608.48 and 10800-10853. The following components are included:

- Regional Components (Volume I)
  - Regional Description and Inventory of Water Supplies
  - Regional Water Balance
  - Water Management Objectives, Activities, and Opportunities
  - Climate Change
  - Recommended Actions
- Supplier Components (Volume II)
  - Cross-Reference to Requirements of SBx7-7
  - Plan Preparation and Adoption
  - Background and Description of Service Area
  - Inventory of Water Supplies
  - Water Balance
  - Climate Change
  - Efficient Water Management Practices and Water Use Efficiency

## Regional Setting and Water Supplies

Water is used in the region throughout the year for a combination of agricultural and environmental purposes. The primary growing season is from April or May of each year to September or October. During the remainder of the year from October through March, water is used to provide important wetlands and aquatic habitat for waterfowl and shorebirds in the Pacific Flyway as well as aquatic fish and reptile species such as salmon, steelhead, and the giant garter snake. Winter water use is also an integral part of rice production in the region, allowing for rice straw decomposition as an alternative to rice burning, which was phased out in the 1990's. Adequate flow and water quality in Butte Creek and the Sutter Bypass is additionally critical to support the migration of salmon and steelhead.

### *History*

Due to the Mediterranean climate of the Sacramento Valley, which is characterized by cool, wet winters and hot, dry summers, the first settlers in the Feather River Region grew grain crops such as wheat, barley, and oats without irrigation, typically planting in the late fall, allowing winter and spring rainfall to support crop growth, and harvesting in the summer; however, as early as the 1800's, forward-thinking settlers recognized the tremendous benefits irrigation could offer to the region. Near the turn of the 20th century, a diversion structure was built along the Feather River at the Hazelbusch Ranch, and the construction of canals and conveyance systems for the diversion of water followed. Rice was introduced around this same time, which is one of the only crops suited to the heavy clay soils that dominate much of the region and is consequently the primary crop grown today. Other crops include orchard crops such as walnuts, prunes, and almonds; a variety of field and truck crops; and pasture, grain, and hay crops.

As the century progressed, GHMWC, PMWC, TMWC, FWD, and Oswald Water District (OWD) were formed along the Feather River downstream of the Sutter-Butte Canal Company. RID, BWGWD, BWD, and SEWD were also formed. These four purchased the pre-1914 water rights and property of the Sutter-Butte Canal Company and formed the Joint Water Districts Board (Joint Districts), which remains in operation today. WCWD, which historically diverted water from the Feather River and currently diverts water from Thermalito Afterbay along with the Joint Districts was formed in 1984 when its water rights and infrastructure were acquired from the Pacific Gas and Electric Company, who had acquired what was formerly known as the Western Canal Company from the Great Western Power Company in 1930.

Water storage reservoirs were built along the Feather River upstream of the area in the 1960's, the largest being Lake Oroville, which is impounded by Oroville Dam and has a capacity of over 3.5 million acre-feet. Construction of Thermalito Afterbay, which lies below the dam, resulted in the need to replace the points of diversion for WCWD and the Joint Districts. The districts now divert water primarily from Thermalito Afterbay, with the exceptions of WCWD which receives a small portion of its supply from Butte Creek and SEWD which receives a portion of its supply from the Feather River at the Sunset Pumps.

Irrigation for agriculture is the primary developed water use in the region. Surface water from the Feather River is the most prominent source of water for irrigation. Groundwater is used in areas without access to surface water and generally throughout the region in the event of a surface water shortage due to drought. Groundwater is also increasingly chosen by individual water users as a source of supply for irrigation in some areas despite the availability of surface water due to potential water quality benefits, such as reduced filtration requirements, and increased flexibility in the timing and amount of water applied. This is particularly true for pressurized irrigation systems increasingly used to irrigate orchard and, in some cases, row crops. Other water uses in the region include municipal and industrial uses in urban and rural residential areas and environmental uses for managed wetlands and other wildlife habitat.

For discussion of the physical characteristics of the region and water management within it, five subareas have been defined. The subarea boundaries are shown in Figure ES-1, along with water supplier service areas and regional hydrography. The subareas are described in greater detail in Volume I of the plan and summarized in Table ES-1.

***Table ES-1. Summary of Regional Subareas.***

| Subarea | Acres | Primary Crop(s) | Surface Water Source(s) | Groundwater Usage | Drainage Destination(s) |
|---|---|---|---|---|---|
| WCWD and Joint Districts | 220,000 | Rice | Thermalito Afterbay, Butte Creek, Little Dry Creek, Cherokee Canal | Variable, but generally limited | Butte Creek, Cherokee Canal, Snake Creek, Wadsworth Canal, Sutter Bypass |
| West of Butte Creek | 86,000 | Rice, Orchards | Sacramento River, Butte Creek, Angel Slough | Primarily along Sacramento River | Sacramento River, Sutter Bypass |
| Butte Sink and Sutter Bypass | 56,000 | Rice, Orchards | Butte Creek; Butte Slough; Wadsworth Canal; DWR Pumping Plants 1, 2, and 3 | Primarily surrounding Sutter Buttes | Sacramento River |
| Sutter Buttes | 43,000 | Range-land | Precipitation | Very limited | Surrounding lands |
| Lower Feather | 69,000 | Orchards, Rice | Feather River, Drains and Sloughs | Primarily around Yuba City | Sutter Bypass, Feather River |

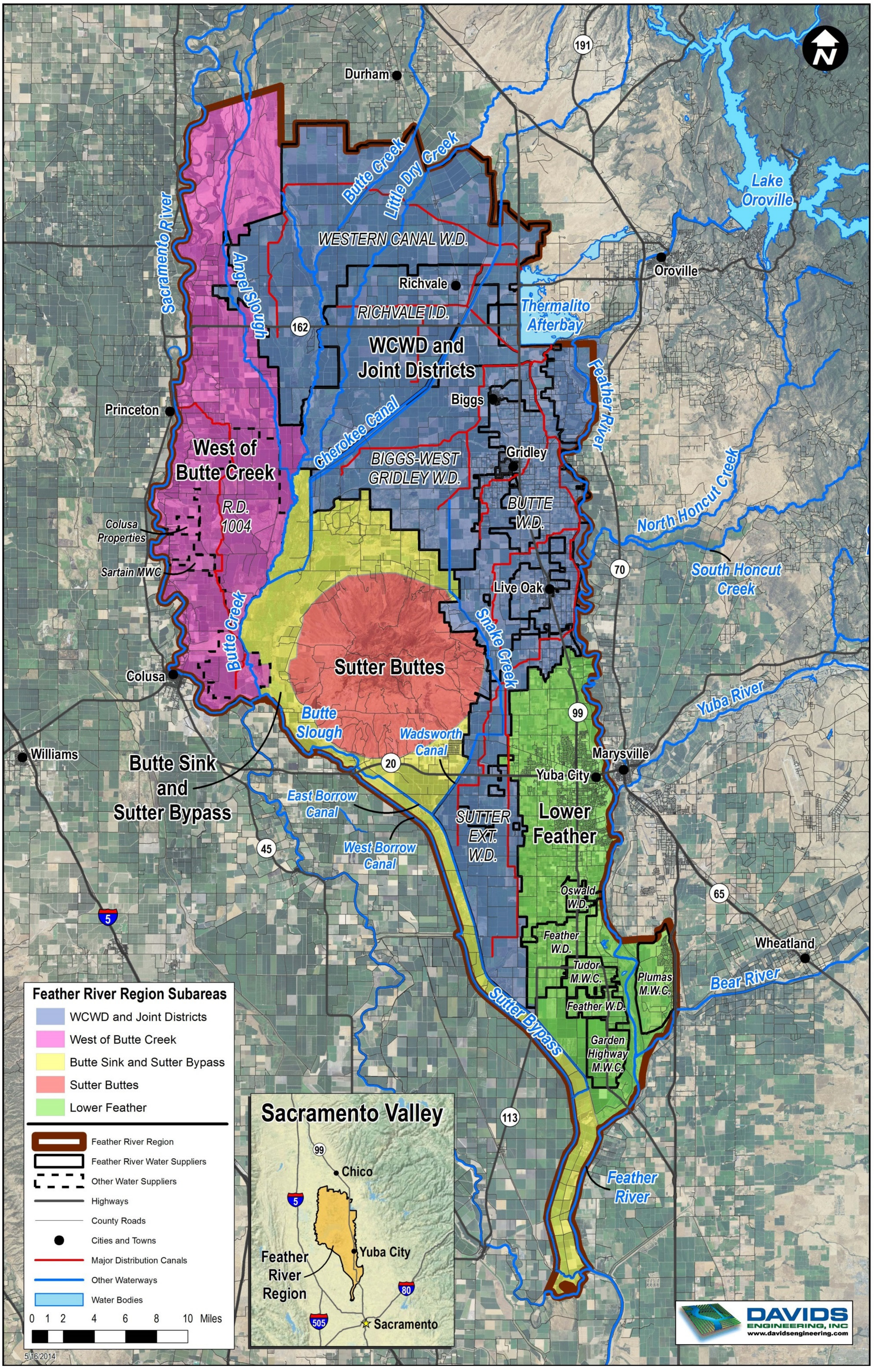


*Figure ES-1. Feather River Region and Subareas.*

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### *Terrain, Soils, and Climate*

With the exception of the Sutter Buttes, the terrain in the region is nearly flat with the land surface elevation gradually decreasing towards the south. The surface soils in the region consist of alluvial deposits from historic flooding of the Sacramento and Feather Rivers. The soils tend to be heavier, clays and clay loams, in areas of rice production. There are also areas of coarser, loamy soils found along the west side the Feather River in areas of orchard production.

The region experiences a Mediterranean climate, typical of the eastern Sacramento Valley, with mild winters and mild to moderate precipitation and warm to hot, dry summers. Average annual reference evapotranspiration ($ET_o$) is approximately 49 inches, ranging from a low of one inch in December and January to a high of over seven inches in June and July. Approximately three quarters of the annual $ET_o$ occurs in the six-month period from April through September. Average annual precipitation is approximately 22.7 inches, with 17.3 inches or slightly more than three quarters occurring in the five month period from November through March. Significantly more precipitation occurs as both rain and snow in the Sierra Nevada Mountains east of the region, which represent the primary source of regional surface water supplies.

### *Water Supplies and Hydrology*

Regional sources of surface water include the Feather River, Sacramento River, Butte Creek, and other, small streams. Surface water users within the region hold various rights and agreements to divert available surface water, and surface water is of good quality for irrigation. Groundwater is generally available throughout the region, with the exception of the Sutter Buttes subarea. Groundwater quality varies within the region, affecting its suitability in some areas, but is generally of good quality for irrigation.

#### Surface Water

The primary source of surface water within the region is the Feather River. Water is diverted from the Feather based on a combination of pre-1914, riparian, and appropriative water rights and based on diversion agreements between Feather River settlement contractors (water suppliers with water rights established prior to construction of the State Water Project) and the State. The Joint Districts entered into an agreement for diversion of water from the Feather River with the State in 1969 following the construction of Lake Oroville stating that they have the right to the diversion of up to 555,000 af of natural flow, subject to reduction during drought. Under a similar agreement entered into between the State and WCWD in 1986, WCWD has a right to the diversion of up to 150,000 af of natural flow from the Feather River, subject to reduction during drought, and a right to 145,000 af of upstream stored water on the North Fork of the Feather River, not subject to reduction. When a reduction is allowed, WCWD and the Joint Districts supplies subject to reduction can be reduced by up to 50 percent in any one year, but not more than 100 percent in any seven years, cumulatively.

GHMWC, PMWC, TMWC, and OWD hold similar diversion agreements with the State and are subject to reductions under the same conditions as WCWD and the Joint Districts. GHMWC, PMWC, and

TMWC additionally hold riparian rights on the Feather River that are not subject to reduction. FWD diverts water under a combination of riparian water rights and agreements with the State and the U.S. Bureau of Reclamation (USBR, or Bureau).

The surface water hydrology of the region can be characterized as a cascading or flow through system, where water entering an area of water use within the region as a diversion, natural inflow, or flood flow is consumed through the processes of evapotranspiration, enters the groundwater system, or returns to the surface water system and can be reused downstream. Water not consumed within the region is available for reuse downstream or may provide beneficial recharge of the groundwater system. Locations of boundary inflows and outflows to and from the region, respectively, are shown in Figure ES-2. In the figure, flow measurement sites are labeled using the site ID for the agency responsible for the site and color-coded based on the availability of flow data for the 1984 to 2012 period.

In order to further understand and evaluate opportunities for and implications of water management actions aimed at meeting water management objectives, a schematic depicting the surface hydrology within the region was developed (Figure ES-3). The schematic identifies local water use areas within each subarea and identifies linkages and flow routing (i.e., direction) to and from adjacent water use areas, natural waterways, and other water sources (i.e., Thermalito Afterbay). The color coding of the symbols denoting measurement locations is consistent with that of Figure ES-2, indicating the percent of time data was available for the period of interest. Available data from many of the sites were used to prepare regional and water supplier water balances describing historical water management included in Volume I, Section 3 and Volume II, Sections 3 through 8 of this AWMP.

Comprehensive surface water quality monitoring is conducted within the region and allows for assessment of the quality of water for agricultural and habitat uses. Based on available data, water from the Feather River and other waterways within the Feather River region is generally of good to excellent quality for irrigation and habitat.

**Groundwater**

The region is located within the Sacramento Valley groundwater basin (Basin 5-21), as described in DWR Bulletin 118 (DWR 2003), which spans the valley floor from approximately Red Bluff in the north to the Cosumnes and Sacramento Rivers in the south and encompasses an area of over 5,800 square miles. The Feather River Region overlies portions of the East Butte (5-21.59), West Butte (5-21.58), Sutter (5-21.62), and South Yuba (5-21-61) subbasins. The subbasins are distinguished from east to west by surface water streams and from north to south by the Sutter Buttes.

Areas in the region that rely on groundwater for irrigation generally fall outside of water supplier service areas, although pumping by agricultural water suppliers and growers within supplier service areas does occur in some cases. Groundwater is replenished through deep percolation of applied irrigation water and precipitation, canal seepage, and stream losses.

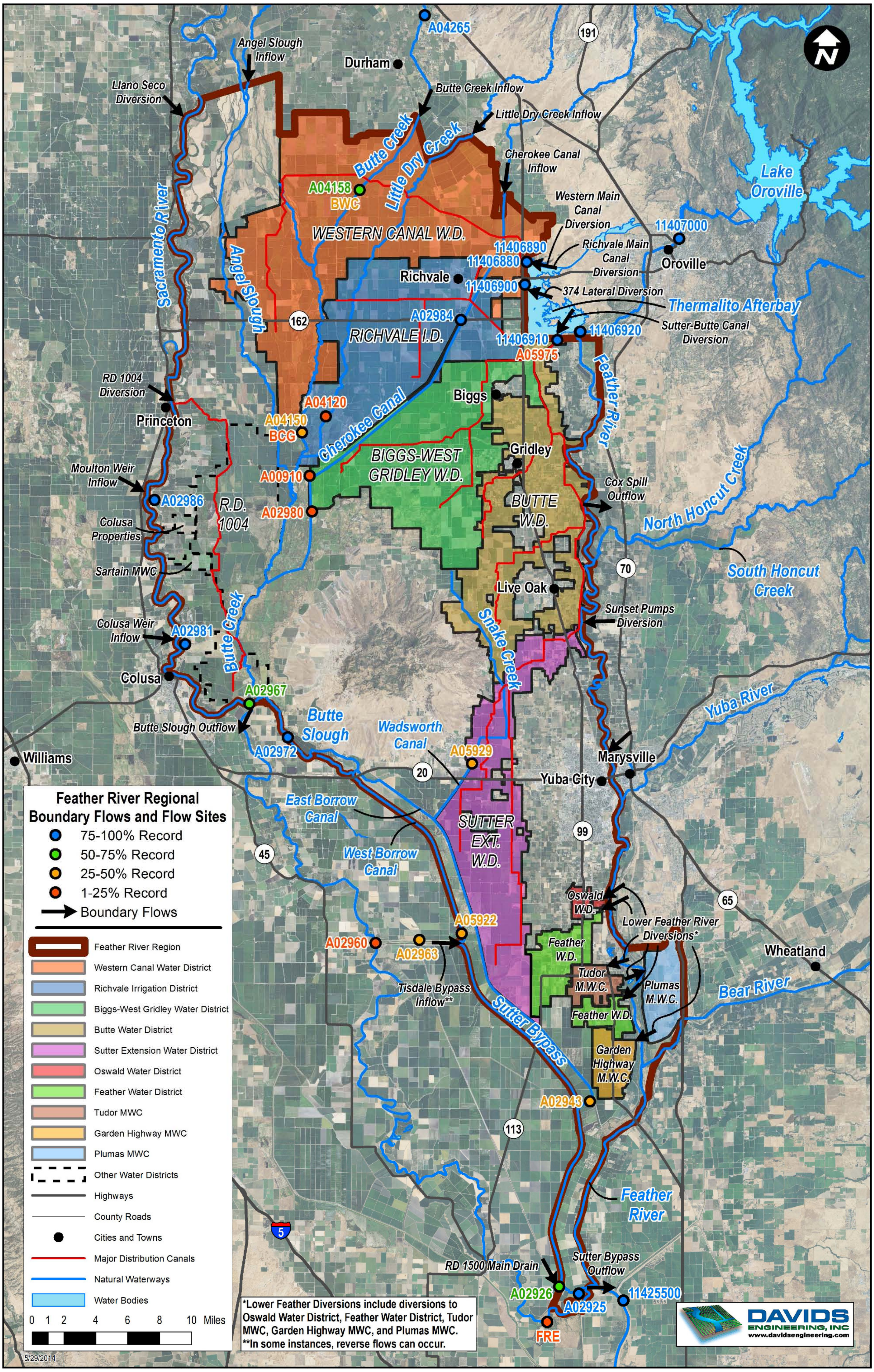
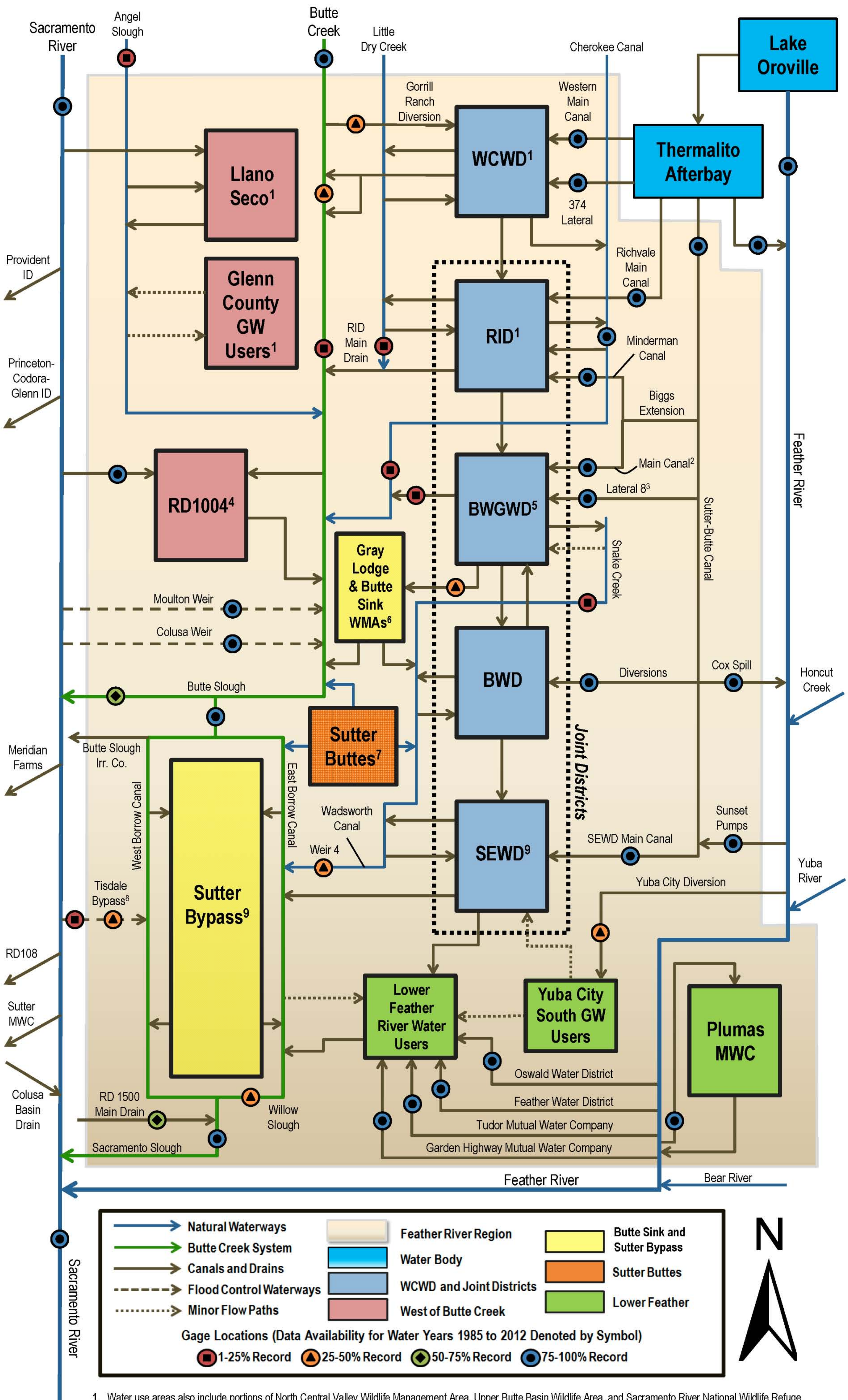



*Figure ES-2. Regional Boundary Flows, Water Suppliers, and Flow Measurement Sites.*




1. Water use areas also include portions of North Central Valley Wildlife Management Area, Upper Butte Basin Wildlife Area, and Sacramento River National Wildlife Refuge.
2. Main canal also includes Branch A diversion and other deliveries.
3. Lateral 8 also includes miscellaneous deliveries to BWGWD.
4. RD 1004 also includes Colusa Properties, Sartain MWC, and others.
5. Water use area includes a portion of Gray Lodge Wildlife Area.
6. Water use area also includes agricultural land adjacent to Sutter Buttes.
7. Flow from Sutter Buttes to surrounding lands is runoff of precipitation in the winter and spring.
8. In some instances, reverse flows can occur.
9. Water use area includes portions of Sutter National Wildlife Refuge.

***Figure ES-3. Feather River Region Surface Hydrology and Water Use Areas.***

The materials making up the Sacramento Valley groundwater basin and its subbasins consist of sediments deposited in both marine and terrestrial environments. The base of fresh water varies from over 1,000 feet below sea level in the northern portion of the region to approximately 400 feet below sea level surrounding the Sutter Buttes.

Based on DWR records, there are approximately 1,800 irrigation wells and 460 dedicated monitoring wells within the region. Irrigation wells tend to be concentrated in areas of crop production without dedicated surface water supplies. These areas include the area east of the Sacramento River south of Rancho Llano Seco and outside of RD1004 and the area west of the Feather River between Thermalito Afterbay and GHMWC. Dedicated monitoring wells are generally distributed across the region, with increased concentration in populated areas.

Groundwater levels fluctuate within a given year and across years. Intra-annual variability occurs as groundwater is extracted from the underlying groundwater system for irrigation during the summer months and recharged during times of precipitation in the winter and spring months. In rice growing areas, shallow groundwater levels often increase during the irrigation season in response to irrigation using surface water. Historically, inter-annual groundwater levels within the region have declined during periods of drought but recovered to pre-drought levels subsequently during wetter periods. In some areas, such as portions of the West Butte subbasin, there are indications of persistent declines in groundwater levels.

Figures ES-4 and ES-5 display average spring and fall groundwater levels, respectively, between 1999 and 2011. The figures include groundwater contours demonstrating the general movement of groundwater from north to the south and west through the region (groundwater moves perpendicular to the contours, from higher elevations to lower elevations). Regional groundwater levels are typically lower in the fall following groundwater pumping for the irrigation season in some areas and preceding the recharge that occurs during winter and spring precipitation. Depth to groundwater varies across the region from less than five feet in much of RID and WCWD to more than 15 feet in the groundwater only area around Yuba City. In areas that are in rice production, (notably in WCWD, RID, and BWGWD) there is typically a groundwater table within five to ten feet of the ground surface. Irrigation wells in the region range from a depth of 35 ft to over 900 ft with an average of approximately 300 ft (DWR 2003).

Most agricultural water suppliers in the region do not actively monitor groundwater quality; however, water quality monitoring is conducted within the region by others and allows for assessment of the quality of water for agricultural and environmental uses. Based on available data, groundwater in the region is generally of good quality, with few exceptions. NCWA has developed a groundwater quality assessment report for the Sacramento Valley to evaluate sources of salt and nitrate loads and potential long-term effects on surface water and groundwater resources. This information will support understanding of sustainable management of surface water and groundwater supplies, including conjunctive management opportunities and limitations.

**Information Gaps**

Review of Figures ES-2 and ES-3 indicates that while information describing inflows to and outflows from the region is relatively abundant and complete, limited information is available describing surface flows between water use areas within the region. In particular, information describing inflows to and flows along the Butte Creek system[2] are limited. Several stream gage sites were established on Butte Creek as part of the Central Valley Project Improvement Act (CVPIA) Anadromous Fish Restoration Program (AFRP) in the late 1990s, but some have been discontinued or are no longer maintained. As a result, current hydrologic conditions and system responses to water management activities are not adequately monitored. The supplier water balance analyses described in Volume II, Sections 3 through 7 of this AWMP provide insight into return flows to the system from irrigation but are estimated and subject to substantial uncertainty. Improved understanding of flows in the Butte Creek/Sutter Bypass system is important for multiple operational and analytical purposes.

Primary information gaps for the groundwater system are related to interactions between the surface and groundwater systems. Exchanges between the surface water and groundwater systems include flows to the groundwater system through deep percolation, seepage, and stream losses and flows from the groundwater system through pumping and shallow groundwater interception (including shallow groundwater uptake by vegetation and accretions in drains and streams). These fluxes cannot be practically directly measured in most cases. Improved understanding of these interactions would enhance the evaluation of conjunctive management opportunities to increase local water supplies to meet local and regional water management objectives. The approach to improve confidence in estimates of interactions between the surface water and groundwater systems is complementary with objectives for closing information gaps related to surface hydrology. The primary sources of uncertainty in estimating surface water-groundwater exchange are surface water outflows at the supplier and regional scales. The contributions of individual surface water-groundwater fluxes to recharge would be better understood through investigations of canal seepage and gains and losses in streams and drains and through field-scale water balances to better estimate deep percolation resulting from irrigation and precipitation.

### *Irrigation, Drainage, and Flood Control Facilities*

Water diversion and conveyance infrastructure in the region tends to be relatively similar in nature, although there are some notable differences between the water suppliers in the northern part of the region that receive the water through the Thermalito Afterbay and facilities and in the southern part of the region that divert water directly from the Feather River. Water delivered to suppliers from Thermalito Afterbay is exclusively via gravity flow with no pumping required and no direct influence on Feather River flows downstream of Lake Oroville. Diversions along the Feather River use pumps to lift water from the river for conveyance through distribution systems via gravity.

[2] The Butte Creek system includes Butte Creek from the northern boundary of WCWD to Buttes Slough and the East Borrow Canal and West Borrow Canal of the Sutter Bypass to Sacramento Slough, which discharges to the Sacramento River near Verona.

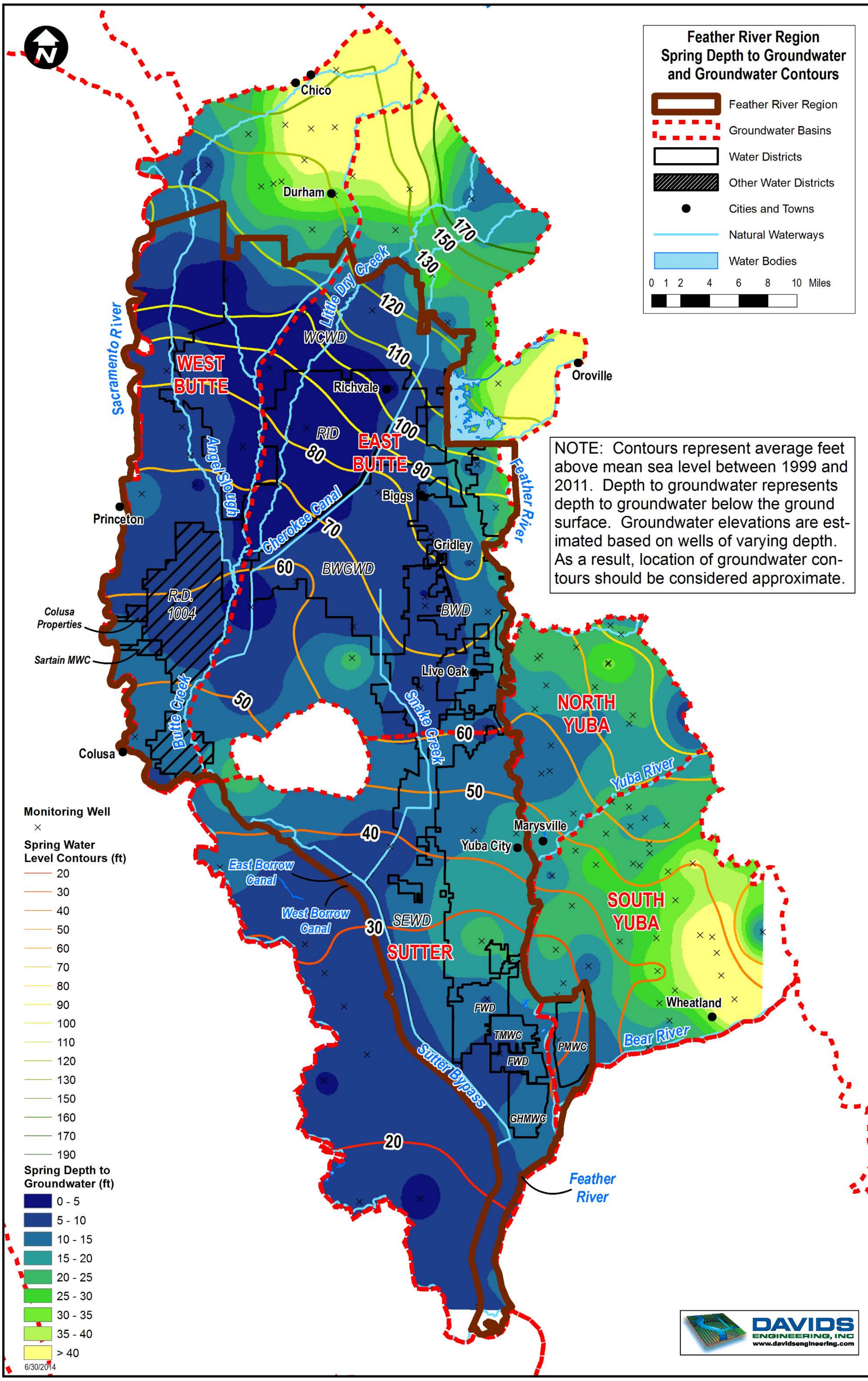



*Figure ES-4. Average Spring Groundwater Levels and Contours for Feather River Region from 1999 to 2011.*

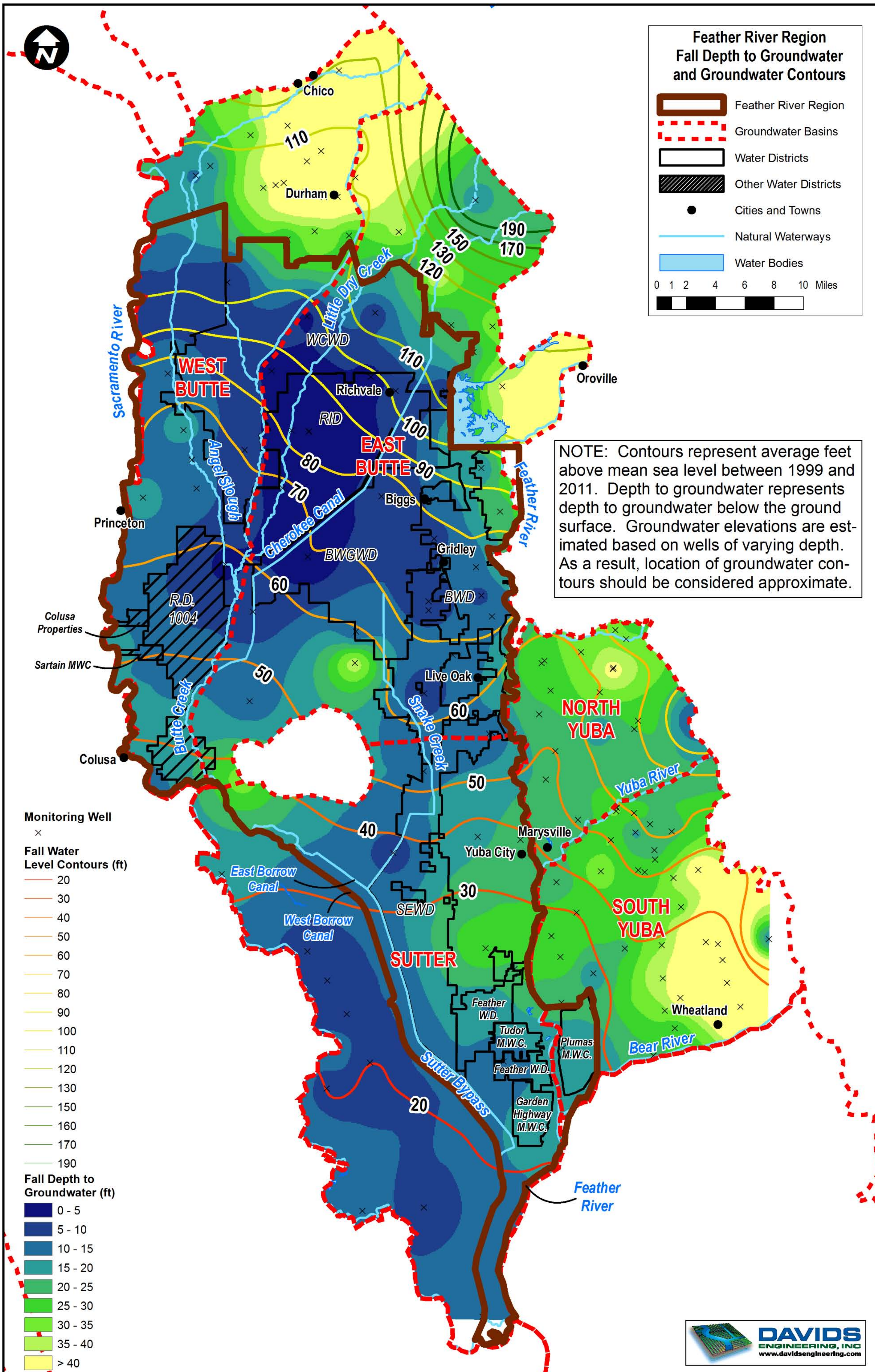



*Figure ES-5. Average Fall Groundwater Levels and Contours for Feather River Region from 1999 to 2011.*

Extensive networks of drains in the region convey direct precipitation, runoff of precipitation and tailwater, and shallow groundwater interception away from fields. The majority of the drains are managed by reclamation districts, drainage districts, or private growers, although some drains are maintained by water suppliers. Suppliers and individual water users take measures to recapture drainwater for reuse through a combination of gravity flow where possible and pumped flow where required. Reuse is extensive throughout the region. Some water users, particularly in the southern subareas of the region, are heavily dependent on drain flows from upstream water use areas.

Flood control within the region is accomplished through operation of Lake Oroville, the Sutter Bypass, and related facilities by DWR and others. Regional drainage networks provide localized flood control and also provide drainage of surface runoff from irrigation and shallow groundwater relief. A detailed evaluation of flood control within the region is not included as part of this regional AWMP. A detailed assessment of flood management priorities within the region and the Central Valley as a whole is provided in the Draft Feather River Regional Flood Management Plan (YCWA et al. 2014) and the 2012 Central Valley Flood Protection Plan (DWR 2011).

### *Rules and Regulations Affecting Water Availability*

Each agricultural water supplier within the region possesses operating rules and regulations accompanied by associated policies. These protocols are described in greater detail in Volume II, Sections 3 through 8. In general, operating rules and regulations include policies on water allocation, water usage, required fees and charges, timing of water deliveries, and water transfers into or out of each supplier's service area. Agreements with the State were made by those diverting water from the Feather River prior to construction of the SWP, and various institutional and regulatory actions have been taken following the construction of the project that affect operations of the Feather River by DWR and individual Feather River water users. Each has the right to divert certain amounts of water, subject to reduction under certain conditions.

Groundwater is a critical source of water supply for areas that rely exclusively on groundwater and important in areas that rely on groundwater as a supplemental water source. Historically, groundwater has been managed through locally-controlled programs. Agencies within the Feather River region that have prepared and adopted groundwater management plans (GMPs) include BWGWD, BWD, FWD, RD1004, RID, SEWD, and WCWD. Additionally, the counties of Butte, Colusa, Glenn, Sutter, and Yuba have prepared and adopted GMPs.

### *Water Measurement, Pricing, and Billing*

Water measurement is practiced throughout the region and varies depending on location and conditions. Water measurement practices among suppliers are influenced by factors including the type of distribution system, irrigation methods employed, cropping, contractual/regulatory requirements, and operational benefits and costs associated with measurement practices. SBx7-7 mandates new customer delivery measurement requirements for agricultural water suppliers. Resulting regulations have had a substantial influence on customer delivery measurement in the region, as WCWD, RID, and BWGWD are mandated to comply regardless of the availability of funding. WCWD has historically implemented a customer delivery measurement program in place that satisfies the requirements. BWGWD and RID have performed an evaluation of customer delivery measurement options, selected a compliant measurement approach, and are in the process of implementing delivery measurement improvements and a pricing structure based at least in part by quantity of water delivered (See Volume II, Sections 3 and 5, respectively).

Existing water supplier pricing structures within the region are influenced by several factors such as external influences on water pricing, operating costs, typical demands based on cropping and irrigation methods, and historical precedent. Water suppliers typically establish rates to recover administrative, O&M, and long-term capital improvement costs. Pricing structures often include a stand-by charge regardless of water usage, and either a per-acre, per-irrigation, or per-acre-foot charge that may vary by crop, irrigation method, time of year, etc. As a result of SBx7-7 and resulting regulations, required suppliers who do not have a pricing structure based in part on volume are developing pricing structures based in part on the volume of water delivered to individual turnouts.

## Regional Water Balance

A water balance has been prepared for the region quantifying all substantial inflows to and outflows from the region on a water year basis (October – September) for the period from 1999 to 2012. The water balance depicts recent changes in water management within the region as well as current management conditions. A total of 26 individual flow paths are estimated, along with the change in surface storage over time. A schematic of the water balance structure is provided in Figure ES-6.

The water balance quantifies key drivers of water management variability across years including precipitation timing and amounts, which affect the amount of surface water available; the potential for voluntary water transfers based on crop idling and/or groundwater substitution; and the amount of groundwater pumping occurring to meet demands. Limited supplies in surface water shortage years are a strong water management driver but occur infrequently for the primary water suppliers in the region, though none occurred during the 1999 to 2012 period.

The analysis results for each flow path are reported with a level of precision (nearest whole acre-foot) that implies a higher degree of accuracy than is actually attainable. The estimated percent uncertainty (approximately equivalent to a 95 percent confidence interval) in each measured or calculated flow path has been estimated as part of the water balance analysis. Table ES-2 lists each flow path included in the water balance indicating whether it is an inflow or an outflow; whether it was measured or calculated; the supporting information and assumptions used to determine it; the estimated uncertainty, expressed as a percent; and average values for the period of analysis. Results for both the full water year and for the primary irrigation season (April to September) are provided. Estimated uncertainties vary from 5% to 100% of the average volume for the irrigation season, with uncertainties generally being less for measured flow paths and greater for calculated flow paths.

The estimated uncertainty of the closure term[3] is also shown. The estimated uncertainty in shallow groundwater interception 170% for the water year as a whole and 72% for the irrigation season. The large uncertainty for the full water year results in large part from the inclusion of winter flood flows from the Sacramento River into and out of the region, which are approximately 2 million af, on average. By focusing on the irrigation season the uncertainty is reduced to 72% but remains relatively large due to uncertainties in other flow paths such as groundwater pumping, crop evapotranspiration, deep percolation, and surface outflows. Despite the large calculated uncertainty in shallow groundwater interception, independent evidence supports the finding that there is shallow groundwater interception in the region.

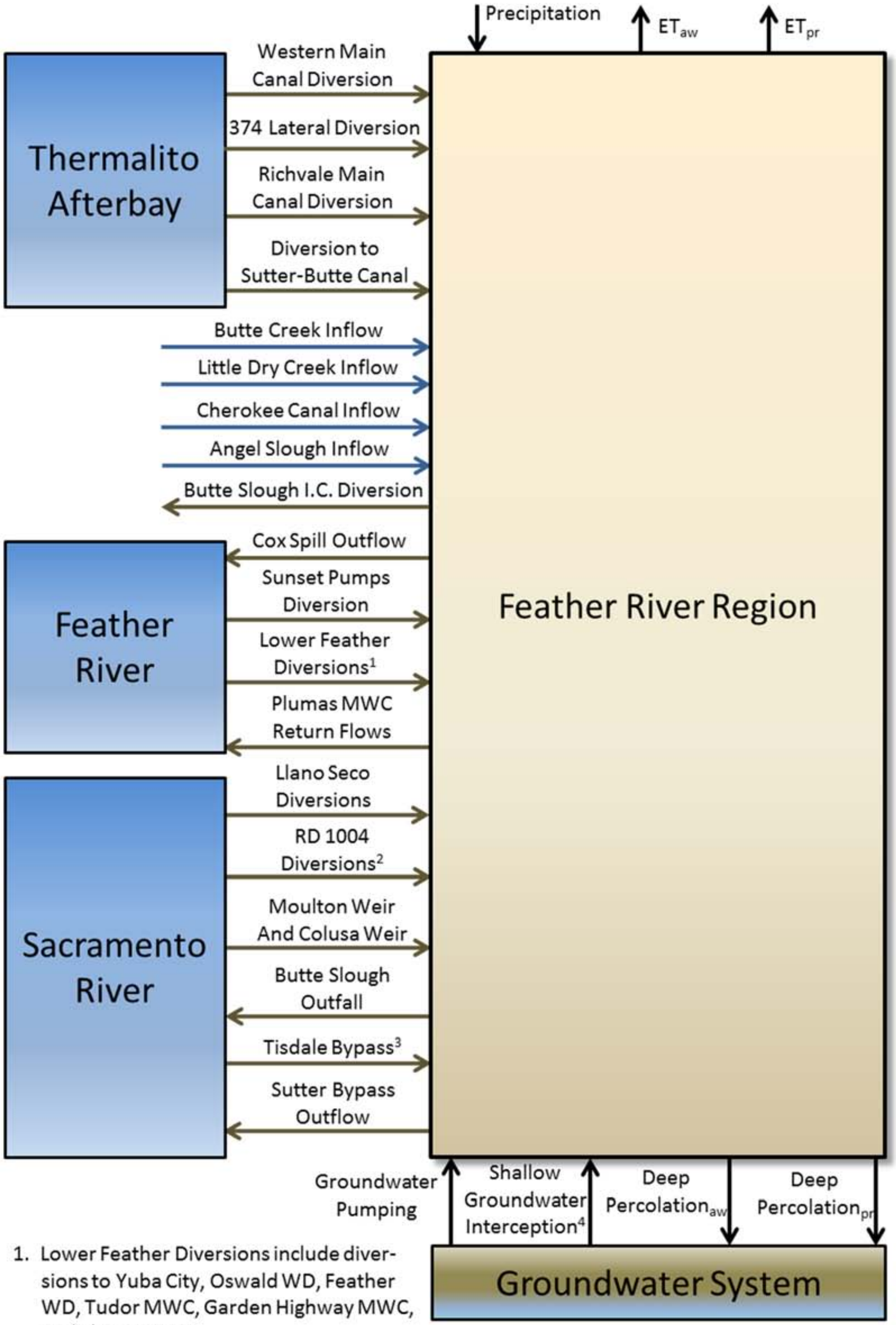
### *Water Uses*

Water uses in the region include agricultural irrigation water; environmental uses to create, maintain, and enhance wetlands and aquatic habitat; and domestic use in developed and rural residential areas.

Between 1999 and 2012, there were an average of 306,000 cropped acres within the region, plus an average of 18,000 additional acres of fallow or idle land. The main crop grown in the region is rice, which was grown on an average of 183,000 acres between 1999 and 2012, representing 60% of the total cropped area or 57% of the irrigable area. Permanent orchard crops, primarily prunes and walnuts, were grown on an average of 88,000 acres or 29% of total cropped area during this period. A variety of other crops including assorted field and truck crops, pasture, hay, and grains were grown on the remaining land, accounted for an average of 34,000 acres or 11% of the total irrigable area. The acreage of these other crops has decreased over time from more than 40,000 acres in the early 2000's to around 28,000 acres in recent years.

Crop evapotranspiration (ET), the consumption of water by crops, was estimated using a crop coefficient approach similar to that described by Allen et al. (1998), whereby estimated crop- and time-specific water use coefficients were multiplied by reference ET ($ET_o$) to calculate consumptive use of water over time. Crop coefficients specific to the Sacramento Valley were developed based on actual ET estimates from a remote sensing analysis using the Surface Energy Balance Algorithm for Land (SEBAL, Bastiaanssen et al. 2005). The monthly consumptive use of water for agricultural lands in the region ranges from approximately 1 inch of total ET in December and January to approximately 7 inches in June and July. The annual consumptive use of water by crops in the region is approximately 45 inches of total crop ET for rice, approximately 35 inches for orchard crops, and approximately 32 inches for other crops. The total annual volume of ET varied between approximately 1.30 million af and 1.44 million af during the 1999 to 2012 period, with an average annual volume of 1.37 million af. On average, approximately 1.05 million af of ET were derived from applied irrigation water (77% of total ET) and 0.32 million af of ET were derived from precipitation (23% of total ET).

[3] The "closure term" is the flow path that is solved for by combining other, independently estimated flow path based on the principle of conservation of mass. For the regional water balance, shallow groundwater interception is the closure term and is calculated as total outflows and change in storage minus total inflows.




1. Lower Feather Diversions include diversions to Yuba City, Oswald WD, Feather WD, Tudor MWC, Garden Highway MWC, and Plumas MWC.
2. RD 1004 Diversions also includes diversions to Colusa Properties and Sartain MWC.
3. In some instances, reverse flows can occur in Tisdale Bypass.
4. Includes seepage from and accretions to canals, drains, and streams.

***Figure ES-6. Water Balance Structure.***

*Table ES-2. Water Balance Flow Paths, Supporting Data, and Estimated Uncertainty.*

| Flow Path Type | Flow Path | Source | Supporting Data | Water Year (Oct. - Sept.) | | Irrigation Season (Apr. - Sept.) | |
|---|---|---|---|---|---|---|---|
| | | | | Average Volume (af) | Estimated Uncertainty (%) | Average Volume (af) | Estimated Uncertainty (%) |
| Inflow | Western Main Canal Diversion | Measurement | USGS Measurement Gage 11406880 | 304,192 | 5% | 223,986 | 5% |
| | Richvale Main Canal Diversion | Measurement | USGS Measurement Gage 11406890 | 147,234 | 5% | 96,232 | 5% |
| | 374 Lateral Diversion | Measurement | USGS Measurement Gage 11406900 | 3,911 | 5% | 3,179 | 5% |
| | Diversion to Sutter-Butte Canal | Measurement | USGS Measurement Gage 11406910 | 578,971 | 5% | 423,162 | 5% |
| | Sunset Pumping Station Diversion | Measurement | SEWD Operational Data | 6,631 | 10% | 6,631 | 10% |
| | Yuba City Diversion | Measurement | Butte Basin Groundwater Model Documentation; Yuba City Urban Water Management Plan | 16,199 | 15% | 10,916 | 15% |
| | Oswald WD Diversion | Measurement | DWR Bulletin 132 | 831 | 5% | 794 | 5% |
| | Feather WD Diversion | Measurement | USBR Reporting | 9,575 | 5% | 9,514 | 5% |
| | Tudor MWC Diversion | Measurement | DWR Bulletin 132 | 3,273 | 5% | 3,179 | 5% |
| | Garden Highway MWC Diversion | Measurement | DWR Bulletin 132 | 14,910 | 5% | 13,279 | 5% |
| | Plumas MWC Diversion | Measurement | DWR Bulletin 132 | 9,731 | 5% | 9,194 | 5% |
| | Butte Creek Inflow | Calculation | California Water Data Library Butte Creek near Durham site A04265 | 244,621 | 10% | 82,867 | 10% |
| | Little Dry Creek Inflow | Calculation | Correlation to Big Chico Creek near Chico based on Butte Basin Groundwater Model | 6,251 | 25% | 1,993 | 25% |
| | Cherokee Canal Inflow | Calculation | Correlation to Big Chico Creek near Chico based on Butte Basin Groundwater Model | 51,723 | 25% | 16,489 | 25% |
| | Angel Slough Inflow | Calculation | Correlation to Big Chico Creek near Chico based on Butte Basin Groundwater Model. Monthly pattern adjusted based on monthly flows at Butte Slough near Meridian. | 40,922 | 25% | 10,463 | 25% |
| | Llano Seco Diversions | Measurement | Butte Basin Groundwater Model average monthly diversions | 6,141 | 25% | 5,407 | 25% |
| | RD1004 Diversions | Measurement | USBR Central Valley Operations Monthly Delivery Reports. Winter diversions based on percent of Apr-Sept diversions by month and year for Feather districts. | 96,149 | 5% | 66,786 | 5% |
| | Moulton Weir | Measurement | Moulton Weir California Water Data Library Site A02986 | 33,124 | 15% | 5,018 | 15% |
| | Colusa Weir | Measurement | Colusa Weir California Water Data Library Site A02981 | 679,016 | 15% | 105,604 | 15% |
| | Tisdale Bypass | Measurement | Tisdale Weir California Water Data Library Site A02960 | 578,357 | 15% | 101,239 | 15% |
| | Precipitation | Calculation | Quality-controlled precipitation from Nicolaus CIMIS station 30 | 769,795 | 15% | 112,966 | 15% |
| | Groundwater Pumping | Calculation | Estimated demand for groundwater only area based on ET estimates, DWR land use surveys and groundwater use information from districts. | 302,295 | 25% | 246,751 | 25% |
| | **Shallow Groundwater Interception** | **Closure** | **Estimated based on closure of annual balance and distributed based on monthly trends.** | **244,711** | **170%** | **246,096** | **72%** |
| Outflow | Cox Spill Outflow | Measurement | Joint Water Districts Board Measurement Site | 8,620 | 10% | 7,458 | 10% |
| | Plumas MWC Return Flows | Calculation | Estimated as 15 percent of Plumas MWC diversions | 1,460 | 35% | 1,379 | 35% |
| | Butte Slough Irr. Co. Diversions | Calculation | Estimated based on service area west of Sutter Bypass, total water right, and monthly diversion pattern by RD1004. | 17,361 | 20% | 12,047 | 20% |
| | Butte Slough Outfall | Measurement | Prior to 2005, California Water Data Library Site A02967; 2005 – 2012 based on multivariate linear regression to surface inflows. Monthly pattern after 2005 adjusted to reflect minimized summer outflows to prevent fish attraction. | 163,918 | 15% | 32,806 | 15% |
| | Sutter Bypass Outflow | Measurement | California Water Data Library site A02925 (Sacramento Slough near Karnak) minus site A02926 (R.D. 1500 Drain to Sacramento Slough near Karnak). Data gaps and flagged values filled based on monthly linear regression to site A02972 (Butte Slough near Meridian). Adjusted to account for unmeasured flood flows from large storm events. | 1,828,880 | 15% | 430,167 | 15% |
| | ET of Applied Water | Calculation | CIMIS reference ET; estimated crop coefficients based on SEBAL 2009 analysis; crop acreages from District records, DWR land use surveys, and agricultural commissioner crop reports; Integrated Water Flow Model Demand Calculator (IDC) analysis to divide total ET into applied water and precipitation components | 1,054,379 | 10% | 811,606 | 10% |
| | ET of Precipitation | Calculation | | 319,094 | 10% | 195,499 | 10% |
| | Deep Percolation of Applied Water | Calculation | IDC analysis, NRCS soils characteristics, CIMIS precipitation data, Integrated Water Flow Model Demand Calculator (IDC) analysis to divide total deep perc. into applied water and precipitation components | 590,292 | 35% | 328,326 | 35% |
| | Deep Percolation of Precipitation | Calculation | | 164,877 | 35% | 54,804 | 35% |
| NA | Change in Storage | Calculation | IDC analysis | -317 | 100% | -72,348 | 50% |

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**Environmental**

Managed wildlife habitat and riparian vegetation comprises approximately 70,000 acres or 15% of lands within the region. Wildlife areas (including refuges and wildlife management areas) in the region provide valuable habitat and opportunities for educational and recreational activities such as bird watching, and hunting. Applied water estimates for managed wetlands average approximately 130,000 af for the October – March period in recent years. Additionally, some water is applied for managed wetlands occurs as early as August, and applied water for semi-permanent wetlands occurs to some extent in the summer months. Estimates of applied water for managed wetlands in the region do not necessarily represent optimal conditions. Wildlife managers face several challenges in meeting water needs for optimal habitat, including increased competition for available water, increased regulation of habitat water management, capacity and timing constraints of existing conveyance facilities, and lack of conveyance facilities in some cases.

In addition to dedicated habitat areas, a majority of the rice fields in the region are flooded in the winter to promote rice straw decomposition and to create winter habitat for migratory birds and other wildlife. It is estimated that approximately 120,000 acres, on average, have been flooded for rice straw decomposition and habitat regionally in recent years. Fields are typically flooded following harvest in October or November and remain flooded to February. Applied water estimates for rice decomposition average approximately 220,000 af annually in recent years.

In addition to use of water within the region to provide winter habitat for migratory birds, surface outflows from the region enter Butte Creek and the Sutter Bypass, providing important instream flows supporting migration of salmon and steelhead and other downstream uses of water for wildlife habitat. Historical Butte Creek flows and habitat requirements are discussed in greater detail in Volume I.

**Transfers and Exchanges**

Water suppliers in the region have participated in several water transfers in recent years. Water transfers in the region have occurred based on crop idling, groundwater substitution, and unused surface water supplies. Crop idling transfers have been most common in recent years, with WCWD and the Joint Districts each participating. Groundwater substitution transfers have been conducted in recent years by water suppliers in the Sutter County portion of the region, including BWD, SEWD, and GHMWC. Additional detail describing water transfers in the region is provided under the description of water uses by each supplier in Volume II, Sections 3 through 8 of this plan.

### *Water Balance Summary*

A regional water balance combining individual inflows and outflows into general categories is shown in Figure ES-7 for the water year and for the April to September primary irrigation season, based on average values between 1999 and 2012. In the figure, average volumes are presented for each inflow and outflow category, as well as average volumes expressed in acre-feet per acre. Average monthly inflows to and outflows from the region are further summarized in Figures ES-8 and ES-9, respectively. Detailed annual water balance results for the region are summarized in Volume I.

Monthly inflow and outflow patterns provide insight into water management within the region, which is heavily influenced by water management for rice. The observed monthly patterns likely differ from individual fields, and reflect the full population of fields in the region.

Diversions begin in April or May and continue at relatively steady levels through August, decreasing in September as fields are drained for harvest. In October and November diversions again increase and continue through December to flood fields and managed wetlands for rice straw decomposition and habitat. Diversions cease in January in preparation for the next year's crop. Monthly ET generally follows the pattern of $ET_o$, increasing in the spring and summer as temperatures and day length and available solar radiation increase and then decreasing in the winter. Actual ET rates are relatively similar to reference values due to the availability of adequate surface water supplies to support crop growth and relatively moist conditions throughout the growing season. Deep percolation is relatively constant over time due to the use of available surface water during the majority of the year, increasing somewhat in the winter as a result of precipitation and decreasing prior to planting and following harvest as a result of dry conditions. Surface outflows increase during the winter as a result of the passage of flood flows through the system and are also influenced by return flows from winter flooding of rice fields and managed wetlands.

The monthly change in storage in the surface layer reflects rice growing and winter flooding as well, with water entering storage in May, remaining relatively constant in June and July, and leaving storage as fields are drained in August and September. Storage then increases again October through December due to winter flooding and decreases in January through March as fields are drained in preparation for planting.

Flows to the groundwater system include deep percolation and seepage from canals, drains, and streams. Flows from the groundwater system to the surface include pumping and shallow groundwater interception. Net recharge through localized seepage and deep percolation replenishes the groundwater system to the benefit of water users within and adjacent to the region. Total deep percolation between 1999 and 2012 averaged approximately 755,000 af per year (1.6 af/ac), with approximately 78% originating from applied water and 22% originating from precipitation. Groundwater pumping in the region averaged approximately 302,000 af per year. Regional shallow groundwater interception averaged approximately 245,000 af annually between 1999 and 2012. Net recharge between 1999 and 2012 in the region averaged approximately 208,000 af per year, or 0.4 af/ac. Year to year variability in net recharge results primarily from variability in deep percolation of precipitation and groundwater pumping.

For the region as a whole, it is estimated that more than 99 percent of available water supplies are consumed by crops and other vegetation or return to the surface or groundwater system where they can be recovered for additional beneficial uses. The only non-recoverable losses are evaporation from canals; no return flows to saline water bodies occur.

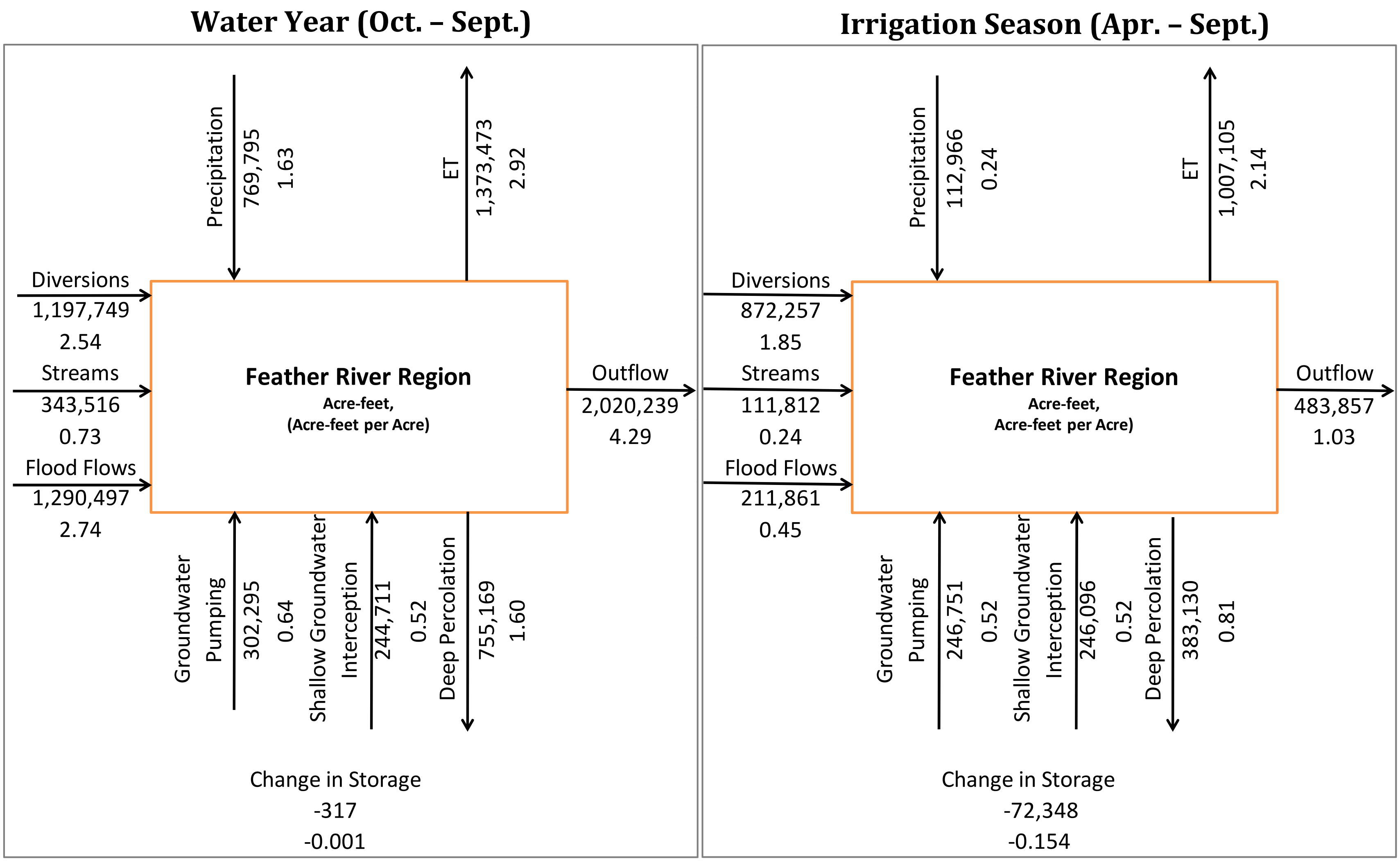


***Figure ES-7. Average Annual Regional Water Balance, 1999-2012 (acre-feet and acre-feet/acre).***

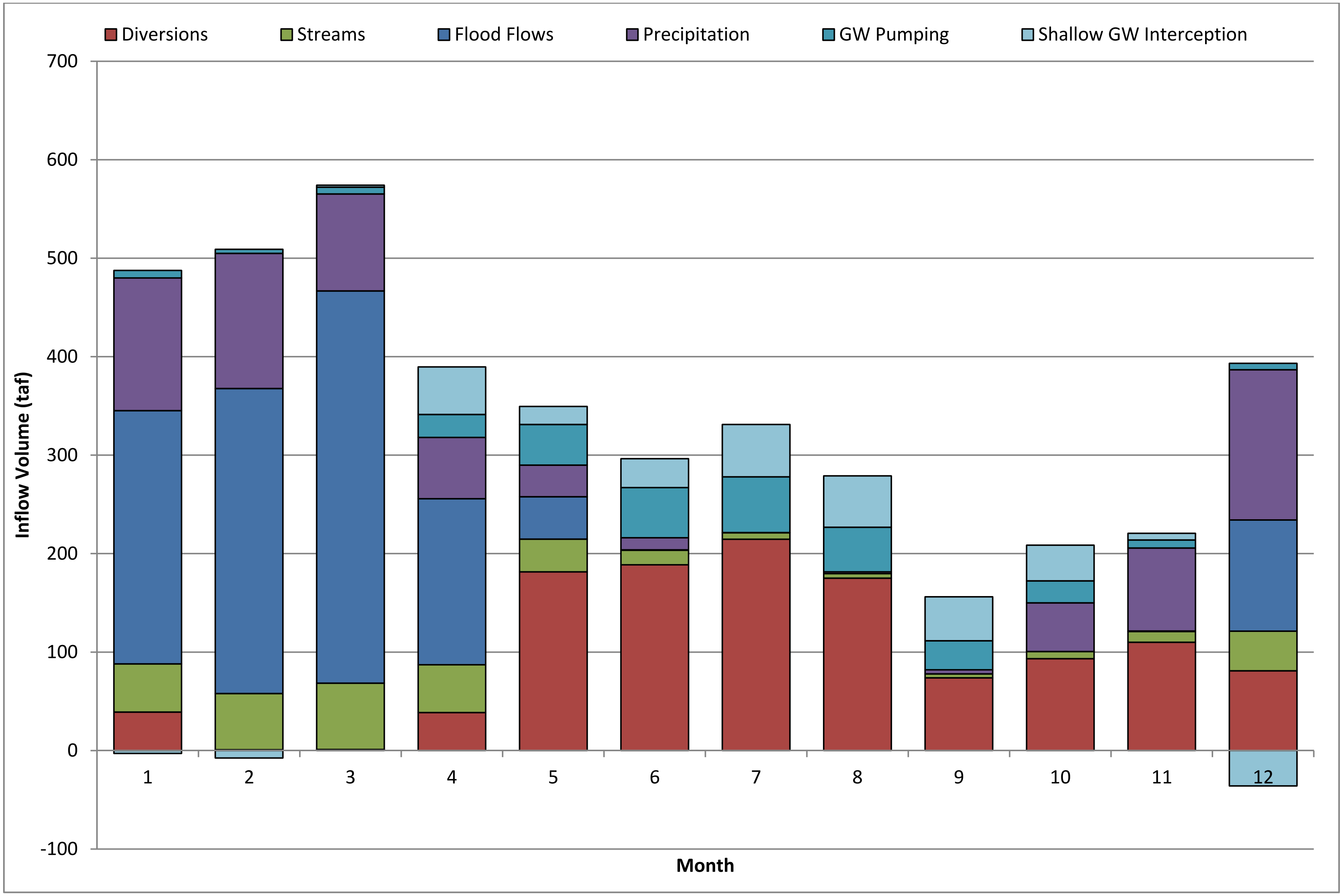


***Figure ES-8. Average Monthly Inflows, 1999-2012.***

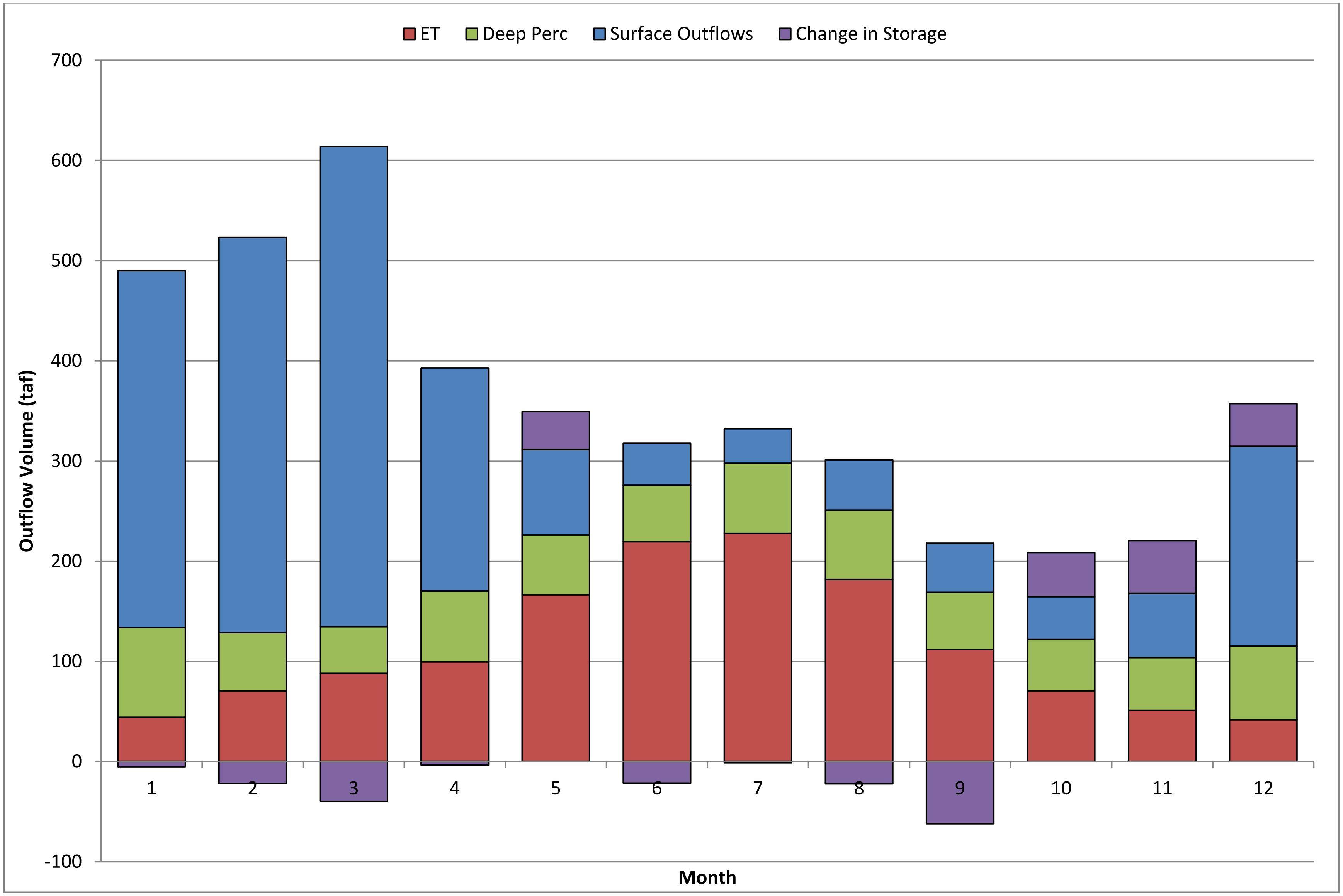


***Figure ES-9. Average Monthly Outflows, 1999-2012.***

Regionally, approximately 80 percent of the irrigation water supply is derived from surface water, demonstrating the reliability of and reliance on surface water supplies by Feather River (and Sacramento River) water suppliers. For the primary Feather River suppliers, between 79 and 100 percent of the irrigation water supply is derived from surface water, with an overall average of 95 percent.

Evaluation of the percentage of irrigation deliveries consumed to produce crops or support habitat reveals the degree of efficiency with which water is used in the region due to efficient on-farm and district water management, as well as reuse among water users. Comparing water management at the farm, district, and regional scales between 1999 and 2012:

- For irrigated lands served by primary Feather suppliers, between 52 and 70 percent of applied water was consumed by crops or habitat, with an average of 61 percent;
- For Feather supplier services areas as a whole (within which reuse occurs), between 61 and 84 percent of applied water was consumed by crops or habitat, with an average of 73 percent; and
- For the region as a whole, 82 percent of applied water was consumed by crops or habitat.

## Water Management Activities, Objectives, and Opportunities

The regional water balance and supplier water balances provide a technical basis for identifying regional water management objectives and specific actions that water users could take to enhance water management and monitoring both within their service areas and collectively within the region. The descriptions of individual suppliers and evaluations of Efficient Water Management Practices (EWMPs) and water use efficiency improvements in Volume II describe ongoing, planned, and potential future activities that could be taken to enhance water management to meet local, regional, or statewide objectives. Additionally, potential consequential effects of changes in water management are identified that should be considered given the flow-through or "cascading" nature of water use in the region, whereby water used in one area for agricultural or environmental uses but not consumed returns to the system for reuse by others. Existing and potential future water management activities represent tools that could be drawn on to meet one or more objectives, depending on conditions and opportunities over time.

### *Water Management Activities*

Water managers in the region have partnered with wildlife managers and others historically to greatly improve habitat for migratory birds, fishes, and other species while maintaining water supply reliability for irrigation and other uses. Historical, current, planned, and potential water management activities are described throughout the plan. Suppliers are implementing technically feasible EWMPs at locally cost effective levels and have achieved substantial WUE improvements over past decades. Additionally, the suppliers have identified and evaluated additional opportunities to enhance water management capabilities to achieve local, regional, or statewide water management objectives (WMOs). These additional efforts are being implemented as funding allows and based on prioritization among many potential projects and myriad requirements that face suppliers on a day-to-day basis in serving their customers.

Efforts to protect, restore, and enhance wetlands habitats in the region and Central Valley as a whole have been led to a large part in recent years by the Central Valley Joint Venture (CVJV), a collaborative group of private organizations, state and federal agencies, and others. CVJV was formed in 1988 under the North American Waterfowl Management Plan (NAWMP) (CVJV 2006). The 1990 CVJV implementation plan identified six conservation objectives for Central Valley waterfowl. These objectives were distributed across nine basins, including two basins encompassing the Feather River region (Butte and Sutter basins). By 2006, substantial progress was made toward meeting the 1990 objectives in the region and the Central Valley as a whole.

The 2006 plan expands the conservation area to include habitat for the additional bird groups listed above and quantifies conservation objectives where possible. To meet refuge water supply requirements in the region, the CVPIA Refuge Water Supply Program has resulted in the construction of new facilities in the region and led to the development of agreements for districts to provide firm water supplies to certain refuges. Other local efforts to provide water for wetlands habitat also occur. For the Butte and Sutter basins, as described by CVJV (2006), 10,835 acres of wetlands had been protected through acquisition of land and easements as of 2003, or 103 percent of basin-specific goals.

The Butte Creek system is complex due to the presence of both spring- and fall-run salmon and steelhead, commingling of Feather River water with Butte Creek water, and other factors. Historically, fish passage problems existed in Butte Creek within the region. These issues have been largely addressed and continue to be addressed through the WCWD Fish Passage Improvement Project, the CVPIA Anadromous Fish Restoration Program (AFRP), and the DWR Fish Passage Improvement Program (FPIP) which have been successful at restoring salmon populations in Butte Creek. There could be opportunities to modify current agricultural water management practices to better meet environmental objectives in Butte Creek related to flows, flow timing, and water quality; however they require case-by-case evaluation and the involvement of both agricultural and environmental water managers in the region, including wetlands managers. One example of a potential opportunity would be to replace existing diversions from Butte Creek in the region with Feather River water.

### *Water Management Objectives*

WMOs vary depending on perspective. From a local, agricultural perspective, the objective of a water supplier is to provide water to customers for irrigation in a manner that supports optimal crop production. Another way to characterize local WMOs is in the context of water use efficiency (WUE) improvement categories including increased supply and supply reliability, improved water quality, and reduced energy costs through reduced pumping and increased energy efficiency.

Regional and statewide WMOs were developed by DWR and the CALFED Bay-Delta Program, a cooperative effort undertaken between 2000 and 2007 among state, federal, and public stakeholders to improve California's water supply and the ecological health of the Sacramento-San Joaquin River Delta. The WMOs developed through the CALFED process are referred to as Targeted Benefits (TBs) and Quantifiable Objectives (QOs). TBs include water quality, quantity, and instream flow and timing and may be considered QOs depending on the level of detail at which the TB is defined (i.e., whether specific quantities of flow are identified). QOs represent numerical targets that could be achieved to attain the targeted benefits. Several of the TBs have been addressed in recent years through regional efforts and are described elsewhere in this plan.

Statewide WMOs generally align with regional objectives described above; benefits to water quantity, quality, or instream flows occurring within the region also benefit the State as a whole. Additionally, statewide WMOs include increasing overall statewide water supply and supply reliability through water transfers across region boundaries.

### *Water Management Opportunities (Potential Projects to Enhance Water Management Capabilities)*

Several projects have been identified and developed with the potential to modify the timing and amount of water in the system or to hold water in storage through local conservation. These projects do not have the potential to increase water supply, but could be used to increase supply reliability or to improve habitat conditions by modifying when and where water flows through the system. Implementation of individual projects would essentially provide tools that could be applied to contribute to one or more WMOs to achieve targeted benefits. For example, a project that would improve supply reliability at a specific time and a specific location could also be used to improve wetlands or aquatic habitat by strategically rerouting flows to another place at another time. A key requirement of many such activities is the ability to store water and release it at the optimum time to contribute to meeting WMOs.

Projects identified and evaluated for each participating water supplier are summarized in Table ES-3. For each project, the following information is provided:

- Supplier – Supplier evaluating project.
- Project – Project evaluated. Individual projects may include several sites to be improved, multiple phases of implementation, and multiple levels of improvement. Projects are described in detail in Volume II, Sections 3 through 8 (supplier projects) and Section 10 (Joint District projects).
- Initial Cost – Upfront costs for final design, permitting, construction, etc.
- Annualized Capital Recovery and O&M – Amortized annual costs for implementation including initial cost, operations, and maintenance. Amortized capital costs estimated by component based on estimated useful life.
- Targeted Flow Paths – Flow paths expected to be modified through implementation.
- Potential Benefits – Water use efficiency (WUE) improvement categories potentially addressed through implementation. Additional discussion of water use efficiency

categories is provided in the descriptions of supplier EWMP implementation and corresponding WUE improvements in Volume II, Sections 3 through 7.

- Modified Flow Quantity – Estimated potential change in targeted flow path, representing potential change in annual volume. These quantities represent the amount of water that could be rerouted to meet water management objectives and do not represent an overall change in regional or statewide water supplies. The indicated range reflects uncertainties in volume changes.
- Unit Implementation Cost – Annual implementation cost per acre-foot of modified flow. The indicated range reflects uncertainties in volume changes.
- Potential Targeted Benefits by Location and Category – Relationship of project to CALFED targeted benefits. A "✓" indicates that the project has the potential to achieve benefits for a given location (e.g., Butte Creek) and benefit category (instream flows, water quality, or water quantity) by changing the timing and amount of water flowing through the system. Specifics of implementation depend on the project and targeted benefit. For example, system modernization by a water supplier could result in reduced operational spillage, allowing for reduced diversions. This water could thus remain in storage and be released at a time and location aligned with a targeted benefit, such as to increase instream flows in the Feather River, for example.

The combination of a large number of potential projects with a large number of potential benefits and corresponding potential tradeoffs necessitates close collaboration among water suppliers and others in the region and state, including wildlife managers, agricultural water users outside of supplier service areas, and project operators. A comprehensive understanding of relative costs, benefits, and tradeoffs is required to optimize water management to provide multiple benefits while maintaining environmental, economic, and social sustainability.

## Climate Change

Climate change has the potential to directly impact surface water resources in the Feather River Region and to indirectly impact groundwater resources. The plan includes a discussion of the potential effects of climate change on the region, followed by a description of the resulting potential impacts on water resources in the region, including impacts to water supply, water demand, water quality, and flood control. Actions by water users in the region that are currently underway or that could be implemented to help mitigate future impacts are identified.

### *Potential Climate Change Effects*

Several potential effects of climate change have been identified by the scientific community, including shorter winters, reduced winter snowpack, more variable and extreme weather conditions, and increased atmospheric water demand (i.e., $ET_o$). Review of the historical flow record for the Feather River at Oroville between 1906 and 2012 reveals potential climate change effects on winter snowpack and spring runoff. Over the last century, April to July full natural flow as a percentage of water year full natural flow appears to show a decreasing trend, resulting in a change of approximately ten percent. In contrast, water year full natural flow has not decreased.

The combination of these two observations suggests that the amount of runoff occurring during the April to July period has decreased, while the amount occurring during the remainder of the year has increased. On average, increases in runoff have occurred in October through March, with decreases in April through August. Recent projections of full natural flow reported by USBR for the Feather River at Oroville suggest that runoff between April and July as a percentage of total runoff could continue to decrease over the next 100 years (USBR 2011). Similar to actual conditions over the past 100 years, the projections do not collectively predict a substantial change in total water year runoff, but rather a shift in timing resulting from reduced snowpack.

### *Potential Climate Change Impacts*

The effects of climate change will likely influence and impact water resources in the Feather River region. The shift in runoff to the winter period has the potential to impact surface water supply in the future if sufficient storage is not available to retain winter runoff until it is needed to meet irrigation demands. According to water supply agreements, all of the participating water suppliers are subject to surface water supply reductions under certain conditions impacted by inflows to Lake Oroville. In the Butte Creek watershed, the potential effect of reduced spring runoff would be to reduce Butte Creek water supplies for agricultural and environmental demands on Butte Creek.

Increased temperature and changes to other climate variables could result in increased crop water demands. Increased erosion and turbidity under climate change, if it occurred, would likely not significantly affect the water quality of the Feather River as it affects agricultural irrigation. Due to the potential for future precipitation to occur as rain rather than snow and corresponding increased runoff during winter months, increasing pressure on regional flood management systems may occur in the future.

### *Strategies to Mitigate Climate Change Impacts*

Although there is general consensus that climate change is occurring and the effects of climate change are being observed, the timing and magnitude of climate change impacts remains uncertain. Several strategies for agricultural water providers and other water resources entities to mitigate climate change impacts have been identified and are already being implemented by the agricultural water suppliers in the region to meet local and regional water management objectives and will be enhanced as needed as climate change impacts occur. Specific resource strategies that are being implemented or could be implemented by the suppliers in the Feather River region are described in Volume I, Section 5, along with additional resources for water management planning for climate change.

*Table ES-3. Summary of Potential Projects to Enhance Water Management Capabilities and Linkage to Targeted Benefits by Location and Category.*

| Supplier | Project | Initial Cost | Annualized Capital Recovery and O&M | Targeted Flow Paths | Potential Benefits | Modified Flow Quantity (af) | Unit Implemen-tation Cost ($/af) | Potential Targeted Benefits by Location and Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Butte Creek | | Feather River | | Sacramento Slough | Gray Lodge | Sutter NWR | Wet-lands[1] | All Affected Lands |
| | | | | | | | | Flow[2] | Quality[3] | Flow[2] | Quality[4] | Quality[5] | Quantity[6] | Quantity[7] | Quantity[8] | Quantity[9] |
| BWGWD | System Modernization | $3,843,975 | $273,566 | Operational Spillage, Tailwater, Drainage Outflows, Deliveries, Diversions | Increased water supply and supply reliability, delivery flexibility, and/or instream flow; improved water quality | 2,000 to 5,000 | $55 to $137 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Boundary Flow and Primary Spill Measurement and Drainwater Recovery | $916,975 | $117,696 | Operational Spillage, Tailwater, Drainage Outflows, Diversions | | 5,000 to 15,000 | $8 to $24 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| BWD | System Modernization | $14,368,423 | $891,896 | Operational Spillage, Tailwater, Drainage Outflows, Deliveries, Diversions | Increased water supply and supply reliability, delivery flexibility, and/or instream flow; improved water quality | 2,000 to 5,000 | $178 to $446 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Boundary Flow and Primary Spill Measurement and Drainwater Recovery | $1,019,755 | $101,132 | Operational Spillage, Tailwater, Drainage Outflows, Diversions | | 3,500 to 10,500 | $10 to $29 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Removal of Bottlenecks | $869,221 | $47,613 | Diversions, Deliveries | Increased refuge water supply and supply reliability, delivery flexibility | See Sutter Butte Conveyance Study (GEI 2006) | | | | | | | | ✓ | ✓ | |
| | Improved Service to Pressurized Systems: Sunset and Webster Pipeline Conversion | $2,416,000 | $333,200 | Diversions, Deliveries, Deep Percolation | Improved air quality, energy conservation, increased water supply and supply reliability | Not estimated at this time | | | ✓ | | | ✓ | | | | ✓ |
| | Improved Service to Pressurized Systems: Improved Turnout Configuration and Debris Management | Unit costs only estimated at this time. Projects to be developed. | | Diversions, Deliveries, Deep Percolation | Improved air quality, energy conservation, increased water supply and supply reliability | Not estimated at this time | | | ✓ | | | ✓ | | | | ✓ |
| RID | System Modernization | $12,822,115 | $941,583 | Operational Spillage, Tailwater, Drainage Outflows, Deliveries, Diversions | Increased water supply and supply reliability, delivery flexibility, and/or instream flow; improved water quality | 5,000 to 12,750 | $74 to $188 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Boundary Flow and Primary Spill Measurement and Drainwater Recovery | $1,333,296 | $116,547 | Operational Spillage, Tailwater, Drainage Outflows, Diversions | | 4,500 to 13,500 | $9 to $26 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Alternative Delivery to Secondary Service Area Using Kelleher Dam | $1,114,000 | $61,000 | Spillage, Seepage, Deliveries | | Not estimated at this time | | | | | | | | | ✓ | |

| Supplier | Project | Initial Cost | Annualized Capital Recovery and O&M | Targeted Flow Paths | Potential Benefits | Modified Flow Quantity (af) | Unit Implemen-tation Cost ($/af) | Potential Targeted Benefits by Location and Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Butte Creek | | Feather River | | Sacramento Slough | Gray Lodge | Sutter NWR | Wet-lands[1] | All Affected Lands |
| | | | | | | | | Flow[2] | Quality[3] | Flow[2] | Quality[4] | Quality[5] | Quantity[6] | Quantity[7] | Quantity[8] | Quantity[9] |
| SEWD | System Modernization | $12,983,535 | $980,638 | Operational Spillage, Tailwater, Drainage Outflows, Deliveries, Diversions | Increased water supply and supply reliability, delivery flexibility, and/or instream flow; improved water quality; energy conservation | 5,200 to 12,750 | $77 to $189 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Boundary Flow and Primary Spill Measurement and Tailwater Recovery | $645,055 | $90,968 | Operational Spillage, Tailwater, Drainage Outflows, Diversions | | 4,000 to 11,000 | $8 to $23 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Improved Service to Pressurized Systems: Improved Turnout Configuration and Debris Management | Unit costs only estimated at this time. Projects to be developed. | | Diversions, Deliveries, Deep Percolation | Improved air quality, energy conservation, increased water supply and supply reliability | Not estimated at this time | | | ✓ | | | ✓ | | | | ✓ |
| WCWD | System Modernization | $11,341,652 | $762,817 | Operational Spillage, Tailwater, Drainage Outflows, Deliveries, Diversions | Increased water supply and supply reliability, delivery flexibility, and/or instream flow; improved water quality | 4,800 to 12,000 | $64 to $159 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Boundary Flow and Primary Spill Measurement | $260,411 | $26,619 | Operational Spillage, Tailwater, Drainage Outflows, Diversions | | 720 to 2,400 | $11 to $37 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Little Butte Creek Reservoir Main Canal Bypass Project | $12,815,000 | $758,000 | Surface Inflows, Surface Outflows | | Not estimated at this time | | ✓ | ✓ | | | | | ✓ | ✓ | |
| FWD | Distribution System Improvements | $1,268,872 | $110,627 | Deliveries, Operational Spillage, Diversions | Increased water supply and supply reliability, delivery flexibility, and/or instream flow; improved water quality; energy conservation | 100 to 250 | $443 to $1,106 | | | ✓ | | ✓ | | | ✓ | |
| GHMWC | System Modernization | $1,115,000 | $79,644 | Operational Spillage, Tailwater, Drainage Outflows, Deliveries, Diversions | Increased water supply and supply reliability, delivery flexibility, and/or instream flow; improved water quality; energy conservation | 300 to 750 | $106 to $265 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Boundary Flow and Primary Spill Measurement | $412,600 | $36,939 | Operational Spillage, Tailwater, Drainage Outflows, Diversions | | 75 to 225 | $164 to $493 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Debris Management | $121,080 | $7,880 | Deliveries, Diversions | Delivery flexibility, improved water quality, energy conservation | Not estimated at this time | | | | | | | | | ✓ | |

| Supplier | Project | Initial Cost | Annualized Capital Recovery and O&M | Targeted Flow Paths | Potential Benefits | Modified Flow Quantity (af) | Unit Implemen-tation Cost ($/af) | Potential Targeted Benefits by Location and Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Butte Creek | | Feather River | | Sacramento Slough | Gray Lodge | Sutter NWR | Wet-lands[1] | All Affected Lands |
| | | | | | | | | Flow[2] | Quality[3] | Flow[2] | Quality[4] | Quality[5] | Quantity[6] | Quantity[7] | Quantity[8] | Quantity[9] |
| PMWC | System Modernization | $721,488 | $48,628 | Operational Spillage, Tailwater, Drainage Outflows, Deliveries, Diversions | Increased water supply and supply reliability, delivery flexibility, and/or instream flow; improved water quality; energy conservation | 240 to 600 | $81 to $203 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| TMWC | Distribution System Improvements | $1,168,389 | $100,131 | Deliveries, Operational Spillage, Diversions | Increased water supply and supply reliability, delivery flexibility, and/or instream flow; improved water quality; energy conservation | 40 to 100 | $1,001 to $2,503 | | | ✓ | | ✓ | | | ✓ | |
| Joint Districts | System Modernization | $3,182,900 | $220,000 | Deliveries, Operational Spillage, Diversions | Increased water supply and supply reliability, delivery flexibility, and/or instream flow; improved water quality | 2,600 to 6,500 | $34 to $85 | ✓ | ✓ | | | | | | | |

1. Also includes other suitable lands, including agriculture.
2. Provide flow to improve aquatic ecosystem conditions. Could occur through conservation of water in a specific location or at a specific time to allow for redirection of flow to a different location at a different time to strategically benefit habitat by utilizing available storag
3. Reduce temperatures to enhance and maintain aquatic species. Could occur through conservation of warm water ultimately flowing to the Creek or through conservation of water in a specific location or at a specific time to allow for delivery to the creek at a different location at a different time to strategically reduce temperature by utilizing available storage.
4. Reduce temperatures and pesticides to enhance and maintain aquatic species. Could occur through conservation of warm water ultimately flowing to the Creek or through conservation of water in a specific location or at a specific time to allow for delivery to the creek at a different location at a different time to strategically reduce temperature by utilizing available storage. Additional strategies include reduced farm runoff through improvements in irrigation technology.
5. Reduce salinity and pesticides to enhance and maintain beneficial uses. Could occur through conservation of water in a specific location or at a specific time to allow for redirection of flow to Sacramento Slough at a different time to strategically benefit habitat by utilizing available storage, or through reductions in tailwater return flows to the Butte Creek/Sutter Bypass system.
6. Provide long-term diversion flexibility to increase water supply. Could occur through conservation of water in a specific location or at a specific time to allow for redirection of flow to Gray Lodge at a different time to strategically benefit habitat by utilizing available stora
7. Provide long-term diversion flexibility to increase water supply. Could occur through conservation of water in a specific location or at a specific time to allow for redirection of flow to Sutter NWR at a different time to strategically benefit habitat by utilizing available stora
8. Provide long-term diversion flexibility to increase water supply. Could occur through conservation of water in a specific location or at a specific time to allow for redirection of flow to or other affected lands at a different time to strategically benefit habitat by utilizing available storage.
9. Decrease nonproductive ET to increase water supply. Nonproductive ET is limited primarily to canal and drain evaporation, a relatively minor consumptive use. Some potential may exist to reduce nonproductive ET by supporting microirrigation to reduce or eliminate wetted soil and drainflows (and corresponding evaporation). May be countered by increased crop ET from improved crop production.

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## Recommendations

Recommendations have been developed through the preparation of the regional AWMP based on the process of characterizing the region with respect to its physical setting; surface water and groundwater hydrology; agricultural water supplier entities, facilities, and policies; water management objectives, activities, and opportunities; and potential effects, impacts, and adaptation strategies for climate change. In general, these recommendations are related to closing information gaps to support improved understanding of regional hydrology, better defining water management objectives, and pursuing opportunities to achieve those objectives.

### *Re-Establish Historical Monitoring Locations and Identify New Sites*

While information describing inflows to and outflows from the region is relatively abundant, limited information is available describing surface flows between water use areas within the region. In particular, information describing inflows to and flows along the Butte Creek system are limited. Several historical stream gage sites have been discontinued or are no longer maintained. As a result, current hydrologic conditions and system responses to water management activities are not adequately monitored. Improved understanding of flows in the Butte Creek/Sutter Bypass system is important for multiple operational and analytical purposes.

It is recommended that consideration be given to re-establishing historical monitoring locations while identifying additional sites to be added. In particular, it would be beneficial re-establish a site to monitor flows from RD1500 into the Sutter Bypass (California Water Data Library site A02926), so that regional outflows could be estimated directly by subtracting these flows from the Sacramento Slough near Karnak site (California Water Data Library site A02925). Additionally, it would be beneficial to establish a monitoring site on the East Borrow Canal below the bifurcation of Butte Slough to improve understanding of the division of flows entering the bypass. Additional sites to characterize reaches of the system located near major inflow locations should be identified and established as a next step. Information describing flows within Butte Creek and the Sutter Bypass, coupled with advances in boundary outflow monitoring by upstream water suppliers would provide a basis for further evaluating opportunities to enhance habitat or meet other WMOs through changes in agricultural water management.

### *Improve Monitoring of Surface Water Outflows and Refine Water Balances to Improve Understanding of Surface-Groundwater Interactions and Net Recharge*

Primary information gaps are related to surface-groundwater interactions. Individual fluxes cannot be practically directly measured in most cases. These include deep percolation, groundwater pumping, seepage, and shallow groundwater interception, which includes both consumptive use of shallow groundwater and accretions of base flow by streams and drains. Improved understanding of these interactions would enhance the evaluation of conjunctive management opportunities to increase local water supplies to meet local and regional water management objectives. The primary value of additional information would be to better understand net exchange between the surface and groundwater systems and the individual fluxes contributing to net exchange, as well as to better understand cause and effect relationships between the use of surface water or groundwater and flows in streams and storage and water levels in underlying aquifers. The approach to improve confidence in estimates of surface water-groundwater interactions is complementary with objectives for closing information gaps related to surface hydrology.

It is recommended that efforts be made to increase information describing surface water outflows from water use areas, followed by refinement of water balances to allow for improved estimation of net recharge. Following improvements to estimates of net recharge, the contributions of individual surface water-groundwater fluxes should be refined through investigations of canal seepage and gains and losses in streams and drains and through field-scale water balances to better estimate deep percolation resulting from irrigation and precipitation. Benefits of these efforts could include enhanced calibration of existing and possible future regional groundwater models used to evaluate potential water management activities under current or potential future conditions to evaluate potential benefits and tradeoffs.

### *Better Define Water Management Objectives*

WMOs are described in this plan from local, regional, and statewide perspectives. Local WMOs are related to supporting optimal crop production or WUE improvements such as increased supply and supply reliability, improved water quality, and reduced energy costs through reduced pumping and increased energy efficiency. Regional WMOs have been developed through the CALFED process in the form of TBs, but there remain opportunities to quantify the timing and amount of changes in flows in the system to meet or contribute to desired benefits.

It is recommended that agricultural and environmental water managers in the region collaborate to identify specific opportunities to achieve targeted benefits. This process would start by developing conceptual strategies identifying sources and destinations of flows to be modified, including potential changes in flow timing. Once a conceptual strategy is developed, timing and amounts of flows to be re-routed would be identified, as well as potential routes to convey the water, as applicable. This information would provide the basis for the development of partnerships among agricultural suppliers and environmental water managers or others, as appropriate. These partnerships could then collaborate to seek funding and develop formal agreements to implement identified projects.

### *Pursue Implementation of Projects Directly Linked to Water Management Objectives*

Several projects identified and evaluated as part of this plan can be directly linked to water management objectives. For example, projects generally would increase local water supply reliability to enable water suppliers to better meet customer demands during periods of shortage. It is recommended that these projects be pursued by individual suppliers to the extent that funding is available. Funding may be available internally or through external sources such as grant programs.

### *Develop Partnerships to Implement Projects Addressing Regional Water Management Objectives*

In many cases, local benefits of enhanced water management through physical and operational improvements are less than implementation costs; however, opportunities may exist to enhance water management capabilities to meet multiple WMOs. For example, partnerships could be established among agricultural suppliers and environmental water managers to modify agricultural water management to re-route flows to desired locations at desired times to provide targeted benefits for managed wetlands or aquatic habitat. At other times, these projects could provide local benefits, such as increased supply reliability to meet customer demands. Partnerships could be directly between individual agricultural suppliers, environmental water managers, or others and could involve several parties working in coordination to achieve multiple benefits. These potential opportunities require refinement of WMOs, as described above. Following the refinement of WMOs, it is recommended that partnerships be pursued to enhance water management through future updates of this regional AWMP and other interim opportunities.

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