6 WATER BUDGETS

This section summarizes the estimated water budgets for the 180/400-Foot Aquifer Subbasin, including information required by the GSP Regulations and information that is important for developing an effective plan to achieve sustainability. In accordance with the SGMA Regulations § 354.18, this water budget provides an accounting and assessment of the total annual volume of surface water and groundwater entering and leaving the basin, including historical, current, and projected water budget conditions, and the change in the volume of groundwater in storage. Water budgets are reported in graphical and tabular formats, where applicable.

The previous water budgets described in the approved GSP was developed using best tools and methods that were available at the time. Since the release and approval of that GSP, a provisional version of the Salinas Valley Integrated Hydrologic Model and an updated version of the Salinas Valley Operational Model were released by the USGS to the SVBGSA for use in developing GSPs. Updating the water budgets for this Subbasin using these new, best available tools is important for maintaining consistency with adjacent SVBGSA Subbasins managed by the SVBGSA. This section describes the water budgets for this Subbasin in a manner consistent with GSPs for other Subbasins in the Valley.

6.1 Overview of Water Budget Development

The water budgets are presented in two subsections: (1) historical and current water budgets, and (2) future water budgets. Within each subsection a surface water budget and groundwater budget are presented.

Historical and current water budgets are developed using a provisional version of the Salinas Valley Integrated Hydrologic Model (SVIHM)[1], developed by the United States Geological Survey (USGS). The SVIHM is a numerical groundwater-surface water model that is constructed using version 2 of the MODFLOW-OWHM code (Boyce *et al.*, 2020). This code is a version of the USGS groundwater flow code MODFLOW that estimates the agricultural supply and demand, through the Farm Process.

[1] These data (model and/or model results) are preliminary or provisional and are subject to revision. This model and model results are being provided to meet the need for timely best science. The model has not received final approval by the U.S. Geological Survey (USGS). No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the model and related material nor shall the fact of release constitute any such warranty. The model is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the model.

The model area covers the Salinas Valley Groundwater Basin from the Monterey-San Luis Obispo County Line in the south to the Pajaro Basin in the north, including the offshore extent of the major aquifers. The model includes operations of the San Antonio and Nacimiento reservoirs. The SVIHM is supported by two sub models: a geologic model known as the Salinas Valley Geologic Model (SVGM) and a watershed model known as the Hydrologic Simulation Program – Fortran (HSPF). The SVIHM is not yet released by the USGS. Details regarding source data, model construction and calibration, and results for historical and current water budgets will be summarized in more detail once the model and associated documentation are available.

Future water budgets are being developed using an evaluation version of the Salinas Valley Operational Model (SVOM), developed by the USGS and Monterey County Water Resources Agency (MCWRA). The SVOM is a numerical groundwater-surface water model constructed with the same framework and processes as the SVIHM. However, the SVOM is designed for simulating future scenarios and includes complex surface water operations in the Surface Water Operations (SWO) module. The SVOM is not yet released by the USGS. Details regarding source data, model construction and calibration, and results for future budgets will be summarized in more detail once the model and associated documentation are available

In accordance with SGMA Regulations § 354.18, an integrated groundwater budget is developed for each principal aquifer for each water budget period. The 180/400-Foot Aquifer Subbasin is pumped from 3 principal aquifers.

6.1.1 Water Budget Components

The water budget is an inventory of the Subbasin's surface water and groundwater inflows and outflows. Some components of the water budget can be measured, such as groundwater pumping from metered wells, precipitation, and surface water diversions. Other components are not easily measured and can be estimated using groundwater models, such as the SVIHM; these include unmetered agricultural pumping, recharge from precipitation and applied irrigation, and change

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of groundwater in storage.

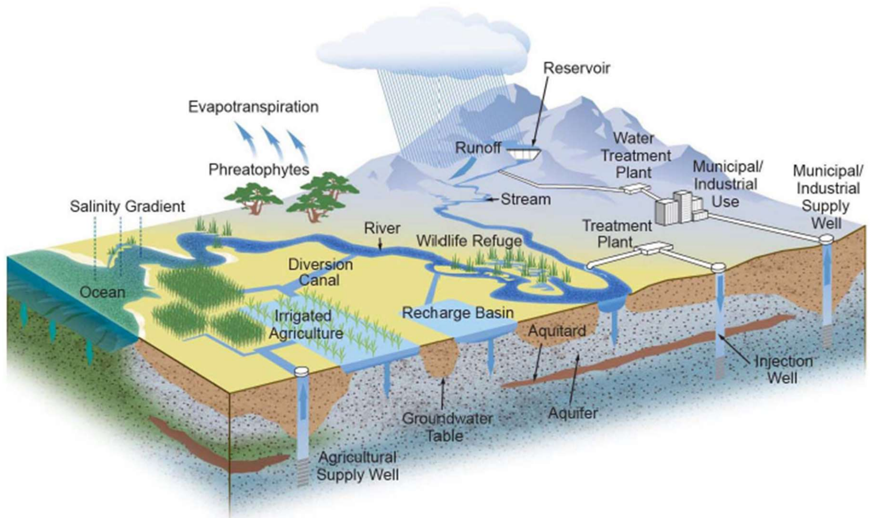

Figure 6-1.

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~~Figure 6-1~~ presents a general schematic diagram of the hydrogeologic conceptual model that is included in the water budget (DWR, ~~2020c~~2020b). **Error! Reference source not found.**~~Figure 6-2~~ delineates the zones and boundary conditions of the SVIHM.

The water budgets for the Subbasin are calculated within the following boundaries:

- Lateral boundaries: The perimeter of the 180/400-Foot Aquifer Subbasin within the SVIHM is shown on **Error! Reference source not found.**~~Figure 6-2~~.
- Bottom: The base of the groundwater subbasin is described in the Hydrogeologic Conceptual Model and is defined as the base of the usable and productive unconsolidated sediments (Durbin *et al.* 1978). This ranges from less than 800 feet below ground surface in the far north of the Subbasin to almost 2,600 feet deep along the Subbasin's southwestern edge. The water budget is not sensitive to the exact definition of this base elevation because the base is defined as a depth below where there is not significant inflow, outflow, or change in storage.
- Top: The top of the water budget area is above the ground surface, so that surface water is included in the water budget.

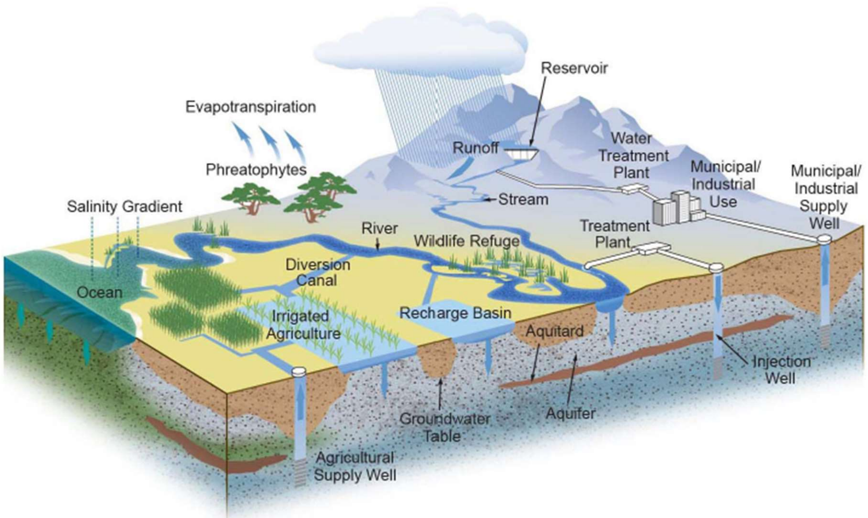

Figure 6-1. Schematic Hydrogeologic Conceptual Model (from DWR, ~~2020c~~2020b)

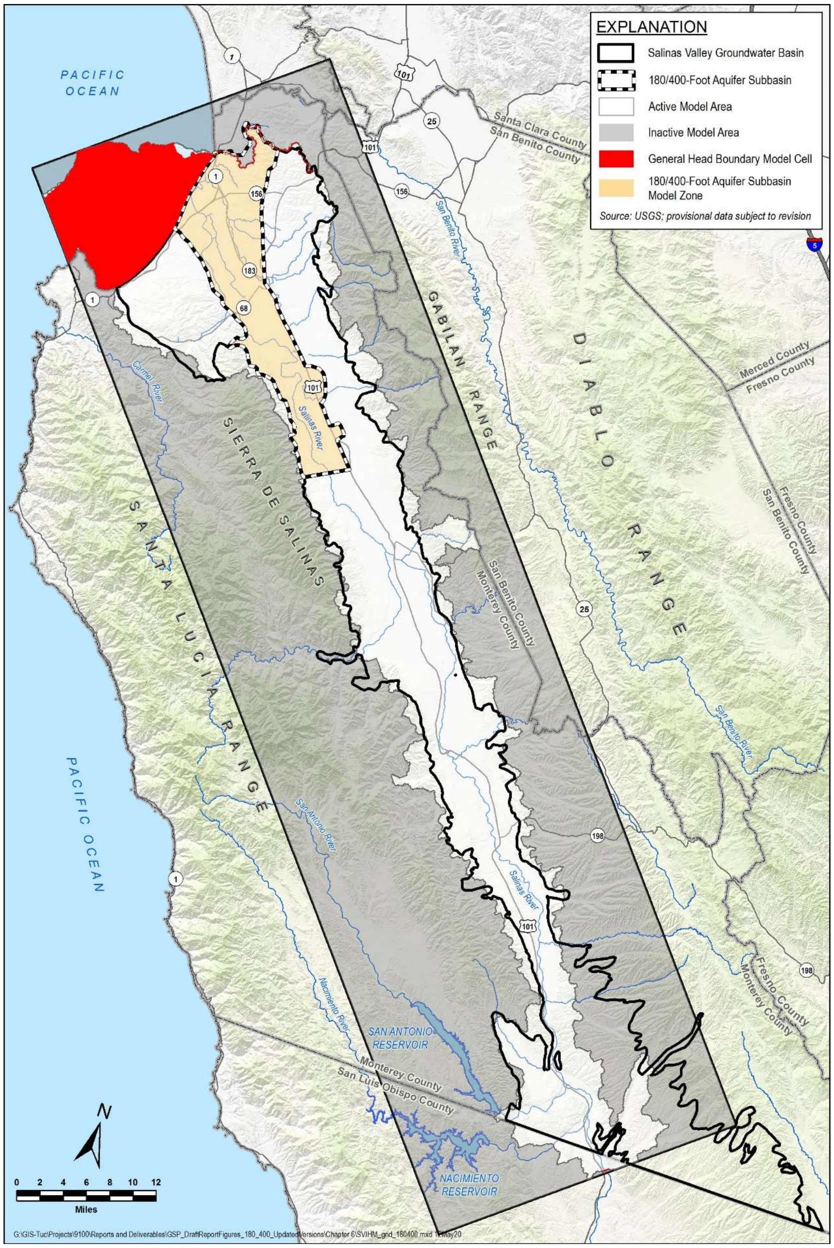

Figure 6-2. Zones and Boundary Conditions for the Salinas Valley Integrated Hydrologic Model

The 180/400-Foot Aquifer Subbasin water budget includes the following components:

Surface Water Budget:

- Inflows
    - Runoff of precipitation
    - Surface water inflows from streams and canals that enter the subbasin, including Salinas River, Chualar Creek, Quail Creek, Alisal Creek, Salinas Reclamation Canal, Santa Rita Creek, and several other smaller creeks
    - Groundwater discharge to streams
- Outflows
    - Stream discharge to groundwater
    - Outflow to the ocean and neighboring subbasins along Salinas River, and other smaller streams

Groundwater Budget:

- Inflows
    - Deep percolation from precipitation and applied irrigation
    - Stream discharge to groundwater
    - Subsurface inflows, including:
        - Inflow from the Forebay Aquifer Subbasin
        - Inflow from the Langley Aquifer Subbasin
        - Inflow from the Eastside Aquifer Subbasin
        - Inflow from the Pajaro Valley Subbasin
        - Inflow from the Monterey Subbasin
        - Inflow from the Pacific Ocean (seawater intrusion)
        - Inflow from the surrounding watershed that are not in other DWR subbasins
- Outflows
    - Crop and riparian evapotranspiration (ET)
    - Groundwater pumping, including municipal, industrial, and agricultural
    - Groundwater discharge to streams

- Groundwater discharge to drains
- Subsurface outflows, including:
  - Outflow to the Forebay Aquifer Subbasin
  - Outflow to the Langley Area Subbasin
  - Outflow to the Eastside Aquifer Subbasin
  - Outflow to the Pajaro Valley Subbasin
  - Outflow to the Monterey Subbasin
  - Outflows to the Pacific Ocean
  - Outflow to surrounding watershed that are not in other DWR subbasins

The difference between groundwater inflows and outflows is equal to the change of groundwater in storage.

6.1.2 Water Budget Time Frames

Time periods must be specified for each of the 3 required water budgets. The SGMA Regulations require water budgets for historical conditions, current conditions, and projected conditions.

- The historical water budget is intended to evaluate how past land use and water supply availability has affected aquifer conditions and the ability of groundwater users to operate within the sustainable yield. GSP Regulations require that the historical water budget include at least the most recent 10 years of water budget information. DWR's Water Budget Best Management Practices (BMP) document further states that the historical water budget should help develop an understanding of how historical conditions concerning hydrology, water demand, and surface water supply availability or reliability have impacted the ability to operate the basin within the sustainable yield. Accordingly, historical conditions should include the most reliable historical data that are available for GSP development and water budgets calculations.
- The current water budget is intended to allow the GSA and DWR to understand the existing supply, demand, and change in storage under the most recent population, land use, and hydrologic conditions. Current conditions are generally the most recent conditions for which adequate data are available and that represent recent climatic and hydrologic conditions. Current conditions are not well defined by DWR but can include an average over a few recent years with various climatic and hydrologic conditions.
- The projected water budget is intended to quantify the estimated future baseline conditions. The projected water budget estimates the future baseline conditions

concerning hydrology, water demand, and surface water supply over a 50-year planning and implementation horizon. It is based on historical trends in hydrologic conditions which are used to project forward 50 years while considering projected climate change and sea level rise if applicable.

Although there is a significant variation between wet and dry seasons, the GSP does not consider separate seasonal water budgets for the groundwater budget. All water budgets are developed for complete water years. Selected time periods for the historical and current water budgets are summarized in **Error! Reference source not found.**~~Table 6-1~~ and on Figure 6-3. ~~Figure 6-3,~~ and described in Sections 6.1.2.1 and 6.1.2.2.

Table 6-1. Summary of Historical and Current Water Budget Time Periods

Time Period	Proposed Date Range	Water Year Types Represented in Time Period	Rationale
Historical	Water years 1980 through 2016	Dry: 11 Dry-Normal: 7 Normal: 5 Wet-Normal: 3 Wet: 11	Provides insights on water budget response to a wide range of variations in climate and groundwater use over an extensive period of record. Begins and ends in years with average precipitation.
Current	Water Year 2016	Dry-Normal: 1	Best reflection of current land use and water use conditions based on best available data.

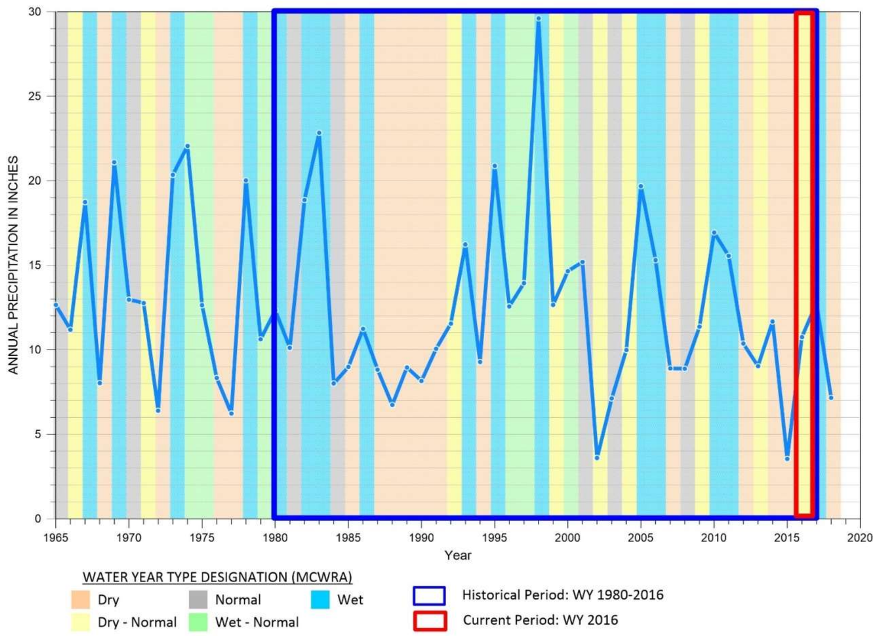

Figure 6-3. Climate and Precipitation for Historical and Current Water Budget Time Periods

6.1.2.1 Historical Water Budgets Time Period

GSP regulations require that the historical water budget be based on at least 10 years of data. The water budget is computed using results from the SVIHM numerical model for the time period from October 1980 through September 2016. The SVIHM simulation covers water years 1967 through 2017; however, model results for years prior to 1980 and the year 2017 were not used for this water budget due to potential limitations and uncertainties in the provisional SVIHM. Water years 1980 through 2016 comprise a representative time period with both wet and dry periods in the Subbasin (Table 6-1~~Table 6-1~~, Figure 6-3~~Figure 6-3~~).

6.1.2.2 Current Water Budget Time Period

The current water budget time period is also computed using the SVIHM numerical model and is based on water year 2016. Water year 2016 is classified as dry-normal and is reflective of current and recent patterns of groundwater use and surface water use. Although Water Year 2016 appropriately meets the regulatory requirement for using the "…most recent hydrology, water supply, water demand, and land use information" (23 California Code of Regulations~~CCR~~ § 354.18 (c)(1)), it is noted that water year 2016 was preceded by multiple dry or dry-normal years.

6.1.2.3 Future Projected Water Budgets Time Period

Future projected conditions are based on model simulations using the SVOM numerical flow model, using current reservoir operations rules, projected climate-change scenario, and estimated sea level rise. The projected water budget represents 47 years of future conditions. Following DWR guidance on implementing climate change factors, the future water budget simulations do not simulate a 47-year projected future, but rather simulate 47 likely hydrologic events that may occur in 2030, and 47 likely hydrologic events that may occur in 2070.

6.2 Overview of Data Sources for Water Budget Development

Table 6-2~~Table 6-2~~ provides the detailed water budget components and known model assumptions and limitations for each. A few water budget components are directly measured, but most water budget components are either estimated as input to the model or simulated by the model. Both estimated and simulated values in the water budgets are underpinned by certain assumptions. These assumptions can lead to uncertainty in the water budget. However, inputs to the preliminary SVIHM were carefully selected by the USGS and cooperating agencies using best available data, reducing the level of uncertainty.

In addition to the model assumptions, additional uncertainty stems from any model's imperfect representation of natural condition and level of calibration. The water budgets for the 180/400-Foot Aquifer Subbasin are based on a preliminary version of the SVIHM, with limited documentation of model construction. The model is in internal review at the USGS, and a final version will likely not be released to the SVBGSA until after the GSP is submitted. Nonetheless, the SVIHM's calibration error is within reasonable bounds. Therefore, the model is the best available tool for estimating water budgets for the GSP.

As GSP implementation proceeds, the SVIHM will be updated and recalibrated with new data to better inform model simulations of historical, current, and projected water budgets. Model assumptions and uncertainty will be described in future updates to this chapter after model documentation is released by the USGS.

Table 6-2. Summary of Water Budget Component Data Source from the Salinas Valley Integrated Hydrologic Model and Other Sources

Water Budget Component	Source of Model Input Data	Limitations
Precipitation	Incorporated in calibrated model as part of land use process	Estimated for missing years
Surface Water Inflows		
Inflow from Streams Entering Basin	Simulated from calibrated model for all creeks	Not all creeks are gauged
Groundwater Discharge to Streams	Simulated from calibrated model	Based on calibration of streamflow to available data from gauged creeks
Overland Runoff	Simulated from calibrated model	Based on land use, precipitation, and soils specified in model
Surface Water Outflows		
Streambed Recharge to Groundwater	Simulated from calibrated model	Based on calibration of streamflow to available data from gauged creeks and groundwater level data from nearby wells
Diversions	Model documentation not available at this time	Based on calibration of streamflow to available data from gauged creeks
Outflow to Streams Leaving Basin	Simulated from calibrated model for all creeks	Not all creeks are gauged
Groundwater Inflows		
Streambed Recharge to Groundwater	Simulated from calibrated model	Based on calibration of streamflow to available data from gauged creeks and groundwater level data from nearby wells
Deep Percolation of Precipitation and Irrigation Water	Simulated from demands based on crop, acreage, temperature, and soil zone processes	No measurements available; based on assumed parameters for crops and soils
Subsurface Inflow from Adjacent Basins and Ocean	Simulated from calibrated model	Limited groundwater calibration data at adjacent subbasin boundaries; seawater intrusion assumed equal to groundwater flow from the ocean across coastline
Subsurface Inflow from Surrounding Watershed Other than Neighboring Basins	Simulated from calibrated model	Limited groundwater calibration data at adjacent subbasin boundaries
Groundwater Outflows		
Groundwater Pumping	Reported data for historical municipal and agricultural pumping, and some small water systems. Model documentation not available at this time.	Water budget pumping reported from the SVIHM contains errors. Domestic pumping not simulated in model. Pumping adjusted according to reported data.
Groundwater Discharge to Streams	Simulated from calibrated model	Based on calibration of streamflow to available data from gauged creeks and groundwater level data from nearby wells

Subsurface Outflow to Adjacent Basins and Ocean	Simulated from calibrated model	Limited calibration data at adjacent subbasin boundaries
Riparian ET	Simulated from calibrated model	Based on representative plant group and uniform extinction depth

6.3 Historical and Current Water Budgets

Water budgets for the historical and current periods are presented below. The surface water budgets are presented first, followed by the groundwater budgets. These water budgets are based on the provisional SVIHM and are subject to change in the future. Water budgets will be updated in future GSP updates after the SVIHM is formally released by the USGS.

6.3.1 Historical and Current Surface Water Budget

The surface water budget accounts for the inflows and outflows for the streams within the Subbasin. This includes streamflows of rivers and tributaries entering and exiting the Subbasin, overland runoff to streams, and stream-aquifer interactions. Evapotranspiration by riparian vegetation along stream channels is estimated by the provisional SVIHM as part of the groundwater system and is accounted for in the groundwater budget.

Figure 6-4~~Figure 6-4~~ shows the surface water network simulated in the provisional SVIHM. The model accounts for surface water flowing in and out across the subbasin boundary. For this water budget, boundary inflows and outflows are the sum of all locations that cross the Subbasin boundary. In some instances, a simulated stream might enter and exit the Subbasin boundary at multiple locations, such as Salinas River, Chualar Creek, and Natividad Creek/Reclamation Canal. The Salinas Valley Aquitard, which extends over much of the Subbasin, limits

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connectivity between surface water and principal aquifers where present.

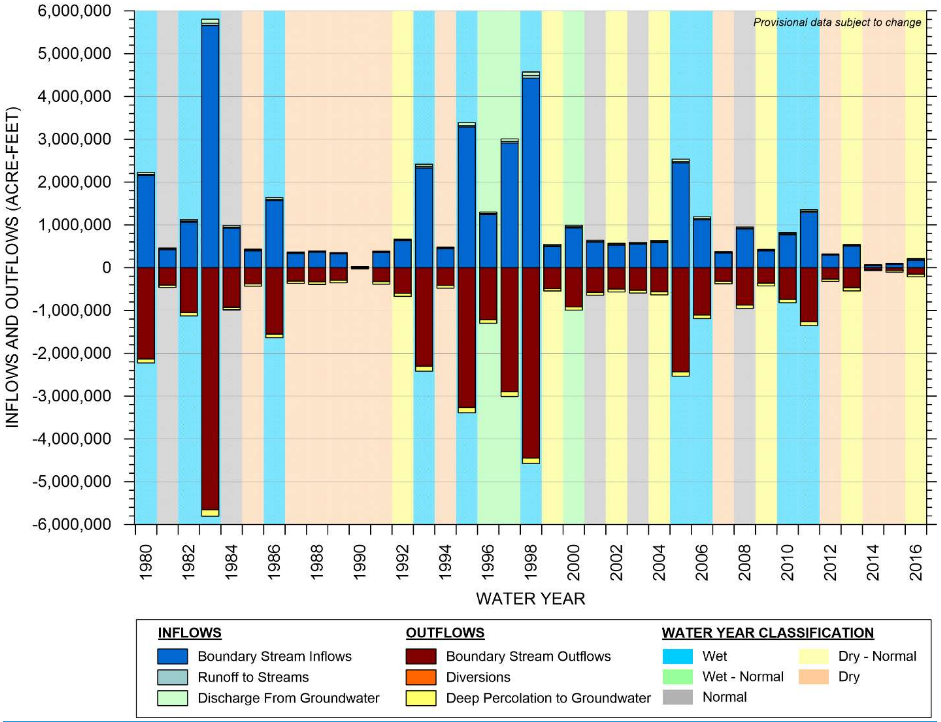

Figure 6-5

~~Figure 6-5~~ shows the surface water budget for the historical period, which also includes the current period. Table 6-3~~Table 6-3~~ shows the average values for components of the surface water budget for the historical and current periods. Positive values are inflows into the stream system, and negative values are outflows from the stream system. Boundary stream inflows and boundary stream outflows are an order of magnitude greater than any other component of the surface water budget. The flow between surface water and groundwater in the Subbasin is generally net negative, which indicates more deep percolation of streamflow to groundwater than groundwater discharge to streams.

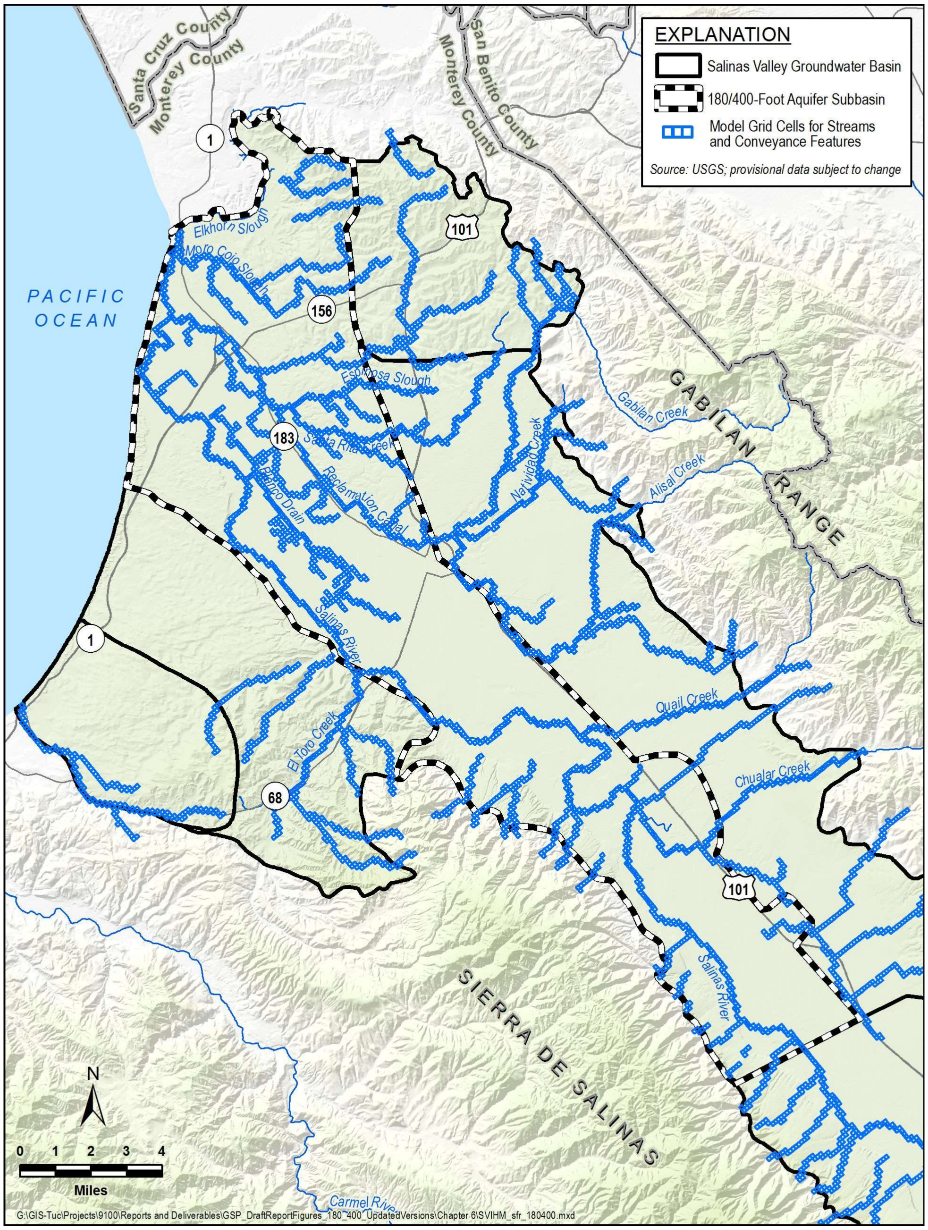

Figure 6-4. Surface Water Network in the 180/400-Foot Aquifer Subbasin from the Salinas Valley Integrated Hydrologic Model

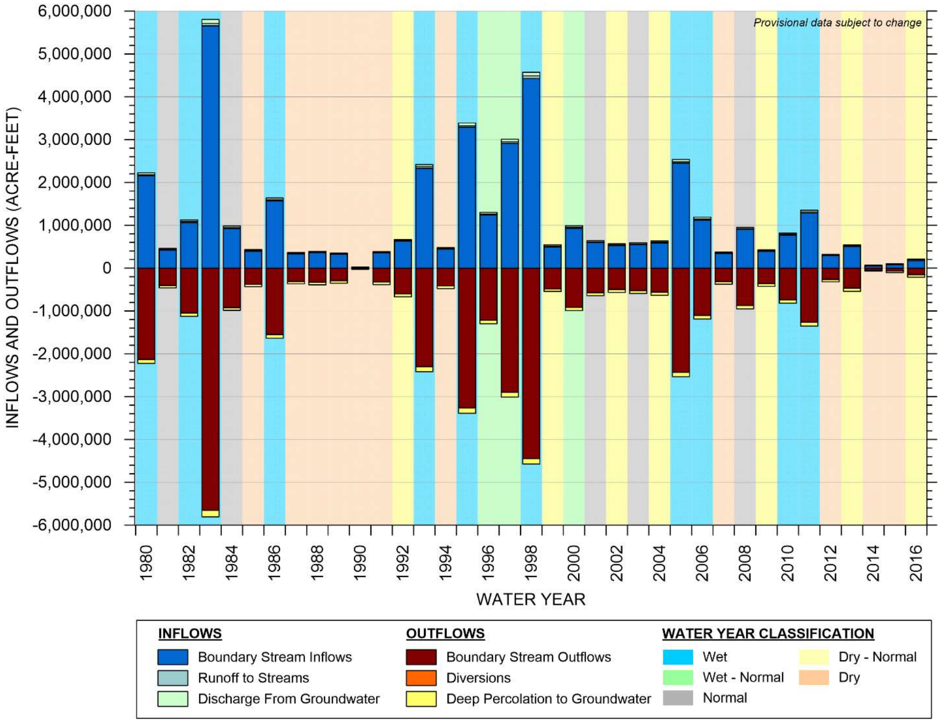

Figure 6-5. Historical and Current Surface Water Budget

Table 6-3. SVIHM Simulated Surface Water Budget Summary (AF/yr.)

	Historical Average (WY 1980 2016)	Current (WY 2016)
Boundary Stream Inflows	1,105,700	174,500
Runoff to Streams	21,400	25,300
Net Flow between Surface Water and Groundwater	-40,700	-43,900
Boundary Stream Outflows	-1,086,100	-156,000
Diversions	-300	0

Note: provisional data subject to change.

6.3.2 Historical and Current Groundwater Budget

The groundwater budget accounts for the inflows and outflows to and from the Subbasin's aquifers, based on results from the SVIHM. This includes subsurface inflows and outflows of groundwater at the Subbasin boundaries, recharge, pumping, evapotranspiration, and net flow between surface water and groundwater.

Figure 6-6~~Figure 6-6~~ shows SVIHM estimated annual groundwater inflows for the historical and current time periods. Inflows vary substantially from year to year. Table 6-4~~Table 6-4~~ provides average groundwater inflows for the historical and current period. The biggest inflow components are deep percolation of streamflow and deep percolation of precipitation and applied irrigation. Deep percolation of streamflow is slightly greater on average but also varies more. Values of 50,000 to 100,000 AF/yr. are typical of each of these components. The most consistent groundwater flows into the Subbasin are from the subsurface, including seawater intrusion. For these water budgets, seawater intrusion is counted as an inflow even though it is not usable. Freshwater subsurface inflows are always between 18,000 and 24,000 AF/yr. Seawater inflows are always between 2,000 and 4,000 AF/yr. These seawater inflows are less than calculated in Chapter 5. This is likely a result of assumptions in the SVIHM that may underestimate seawater intrusion. Developing a variable density groundwater model will address this underestimation. Total annual recharge is similar for the historical period and current period, with each equal to about 158,000 AF/yr.

Figure 6-7~~Figure 6-7~~ shows the SVIHM estimated groundwater outflows for the historical and current time periods. Outflows vary from year to year; however, the annual variation is dampened compared to the inflows. Table 6-5 provides the SVIHM estimated average groundwater outflows of the historical and current periods. In all but the wettest years, the greatest groundwater outflow is pumping. Averaged over the historical period, groundwater pumping accounts for more than 50% of all groundwater outflows in the Subbasin. In the driest water years, like 1990 and 2014, it accounts for more than 70%. Total average annual groundwater outflow was about 172,000 AF for the historical period and 137,000 AF for the current period. All outflows are shown as negative values.

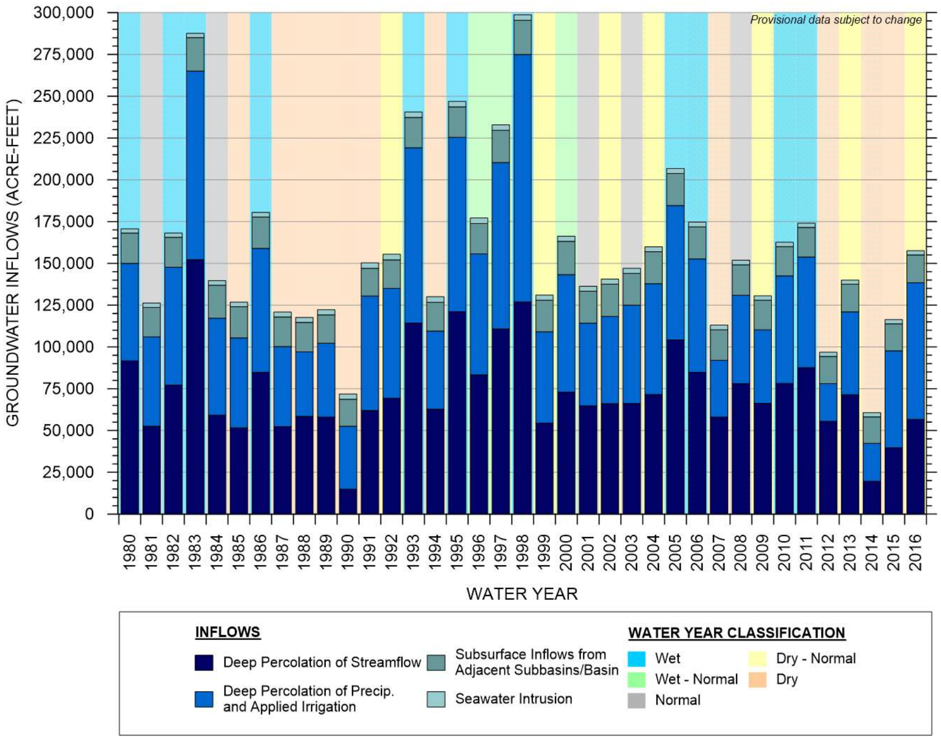

Figure 6-6. SVIHM Simulated Inflows to the Groundwater System

Table 6-4. SVIHM Simulated Groundwater Inflows Summary (AF/yr.)

	Historical Average (WY 1980 2016)	Current (WY 2016)
Deep Percolation of Streamflow	73,000	56,700
Deep Percolation of Precipitation and Applied Irrigation	63,600	81,700
Subsurface Inflow from Adjacent Subbasins	18,100	16,700
Seawater Intrusion	2,900	2,500
Total Inflows	157,600	157,600

Note: provisional data subject to change.

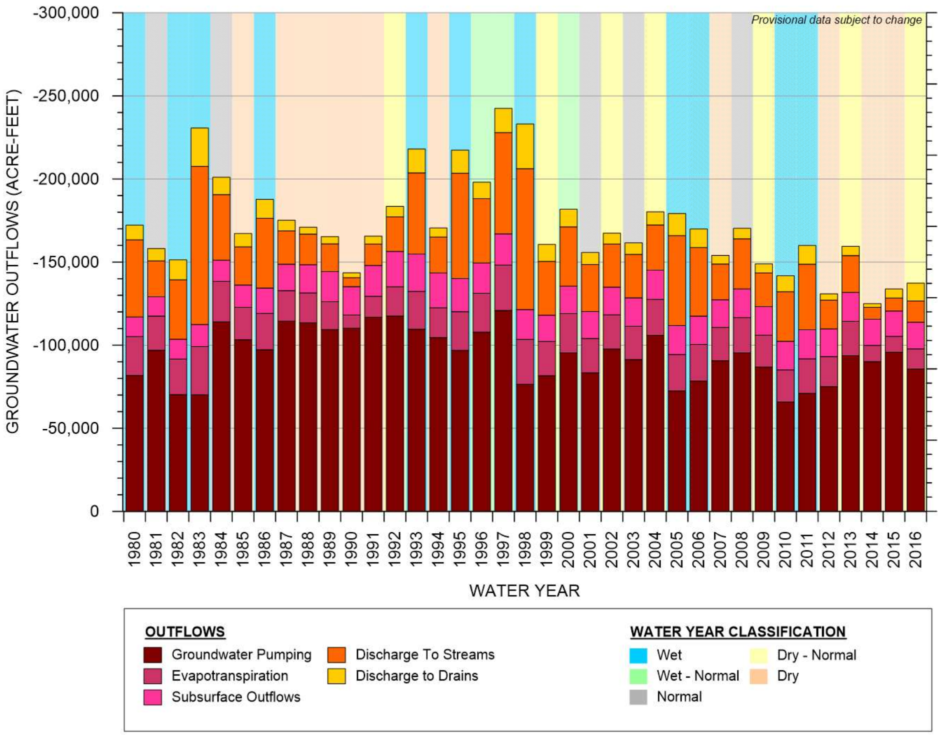

Figure 6-7. SVIHM Simulated Outflows from the Groundwater System

Table 6-5. SVIHM Simulated and Adjusted Groundwater Outflows Summary (AF/yr.)

	Simulated		Adjusted	
	Historical Average (WY 1980 2016)	Current (WY 2016)	Historical Average (WY 1980 2016)	Current (WY 2016)
Groundwater Pumping	-94,300	-85,700	-132,800	-120,700
Groundwater Evapotranspiration	-19,900	-12,100	-19,900	-12,100
Subsurface Outflows	-16,700	-16,000	-16,700	-16,000
Discharge to Streams	-32,300	-12,800	-32,300	-12,800
Discharge to Drains	-9,000	-10,800	-9,000	-10,800
Total Outflows	-172,200	-137,400	-210,700	-172,400

Note: provisional data subject to change.
Adjusted pumping is described below.

Comparing SVIHM output to Groundwater Extraction Management System (GEMS) data reveals that, on average, the preliminary SVIHM estimates only approximately 71% of the pumping reported in the GEMS database for the Subbasin between 1995 and 2016. The historical average groundwater extraction reported to GEMS is 125,500 AF/yr., and the current (2016) extraction is 120,400 AF/yr. These GEMS data are likely more representative of historical conditions than the model generated pumping numbers; however, reliable GEMS data are only available since 1995. To accurately estimate groundwater extraction for the full historical period, this 71% ratio was applied to the SVIHM estimated historical pumping shown in Table 6-5 and Table 6-6, yielding an estimated (adjusted) historical average pumping rate of 132,800 AF/yr.

Figure 6-8~~Figure 6-8~~ and Table 6-6 show SVIHM simulated groundwater pumping by water use sector. More than 85% of groundwater pumping in the Subbasin is used for agricultural purposes. Groundwater pumping varies from year to year; however, total pumping in the Subbasin has generally decreased since its peak in the 1980s and 1990s. Municipal and agricultural pumping are simulated in the SVIHM; however, domestic pumping, including *de minimis* pumping, is not included in the model, including pumping that occurs from a well with a discharge pipe of less than 3 inches. The SVIHM does not simulate domestic pumping because it is a relatively small portion of overall groundwater pumping in Salinas Valley Basin, and it is not included in the 180/400-Foot Subbasin water budget. The historical average in Table 6-6 is not strictly comparable to the GEMS historical average because the time periods used to calculate the averages are different; however, the ratio between these values is used to adjust simulated pumping to be more consistent with GEMS data.

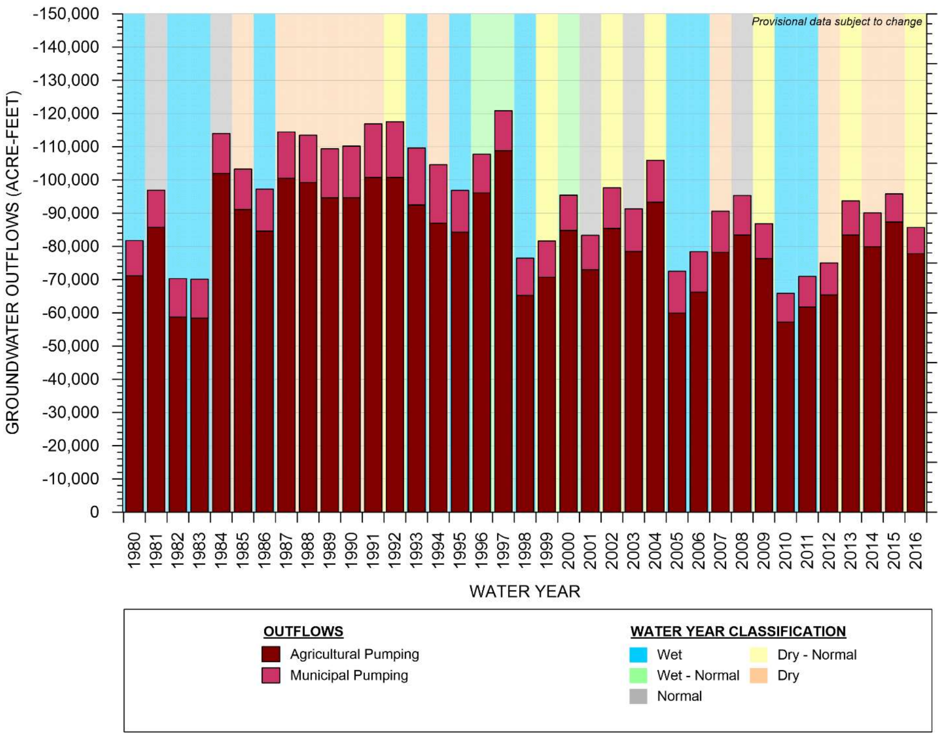

Figure 6-8. SVIHM Simulated Groundwater Pumping by Water Use Sector

Table 6-6. SVIHM Simulated and Adjusted Groundwater Pumping by Water Use Sector (AF/yr.)

	Simulated		GEMS		Adjusted	
	Historical Average (WY 1980 2016)	Current (WY 2016)	Historical Average (WY ~~1980~~1995 2016)	Current (WY 2016)	Historical Average (WY 1980 2016)	Current (WY 2016)
Municipal & Industrial	-12,200	-7,900	-14,100	-11,000	-17,200	-11,100
Agricultural	-82,100	-77,800	-111,500	-109,400	-115,600	-109,600
Total Pumping	-94,300	-85,700	-125,600	-120,400	-132,800	-120,700

Note: provisional data subject to change.

1 Adjusted agricultural pumping is based on the ratio between SVIHM and GEMS agricultural pumping, as described in text above.

Figure 6-9~~Figure 6-9~~ shows SVIHM estimated net subsurface flows entering and exiting the Subbasin by watershed and neighboring subbasin. Historically, the Subbasin's subsurface inflows have been about 10% greater than its outflows for a net inflow of about 2,000 AF/yr. Table 6-7 shows SVIHM estimated historical mean and current year subsurface flows.

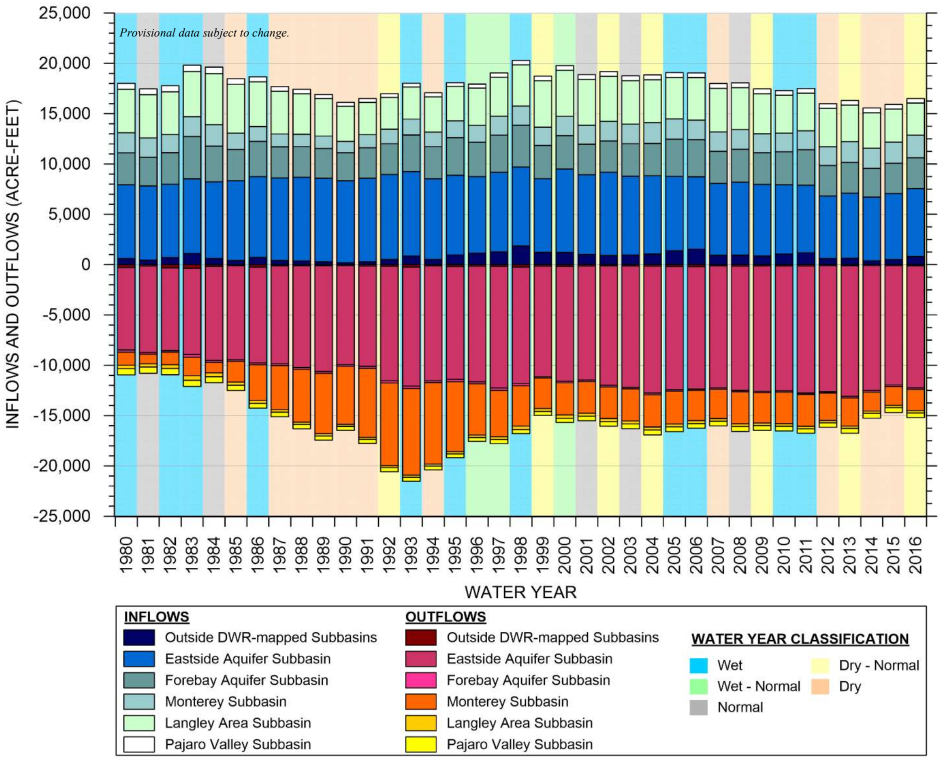

Figure 6-9. SVIHM Simulated Subsurface Inflows and Outflows from Watershed Areas and Neighboring Basins/Subbasins

Table 6-7. SVIHM Simulated Net Subbasin Boundary Flows (AF/yr.)

	Historical Average (WY 1980 2016)	Current (WY 2016)
Eastside Aquifer Subbasin	-3,600	-5,400

Forebay Aquifer Subbasin	3,100	2,900
Monterey Subbasin	-1,900	100
Langley Area Subbasin	3,700	2,900
Pajaro Valley Subbasin	-100	0
Outside Areas	700	700

Note: provisional data subject to change.

Change in groundwater storage is equal to inflow to storage (such as deep percolation) minus outflows from storage (such as pumping). A negative change in groundwater storage value indicates groundwater storage depletion associated with lower groundwater levels; while a positive value indicates groundwater storage accretion associated with higher groundwater levels. Averaged over the historical period, the preliminary SVIHM estimates that the 180/400-Foot Aquifer Subbasin is in overdraft by 14,800 AF/yr. Model results represent storage loss from all aquifer layers, including the Deep Aquifers. However, this simulated overdraft contains significant variability and uncertainty. Figure 6-10~~Figure 6-10~~ shows considerable variability in change in storage from one year to the next. In water year 1998, inflows exceeded outflows by more than 65,000 AF, while in 1988 outflows exceeded inflows by roughly 60,000 AF. The current period represents a snapshot in time showing variability within the model simulation and are not necessarily representative of actual current conditions.

Estimating storage loss from groundwater levels in the 180/400-Foot Subbasin is difficult because groundwater is pumped from a combination of confined and unconfined aquifers. Groundwater levels react differently to pumping depending on the type of aquifer. The decline in groundwater storage based on measured groundwater elevations from ~~1944~~ 1995 through 2019 is estimated to be about ~~600~~ 800 AF/yr. in the Subbasin, as described in Section 5.2.2. Based on measured groundwater levels from 1944 through 2013, a report by Brown and Caldwell (2015) estimates that groundwater storage decreased at an average rate of 200 AF/yr. (assuming confined conditions) to 1,600 AF/yr. (assuming unconfined conditions). During the drought years of 1984 through 1991, Brown and Caldwell estimates that groundwater storage in the 180/400-Foot Subbasin declined by 1,000 to 2,000 AF/yr. (confined) and 10,000 to 20,000 AF/yr. (unconfined) (Brown and Caldwell, 2015). The long-term average accounts for the short-term increase in storage loss during the drought period. The long-term historical average value reported in Section 5.2.2 is in the middle of the range of average values reported for confined and unconfined conditions by Brown and Caldwell, suggesting that the groundwater measurement dataset represents both confined and unconfined conditions. However, the storage loss estimate from Section 5.2.2 is likely underestimated because it does not account for conditions in the Deep Aquifers, due to lack of data. That estimate will be improved in the future after investigations of the Deep Aquifers.

Uncertainties exist in groundwater storage estimates from both the SVIHM and the analyses using groundwater level measurements. Therefore, based on the average of groundwater level measurements reported in Section 5.2.2, this GSP considers ~~600~~ 800 AF as the historical average annual decline in storage due to change in groundwater elevations. This value is used for water budget adjustments described below.

Additional groundwater storage loss occurs due to seawater intrusion. Averaged over the historical period, the preliminary SVIHM estimates groundwater storage loss due to seawater intrusion occurs at a rate of 2,900 AF/yr. in the Subbasin, accounting for all three aquifers. The decline in groundwater storage due to seawater intrusion based on the change in mapped intruded area is estimated to be 12,600 AF/yr. in the Subbasin, as described in Section 5.2.3. This GSP considers 12,600 AF/yr. to be the annual rate of storage loss due to seawater intrusion. Furthermore, the change in groundwater storage calculated by the SVIHM is not comparable to, and should not be equated with, the change in groundwater storage calculated in Section 5.2.2. The SVIHM water budget is an accounting of all flows across the subbasin boundaries. The change in groundwater storage calculated in Section 5.2.2 is an estimate of usable groundwater, and excludes all areas with seawater intrusion.

6.3.3 Historical and Current Groundwater Budget Summary

The main groundwater inflows into the subbasin are: (1) deep percolation of precipitation and irrigation water, (2) subsurface inflow from adjacent DWR groundwater basins and subbasins, and (3) stream recharge. Groundwater pumping is the predominant groundwater outflow. The smaller outflow terms are subsurface outflows to adjacent subbasins, evapotranspiration, discharge to streams, and flows to drains.

Figure 6-10~~Figure 6-10~~ shows the entire groundwater water budget from the SVIHM and includes annual change in groundwater storage. Changes in groundwater storage are strongly correlated with changes in deep percolation of precipitation and stream flows. For example, 1983 and 1998 were comparatively very wet years and represent the greatest increases in deep percolation and, correspondingly, the greatest increases in groundwater storage over the historical period. Estimated cumulative change in groundwater storage has steadily declined over time with slight increases in response to wet periods.

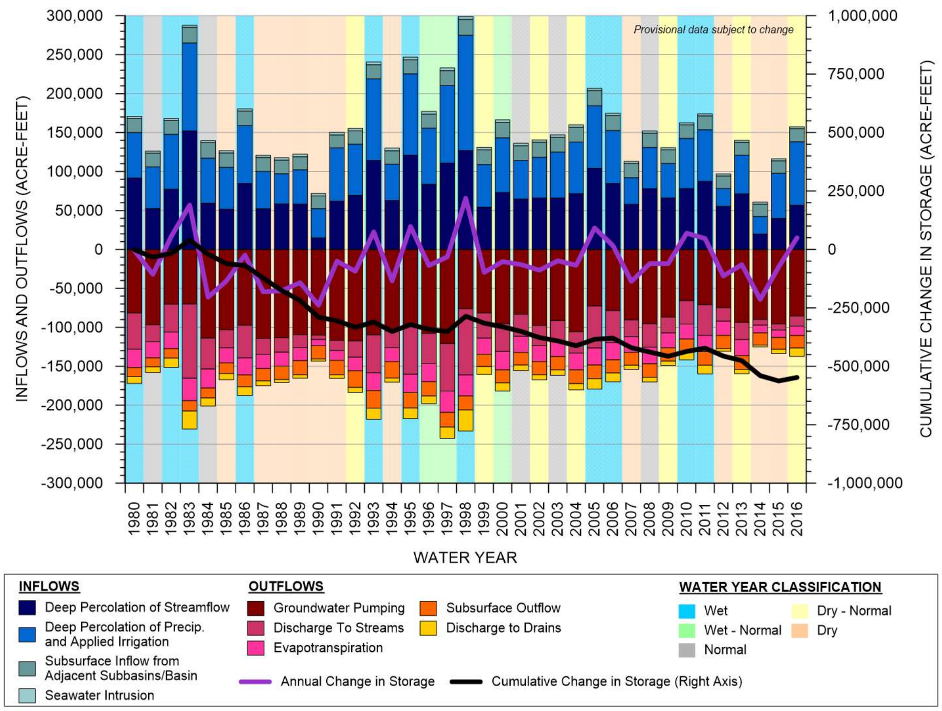

Figure 6-10. SVIHM Simulated Historical and Current Groundwater Budget

The SVIHM estimated the historical annual decline in storage to be 14,800 AF/yr. However, this decline is greater than estimated using groundwater level data, and this GSP considers the average annual historical decline in storage to be ~~600~~ 800 AF/yr., as explained above.

A comparison of the historical and current groundwater budgets is shown in Table 6-8. The values in the table are based on the inflows and outflows presented in previous tables. Negative values indicate outflows or depletions. This table is informative in showing the relative magnitude of various water budget components; however, these results are based on a provisional model and will be updated in future updates to this chapter after the SVIHM is completed and released by the USGS.

Table 6-8. Summary of Groundwater Budget (AF/yr)

	Historical Average (WY 1980 2016)	Current (WY 2016)
Groundwater Pumping	-132,800	-120,700
Flow to Drains	-9,000	-10,800
Net Stream Exchange	40,700	43,900
Deep Percolation of Precipitation and Applied Irrigation	63,600	81,700
Net Flow from Adjacent Subbasins/Basin	1,900	1,300
Seawater Intrusion	2,900	2,500
Flow to Ocean	-500	-600
Groundwater Evapotranspiration	-19,900	-12,100
Net Storage Gain (+) or Loss (-)	-~~600~~800	-15,000

Note: provisional data subject to change.

The net storage value is the estimated historical overdraft based on observed groundwater levels, as described in Sections 5.2.2 and 6.3.2. Water budget error, as reflected in change in storage, for the historical average period is 33%, which is considered unreasonably large and will be addressed and improved in future updates to the GSP.

6.3.4 Historical and Current Sustainable Yield

The historical and current sustainable yields reflect the amount of Subbasin-wide pumping reduction needed to balance the water budget, resulting in no net decrease in storage of useable groundwater. The sustainable yield can be estimated as:

Sustainable yield = pumping + change in storage + seawater intrusion

Table 6-9 provides a likely range of sustainable yields based on the GEMS derived historical pumping. This range represents the average GEMS reported pumping from 1995 to 2016, as shown in Table 6-6, plus and minus one standard deviation. The adjusted change in groundwater storage (loss) of ~~600~~ 800 AF/yr., described in Sections 5.2.2 and 6.3.3, is used for this calculation, as well as the seawater intrusion estimate described in Section 5.3.2, which is related to the change in volume of useable water rather than flows across the subbasin boundaries. These values are the likely range of the sustainable yield of the Subbasin. This does not include overdraft in the Deep Aquifers due to insufficient data, which is a data gap that will be filled during GSP implementation. This GSP adopts this range of likely sustainable yields as the best estimate for the Subbasin.

Table 6-9. Historical Sustainable Yield for the 180/400 Subbasin Derived from GEMS, Observed Groundwater Levels, and Mapped Seawater Intrusion Areas (AF/yr.)

	Low Historical Average	High Historical Average
Total Subbasin Pumping	114,800	136,600
Change in Storage	-~~600~~800	-~~600~~800
Seawater Intrusion	-12,600	-12,600
Estimated Sustainable Yield	101,~~600~~400	123,~~400~~200

Note: Pumping is shown as positive value for this computation. Change in storage value is based on observed groundwater measurements and seawater intrusion is based on mapped areas of intrusion, as previously described in the text.

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6.4 Projected Water Budgets

Projected water budgets are extracted from the SVOM, which simulates future hydrologic conditions with assumed climate change. Two projected water budgets are presented, one incorporating estimated 2030 climate change projections and one incorporating estimated 2070 climate change projections.

The climate change projections are based on data provided by DWR (2018). Projected water budgets are useful for showing that sustainability will be achieved in the 20-year implementation period and maintained over the 50-year planning and implementation horizon. However, the projected water budgets are based on a provisional version of the SVOM and are subject to change. Model information and assumptions summarized in this section of the report are based on provisional documentation on the model. Additional information will be provided in future GSP updates after the model is released by the USGS.

6.4.1 Assumptions Used in Projected Water Budget Development

The assumptions incorporated into the SVOM for the projected water budget simulations include:

- Land Use: The land use is assumed to be static, aside from a semi-annual change to represent crop seasonality. The annual pattern is repeated every year in the model. Land use specified in the model by USGS reflects the 2014 land use.

- No urban growth is included in this simulation to remain consistent with USGS assumptions. If urban growth is infill, this assumption may result in an underestimate of net pumping increases and an underestimate of the Subbasin's future overdraft. If urban growth replaces agricultural irrigation, the impact may be minimal because the urban growth will replace existing agricultural water use.
- Reservoir Operations: The reservoir operations reflect MCWRA's current approach to reservoir management.
- Stream Diversions: The SVOM explicitly simulates only two stream diversions in the Salinas Valley Basin: Clark Colony and the Salinas River Diversion Facility (SRDF). The Clark Colony diversion is located along Arroyo Seco and diverts stream water to an agricultural area nearby. The SRDF came online in 2010 and diverts water from the Salinas River to the Castroville Seawater Intrusion Project (CSIP) area. Clark Colony diversions are repeated from the historical record to match the water year. SRDF diversions are made throughout the duration of the SVOM whenever reservoir storage and streamflow conditions allow during the period from April through October. For purposes of the projected water budgets, SRDF diversions are specified at a rate of 18 cubic feet per second.
- Recycled Water Deliveries: Recycled water has been delivered to the CSIP area since 1998 as irrigation supply. The SVOM includes recycled water deliveries throughout the duration of the model.

6.4.1.1 Future Projected Climate Assumptions

Several modifications were made to the SVOM in accordance with recommendations made by DWR in their *Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development* (DWR, 2018). Three types of datasets were modified to account for 2030 and 2070 projected climate change: climate data including precipitation and potential evapotranspiration, streamflow, and sea level.

Climate Data

This GSP uses the climate change datasets provided by DWR for use by GSAs. The climate scenarios were derived by taking the historical interannual variability from 1915 through 2011 and increasing or decreasing the magnitude of events based on projected changes in precipitation and temperature from general circulation models. These datasets of climate projections for 2030 and 2070 conditions were derived from a selection of 20 global climate projections recommended by the Climate Change Technical Advisory Group as the most appropriate projections for California water resources evaluation and planning. Because the DWR climate datasets are only available through December 2011 and the SVOM uses a climate time series through December 2014, monthly change factors for January 2012 to December 2014 are assumed. DWR provided climate datasets for central tendency scenarios, as well as extreme wet and dry scenarios; the future water budgets described herein are based on the DWR central tendency scenarios for 2030 and 2070. Historical data were analyzed from the Salinas Airport precipitation gauge record to identify years from 1968 to 2011 that were most similar to conditions in 2012, 2013 and 2014. Based on this analysis, climate data from 1981, 2002, and 2004 are applied as the climate inputs for 2012, 2013, and 2014, respectively.

The modified monthly climate data for the entire model period are applied as inputs to the model, which reads precipitation and potential evapotranspiration data on a monthly basis.

Streamflow

DWR provided monthly change factors for unimpaired streamflow throughout California. For the Salinas Valley and other areas outside of the Central Valley, these change factors are provided as a single time series for each major watershed. Streamflows along the margins of the Basin are modified by the monthly change factors. As with the climate data, an assumption is required to extend the streamflow change factor time series through December 2014. It is assumed that the similarity in rainfall years at the Salinas Airport rainfall gauge could reasonably be expected to produce similar amounts of streamflow; therefore, the same years of 1981, 2002, and 2004 are repeated to represent the 2012, 2013, and 2014 streamflows.

Sea Level

DWR guidance recommends using a single static value of sea level rise for each of the climate change scenarios (DWR, 2018). For the 2030 climate change scenario, the DWR-recommended sea level rise value of 15 centimeters is used. For the 2070 climate change scenario, the DWR-recommended sea level rise value of 45 centimeters is used. The amount of sea level rise is assumed to be static throughout the duration of each of the climate change scenarios.

6.4.2 Projected Surface Water Budget

Average projected surface water budget inflows and outflows for the 47-year future simulation period with 2030 and 2070 climate change assumptions are quantified in Table 6-10~~Table 6-10~~. As with the current water budget, the boundary stream inflows and outflows are much greater than the other components.

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Table 6-10: SVOM Simulated Average Surface Water Inflow and Outflow Components for Projected Climate Change Conditions (AF/yr.)

Projected Climate Change Timeframe	2030	2070
Overland Runoff to Streams	20,500	21,800
Boundary Stream Inflows	1,184,000	1,327,200
Net Flow Between Surface Water and Groundwater	-53,600	-54,400
Boundary Stream Outflows	-1,144,300	-1,288,100
Diversions	-6,500	-6,600

Note: provisional data subject to change.

6.4.3 Projected Groundwater Budget

Average projected groundwater budget inflows for the 47-year future simulation period with 2030 and 2070 climate change assumptions are quantified in Table 6-11~~Table 6-11~~. In both the 2030 and 2070 simulations, the biggest contributors to groundwater inflows are deep percolation of stream flow and deep percolation of precipitation and irrigation.

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Table 6-11: SVOM Simulated Average Groundwater Inflow Components for Projected Climate Change Conditions (AF/yr.)

Projected Climate Change Timeframe	2030	2070
Deep Percolation of Stream Flow	56,500	57,800
Deep Percolation of Precipitation. and Irrigation	61,700	65,700
Underflow from Eastside Aquifer Subbasin	8,400	8,800
Underflow from Forebay Aquifer Subbasin	2,600	2,600
Underflow from Monterey Subbasin	1,900	2,000
Underflow from Langley Area Subbasin	4,400	4,600
Underflow from Pajaro Valley Subbasin	800	800
Underflow from Surrounding Watersheds	1,300	1,400
Underflow from Ocean (Seawater Intrusion)	2,900	3,100
Total Inflows	140,500	146,800

Note: provisional data subject to change.

Average SVOM projected groundwater budget outflows for the 47-year future simulation period with 2030 and 2070 climate change assumptions are quantified in Table 6-12~~Table 6-12~~. As in the historical and current water budgets, the greatest outflow is groundwater pumping. Negative values are shown in Table 6-12~~Table 6-12~~ to represent outflows.

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Table 6-12: SVOM Simulated Average Groundwater Outflow Components for Projected Climate Change Conditions (AF/yr.)

	Simulated		Adjusted	
Projected Climate Change Timeframe	2030	2070	2030	2070

Groundwater Pumping	-88,500	-92,500	-124,600	-130,300
Flows to Drains	-8,200	-8,800	-8,200	-8,800
Flow to Streams	-3,000	-3,400	-3,000	-3,400
Groundwater Evapotranspiration	-35,200	-37,000	-35,200	-37,000
Underflow to Eastside Aquifer Subbasin	-11,100	-11,300	-11,100	-11,300
Underflow to Forebay Aquifer Subbasin	-200	-200	-200	-200
Underflow to Monterey Subbasin	-2,600	-2,500	-2,600	-2,500
Underflow to Langley Area Subbasin	-300	-400	-300	-400
Underflow to Pajaro Valley Subbasin	-1,000	-1,000	-1,000	-1,000
Underflow to Surrounding Watersheds	-300	-300	-300	-300
Underflow to Ocean	-300	-300	-300	-300
Total Outflows	-150,700	-157,700	-186,800	-205,500

Note: provisional data subject to change.

[1] Adjusted pumping is based on the ratio between historical average SVIHM and GEMS agricultural pumping, as described in Section 6.3.2.

As described in Section 5.2.2 for the historical water budget, data indicate that the Subbasin has historically been in overdraft (on the order of ~~600~~ 800 AF/yr. decline)~~, as described in Section 5.2.2~~. Even though the SVOM ~~anticipates~~ projects -10,500 and -11,300 AF/yr. change in storage for 2030 and 2070, respectively, the adjusted historical decline in storage is used with the adjusted future pumping estimates to provide a likely more reasonable estimate for projected sustainable yield. The loss of in groundwater storage is slightly less in the projected simulations than in the historical simulations, even though there is no change in land use. This smaller decrease in groundwater storage is likely due to climate change, which is expected to be warmer and wetter according to DWR climate change factors. The model includes increased precipitation from climate change; however, it does not account for the frequency and magnitude of storm events. If storm events concentrate precipitation within short periods, more water may run off than infiltrate. More analysis needs to be done with regards to future recharge. ~~Therefore, t~~This projected water budget adopts the historical average annual change in storage as the most reasonable estimate for the future, assuming extraction continues. Since land use is assumed at 2014 conditions and does not change over time in the SVOM, groundwater storage declines are assumed to continue into the future at the historical average rate. This is reflected in the adjusted average change in storage in Table 6-13~~Table 6-13~~, which is set to a decline of ~~600~~ 800 AF/yr. However, as described above, this storage loss estimate is likely underestimated because it does not account for conditions in the Deep Aquifers, due to lack of data. The estimate will be improved in the future after additional hydrogeologic investigations of the Deep Aquifers.

Combining Table 6-11~~Table 6-11~~ and Table 6-12~~Table 6-12~~ yields the SVOM simulated net groundwater inflow and outflow data for the 47-year future simulation with 2030 and 2070 climate change assumptions. These flows are shown in Table 6-13~~Table 6-13~~. Negative values indicate outflows or depletions. The net storage changes in the last row closely match the sums of the other rows. It is not an exact match due to rounding error and model error.

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Table 6-13: Average SVOM Simulated and Adjusted Annual Groundwater Budget for Projected Climate Change Conditions (AF/yr.)

	Simulated		Adjusted	
Projected Climate Change Timeframe	2030	2070	2030	2070
Groundwater Pumping	-88,500	-92,500	-124,600	-130,300
Flow to Drains	-8,200	-8,800	-8,200	-8,800
Net Stream Exchange	53,600	54,400	53,600	54,400
Deep Percolation of Precipitation and Applied Irrigation	61,700	65,700	61,700	65,700
Net Flow from Adjacent Subbasins/Basin	3,800	4,400	3,800	4,400
Seawater Intrusion	2,900	3,100	2,900	3,100
Flow to Ocean	-300	-300	-300	-300
Net Groundwater Evapotranspiration	-35,200	-37,000	-35,200	-37,000
Net Storage Gain (+) or Loss (-)	-10,500	-11,300	-~~600~~800	-~~600~~800

Note: provisional data subject to change.

Based on the adjusted change in storage, which is the historical average decline as described in the text, model error is 32% for 2030 and 39% for 2070; these error values are unreasonably large and will be addressed and improved in future updates to the GSP.

[1] Adjusted pumping is based on the ratio between historical average SVIHM and GEMS agricultural pumping, as described in Section 6.3.2.

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SVOM projected groundwater pumping by water use sector is summarized in Table 6-14~~Table 6-14~~. Because the model assumes no urban growth, future municipal pumping was assumed to be equal to current municipal pumping. Future agricultural pumping is then calculated as the total projected pumping minus the current municipal pumping. The 2030 and 2070 model simulations predict that agriculture will account for about 90% of pumping. Similar to the SVIHM, domestic pumping is not included in the SVOM future projections simulation.

Table 6-14: SVOM Simulated Projected Annual Groundwater Pumping by Water Use Sector (AF/yr.)

	Simulated		Adjusted	
Water Use Sector	2030	2070	2030	2070
Urban Pumping	-7,900	-7,900	-11,000	-11,000
Agricultural Pumping	-80,600	-84,600	-113,600	-129,300
Total Pumping	-88,500	-92,500	-124,600	-130,300

Note: provisional data subject to change.

[1] Adjusted pumping is based on the ratio between historical average SVIHM and GEMS agricultural pumping, as described in Section 6.3.2.

6.4.4 Projected Sustainable Yield

Projected sustainable yield is the long-term pumping that can be sustained once all undesirable results have been addressed. However, it is not the amount of pumping needed to stop undesirable results before sustainability is reached. The SVBGSA recognizes that depending on the success of various proposed projects and management actions there may be some years when pumping must be held at a lower level to achieve necessary rises in groundwater elevation. The actual amount of allowable pumping from the Subbasin will be adjusted in the future based on the success of projects and management actions.

To retain consistency with the historical sustainable yield, projected sustainable yield can be estimated by summing all the average groundwater extractions, subtracting the average loss in storage, and subtracting the average seawater intrusion. This represents the change in pumping that results in no change in storage of useable groundwater, assuming no other projects or management actions are implemented. For this sustainable yield discussion and associated computations, groundwater pumping outflows are reported as positive values, which is opposite of how the values are reported in the water budget tables. As discussed earlier, the current, preliminary version of the SVIHM, and by inference the SVOM, appears to overestimate the historical overdraft in the Subbasin and therefore underestimate the historical sustainable yield. The sustainable yield value will be updated in future GSP updates as more data are collected and additional analyses are conducted.

Although the sustainable yield values provide guidance for achieving sustainability, simply reducing pumping to within the sustainable yield is not proof of sustainability. Sustainability must be demonstrated through the Sustainable Management Criteria (SMC). Table 6-15 provides estimates of the future sustainable yield using estimated future pumping calculated in Table 6-14~~Table 6-14~~. As described for the historical sustainable yield, data indicate that the Subbasin has historically been in overdraft (on the order of ~~600~~ 800 AF/yr. decline, not including the Deep Aquifers). This historical decline in storage is used with the adjusted SVOM pumping estimates to provide a likely more reasonable estimate for projected sustainable yield. Therefore, although change in storage projected by the preliminary SVOM is on the order of -11,000 AF/yr., the historical average change in storage in Table 6-15 is set to a decline of ~~600~~ 800 AF/yr. This does not include the Deep Aquifers, which is a data gap that will be filled during GSP implementation. Similarly, the historical average seawater intrusion rate of 12,600 AF/yr. is also used for this calculation.

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Table 6-15. Adjusted Projected Sustainable Yields for the 180/400 Subbasin Derived from GEMS, Observed Groundwater Levels, and Mapped Seawater Intrusion Areas (AF/yr.)

	2030 Projected Sustainable Yield	2070 Projected Sustainable Yield	Historical Sustainable Yield Range
Groundwater Pumping	124,600	130,300	114,800 to 136,600
Seawater Intrusion	-12,600	-12,600	-12,600
Change in Storage	-~~600~~800	-~~600~~800	-600
Projected Sustainable Yield	111,~~400~~200	~~127,100~~116,900	101,~~600~~ 400 to 123,~~400~~200

Note: Pumping is shown as positive value for this computation. Change in storage value is based on observed groundwater measurements and seawater intrusion is based on mapped areas of intrusion, as previously described in the text for historical water budgets.

Table 6-15 includes the adjusted estimate of historical sustainable yield for comparison purposes. Although the sustainable yield values provide guidance for achieving sustainability, simply reducing pumping to within the sustainable yield is not proof of sustainability. Sustainability must be demonstrated through the SMC. The sustainable yield value will be modified and updated as more data are collected, and more analyses are performed.

6.4.5 Uncertainties in Projected Water Budget Simulations

Models are mathematical representations of physical systems. They have limitations in their ability to represent physical systems exactly and due to limitations in the data inputs used. There is also inherent uncertainty in groundwater flow modeling itself, since mathematical (or numerical) models can only approximate physical systems and have limitations in how they compute data. However, DWR (2018) recognizes that although models are not exact representations of physical systems because mathematical depictions are imperfect, they are powerful tools that can provide useful insights.

There is additional inherent uncertainty involved in projecting water budgets with projected climate change based on the available scenarios and methods. The recommended 2030 and 2070 central tendency scenarios that are used to develop the projected water budgets with the SVIHM provide a dataset that can be interpreted as what might be considered the most likely future conditions; there is an approximately equal likelihood that actual future conditions will be more stressful or less stressful than those described by the recommended scenarios (DWR, 2018).

As stated in DWR (2018):

> *"Although it is not possible to predict future hydrology and water use with certainty, the models, data, and tools provided [by DWR] are considered current best available science and, when used appropriately should provide GSAs with a reasonable point of reference for future planning."*

6.5 Subbasin Water Supply Availability and Reliability

Water is not imported into the 180/400-Foot Aquifer Subbasin. However, a significant portion of the Subbasin's recharge is derived from reservoir releases that regulate Salinas River streamflow. The historical water budget incorporates years when there was little availability of surface water flow and groundwater elevations declined as a result. Figure 6-5~~Figure 6-5~~ shows that when Salinas River flows were low, deep percolation to groundwater was also low. Declines in groundwater levels during these years contributed to chronic groundwater storage loss and seawater intrusion during the historical period. The projected water budgets are developed with the SVOM, which is based on historical surface water flows and groundwater conditions, and therefore projected water budgets incorporate reasonable fluctuations in water supply availability. MCWRA plans to revise the Habitat Conservation Plan (HCP) for the Salinas~~ans~~ River, which may change the current reservoir release schedule. A revised reservoir release schedule could influence the reliability of groundwater recharge.

6.6 Uncertainties in Water Budget Calculations

The level of accuracy and certainty is highly variable between water budget components. A few water budget components are directly measured, but most water budget components are either estimated inputs to the model or simulated by the model. Additional model uncertainty stems from an imperfect representation of natural condition and is reflected in model calibration error. However, inputs to the models are carefully selected using best available data, the model's calculations represent established science for groundwater flow, and the model calibration error is within acceptable bounds. Therefore, the models are the best available tools for estimating water budgets. The model results are provisional and subject to change in future GSP updates after the models are released by the USGS.

The following list groups water budget components in increasing order of uncertainty.

- Measured: metered municipal, agricultural, and some small water system pumping
- Estimated: domestic pumping, including depth, rate, and location
- Simulated primarily based on climate data: precipitation, evapotranspiration, irrigation pumping
- Simulated based on calibrated model: all other water budget components

Simulated components based on calibrated model have the most uncertainty because those simulated results encompass uncertainty of other water budget components used in the model in addition to model calibration error.