Cuyama Valley Groundwater Basin Groundwater Sustainability Plan Water Budget Draft

Prepared by:

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Chapter 2 Basin Setting

This document includes the Water Budget Section will be included as part of a report section in the Cuyama Basin Groundwater Sustainability Plan that satisfies § 354.18 of the Sustainable Groundwater Management Act Regulations. The Water Budget section is a portion of the Basin Settings portion of a Groundwater Sustainability Plan. The Basin Settings contains three main subsections:

- Hydrogeologic Conceptual Model – This section provides the geologic information needed to understand the framework that water moves through in the basin. It focuses on geologic formations, aquifers, structural features, and topography.
- Groundwater Conditions - This section describes and presents groundwater trends, levels, hydrographs and level contour maps, estimates changes in groundwater storage, identifies groundwater quality issues, addresses subsidence and surface water interconnection.
- Water Budget – This section, presented here, provides the data used in water budget development, discusses how the budget was calculated, and provides water budget estimates for historical conditions, current conditions and projected conditions.

Acronyms

AF	Acre-feet
AFY	Acre-feet per year
Basin	Cuyama Valley Groundwater Basin
CALSIMETAW	California Simulation of Evapotranspiration of Applied Water
CBGSA	Cuyama Basin Groundwater Sustainability Agency
CCSD	Cuyama Community Services District
DWR	Department of Water Resources
ET	Evapotranspiration
IDC	IWFM Demand Calculator
IWFM	Integrated Water Flow Model
METRIC	Mapping Evapotranspiration at High Resolution and Internalized Calibration
PRISM	Precipitation-Elevation Regressions on Independent Slopes Model

2.3 Water Budget

This section describes the historical, current and projected water budgets for the Cuyama Valley Groundwater Basin (Basin).

As defined by the Groundwater Sustainability Plan (GSP) regulations promulgated by the California Department of Water Resources (DWR), the water budgets section is intended to quantify the following:

(1) Total surface water entering and leaving a basin by water source type.

(2) Inflow to the groundwater system by water source type

(3) Outflows from the groundwater system by water use sector

(4) The change in the annual volume of groundwater in storage between seasonal high conditions

(5) If overdraft conditions occur, a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions.

(6) The water year type associated with the annual supply, demand, and change in groundwater stored.

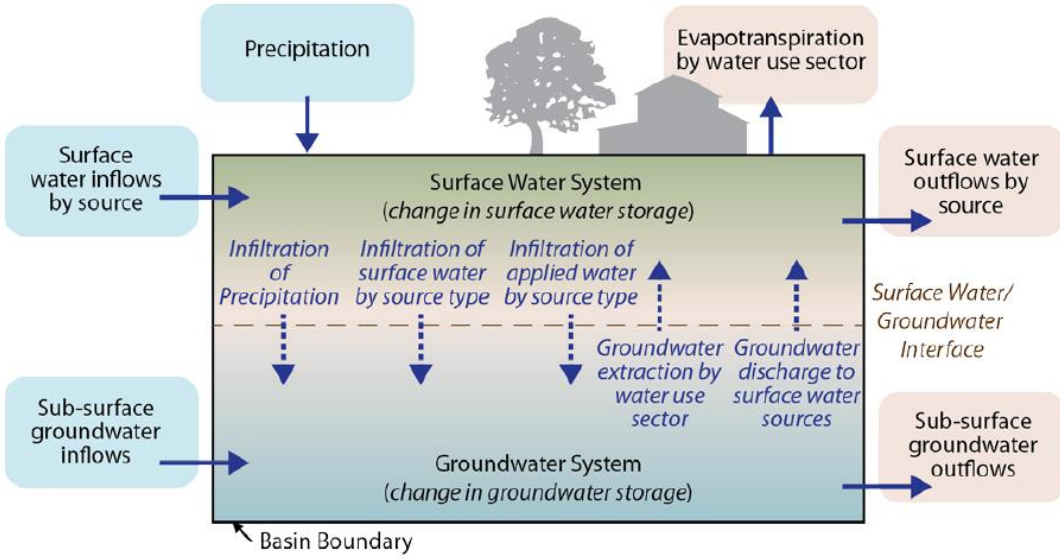
(7) An estimate of sustainable yield for the basin.

2.3.1 Water Budget Information

Water budgets were developed to provide a quantitative accounting of water entering and leaving the Basin. Water entering the Basin includes water entering at the surface and entering through the subsurface. Similarly, water leaving the Basin leaves at the surface and through the subsurface. Water enters and leaves naturally, such as precipitation and streamflow, and through human activities, such as pumping and recharge from irrigation. Figure 2.3-1 presents a vertical slice through the land surface and aquifer to summarize the water balance components utilized in this analysis.

The values presented in the water budget provide information on historical, current, and projected conditions as they relate to hydrology, water demand, water supply, land use, population, climate change, sea level rise (not applicable in the Basin), groundwater and surface water interaction, and subsurface groundwater flow. This information can assist in management of the Basin, by identifying the scale of different uses, highlighting potential risks, and identifying potential opportunities to improve water supply conditions, among others.

Figure 2.3-1: Generalized Water Budget Diagram



(source: DWR)

Water budgets can be developed on different spatial scales. In agricultural use, water budgets may be limited to the root zone, improving irrigation techniques by estimating the inflows and outflows of water from the upper portion of the soil accessible to plants through their roots. In a pure groundwater study, water budgets may be limited to water flow within the subsurface, aiding in understanding how water flows beneath the surface. Global climate models simulate water budgets that incorporate atmospheric water, allowing for simulation of climate change conditions. In this document, consistent with the Regulations (California Code of Regulations), the water budgets investigate the combined surface water and groundwater system in the Basin.

Water budgets can also be developed at different temporal scales. Daily water budgets may be used to demonstrate how evaporation and transpiration increase during the day and decrease at night. Monthly water budgets may be used to demonstrate how groundwater pumping increases in the dry, hot summer months and decreases in the cool, wet winter months. In this document, consistent with the Regulations, the water budgets focus on the full water year (12 months spanning October of the previous year to September), with some consideration to monthly variability.

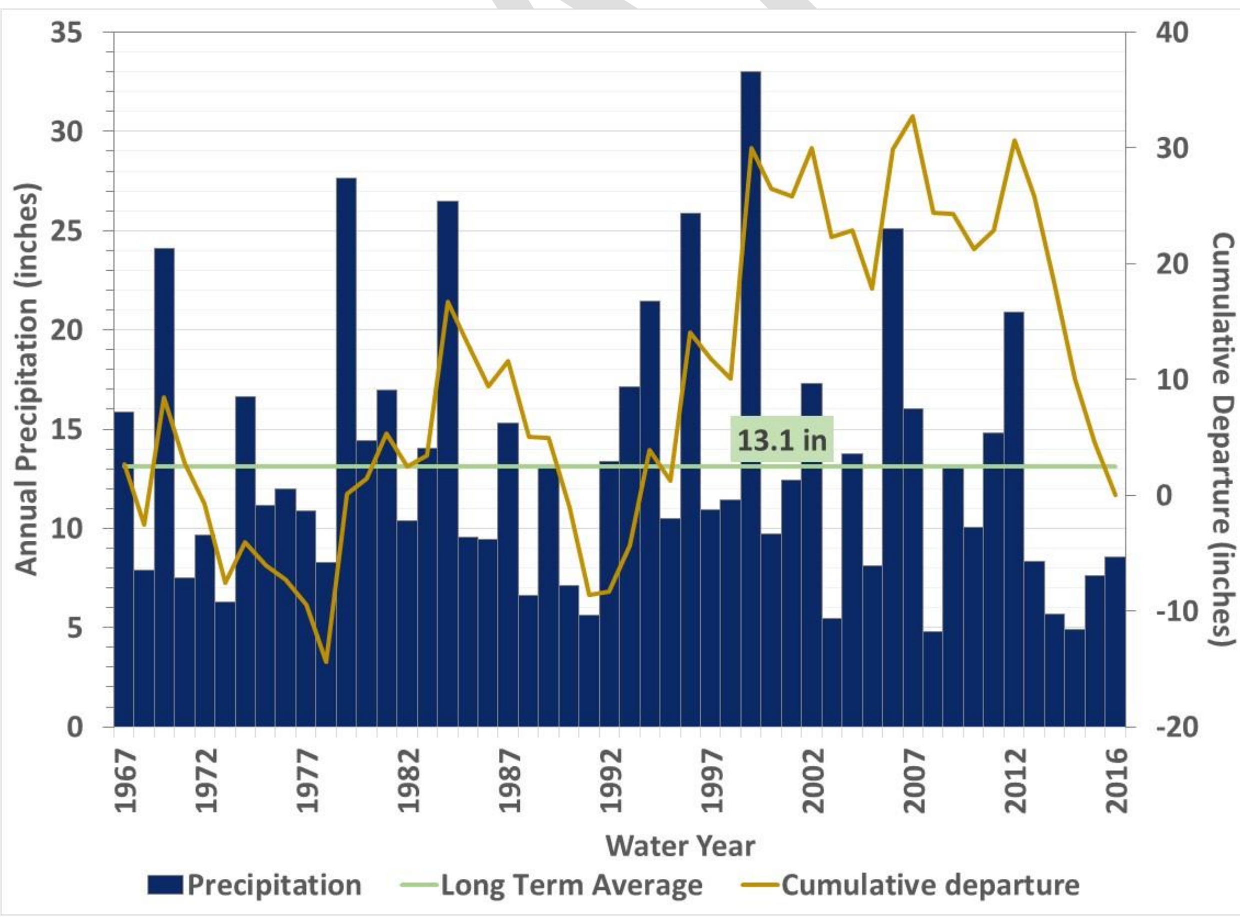
The Regulations require the annual water budgets be based on three different conditions: historical, current, and projected. Budgets are developed to capture typical conditions during these time periods. Typical conditions are developed through averaging over hydrologic conditions that incorporate droughts, wet periods, and normal periods. By incorporating these varied conditions within the budgets, analysis of the system under certain hydrologic conditions, such as drought, can be performed along with analysis of long-term averages. Information is provided in the following subsections on the hydrology dataset used to identify time periods for budget analysis, the usage of the Cuyama Basin Integrated Water Flow Model (IWFM) and associated data in water budget development, and on the budget estimates.

2.3.2 Identification of Hydrologic Periods

Hydrologic periods were selected to meet the needs of developing historical, current, and projected water budgets. The Regulations require that the projected water budget reflect 50 years of historical hydrology, in order to reflect long-term average hydrologic conditions. Historical precipitation data for the Basin was utilized to identify hydrologic periods that would provide a representation of wet and dry periods and long-term average conditions needed for budget analyses. Analysis of a long-term historical period time provides information that is expected to be representative of long-term future conditions.

Figure 2.3-2 shows annual precipitation in the Basin for water years 1968 to 2017. The chart includes bars displaying annual precipitation for each water year and a horizontal line representing the mean precipitation of 13.1 inches. Rainfall data for the Basin is derived from the PRISM (Precipitation-Elevation Regressions on Independent Slopes Model) dataset of the DWR's CALSIMETAW (California Simulation of Evapotranspiration of Applied Water) model. Identification of periods with a balance of wet and dry periods was performed using the cumulative departure from mean precipitation method. Under this method, the long-term average precipitation is subtracted from annual precipitation within each water year to develop the departure from mean precipitation for each water year. Wet years have a positive departure and dry years have a negative departure; a year with exactly average precipitation would have zero departure. Starting at the first year analyzed, the departures are added cumulatively for each year. So, if the departure for Year 1 is 5 inches and the departure for Year 2 is -2 inches, the cumulative departure would be 5 inches for Year 1 and 3 inches (5 plus -2) for Year 2. The cumulative departure of the spatially averaged of the rainfall within the Basin is shown on the figure. The cumulative departure from mean precipitation is based on these data sets and is displayed as a line that starts at zero and highlights wet periods with upward slopes and dry periods with downward slopes. More severe events are shown by steeper slopes and greater changes. Thus, the period from 2013 to 2014 illustrates a short period with a dramatically dry conditions (16-inch decline in cumulative departure over 2 years).

Figure 2.3-2: 50-Year Historical Precipitation and Cumulative Departure from Mean Precipitation in the Cuyama Valley Groundwater Basin



2.3.3 Usage of the IWFM Model and Associated Data in Water Budget Development

Water budgets were developed utilizing the Cuyama Basin IWFM model, a fully integrated surface and groundwater flow model that covers the entire Basin. The model integrates the groundwater aquifer with the surface hydrologic system and land surface processes and operations. The IWFM model was calibrated for the hydrologic period of October 1995 to September 2015 by comparing simulated evapotranspiration, groundwater levels, and streamflow records with historical observed records. Development of the model involved the study and analysis of hydrogeologic conditions, agricultural and urban water demands, agricultural and urban water supplies, and an evaluation of regional water quality conditions.

Additional information on the development and calibration of the IWFM model will be included as an appendix to the GSP.

IWFM model simulations were developed to allow for the estimation of water budgets. Model simulations were used to develop the water budgets for historical, current, and projected conditions, which are discussed in detail below:

- The **historical water budget** was based on a simulation of historical conditions in the Basin.
- The **current water budget** was based on a simulation of current (2015) land and water use over historical hydrologic conditions, assuming no other changes in population, water demands, land use, or other conditions.
- The **projected water budget** was based on a simulation of future land and water use over the historical hydrologic conditions. Since future land and water use in the Cuyama Basin is assumed to be the same as current conditions, the projected water budget is the same as the current water budget.

2.3.4 Water Budget Definitions and Assumptions

Definitions and assumptions for the historical, current, and projected water budgets are provided below. Table 2.3-1 provides a summary of the assumptions.

Historical Water Budget

The historical water budget is intended to evaluate availability and reliability of past surface water supply deliveries, aquifer response to water supply, and demand trends relative to water year type. The hydrologic period of 1998 through 2017 was selected for the historical water budget to provide a period of representative hydrology while capturing recent Basin operations. The period 1998 through 2017 has an average annual precipitation of 12.2 inches, nearly the same as the long-term average of 13.1 inches and includes the recent 2012-2017 drought, the wet years of 1998 and 2005, and periods of normal precipitation.

Current and Projected Water Budget

While a budget indicative of current conditions could be developed using the historical calibration model, like the historical water budget, such an analysis would be difficult to interpret due to the extreme weather conditions of the past several years and its effect on local agricultural operations. Instead, in order to analyze the effects of current land and water use on groundwater conditions and to accurately estimate current inflows and outflows for the basin, a current and projected conditions baseline scenario was developed using the IWFM model. This baseline uses current land and water use conditions approximating year 2017 conditions with a historical precipitation sequence. Because there is no basis to assume any changes in Cuyama Basin population or land use in the future as compared to current conditions (in the absence of projects or actions), a single baseline has been developed that reflects both current and projected conditions.

The current and projected conditions baseline includes the following conditions:

- Hydrologic period:
    - Water Years 1968-2017 (50-year hydrology)
- Precipitation is based on:
    - PRISM dataset for the 1968-2017 period
- Land use is based on:
    - Land use estimates developed by the DWR and the CBGSA using remote sensing data
    - Land use information for historical years provided by private landowners
- Domestic water use is based on:
    - Current population estimates
    - Cuyama Community Services District (CCSD) delivery records
- Agricultural water demand is based on:
    - The IWFM Demand Calculator (IDC) in conjunction with historical remote sensing technology, Mapping Evapotranspiration at High Resolution and Internalized Calibration (METRIC)

Table 2.3-1: Summary of Groundwater Budget Assumptions

Water Budget Type	Historical	Current and Projected
Scenario	Historical Simulation	Current and Projected Conditions Baseline
Hydrologic Years	WY 1998-2017	WY 1968-2017
Development	Historical	Current
Ag Demand	Historical Land Use	Current Conditions
Domestic Use	Historical Records	Current Conditions

2.3.5 Water Budget Estimates

Land surface and groundwater budgets are reported for the historical period and for current and projected conditions.

The following components are included in the land surface water budget:

- Inflows:
    - Precipitation
    - Applied Water

- Outflows:
  - Evapotranspiration
    - Agriculture
    - Native vegetation
  - Domestic water use
  - Deep percolation
    - From precipitation
    - From applied water
  - Runoff
    - Stream seepage to groundwater
    - Flow out of Basin

The following components are included in the groundwater budget:

- Inflows:
  - Deep percolation
  - Stream seepage
  - Subsurface inflow
- Outflows:
  - Groundwater pumping
- Reduction in storage

The estimated average annual water budgets are provided in Tables 2.3-2 and 2.3-3 for the historical period and for current and projected conditions. The following sections provide additional information regarding each water budget.

Table 2.3-2: Average Annual Land Surface Water Budget

Component	Historical Water Volume (AFY)	Current and Projected Water Volume (AFY)
Inflows		
Precipitation	226,000	230,000
Applied Water	58,000	59,000
Total Inflow	285,000	289,000
Outflows		
Evapotranspiration		
Agriculture	58,000	63,000
Native vegetation	167,000	174,000
Domestic water use	300	400
Deep percolation		
From precipitation	18,000	15,000
From applied water	10,000	11,000
Runoff	32,000	26,000
Total Outflow	285,000	289,000

Table 2.3-3: Average Annual Groundwater Budget

Component	Historical Water Volume (AFY)	Current and Projected Water Volume (AFY)
Inflows		
Deep percolation	28,000	25,000
Stream seepage	3,000	5,000
Subsurface inflow	5,000	5,000
Total Inflow	36,000	35,000
Outflows		
Groundwater pumping	59,000	60,000
Total Outflow	59,000	60,000
Change in Storage	(23,000)	(25,000)

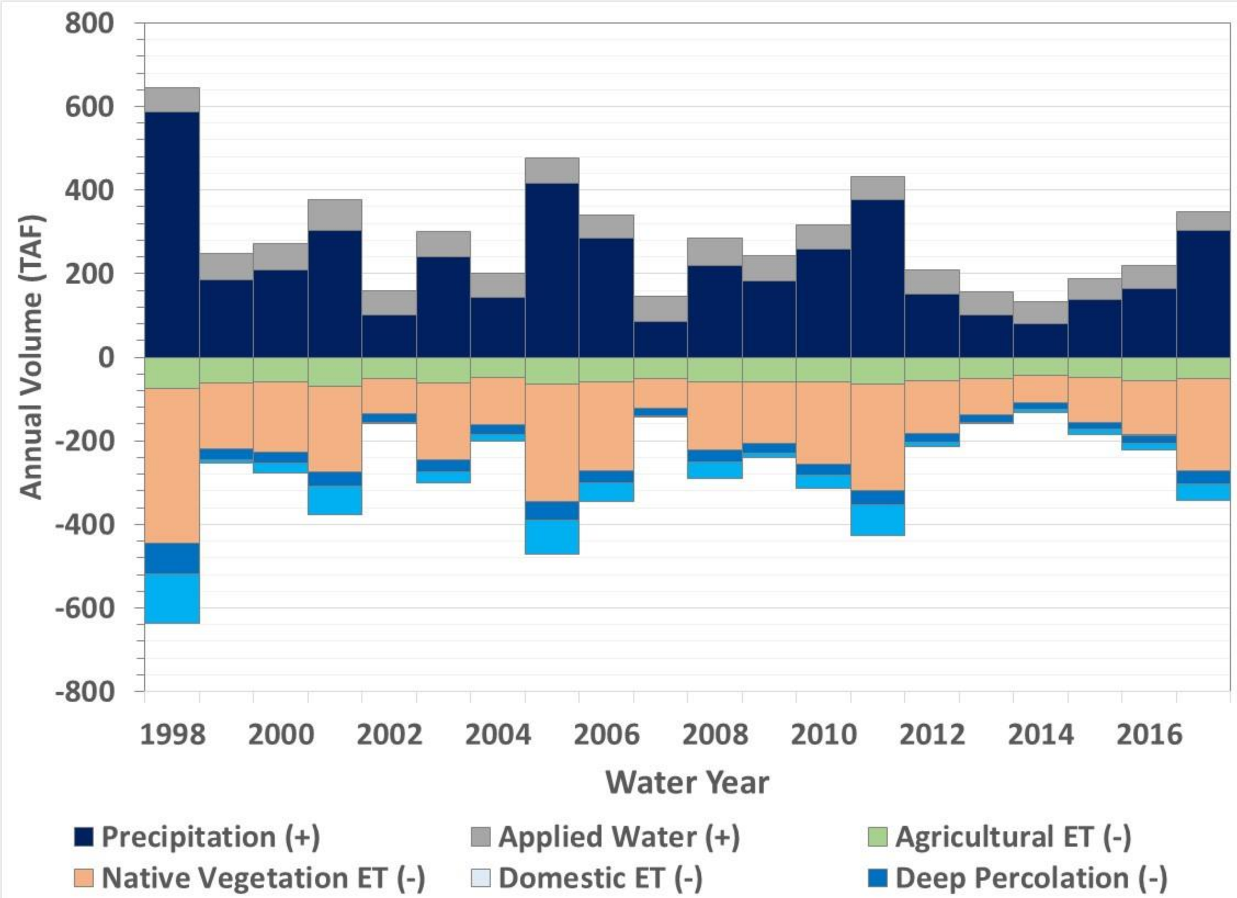
2.3.6 Historical Water Budget

The historical water budget is a quantitative evaluation of the historical surface and groundwater supply covering the 20-year period from 1998 to 2017. This period was selected as the representative hydrologic period to calibrate and reduce the uncertainty of the IWFM model. Proper analysis and calibration of water budgets within IWFM model ensures the hydrologic characteristics of the groundwater basin are accurately represented. The goal of the water budget analysis is to characterize the supply and demand, while summarizing the hydrologic flow within the Basin, including the movement of all primary sources of water such as rainfall, irrigation, streamflow, and subsurface flows.

Figure 2.3-3 summarizes the average annual historical land surface inflows and outflows in the Basin. Figure 2.3-4 shows the annual time series of historical land surface inflows and outflows.

Figure 2.3-3: Historical Average Annual Land Surface Water Budget

Figure 2.3-4: Historical Land Surface Water Budget Annual Time Series



The Basin experiences about 285,000 AF of inflows each year, of which 226,000 AF is from precipitation and the remainder is from applied water. About 225,000 AFY is consumed as evapotranspiration or domestic use, with the remainder either recharging the groundwater aquifer as deep percolation or stream seepage or leaving the Basin as river flow.

The annual time series shows large year-to-year variability in the availability of water, with land surface inflows ranging from a low of about 132,000 AF to a high of 645,000 AF. These year-to-year changes in inflows result in corresponding differences in outflows, with total annual agricultural, native vegetation and domestic evapotranspiration ranging from 108,000 AF to 444,000 AF.

Figure 2.3-5 summarizes the average annual historical groundwater inflows and outflows in the Basin. Figure 2.3-6 shows the annual time series of historical groundwater inflows and outflows. The Basin average annual historical groundwater budget has greater outflows than inflows, leading to an average annual decrease in groundwater storage of 23,000 AF. The groundwater storage decreases consistently over time, despite year-to-year variability in groundwater inflows.

Figure 2.3-5: Historical Average Annual Groundwater Budget

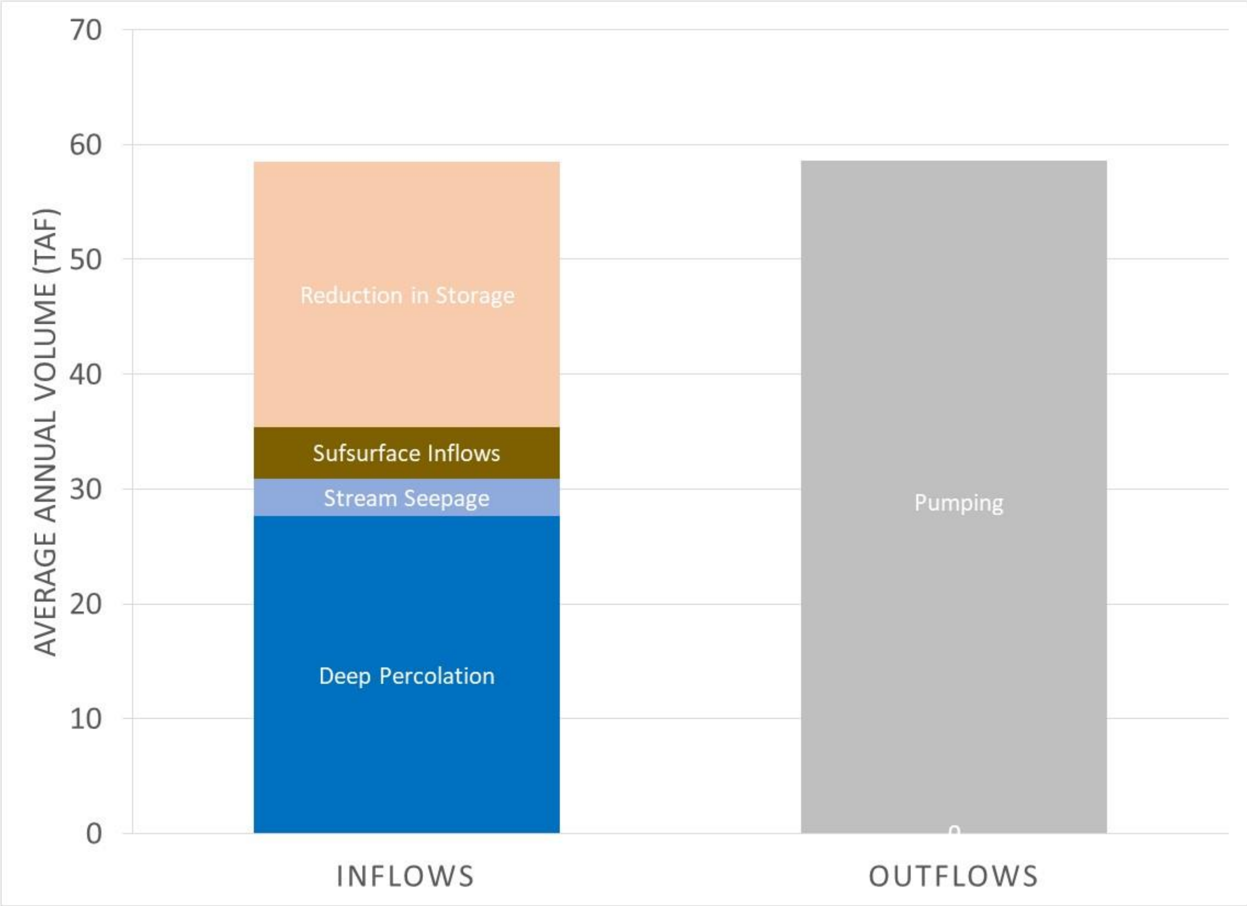
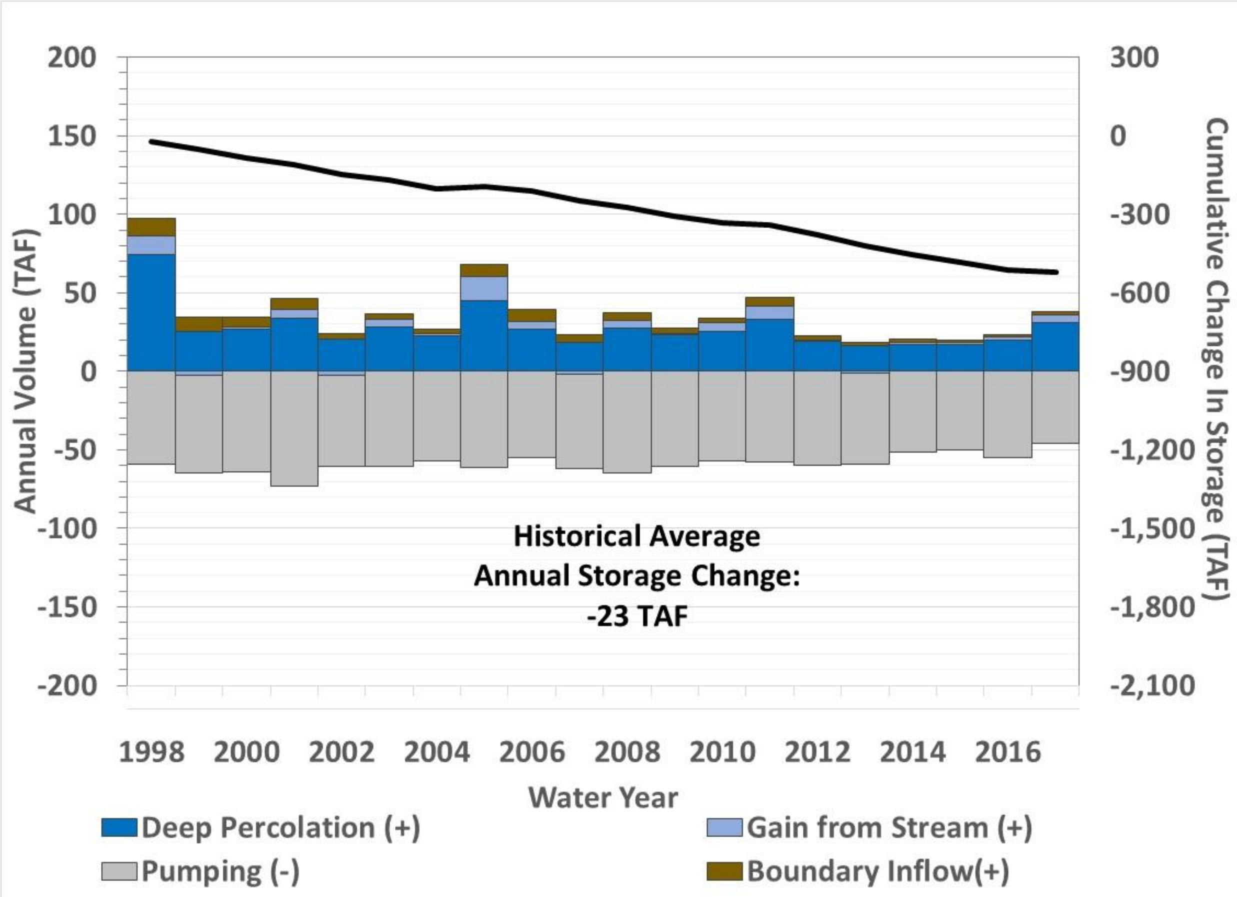


Figure 2.3-6: Historical Groundwater Budget Annual Time Series



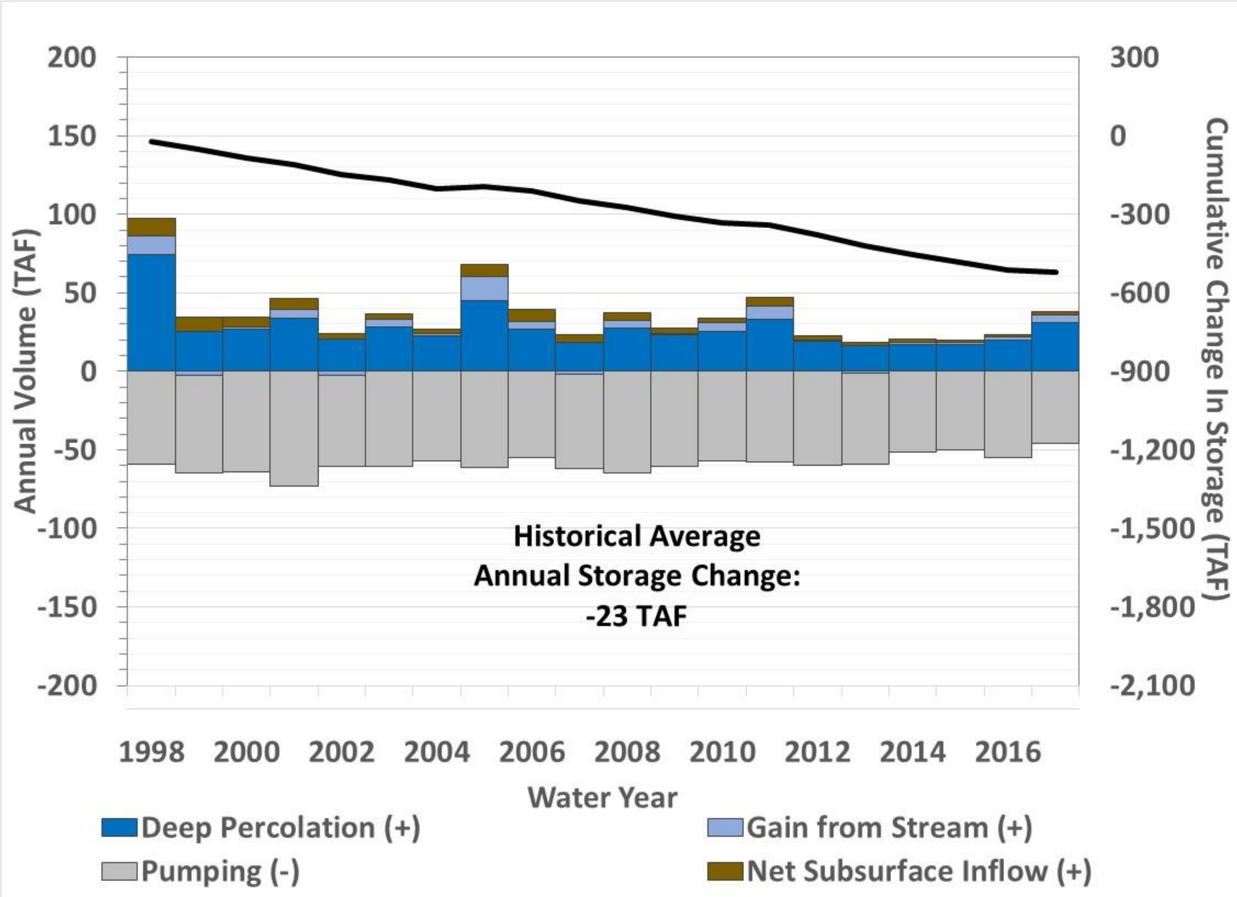
2.3.7 Current and Projected Water Budget

The current and projected water budget quantifies inflows to and outflows from the basin using 50-years of hydrology in conjunction with 2017 population, water use, and land use information.

Figure 2.3-7 summarizes the average annual current and projected land surface inflows and outflows in the Basin. Figure 2.3-8 shows the annual time series of current and projected land surface inflows and outflows.

Figure 2.3-7: Current and Projected Average Annual Land Surface Water Budget

Figure 2.3-8: Current and Projected Land Surface Water Budget Annual Time Series



Under current and projected conditions, the Basin experiences about 290,000 AF of inflows each year, of which 230,000 AF is from precipitation and the remainder is from applied water. About 238,000 AFY is consumed as evapotranspiration or domestic use, with the remainder either recharging the groundwater aquifer as deep percolation or stream seepage or leaving the Basin as river flow.

The annual time series shows the year-to-year variability in the availability of water, with land surface inflows ranging from a low of about 147,000 AF to a high of 628,000 AF. These year-to-year changes in inflows result in corresponding differences in outflows, with total annual agricultural, native vegetation and domestic evapotranspiration ranging from 127,000 AF to 429,000 AF.

Figure 2.3-9 summarizes the average annual historical groundwater inflows and outflows in the Basin. Figure 2.3-10 shows the annual time series of historical groundwater inflows and outflows. The Basin average annual historical groundwater budget has greater outflows than inflows, leading to an average annual decrease in groundwater storage of 25,000 AF. As with the historical conditions, the groundwater storage decreases consistently over time, despite year-to-year variability in groundwater inflows.

Figure 2.3-9: Current and Projected Average Annual Groundwater Budget

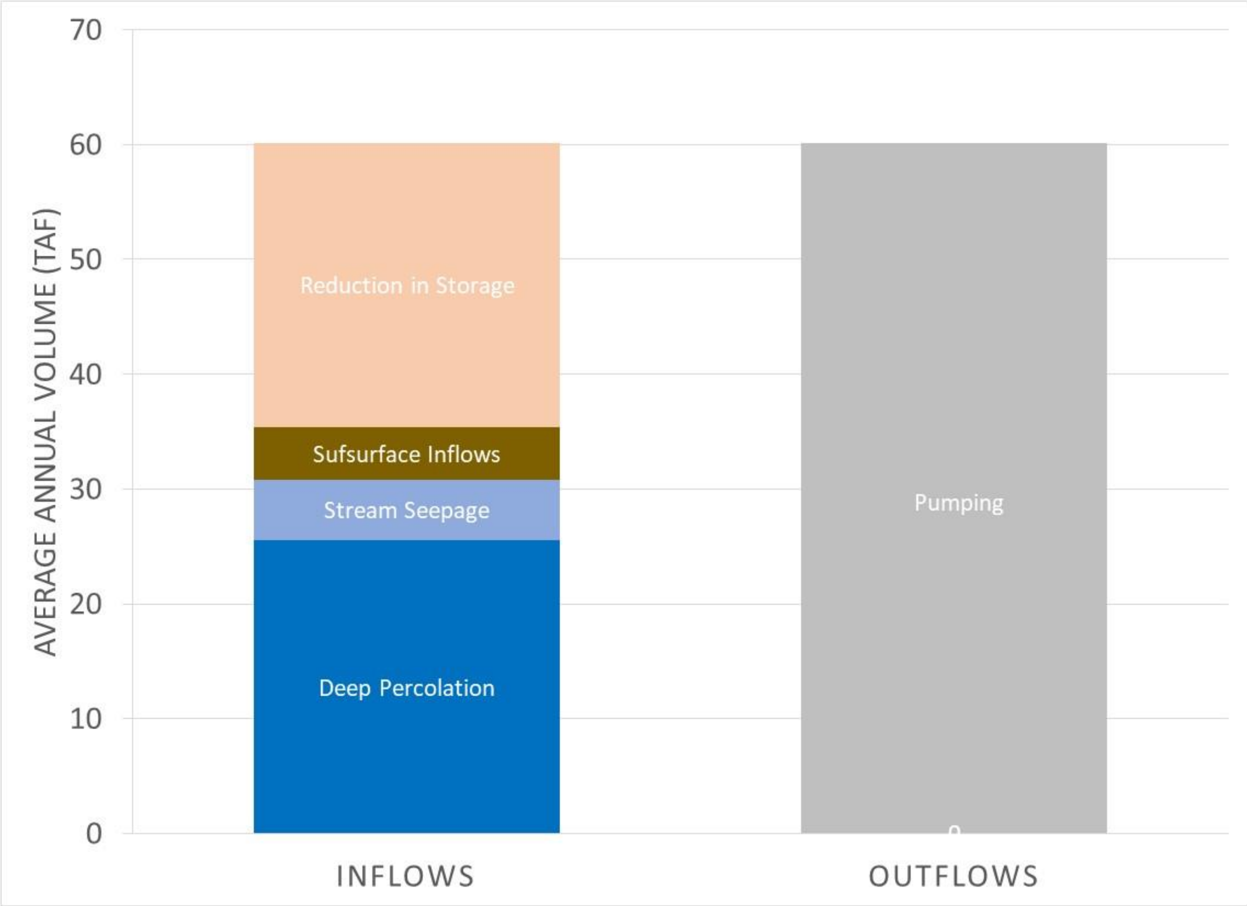
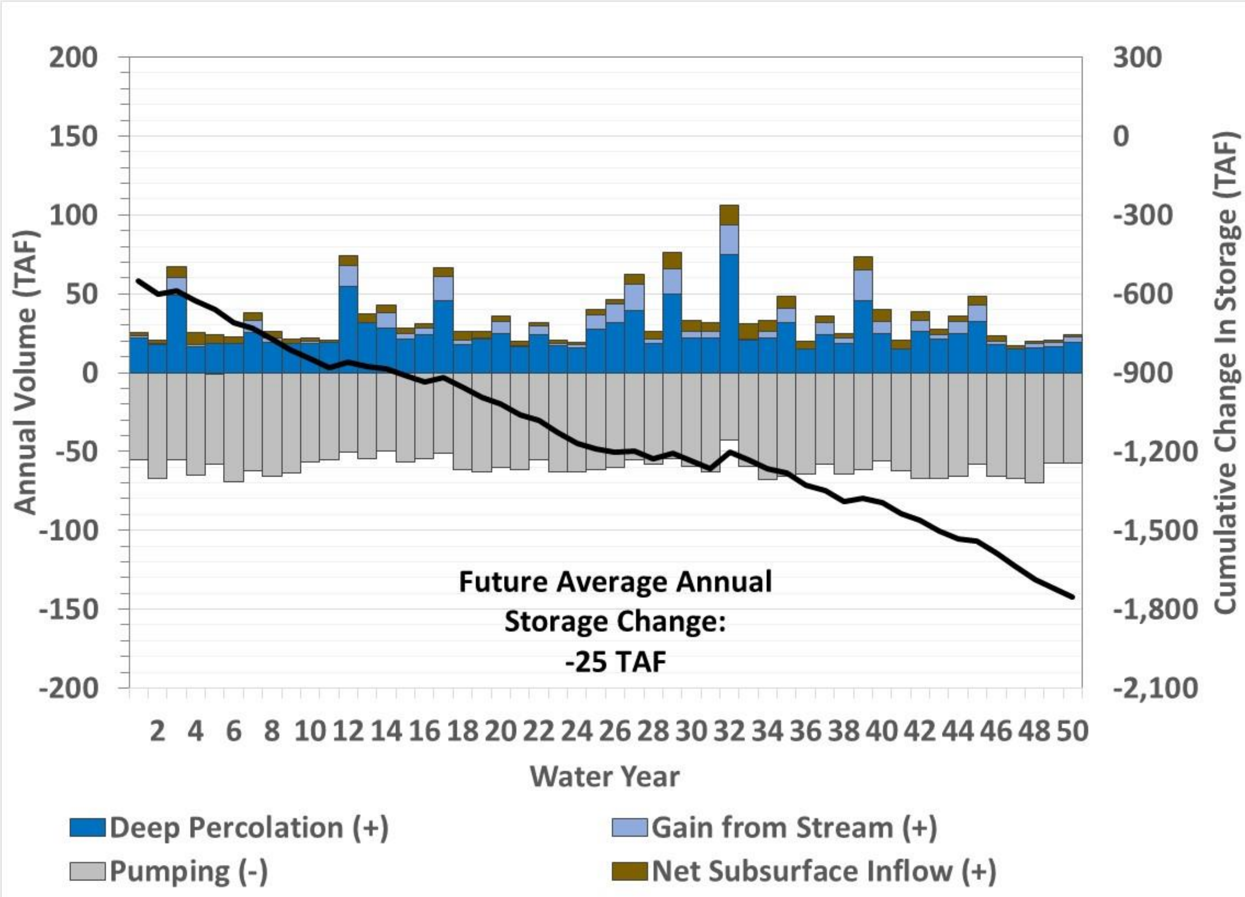


Figure 2.3-10: Current and Projected Groundwater Budget Annual Time Series



The current and projected water demand, water supply, and change in groundwater storage vary by water year type, as shown in Table 2.3-4. In wet years, precipitation meets a relative high proportion of the water demand, which reduces the need for groundwater. By contrast, in drier years more groundwater pumping is required to meet the agricultural demand not met by precipitation. This leads to an increase in groundwater storage in wet years and a decrease in the other year types.

Table 2.3-4: Current and Projected Average Annual Supply, Demand, and Change in Groundwater Storage by Water Year Type

Component	Water Year Type				
	Wet	Above Normal	Below Normal	Dry	Critical
Water Demand					
Agricultural ET	64,000	63,000	64,000	63,000	60,000
Domestic Use	500	400	400	300	200
Total Demand	64,000	63,000	64,000	63,000	60,000
Water Supply					
Groundwater Pumping	54,000	59,000	62,000	61,000	66,000
Total Supply	54,000	59,000	62,000	61,000	66,000
Change in Storage	18,000	(21,000)	(34,000)	(37,000)	(46,000)

2.3.8 Sustainable Yield Estimate

This section will be developed when the projects and management actions modeling analysis is complete.