FINAL REPORT

Red Bluff Subbasin

Sustainable Groundwater Management Act

Groundwater Sustainability Plan

(Chapter 2C – Water Budget)

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Prepared For:

Tehama County Flood Control and Water Conservation District

Prepared By:

Luhdorff & Scalmanini, Consulting Engineers

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Appendix 2-J	Tehama Integrated Hydrologic Model Documentation Report
Appendix 2-K	Detailed Water Budget Results

LIST OF ACRONYMS & ABBREVIATIONS

af	Acre-feet
AN	Above normal Sacramento Valley water year type
AWMP	Agricultural Water Management Plan
BMP	Best Management Practice
BN	Below normal Sacramento Valley water year type
C	Critical (dry) Sacramento Valley water year type
CCR	California Code of Regulations
D	Dry Sacramento Valley water year type
DWR	Department of Water Resources
ET	Evapotranspiration
GMP	Groundwater Management Plan
GSP	Groundwater Sustainability Plan
GWS	Groundwater System
SWS	Surface Water System
taf	Thousand acre-feet
Tehama IHM	Tehama Integrated Hydrologic Model
UWMP	Urban Water Management Plan
W	Wet Sacramento Valley water year type
WMP	Water Management Plan

2 SUBBASIN PLAN AREA AND BASIN SETTING (REG. § 354.8)

2.1 Description of Plan Area

2.2 Basin Setting

2.3 Water Budget (Reg. § 354.18)

An integral component of the GSP is the quantification of the water budget, which is an accounting of water movement and storage between the different systems of the hydrologic cycle (**Figure 2-59**). The Subbasin water budget includes an accounting of all inflows and outflows to the Subbasin. The difference between the volume of inflow and outflow to the Subbasin is equal to the change in storage as illustrated in **Equation 2-1**.

$$\text{Inflows} - \text{Outflows} = \text{Change in Storage}$$

Equation 2-1. Water Budget Equation

DWR has published guidance and Best Management Practice (BMP) documents related to the development of GSPs, including Water Budget BMPs (DWR, 2016a). The Water Budget BMPs recommend a water budget accounting structure, or conceptual model, which distinguishes the subbasin surface water system (SWS) and groundwater system (GWS). The SWS represents the land surface down to the bottom of plant root zone[1], within the lateral boundaries of the Subbasin. The GWS extends from the bottom of the root zone to the definable bottom of the Subbasin, within the lateral boundaries of the Subbasin. The complete Subbasin water budget is a product of the interconnected SWS and GWS water budgets. The lateral and vertical boundaries of the Subbasin are described in **Section 2.2** of the GSP.

Consistent with these BMPs, this section presents the methodology and results for the historical, current, and projected water budgets of the Red Bluff Subbasin. The water budgets were developed through application of the Tehama Integrated Hydrologic Model (Tehama IHM), a numerical groundwater flow model developed for the Subbasin area that characterizes surface water and groundwater movement and storage across the entire Subbasin, including extending into areas extending outside of the Subbasin. The Tehama IHM is an integrated groundwater and surface water model developed for the purpose of conducting sustainability analyses within Tehama County, including for the Red Bluff Subbasin. The model utilized foundational elements of DWR's SVSim regional model for the Sacramento Valley (DWR, 2021) and was refined locally for improved application in the Subbasin area. Key model refinements made during development of the Tehama IHM include, but are not limited to, extending of the simulation period through water year 2019, refinement of land use conditions based on recent land use mapping information, review and modification to land use crop coefficients based on local remote sensing energy balance data, refinement of surface water supplies and diversions, and enhancements to the sediment textural model used for aquifer parameter. After conducting refinements, the Tehama IHM was calibrated using local groundwater level and streamflow data. The Tehama IHM has a historical simulation period spanning from water year 1985 through 2019, although the calibration period is 1990-2019. Detailed documentation associated with the development of the Tehama IHM is included in **Appendix 2-J.**

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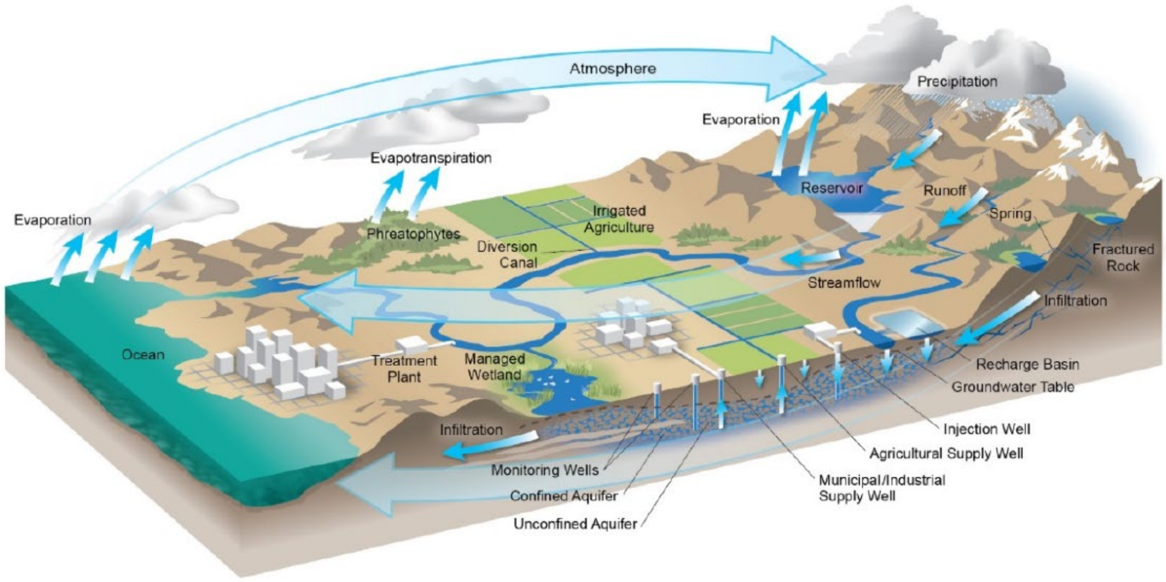
[1] The root zone is defined as "the upper portion of the soil where water extraction by plant roots occurs." The depth to the bottom of the root zone varies by crop, but typically ranges from 2-7 feet (ASCE, 2016).

This section presents the historical, current, and projected water budget results for the Red Bluff Subbasin. Water budget results for the SWS and GWS are presented individually and as part of a complete water budget for the Subbasin. This section describes the different water budget components and the results of water budget estimates derived from the Tehama IHM. The section includes discussion of the estimated uncertainties associated with the water budget analysis, data sources, and results with additional details related to these topics also described in the model documentation included as **Appendix 2-J**. The water budget results presented in this section are rounded to two significant digits consistent with the typical uncertainty associated with the methods and sources used in the analysis. Water budget component results may not sum to the totals presented because of rounding.



2.3.1 Water Budget Conceptual Model

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume[2] over a specified period of time. When the water budget is computed for a subbasin, the water budget facilitates assessment of the total volume of groundwater and surface water entering and leaving the subbasin over time, along with the change in volume of water stored within the subbasin.

2.3.1.1 Water Budget Structure

For accounting purposes, the Subbasin's water budget is divided into the surface water system (SWS) and groundwater system (GWS), described above. These systems are referred to as *accounting centers*. Flows between accounting centers and storage within each accounting center are water budget *components*. A schematic of the general water budget accounting structure is provided in **Figure 2-60**.

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[2] Where 'volume' refers to a space with length, width and depth properties, which for purposes of the GSP means the defined aquifer and associated surface water system.

The conceptual model (or structure) for the Subbasin water budget is presented in **Figure 2-61**, including presentation of terms used in the following section to describe individual aspects of the water budget. The required components for each accounting center are listed in **Table 2-11**, along with the corresponding section of the GSP Regulations (California Code of Regulations Title 23[3] (23 CCR) §354). Separate but related water budgets were prepared for each accounting center that together represent the overall water budget for the Subbasin.

This section discusses the inflows and outflows from each of the SWS and GWS parts of the Subbasin. The water budgets are calculated using the Tehama IHM, which integrates flows between the SWS and GWS. The GWS water budget incorporates all inflows and outflows from the SWS into an accounting of the net effect of the hydrology and water use on groundwater storage in the Subbasin.

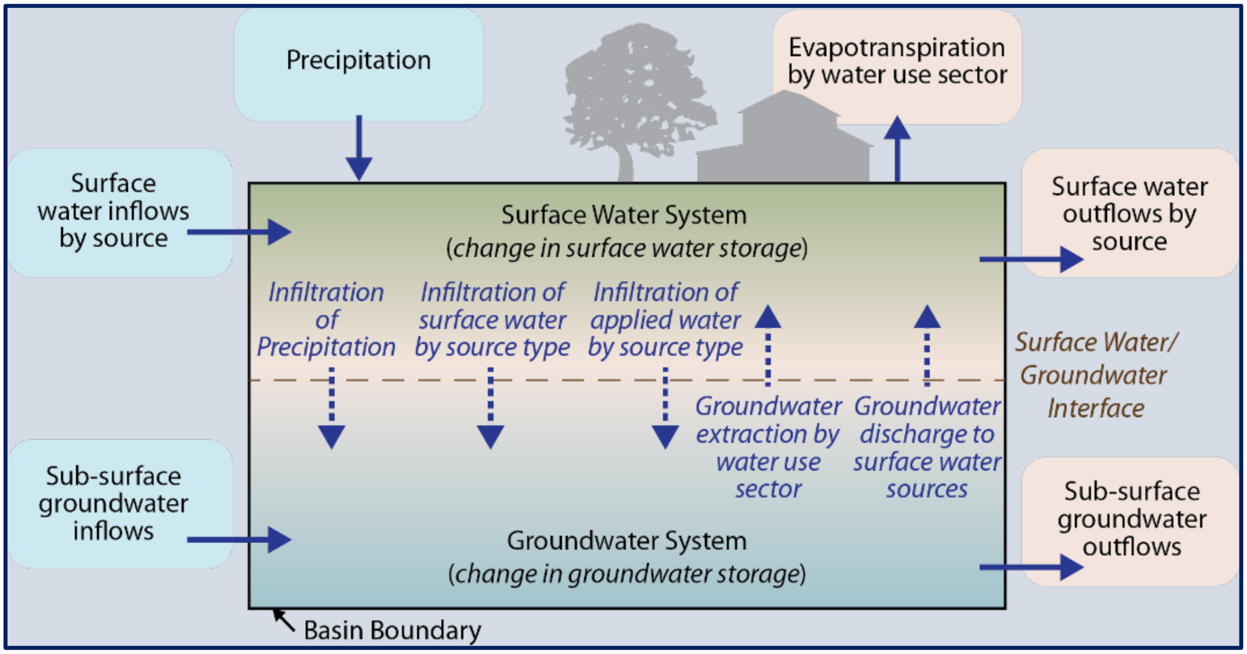

Figure 2-60. Water Budget Accounting Structure (Source: DWR, 2016a)

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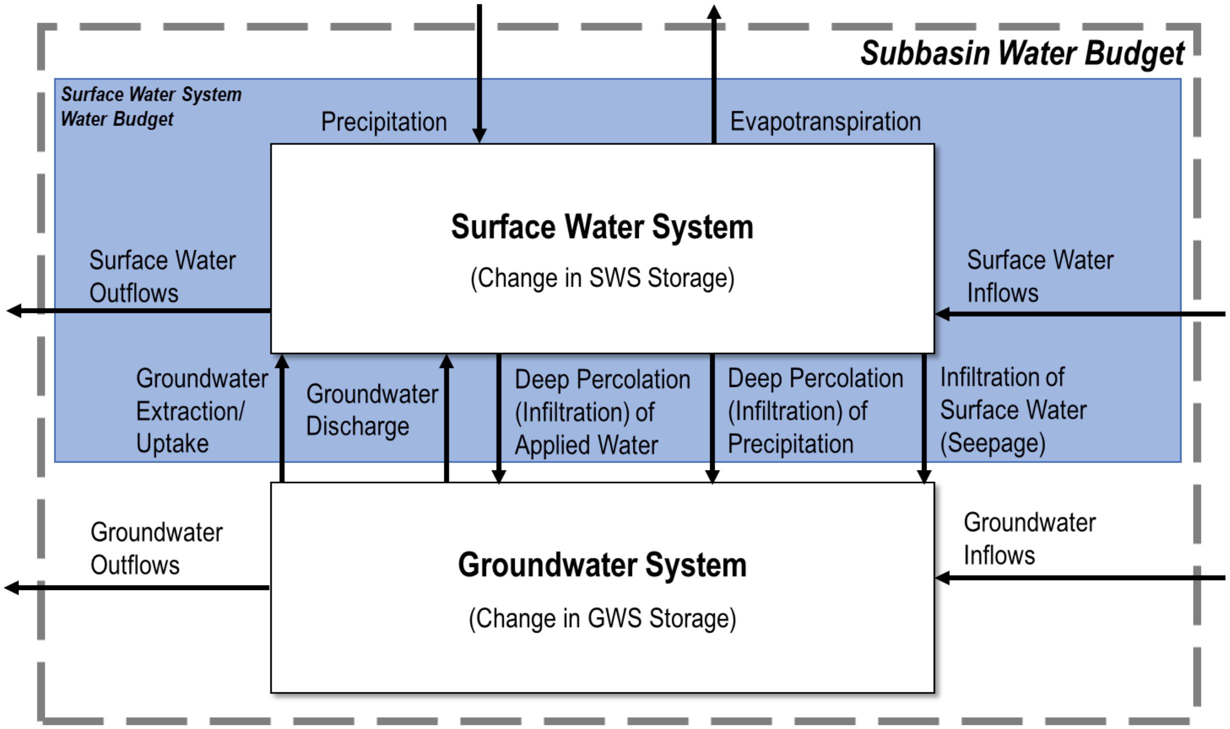
[3] California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5 Plan Contents



Net Recharge from the SWS =
(Deep Percolation of Applied Water + Deep Percolation of Precipitation +
Infiltration of Surface Water) – Groundwater Extraction/Uptake

Figure 2-61. Subbasin Water Budget Conceptual Model

Table 2-11. Water Budget Components by Accounting Center and Associated GSP Regulations

ACCOUNTING CENTER	WATER BUDGET COMPONENT (FLOW DIRECTION)	GSP REGULATION SECTION[1]
Basin	Surface Water Inflow[2] (+)	§354.18(b)(1)
	Precipitation (+)	Implied
	Subsurface Groundwater Inflow (+)	§354.18(b)(2)
	Evapotranspiration[3] (-)	§354.18(b)(3)
	Surface Water Outflow[2] (-)	§354.18(b)(1)
	Subsurface Groundwater Outflow (-)	§354.18(b)(3)
	Change in Storage	§354.18(b)(4)
Surface Water System	Surface Water Inflow[2] (+)	§354.18(b)(1)
	Precipitation (+)	Implied
	Groundwater Extraction (+)	§354.18(b)(3)
	Groundwater Discharge (+)	§354.18(b)(3)
	Evapotranspiration[3] (-)	§354.18(b)(3)
	Surface Water Outflow[2] (-)	§354.18(b)(1)
	Infiltration of Applied Water[4,5] (-)	§354.18(b)(2)
	Infiltration of Precipitation[4] (-)	§354.18(b)(2)
	Infiltration of Surface Water[6] (-)	§354.18(b)(2)
	Change in SWS Storage[7]	§354.18(a)
Groundwater System	Subsurface Groundwater Inflow (+)	§354.18(b)(2)
	Infiltration of Applied Water[4,5] (+)	§354.18(b)(2)
	Infiltration of Precipitation[4] (+)	§354.18(b)(2)
	Infiltration of Surface Water[6] (+)	§354.18(b)(2)
	Subsurface Groundwater Outflow (-)	§354.18(b)(3)
	Groundwater Extraction (-)	§354.18(b)(3)
	Groundwater Discharge (-)	§354.18(b)(3)
	Change in GWS Storage	§354.18(b)(4)

1. California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5 Plan Contents
2. By water source type.
3. Evapotranspiration includes total evapotranspiration and evaporation, by water use sector. Total evapotranspiration includes the combined evaporation from the soil and transpiration from plants, resulting from both applied water and precipitation. In this context, evaporation is the direct evaporation from open water surfaces.
4. Synonymous with deep percolation.
5. Includes infiltration of applied surface water, groundwater, and reused water
6. Synonymous with seepage. Includes infiltration of lakes, streams, canals, drains, and springs.
7. Change in storage of root zone soil moisture, not groundwater.

2.3.2 Water Budget Analysis Periods

Per 23 CCR §354.18, each GSP must quantify the historical, current, and projected water budget conditions for the Subbasin.

2.3.2.1 Historical and Current Water Budget Periods

The historical water budget for the Subbasin must quantify all required water budget components starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the water budget (23 CCR § 354.18(c)(2)(B)). The historical water budget period effectively represents long-term average hydrologic conditions. The current water budget must include the most recent hydrology, water supply, water demand, and land use information (23 CCR § 354.18(c)(1)). The historical water budget enables evaluation of the effects of historical hydrologic conditions and water demands on the water budget and groundwater conditions within the Subbasin over a period representative of long-term hydrologic conditions. The current water budget presents information on the effects of recent hydrologic and water demand conditions on the groundwater system.

The historical and current water budget periods were selected to evaluate conditions over discrete representative periods considering the following criteria: Sacramento Valley water year type; long-term mean annual water supply; inclusion of both wet and dry periods, antecedent dry conditions, adequate data availability; and inclusion of current hydrologic, cultural, and water management conditions in the Subbasin. Water years, as opposed to calendar years, are used as the time unit for defining analysis, following the DWR standard water year period (October 1 through September 30). Unless otherwise noted, all years referenced in this section are water years.

Based on these criteria, the following periods were identified for presentation of historical and current water budgets:

- **Historical Water Budget Period**: Water years 1990-2018 (29 years) using historical hydrologic, climate, water supply, and land use data.
- **Current Water Budget Periods**: Consideration of five different recent water year periods (listed below) using the historical hydrologic, climate, water supply, and land use data over each period.
    - Recent 10 years (2009-2018)
    - Recent 5 years (2014-2018)
    - Recent 3 years (2016-2018)
    - Recent 1 year (2018)
    - Recent 1 year (2019)

For the historical water budget, the period from 1990-2018 was selected to represent long-term average hydrologic conditions following evaluation of precipitation records and DWR Sacramento Valley water year type classification (**Table 2-12**). Further information and discussion of the historical water budget period, including discussion of historical hydrology and the base period selection process, are presented in **Section 2.2** of this GSP. Discussion of the historical water budget water results is included in **Section 2.3.4.**

Table 2-12. Sacramento Valley Water Year Type Classification during the Historical Water Budget Period (1990-2018)

SACRAMENTO VALLEY WATER YEAR TYPE	ABBREVIATION	NUMBER OF YEARS,1990-2018	PERCENT TOTAL YEARS,1990-2018
Wet	W	8	28%
Above Normal	AN	4	14%
Below Normal	BN	5	17%
Dry	D	5	17%
Critical	C	7	24%
Total		**29**	**100%**

For consideration in estimating the current water budget, the results for several recent periods were presented, including recent 1-year, 3-year, 5-year, and 10-year periods. These various periods result in widely varied inflows and outflows, much of which is attributed to varied precipitation and water supplies in individual years (see results in **Section 2.3.5**). Although the model simulations were run for the period 1990-2072, results for 2019 are only shown in the current water budget comparison table for the purpose of considering variability in water budget over different recent time periods. The water budget for year 2019 is not explicitly included in the historical, current, or projected water budgets for the Subbasin although it was simulated in the model to span the years between historical (1990-2018) and projected (2022-2072) water budget periods. Details of model inputs are presented in **Appendix 2-J**. Because of the year-to-year variability in water budget results, the current water budget summarizes results from the various recent periods considered to provide an appropriate and reasonable representation of the current water budget based on recent conditions.

2.3.2.2 Projected 50-Year Hydrology and Water Budget Period (§354.18c3)

The projected water budget is intended to evaluate the effects of anticipated future conditions of hydrology, water supply availability, and water demand over a 50-year GSP planning period on the Subbasin water budget and groundwater conditions. The projected water budget incorporates consideration of potential climate change and water supply availability scenarios and evaluation of the need for and benefit of any projects and management actions to be implemented in the Subbasin to maintain or achieve sustainability. The 51-year projected water budget uses hydrologic conditions representative of the most recent 50 years of hydrology in the Subbasin, with adjustments applied in scenarios for evaluating the water budget under climate change and/or altered water supply and demand conditions.

To evaluate projected water budgets, fifty years of future hydrology inputs to the Tehama IHM were developed through consideration of the historical hydrology from 1968 to 2018. Because of the availability of higher quality data and characterization of conditions in the Subbasin during more recent years spanning the historical base period (1990-2018), the projected water budget analyses used surrogate years from the historical period to construct a future hydrology and water budget period representative and consistent with hydrologic conditions over a historical 50-years period from 1968 to 2018. Surrogate years from the historical period were assigned to represent 50 years of future hydrology based on 1) the Sacramento Valley water year index from DWR for each year, 2) mimicking variability (wet and dry) in the historical precipitation conditions in the Subbasin and replicating precipitation consistent with the annual average historical precipitation, and (3) replicating regional streamflow conditions based on flows in the Sacramento River. The frequency of water year types used in the projected hydrology is representative of the 50 years of hydrology for the period 1969-2019 and includes approximately equal proportions of water years with above normal (wet and above normal; 48%) and below normal (below normal, dry, critical; 52%) hydrologic conditions (**Table 2-13**).

The approach and inputs used in development of the projected water budget are described in greater detail in the Tehama IHM documentation included as **Appendix 2-J**.

Table 2-13. Sacramento Valley Water Year Type Classification Over the Projected Water Budget Period (2022-2072)

SACRAMENTO VALLEY WATER YEAR TYPE	ABBREVIATION	NUMBER OF YEARS,2022-2072	PERCENT TOTAL YEARS, 2022-2072
Wet	W	18	35%
Above Normal	AN	7	14%
Below Normal	BN	7	14%
Dry	D	9	18%
Critical	C	10	20%
Total		51	100%

2.3.3 Surface Water System (SWS) Water Budget Description

Water budgets for the SWS were developed to characterize historical and current conditions in the Subbasin relating to the individual inflows and outflows and overall SWS water budget. The general approach used in the SWS water budget calculations is described in **Section 2.3.3.1**. **Section 2.3.4** presents the results of the historical SWS water budgets within the boundary of the Subbasin and **Section 2.3.5** presents results for current SWS water budget analyses. The analyses and results relating to the projected water budget are presented in **Sections 2.3.6** through **2.3.8**. Additional detailed discussion of the procedures and results of the SWS water budgets is included in documentation of the Tehama IHM development and results presented in **Appendix 2-J.**

2.3.3.1 General SWS Water Budget Components and Calculations

SWS inflows and outflows were quantified on a monthly basis, including accounting for any changes in SWS storage, such as changes in water stored in the root zone (**Equation 2-2**).

Total SWS Inflows – Total SWS Outflows = Change in SWS Storage (monthly)

Equation 2-2. Equation for Red Bluff Subbasin SWS Water Budget Analysis

As shown in **Figure 2-60** and **Table 2-11**, inflows to the SWS include surface water inflows (in various rivers, streams, and canals), precipitation, groundwater extraction (pumping and groundwater uptake), and groundwater discharge to surface water sources (from areas of high groundwater levels). Outflows include evapotranspiration (ET), surface water outflows (in various rivers, streams, and canals), infiltration of applied water (deep percolation from irrigation), infiltration of precipitation (deep percolation from precipitation), and infiltration of surface water (seepage).

The ET outflow component includes the following: ET of applied water (ET from soil and crop surfaces, of water that is derived from applied surface water, groundwater, and reused water); ET of precipitation (ET from soil and crop surfaces, of water that is derived from precipitation); and evaporation from rivers, streams, canals, reservoirs, and other water bodies. 'ET of applied water' differs from 'applied water' in that applied water is the volume of water that is directly applied to the land surface by irrigators (from all water sources), whereas ET of applied water is the volume of that applied water that is consumptively used by crops, vegetation, and soil surfaces.

Change in SWS storage is also depicted in **Figure 2-60** and **Table 2-11**. This represents the change in root zone soil moisture throughout the year. This is not the same as change in groundwater storage.

Net recharge from the SWS is defined as the total groundwater recharge (total infiltration from all sources) minus groundwater outflows to the surface water system, including both groundwater extraction and groundwater uptake by crops and vegetation.[4] Groundwater discharge to the SWS is not included in the net recharge term but is summarized separately as an exchange between the SWS and GWS. Net recharge from the SWS is a useful metric that equates only the impacts of the SWS on recharge and extraction from the GWS, providing valuable insight to the combined effects of land surface processes on the underlying GWS.

More information about the net exchanges of surface water and groundwater in the Subbasin is provided in **Appendix 2-K**.

2.3.3.2 Detailed SWS Water Budget Accounting Centers and Components

To estimate the water budget components required by the GSP Regulations (**Table 2-11**), the SWS water budget accounting center is subdivided into detailed accounting centers representing the Land Surface System, the Canal System, and the Rivers, Streams, and Small Watersheds System (waterways conveying natural flow and surface water supplies into the Subbasin).

The Land Surface System represents inflows and outflows from irrigated and non-irrigated land. The Canals System represents flows through the canals and conveyance systems of diverters with access to surface water. The Rivers, Streams, and Small Watershed Systems represent inflows and outflows through waterways that convey natural flow, upgradient runoff, and drainage.

The Land Surface System is further subdivided into water use sectors, defined in the GSP Regulations as "categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation" (23 CCR Section 351(al)). Principal water use sectors in the Subbasin include Agricultural (irrigated crop land and idle agricultural land), Native Vegetation (native and riparian vegetation), and Urban (urban, residential, industrial, and semi-agricultural[5]).

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[4] Groundwater discharge to surface water is not included in the calculation of net recharge from the SWS, as groundwater discharge is more dependent on shallow groundwater and soil characteristics along waterways and is much less dependent on the management of the surface layer. Net recharge from the SWS is intended to describe the impacts of the SWS on the GWS, but groundwater discharge is more reflective of the GWS effects on the SWS.

[5] As defined in the DWR crop mapping metadata, semi-agricultural land includes farmsteads and miscellaneous land use incidental to agriculture (small roads, ditches, etc.) (DWR, 2016b).

2.3.3.2.1*SWS Inflows*

2.3.3.2.1.1 *Surface Water Inflow by Water Source Type*

Per the GSP Regulations, surface inflows must be reported by water source type. According to the Regulations (23 CCR § 351(ak)):

> *"Water source type" represents the source from which water is derived to meet the applied beneficial uses, including groundwater, recycled water, reused water, and surface water sources identified as Central Valley Project, the State Water Project, the Colorado River Project, local supplies, and local imported supplies.*

Major surface water inflows to the Red Bluff Subbasin are summarized below according to water source type. Additionally, runoff of precipitation from upgradient areas adjacent to the Subbasin represents a potential source of SWS inflow.

Local Supplies

Local supply inflows to the Red Bluff Subbasin predominantly include runoff from upgradient small watersheds adjacent to the Subbasin and surface inflows along Red Bank Creek and Elder Creek. A portion of these local supplies are diverted by local water rights users for beneficial use within the Subbasin.

Central Valley Project

Central Valley Project (CVP) inflows to the Red Bluff Subbasin include surface water delivered along the Corning Canal to Proberta Water District and the portions of Thomes Creek Water District that overlie the Red Bluff Subbasin.

2.3.3.2.1.2 *Precipitation*

Precipitation falling on the landscape within the Subbasin is an inflow to the SWS. Precipitation inflows are accounted for by the land use (water use sector) on which they occur.

2.3.3.2.1.3 *Groundwater Extraction and Uptake*

Groundwater extraction is an inflow to the SWS (an outflow from the GWS). Groundwater extraction is accounted for by agricultural and urban (urban, residential, semi-agricultural, industrial) water use sectors. Urban groundwater pumping includes domestic well pumping. Groundwater uptake is water taken up by plant roots directly from the GWS.

2.3.3.2.1.4 *Groundwater Discharge to Surface Water*

Groundwater discharging to surface water features can occur where groundwater is very shallow and where groundwater levels are higher than the stage in surface water bodies. Groundwater discharge to surface water represents an inflow to the SWS (an outflow from the GWS).

2.3.3.2.2*SWS Outflows*

2.3.3.2.2.1 *Evapotranspiration*

Evapotranspiration (ET) is accounted for by water use sector (urban, agriculture, native) and according to the source water (applied water or precipitation). ET from land includes from applied water and precipitation sources. Evaporation also occurs from rivers, streams, canals, and drains throughout the Subbasin.

2.3.3.2.2.2 *Infiltration*

Infiltration (deep percolation) is water that infiltrates below the root zone and recharges the GWS. Infiltration can occur from applied water (e.g., irrigation) or precipitation occurring on the landscape within the Subbasin. Alternatively, infiltration of surface water (stream seepage) can occur from surface water that seeps through the bottom of surface water features and recharges the GWS.

2.3.3.2.2.3 *Surface Water Outflow*

In the Red Bluff Subbasin, surface water outflows consist entirely of local supplies that traverse the Subbasin, or that drain from lands within the Subbasin or runoff into the Subbasin from upland areas outside the Subbasin. As described above, substantial local supply volumes enter the Red Bluff Subbasin along Sacramento River and tributary waterways, although much of this water passes through the Subbasin.

2.3.3.3 SWS Water Budget Overview

Water budget components are defined for each detailed accounting center in **Table 2-14** through **Table 2-16**. Within the Land Surface System accounting center, water budget components are also defined for each water use sector. These detailed water budget accounting centers and components are quantified based on the best available data and science, including information from water management plans (WMPs), groundwater management plans (GMPs), agricultural water management plans (AWMPs), urban water management plans (UWMPs), and other sources.

Each detailed accounting center was computed for the Subbasin. The Subbasin boundary SWS water budget components are identified in **Table 2-17**. The water budget includes the crop demands, available water supplies, and other characteristics specific to the Subbasin, including diversions, evaporation, and infiltration of surface water within the Subbasin.

Table 2-14. Land Surface System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Land Surface System *Water Use Sectors: Agricultural, Native Vegetation, Urban*	Deliveries	Inflow	Deliveries of surface water supply for use within the Subbasin.
	Groundwater Extraction	Inflow	Groundwater pumping to meet water demands, and groundwater uptake by crops and vegetation.
	Precipitation	Inflow	Direct precipitation on the land surface.
	Reuse	Inflow	Reuse of percolated water from the unsaturated zone[1].
	ET of Applied Water	Outflow	Consumptive use of applied irrigation water.
	ET of Groundwater Uptake	Outflow	Consumptive use of shallow groundwater uptake.
	ET of Precipitation	Outflow	Consumptive use of infiltrated precipitation.
	Net Return Flow	Outflow	Net runoff of applied irrigation water, accounting for reuse[2].
	Runoff of Precipitation	Outflow	Direct runoff of precipitation.
	Infiltration of Applied Water	Outflow	Deep percolation of applied water below the root zone.
	Infiltration of Precipitation	Outflow	Deep percolation of precipitation below the root zone.
	Change in SWS Storage	Storage	Change in root zone soil moisture throughout the year; does not represent change in groundwater storage.

[1] "The unsaturated zone is below the land surface system and represents the portion of the basin that receives percolated water from the root zone and either transmits it as deep percolation to the GWS or to reuse within the land surface system, or both." (DWR, 2016a).

[2] Includes tailwater and pond drainage for ponded crops.

Table 2-15. Canal System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Canal System	Diversions	Inflow	Diversions of surface water supply from waterways, a portion of which is delivered and used within the Subbasin.
	Deliveries	Outflow	Deliveries of surface water supply for use within the Subbasin.
	Infiltration of Surface Water (Seepage)	Outflow	Seepage from canals to the GWS.
	Evaporation	Outflow	Direct evaporation from canal water surfaces.
	Spillage	Outflow	Spillage from canals used for conveyance.

Table 2-16. Rivers, Streams, and Small Watersheds System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Rivers, Streams, and Small Watersheds System	Stream Inflows	Inflow	Surface water inflows at the upstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces upgradient of the Subbasin.
	Small Watershed Inflows	Inflow	Surface water inflows of drainage from upgradient small watersheds.
	Groundwater Discharge	Inflow	Discharge from shallow groundwater into rivers and streams.
	Spillage	Inflow	Spillage from canals used for conveyance.
	Stream Outflows	Outflow	Surface water outflows at the downstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces.
	Small Watershed Outflows	Outflow	Surface water outflows of drainage from upgradient small watersheds at the downgradient boundary of the Subbasin.
	Diversions	Outflow	Diversions of surface water supply from waterways, a portion of which is delivered and used within the Subbasin.
	Infiltration of Surface Water (Seepage)	Outflow	Seepage from rivers, streams, and small watershed inflows to the GWS.
	Evaporation	Outflow	Direct evaporation from river and stream water surfaces.

Table 2-17. Subbasin Boundary Surface Water System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Rivers, Streams, and Small Watersheds System	Stream Inflows	Inflow	Surface water inflows at the upstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces upgradient of the Subbasin.
	Small Watershed Inflows	Inflow	Surface water inflows of drainage from upgradient small watersheds.
	Groundwater Discharge	Inflow	Discharge from shallow groundwater into rivers and streams.
Canal System	Diversions *(in select cases)*	Inflow	Diversions of surface water supply from waterways *at a point outside or along the boundary of the Subbasin*, a portion of which is delivered and used within the Subbasin.
Land Surface System *Water Use Sectors: Agricultural, Native Vegetation, Urban*	Groundwater Extraction	Inflow	Groundwater pumping to meet water demands, and groundwater uptake by crops and vegetation.
	Precipitation	Inflow	Direct precipitation on the land surface.
	ET of Applied Water	Outflow	Consumptive use of applied irrigation water.
	ET of Groundwater Uptake	Outflow	Consumptive use of shallow groundwater uptake.
	ET of Precipitation	Outflow	Consumptive use of infiltrated precipitation.
	Runoff of Applied Water	Outflow	Direct runoff of applied irrigation water[2].
	Runoff of Precipitation	Outflow	Direct runoff of precipitation.
	Infiltration of Applied Water	Outflow	Deep percolation of applied water below the root zone.
	Infiltration of Precipitation	Outflow	Deep percolation of precipitation below the root zone.
	Change in SWS Storage	Storage	Change in root zone soil moisture throughout the year; (not change in groundwater storage)
Canal System; and Rivers, Streams, and Small Watersheds System	Infiltration of Surface Water (Seepage)	Outflow	Seepage from canals, streams, and small watershed inflows to the GWS.
	Evaporation	Outflow	Direct evaporation from canals, rivers, and streams.
Canal System	Spillage	Outflow	Spillage from canals used for interior conveyance.
Rivers, Streams, and Small Watersheds System	Stream Outflows	Outflow	Surface water outflows at the downstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces.
	Small Watershed Outflows	Outflow	Surface water outflows of drainage from upgradient small watersheds at the downgradient boundary of the Subbasin.

2.3.4 Groundwater System (GWS) Water Budget Description

Water budgets for the GWS were developed to characterize historical and current conditions in the Subbasin utilizing the Tehama IHM for different historical and current time periods described above. **Sections 2.3.4** and **2.3.5** present the results of the historical and current GWS water budgets within the lateral and vertical boundaries of the Subbasin. Discussion of the general approach used in developing model scenarios to evaluate projected GWS water budgets for the Subbasin with the Tehama IHM and the results from these projected water budget analyses are included in **Sections 2.3.6** through **2.3.8**. More details related to the procedures and results of the GWS water budgets are also included in documentation of the Tehama IHM development presented in **Appendices 2-J and 2-K.**

2.3.4.1 GWS Water Budget Components and Calculations

Inflows and outflows of the GWS were quantified on a monthly basis, including accounting for any changes in GWS storage (**Equation 2-3**).

$$\text{Total GWS Inflows} - \text{Total GWS Outflows} = \text{Change in GWS Storage (monthly)}$$

Equation 2-3. Equation for Red Bluff Subbasin GWS Water Budget Analysis

As shown in **Figure 2-60** and **Table 2-11**, inflows to the GWS include some of the outflow components from the SWS including infiltration (deep percolation) of precipitation and applied water and infiltration (seepage) of surface water. Additional GWS inflows include lateral subsurface groundwater inflows from adjacent subbasins and from adjacent upland or foothill areas outside the Subbasin (small watersheds). GWS outflows include exchanges with the SWS including groundwater discharge to surface waterways, groundwater extraction through pumping, and root water uptake by plants occurring directly from shallow groundwater. Lateral subsurface groundwater flows to adjacent subbasins represent additional GWS outflows. Water budget components representing exchanges between the GWS and the SWS are also included in discussions and presentations of the SWS conceptual water budget and results.

2.3.4.1.1 *Lateral Subsurface Flows*

Subsurface groundwater flows to and from the Red Bluff Subbasin occur between the Bowman Subbasin to the north, the South Battle Creek Subbasin to the northeast, the Bend, Antelope, and Los Molinos Subbasins to the east, and the Corning Subbasin to the south. Additional subsurface groundwater inflows occur from the upland (small watershed) areas adjoining the Red Bluff Subbasin.

2.3.4.1.2 *Deep Percolation From the SWS*

Deep percolation from the SWS includes infiltration of water below the root zone (deep percolation) from precipitation and applied water. These two water budget components represent inflows to the GWS and are also included in the SWS water budget as outflows from the SWS.

2.3.4.1.3 *Net Stream Seepage/Groundwater Discharge to Surface Water*

The flow of water between the GWS and SWS through seepage of water from streams and canals and groundwater discharging into streams is discussed as part of the SWS water budget. These components are combined in the GWS water budget as a net volume of stream seepage. Positive total net seepage values represent a net inflow of water from the SWS to the GWS via stream and canal seepage indicating that the overall volume of stream seepage is greater than the volume of any groundwater discharging into surface waterways. Negative net seepage values represent a net outflow of groundwater from the GWS to the SWS through groundwater discharge to surface water. When net seepage is negative, it means that more groundwater is discharging into the surface waterways than is seeping from surface waterways into the GWS.

2.3.4.1.4 *Groundwater Extraction and Uptake*

Groundwater extractions and groundwater uptake are exchanges that occur between the GWS and the SWS and represent an outflow from the GWS. Groundwater extraction from the GWS occurs through groundwater pumping to meet water demands for urban and agricultural needs whereas groundwater uptake occurs through uptake of water by plants directly from the GWS.

2.3.4.2 GWS Water Budget Overview

Change in GWS storage as represented by change in groundwater storage is also depicted in **Figure 2-60** and **Table 2-11**. The change in groundwater storage represents the total change in the volume of water in storage in the groundwater system as a result of exchanges between the GWS and the SWS and the balance of all inflows and outflows of the GWS. The change in groundwater storage is directly related to changes in water levels in the groundwater system, both of which are sustainability indicators to be considered during development of a sustainable yield for the Subbasin. Each of the detailed components of the Subbasin boundary GWS water budget are identified in **Table 2-18** and were computed for the Subbasin to develop a complete GWS water budget. The HCM discussed in **Section 2.2** identifies two principal aquifers within the GWS: an Upper Aquifer and Lower Aquifer. Vertical groundwater flow does occur between these aquifers and change in storage of the entire GWS and also within each principal aquifer zone are considerations for sustainable groundwater management.

Table 2-18. Subbasin Boundary Groundwater System Water Budget Components

ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Groundwater System	Lateral Subsurface Groundwater Flows Between Adjacent Subbasins	Inflow	Lateral subsurface groundwater inflow from adjacent subbasin.
	Lateral Subsurface Groundwater Flows Between Adjacent Upland or Foothill Areas	Inflow	Lateral subsurface groundwater inflow from adjacent upland or foothill areas.
	Infiltration of Surface Water (Seepage)	Inflow	Seepage from canal, streams, and small watershed inflows from the SWS.
	Infiltration (Deep Percolation) of Applied Water	Inflow	Deep percolation of applied water below the root zone from the SWS.
	Infiltration (Deep Percolation) of Precipitation	Inflow	Deep percolation of precipitation below the root zone from the SWS.
	Lateral Subsurface Groundwater Flows Between Adjacent Subbasins	Outflow	Lateral subsurface groundwater outflow to adjacent subbasin.
	Groundwater Extraction	Outflow	Groundwater pumping to meet water demands, and groundwater uptake by crops and vegetation.
	Groundwater Discharge	Outflow	Discharge from shallow groundwater into rivers and streams.
	Vertical Subsurface Groundwater Flows within the GWS	Storage	Vertical subsurface groundwater flows between the Upper and Lower Aquifers within the GWS
	Change in GWS Storage	Storage	Change in volume of water stored within the groundwater system, representative of total accrual or depletion of groundwater storage.

2.3.5 Historical Water Budget

The following section summarizes the analyses and results relating to the historical SWS water budget for the Subbasin. Detailed descriptions and presentation of results for each of the individual water budget components, and the processes and data sources used in their development are included in **Appendices 2-J and 2-K**.

2.3.5.1 Land Use

Characterizing historical land use is foundational for accurately quantifying how and where water is beneficially used. Land use areas are also used to distinguish the water use sector in which water is consumed, as required by the GSP Regulations. **Figure 2-62** and **Table 2-19** summarize the annual land use areas over the historical period (1990-2018) in the Red Bluff Subbasin by water use sector, as defined by the GSP Regulations (23 CCR § 351(al)). In the Red Bluff Subbasin, water use sectors include agricultural, urban, and native vegetation land uses. The urban water use sector covers all urban, residential, industrial, and semi-agricultural[6] land uses. See Plan Area section 2.1.1.2, Land Use

On average, agricultural, urban, and native vegetation land uses covered approximately 36,000 acres, 6,400 acres, and 229,500 acres, respectively, between 1990 and 2018. Since 1990, the total area of native vegetation has decreased by approximately 10,000 acres, corresponding with a similar increase in agricultural acreage.

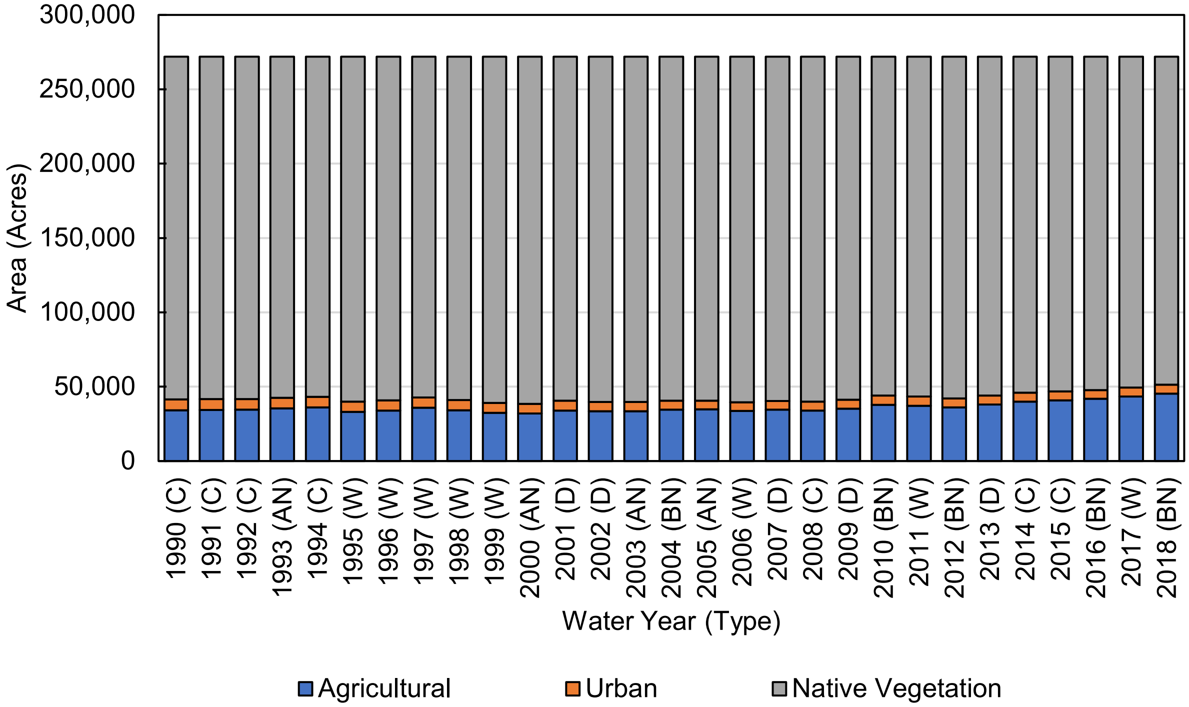

Figure 2-62. Red Bluff Subbasin Land Use Areas, by Water Use Sector

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[6] As defined in the DWR crop mapping metadata, semi-agricultural land use subclasses include farmsteads, livestock feed lot operations, dairies, poultry farms, and miscellaneous semi-agricultural land use incidental to agriculture (small roads, ditches, non-planted areas of cropped fields (DWR, 2016b).

Table 2-19. Red Bluff Subbasin Land Use Areas, by Water Use Sector

WATER YEAR (TYPE)	AGRICULTURAL	URBAN[1]	NATIVE VEGETATION	TOTAL
1990 (C)	34,117	7,351	230,485	271,953
1991 (C)	34,375	7,265	230,312	271,953
1992 (C)	34,486	7,177	230,290	271,953
1993 (AN)	35,338	7,124	229,491	271,953
1994 (C)	36,057	7,078	228,818	271,953
1995 (W)	32,991	6,917	232,045	271,953
1996 (W)	33,955	6,937	231,062	271,953
1997 (W)	35,768	6,911	229,275	271,953
1998 (W)	34,140	6,842	230,971	271,953
1999 (W)	32,329	6,780	232,844	271,953
2000 (AN)	31,918	6,582	233,453	271,953
2001 (D)	33,998	6,503	231,452	271,953
2002 (D)	33,493	6,357	232,103	271,953
2003 (AN)	33,518	6,191	232,244	271,953
2004 (BN)	34,617	6,051	231,286	271,953
2005 (AN)	34,721	5,931	231,301	271,953
2006 (W)	33,633	5,921	232,399	271,953
2007 (D)	34,542	5,955	231,455	271,953
2008 (C)	33,992	5,935	232,026	271,953
2009 (D)	35,280	6,050	230,623	271,953
2010 (BN)	37,851	6,099	228,003	271,953
2011 (W)	37,252	6,098	228,603	271,953
2012 (BN)	36,018	6,115	229,820	271,953
2013 (D)	37,950	6,077	227,926	271,953
2014 (C)	39,884	6,043	226,025	271,953
2015 (C)	40,839	6,004	225,110	271,953
2016 (BN)	41,839	5,961	224,153	271,953
2017 (W)	43,342	6,065	222,546	271,953
2018 (BN)	45,309	6,115	220,529	271,953
Average (1990-2018)	35,985	6,429	229,540	271,953

[1] Area includes land classified as urban, residential, industrial, and semi-agricultural.

Agricultural land uses are further detailed in **Figure 2-63**and **Table 2-20**. Historically, a majority of the agricultural area in the Red Bluff Subbasin has been comprised of pasture, grain, and various orchard crops. Since the early 2000s, irrigated agricultural areas within the Red Bluff Subbasin have expanded, primarily due to increases in orchard acreage, especially walnuts and almonds.

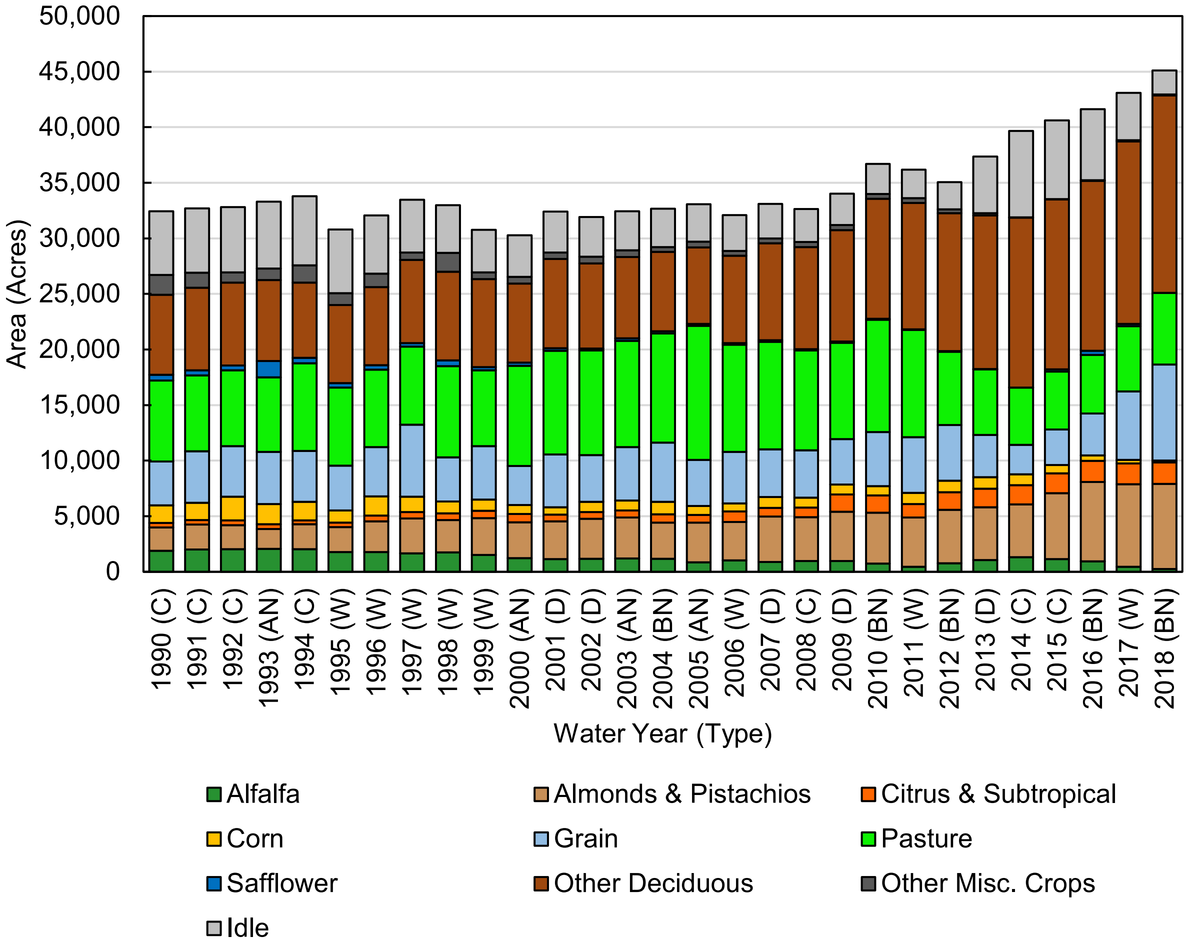

Figure 2-63. Red Bluff Subbasin Agricultural Land Use Areas

Table 2-20. Red Bluff Subbasin Agricultural Land Use Areas (acres)

WATER YEAR (TYPE)	ALFALFA	ALMONDS & PISTACHIOS	CITRUS & SUB-TROPICAL	CORN	GRAIN	PASTURE	PONDED (RICE)	SAFFLOWER	OTHER DECIDUOUS[1]	OTHER MISC. CROPS[2]	IDLE	TOTAL
1990 (C)	1,902	2,092	414	1,566	3,954	7,271	1,672	525	7,206	1,793	5,722	34,117
1991 (C)	2,001	2,249	407	1,565	4,611	6,840	1,668	468	7,408	1,366	5,793	34,375
1992 (C)	2,026	2,162	442	2,117	4,565	6,822	1,661	417	7,481	917	5,876	34,486
1993 (AN)	2,056	1,793	423	1,834	4,691	6,690	2,036	1,489	7,287	1,038	6,002	35,338
1994 (C)	2,038	2,231	365	1,668	4,563	7,895	2,258	479	6,783	1,553	6,224	36,057
1995 (W)	1,770	2,259	400	1,077	4,036	7,042	2,200	383	7,046	1,062	5,716	32,991
1996 (W)	1,773	2,772	507	1,727	4,440	6,974	1,880	397	7,034	1,190	5,261	33,955
1997 (W)	1,659	3,156	559	1,379	6,471	7,049	2,288	303	7,488	663	4,754	35,768
1998 (W)	1,740	2,911	606	1,057	3,984	8,206	1,148	530	7,961	1,688	4,308	34,140
1999 (W)	1,505	3,335	661	999	4,818	6,800	1,547	286	7,929	617	3,833	32,329
2000 (AN)	1,229	3,230	731	816	3,513	9,018	1,631	282	7,114	619	3,737	31,918
2001 (D)	1,155	3,396	605	643	4,757	9,337	1,601	234	8,014	594	3,661	33,998
2002 (D)	1,169	3,593	617	931	4,197	9,396	1,561	191	7,649	604	3,587	33,493
2003 (AN)	1,215	3,663	636	893	4,812	9,556	1,071	240	7,314	587	3,533	33,518
2004 (BN)	1,167	3,263	733	1,143	5,306	9,827	1,951	194	7,151	435	3,448	34,617
2005 (AN)	869	3,558	697	794	4,146	12,083	1,648	170	6,865	536	3,357	34,721
2006 (W)	1,027	3,460	941	725	4,649	9,630	1,548	154	7,841	428	3,230	33,633
2007 (D)	900	4,060	794	968	4,293	9,673	1,451	139	8,732	446	3,088	34,542
2008 (C)	965	3,960	858	882	4,277	8,974	1,356	123	9,178	468	2,952	33,992
2009 (D)	965	4,440	1,563	896	4,069	8,682	1,261	106	10,006	474	2,818	35,280
2010 (BN)	735	4,592	1,544	850	4,859	10,109	1,163	89	10,782	442	2,686	37,851
2011 (W)	445	4,429	1,227	1,007	5,016	9,632	1,066	71	11,357	443	2,560	37,252
2012 (BN)	783	4,797	1,577	1,051	4,997	6,606	971	53	12,413	344	2,425	36,018
2013 (D)	1,062	4,761	1,656	1,025	3,825	5,881	590	28	13,835	187	5,100	37,950
2014 (C)	1,322	4,735	1,737	987	2,642	5,163	209	4	15,265	30	7,790	39,884
2015 (C)	1,135	5,945	1,783	746	3,196	5,224	215	194	15,269	53	7,079	40,839
2016 (BN)	953	7,142	1,897	492	3,749	5,277	219	385	15,269	78	6,379	41,839
2017 (W)	458	7,423	1,861	321	6,179	5,865	241	195	16,422	95	4,281	43,342
2018 (BN)	250	7,655	1,945	170	8,626	6,442	212	6	17,758	109	2,140	45,309
Average (1990-2018)	1,251	3,899	972	1,046	4,594	7,861	1,322	280	9,719	650	4,391	35,985

[1] Includes primarily walnuts and prunes.

[2] Area includes land classified as cotton, cucurbits, dry beans, onions & garlic, potatoes, sugar beets, tomatoes, vineyards, other field crops, and other truck crops.

2.3.5.2 Historical Surface Water System Water Budget Summary

Annual inflows, outflows, and change in SWS root zone storage during the historical water budget period (1990-2018) are summarized in **Figure 2-64** and **Table 2-21.** Inflows in **Figure 2-64** are shown as positive values, while outflows and change in SWS root zone storage are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the SWS water budget.

Of particular note in the historical SWS water budget results are the volume of precipitation that makes up a large part of the Subbasin SWS inflows. Over the historical period, precipitation to surface water averaged about 580 taf per year. Surface water inflows and groundwater extraction/ uptake also represent large SWS inflow components averaging about 120 and 90 taf per year, respectively. Groundwater discharge to surface water and groundwater extraction/ uptake represent relatively smaller SWS inflows in the Subbasin averaging about 42 taf per year over the historical water budget period.

Among the outflows from the Subbasin SWS, ET of precipitation and surface water outflow make up large fractions of the total Subbasin SWS outflows. ET of precipitation averages about 350 taf per year. The surface water outflows total about 340 taf per year on average, a value that corresponds with the large volumes of precipitation and surface water inflow (a total of about 700 taf per year). By comparison, other SWS outflows in the Subbasin are relatively smaller, with values for ET of applied water and deep percolation of precipitation averaging about 61 and 55 taf per year, respectively. The outflows of deep percolation of applied water, ET of groundwater uptake and infiltration (seepage) of surface water are about 15, 9.7, and 2.4 taf per year on average, respectively. Evaporation from surface water averages about 0.7 taf per year over the historical water budget period.

Detailed results for the historical SWS water budget are presented in **Appendix 2-K**.

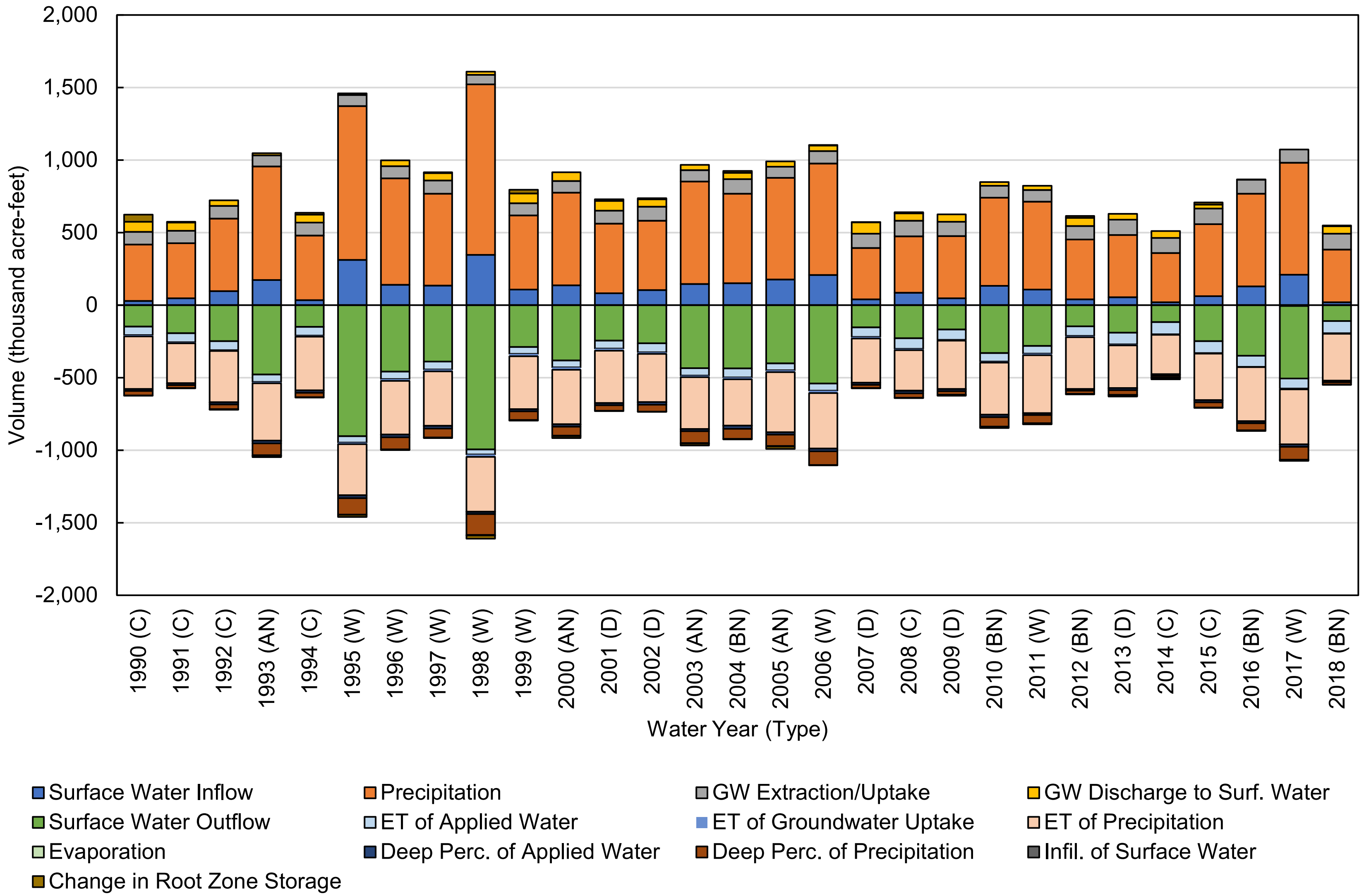

Figure 2-64. Red Bluff Subbasin Surface Water System Historical Water Budget, 1990-2018

Table 2-21. Red Bluff Subbasin Surface Water System Historical Water Budget, 1990-2018 (acre-feet)

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION/ UPTAKE	GROUND-WATER DIS-CHARGE[1]	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
1990 (C)	29,000	390,000	87,000	69,000	150,000	58,000	9,400	360,000	240	13,000	31,000	2,100	-50,000
1991 (C)	47,000	380,000	87,000	57,000	190,000	62,000	6,300	280,000	330	13,000	21,000	2,000	-4,200
1992 (C)	97,000	500,000	87,000	38,000	250,000	62,000	5,800	350,000	380	14,000	34,000	2,200	1,600
1993 (AN)	170,000	780,000	76,000	15,000	480,000	52,000	7,900	400,000	280	17,000	83,000	2,800	10,000
1994 (C)	35,000	440,000	90,000	55,000	150,000	60,000	7,200	370,000	290	15,000	31,000	2,100	-12,000
1995 (W)	310,000	1,100,000	76,000	11,000	900,000	45,000	10,000	350,000	280	20,000	110,000	2,900	14,000
1996 (W)	140,000	730,000	84,000	40,000	460,000	51,000	13,000	370,000	440	18,000	84,000	2,800	310
1997 (W)	130,000	630,000	92,000	50,000	390,000	55,000	13,000	370,000	560	17,000	63,000	2,400	-6,100
1998 (W)	350,000	1,200,000	66,000	21,000	1,000,000	35,000	16,000	380,000	380	15,000	150,000	3,000	21,000
1999 (W)	110,000	510,000	83,000	67,000	290,000	48,000	17,000	360,000	690	16,000	59,000	2,800	-26,000
2000 (AN)	140,000	640,000	81,000	59,000	380,000	48,000	15,000	380,000	640	16,000	63,000	2,800	13,000
2001 (D)	83,000	480,000	89,000	68,000	250,000	55,000	13,000	360,000	690	14,000	39,000	2,400	-11,000
2002 (D)	100,000	480,000	97,000	51,000	260,000	62,000	11,000	330,000	760	17,000	48,000	2,600	-7,300
2003 (AN)	150,000	710,000	79,000	37,000	430,000	51,000	12,000	360,000	700	15,000	82,000	2,600	13,000
2004 (BN)	150,000	620,000	100,000	44,000	440,000	62,000	13,000	320,000	920	21,000	70,000	3,000	-13,000
2005 (AN)	180,000	700,000	77,000	35,000	400,000	47,000	13,000	410,000	580	15,000	80,000	2,600	16,000
2006 (W)	210,000	770,000	87,000	37,000	540,000	49,000	16,000	380,000	630	18,000	95,000	3,000	-5,100
2007 (D)	40,000	350,000	98,000	78,000	150,000	64,000	12,000	300,000	800	15,000	21,000	2,300	-2,500
2008 (C)	85,000	390,000	110,000	51,000	230,000	73,000	9,400	280,000	1,000	17,000	31,000	2,400	-8,400
2009 (D)	47,000	430,000	97,000	51,000	170,000	70,000	6,900	330,000	910	14,000	24,000	2,100	6,000

WATER YEAR (TYPE)		INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
		SURFACE WATER INFLOW	PRECIPITATION	GROUNDWATER EXTRACTION/ UPTAKE	GROUNDWATER DISCHARGE[1]	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUNDWATER UPTAKE	ET OF PRECIPITATION	EVAPORATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPITATION	INFIL. OF SURFACE WATER	
2010 (BN)		130,000	610,000	82,000	26,000	330,000	58,000	7,900	360,000	780	15,000	67,000	2,400	7,500
2011 (W)		110,000	600,000	80,000	29,000	280,000	54,000	9,900	400,000	680	13,000	57,000	2,500	4,500
2012 (BN)		41,000	410,000	93,000	57,000	150,000	66,000	8,800	360,000	810	11,000	22,000	2,300	-12,000
2013 (D)		54,000	430,000	110,000	41,000	190,000	81,000	6,500	290,000	1,100	15,000	31,000	2,500	9,200
2014 (C)		20,000	340,000	100,000	48,000	120,000	85,000	3,800	270,000	940	8,800	13,000	1,600	11,000
2015 (C)		62,000	500,000	110,000	28,000	250,000	82,000	3,200	320,000	900	13,000	37,000	1,700	-14,000
2016 (BN)		130,000	640,000	96,000	2,200	350,000	76,000	3,400	370,000	1,100	13,000	50,000	2,200	830
2017 (W)		210,000	770,000	91,000	-6,300	500,000	68,000	6,600	380,000	950	16,000	90,000	2,500	4,200
2018 (BN)		20,000	360,000	110,000	51,000	110,000	85,000	4,200	320,000	850	9,700	17,000	2,000	-6,100
Average (1990-2018)		120,000	580,000	90,000	42,000	340,000	61,000	9,700	350,000	670	15,000	55,000	2,400	-1,600
1990-2018	W	200,000	780,000	82,000	31,000	540,000	51,000	13,000	380,000	580	17,000	88,000	2,700	930
	AN	160,000	710,000	78,000	37,000	420,000	49,000	12,000	390,000	550	16,000	77,000	2,700	13,000
	BN	95,000	530,000	96,000	36,000	270,000	69,000	7,500	350,000	890	14,000	45,000	2,400	-4,500
	D	65,000	430,000	97,000	58,000	200,000	67,000	10,000	320,000	850	15,000	32,000	2,400	-1,200
	C	53,000	420,000	95,000	50,000	190,000	69,000	6,400	320,000	580	13,000	28,000	2,000	-11,000

2.3.5.3 Historical Groundwater System Water Budget Summary

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Figure 2-65** and **Table 2-22**. Among the outflows from the Subbasin SWS, groundwater pumping makes up the largest fraction of the total SWS outflows (on average -80 taf per year). Highly negative net seepage values (on average -39 taf per year) represent net groundwater discharging to surface waterways and leaving the GWS. Deep percolation is the largest net inflow component averaging about 70 taf per year. Positive net subsurface flows (on average 49 taf per year) represent the combined subsurface inflows from adjacent subbasins and upland areas.

Groundwater (root water) uptake directly from shallow groundwater (on average -9.7 taf per year) represents a smaller outflow from the GWS. Overall, the water budget results for the 29-year historic period indicate a cumulative change in groundwater storage of about -310 taf, which equals an average annual change in groundwater storage of only about -11 taf per year. This change in storage estimates equate to total decreases in storage in the Subbasin of about 1.1 acre-feet per acre on average over the 29 years and an annual decrease of less than 0.04 acre-feet per acre across the entire Subbasin (approximately 272,000 acres). **Figure 2-65** provides a conceptual illustration of the historical water budget. **Figure 2-66** highlights the cumulative change in groundwater storage that has occurred over the 1990-2018 period, with a notable decline in storage over the generally dry period since the mid-2000s. The decrease of groundwater storage during relatively dry years is not an indication of overdraft, but likely due to removal of temporary surplus of groundwater. Temporary surplus removal is the extraction of a volume of aquifer storage to enable the capture of recharge and reduction in subsurface outflow from the subbasin without impacting beneficial users of groundwater creating unreasonable results. In contrast, overdraft is defined as “the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions. Overdraft can be characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years. If overdraft continues for a number of years, significant adverse impacts may occur, including increased extraction costs, costs of well deepening or replacement, land subsidence, water quality degradation, and environmental impacts” (DWR, 2003).

Additional details on the historical GWS water budget are presented in **Appendix 2-K**.

Figure 2-65. Diagram of the Red Bluff Subbasin Historical Average Annual Water Budget (1990-2018)

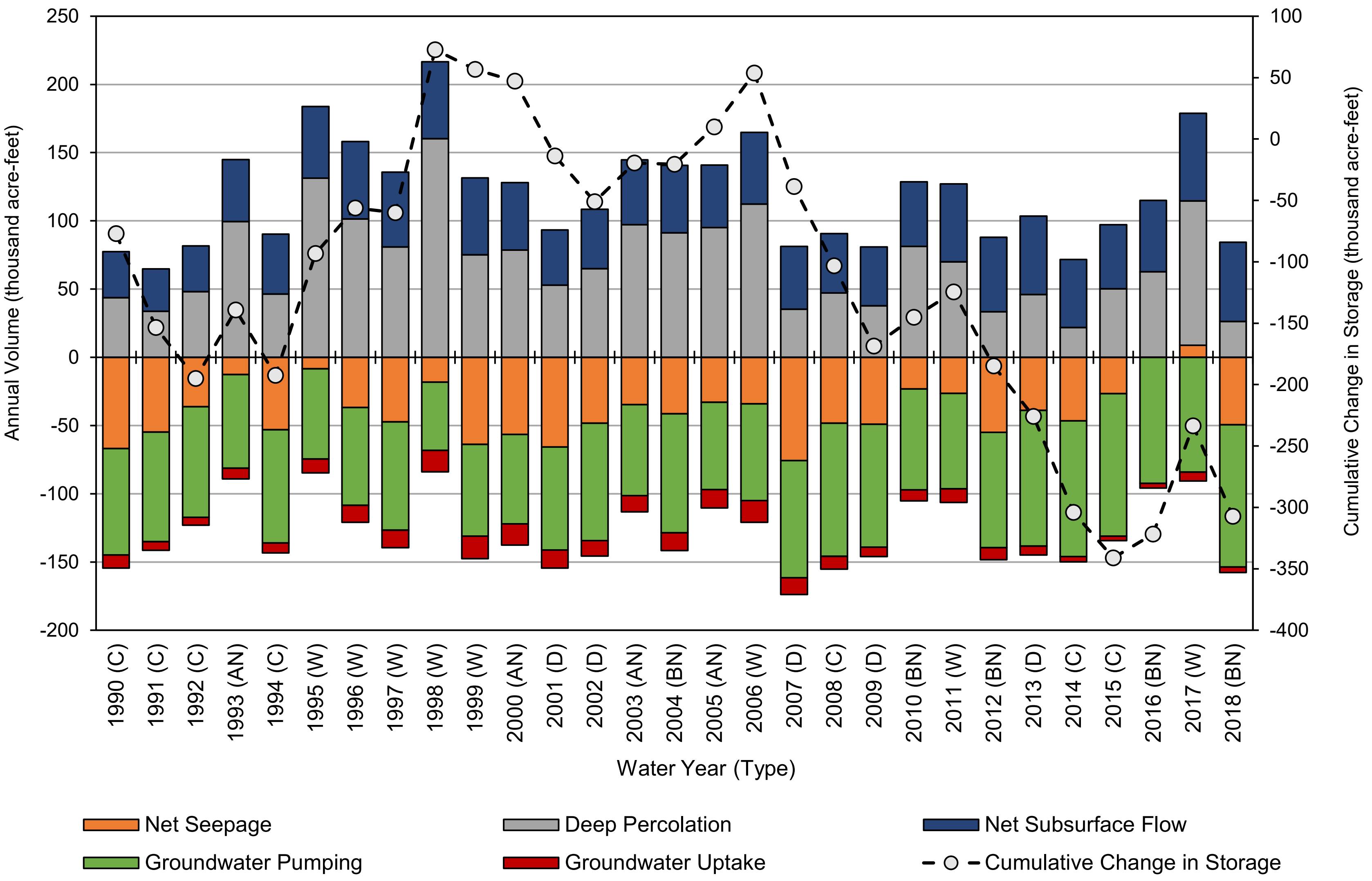

Figure 2-66. Red Bluff Subbasin Historical Water Budget Summary

Table 2-22. Red Bluff Subbasin Historical Water Budget Summary (acre-feet)

WATER YEAR (TYPE)	NET SEEPAGE	DEEP PERCOLATION	NET SUBSURFACE FLOWS	GROUNDWATER PUMPING	GROUNDWATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
1990 (C)	-67,000	44,000	34,000	-78,000	-9,400	-77,000	-77,000
1991 (C)	-55,000	34,000	31,000	-80,000	-6,300	-77,000	-150,000
1992 (C)	-36,000	48,000	33,000	-81,000	-5,800	-41,000	-200,000
1993 (AN)	-13,000	100,000	45,000	-69,000	-7,900	56,000	-140,000
1994 (C)	-53,000	46,000	44,000	-83,000	-7,200	-53,000	-190,000
1995 (W)	-8,300	130,000	53,000	-66,000	-10,000	99,000	-93,000
1996 (W)	-37,000	100,000	57,000	-72,000	-13,000	37,000	-56,000
1997 (W)	-47,000	81,000	55,000	-79,000	-13,000	-3,900	-60,000
1998 (W)	-18,000	160,000	56,000	-50,000	-16,000	130,000	73,000
1999 (W)	-64,000	75,000	57,000	-67,000	-17,000	-16,000	57,000
2000 (AN)	-57,000	79,000	49,000	-66,000	-15,000	-9,500	47,000
2001 (D)	-66,000	53,000	40,000	-76,000	-13,000	-61,000	-14,000
2002 (D)	-48,000	65,000	44,000	-86,000	-11,000	-37,000	-51,000
2003 (AN)	-35,000	97,000	48,000	-67,000	-12,000	31,000	-20,000
2004 (BN)	-41,000	91,000	49,000	-87,000	-13,000	-1,000	-21,000
2005 (AN)	-33,000	95,000	46,000	-64,000	-13,000	30,000	9,900
2006 (W)	-34,000	110,000	52,000	-71,000	-16,000	44,000	54,000
2007 (D)	-76,000	35,000	46,000	-86,000	-12,000	-93,000	-39,000
2008 (C)	-48,000	47,000	44,000	-98,000	-9,400	-65,000	-100,000
2009 (D)	-49,000	38,000	43,000	-90,000	-6,900	-65,000	-170,000
2010 (BN)	-23,000	81,000	47,000	-74,000	-7,900	23,000	-150,000
2011 (W)	-26,000	70,000	57,000	-70,000	-9,900	21,000	-120,000
2012 (BN)	-55,000	33,000	55,000	-85,000	-8,800	-60,000	-180,000
2013 (D)	-39,000	46,000	58,000	-99,000	-6,500	-41,000	-230,000
2014 (C)	-47,000	22,000	50,000	-99,000	-3,800	-78,000	-300,000
2015 (C)	-27,000	50,000	47,000	-100,000	-3,200	-37,000	-340,000
2016 (BN)	82	63,000	52,000	-92,000	-3,400	19,000	-320,000
2017 (W)	8,800	110,000	64,000	-84,000	-6,600	88,000	-230,000
2018 (BN)	-49,000	26,000	58,000	-100,000	-4,200	-74,000	-310,000
Average (1990-2018)	-39,000	70,000	49,000	-80,000	-9,700	-11,000	
1990-2018 W	-28,000	100,000	56,000	-70,000	-13,000	50,000	
AN	-34,000	93,000	47,000	-66,000	-12,000	27,000	
BN	-34,000	59,000	52,000	-88,000	-7,500	-18,000	
D	-56,000	47,000	46,000	-87,000	-10,000	-59,000	
C	-48,000	42,000	40,000	-89,000	-6,400	-61,000	

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.6 Current Water Budget

As described above in **Section 2.3.2**, several recent water budget periods have been considered for use in representing the current water budget. Because the hydrology and land use conditions can vary year to year, estimating the current water budget can be challenging. To evaluate the current water budget, water budget results from the historical model run were summarized for five different recent time periods to evaluate variability and trends. The five different recent water budget periods evaluated include the following:

- Most recent 10 years (2009-2018)
- Most recent 5 year (2014-2018)
- Most recent 3 years (2016-2018)
- Recent single year 2018
- Recent single year 2019

Comparison of these recent water budget periods provides a representation of how water use varies with precipitation and water supply conditions from year to year. Based on these comparisons and consideration of the hydrologic conditions over these recent periods, the recent three-year period from 2016 through 2018 is believed to provide a reasonable representation of the recent water budget conditions. For reporting a current water budget in the GSP, the average water budget for the three-year period between 2016 and 2018 is considered to be representative of the current water budget and representative of current hydrologic and land use conditions. This period incorporates recent land use conditions and spans three years (two below normal years and one wet year) that collectively have precipitation and hydrology similar to the long-term average. Although the 2016 through 2018 period provides a summary of the water budget for recent years that appear to be reasonably representative of recent typical conditions, it is not necessarily representative of any longer-term average conditions. Understanding the recent water budget years is helpful in anticipating longer-term conditions under a scenario where current land uses are maintained in the Subbasin (see **section 2.3.7**). The results from comparisons of the recent water budget periods evaluated are presented below, including the results and discussion of the selected current water budget period of 2016-2018. The projected water budget with a current land use condition, as described in **Section 2.3.6** also is insightful on the current water budget conditions

2.3.6.1 Surface Water System Water Budget Summary

The comparison of the different recent SWS water budget periods provides a representation of how individual SWS water budget components vary from year to year depending on water demands, precipitation, and water supply conditions. The SWS water budget results for these different recent time periods are presented in **Table 2-23**. The single year SWS water budget results highlight the high variability between these two years, which included a below normal year in 2018 and a wet year in 2019. The water budget inflows and outflows from the SWS vary by about 660 taf between these two single years. Most of the variability in the total SWS inflows and outflows is a result of variability in precipitation, surface water inflow and surface water outflow. When comparing the average annual water budget results for recent multi-year periods, the variability is considerably reduced with a maximum difference in both inflows and outflows of about 110 taf per year between the three different recent multi-year periods evaluated.

The selected current water budget period of 2016-2018 (highlighted blue in **Table 2-23**) has total SWS inflows and outflows of about 830 taf per year, with the largest SWS inflows being precipitation (590 taf per year) and the largest SWS outflow being the ET of precipitation (360 taf per year). Current SWS water budget inflows also include 120 taf per year of surface water inflow, 98 taf per year of groundwater extraction and uptake, and 16 taf per year of groundwater discharge to surface water. Other SWS outflows in the current SWS water budget include 320 taf per year surface water outflow, 76 taf per year ET of applied water, 52 taf per year deep percolation of precipitation, 13 taf per year of deep percolation of applied water, and additional smaller outflows for infiltration of surface water, ET of groundwater uptake, and evaporation from surface water.

Table 2-23. Comparison of Recent SWS Water Budget Periods (acre-feet)

FLOW PATH		RECENT WATER BUDGET PERIODS				
		RECENT 10 YEARS	RECENT 5 YEARS	RECENT 3 YEARS	RECENT 1 YEAR	RECENT 1 YEAR
		(2009-2018)	(2014-2018)	(2016-2018)	2018	2019
Inflow	Surface Water Inflow	83,000	88,000	120,000	20,000	200,000
	Precipitation	510,000	520,000	590,000	360,000	880,000
	Groundwater Extraction/Uptake	96,000	100,000	98,000	110,000	88,000
	Groundwater Discharge to Surface Water	33,000	25,000	16,000	51,000	-20
	Total Inflows	***720,000***	***740,000***	***830,000***	***540,000***	***1,200,000***
Outflow	Surface Water Outflow	240,000	260,000	320,000	110,000	580,000
	ET of Applied Water	72,000	79,000	76,000	85,000	71,000
	ET of Groundwater Uptake	6,100	4,200	4,700	4,200	6,300
	ET of Precipitation	340,000	330,000	360,000	320,000	400,000
	Evaporation	900	940	960	850	800
	Deep Percolation of Applied Water	13,000	12,000	13,000	9,700	15,000
	Deep Percolation of Precipitation	41,000	41,000	52,000	17,000	82,000
	Infiltration of Surface Water (Seepage)	2,200	2,000	2,300	2,000	2,800
	Change in Root Zone Storage	1,100	-880	-380	-6,100	16,000
	Total Outflows	***720,000***	***740,000***	***830,000***	***540,000***	***1,200,000***

2.3.6.2 Groundwater System Water Budget Summary

Comparing the different recent water budget periods provides a representation of how the overall GWS water budget components vary from year to year depending on conditions including inflows/outflows between the SWS and subsurface flows. The GWS water budget results for these different recent time periods are presented in **Table 2-24**. As with the results for the current SWS water budget summaries, the single year results for the GWS water budget highlight the high variability between the two individual years of 2018 and 2019, which included a below normal year (2018) and a wet year (2019). Although some of the individual water budget components are relatively stable between the two different recent water budget years, the total change in groundwater storage varied by about 149 taf ranging from a decrease in storage of about -74 taf in 2018 (a below normal year) to an increase in storage of nearly 75 taf in 2019 (a wet year). Differences in net seepage and deep percolation account for most of the difference in change in storage between the two single years. There is considerably less variability in most of the different water budget components when comparing between the three different recent multi-year periods, although the net seepage and deep percolation do show relatively higher differences between the three recent periods. Average annual change in storage is between -20 taf and -16 taf per year for the recent 10-year and 5-year periods, respectively, and indicates an average increase in storage of about 11 taf per year for the recent three-year period. This difference is likely attributable to the drought years consisting of dry and critical years that occurred between 2013 and 2015, which are included in the recent five- and ten-year periods, but not included in the most recent three-year period from 2016-2018.

The selected current water budget period of 2016-2018 (highlighted blue in **Table 2-24**) has total net seepage of about -13 taf per year, indicating net discharge of groundwater to surface waterways. Net subsurface flows total about 58 taf per year of inflow on average over the current water budget period and deep percolation represents an additional 65 taf per year of inflow to the GWS. Groundwater pumping is an outflow from the GWS and averages about -94 taf per year during the current water budget period; groundwater uptake represents an additional GWS outflow of about -4.7 taf per year.

Table 2-24. Comparison of Recent GWS Water Budget Periods (acre-feet)

GWS WATER BUDGET COMPONENT	RECENT WATER BUDGET PERIODS				
	RECENT 10 YEARS	RECENT 5 YEARS	RECENT 3 YEARS	RECENT 1 YEAR	RECENT 1 YEAR
	(2009-2018)	(2014-2018)	(2016-2018)	2018	2019
Net Seepage	-31,000	-23,000	-13,000	-49,000	1,000
Deep Percolation	54,000	53,000	65,000	26,000	96,000
Net Subsurface Flows	53,000	54,000	58,000	58,000	66,000
Groundwater Pumping	-90,000	-97,000	-94,000	-100,000	-82,000
Groundwater Uptake	-6,100	-4,200	-4,700	-4,200	-6,300
Annual Groundwater Storage Change	-20,000	-16,000	11,000	-74,000	75,000

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.7 Projected Water Budgets

To evaluate projected water budgets in the future, projected model runs were developed using Tehama IHM. The projected model runs are intended to evaluate the effects of anticipated future conditions of hydrology, water supply availability, and water demand on the Red Bluff Subbasin water budget and groundwater conditions over a 50-year GSP planning period. The projected model runs also incorporate consideration of potential climate change and water supply availability scenarios and evaluation of the need for and benefit of any projects and management actions to be implemented in the Subbasin to maintain or achieve sustainability. The projected model runs use hydrologic conditions representative of the most recent 50 years of hydrology in the Subbasin, with adjustments applied in scenarios for evaluating the water budget under climate change and/or altered water supply and demand conditions. A number of projected future scenarios were simulated in Tehama IHM to compare possible outcomes, including different projected land uses and potential climate change impacts. Additional information about the development of the projected model scenarios is provided in **Appendix 2-J**.

2.3.7.1 Projected (Current Land Use) Water Budget

This section presents the results of the Projected (Current Land Use) scenario. The Current Land Use scenario assumes constant land use conditions based on 2018 conditions.

2.3.7.1.1 *Projected (Current Land Use) Surface Water System Water Budget Summary*

Annual inflows, outflows, and change in SWS root zone storage during the projected (current land use) water budget period (2022-2072) are summarized in **Figure 2-67** and **Table 2-25.** Inflows in **Figure 2-67** are shown as positive values, while outflows are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the SWS water budget.

Of particular note in the projected (current land use) SWS water budget results are the volume of precipitation that makes up a large part of the Subbasin SWS inflows (average about 600 taf over the projected period). Surface water inflows and groundwater extraction also represent large SWS inflow components averaging about 120 and 100 taf per year, respectively. Groundwater discharge to surface water is a relatively smaller SWS inflow in the Subbasin averaging about 26 taf per year over the projected (current land use) water budget period.

Among the outflows from the Subbasin SWS, ET of precipitation and surface water outflow make up large fractions of the total Subbasin SWS outflows. ET of precipitation averages about 360 taf per year. The surface water outflows total about 330 taf per year on average, a value that corresponds with the large volumes of precipitation and surface water inflow (a total of about 720 taf per year). By comparison, other SWS outflows in the Subbasin are relatively smaller, with values for ET of applied water and deep percolation of precipitation averaging about 80 and 54 taf per year, respectively. The outflows of deep percolation of applied water, ET of groundwater uptake and infiltration (seepage) of surface water are about 13, 6.3, and 4.5 taf per year on average, respectively. Evaporation from surface water averages about 0.9 taf per year over the projected (current land use) water budget period.

Detailed results for the projected (current land use) SWS water budget are presented in **Appendix 2-K**.

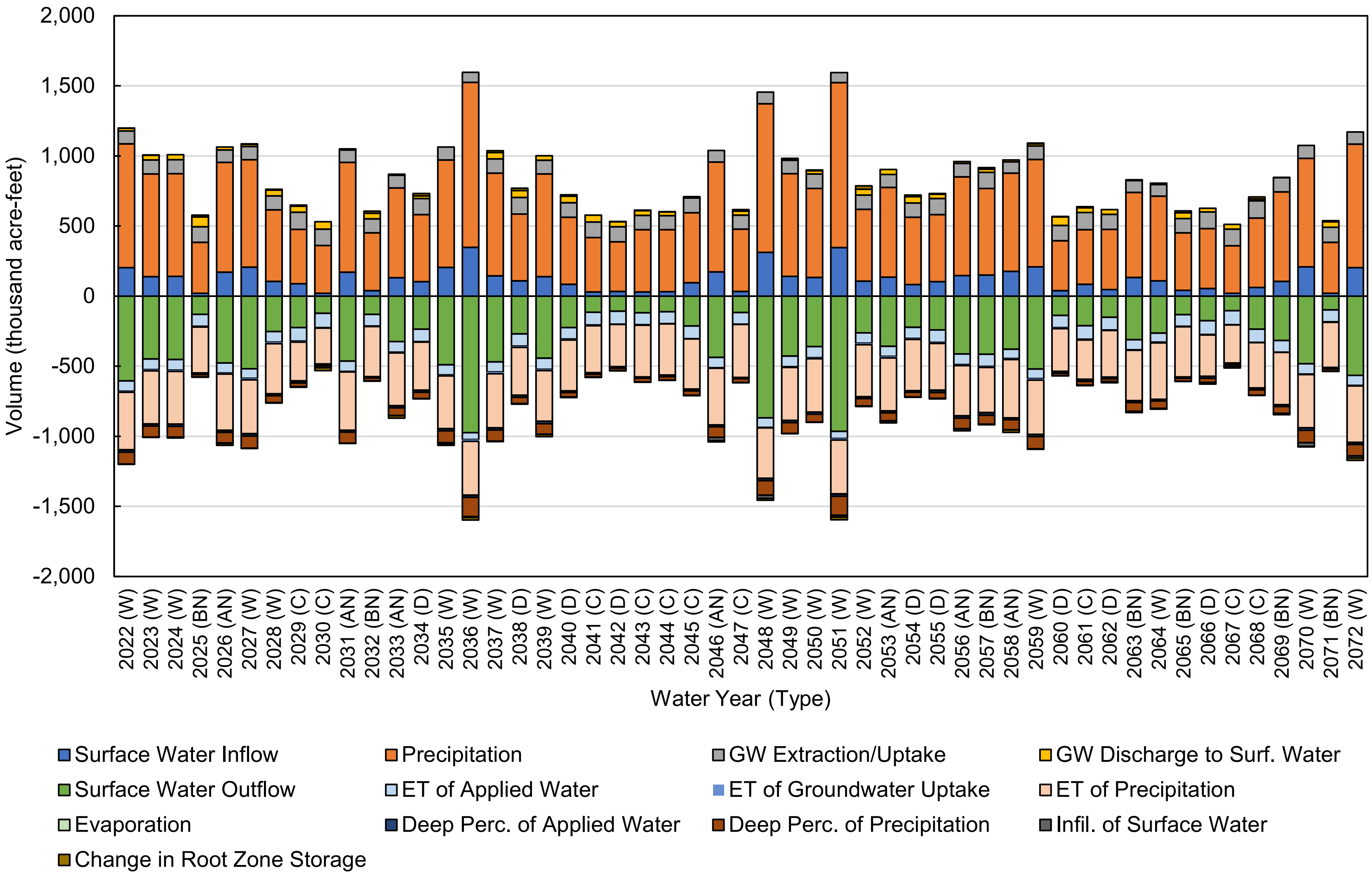

Figure 2-67. Red Bluff Subbasin Surface Water System Projected (Current Land Use) Water Budget, 2022-2072

Table 2-25. Red Bluff Subbasin Surface Water System Projected (Current Land Use) Water Budget, 2022-2072 (acre-feet)

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPITATION	GROUNDWATER EXTRACTION / UPTAKE	GROUNDWATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUNDWATER UPTAKE	ET OF PRECIPITATION	EVAPORATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPITATION	INFIL. OF SURFACE WATER	
2022 (W)	200,000	880,000	93,000	19,000	600,000	73,000	7,300	410,000	760	16,000	84,000	2,700	-2,000
2023 (W)	140,000	730,000	100,000	34,000	450,000	75,000	9,300	380,000	890	15,000	78,000	2,700	-2,100
2024 (W)	140,000	730,000	100,000	36,000	450,000	75,000	10,000	380,000	870	15,000	77,000	2,800	60
2025 (BN)	21,000	360,000	110,000	70,000	130,000	85,000	6,700	330,000	910	10,000	17,000	2,000	-14,000
2026 (AN)	170,000	780,000	89,000	20,000	480,000	72,000	7,600	400,000	900	13,000	77,000	2,900	13,000
2027 (W)	210,000	770,000	94,000	15,000	520,000	68,000	11,000	390,000	720	15,000	87,000	2,900	-4,800
2028 (W)	100,000	510,000	100,000	41,000	250,000	75,000	11,000	360,000	880	13,000	49,000	2,700	-5,500
2029 (C)	88,000	390,000	120,000	44,000	220,000	95,000	7,800	280,000	1,200	13,000	28,000	2,500	-6,200
2030 (C)	21,000	340,000	120,000	52,000	120,000	100,000	3,700	260,000	1,000	10,000	13,000	1,700	21,000
2031 (AN)	170,000	780,000	89,000	2,700	460,000	73,000	4,900	420,000	1,000	13,000	78,000	2,900	-4,700
2032 (BN)	40,000	410,000	100,000	41,000	130,000	83,000	4,200	360,000	810	8,800	20,000	2,300	-14,000
2033 (AN)	130,000	640,000	91,000	7,300	320,000	75,000	4,800	380,000	910	13,000	54,000	2,600	16,000
2034 (D)	100,000	480,000	110,000	20,000	240,000	88,000	5,000	340,000	1,000	14,000	44,000	2,600	-17,000
2035 (W)	210,000	770,000	92,000	0	490,000	73,000	7,200	380,000	850	15,000	84,000	9,500	10,000
2036 (W)	350,000	1,200,000	73,000	0	970,000	50,000	12,000	380,000	460	15,000	140,000	5,600	20,000
2037 (W)	150,000	730,000	100,000	45,000	470,000	71,000	14,000	390,000	780	15,000	79,000	2,900	-14,000
2038 (D)	110,000	480,000	120,000	49,000	270,000	85,000	11,000	340,000	1,100	15,000	45,000	2,700	-16,000
2039 (W)	140,000	730,000	99,000	32,000	440,000	78,000	9,900	360,000	890	15,000	75,000	2,800	15,000
2040 (D)	84,000	480,000	100,000	48,000	220,000	79,000	8,300	360,000	970	11,000	33,000	2,500	-9,500
2041 (C)	30,000	390,000	110,000	49,000	120,000	90,000	4,700	340,000	900	9,900	18,000	2,100	570

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPITATION	GROUNDWATER EXTRACTION / UPTAKE	GROUNDWATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUNDWATER UPTAKE	ET OF PRECIPITATION	EVAPORATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPITATION	INFIL. OF SURFACE WATER	
2042 (D)	33,000	350,000	110,000	37,000	110,000	92,000	3,000	300,000	920	11,000	16,000	1,800	-830
2043 (C)	30,000	440,000	100,000	34,000	120,000	86,000	2,500	370,000	800	10,000	25,000	1,800	-2,800
2044 (C)	31,000	440,000	99,000	27,000	110,000	85,000	1,900	370,000	830	9,800	24,000	1,900	-80
2045 (C)	96,000	500,000	110,000	8,000	210,000	90,000	1,700	360,000	1,100	11,000	30,000	2,100	1,200
2046 (AN)	170,000	780,000	84,000	0	440,000	73,000	2,600	410,000	1,100	13,000	76,000	21,000	10,000
2047 (C)	35,000	440,000	98,000	29,000	120,000	82,000	2,400	380,000	890	9,600	26,000	2,100	-12,000
2048 (W)	310,000	1,100,000	84,000	0	870,000	66,000	4,300	360,000	830	16,000	100,000	23,000	13,000
2049 (W)	140,000	730,000	96,000	11,000	430,000	76,000	6,200	380,000	1,100	14,000	76,000	2,700	-510
2050 (W)	130,000	630,000	100,000	23,000	360,000	80,000	6,800	380,000	1,100	14,000	57,000	2,400	-5,200
2051 (W)	350,000	1,200,000	72,000	0	960,000	51,000	11,000	390,000	480	15,000	140,000	13,000	19,000
2052 (W)	110,000	510,000	100,000	42,000	260,000	73,000	12,000	370,000	860	13,000	54,000	2,800	-25,000
2053 (AN)	140,000	640,000	93,000	35,000	360,000	72,000	10,000	380,000	800	13,000	56,000	2,800	12,000
2054 (D)	83,000	480,000	100,000	46,000	220,000	79,000	7,900	360,000	960	11,000	33,000	2,400	-11,000
2055 (D)	100,000	480,000	120,000	29,000	240,000	90,000	6,200	330,000	1,000	15,000	43,000	2,600	-6,100
2056 (AN)	150,000	710,000	95,000	14,000	410,000	76,000	6,600	360,000	920	15,000	76,000	2,600	13,000
2057 (BN)	150,000	620,000	120,000	22,000	410,000	87,000	7,800	320,000	1,200	18,000	64,000	3,000	-12,000
2058 (AN)	180,000	700,000	82,000	12,000	380,000	65,000	8,700	420,000	670	12,000	72,000	2,600	15,000
2059 (W)	210,000	770,000	96,000	14,000	520,000	68,000	12,000	390,000	720	15,000	87,000	3,000	-6,100
2060 (D)	40,000	350,000	110,000	60,000	140,000	88,000	7,800	310,000	1,000	11,000	17,000	2,300	-4,200
2061 (C)	85,000	390,000	120,000	32,000	210,000	97,000	5,100	280,000	1,100	13,000	28,000	2,400	-7,700
2062 (D)	47,000	430,000	110,000	34,000	150,000	91,000	3,300	330,000	980	10,000	21,000	2,100	4,800

WATER YEAR (TYPE)		INFLOWS			OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
2063 (BN)	130,000	610,000	84,000	6,100	310,000	70,000	4,000	360,000	910	12,000	61,000	2,400	6,900
2064 (W)	110,000	600,000	83,000	11,000	260,000	65,000	5,500	400,000	810	11,000	52,000	2,500	4,200
2065 (BN)	40,000	410,000	100,000	42,000	130,000	82,000	4,700	360,000	800	8,800	20,000	2,300	-14,000
2066 (D)	54,000	430,000	120,000	26,000	170,000	99,000	3,400	290,000	1,000	13,000	30,000	2,500	8,400
2067 (C)	20,000	340,000	120,000	35,000	100,000	100,000	2,000	270,000	940	10,000	13,000	1,600	10,000
2068 (C)	62,000	500,000	120,000	14,000	240,000	95,000	1,500	320,000	940	14,000	36,000	1,700	-14,000
2069 (BN)	100,000	640,000	100,000	0	320,000	84,000	1,600	370,000	1,200	13,000	49,000	9,100	-60
2070 (W)	210,000	770,000	93,000	0	480,000	74,000	3,400	380,000	1,100	16,000	89,000	27,000	3,300
2071 (BN)	20,000	360,000	110,000	40,000	97,000	86,000	2,500	320,000	890	9,800	16,000	2,000	-7,000
2072 (W)	200,000	880,000	85,000	0	560,000	72,000	3,900	400,000	900	14,000	81,000	15,000	16,000
Average (2022-2072)	120,000	600,000	100,000	26,000	330,000	80,000	6,300	360,000	910	13,000	54,000	4,500	-50
2022-2072 W	190,000	790,000	93,000	18,000	520,000	70,000	8,700	380,000	830	15,000	82,000	7,000	2,000
AN	160,000	720,000	89,000	13,000	410,000	72,000	6,500	390,000	900	13,000	70,000	5,300	11,000
BN	73,000	490,000	100,000	32,000	220,000	82,000	4,500	350,000	950	11,000	35,000	3,300	-7,700
D	73,000	440,000	110,000	39,000	200,000	88,000	6,200	330,000	1,000	12,000	31,000	2,400	-5,700
C	50,000	420,000	110,000	32,000	160,000	92,000	3,300	320,000	970	11,000	24,000	2,000	-910

2.3.7.2 Projected (Current Land Use) Groundwater System Water Budget Summary

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Figure 2-68** and **Table 2-26**. Among the outflows from the Subbasin SWS, groundwater pumping makes up the largest fraction of the total SWS outflows (on average -94 taf per year). Highly negative net seepage values (on average -21 taf per year) represent net groundwater discharging to surface waterways and leaving the GWS. Deep percolation is the largest net inflow component averaging about 67 taf per year. Positive net subsurface flows (on average 53 taf per year) represent the combined subsurface inflows from adjacent subbasins and upland areas.

Groundwater (root water) uptake directly from shallow groundwater (on average -6.3 taf per year) represents a smaller outflow from the GWS. Overall, the water budget results for the 59-year projected (current land use) period indicate a cumulative change in groundwater storage of about -94 taf, which equals an average annual change in groundwater storage of only about -1.8 taf per year. This change in storage estimates equate to total decreases in storage in the Subbasin of about 0.34 acre-feet per acre on average over the 59 years and an annual decrease of less than 0.01 acre-feet per acre across the entire Subbasin (approximately 272,000 acres). **Figure 2-68** provides a conceptual illustration of the projected (current land use) water budget. **Figure 2-69** highlights the cumulative change in groundwater storage that would occur during anticipated multi-year wet and dry periods within the projected period.

Detailed results for the projected (current land use) period GWS water budget are presented in **Appendix 2-K**.

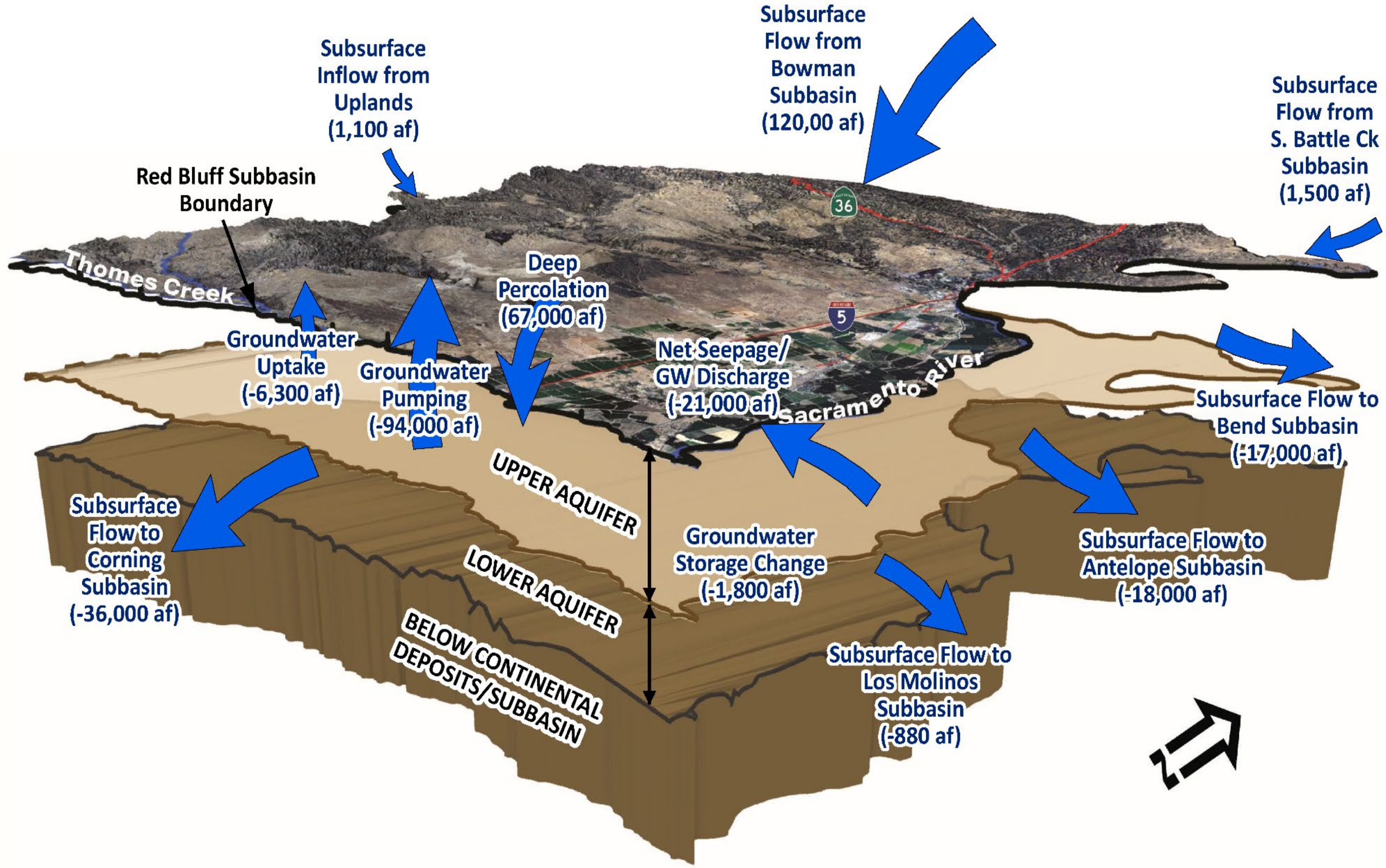

Figure 2-68. Diagram of the Red Bluff Subbasin Projected (Current Land Use) Average Annual Water Budget, 2022-2072

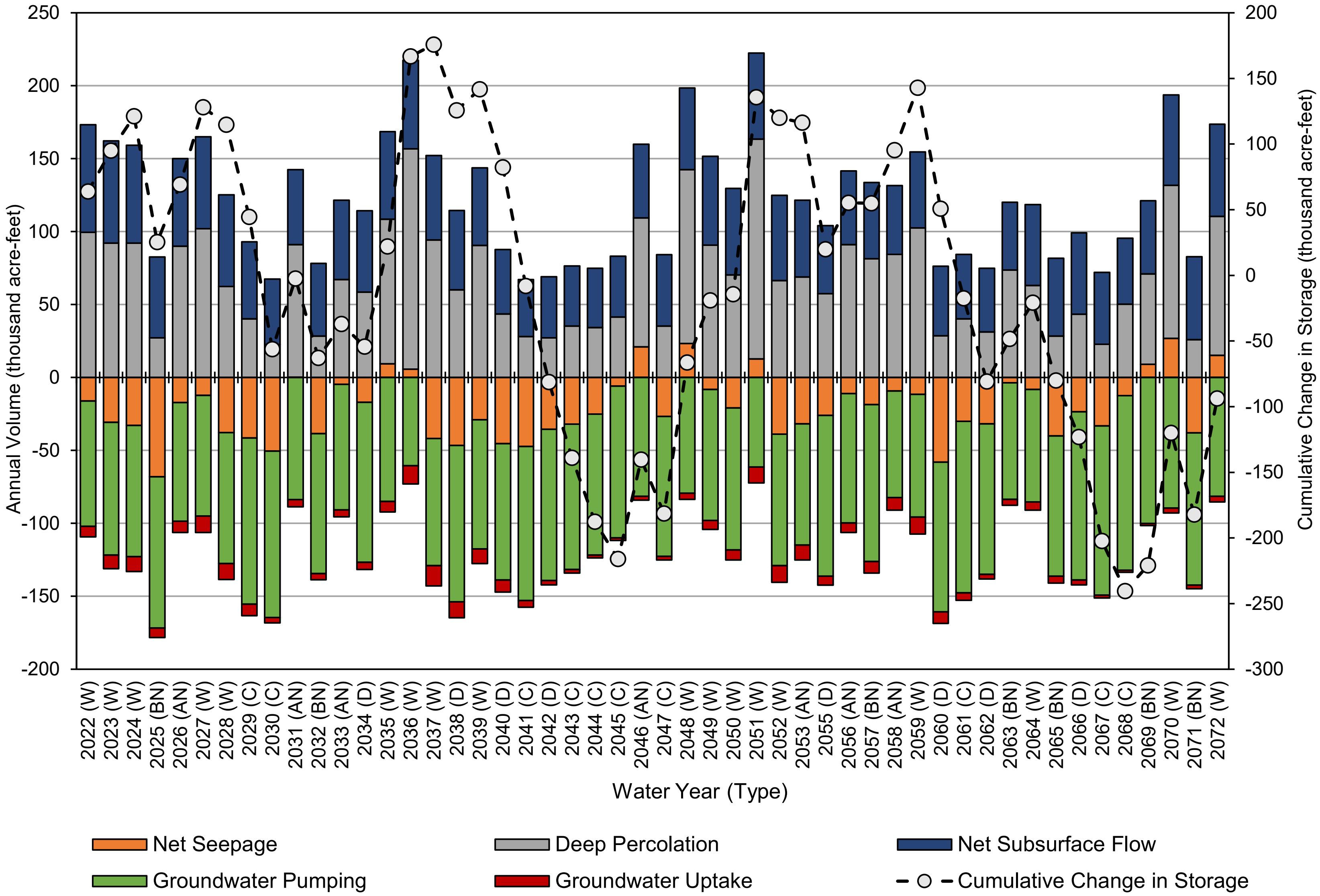

Figure 2-69 Red Bluff Subbasin Projected (Current Land Use) Water Budget Summary

Table 2-26. Red Bluff Subbasin Projected (Current Land Use) Water Budget Summary (acre-feet)

WATER YEAR (TYPE)	NET SEEPAGE	DEEP PER-COLATION	NET SUBSURFACE FLOWS	GROUND-WATER PUMPING	GROUND-WATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
2022 (W)	-16,000	100,000	74,000	-86,000	-7,300	64,000	64,000
2023 (W)	-31,000	92,000	70,000	-91,000	-9,300	31,000	95,000
2024 (W)	-33,000	92,000	67,000	-90,000	-10,000	26,000	120,000
2025 (BN)	-68,000	27,000	55,000	-100,000	-6,700	-96,000	25,000
2026 (AN)	-17,000	90,000	60,000	-81,000	-7,600	44,000	69,000
2027 (W)	-12,000	100,000	63,000	-83,000	-11,000	59,000	130,000
2028 (W)	-38,000	62,000	63,000	-90,000	-11,000	-13,000	110,000
2029 (C)	-42,000	40,000	53,000	-110,000	-7,800	-70,000	45,000
2030 (C)	-50,000	23,000	45,000	-110,000	-3,700	-100,000	-56,000
2031 (AN)	170	91,000	51,000	-84,000	-4,900	54,000	-2,400
2032 (BN)	-39,000	28,000	50,000	-96,000	-4,200	-61,000	-63,000
2033 (AN)	-4,700	67,000	54,000	-86,000	-4,800	26,000	-37,000
2034 (D)	-17,000	59,000	56,000	-110,000	-5,000	-17,000	-54,000
2035 (W)	9,500	99,000	60,000	-85,000	-7,200	76,000	22,000
2036 (W)	5,600	150,000	61,000	-60,000	-12,000	140,000	170,000
2037 (W)	-42,000	94,000	58,000	-87,000	-14,000	9,200	180,000
2038 (D)	-47,000	60,000	55,000	-110,000	-11,000	-50,000	130,000
2039 (W)	-29,000	91,000	53,000	-89,000	-9,900	16,000	140,000
2040 (D)	-45,000	44,000	44,000	-94,000	-8,300	-59,000	82,000
2041 (C)	-47,000	28,000	39,000	-110,000	-4,700	-90,000	-8,100
2042 (D)	-36,000	27,000	42,000	-100,000	-3,000	-73,000	-81,000
2043 (C)	-32,000	35,000	41,000	-100,000	-2,500	-58,000	-140,000
2044 (C)	-25,000	34,000	41,000	-97,000	-1,900	-49,000	-190,000
2045 (C)	-5,900	41,000	42,000	-100,000	-1,700	-28,000	-220,000
2046 (AN)	21,000	88,000	50,000	-81,000	-2,600	76,000	-140,000
2047 (C)	-27,000	35,000	49,000	-96,000	-2,400	-41,000	-180,000
2048 (W)	23,000	120,000	56,000	-79,000	-4,300	110,000	-66,000
2049 (W)	-8,200	91,000	61,000	-90,000	-6,200	47,000	-19,000
2050 (W)	-21,000	70,000	59,000	-97,000	-6,800	4,600	-14,000
2051 (W)	13,000	150,000	59,000	-61,000	-11,000	150,000	140,000
2052 (W)	-39,000	66,000	58,000	-90,000	-12,000	-16,000	120,000
2053 (AN)	-32,000	69,000	53,000	-83,000	-10,000	-3,600	120,000
2054 (D)	-44,000	44,000	43,000	-94,000	-7,900	-58,000	58,000
2055 (D)	-26,000	58,000	47,000	-110,000	-6,200	-38,000	20,000
2056 (AN)	-11,000	91,000	51,000	-89,000	-6,600	35,000	55,000
2057 (BN)	-19,000	81,000	52,000	-110,000	-7,800	-380	55,000
2058 (AN)	-9,300	84,000	47,000	-73,000	-8,700	41,000	95,000
2059 (W)	-12,000	100,000	52,000	-84,000	-12,000	47,000	140,000

WATER YEAR (TYPE)	NET SEEPAGE	DEEP PER-COLATION	NET SUBSURFACE FLOWS	GROUND-WATER PUMPING	GROUND-WATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
2060 (D)	-58,000	29,000	48,000	-100,000	-7,800	-92,000	51,000
2061 (C)	-30,000	40,000	44,000	-120,000	-5,100	-68,000	-18,000
2062 (D)	-32,000	31,000	44,000	-100,000	-3,300	-63,000	-81,000
2063 (BN)	-3,700	74,000	47,000	-80,000	-4,000	32,000	-48,000
2064 (W)	-8,100	63,000	55,000	-77,000	-5,500	28,000	-21,000
2065 (BN)	-40,000	28,000	53,000	-96,000	-4,700	-59,000	-80,000
2066 (D)	-24,000	43,000	56,000	-120,000	-3,400	-43,000	-120,000
2067 (C)	-33,000	23,000	49,000	-120,000	-1,900	-79,000	-200,000
2068 (C)	-12,000	50,000	45,000	-120,000	-1,500	-38,000	-240,000
2069 (BN)	9,100	62,000	50,000	-100,000	-1,600	20,000	-220,000
2070 (W)	27,000	100,000	62,000	-89,000	-3,400	100,000	-120,000
2071 (BN)	-38,000	26,000	57,000	-100,000	-2,400	-62,000	-180,000
2072 (W)	15,000	95,000	63,000	-81,000	-3,900	88,000	-94,000
Average (2022-2072)	-21,000	67,000	53,000	-94,000	-6,300	-1,800	
2022-2072 W	-11,000	97,000	61,000	-84,000	-8,700	54,000	
AN	-7,500	83,000	52,000	-83,000	-6,500	39,000	
BN	-28,000	47,000	52,000	-98,000	-4,500	-32,000	
D	-36,000	44,000	48,000	-100,000	-6,200	-55,000	
C	-30,000	35,000	45,000	-110,000	-3,300	-62,000	

2.3.8 Projected (Future Land Use) Water Budget Summary

This section presents the results of the Projected (Future Land Use) scenario. The Future Land Use scenario assumes a static (held constant over the entire projected period) land use condition reflecting a potential future development or land use condition envisioned for the Subbasin at the end of the 50-year GSP planning horizon. The future land use condition was developed through discussion with local stakeholders and consultation with the Tehama County Planning Department. The future land use condition includes an increase in urban area reflective of the recent rate of urban increase experienced for the County, especially in more densely urbanized areas around the City of Red Bluff. Additionally, the future land use condition envisioned by the Subbasin includes increased agricultural development in previously undeveloped areas of the Subbasin with soil characteristics suitable for agricultural production.

Land uses in the projected (future land use) condition include approximately 58,000 acres of agricultural land, 7,000 acres of urban area, and about 207,000 acres of native vegetation. The future land use condition evaluated at the end of the 50-year GSP planning horizon represents increases in agricultural acreage of about 13,000 acres and in urban area of about 500 acres over the current (2018) land use condition. The additional agricultural acres in the future land use condition are represented as almond orchards for the purpose of the water budget analyses. The projected (future land use) condition includes an overall decrease in native vegetation area over the 50-year planning horizon by about 14,000 acres from the current land use condition.

Land use areas are used to distinguish the water use sector in which water is consumed, as required by the GSP Regulations. **Figure 2-70** and **Table 2-27** summarize the annual land use areas over the projected (future land use) period (2022-2072) in the Red Bluff Subbasin by water use sector, as defined by the GSP Regulations (23 CCR § 351(al)). In the Red Bluff Subbasin, water use sectors include agricultural, urban, and native vegetation land uses. The urban water use sector covers all urban, residential, industrial, and semi-agricultural[7] land uses.

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[7] As defined in the DWR crop mapping metadata, semi-agricultural land use subclasses include farmsteads, livestock feed lot operations, dairies, poultry farms, and miscellaneous semi-agricultural land use incidental to agriculture (small roads, ditches, non-planted areas of cropped fields (DWR, 2016b).

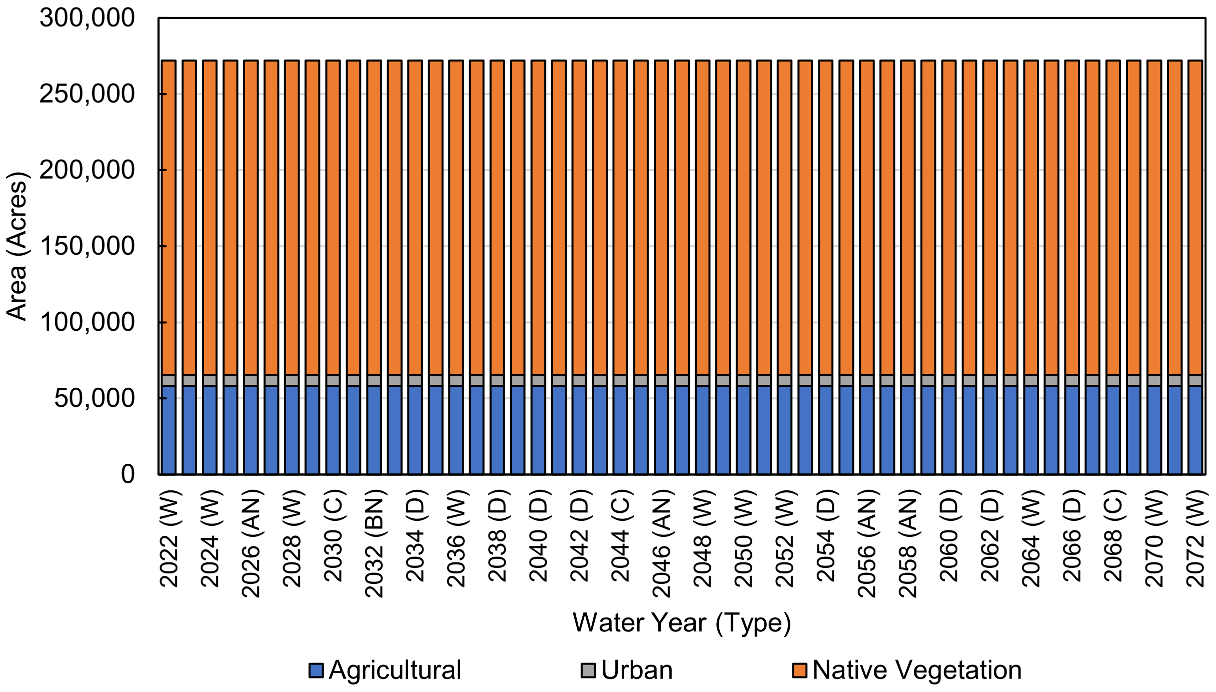

Figure 2-70. Red Bluff Subbasin Future Land Use Areas, by Water Use Sector

Table 2-27. Red Bluff Subbasin Future Land Use Areas, by Water Use Sector (acres)

PROJECTED PERIOD (FUTURE LAND USE)	AGRICULTURAL	URBAN[1]	NATIVE VEGETATION	TOTAL
2022 -2072	58,360	6,970	206,610	271,940

[1] Area includes land classified as urban, residential, industrial, and semi-agricultural.

Projected future agricultural land uses are further detailed in **Figure 2-71** and **Table 2-28**. In the future, a majority of the agricultural area in the Red Bluff Subbasin is projected to consist of almonds/pistachio, deciduous crops, grain, and pasture. Because the projected (future land use) model scenario evaluates the water budget under a land use condition projected to exist in 2072 over a 50-year projected hydrologic period, all land use areas within the Red Bluff Subbasin remain stable during the entire projected period.

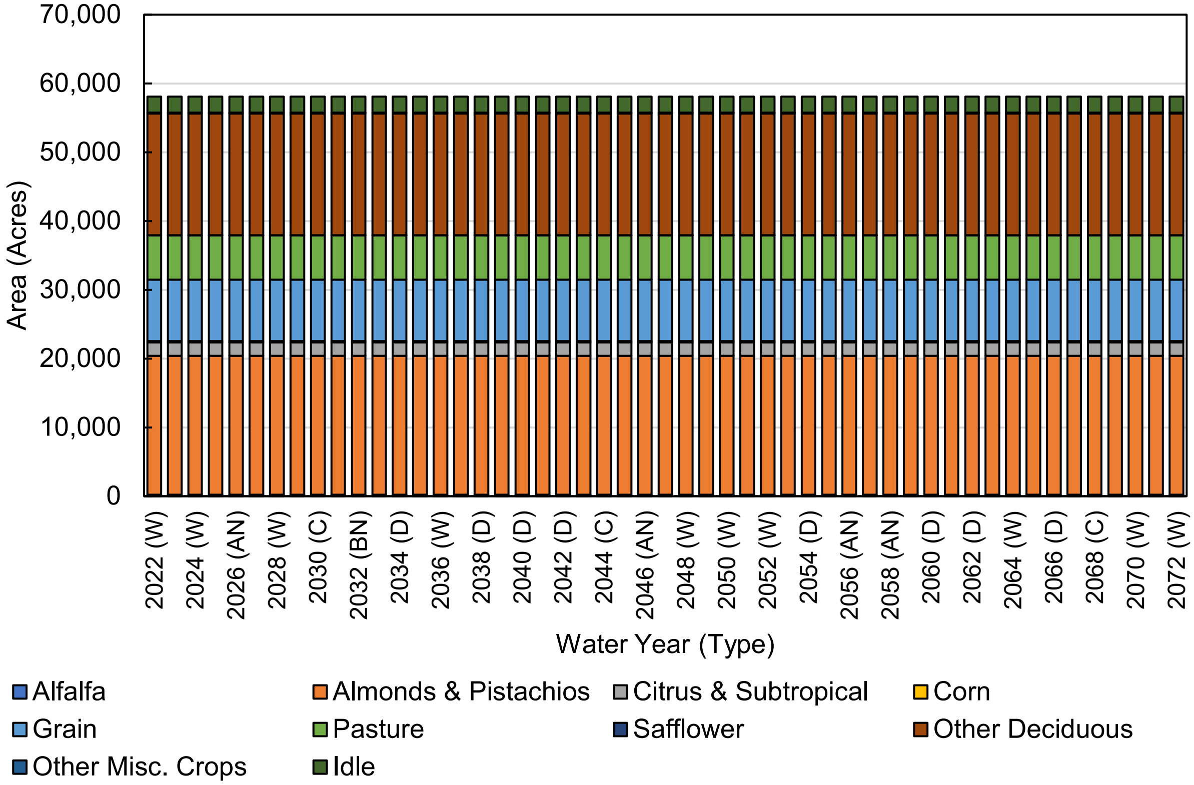

Figure 2-71. Red Bluff Subbasin Projected Agricultural Land Use Areas

Table 2-28. Red Bluff Subbasin Projected Agricultural Land Use Areas (acres)

PROJECTED PERIOD (FUTURE LAND USE)	ALFALFA	ALMONDS & PISTACHIOS	CITRUS & SUB TROPICAL	CORN	GRAIN	PASTURE	PONDED (RICE, REFUGE)	SAFFLOWER	OTHER DECIDUOUS	OTHER MISC. CROPS	IDLE	TOTAL
2022-2072	230	20,160	1,990	170	8,930	6,440	260	10	17,690	130	2,350	58,360

2.3.8.1 Projected (Future Land Use) Surface Water System Water Budget Summary

Annual inflows, outflows, and change in SWS root zone storage during the projected (future land use) water budget period (2022-2072) are summarized in **Figure 2-72** and **Table 2-29**. Inflows in **Figure 2-72** are shown as positive values, while outflows are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the SWS water budget.

Of particular note in the projected (future land use) SWS water budget results are the volume of precipitation that makes up a large part of the Subbasin SWS inflows (average about 600 taf over the projected period). Groundwater extraction and surface water inflows also represent large SWS inflow components averaging about 140 and 120 taf per year, respectively. Groundwater discharge to surface water is a relatively smaller SWS inflow in the Subbasin averaging about 16 taf per year over the projected (future land use) water budget period.

Among the outflows from the Subbasin SWS, ET of precipitation and surface water outflow make up large fractions of the total Subbasin SWS outflows. ET of precipitation averages about 360 taf per year. The surface water outflows total about 330 taf per year on average, a value that corresponds with the large volumes of precipitation and surface water inflow (a total of about 720 taf per year). By comparison, other SWS outflows in the Subbasin are relatively smaller, with values for ET of applied water and deep percolation of precipitation averaging about 110 and 51 taf per year, respectively. The outflows of deep percolation of applied water, ET of groundwater uptake and infiltration (seepage) of surface water are about 17, 4.8, and 7.1 taf per year on average, respectively. Evaporation from surface water averages about 0.97 taf per year over the projected (current land use) water budget period.

Detailed results for the projected (current land use) SWS water budget are presented in **Appendix 2-K**.

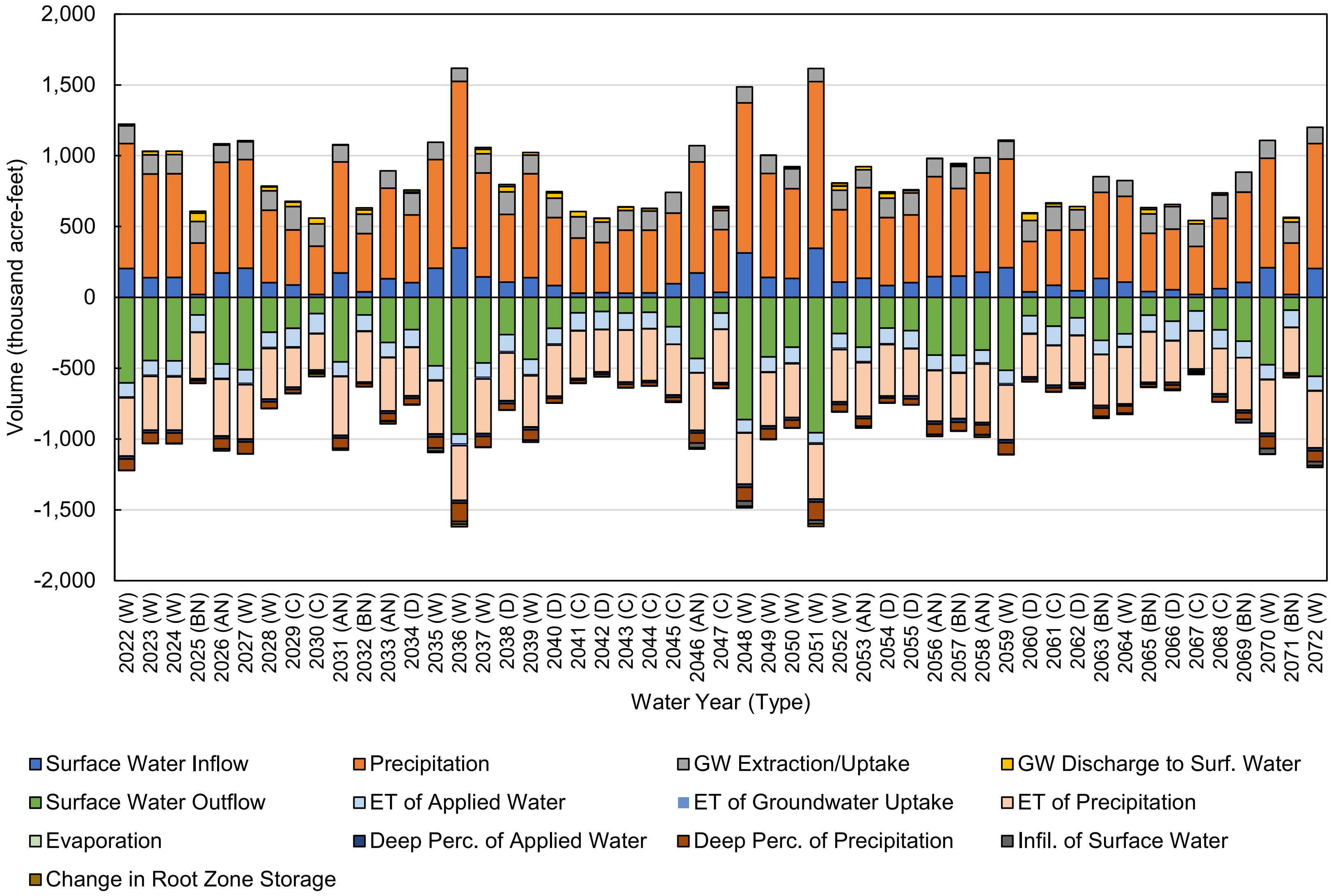

Figure 2-72. Red Bluff Subbasin Surface Water System Projected (Future Land Use) Water Budget, 2022-2072

Table 2-29. Red Bluff Subbasin Surface Water System Projected (Future Land Use) Water Budget, 2022-2072 (acre-feet)

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPITATION	GROUNDWATER EXTRACTION/ UPTAKE	GROUNDWATER DISCHARGE TO SURFACE WATER	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUNDWATER UPTAKE	ET OF PRECIPITATION	EVAPORATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPITATION	INFIL. OF SURFACE WATER	
2022 (W)	200,000	880,000	130,000	9,800	600,000	100,000	5,900	410,000	800	21,000	79,000	2,700	-2,300
2023 (W)	140,000	730,000	140,000	24,000	450,000	100,000	7,600	380,000	950	19,000	73,000	2,700	-1,100
2024 (W)	140,000	730,000	130,000	25,000	450,000	110,000	8,200	380,000	940	19,000	73,000	2,800	20
2025 (BN)	21,000	360,000	150,000	60,000	120,000	120,000	4,900	330,000	880	13,000	17,000	2,000	-12,000
2026 (AN)	170,000	780,000	120,000	8,500	470,000	100,000	5,800	400,000	980	17,000	72,000	2,900	13,000
2027 (W)	210,000	770,000	130,000	2,900	510,000	95,000	8,900	390,000	770	19,000	82,000	2,900	-4,500
2028 (W)	100,000	510,000	140,000	29,000	250,000	110,000	8,500	360,000	950	17,000	47,000	2,700	-5,200
2029 (C)	88,000	390,000	160,000	32,000	220,000	130,000	5,800	280,000	1,200	16,000	26,000	2,500	-5,700
2030 (C)	21,000	340,000	160,000	41,000	110,000	140,000	2,900	260,000	1,100	13,000	12,000	1,700	18,000
2031 (AN)	170,000	780,000	120,000	0	460,000	100,000	3,500	420,000	1,100	16,000	74,000	13,000	-3,200
2032 (BN)	40,000	410,000	140,000	30,000	120,000	110,000	3,100	360,000	890	12,000	19,000	2,300	-13,000
2033 (AN)	130,000	640,000	120,000	0	320,000	100,000	3,500	380,000	940	17,000	51,000	7,600	15,000
2034 (D)	100,000	480,000	150,000	7,800	230,000	120,000	3,700	340,000	1,000	18,000	43,000	2,600	-16,000
2035 (W)	210,000	770,000	120,000	0	480,000	100,000	5,400	380,000	910	20,000	79,000	23,000	9,300
2036 (W)	350,000	1,200,000	94,000	0	970,000	71,000	10,000	390,000	490	19,000	130,000	19,000	18,000
2037 (W)	150,000	730,000	130,000	33,000	460,000	100,000	11,000	390,000	830	19,000	75,000	2,900	-13,000
2038 (D)	110,000	480,000	160,000	37,000	260,000	120,000	8,600	340,000	1,100	19,000	43,000	2,700	-14,000
2039 (W)	140,000	730,000	130,000	19,000	440,000	110,000	7,600	360,000	970	20,000	70,000	2,800	14,000
2040 (D)	84,000	480,000	140,000	36,000	220,000	110,000	6,100	360,000	1,000	14,000	31,000	2,500	-8,900
2041 (C)	30,000	390,000	150,000	38,000	110,000	120,000	3,400	330,000	1,000	13,000	18,000	2,100	1,500

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECI-PITATION	GROUND-WATER EXTRACTION/ UPTAKE	GROUND-WATER DISCHARGE TO SURFACE WATER	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIP-ITATION	EVAPO-RATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
2042 (D)	33,000	350,000	140,000	26,000	100,000	130,000	2,300	300,000	1,000	15,000	16,000	1,800	-2,500
2043 (C)	31,000	440,000	140,000	23,000	110,000	120,000	1,800	370,000	860	14,000	24,000	1,800	-1,100
2044 (C)	31,000	440,000	130,000	16,000	100,000	120,000	1,400	360,000	870	13,000	24,000	1,900	-40
2045 (C)	96,000	500,000	150,000	0	210,000	120,000	1,200	360,000	1,100	15,000	29,000	5,300	1,300
2046 (AN)	170,000	780,000	120,000	0	430,000	100,000	1,900	410,000	1,200	17,000	71,000	34,000	9,700
2047 (C)	35,000	440,000	130,000	18,000	110,000	110,000	1,800	380,000	960	13,000	25,000	2,100	-11,000
2048 (W)	310,000	1,100,000	110,000	0	860,000	92,000	3,100	360,000	900	21,000	97,000	36,000	12,000
2049 (W)	140,000	730,000	130,000	0	420,000	110,000	4,500	380,000	1,100	19,000	72,000	4,400	-1,300
2050 (W)	130,000	630,000	140,000	11,000	350,000	110,000	5,000	380,000	1,100	18,000	54,000	2,400	-4,400
2051 (W)	350,000	1,200,000	94,000	0	960,000	71,000	8,700	390,000	510	19,000	130,000	26,000	18,000
2052 (W)	110,000	510,000	140,000	30,000	260,000	100,000	9,100	370,000	930	17,000	51,000	2,800	-23,000
2053 (AN)	140,000	640,000	120,000	23,000	350,000	100,000	7,800	380,000	870	17,000	53,000	2,800	11,000
2054 (D)	83,000	480,000	140,000	35,000	220,000	110,000	5,800	360,000	990	14,000	32,000	2,400	-11,000
2055 (D)	100,000	480,000	160,000	17,000	230,000	120,000	4,500	330,000	1,000	19,000	41,000	2,600	-4,800
2056 (AN)	150,000	710,000	130,000	810	410,000	110,000	4,800	360,000	990	20,000	72,000	2,600	12,000
2057 (BN)	150,000	620,000	160,000	8,800	410,000	120,000	5,800	320,000	1,200	23,000	61,000	3,000	-11,000
2058 (AN)	180,000	700,000	110,000	0	370,000	91,000	6,400	410,000	730	16,000	68,000	3,700	14,000
2059 (W)	210,000	770,000	130,000	1,700	510,000	96,000	9,100	390,000	770	20,000	82,000	3,000	-5,500
2060 (D)	40,000	350,000	150,000	49,000	130,000	120,000	5,500	300,000	1,100	15,000	17,000	2,300	-5,400
2061 (C)	86,000	390,000	170,000	21,000	200,000	130,000	3,700	280,000	1,200	17,000	26,000	2,400	-5,500
2062 (D)	47,000	430,000	140,000	22,000	140,000	120,000	2,500	330,000	1,100	14,000	20,000	2,100	4,400
2063 (BN)	130,000	610,000	110,000	0	300,000	97,000	3,000	360,000	940	16,000	58,000	8,600	6,100

WATER YEAR (TYPE)		INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
		SURFACE WATER INFLOW	PRECIPITATION	GROUNDWATER EXTRACTION/ UPTAKE	GROUNDWATER DISCHARGE TO SURFACE WATER	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUNDWATER UPTAKE	ET OF PRECIPITATION	EVAPORATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPITATION	INFIL. OF SURFACE WATER	
2064 (W)		110,000	600,000	110,000	0	260,000	91,000	4,000	400,000	890	14,000	50,000	3,600	4,500
2065 (BN)		41,000	410,000	140,000	32,000	130,000	110,000	3,500	360,000	850	12,000	19,000	2,300	-13,000
2066 (D)		54,000	430,000	160,000	15,000	170,000	140,000	2,600	290,000	1,100	18,000	29,000	2,500	6,600
2067 (C)		20,000	340,000	160,000	24,000	96,000	140,000	1,400	270,000	1,000	13,000	13,000	1,600	10,000
2068 (C)		62,000	500,000	160,000	2,800	230,000	130,000	1,100	320,000	1,000	19,000	35,000	1,700	-13,000
2069 (BN)		110,000	640,000	140,000	0	310,000	120,000	1,100	370,000	1,200	17,000	47,000	21,000	820
2070 (W)		210,000	770,000	130,000	0	480,000	100,000	2,500	380,000	1,200	22,000	84,000	40,000	2,100
2071 (BN)		21,000	360,000	150,000	29,000	90,000	120,000	1,800	320,000	950	13,000	16,000	2,000	-5,700
2072 (W)		200,000	880,000	110,000	0	560,000	100,000	2,800	400,000	970	19,000	76,000	28,000	13,000
Average (2022-2072)		120,000	600,000	140,000	16,000	330,000	110,000	4,800	360,000	970	17,000	51,000	7,100	-50
2022-2072	W	190,000	790,000	120,000	10,000	510,000	98,000	6,800	380,000	880	19,000	78,000	12,000	1,700
	AN	160,000	720,000	120,000	4,600	400,000	100,000	4,800	390,000	960	17,000	66,000	9,400	10,000
	BN	73,000	490,000	140,000	23,000	210,000	110,000	3,300	340,000	990	15,000	34,000	5,900	-7,000
	D	73,000	440,000	150,000	27,000	190,000	120,000	4,600	330,000	1,100	16,000	30,000	2,400	-5,700
	C	50,000	420,000	150,000	22,000	150,000	130,000	2,400	320,000	1,000	15,000	23,000	2,300	-500

2.3.8.2 Projected (Future Land Use) Groundwater System Water Budget Summary

Summarized results for major components of the projected (future land use) water budget as they relate to the GWS are presented in **Figure 2-73** and **Table 2-30**. Among the outflows from the Subbasin SWS, groundwater pumping makes up the largest fraction of the total SWS outflows (on average -130 taf per year). Negative net seepage values (on average -9.3 taf per year) represent net groundwater discharging to surface waterways and leaving the GWS. Positive net subsurface flows and deep percolation are the largest net inflow components averaging about 74 and 68 taf per year, respectively. Groundwater (root water) uptake directly from shallow groundwater (on average -4.8 taf per year) represents a smaller outflow from the GWS. Overall, the water budget results for the 51-year projected (future land use) period indicate a cumulative change in groundwater storage of about -150 taf, which equals an average annual change in groundwater storage of only about -2.9 taf per year. This change in storage estimates equate to total decreases in storage in the Subbasin of about 0.54 acre-feet per acre on average over the 51 years and an annual decrease of about 0.01 acre-feet per acre across the entire Subbasin (approximately 272,000 acres). **Figure 2-73** provides a conceptual illustration of the projected (future land use) water budget. **Figure 2-74** highlights the cumulative change in groundwater storage that would occur during anticipated multi-year wet and dry periods within the projected period.

Detailed results for the projected (future land use) GWS water budget are presented in **Appendix 2-K**.

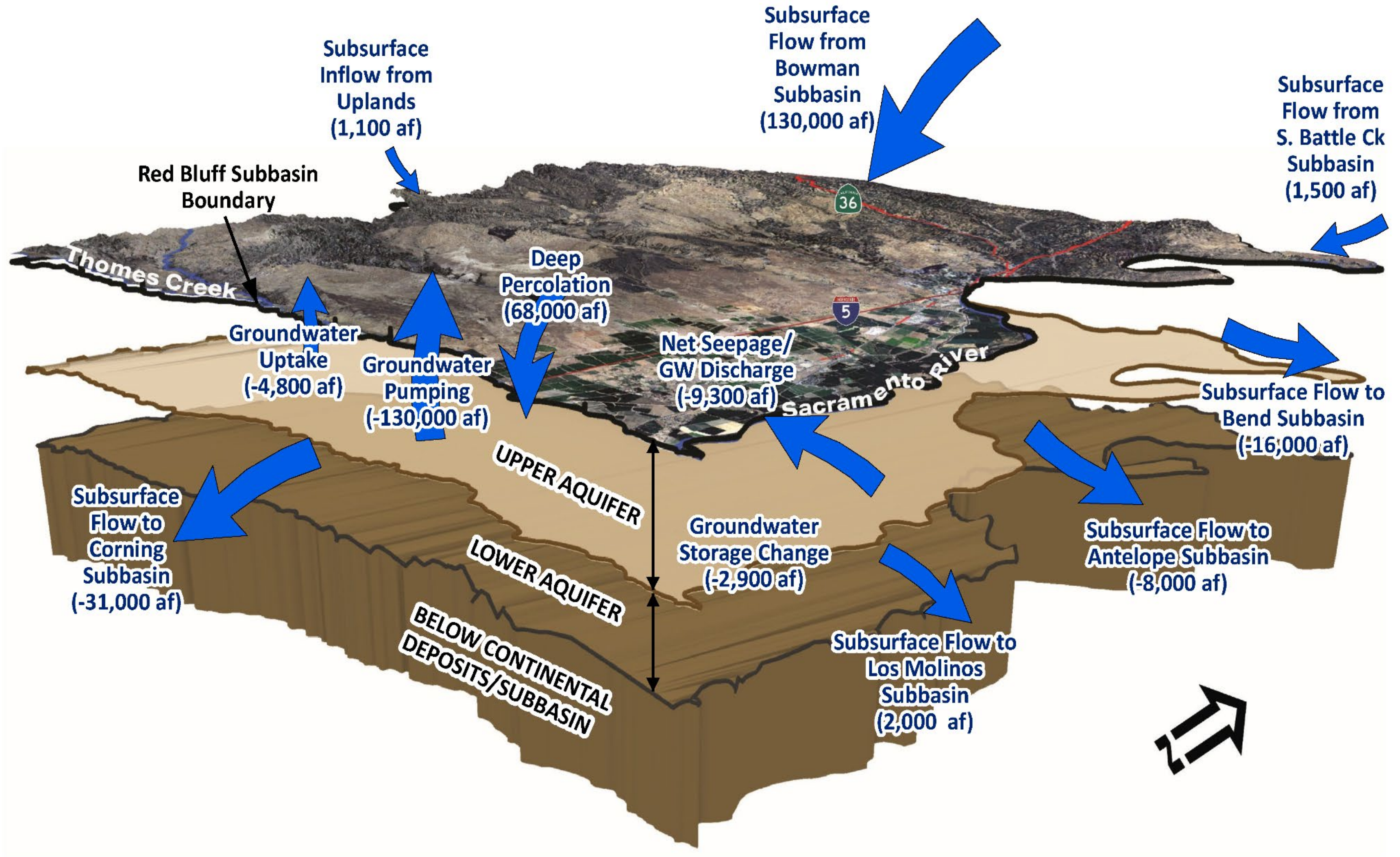

Figure 2-73. Diagram of the Red Bluff Subbasin Projected (Future Land Use) Average Annual Water Budget, 2022-2072

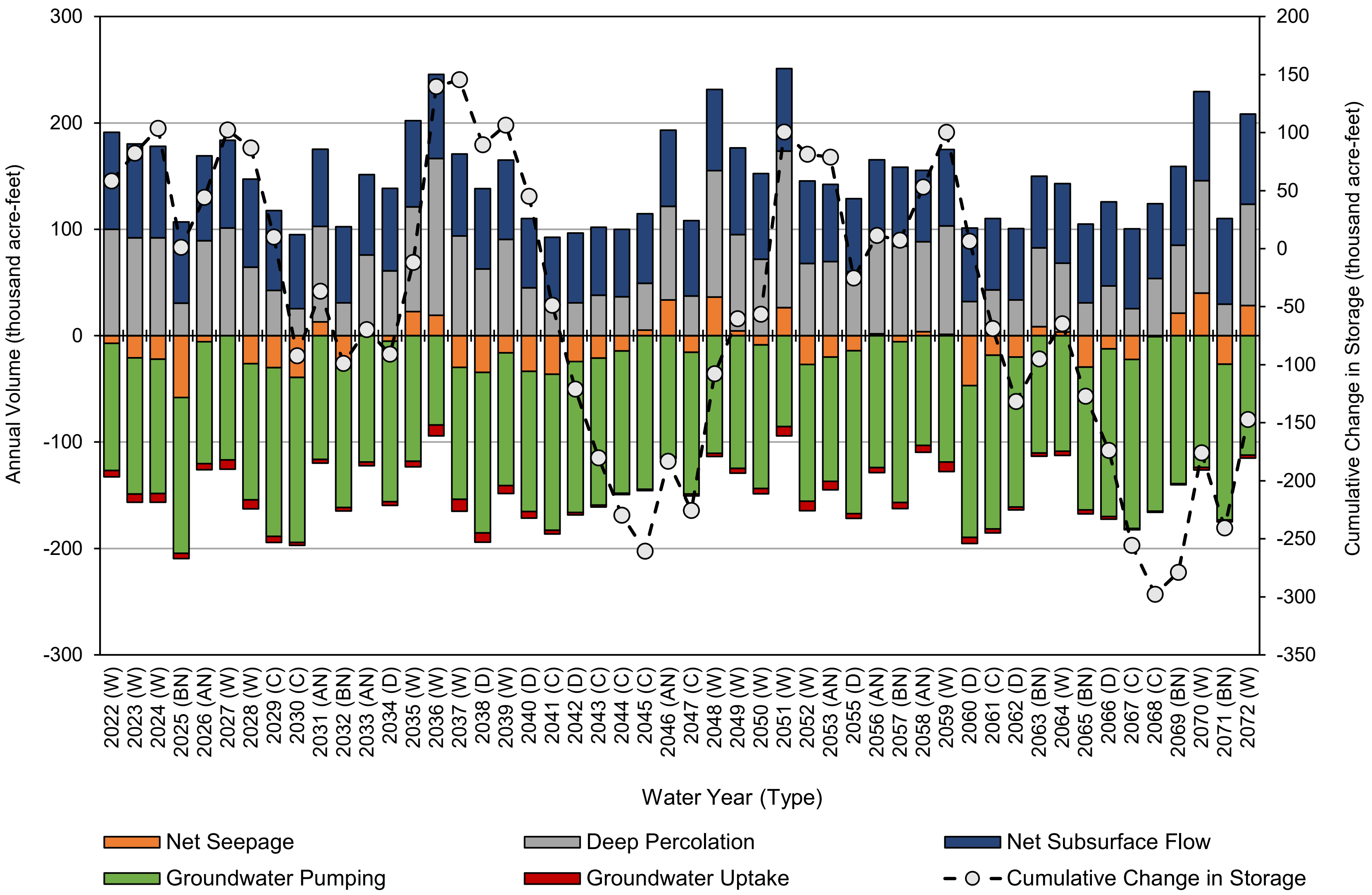

Figure 2-74. Red Bluff Subbasin Projected (Future Land Use) Water Budget Summary

Table 2-30. Red Bluff Subbasin Projected (Future Land Use) Water Budget Summary (acre-feet)

WATER YEAR (TYPE)	NET SEEPAGE	DEEP PERCOLATION	NET SUBSURFACE FLOWS	GROUND-WATER PUMPING	GROUNDWATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
2022 (W)	-7,000	100,000	91,000	-120,000	-5,900	58,000	58,000
2023 (W)	-21,000	92,000	88,000	-130,000	-7,600	24,000	82,000
2024 (W)	-22,000	92,000	86,000	-130,000	-8,200	21,000	100,000
2025 (BN)	-58,000	31,000	76,000	-150,000	-4,900	-100,000	1,000
2026 (AN)	-5,600	89,000	80,000	-110,000	-5,800	43,000	44,000
2027 (W)	-47	100,000	83,000	-120,000	-8,900	58,000	100,000
2028 (W)	-26,000	64,000	83,000	-130,000	-8,500	-16,000	87,000
2029 (C)	-30,000	43,000	75,000	-160,000	-5,800	-77,000	10,000
2030 (C)	-39,000	25,000	69,000	-160,000	-2,900	-100,000	-92,000
2031 (AN)	13,000	90,000	73,000	-120,000	-3,500	56,000	-37,000
2032 (BN)	-27,000	31,000	72,000	-130,000	-3,100	-62,000	-99,000
2033 (AN)	7,600	68,000	76,000	-120,000	-3,500	29,000	-70,000
2034 (D)	-5,300	61,000	77,000	-150,000	-3,700	-21,000	-91,000
2035 (W)	23,000	99,000	81,000	-120,000	-5,400	79,000	-12,000
2036 (W)	19,000	150,000	79,000	-84,000	-10,000	150,000	140,000
2037 (W)	-30,000	94,000	77,000	-120,000	-11,000	5,900	150,000
2038 (D)	-35,000	63,000	76,000	-150,000	-8,600	-56,000	90,000
2039 (W)	-16,000	90,000	75,000	-120,000	-7,600	17,000	110,000
2040 (D)	-34,000	45,000	65,000	-130,000	-6,100	-61,000	45,000
2041 (C)	-36,000	31,000	61,000	-150,000	-3,400	-94,000	-49,000
2042 (D)	-24,000	31,000	66,000	-140,000	-2,300	-72,000	-120,000
2043 (C)	-21,000	38,000	64,000	-140,000	-1,800	-59,000	-180,000
2044 (C)	-14,000	37,000	63,000	-130,000	-1,400	-50,000	-230,000
2045 (C)	5,300	44,000	65,000	-140,000	-1,200	-31,000	-260,000
2046 (AN)	34,000	88,000	72,000	-110,000	-1,900	78,000	-180,000
2047 (C)	-16,000	37,000	71,000	-130,000	-1,800	-42,000	-230,000
2048 (W)	36,000	120,000	76,000	-110,000	-3,100	120,000	-110,000
2049 (W)	4,400	90,000	82,000	-120,000	-4,400	47,000	-60,000
2050 (W)	-8,600	72,000	81,000	-130,000	-5,000	4,000	-56,000
2051 (W)	26,000	150,000	78,000	-85,000	-8,700	160,000	100,000
2052 (W)	-27,000	68,000	78,000	-130,000	-9,000	-19,000	81,000
2053 (AN)	-20,000	70,000	73,000	-120,000	-7,800	-2,600	79,000
2054 (D)	-33,000	45,000	63,000	-130,000	-5,800	-61,000	18,000
2055 (D)	-14,000	60,000	69,000	-150,000	-4,500	-43,000	-25,000
2056 (AN)	1,800	91,000	72,000	-120,000	-4,800	37,000	11,000
2057 (BN)	-5,800	84,000	74,000	-150,000	-5,800	-4,100	7,200
2058 (AN)	3,700	85,000	67,000	-100,000	-6,400	46,000	53,000
2059 (W)	1,300	100,000	72,000	-120,000	-9,000	47,000	100,000

WATER YEAR (TYPE)		NET SEEPAGE	DEEP PERCOLATION	NET SUBSURFACE FLOWS	GROUND-WATER PUMPING	GROUNDWATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
2060 (D)		-47,000	32,000	69,000	-140,000	-5,500	-94,000	6,300
2061 (C)		-18,000	43,000	67,000	-160,000	-3,700	-75,000	-69,000
2062 (D)		-20,000	34,000	67,000	-140,000	-2,500	-63,000	-130,000
2063 (BN)		8,600	74,000	67,000	-110,000	-2,900	37,000	-95,000
2064 (W)		3,600	65,000	75,000	-110,000	-4,000	30,000	-65,000
2065 (BN)		-30,000	31,000	74,000	-130,000	-3,500	-62,000	-130,000
2066 (D)		-12,000	47,000	79,000	-160,000	-2,600	-47,000	-170,000
2067 (C)		-22,000	26,000	75,000	-160,000	-1,400	-82,000	-260,000
2068 (C)		-1,000	54,000	70,000	-160,000	-1,000	-42,000	-300,000
2069 (BN)		21,000	64,000	74,000	-140,000	-1,100	19,000	-280,000
2070 (W)		40,000	110,000	84,000	-120,000	-2,500	100,000	-180,000
2071 (BN)		-27,000	30,000	81,000	-150,000	-1,800	-65,000	-240,000
2072 (W)		28,000	95,000	85,000	-110,000	-2,800	93,000	-150,000
Average (2022-2072)		-9,300	68,000	74,000	-130,000	-4,800	-2,900	
2022-2072	W	1,300	97,000	81,000	-120,000	-6,800	54,000	
	AN	4,800	83,000	73,000	-120,000	-4,800	41,000	
	BN	-17,000	49,000	74,000	-140,000	-3,300	-34,000	
	D	-25,000	46,000	70,000	-140,000	-4,600	-58,000	
	C	-19,000	38,000	68,000	-150,000	-2,400	-65,000	

2.3.9 Projected Water Budgets with Climate Change

Additional projected scenarios were developed to model potential climate change scenarios. Climate change scenarios were developed using the DWR guidance for the 2030 and 2070 central tendencies. The climate change scenarios were implemented following DWR's guidance related to the 2030 and 2070 central tendency climate change scenarios and associated adjustment factors applied to model inputs such as precipitation, ET, and surface water inflows. In the Tehama IHM area, the DWR climate change guidance and adjustment factors tend to result in increases in precipitation, ET, and streamflows. Additional detail about the development and results of these scenarios can be found in **Appendices 2-J and 2-K**.

2.3.9.1 Projected (Current Land Use) Water Budget

A comparison of the major components of the projected (current land use) water budget as they relate to the GWS are presented in **Table 2-31**. Net seepage becomes less negative under climate change scenarios, indicating less groundwater flow to SWS. Greater streamflow volumes entering the Subbasin under the climate change scenarios likely results in greater stream seepage although deep percolation and net subsurface flows remain change only minimally under climate change scenarios. Groundwater pumping increases by between 5.0 and 16 taf per year under climate change scenarios, becoming a greater outflow from the groundwater system. Still, the overall water budget results suggest that annual change in storage is only very slightly more negative under the climate change scenarios.

Table 2-31. Comparison of Annual Projected (Current Land Use) GWS Water Budgets with Climate Change Adjustments (acre-feet)

GWS WATER BUDGET COMPONENT	PROJECTED (CURRENT LAND USE)		
	NO CLIMATE CHANGE ADJUSTMENT	CLIMATE CHANGE (2030)	CLIMATE CHANGE (2070)
Net Seepage	-21,000	-18,000	-12,000
Deep Percolation	67,000	67,000	64,000
Net Subsurface Flows	53,000	54,000	56,000
Groundwater Extractions (Pumping and Uptake)	-100,000	-100,000	-110,000
Annual Groundwater Storage Change	***-1,800***	***-1,900***	***-2,400***

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.9.2 Projected (Future Land Use) Water Budget

A comparison of the major components of the projected (future land use) water budget as they relate to the GWS are presented in **Table 2-32**. Overall, the climate change scenarios to not appear to change the overall Subbasin GWS water budget in a considerable way, at similar magnitudes as in the projected (current land use) conditions. Net seepage becomes less negative under 2030 climate change scenario indicating a reduction of groundwater flow to SWS. Net seepage becomes slightly positive under 2070 climate change scenario indicating seepage from surface water to GWS. Deep percolation remains nearly unchanged under climate change scenarios. Net subsurface flows to the Subbasin slightly increase under climate change scenarios. Groundwater pumping increases between about 10 taf per year under the climate change scenarios; however, overall change in storage is only slightly more negative under the climate change scenarios.

Table 2-32. Comparison of Projected (Future Land Use) GWS Water Budgets with Climate Change Adjustments (acre-feet)

GWS WATER BUDGET COMPONENT	PROJECTED (FUTURE LAND USE)		
	NO CLIMATE CHANGE ADJUSTMENT	CLIMATE CHANGE (2030)	CLIMATE CHANGE (2070)
Net Seepage	-9,300	-6,000	830
Deep Percolation	68,000	68,000	66,000
Net Subsurface Flows	74,000	77,000	80,000
Groundwater Extractions (Pumping and Uptake)	-140,000	-140,000	-150,000
Annual Groundwater Storage Change	***-2,900***	***-3,000***	***-4,100***

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.10 Projected Groundwater Storage Change by Aquifer

This section presents the projected groundwater storage change in the Upper Aquifer and Lower Aquifer under Current Land Use and Future Land Use conditions with and without the climate change conditions. Note that the total water budget numbers presented below by aquifer may differ from the sum of the average annual values because of rounding. Additional detail about the development and results of these scenarios can be found in **Appendices 2-J and 2-K**.

2.3.10.1 Projected (Current Land Use) Storage Change

A comparison of the groundwater storage change under the projected (current land use) conditions with different climate change assumptions is presented in **Table 2-33**. The results suggest reduction of storage is only slightly greater under climate chance scenarios, with more of the storage change occurring in the Lower Aquifer. Overall projected storage change in the Subbasin is relatively small and differs little between the various climate change conditions evaluated. The projected average annual storage change decreases range from -1.8 to -2.4 taf per year and are equivalent to very minimal change on a per-acre basis over the 51-year projected period. Projected annual storage changes in the Upper Aquifer range from annual storage decreases of -0.51 to -0.75 taf per year with and without climate change conditions. Storage changes in the Lower Aquifer range from decreases of about -1.3 taf per year without climate change to -1.7 taf per year on average with 2070 climate change. The small amounts of change in the entire Subbasin, including individual aquifers, is small and is likely within the range of uncertainty of the water budget results, considering the magnitude of many of the other water budget components. For the projected (current land use) conditions with 2070 climate change factors, storage changes in the Upper and Lower Aquifers equate to annual basinwide storage changes of about -0.009 acre-feet per acre per year on average and about -0.44 acre-feet per acre cumulatively over the 51-year projected period.

Table 2-33. Comparison of Annual Projected (Current Land Use) Aquifer-Specific GWS Water Budgets with Climate Change Adjustments

PROJECTED (CURRENT LAND USE)		AVERAGE ANNUAL CHANGE IN STORAGE			CUMULATIVE CHANGE IN STORAGE		
		UPPER AQUIFER	LOWER AQUIFER	TOTAL	UPPER AQUIFER	LOWER AQUIFER	TOTAL
No Climate Change Adjustment	acre-feet	-510	-1,300	-1,800	-26,000	-68,000	-94,000
	acre-feet per acre	*-0.002*	*-0.005*	*-0.007*	*-0.10*	*-0.25*	*-0.34*
Climate Change 2030	acre-feet	-560	-1,400	-1,900	-28,000	-70,000	-98,000
	acre-feet per acre	*-0.002*	*-0.005*	*-0.007*	*-0.10*	*-0.26*	*-0.36*
Climate Change 2070	acre-feet	-750	-1,700	-2,400	-38,000	-86,000	-120,000
	acre-feet per acre	*-0.003*	*-0.006*	*-0.009*	*-0.13*	*-0.31*	*-0.44*

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.10.2 Projected (Future Land Use) Water Budget

A comparison of the groundwater storage change in primary aquifers under the projected (future land use) conditions with different climate change assumptions is presented in **Table 2-34**. Consistent with the comparison project (current land use) results, the results suggest reduction of storage is only slightly greater under climate chance scenarios, with more of the storage change occurring in the Lower Aquifer. Overall projected storage change in the Subbasin is relatively small and differs little between the various climate change conditions evaluated. The projected average annual storage change decreases range from -2.9 to -4.1 taf per year and are equivalent to small changes on a per-acre basis over the 51-year projected period. Projected annual storage changes in the Upper Aquifer range from annual storage decreases of -0.74 to -1.1 taf per year with and without climate change conditions. Storage changes in the Lower Aquifer range from decreases of between -2.1 taf per year without climate change to -3.0 taf per year on average with 2070 climate change. The small amounts of change in the entire Subbasin, including individual aquifers, is small and is likely within the range of uncertainty of the water budget results, considering the magnitude of many of the other water budget components. For the projected (current land use) conditions with 2070 climate change factors, storage changes in the Upper and Lower Aquifers equate to annual basinwide storage changes of about -0.015 acre-feet per acre per year on average and about -0.77 acre-feet per acre cumulatively over the 51-year projected period.

Table 2-34. Comparison of Projected (Future Land Use) Aquifer-Specific GWS Water Budgets with Climate Change Adjustments

PROJECTED (CURRENT LAND USE)		AVERAGE ANNUAL CHANGE IN STORAGE			CUMULATIVE CHANGE IN STORAGE		
		UPPER AQUIFER	LOWER AQUIFER	TOTAL	UPPER AQUIFER	LOWER AQUIFER	TOTAL
No Climate Change Adjustment	acre-feet	-740	-2,100	-2,900	-38,000	-110,000	-150,000
	acre-feet per	*-0.003*	*-0.008*	*-0.011*	*-0.14*	*-0.40*	*-0.55*
Climate Change 2030	acre-feet	-810	-2,200	-3,000	-41,000	-110,000	-150,000
	acre-feet per	*-0.003*	*-0.008*	*-0.011*	*-0.15*	*-0.42*	*-0.57*
Climate Change 2070	acre-feet	-1,100	-3,000	-4,100	-58,000	-152,000	-210,000
	acre-feet per acre	*-0.004*	*-0.011*	*-0.015*	*-0.21*	*-0.56*	*-0.77*

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.11 Uncertainty in Water Budget Estimates

2.3.11.1 Uncertainty in SWS Water Budget

Uncertainties associated with each SWS water budget component have been computed or estimated following the process described by Clemmens and Burt (1997). In summary:

1. The uncertainty of each independently-estimated water budget component (excluding the closure term) is calculated or estimated as a percentage that approximately represents a 95 percent confidence interval for the average annual component volume of the component. Uncertainty percentages are based on the accuracy of measurement devices, the uncertainty of supporting calculations and estimation procedures, and professional judgement.
2. Assuming random, normally-distributed error, the standard deviation is calculated for each independently-estimated component as the average uncertainty on a volumetric basis (uncertainty percentage multiplied by the average annual component volume) divided by two.
3. The variance is calculated for each independently-estimated component as the square of the standard deviation.
4. The variance of the closure term is estimated as the sum of variances of all independently-estimated components.
5. The standard deviation of the closure term is estimated as the square root of the sum of variances.
6. The 95 percent confidence interval of the closure term is estimated as twice the estimated standard deviation.

Estimated uncertainties were calculated following the above procedure for the Subbasin water budget and all GSA water budgets. **Table 2-35** provides a summary of typical uncertainty values associated with major SWS inflows and outflows, along with the sources of these uncertainty values. For surface water flows, deliveries, and diversions, the uncertainty is estimated based on typical accuracy of streamflow gages and measurement devices. For IDC root zone water budget inflows and outflows, the uncertainty is based on typical accuracies given in technical literature and the cumulative estimated accuracy of all inputs used to calculate the components. These uncertainties provide a basis for evaluating confidence in water budget results and help to identify data needs that may be addressed during GSP implementation.

Table 2-35. Estimated Uncertainty of Major Water Budget Components

FLOWPATH DIRECTION (RELATIVE TO SWS)	WATER BUDGET COMPONENT	DATA SOURCE	ESTIMATED UNCERTAINTY (%)	SOURCE
Inflows	Surface Water Inflows	Measurement	5%[1]	Accuracy of USGS streamflow gages, with adjustment for infiltration and evaporation of inflows upstream/downstream of nearest measurement site.
	Deliveries	Measurement	6%	Required delivery measurement accuracy for Reclamation contractors, per the USGS 2017 Standard Criteria for Agricultural Water Management Plans)
	Water Rights Diversions	Measurement / Estimate	10%	Required diversion measurement accuracy, per California Senate Bill 88.
	Precipitation	Calculation	20%[2]	Clemmens, A.J. and C.M. Burt, 1997.
	Groundwater Extraction	Calculation	20%	Typical uncertainty when calculated for Land Surface System water budget closure. The uncertainty of the accounting center closure is a product of the combined uncertainty of all other inflows and outflows, and the relative magnitude of each component.
Outflows	Surface Water Outflows	Measurement	15%	Estimated streamflow measurement accuracy with adjustment for infiltration and evaporation.
	Evaporation	Calculation	20%	Clemmens and Burt, 1997; typical accuracy of calculation based on CIMIS reference ET and free water surface evaporation coefficient.
	ET of Applied Water	Calculation	10%	Clemmens and Burt, 1997; typical accuracy of total irrigation water consumption on irrigated land, parsed into ET of Applied Water and ET of Precipitation by daily root zone water budget component based on reference ET, precipitation, surface energy balance crop coefficients, and annual land use.
	ET of Precipitation	Calculation	10%[2]	Clemmens and Burt, 1997; accuracy of total water consumption on irrigated land, parsed into ET of Applied Water and ET of Precipitation by daily root zone water budget component based on reference ET, precipitation, surface energy balance crop coefficients, and annual land use.
	Infiltration of Applied Water	Calculation	20%[2]	Estimated accuracy of daily IDC root zone water budget based on annual land use and NRCS soils characteristics. Similar accuracy anticipated for monthly results.
	Infiltration of Precipitation	Calculation	20%[2]	Estimated accuracy of daily IDC root zone water budget based on annual land use, NRCS soils characteristics, and CIMIS precipitation.
	Infiltration of Surface Water	Calculation	15%	Typical accuracy of daily seepage calculation using NRCS soils characteristics and measured streamflow data compared to field measurements.

[1] Higher uncertainty of 10-20 percent is typical for estimated surface water inflows, including ungaged inflows from small watersheds into creeks that enter the Subbasin.

[2] IDC root zone water budget inflows and outflows. The uncertainty of these water budget components is based on typical accuracies given in technical literature and the cumulative estimated accuracy of all inputs used to calculate the components.

2.3.11.2 GWS Water Budget Uncertainty

Uncertainty associated with the GWS water budget results estimated using the Tehama IHM depends in part on the model inputs relating to the SWS with additional sources of uncertainty associated with model inputs relating to the GWS, including aquifer and streambed properties, specification of boundary conditions, and other factors. The uncertainty estimates associated with SWS water budget components that are also inputs or outputs of the GWS water budget are noted above. The overall uncertainty of other water budget components simulated for the GWS, including subsurface flows, groundwater discharging to surface water, and change in groundwater storage are estimated to be slightly higher, in the range of 15 to 30 percent. These GWS water budget components are subject to higher uncertainty as a result of limitations in available input data and simplification required in modeling of the subsurface heterogeneity. However, the uncertainty in GWS water budget results derived from a numerical model such as the Tehama IHM depends to a considerable degree on the calibration of the model and can vary by location and depth within the Subbasin. The Tehama IHM is a product of local refinement and improvements made to the SVSim model and calibration at a more local scale. The Tehama IHM simulates the integrated groundwater and surface water system and metrics relating to the calibration of the model indicate the model is reasonably well calibrated in accordance with generally accepted professional guidelines and is sufficient for GSP-related applications. The calibration and sensitivity of the model and different model parameters are presented in **Appendix 2-J**.

2.3.12 Estimate of Sustainable Yield

GSP Regulations require the GSP quantify the sustainable yield for the Subbasin. Sustainable yield is defined as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, which can be withdrawn annually from a groundwater supply without causing an undesirable result" (CWC Section 10721(w)). Historical and projected model results show that the conditions in the Subbasin under the historical and anticipated future land use conditions and hydrology, including with potential climate change conditions (2030 and 2070), will not cause the occurrence of undesirable results in the Subbasin over the 50-year GSP planning period based on sustainability indicator Minimum Thresholds (MTs) developed for the Subbasin.

A summary comparison of the results from the different historical and projected water budget scenarios is included in **Table 2-36**. Over the historical base period, the average annual volume of groundwater pumping in the Red Bluff Subbasin is estimated to be about 80,000 acre-feet per year. An additional 9,700 acre-feet of groundwater was estimated to be taken up and consumed directly by plants reflecting a total historical groundwater extraction volume of about 90,000 acre-feet per year on average. Observed groundwater level conditions and simulated water budget results suggest there has been some historical long-term change in groundwater storage in the Subbasin, although areas of observed groundwater storage depletion are more localized resulting from local hydrogeologic characteristics and are not representative of basinwide conditions.

Projected water budgets intended to assess longer-term conditions over a 50-year planning horizon with hydrology consistent with the most recent 50 years of hydrology suggest relatively little or no change in storage is anticipated under the future projected scenarios evaluated. In the projected water budget scenarios (current land use and future land use conditions) without any assumed climate change, total groundwater extraction (combination of groundwater pumping and uptake) within the Subbasin increases overall to about 100,000 acre-feet per year for the projected (current land use) condition and to approximately 135,000 acre-feet per year for the projected (future land use) condition. The projected water budgets with climate change conditions indicate total groundwater extraction rates of between 105,000 to 154,000 acre-feet per year, depending on the land use and climate change scenario (**Table 2-36**).

Table 2-36. Summary Comparison of Annual Historical and Projected Water Budgets (acre-feet)

WATER BUDGET COMPONENT	HISTORICAL	PROJECTED (CURRENT LAND USE)			PROJECTED (FUTURE LAND USE)		
		BASE-LINE	CLIMATE CHANGE (2030)	CLIMATE CHANGE (2070)	BASELINE	CLIMATE CHANGE (2030)	CLIMATE CHANGE (2070)
Net Seepage	-39,000	-21,000	-18,000	-12,000	-9,300	-6,000	830
Deep Percolation	70,000	67,000	67,000	64,000	68,000	68,000	66,000
Groundwater Pumping	-80,000	-94,000	-99,000	-110,000	-130,000	-140,000	-150,000
Groundwater Uptake	-9,700	-6,300	-6,200	-5,500	-4,800	-4,600	-4,100
Total Net Subsurface Flows	49,000	53,000	54,000	56,000	74,000	77,000	80,000
Flow from/to Antelope Subbasin	*-25,000*	*-18,000*	*-17,000*	*-15,000*	*-8,000*	*-6,800*	*-4,400*
Flow from/to Los Molinos Subbasin	*-2,200*	*-880*	*-390*	*360*	*2,000*	*2,600*	*3,700*
Flow from/to Bowman Subbasin	*120,000*	*120,000*	*120,000*	*120,000*	*130,000*	*130,000*	*130,000*
Flow from/to Corning Subbasin	*-28,000*	*-36,000*	*-36,000*	*-37,000*	*-31,000*	*-31,000*	*-31,000*
Flow from/to South Battle Creek Subbasin	*1,500*	*1,500*	*1,500*	*1,500*	*1,500*	*1,500*	*1,500*
Flow from/to Bend Subbasin	*-18,000*	*-17,000*	*-17,000*	*-17,000*	*-16,000*	*-16,000*	*-16,000*
Flow from Uplands	*1,100*	*1,100*	*1,100*	*1,100*	*1,100*	*1,100*	*1,100*
Annual Change in Groundwater Storage	**-11,000**	**-1,800**	**-1,900**	**-2,400**	**-2,900**	**-3,000**	**-4,100**

While the groundwater extraction water budget component increases in the projected water budgets, the increased groundwater extractions are counterbalanced by increased subsurface inflows and net seepage. As a result, the projected water budgets suggest very little or no change in storage under all of the projected scenarios, when considered in the context of the typical uncertainty associated with water budget estimates and the magnitude of other water budget components. Review of results from the projected model simulations suggests that the Subbasin will be sustainable for at least the 50-year GSP planning horizon by avoiding undesirable results as defined in the GSP. The simulated changes in projected subsurface flows, most notably increases in subsurface inflows from Bowman and decreases of subsurface outflows to Antelope Subbasins, are not unreasonable changes and are not expected to adversely affect the ability of any adjacent Subbasins to achieve or maintain sustainability.

Potential for significant and unreasonable stream depletion resulting in adverse impacts on surface water beneficial users through decreased groundwater discharging to surface water or increased induced stream seepage in and along the Subbasin was also considered in estimating the sustainable yield of the Subbasin. The projected net seepage volumes do exhibit change across the different water budget scenarios. Differences in hydrology between historical and projected water budget periods and also climate change scenarios can greatly affect the net seepage. Understanding the influences of projected conditions on interconnected surface water is confounded by the different factors involved. While net seepage quantities the overall exchange of groundwater and surface water, it does not distinguish changes that are a result of groundwater conditions from changes that result from streamflow conditions. Both groundwater conditions and streamflow conditions can and do change based on the hydrology (e.g., precipitation, surface water inflows) and climate. For example, increases in streamflow entering the Subbasin can result in greater stream seepage and increases in net seepage (i.e., less negative, or more positive net seepage number); conversely decreased streamflow entering the Subbasin can result in lowered stream seepage and lowered net seepage numbers. Similarly, lowered groundwater levels can lead to decreased groundwater discharge resulting in increased net seepage.

A review of simulated net streamflow gains from groundwater in the Sacramento River in the reach traversing the Red Bluff Subbasin in different projected scenarios provides a meaningful comparison of the influence of Subbasin conditions on the exchange of groundwater and surface water, especially in relation to surface water beneficial users. **Figures 2-75** and **2-76** and **Table 2-37** present the net streamflow gains in the Sacramento River as it traverses the Subbasin for the different water budget scenarios and highlight the small changes in streamflow gains from groundwater that occur through the Subbasin under the different projected scenarios in relation to the total volume of streamflow in the River. Notably, the simulated results indicate the River is gaining flow from groundwater through this reach during all water year types and all water budget scenarios, with average annual streamflow gains from groundwater of about 9 to 10 taf per year with lower values occurring in the projected climate change scenarios when compared to similar runs without climate change (**Figure 2-75**). The differences in annual gain in flow from groundwater between the projected current and future land use scenarios is very small, especially when considered as a fraction of the total streamflow in the River (**Figure 2-76**).

Although the scenarios with climate change tend to exhibit relatively less flow gained from groundwater, the higher streamflows anticipated to occur during some months under the climate change scenarios (most notably the 2070 climate change scenario) will have a tendency to reduce the net discharge of groundwater to surface water features resulting in reduced gains from groundwater. Therefore, the volume of net flow gain from groundwater in climate change scenarios is affected by the different streamflow conditions that are unrelated to groundwater management in the Subbasin. Direct comparisons of projected and historical streamflow gains are confounded by the differences in hydrology between the water budget periods; however, comparing simulated streamflow gains between projected scenarios suggests the streamflow gains from groundwater are equally or more sensitive to the climate conditions than land use and associated groundwater conditions. Simulated streamflows in the Sacramento River indicate that on an average monthly basis, the months of June through August exhibit streamflow conditions that decrease in a downstream direction. It is notable that monthly streamflow gains from groundwater in the Sacramento River through the Red Bluff Subbasin are relatively stable between months (and always positive), including during the months of June through August.

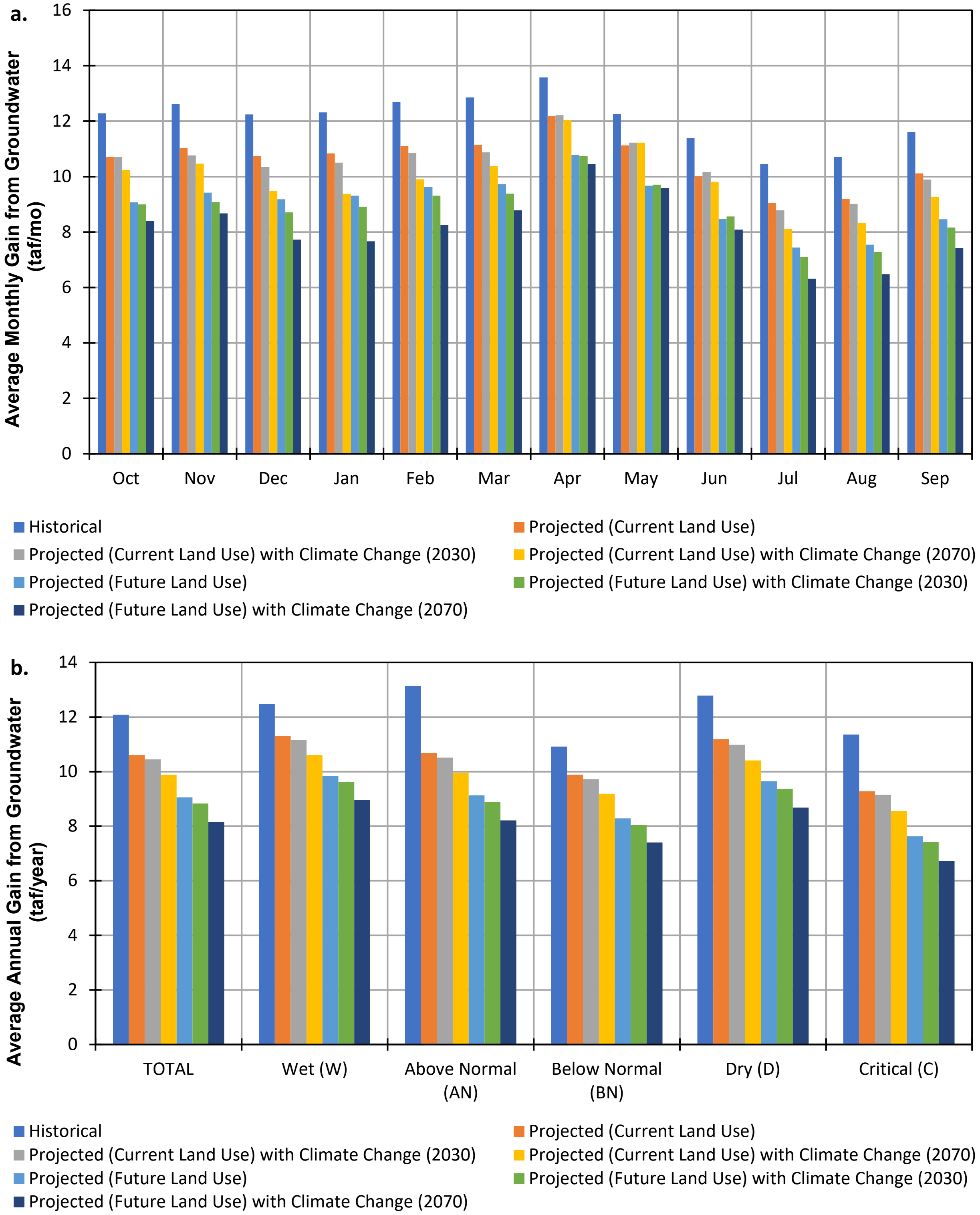

Figure 2-75. Comparison of Gains from Groundwater in the Sacramento River through the Red Bluff Subbasin by Water Year Type and Month

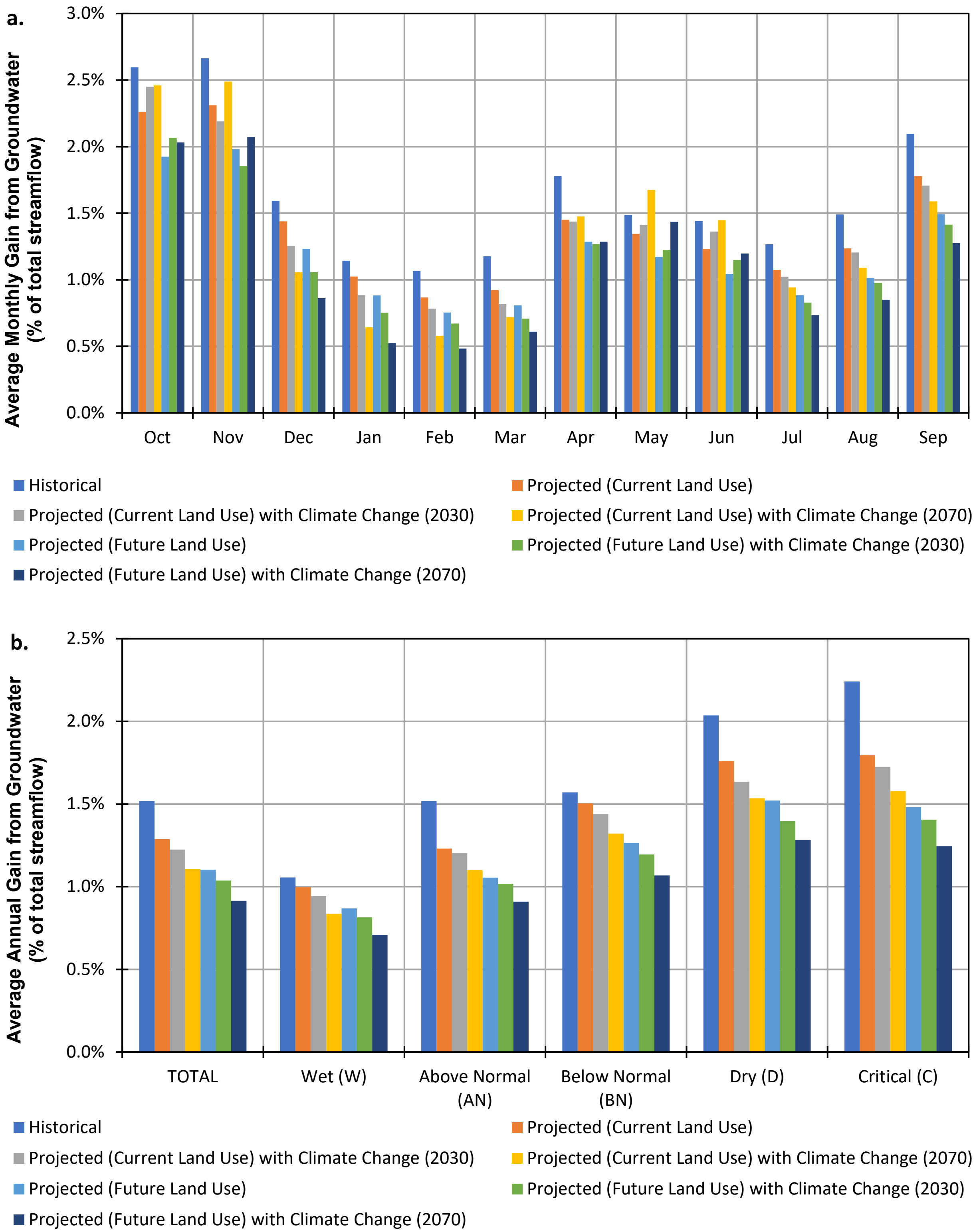

Figure 2-76. Comparison of Gains from Groundwater in the Sacramento River through the Red Bluff Subbasin as Percent of Total Streamflow by Water Year Type and Month

Table 2-37. Sacramento River Streamflow Gains through the Red Bluff Subbasin as Percent of Total Streamflow

		HISTORICAL	PROJECTED (CURRENT LAND USE)	PROJECTED (CURRENT LAND USE) WITH CLIMATE CHANGE (2030)	PROJECTED (CURRENT LAND USE) WITH CLIMATE CHANGE (2070)	PROJECTED (FUTURE LAND USE)	PROJECTED (FUTURE LAND USE) WITH CLIMATE CHANGE (2030)	PROJECTED (FUTURE LAND USE) WITH CLIMATE CHANGE (2070)
Average Monthly Gain from Groundwater (percent of total streamflow)	Oct	2.6%	2.3%	2.4%	2.5%	1.9%	2.1%	2.0%
	Nov	2.7%	2.3%	2.2%	2.5%	2.0%	1.9%	2.1%
	Dec	1.6%	1.4%	1.3%	1.1%	1.2%	1.1%	0.9%
	Jan	1.1%	1.0%	0.9%	0.6%	0.9%	0.8%	0.5%
	Feb	1.1%	0.9%	0.8%	0.6%	0.8%	0.7%	0.5%
	Mar	1.2%	0.9%	0.8%	0.7%	0.8%	0.7%	0.6%
	Apr	1.8%	1.5%	1.4%	1.5%	1.3%	1.3%	1.3%
	May	1.5%	1.3%	1.4%	1.7%	1.2%	1.2%	1.4%
	Jun	1.4%	1.2%	1.4%	1.4%	1.0%	1.1%	1.2%
	Jul	1.3%	1.1%	1.0%	0.9%	0.9%	0.8%	0.7%
	Aug	1.5%	1.2%	1.2%	1.1%	1.0%	1.0%	0.9%
	Sep	2.1%	1.8%	1.7%	1.6%	1.5%	1.4%	1.3%
Average Annual Gain from Groundwater (% of total	TOTAL	1.5%	1.3%	1.2%	1.1%	1.1%	1.0%	0.9%
	W	1.1%	1.0%	0.9%	0.8%	0.9%	0.8%	0.7%
	AN	1.5%	1.2%	1.2%	1.1%	1.1%	1.0%	0.9%
	BN	1.6%	1.5%	1.4%	1.3%	1.3%	1.2%	1.1%
	D	2.0%	1.8%	1.6%	1.5%	1.5%	1.4%	1.3%
	C	2.2%	1.8%	1.7%	1.6%	1.5%	1.4%	1.2%

Simulated results also indicate minimal influence on streamflows in Thomes Creek and Elder Creek, two westside tributary streams in the southern part of the Subbasin where groundwater withdrawals tend to be greater. As illustrated in **Figures 2-77** and **2-78,** monthly gains from groundwater in Thomes and Elder Creeks exhibit small changes under the different projected water budget scenarios, especially when comparing between projected conditions that utilize the same hydrology (e.g., projected current land use and projected future land use). Positive gain values in **Figures 2-77** and **2-78** indicate net groundwater discharging to the surface feature whereas negative gain values indicate net losing streamflow conditions (streamflow seeping into groundwater). The magnitude of the volume of groundwater losses is greatest during the months of December through May, when streamflows are high in the creeks; however, these losses and the changes in losses between different projected scenarios represent a small fraction of the total streamflow. Available historical streamflow gage data over the period between 1949 and 1980 indicate that Thomes Creek and Elder Creek can be characterized as intermittent streams near to where they join the Sacramento River. Historical gage data indicate that average monthly flows during the months of July through October are very small with a high percentage of years experiencing zero streamflow during these months. In fact, historical gage data indicate zero streamflow conditions in the creeks during July in approximately one third of the years and during August through October zero streamflow conditions occurred during approximately two-thirds to three-quarters of the years with gage data. This trend is consistent with the graphs of simulated gains from groundwater, which indicate a very small volume of exchange during the months of July through October and very small changes in the volumes of gain from groundwater between different projected scenarios. The larger magnitude of simulated losses as a percentage of the total streamflow occurring during these months are a function of the very small amount of streamflow occurring during these dry months. The projected modeling suggests limited effects on streamflow in these tributary streams in the projected runs, especially when considering the uncertainty that should be associated with simulated results.

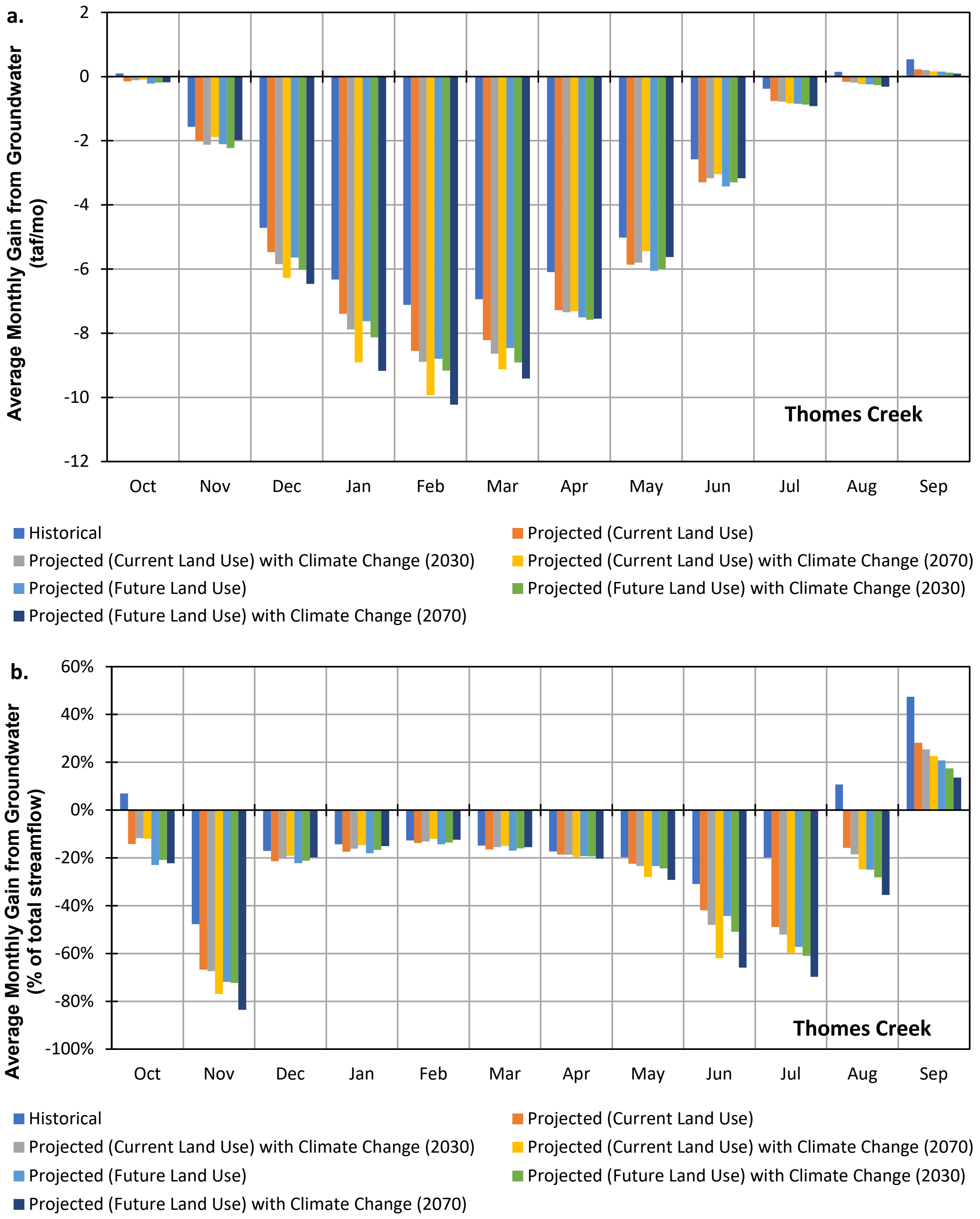

Figure 2-77. Comparison of Monthly Gains from Groundwater in Thomes Creek

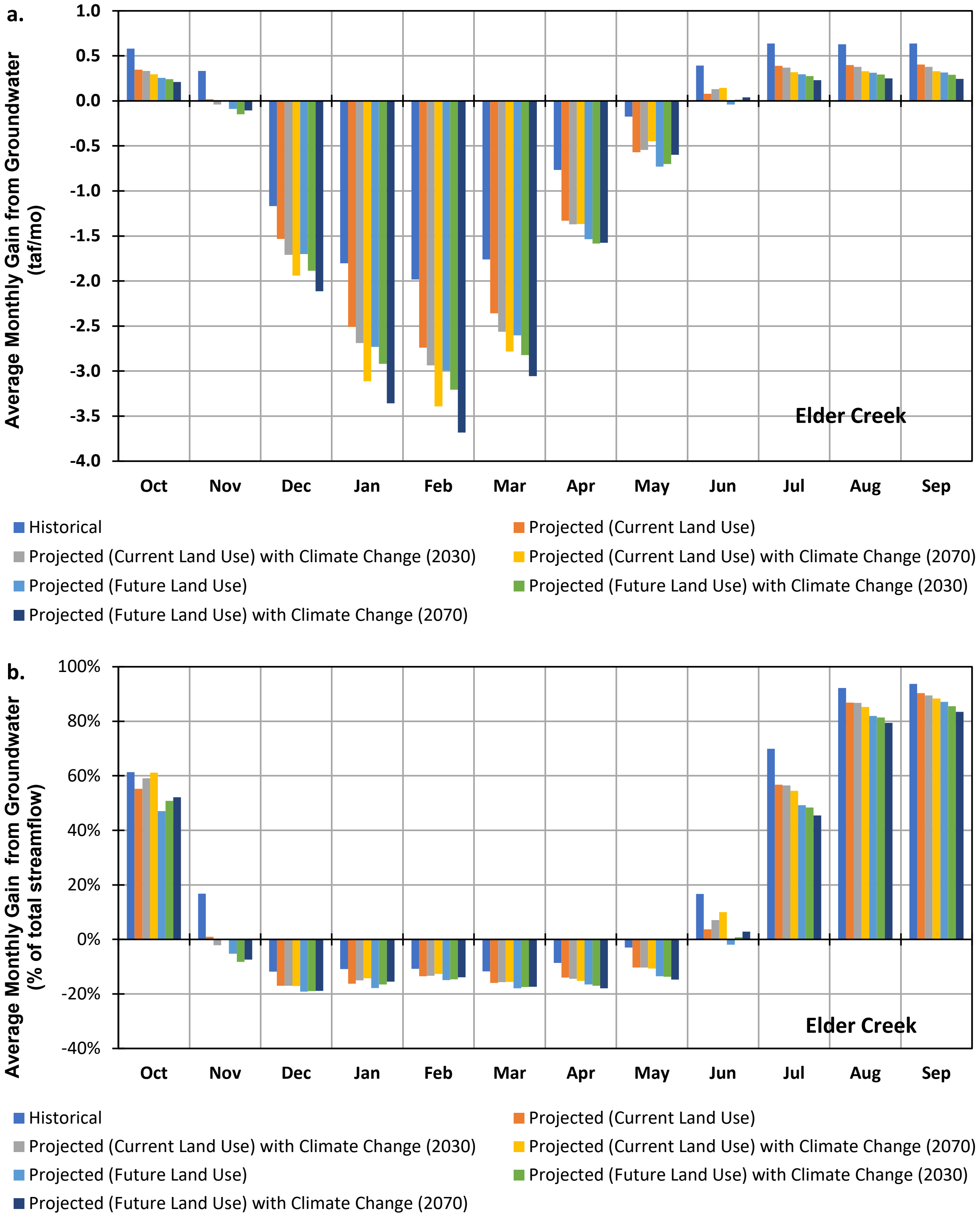

Figure 2-78. Comparison of Monthly Gains from Groundwater in Elder Creek

The small magnitude of potential change in streamflow exhibited in the Sacramento River and in tributary streams under the projected future conditions, including with climate change suggests that it is unlikely that any beneficial users of surface water would be significantly and unreasonably adversely affected by groundwater management under any of the projected future conditions evaluated. Accordingly, for the purpose of the GSP, the sustainable yield is estimated to be 150,000 acre-feet per year, which is equal to the volume of groundwater extracted annually in the Subbasin (by pumping and by uptake) minus the simulated annual decrease in storage under the projected model scenario with future land use and 2070 climate change conditions and considering the level of uncertainty associated with water budget estimates. This volume is approximately equal to the annual volume of vertical inflows from deep percolation and lateral inflows from subsurface flow occurring within the Subbasin. Assuming potential uncertainty of 25 percent associated with the water budget estimates, an associated range of values for the estimated sustainable yield would be 112,500 to 187,500 acre-feet per year. It is possible that the true sustainable yield is higher as no model scenarios were developed to test the maximum possible volume of groundwater extraction. The sustainable yield estimate provided here is consistent with the sustainability goal for the Subbasin and will be reviewed as the Subbasin implements the GSP, including through periodic review and updates to the Tehama IHM and water budget results, ongoing monitoring of Subbasin conditions as required by GSP Regulations, and filling of any data gaps identified in the GSP or during GSP implementation.

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