TECHNICAL MEMORANDUM

TO: Merced Subbasin GSA Board
Merced Irrigation-Urban GSA Board
Turner Island Water District GSA #1 Board

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DATE: April 8, 2019 (update of March 5, 2019 TM)

RE: Water Budget for Merced Subbasin Groundwater Sustainability Plan

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Background

This memorandum summarizes the Water Budget that will be included as a section in the Merced Subbasin Groundwater Sustainability Plan (GSP), which satisfies § 354.18 of the Sustainable Groundwater Management Act (SGMA) Regulations. The Water Budget section is a portion of the Basin Settings part of a GSP. The Basin Settings contains three main subsections:

- Hydrogeologic Conceptual Model (HCM) – This section provides the geologic information needed to understand the framework of how water moves through 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, and 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.

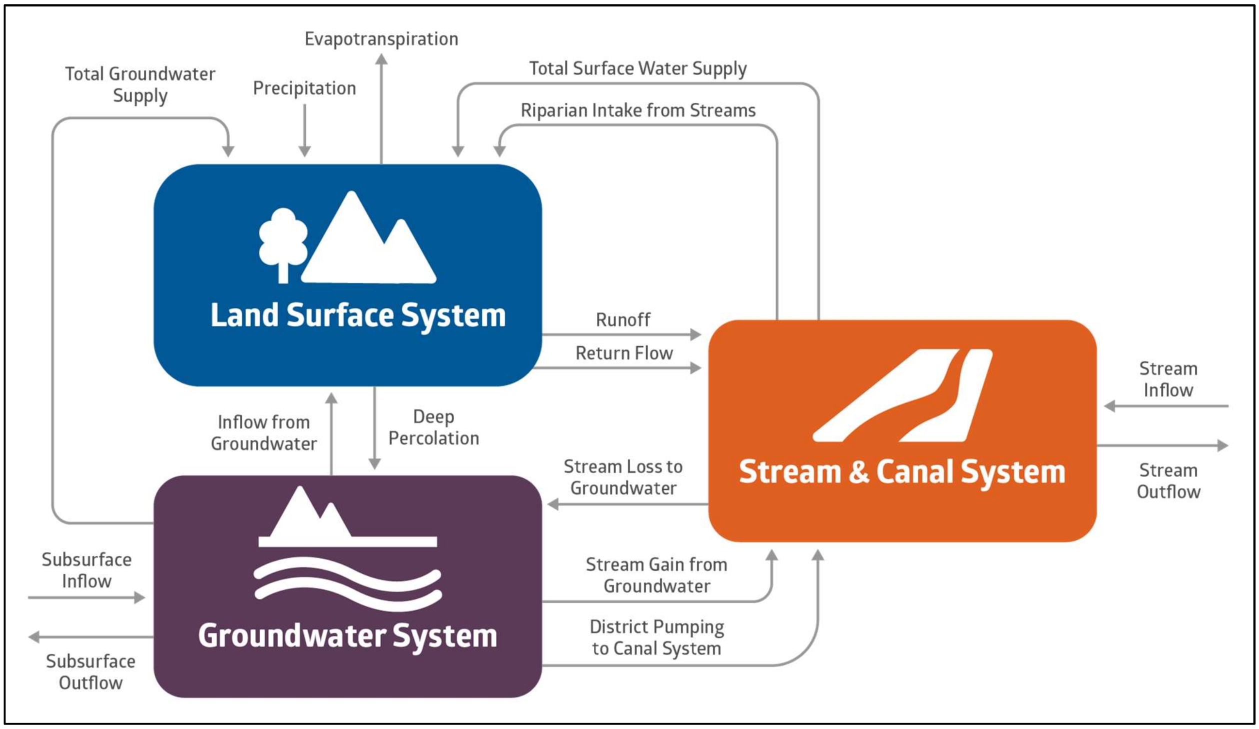
The HCM has already been through a review cycle with the Coordinating and Stakeholder Committees. The Groundwater Conditions section is currently under development and will be released for review when completed. Preliminary water budgets have been shown in presentations to the Coordinating and Stakeholder Committees, and GSA boards.

1.1 Water Budget Information

Water budgets were developed to provide a quantitative account of water entering and leaving the Merced Subbasin. Water entering the Subbasin includes water entering at the surface and through the subsurface. Similarly, water leaving the Subbasin 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 1 highlights the interconnectivity of stream, surface, and groundwater components of the natural and human related hydrologic system used 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 Merced Subbasin), groundwater and surface water interaction, and subsurface groundwater flow. This information can assist in management of the Subbasin, by identifying the scale of different uses, highlighting potential risks, and identifying potential opportunities to improve water supply conditions, among others.

Figure 1: Generalized Water Budget Diagram



Water budgets can be developed on different 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 land surface, stream, and groundwater systems, specifically for the Merced Subbasin.

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, water budgets are represented based on Water Year, with some consideration to monthly variability.

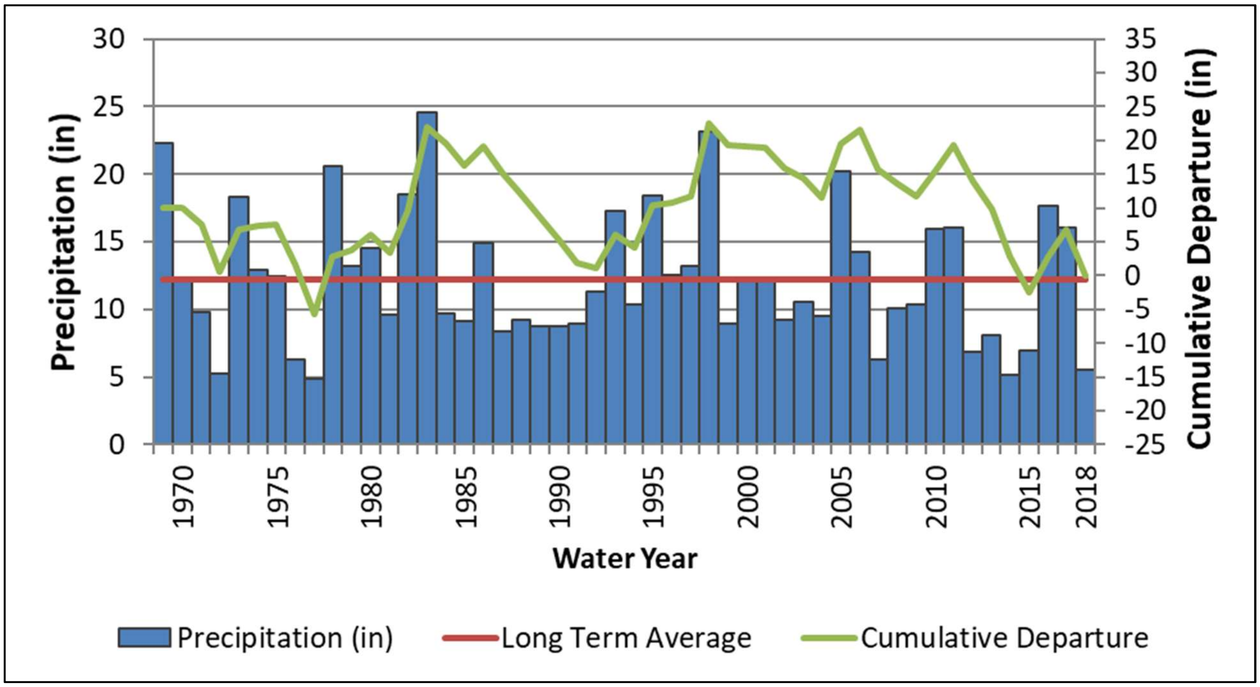
The Regulations require the annual water budgets be based on three different levels of development: historical, current, and projected conditions. Budgets are developed to capture typical conditions during these time periods. Typical conditions are developed through averaging hydrologic conditions that 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 Merced Water Resources Model (MercedWRM) and associated data in water budget development, and on the budget estimates.

1.2 Identification of Hydrologic Periods

Hydrologic periods were selected to meet the needs of developing historical, current, and projected water budgets. The Regulation requires that the projected water budget reflect a 50-year hydrologic period, in order to reflect long-term average hydrologic conditions. Precipitation for the Merced Subbasin was used to identify hydrologic periods that would provide a representation of wet and dry periods and long-term average conditions needed for water budget analyses.

Rainfall data for the Subbasin 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 by evaluating the cumulative departure from mean precipitation. 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. A chart is used to graphically illustrate the cumulative departure of the spatially averaged of the rainfall within the Merced Subbasin (Figure 2). The chart includes bars displaying annual precipitation for each water year from 1969 through 2018 and a horizontal line representing the mean precipitation of 12.2 inches. 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 1976 to 1977 illustrates a short period with a dramatically dry conditions (13-inch decline in cumulative departure over 2 years).

Figure 2: 50-Year Historical Precipitation and Cumulative Departure from Mean Precipitation, Merced, California



1.3 Usage of the MercedWRM and Associated Data in Water Budget Development

Water budgets were developed utilizing the MercedWRM, a fully integrated surface and groundwater flow model covering approximately 1,500 square miles of the Merced Groundwater Region (Region). The MercedWRM, a quasi-three-dimensional finite element model, was developed using the Integrated Water Flow Model (IWFM) 2015 software package to simulate the relevant hydrologic processes prevailing in the Region. The Model integrates the groundwater aquifer with the surface hydrologic system and land surface processes and operations. Using data from Federal, State, and local resources, the MercedWRM 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 analyses of hydrogeologic conditions, agricultural and urban water demands, agricultural and urban water supplies, and an evaluation of regional water quality conditions (RMC Water and Environment).

Additional information on the data used to develop the MercedWRM will be included as an appendix to the GSP.

With the MercedWRM as the underlying framework, model simulations were developed to allow for the estimation of water budgets. Three 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** is based on a simulation of historical conditions in the Merced Subbasin.
- The **current water budget** is 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** is based on a simulation of future land and water use over the historical hydrologic conditions.

1.4 Water Budget Definitions and Assumptions

Definitions and assumptions for the historical, current, and projected water budgets are provided below.

1.4.1 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 historical calibration of the Merced Water Resource Model was last updated to reflect the historical conditions in the Merced Subbasin through WY 2015. The hydrologic period of WY 2006 through 2015 is selected for the GSP historical water budget based on input from the stakeholder and coordinating committees, because it provides a period of representative hydrology, while capturing recent Subbasin operations, particularly the 2005 consolidation of El Nido Irrigation District into the MID service area. The period WY 2006 through 2015 has an average annual precipitation of approximately 10.0 inches, compared to the long-term average of 12.2 inches and includes the recent 2012-2015 drought, the wetter years of 2010-2011, and periods of normal precipitation.

As water years 1996-2015 were used to develop and calibrate the MercedWRM, along with being a longer period of hydrology, a 20-year period is also included in the detailed tables below for comparative purposes. Additional details of the data used in the development of the historical calibration model will be included as an appendix to the GSP.

1.4.2 Current Water Budget

While a budget indicative of current conditions could be developed using the most recent historical conditions, like the historical water budget, such an analysis would be difficult to interpret due to the drought conditions of the 2012-15 and its effect on local agricultural operations. Instead, in order to analyze the long-term effects of current land and water use on groundwater conditions and to accurately estimate current inflows and outflows for the basin, a Current Conditions Baseline scenario is developed using the MercedWRM. This baseline applies current land and water use conditions to historical hydrology.

The Current Conditions Baseline includes the following conditions:

- Hydrologic Period:
    - Water Years 1969-2018 (50-year hydrology)
- River Flow is Based on:
    - Merced River: MercedSIM releases from New Exchequer under the 2018 FERC Requirements
    - San Joaquin River and Local Tributaries: historical records from the United States Geological Survey (USGS), California Data Exchange Center (CDEC), MID stream gauges, and the simulation of small-stream watersheds
- Land Use is Based on:
    - 2013 United States Department of Agriculture's (USDA) CropScape Cropland Data Layer (CDL), which reflects the pre-drought conditions
    - Local ground truthing and refinement
- Urban Water Demand is Based on:
    - 2015 demands as reported in the 2015 Urban Water Management Plan (UWMP)
    - Municipal Pumping 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)
- Surface Water Deliveries Based on:
  - Merced Irrigation District (MID)
  - Stevinson Water District (SWD)
  - Merquin County Water District (MCWD)
  - Turner Island Water District (TIWD)
  - Lone Tree Mutual Water Company (LTMWC)

1.4.3 Projected Water Budget

The projected water budget is intended to assess the conditions of the Subbasin under estimate future and projected conditions of water supply, agricultural and urban demand, including quantification of uncertainties in the projected water budget components. The Projected Conditions Baseline applies future land and water use conditions and uses the 50-year hydrologic period of WY 2016-2065. The first twenty-five years of the Projected Conditions Baseline is assumed to be the implementation period of the GSP, and as such is represented using existing conditions; years 2040 and beyond are represented using projected population (General Plans), land use (General Plans), and water demand and supply projections (AWMP/UWMPs).

The Projected Conditions Baseline includes the following conditions:

- Hydrologic Period:
  - Water Years 1969-2018 (50-year hydrology)
- River Flow is Based on:
  - Merced River: MercedSIM releases from New Exchequer under FERC FEIS Requirements
  - San Joaquin River and Local Tributaries: historical records from the United States Geological Survey (USGS), California Data Exchange Center (CDEC), MID stream gauges, and the simulation of small-stream watersheds
- Land Use is Based on:
  - 2013 United States Department of Agriculture's (USDA) CropScape Cropland Data Layer (CDL)
  - 2015 Agricultural Water Management Plan projections
  - Direct communication on future projections with local agencies and farmers
- Urban Water Demand is Based on:
  - Decadal population projections from 2015 Urban Water Management Plans (UWMPs)
  - Projected GPCD calculated from historical pumping records with conservation reductions
- 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)

- Surface Water Deliveries Based on:
    - 2040 estimates provided by Merced Irrigation District (MID)
    - 2040 estimates provided by Stevinson Water District (SWD)
    - 2040 estimates provided by Merquin County Water District (MCWD)
    - 2040 estimates provided by Turner Island Water District (TIWD)
    - 2040 estimates provided by Lone Tree Mutual Water Company (LTMWC)

Table 1: Summary of Groundwater Budget Assumptions

Water Budget Type	Historical	Current	Projected
Tool	MercedWRM	MercedWRM	MercedWRM
Scenario	Historical Simulation	Current Conditions Baseline	Projected Conditions Baseline
Hydrologic Years	WY 2006-2015	WY 1969-2018	WY 1969-2018
Level of Development	Historical	Current	General Plan buildout
Agricultural Demand	Historical Records	Current Conditions	Projected based on local AWMP data
Urban Demand	Historical Records	Current Conditions	Projected based on local UWMP data
Water Supplies	Historical Records	Current Conditions	Projected based on local reservoir operations model

1.5 Water Budget Estimates

The MercedWRM is an integrated groundwater model and simulates the major hydrologic processes that affect the land surface, stream, and groundwater flows in the Merced Subbasin.

The primary components of the stream and canal system are:

- Inflows:
    - Stream inflows
    - Stream gain from the groundwater system
    - Surface runoff to the stream system
    - Return flow to stream system
    - Groundwater pumping to canal systems
- Outflows:
    - San Joaquin river outflows

  - Stream losses to groundwater
  - Surface water deliveries
  - Groundwater delivery via canal system
  - Riparian uptake from streams

The primary components of the land surface system are:

- Inflows:
  - Precipitation
  - Surface water supplies
  - Groundwater supplies
  - Riparian uptake from streams
  - Inflow from the groundwater system
- Outflows:
  - Evaporation
  - Surface runoff to the stream system
  - Return flow to the stream system
  - Deep percolation

The primary components of the groundwater system are:

- Inflows:
  - Deep percolation
  - Stream losses to the groundwater system
  - Subsurface inflow
- Outflows:
  - Stream gain from the groundwater system
  - Groundwater production
  - Subsurface outflow
- Change in groundwater storage

The estimated water budgets are provided below for the historical, current, and projected water budgets. Detailed results are summarized in Table 2 through Table 4.

Table 2: Average Annual Water Budget – Stream and Canal Systems, Merced Subbasin (AFY)

Component	Historical Condition Water Budget	Historical Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget
Hydrologic Period	**WY 1996- 2015**	**WY 2006- 2015**	**WY 1969 - 2018**	**WY 1969 - 2018**
Inflows				
Stream Inflows	2,050,000	1,731,000	2,480,000	2,480,000
Merced River	980,000	892,000	981,000	981,000
East Side Bypass	644,000	442,000	773,000	773,000
San Joaquin River	300,000	295,000	581,000	581,000
Chowchilla River	59,000	54,000	72,000	72,000
Local Tributaries[1]	67,000	48,000	74,000	74,000
Stream Gain from Groundwater	49,000	42,000	51,000	49,000
Merced Subbasin	30,000	26,000	31,000	29,000
Merced River	7,000	6,000	10,000	9,000
East Side Bypass	1,000	1,000	1,000	1,000
San Joaquin River	9,000	8,000	7,000	7,000
Chowchilla River	1,000	2,000	2,000	2,000
Local Tributaries[1]	11,000	10,000	11,000	11,000
Other Subbasins[2]	20,000	17,000	21,000	20,000
Merced River	9,000	7,000	11,000	10,000
San Joaquin River	8,000	7,000	6,000	6,000
Chowchilla River	3,000	3,000	3,000	3,000
Surface Runoff to the Streams	322,000	244,000	355,000	357,000
Merced Subbasin	188,000	147,000	204,000	206,000
Other Subbasins[2]	133,000	97,000	151,000	151,000
Return Flow to Streams	102,000	106,000	126,000	143,000
Merced Subbasin	75,000	74,000	63,000	79,000
Other Subbasins[2]	27,000	32,000	62,000	64,000
Groundwater Pumping to Canals	49,000	61,000	45,000	45,000
Other[3]	*62,000*	*85,000*	*33,000*	*32,000*
Total Inflow	***2,634,000***	***2,270,000***	***3,090,000***	***3,105,000***
Outflows				
San Joaquin River Outflows	1,946,000	1,603,000	2,341,000	2,360,000
Stream Losses to Groundwater	332,000	349,000	389,000	401,000
Merced Subbasin	260,000	272,000	312,000	318,000
Merced River	45,000	48,000	37,000	42,000
East Side Bypass	28,000	29,000	39,000	44,000
San Joaquin River	23,000	25,000	34,000	36,000
Chowchilla River	2,000	2,000	2,000	2,000
Local Tributaries[1]	45,000	40,000	50,000	52,000
Canal Recharge	116,000	129,000	149,000	141,000
Other Subbasins[2]	72,000	77,000	77,000	83,000
Merced River	45,000	48,000	37,000	42,000

San Joaquin River	26,000	27,000	38,000	39,000
Chowchilla River	1,000	1,000	2,000	2,000
Surface Water Deliveries	282,000	232,000	290,000	274,000
Groundwater Delivery via Canals	49,000	61,000	45,000	45,000
Riparian Uptake from Streams	25,000	25,000	25,000	25,000
Merced Subbasin	18,000	16,000	15,000	14,000
Other Subbasins	6,000	9,000	10,000	11,000
Total Outflow	***2,634,000***	***2,270,000***	***3,090,000***	***3,105,000***

Notes:

[1]Local Tributaries include Bear Creek, Black Rascal Creek, Deadman Creek, Duck Slough, Dutchman Creek Mariposa Creek, Miles Creek, and Owens Creek.

[2]Other Subbasins include the Turlock, Chowchilla, and Delta-Mendota Subbasins. As supporting data was not available, modeling inputs such as curve number and return flow fractions were assumed to be similar to those used in the Merced Subbasin.

[3]Other flows is a closure term that captures the stream and canal system include gains and losses not directly measured or simulated within IWFM. Some of these features include but may not be limited to direct precipitation, evaporation, unmeasured riparian diversions and return flow, temporary storage in local lakes and regulating reservoirs, and inflow discrepancies resulting from simulating impaired flows.

Table 3: Average Annual Water Budget – Land Surface System, Merced Subbasin (AFY)

Component	Historic Condition Water Budget	Historic Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget
Hydrologic Period	**WY 1996- 2015**	**WY 2006- 2015**	**WY 1969 - 2018**	**WY 1969 - 2018**
Inflows				
Precipitation	*475,000*	*404,000*	*506,000*	*506,000*
Total Surface Water Supply	*282,000*	*232,000*	*290,000*	*274,000*
Surface Water - Local	*235,000*	*187,000*	*244,000*	*229,000*
Surface Water - Riparian	*47,000*	*45,000*	*46,000*	*46,000*
Total Groundwater Supply	*612,000*	*723,000*	*598,000*	*660,000*
Agricultural - Agency	*49,000*	*61,000*	*45,000*	*45,000*
Agricultural - Private	*484,000*	*580,000*	*490,000*	*526,000*
Urban - Municipal	*44,000*	*44,000*	*36,000*	*50,000*
Urban - Domestic	*34,000*	*37,000*	*28,000*	*39,000*
Riparian Uptake from Streams	*18,000*	*16,000*	*15,000*	*14,000*
Inflow from Groundwater System	*12,000*	*11,000*	*12,000*	*12,000*
Total Inflow	***1,399,000***	***1,386,000***	***1,420,000***	***1,466,000***
Outflows				
Evapotranspiration	*821,000*	*847,000*	*834,000*	*853,000*
Agricultural	*641,000*	*683,000*	*661,000*	*682,000*
Municipal and Domestic	*41,000*	*42,000*	*31,000*	*37,000*
Refuge, Native, and Riparian	*139,000*	*122,000*	*142,000*	*134,000*
Runoff to the Stream System	*188,000*	*147,000*	*204,000*	*206,000*
Return Flow to the Stream System	*75,000*	*74,000*	*63,000*	*79,000*
Agricultural	*28,000*	*25,000*	*25,000*	*26,000*
Municipal and Domestic	*47,000*	*49,000*	*38,000*	*54,000*
Deep Percolation	*314,000*	*316,000*	*318,000*	*327,000*
Precipitation	*76,000*	*67,000*	*81,000*	*79,000*
Surface Water	*75,000*	*60,000*	*78,000*	*73,000*
Surface Water - Local	*62,000*	*49,000*	*65,000*	*61,000*
Surface Water - Riparian	*12,000*	*12,000*	*12,000*	*12,000*
Groundwater	*163,000*	*188,000*	*160,000*	*175,000*
Agricultural - Agency	*13,000*	*16,000*	*12,000*	*12,000*
Agricultural - Private	*129,000*	*151,000*	*131,000*	*139,000*
Urban - Municipal	*12,000*	*12,000*	*10,000*	*13,000*
Urban - Private	*9,000*	*10,000*	*7,000*	*10,000*
Other[1]	*1,000*	*1,000*	*1,000*	*1,000*
Total Outflow	***1,399,000***	***1,386,000***	***1,420,000***	***1,466,000***

Notes:

[1]Other flows is a closure term that captures the gains and losses due to land expansion and seasonal storage in the root-zone.

Table 4: Average Annual Water Budget – Groundwater System, Merced Subbasin (AFY)

Component	Historic Condition Water Budget	Historic Condition Water Budget	Current Condition Water Budget	Projected Condition Water Budget
Hydrologic Period	**WY 1996- 2015**	**WY 2006- 2015**	**WY 1969 - 2018**	**WY 1969 - 2018**
Inflows				
Deep Percolation	314,000	316,000	318,000	327,000
Precipitation	76,000	67,000	81,000	79,000
Surface Water	75,000	60,000	78,000	73,000
Surface Water - Local	62,000	49,000	65,000	61,000
Surface Water - Riparian	12,000	12,000	12,000	12,000
Groundwater	163,000	188,000	160,000	175,000
Agricultural - Agency	13,000	16,000	12,000	12,000
Agricultural - Private	129,000	151,000	131,000	139,000
Urban - Municipal	12,000	12,000	10,000	13,000
Urban - Private	9,000	10,000	7,000	10,000
Stream Losses to Groundwater	260,000	272,000	312,000	318,000
Merced River	45,000	48,000	37,000	42,000
East Side Bypass	28,000	29,000	39,000	44,000
San Joaquin River	23,000	25,000	34,000	36,000
Chowchilla River	2,000	2,000	2,000	2,000
Local Tributaries[1]	45,000	40,000	50,000	52,000
Canal Recharge	116,000	129,000	149,000	141,000
Subsurface Inflow	70,000	75,000	69,000	79,000
Total Inflow	***643,000***	***663,000***	***700,000***	***723,000***
Outflows				
Stream Gain from Groundwater	30,000	26,000	31,000	29,000
Merced River	7,000	6,000	10,000	9,000
East Side Bypass	1,000	1,000	1,000	1,000
San Joaquin River	9,000	8,000	7,000	7,000
Chowchilla River	1,000	2,000	2,000	2,000
Local Tributaries	11,000	10,000	11,000	11,000
Groundwater Production	612,000	723,000	598,000	660,000
Agricultural - Agency	49,000	61,000	45,000	45,000
Agricultural - Private	484,000	580,000	490,000	526,000
Urban - Municipal	44,000	44,000	36,000	50,000
Urban - Private	34,000	37,000	28,000	39,000
Subsurface Outflow[2]	96,000	92,000	110,000	103,000
Outflow to Land Surface System	12,000	11,000	12,000	12,000
Other[3]	*2,000*	3,000	*1,000*	*1,000*
Total Outflow	***752,000***	***855,000***	***752,000***	***805,000***
Change in Storage	***-109,000***	***-192,000***	***-52,000***	***-82,000***

Notes:

[1]Local Tributaries include Bear Creek, Black Rascal Creek, Deadman Creek, Duck Slough, Dutchman Creek Mariposa Creek, Miles Creek, and Owens Creek.
[2]The goal of projecting interbasin flows is to maintain a reasonable balance between the neighboring Subbasins. The results are within 10-12%, which is within the reasonable range, given the availability of projected land use, population, surface water delivery, and groundwater production data from areas outside of the Merced Subbasin.
[3]Other flows within the groundwater system including temporary storage in the vadose zone, and root water uptake from the aquifer system.

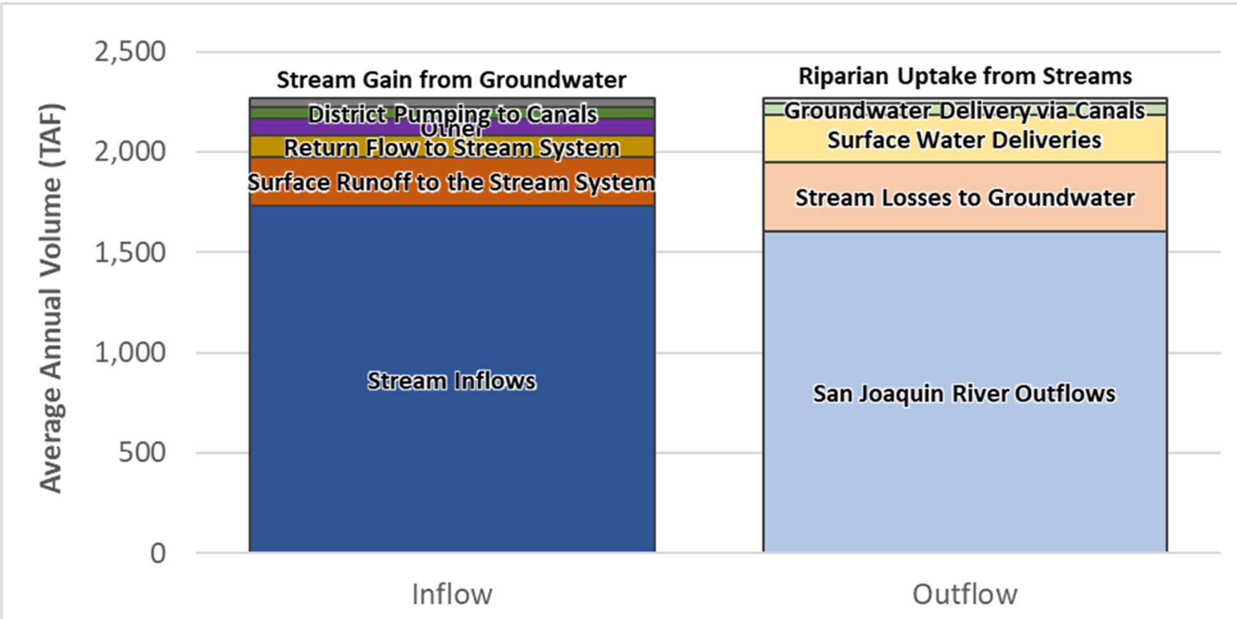
1.5.1 Historical Water Budget

The historical water budget is a quantitative evaluation of the historical surface and groundwater supply covering the 20-year period from WY 1996 to 2015. This period was selected as the representative hydrologic period to calibrate and reduce the uncertainty of the MercedWRM. Proper analysis and calibration of water budgets within the MercedWRM 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 Subbasin, including the movement of all primary sources of water such as rainfall, irrigation, streamflow, and subsurface flows.

The existing stream and canal network supplies multiple water users and agencies in the Merced Groundwater Subbasin, including Merced Irrigation District (MID), Stevinson Water District (SWD), Merquin County Water District (MCWD), Turner-Island Water District (TIWD), and Lone Tree Mutual Water Company (LTMWC). When analyzing the stream and canal system, it is important to note potentially significant effects resulting from the natural interactions and managed operations of adjacent groundwater subbasins. Because of this, the water budget in Table 1 and Figure 3 below attempt to not only quantify surface and canal system flows within the Merced Subbasin, but also estimate contributions from adjoining areas.

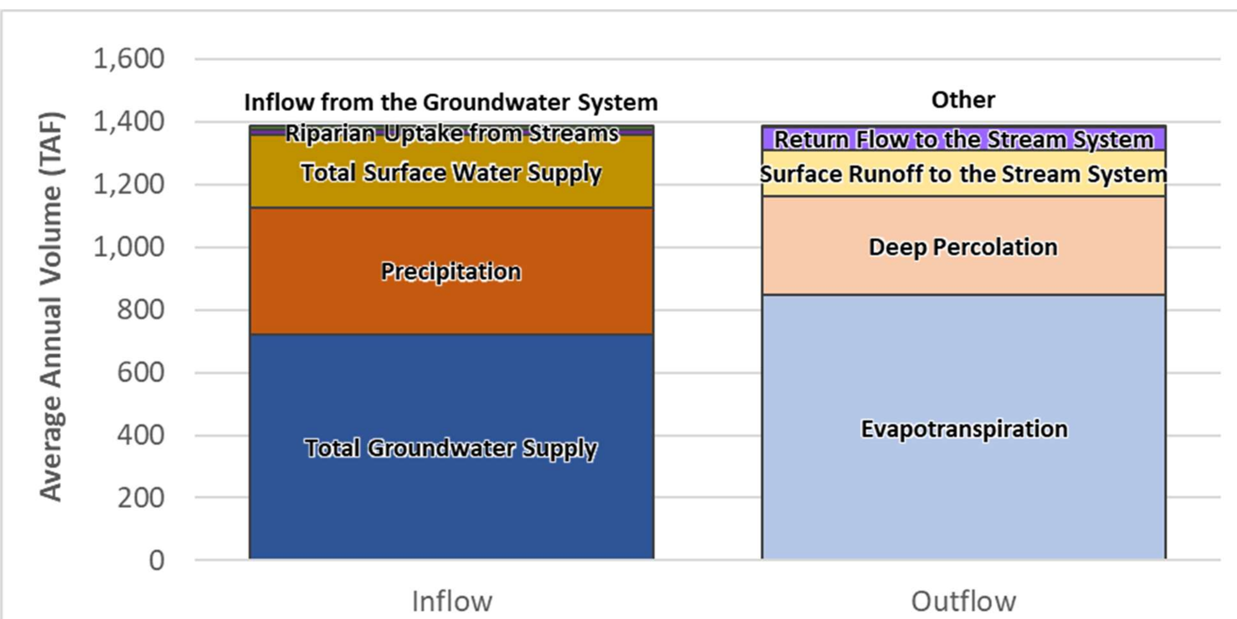
Average annual surface water inflows of 2,268,000 AF travel through or along the Subbasin boundary. The majority of these flows enter the subbasin through inflows from natural streams and the East Side Bypass (1,731,000 AF) and are supplemented by surface runoff (244,000 AF), return flow (106,000 AF), natural groundwater contributions (42,000 AF), and groundwater pumping from local water agencies (60,000 AF). Outflows of the Merced Subbasin stream and canal system total 2,269,000 AF and include downstream flow from the San Joaquin River (1,603,000 AF), stream losses to the aquifer system (349,000 AF), surface water deliveries (232,000 AF), groundwater delivered via local canal systems (60,000 AF), and riparian uptake (25,000 AF).

Figure 3: Historical Average Annual Water Budget – Stream and Canal Systems, Merced Subbasin



The land surface system of the Merced Subbasin, shown below in Figure 4, experiences 1,386,000 acre-feet of inflows each year, a combination of precipitation (404,000 AF), surface water deliveries (232,000 AF), groundwater pumping (723,000 AF), riparian uptake from the stream system (16,000 AF), and natural inflow from the aquifer system (11,000 AF). Equivalent to the inflows in magnitude, outflows from the land surface system are comprised of evapotranspiration (847,000 AF), surface runoff (147,000 AF) and return flow (74,000 AF) to the stream and canal system, and deep percolation (316,000 AF).

Figure 4: Historical Average Annual Water Budget – Land Surface System, Merced Subbasin

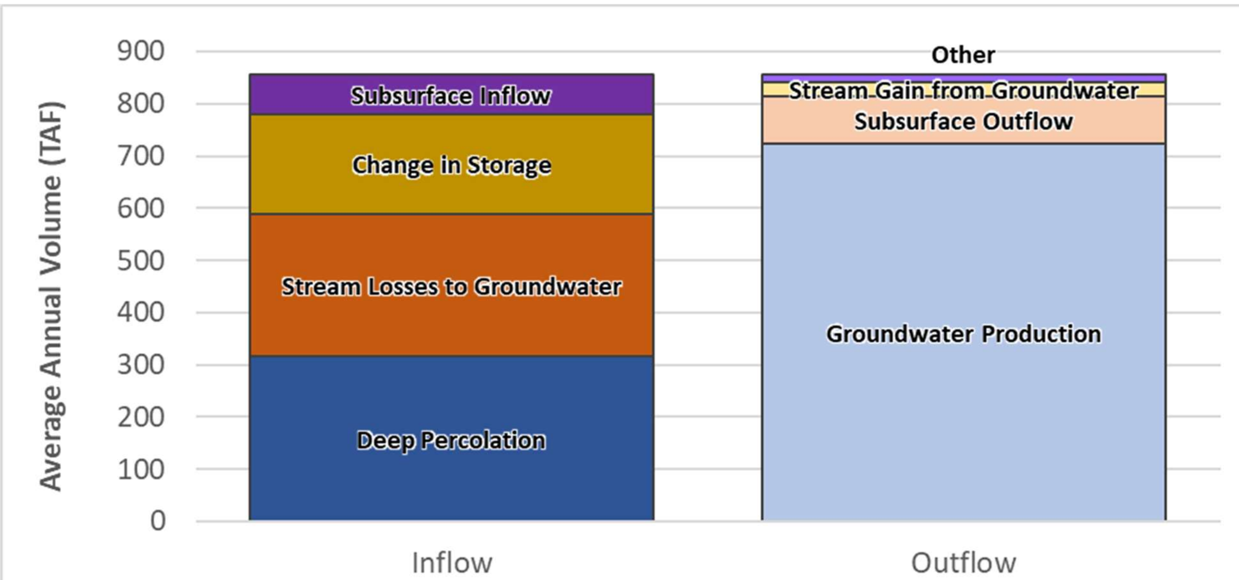


The groundwater system of the Merced Subbasin experiences over 855,000 acre-feet of inflows each year, of which 316,000 AF is surface infiltration. There is also recharge from rivers streams, and canals (272,000 AF), and subsurface inflows (75,000 AF) from the Sierra Nevada foothills and the neighboring subbasins of Turlock, Delta-Mendota, and Chowchilla.

On average, the inflows do not meet the entire groundwater demand. The primary outflow of the groundwater system is pumping (723,000 AF), followed by subsurface flow into neighboring subbasins (92,000 AF) and losses due to local stream-groundwater interaction (26,000 AF).

The Merced Subbasin average historical groundwater budget has greater outflows than inflows, leading to an average annual decrease in groundwater storage of 192,000 acre-feet. **Error! Reference source not found.**Figure 5 summarizes the average historical groundwater inflows and outflows in the Merced Subbasin.

Figure 5: Historical Average Annual Water Budget – Groundwater System, Merced Subbasin



The historical inflows and outflows change by water year type. In wet years, precipitation meets some of the water demand, and greater availability to surface water reduces the need for groundwater. However, in dry years, more groundwater is pumped to meet the agricultural demand not met by surface water or precipitation. This leads to an increase in groundwater storage in wet years and a decrease in dry years. While demand of applied water increases in dry years due to lack of precipitation, surface water supply remains consistent in most non-critical years. Note the surface water supply in this water budget is reflective of the volume available to the grower, and thus does not include including operational spills, canal seepage or evaporative losses. Table 5 breaks down the average historical water supply and demand by water year type.

Table 5: Average Annual Values for Key Components of Water Budget by Year Type(AFY)

Component	Water Year Type (San Joaquin River Index)					
	Wet	Above Normal	Below Normal	Dry	Critical	10-Year Average WY 2005-15
Water Demand						
Ag Demand	790,000	873,000	824,000	917,000	907,000	873,000
Urban Demand	81,000	82,000	80,000	83,000	82,000	82,000
Total Demand	***871,000***	***955,000***	***904,000***	***1,000,000***	***990,000***	***955,000***
Water Supply						
Total Surface Water Supply	309,000	306,000	269,000	319,000	161,000	232,000
Local	263,000	262,000	217,000	266,000	118,000	186,000
Riparian	46,000	44,000	52,000	53,000	42,000	45,000
Total Groundwater Supply	562,000	649,000	634,000	681,000	829,000	723,000
Agricultural - Agency	29,000	32,000	46,000	41,000	87,000	61,000
Agricultural - Private	452,000	535,000	509,000	557,000	659,000	580,000
Urban - Municipal	44,000	45,000	44,000	45,000	45,000	44,000
Urban - Domestic	37,000	37,000	36,000	38,000	37,000	37,000
Total Supply	***871,000***	***955,000***	***904,000***	***1,000,000***	***990,000***	***955,000***
Change in GW Storage	***49,000***	***-46,000***	***-121,000***	***-185,000***	***-333,000***	***-191,900***

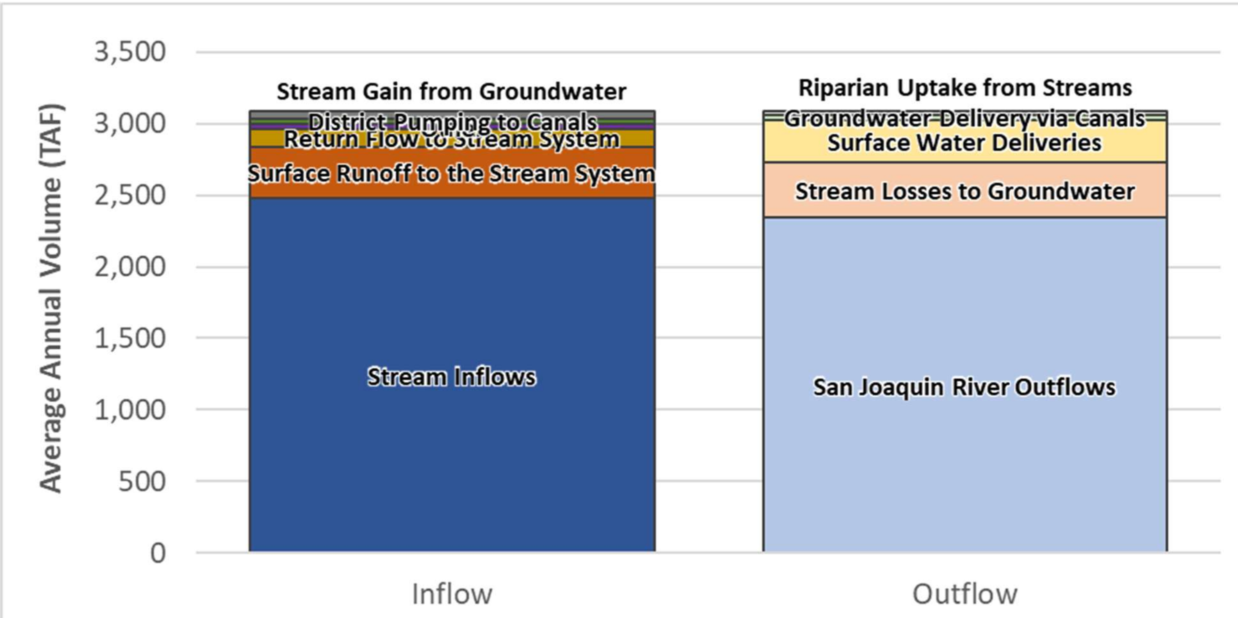
1.5.2 Current Water Budget

The current water budget quantifies inflows to and outflows from the basin using 50-years of hydrology in conjunction with 2015 water supply, demand, and land use information. These conditions are incorporated in the Current Conditions Baseline simulation of the MercedWRM.

The stream and canal system in the Current Conditions Baseline supplies agricultural users with an average of 290,000 acre-feet in surface water diversions from local streams with an additional 45,000 acre-feet of pumping by local surface water purveyors supplementing their conveyance system. In addition to these volumes, on average, 2,341,000 AFY leaves the Subbasin’s surface water features as downstream flow in the San Joaquin River, 389,000 AFY is lost to the groundwater system, and 25,000 AFY is used by riparian vegetation as direct-uptake.

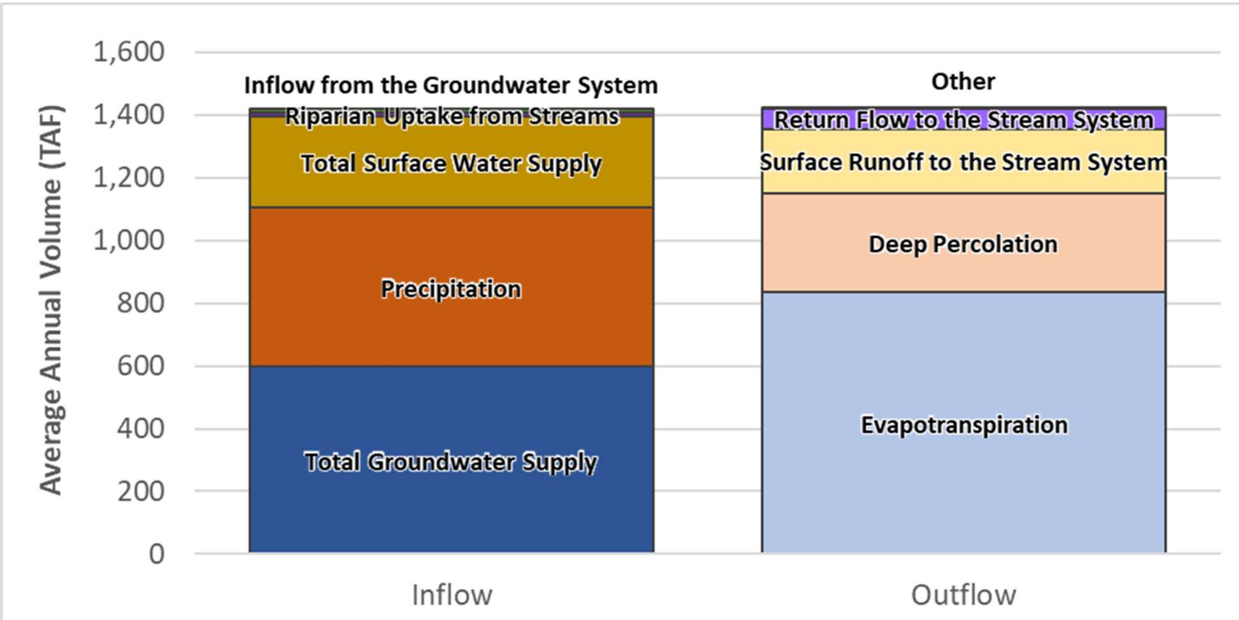
These demands are fed by 2,480,000 AFY of local stream inflow, 355,000 AFY of surface runoff, 126,000 of return flow, 51,000 AFY of groundwater contributions, 45,000 AFY of district pumping, and 33,000 AFY of uncategorized flows. Figure 6 summarizes the average annual inflows and outflow of the Current Conditions Baseline in the Merced Subbasin surface water network.

Figure 6: Current Conditions Average Annual Water Budget – Stream and Canal Systems, Merced Subbasin



Based on pre-drought cropping patterns and 2015 urban buildout, over the simulation period, the Current Conditions land surface water budget simulates annual inflows of 1,421,000 AF, including 506,000 AF of precipitation, 880,000 AF of applied water (290,000 AF of surface water and 598,000 AF of groundwater), 15,000 AF of riparian uptake from the stream system, and 12,000 AF of inflow from the groundwater system. To balance the Current Conditions Baseline land surface water budget, the 1,420,000 of outflows include evapotranspiration (834,000 AF), surface runoff to the stream system (204,000 AF), return flow to the stream system (63,000 AF), deep percolation (318,000 AF), and other flows (1,000 AF).**Error! Reference source not found.** Figure 7 summarizes the average annual current condition inflows and outflows in the land surface budget for the Merced Subbasin.

Figure 7: Current Conditions Average Annual Water Budget – Land Surface System, Merced Subbasin



The Current Conditions Baseline simulates 50 years of hydrology whose initial conditions are reflective of the start of the 2016 water year. Over the simulation period, the Current Conditions groundwater water budget simulates annual inflows of 700,000 AF, including 318,000 AF of deep percolation, 312,000 AF of stream and canal seepage, and subsurface inflows totaling 69,000 AF.

Similar to the historical water budget, average aquifer outflows exceed the inflows under existing conditions. Groundwater production (598,000 AF) remains the largest point of aquifer discharge, with subsurface depletions (110,000 AF), losses to the local stream system (31,000 AF), and other flows (13,000 AF) bringing the total system outflows to 752,000 acre-feet annually.

The Merced Subbasin existing conditions groundwater budget has greater outflows than inflows, resulting in an average annual deficit in groundwater storage of 52,000 acre-feet. Figure 8**Error! Reference source not found.** summarizes the average current conditions groundwater inflows and outflows in the Merced Subbasin.

Figure 8: Current Conditions Average Annual Water Budget – Groundwater System, Merced Subbasin

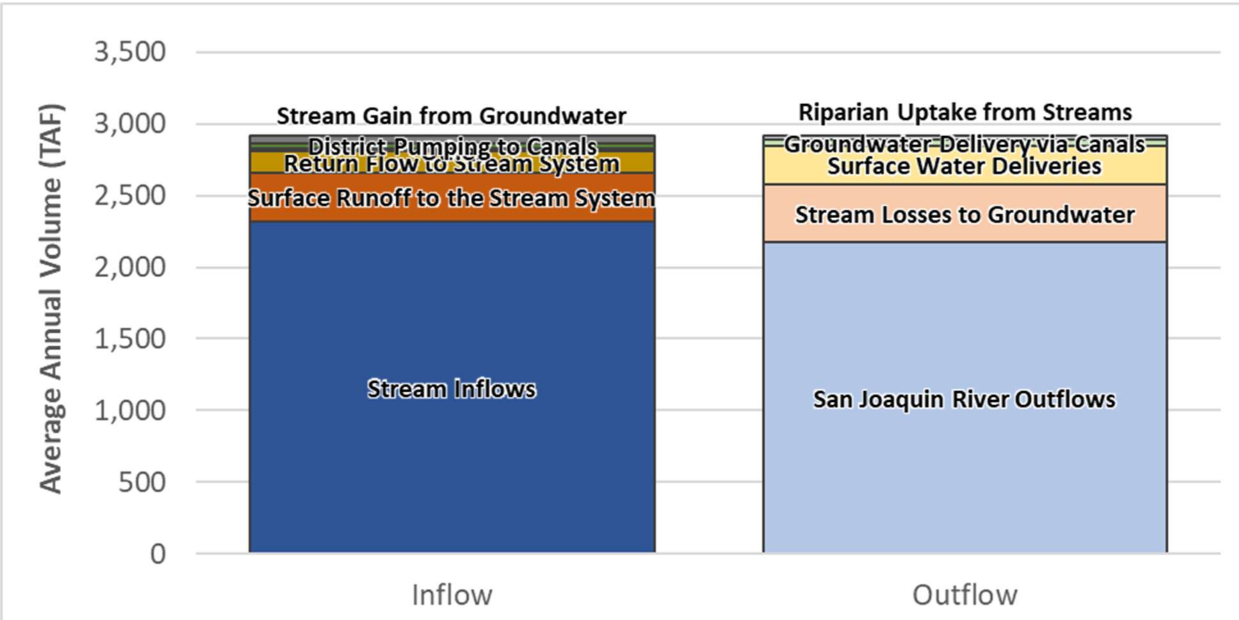
1.5.3 Projected Water Budget

The projected water budget is used to estimate future baseline conditions of supply, demand, and aquifer response to plan implementation. The Projected Conditions Baseline simulation of the MercedWRM is used to evaluate the projected conditions of the water budget using the hydrology from 1969 to 2018. As previously discussed, this represents a hydrologic period of at least 50 years and has average precipitation similar to the long-term average.

Development of the projected water demand is based on the population growth trends reported in the 2015 UWMP, and land use, evapotranspiration, and crop coefficient information from the 2015 AWMP. This data has been adjusted based on projected growth identified in general, agricultural, and urban water management plans to evaluate future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate. Similarly, projected surface water supplies were determined through analysis of MercedSIM, Merced Irrigation District's reservoir and surface water operations model, and accounts for the Federal Energy Regulatory Commission's (FERC) operations schedule under their Final Environmental Impact Statement (FEIS) for the 2018 licensing of the Lake McClure Reservoir.

Average annual surface water inflows to the Merced Subbasin's stream and canal system total an average of 2,918,00 acre-feet. Under projected conditions, local water district pumping will supplement surface water supplies with 45,000 acre-feet of groundwater production. Of these volumes, it is anticipated that 319,000 acre-feet will be distributed to local growers to meet agricultural demand (274,000 AF of surface water deliveries 45,000 AF of groundwater deliveries) and the remaining amount will leave the system in the form of San Joaquin River outflow (2,173,000 AF), aquifer recharge (401,000 AF), or riparian uptake (25,000 AF). Figure 9 summarizes the average projected inflows and outflows in the Merced Subbasin surface water network.

Figure 9: Current Conditions Average Annual Water Budget – Stream and Canal Systems, Merced Subbasin



The land surface water budget for the Projected Conditions Baseline has annual average inflows and outflows of 1,466,000 AF. Inflows are comprised of precipitation (506,000 AF), applied surface water (274,000 AF), applied groundwater (660,000 AF), riparian uptake from streams (14,000 AF), and inflow from the aquifer system (14,000 AF). The balance of this is the summation of average annual evapotranspiration (853,000 AF), surface runoff (206,000 AF) and return flow (79,000 AF) to the stream system, deep percolation (327,000 AF) and other flows (1,000 AF). A summary of these flows can be seen below in Figure 10.

Figure 10 Projected Conditions Average Annual Water Budget – Land Surface System, Merced Subbasin

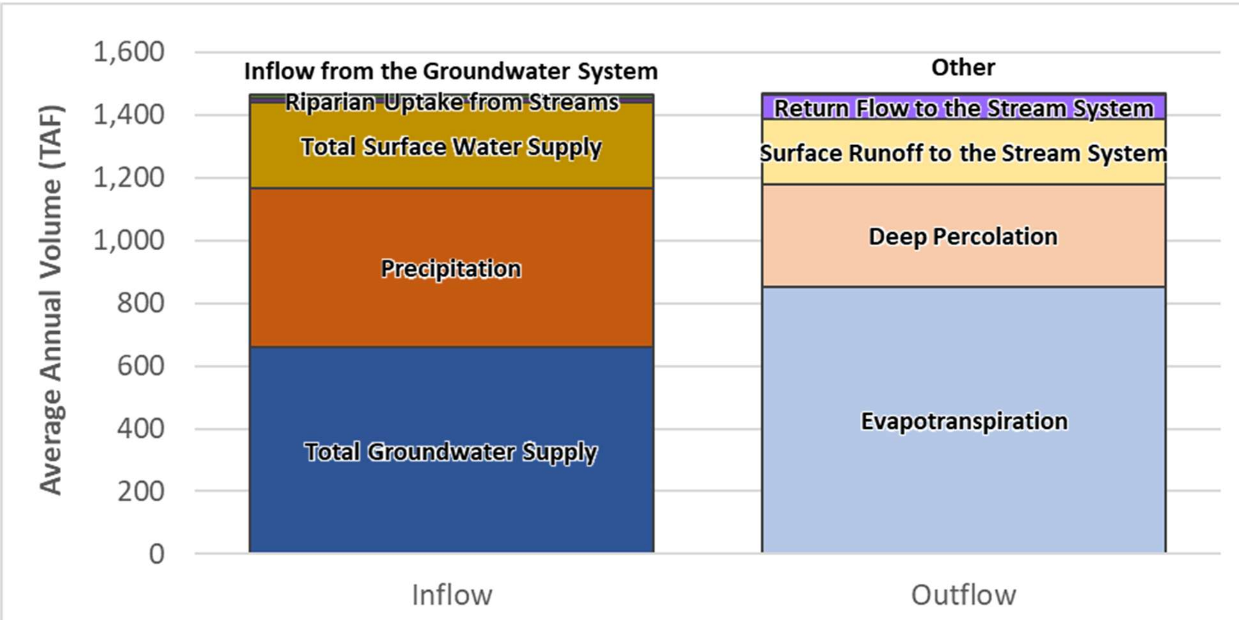
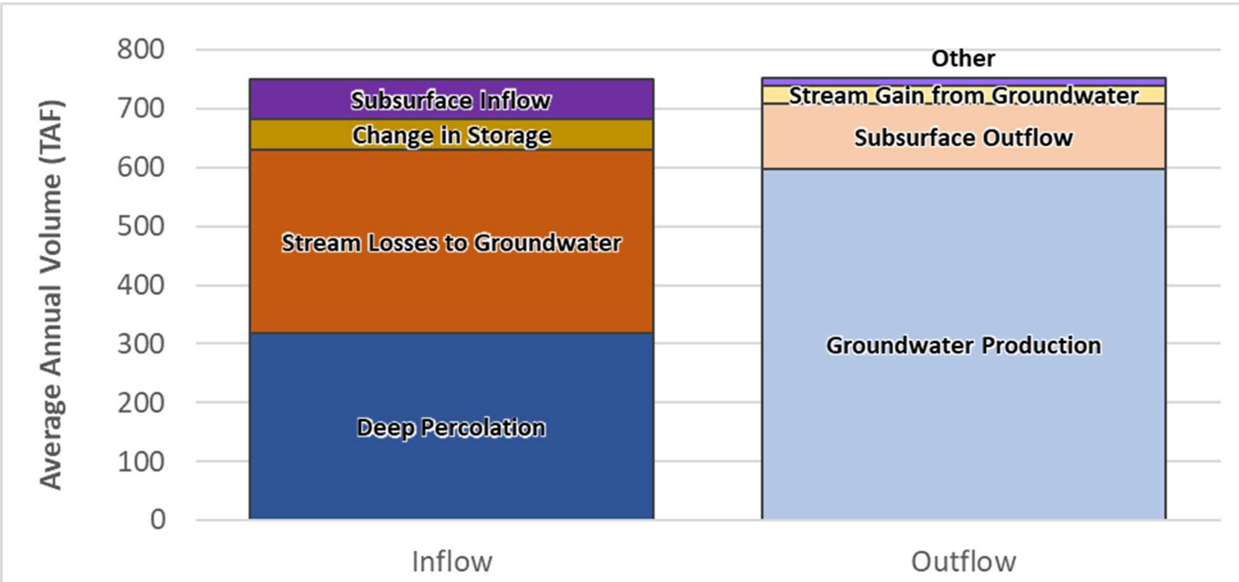


Figure 11 below shows how anticipated growth in the Projected Conditions Baseline is reflected in increases to groundwater production (660,000 AF) across the Subbasin. Subsurface outflow to neighboring subbasins (103,000 AF), stream gain from groundwater (29,000 AF), and other flows (13,000 AF) bring the total Subbasin discharges to 805,000 acre-feet per year.

Under projected conditions, the groundwater system of the Merced Subbasin experiences an average of 723,000 acre-feet of inflows each year, of which 327,000 AF is deep percolation. There is also recharge from rivers, streams and canals (318,000 AF), and subsurface inflows (79,000 AF) from the Sierra Nevada foothills and the neighboring subbasins of Turlock, Delta-Mendota, and Chowchilla.

The Projected Conditions Baseline has greater outflows than inflows, resulting in an average annual deficit in groundwater storage of 82,000 acre-feet. Figure 11**Error! Reference source not found.** summarizes the average projected groundwater inflows and outflows in the Merced Subbasin.

Figure 11: Projected Conditions Average Annual Water Budget – Groundwater System, Merced Subbasin



1.6 Sustainable Yield Estimate

Sustainable yield is defined for SGMA purposes as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result." (CWC 10721(w)). Sustainable yield for the Merced Subbasin was calculated through development of a MercedWRM scenario whereas the long-term (50-year) change in Subbasin storage is zero. In order to account for the challenges of implementation, it was assumed the projected operations will remain consistent for a 25-year period and groundwater levels may continue to decline until 2040, at which point the basin will operate sustainably. The sustainable yield water budget is based on the Projected Conditions Baseline and is modified by lowering groundwater production through reduced agricultural and urban demand across the model domain.

The Sustainable Yield Scenario varies from the Projected Conditions Baseline in the following ways:

- Planning Period: Water Years 2041-2090 (1969-2018 hydrologic period)
- Agricultural Water Demand: Reductions in agricultural water demand are implemented through a reduction in agricultural land use by globally reducing the projected 2040 land use at the element level.
- Urban Water Demand: Reductions in urban water use are implemented through a reduction in the per-capita water use.

The sustainable yield water budget is intended to estimate future conditions of supply, demand, and aquifer response to implementation of sustainable conditions in the Subbasin. Like the current and projected water budgets, the sustainable yield water budget is estimated using the sustainable conditions scenario for MercedWRM. In order to achieve a net-zero change in groundwater storage over a 50-year planning period, agricultural and urban groundwater demand in the Merced Subbasin would need to be reduced by approximately ten percent, absent implementation of any new supply-side projects.

Because of the reduction of agricultural supply and demand, the sustainable groundwater management condition scenario simulates reductions in evapotranspiration (reduced to 798,000 AF) and groundwater production (reduced to 570,000 AF) across the Subbasin. Subsurface outflow to neighboring subbasins (93,000 AF), stream discharge (29,000 AF), and other flows (10,000 AF) bring the total Subbasin discharges to 702,000 acre-feet per year.

Under sustainable groundwater management conditions, the groundwater system of the Merced Subbasin maintains inflows equal to its outflow volume of 702,000 acre-feet each year, of which 293,000 AF is deep percolation. There is also recharge from rivers, streams, and canals (321,000 AF), and subsurface inflows (87,000 AF) from the Sierra Nevada foothills and the neighboring subbasins of Turlock, Delta-Mendota, and Chowchilla.

The sustainable groundwater management scenario results in groundwater outflows equal to groundwater inflows, bringing the long term (50-year) average change in groundwater storage to a net-zero. Figure 12 summarizes the average projected groundwater inflows and outflows in the Merced Subbasin. Based on this analysis, the sustainable yield of the basin is approximately 570,000 AF/yr.

Figure 12: Groundwater Water Budget under Sustainable Groundwater Management Conditions Long-Term (50-Year) Average Annual