North San Benito County Groundwater Sustainability Plan Draft: Water Budget

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5. WATER BALANCE

This section provides a quantitative assessment of the water balance (or water budget) of the North San Benito Subbasin (or Basin), including estimates of inflows and outflows for individual Management Areas. Annual balances based on historical data are presented for water years 1975-2017, and average annual balances are presented for three intervals within that period. Water balances under future conditions were simulated for an 86-year period corresponding to hydrologic conditions during water years 1922-2007. Methods of analysis are summarized below. Findings are presented in terms of surface water balances, groundwater balances, and cumulative change in groundwater storage. Sustainable yield is also discussed.

This water balance has been developed based on the numerical model. It builds on water balances previously prepared for the Annual Groundwater Reports, but some water balance elements differ from previous estimates. This reflects not only the use of currently available data for the entire North San Benito Subbasin, but also the fact that the numerical model allows a dynamic and comprehensive quantification of the water balance wherein all estimated water balance elements fit together and are calibrated to groundwater level changes over time. Accordingly, the numerical model is the best tool to quantify the North San Benito water balance. It will be updated regularly through the GSP process, providing a better understanding of the surface water-groundwater system and a tool to evaluate future conditions and management actions.

5.1. WATER YEAR TYPE

GSP Regulations require quantification of the water budget by water year type, which is a classification based on the amount of annual precipitation in a basin. **Figure 5-1** shows annual rainfall in Hollister from water year 1922 through 2018; the average annual amount is 13.4 inches. Water year type is intended to aid in the evaluation of information such as water level hydrographs and groundwater storage changes. **Table 5-1** documents the classification developed for North San Benito, which describes five water year types (critically dry, dry, normal, above normal, wet). The methodology for defining the water year types is based on DWR's Water Budget Best Management Practice (BMPs) Document (DWR, 2016). For North San Benito, the annual rainfall amounts in Hollister over the period of record (1922-2018) were expressed as percentages of average annual rainfall. These were then sorted into quintiles, reflecting the five categories. The sorting into quintiles resulted in the classification shown in **Table 5-1**. The water years from 1922 to 2018 were then classified using the numeric values in **Table 5-1** as illustrated in **Figure 5-1.**

The water year classification is based on local Hollister rainfall as representative of the Basin and surrounding watershed. Local precipitation is important for the overall water balance of the area. While CVP allocations are critical to avoiding overdraft and are based on precipitation patterns in the Sierra Nevada and Central Valley, local precipitation has a larger effect by volume on the groundwater basin. Surface water recharge, deep percolation, and irrigation demand are all dependent on local rainfall.

Table 5-1. Water Year Type Classification

Water Year Type		Range of percent normal	Precipitation Range (in)
Wet	W	>130	> 17.5
Above Normal	AN	105-130	14.1 - 17.5
Normal	N	85-105	11.4 - 14.1
Dry	D	70-85	9.4 - 11.4
Critically Dry	C	<70	< 9.4
Average Rainfall 13.4 inches per year			

5.2. WATER BALANCE ANALYSIS PERIODS

GSP Regulations require evaluation of the water balance over historical, current, and future periods. The historical period must include ten recent years at a minimum and the future involves projection of 50 years of historical hydrologic conditions. For the North San Benito Subbasin, the historical period for water balance analysis is defined over water years 1975 – 2014 and is subdivided into two distinct historical periods. These periods were selected on the basis of cumulative departure of annual precipitation in Hollister during water years 1922-2018, on land use changes, and on availability of imported CVP water. While recognizing that CVP water is not directly available to all Management Areas, it has been critical to the water balance of North San Benito Subbasin as a whole. Hence two historical periods have been defined plus current and future periods, as described below

- **Pre-CVP Historical (1975-1988)** – The Pre-CVP Historical period represents the period before CVP water was imported into the basin. Groundwater (with some replenishment by local surface water) was the sole water supply. The average annual precipitation was close to the long-term average, at 114 percent of normal.
- **Historical Recovery (1989-2014)** – The Historical Recovery period is marked by the beginning of CVP imports to supplement groundwater. While having direct effects only on Hollister and San Juan MAs, CVP supply was critical to basin-wide recovery. The average annual precipitation was close to the long-term average, at 102 percent of normal.
- **Current (2015-2017)** – The Current period is a snapshot view of recent conditions as required by SGMA regulations. Future annual reports will examine changes that have occurred since 2015. This relatively brief period included a dry, above average, and wet year. The average annual precipitation over those three years (16.28 inches) was 121 percent of the long-term average.
- **Future (2018-2068)** – The Future period represents conditions expected to occur over the next 50 years. The "future baseline" simulation of this period spans an 86-year period corresponding to hydrologic conditions during water years 1922-2007. Two intervals totaling 50 years were selected from that overall period as the basis

for calculating average annual future water balances. This process is described in greater detail in Section 5.4.3. In general, the future baseline simulation assumes a continuation of existing land use, urban water demand, water and wastewater treatment and CVP availability.

5.3. Management Areas

As defined in the GSP Regulations, a Management Area (or MA) is an area within a basin for which the GSP may identify different minimum thresholds, measurable objectives, monitoring, or projects and management actions based on differences in water use sector, water source type, geology, aquifer characteristics, or other factors. The North San Benito Basin has been divided into four MAs, as described in the Definition of Management Areas for North San Benito Basin GSP technical memorandum, included as **Appendix F** to the GSP. The four MAs – Southern, Hollister, San Juan, and Bolsa are shown in **Figure 5-2** and briefly described below.

5.3.1. Southern Management Area

The Southern MA is characterized by uplands and small valleys along the San Benito River and Tres Pinos Creek. Land uses are predominantly rural residential, rangeland, and agricultural (mostly truck crops and vineyards), which rely on groundwater supply provided mostly by private wells.

A key factor differentiating the Southern MA from the other MAs is access to local surface water and the absence of effects of Central Valley Project (CVP) water. Pumping in the Southern MA is also distant from the adjoining Hollister MA. Most of the pumping is in Paicines and Tres Pinos Creek Valleys, which are separated from the Hollister MA by three miles of rugged terrain where there is little pumping. Groundwater in Southern MA is recharged in part by releases from Hernandez and Paicines reservoirs.

5.3.2. Hollister Management Area

The Hollister MA includes the Hollister Valley and adjacent uplands mostly to the south. The Hollister MA differs from the adjoining MAs because of its variety of land uses, multiple jurisdictions, and multiple sources of water supply. Its boundary with the Bolsa and Southern MAs follows the boundary of Zone 6. The boundary with the San Juan MA—which includes part of Zone 6—crosses the narrow point in the valley floor at the upstream end of the San Juan Valley and traces the topographic divides on either side of the gap. The Hollister Valley includes intensive agriculture, rangeland, rural residential, urban, and industrial land uses. The MA includes all or portions of the City of Hollister, Sunnyslope County Water District, Pacheco Pass Water District, Tres Pinos County Water District, Hollister Hills SVRA, and the part of Pacheco Creek Valley that extends north into Santa Clara County.

Sources of water supply include local groundwater (recharged in part by releases from Hernandez and Paicines reservoirs to the San Benito River and releases from Pacheco

Reservoir to Pacheco Creek), CVP imported water, and recycled water. A small amount of CVP water also is provided by SCVWD to a few customers in Santa Clara County parts of the MA. Production wells include irrigation, domestic, and public water supply wells throughout the MA, but well density is greater in the northern half of the MA. Domestic wells are relatively dense along Fairview Road, with minimum well depths less than 150 feet.

5.3.3. San Juan Management Area

The San Juan MA includes the San Juan Valley and adjacent uplands. Important characteristics of the San Juan MA are the various land uses, multiple jurisdictions, and multiple sources of water supply. The San Juan Valley is characterized by prime farmland and intensive agriculture, while the uplands are mostly rangeland with some rural residential and industrial land uses. The MA includes most of the City of San Juan Bautista and small areas of the City of Hollister, Aromas Water District, and Santa Clara County. Sources of water supply include local groundwater (recharged in part by releases from Hernandez and Paicines reservoirs) and CVP imported water. The MA differs from the Hollister MA primarily because of a much higher proportion of agricultural land and water use, generally poorer groundwater quality, and an absence of recycled water use.

Irrigation wells are most numerous along the axis of the valley, while domestic wells are most numerous in the vicinity of San Juan Bautista and toward Aromas on the west, where the highest densities and shallowest wells have been documented by DWR.

5.3.4. Bolsa Management Area

The Bolsa area has long been recognized for its distinct topography and groundwater conditions (e.g., Clark, 1924), although its boundaries have been defined variously by USGS, DWR, and SBCWD. As shown in **Figure 5-2,** the Bolsa is a predominantly flat, relatively low-elevation area. It shares a watershed boundary with the San Juan MA and the Zone 6 boundary with the Hollister MA. It is the only MA bounding another groundwater basin, the Llagas Subbasin in Santa Clara County. It also differs from the adjacent Hollister and San Juan MAs by not having direct access to CVP imports or managed recharge from Hernandez and Paicines Reservoirs.

Important characteristics of the Bolsa MA include the predominantly agricultural and rural land uses and complete reliance on groundwater supply provided by private wells.

5.4. METHODS OF ANALYSIS

Complete, itemized surface water and groundwater balances were estimated by combining raw data (rainfall, stream flow, municipal pumping, wastewater percolation) with values simulated using models[1]. Collectively, the models simulate the entire hydrologic system, but

[1] Water balance values are shown to nearest acre-foot to retain small items, but entries are probably accurate to only two significant digits.

each model or model module focuses on part of the system, as described below. In general, the models were used to estimate flows in the surface water and groundwater balances that are difficult to measure directly or that depend on current groundwater levels. These include surface and subsurface inflows from tributary areas, percolation from stream reaches within the Basin, groundwater discharge to streams, subsurface flow from the Llagas Subbasin and between Management Areas, the locations and discharges of flowing wells, consumptive use of groundwater by riparian vegetation, and changes in groundwater storage.

5.4.1. Rainfall-Runoff-Recharge Model

This Fortran-based model simulates hydrologic processes that occur over the entire land surface, including precipitation, interception[2], infiltration, runoff, evapotranspiration, irrigation, effects of impervious surfaces, pipe leaks in urban areas, deep percolation below the root zone, and shallow groundwater flow to streams and deep recharge. The model simulates these processes on a daily time step for 2,768 "recharge zones" delineated to reflect differences in physical characteristics as well as basin and jurisdictional boundaries. The recharge zones cover the entire watershed tributary to the groundwater basin except the San Benito River watershed south of the Southern MA. Simulation of watershed areas outside the Basin provided estimates of stream flow and subsurface flow entering the Basin. San Benito River inflow to the Southern MA was obtained directly from stream gauge data. Daily simulation results were subtotaled to monthly values for input to the groundwater model. Additional details regarding the rainfall-runoff-recharge model can be found in **Appendix G** (not yet available).

5.4.2. Groundwater Model

A numerical groundwater flow model of northern San Benito County was originally developed in 2002 and previously updated in 2015 (Yates and Zhang, 2001; Todd Groundwater, 2015). For GSP purposes, the model footprint was expanded to cover the entire Southern MA and all of the Pacheco Creek Valley part of the basin located in Santa Clara County. Also, the simulation period was updated to include water years 1975-2017 and to reflect 2014 land use as mapped by DWR and made available via the SGMA Data Portal website. The model uses the MODFLOW 2005 code developed by the U.S. Geological Survey, with pre- and post-processing facilitated by using Groundwater Vistas, a readily available commercial software package. The model produces linked simulation of surface water and groundwater, as described below. **Figure 5-3** shows the modeled area and key features. Additional documentation of the model update and recalibration is provided in **Appendix G**.

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[2] Interception refers to precipitation that does not reach the soil, but instead falls on (and is intercepted by) plant leaves, branches, and plant litter, and is subject to evaporation loss.

5.4.2.1. Surface Water Module

The stream flow routing module of MODFLOW simulates flow in creeks and rivers that cross the groundwater Basin (see **Figure 5-3**). Surface flow in these streams where they enter the Basin is provided by the user (from gauged flows or the rainfall-runoff-recharge model), and the flow is routed across the Basin from reach to reach. Each model grid cell traversed by a creek or river corresponds to a reach. Along each reach mass balance is conserved in the stream, including inflow from the upstream reach and tributaries, inflow from local runoff and CVP discharges, head-dependent flow across the stream bed to or from groundwater, and outflow to the next downstream reach. Flow across the stream bed is a function of the wetted channel length and width, the bed permeability and the difference in elevation between the stream surface and groundwater at the reach cell. Wetted width and depth of the stream are functions of stream flow.

5.4.2.2. Groundwater Module

MODFLOW simulates subsurface flow by combining equations representing flow through porous sediments (the Darcy Equation) with equations that enforce conservation of mass. The equations are implemented numerically, which means they are applied simultaneously between all adjoining cells in a model grid through an iterative process. Dispersed recharge to the top layer of the model grid from deep percolation of rainfall, irrigation water and pipe leaks is obtained from the rainfall-runoff-recharge model. Bedrock inflow is also obtained from that model and simulated as a series of injection wells around the periphery of the Basin. Percolation at wastewater treatment plants is similarly simulated as shallow injection wells in model cells at the wastewater pond locations. Irrigation pumping is estimated for each recharge zone by the rainfall-runoff-recharge model and assigned to the groundwater model cell closest to the center of the recharge zone. Evapotranspiration (ET) by riparian vegetation is simulated using the MODFLOW EVT module, which allows the ET rate to decrease as the water table drops to the bottom of the root zone. Where flowing wells are present during periods of relatively high groundwater levels, MODFLOW drain cells are used to cap the simulated water levels at the ground surface elevation. Groundwater inflow from the Llagas Subbasin is simulated as a function of cell cross-sectional area, permeability, and water-level difference between the cell and the estimated external groundwater level (estimated from measured water levels near the southern boundary of the Llagas Subbasin).

5.4.3. Simulation of Future Conditions

GSP regulations §354.18(c)(3) require simulation of several future scenarios to determine their effects on water balances, yield and sustainability indicators. The following three scenarios are prescribed:

> **Future Baseline.** This represents a continuation of existing land and water use patterns, imported water availability, and climate.
>
> **Climate Change.** This represents a continuation of existing land and water use patterns, but with anticipated effects of future climate change on local hydrology (rainfall recharge and stream percolation) and on the availability of imported water supplies.

Growth. This scenario implements anticipated changes in land use and associated water use, such as urban expansion, new irrigated areas and changes in crop types.

Each of these scenarios must cover a 50-year period. The groundwater model used to evaluate historical conditions simulates a 43-year period (water years 1975-2017). To obtain 50 years of analysis, future simulations were completed as back-to-back simulations of two 43-year periods: water years 1922-1964 and 1965-2007. This period takes advantage of DWR's CalSim2 simulations of CVP availability, which cover the period 1922-2003. It also includes the two largest droughts in the historical record: 1923-1935 and 1987-1992. Except for water quality, undesirable results for all sustainability indicators are most common and/or most severe during droughts.

The simulations produce 86 years of simulated water levels and water balances. For GSP compliance average water balances were calculated for the combined periods of 1922-1953 and 1982-2002, which together total 50 years. Two periods were selected instead of a single continuous period in order to include the two large droughts. The specific date windows were selected on the basis of cumulative departure graphs of Hollister precipitation and CVP availability, which are shown in **Figures 5-4 and 5-5**, respectively. For both metrics, the early period was drier than average, and the late period was wetter. When combined, average precipitation and CVP availability were within 3 percent of their long-term averages.

The following paragraphs describe how hydrologic data and model input assumptions were developed for the future baseline scenario. Preparation and results of the climate change and growth scenarios are described in Chapter 8 "Projects and Management Actions". Specific assumptions and data included in the future baseline simulation are as follows:

- Initial water levels are simulated water levels for September 2012 from the historical calibration simulation. That year represents relatively recent, non-drought conditions.
- Land use remains the same as existing conditions. In the model these are represented by 2014 land use mapped by remote sensing methods and obtained from DWR.
- Daily precipitation in Hollister was estimated back to 1922 based on correlations with gauged precipitation in Gilroy, Watsonville and Salinas. Daily ETo was estimated by adjusting the average ETo for each calendar month to reflect historical daily temperatures, using regressions of temperature and ETo for each calendar month.
- Small stream inflows and bedrock inflow were simulated for 1922-2007 using the rainfall-runoff-recharge model from the historical simulation, with existing land use and the above daily time series of precipitation and ETo.
- Monthly outflow from the existing Pacheco Reservoir to Pacheco Creek during 1922-2003 was simulated assuming that winter inflows are stored up to the 5,500 AF capacity of the reservoir and released during June-September at 15 cfs, as long as sufficient water remains to supply those releases.
- San Benito River inflow at the model boundary for 1922-1974 was reconstructed using simple rainfall-runoff and reservoir operations models. Linear relationships

between Hollister rainfall and flows at the gauge near Willow Creek School (near the model boundary) were developed for 1941-1961, which was the period of record prior to construction of Hernandez Reservoir. In the reservoir operations model, simulated runoff from the part of the watershed tributary to the Hernandez Reservoir site was stored in winter up to the reservoir capacity of 17,500 AF and released at 50 cfs from June through August as long as water was still available. The releases (and winter spills) were combined with runoff from the unregulated part of the watershed to obtain estimated flows at Willow Creek School. This implicitly assumed that Hernandez Reservoir will be operated as it was in the past.

- M&I and rural domestic pumping were assumed to remain at existing levels. Those were obtained by calculating average pumping for each calendar month during 2015-2017 and applying those averages in every year of the future simulation. This implicitly assumes no growth in those water use categories.
- Wastewater percolation and recycled water use for irrigation were assumed to remain at existing levels and were calculated using the same procedure as for M&I and domestic pumping.
- Monthly delivery of CVP water was obtained from DWR's CalSim 2 operations model, which produces simulated allocations for south-of-Delta contractors. The CalSim 2 simulation applied existing CVP operational rules and 2030 climate conditions in CVP source areas. For GSP purposes, actual use of CVP M&I water by the City of Hollister and Sunnyslope County Water District was set equal to the smaller of 1) the CalSim 2 M&I allocation, 2) the combined capacity of the Lessalt and West Hills water treatment plants (approximately 5,900 AFY), or 3) the amount of CVP water needed to achieve a 70%/30% blend of CVP water and groundwater. Other CVP M&I users were assumed to use 1,500 AFY (which is the recent historical usage) and be reduced by the same proportion as the two municipal water purveyors in years when the CVP allocation could not meet the normal demand. In the modeling, surplus CVP M&I water in wet years was transferred to agricultural use, although in practice it would likely be percolated to groundwater. Agricultural users were assumed to always accept all of the CalSim 2 agricultural water allocation.

Simulated future baseline water balances for the Management Areas are presented in the next sections, where they are compared with historical and current water balances. Simulated groundwater levels are compared with simulated water levels for other future scenarios in Chapter 8.

5.5. Surface Water Balance

This section describes and quantifies the water balance of creeks and rivers that cross the Basin. All significant inflows to and outflows from these surface water bodies are included in the water balance. The surface water balance shares two flows in common with the groundwater balance: percolation from surface water to groundwater and seepage of groundwater into surface water. Each of these is an outflow from one system and an inflow to the other.

Annual surface water balances during 1975-2017 were compiled from monthly data for each Management Area. Average annual water balances for each Management Area during each of the four analysis periods are presented in Section 5.5.3. Annual basin wide surface water balances for 1975 to 2017 are shown in **Figure 5-6** and demonstrate how most of the surface water volume simply passes through the Basin.

5.5.1. Inflows to Surface Water

5.5.1.1. Precipitation and Evaporation

Precipitation and evaporation on the land surface are accounted for in the rainfall-runoff-recharge model. Those processes are not included in the surface water balances, which address only water in stream channels and imported water. Also, precipitation and evaporation on the surface of creeks and rivers is invariably a miniscule percentage of total stream flow. These small fluxes are not included in the surface water balances.

5.5.1.2. Tributary Inflows

Tributary inflows are the flows in creeks where they enter the Basin. With two exceptions, these flows are obtained from the rainfall-runoff-recharge model and passed to the surface water module of the groundwater flow model. The two exceptions are Pacheco Creek and the San Benito River, both of which have flows that are regulated by reservoir operation. For the historical and future baseline simulations, inflows to Pacheco Reservoir generated by the rainfall-runoff-recharge model were assumed to be stored in winter up to the 5,500 AF reservoir storage capacity and released at 15 cfs during June-September or until the reservoir was emptied, whichever occurred first. For the historical simulation of the San Benito River, inflows at the model boundary were set equal to measured flows at the gauge near Willow Creek School. Those flows reflect actual historical operation of Hernandez Reservoir. For the future baseline simulation, 39 percent of the simulated runoff for the entire watershed upstream of the model area was assumed to be regulated by Hernandez Dam. Inflow in winter was stored up to the 17,500 AF storage capacity of the reservoir and released during June-August at a rate of 50 cfs as long as sufficient storage was available to do so.

Stream flows entering one Management Area from another Management Area are itemized separately so the magnitude of discharge from local tributaries can be compared with the amount of water flowing through the Management Area in major creeks and rivers.

5.5.1.3. Valley Floor Runoff

Valley floor areas are flatter than the tributary watersheds, and the amount of runoff per acre is consequently smaller. The rainfall-runoff-recharge model simulates runoff from valley floor areas, and those flows are added to the inflows of nearby stream segments in the groundwater model.

5.5.1.4. CVP Imported Water

Two Management Areas (Hollister and San Juan) receive imported water from the CVP, which is delivered to municipal and agricultural users and formerly was also percolated in local streams to enhance groundwater recharge. Little of the imported water delivered to customers ends up in the stream network, given that efficient irrigation practices and urban water conservation are widespread and provide little opportunity for losses to streams. CVP imports are included in the water balances to provide a complete picture of surface water resources that are being or could potentially be harnessed to meet local water demands.

Annual deliveries of CVP are shown in **Figure 5-7**. Deliveries of imported water began in 1988 serving almost exclusively agricultural customers. During 1988-2001, substantial amounts of CVP water were percolated in local creeks to accelerate replenishment of groundwater storage following the 1987-1992 drought and prior decades of overdraft. The recovery effort was successful, and percolation of CVP water was greatly reduced. In 2008, concerns arose over potential introduction of invasive non-native species (zebra mussels) and discharges of CVP water to local creeks were discontinued. A new strategy of percolating CVP water in off-channel ponds was initiated in 2017. Use of CVP M&I water was limited to a few commercial users and small water systems until 2003, when completion of the Lessalt water treatment plant allowed much larger quantities to be treated and included in the City of Hollister water supply. The ability to use CVP M&I water was further increased by the West Hills water treatment plant, which became fully functional in 2017. In 2018, use of M&I water totaled 5,769 AF, or 70 percent of the maximum allocation. The CVP water delivered to growers and urban users reduces the amount of pumping needed to meet their respective water demands. During dry years when CVP allocations are low, groundwater pumping increases; and the opposite occurs in wet years. Thus, conjunctive use of CVP water and groundwater is a central element of local groundwater management.

CVP water is delivered to agricultural customers in the Hollister and San Juan MAs. In many years, agricultural use of CVP water has been limited by its availability. In wet years availability sometimes exceeds the demand. Although CVP water is more expensive than groundwater, it has much better water quality and is delivered with pressure. In 2009, regulatory changes in the CVP system resulted in decreased allocations for imported water. This change combined with drought conditions significantly reduced the amount of CVP imported for agricultural use during 2009-2017.

CVP imported water stored in San Justo Reservoir seeps from the reservoir to the local groundwater. In addition, water evaporates from the surfaces. These seepage and evaporation losses remain consistent through the period of record and are not shown in the surface water balance, although seepage from San Justo Reservoir is included in the groundwater model.

5.5.1.5. Seepage from Groundwater

When the water table elevation near a stream is higher than the water surface of the stream, groundwater will seep through the stream bed and add to flow in the stream. This flux depends strongly on groundwater elevation and is calculated by the stream flow routing module of the groundwater model.

5.5.2. Outflows of Surface Water

5.5.2.1. Surface Outflow from Management Areas and the Basin

Surface water outflow occurs where creeks and rivers cross the downstream boundary of a management area. For example, Pacheco Creek and Tequisquita Slough cross from the

Hollister to the Bolsa MA, and Tres Pinos Creek and the San Benito River cross from the Southern to the Hollister MA. The ultimate surface water outflow from the Basin is outflow to the Pajaro River at the western end of the San Juan MA. Surface flows at the boundaries between MAs and at the downstream end of the Basin are simulated by the stream flow routing module of the groundwater model.

5.5.2.2. Surface Water Percolation to Groundwater

Percolation from streams to groundwater occurs when the water level in a stream is higher than the nearby water table and is simulated using the same equation used for groundwater seepage into streams. The direction of flow across the stream bed simply depends on whether the stream surface is higher than the water table or vice versa.

5.5.3. Summary by Management Area

5.5.3.1. Southern MA

Table 5-2 summarizes surface water balances for the Southern MA. As shown, tributary watersheds supply almost all surface water inflows to the Southern MA, with the San Benito River watershed contributing about 43 percent of those inflows. Percolation to and from groundwater are both relatively high in this Management Area, primarily because of the long reaches of the San Benito River and Tres Pinos Creek that pass through. The relatively low value of seepage from groundwater into streams during the current period is likely due to delayed recovery of groundwater levels following the 2013-2015 drought. That is, 2017 was very wet in terms of rainfall, runoff and streamflow, but groundwater levels were still recovering from the drought. Tributary inflows and valley floor runoff were lower in the future baseline simulation than during the three historical periods because average annual rainfall over the 1922-2017 period was less than the averages during each of the three historical periods. This rainfall difference was amplified by the nonlinear relationships between rainfall, runoff and recharge: for a given percent increase in rainfall, simulated stream flow will increase by a larger percentage.

As shown in the Totals and bottom row of **Table 5-2**, total surface water inflows are equal to total surface water outflows. This reflects the lack of appreciable surface water storage in the MA, even with Paicines Reservoir, such that inflows quickly become outflows relative to the time frames considered here.

Table 5-2. Average Annual Surface Water Balances, Southern Management Area (AFY)

Water Balance Items	Historical Pre-CVP 1975-1988	Historical Recovery 1989-2014	Current 2015-2017	Future[1]
Surface Water Inflows				
Local watershed inflows	47,603	43,347	44,614	42,061
Valley floor runoff	3,996	3,854	5,509	2,708
Inflow from other MAs	0	0	0	0
CVP imports	*0*	*0*	*0*	*0*
Seepage from groundwater	20,482	18,851	12,911	19,297
Total	**72,081**	**66,053**	**63,034**	**64,066**
Surface Water Outflows				
Outflow from Southern to Hollister MA	-43,840	-41,599	-37,478	-39,540
Percolation to groundwater	-28,241	-24,454	-25,556	-24,526
Total	**-72,081**	**-66,053**	**-63,034**	**-64,066**
Net Inflow				
Inflows (except CVP) - outflows	**0**	**0**	**0**	**0**

1. Average for 1925-1953 and 1982-2002 combined (50 years total).

5.5.3.2. Hollister MA

As shown in **Table 5-3,** summarizing the Hollister MA surface water balances, local watershed inflows (from Pacheco Creek, Arroyo de las Viboras, Arroyo Dos Picachos and Santa Ana Creek) are similar to the amount of surface inflow from the Southern MA (Tres Pinos Creek and the San Benito River). Percolation to groundwater decreased and groundwater seepage into surface water increased from the pre-CVP historical to the recovery period because of the rise in groundwater levels as the Basin recovered. Net recharge to groundwater decreased from 31 percent of stream inflows during the pre-CVP historical period to 25 percent during the recovery and current periods. Future tributary inflows and valley floor runoff are smaller than any of the historical and current periods because of less average annual rainfall combined with the nonlinear relationship of runoff to rainfall. Future CVP use is estimated to be similar to use during the recovery period. This reflects SBCWD's increased ability to use more M&I CVP water when it is available (due to the water treatment plants) and the assumption that all agricultural allocations will be accepted and put to use.

As shown in the table, total surface water inflows equal total outflows; this is because of the lack of surface water storage in the Hollister MA.

Table 5-3. Average Annual Surface Water Balances, Hollister Management Area (AFY)

Water Balance Items	Historical		Current	Future[1]
	Pre-CVP 1975-1988	Recovery 1989-2014	2015-2017	
Surface Water Inflows				
Local watershed inflows	46,235	43,596	56,273	33,056
Valley floor runoff	3,397	3,354	4,056	2,721
Inflow from Southern MA	43,840	41,599	37,478	39,540
CVP imports	*784*	*11,963*	*6,801*	*12,308*
Seepage from groundwater	844	2,541	635	2,203
Total	**95,100**	**103,052**	**105,243**	**89,828**
Surface Water Outflows				
Outflow from Hollister to Bolsa MA	-46,803	-49,961	-59,370	-41,736
Outflow from Hollister to San Juan MA	-17,492	-16,298	-10,880	-14,113
Percolation to groundwater	-30,021	-24,831	-28,192	-21,671
Total	**-94,316**	**-91,089**	**-98,442**	**-77,520**
Net Inflow				
Inflows (except CVP) - outflows	**0**	**0**	**0**	**0**

1. Average for 1925-1953 and 1982-2002 combined (50 years total).

5.5.3.3. San Juan MA

Table 5-4 summarizes the surface water balances for San Juan MA. As shown, by far the largest item in the San Juan MA water balance is Pajaro River inflow from the Bolsa MA. The river hugs the downstream edge of the Basin with little net exchange with groundwater; almost all of the inflow becomes outflow. The San Benito River is the next largest surface inflow. San Juan Creek inflow is about one-fourth as large, and valley floor and nearby hillside runoff totals about half the San Juan Creek flow. There is a steady decrease in percolation to groundwater and increase in groundwater discharge to streams from each analysis period to the next, probably reflecting long-term recovery of groundwater levels. As in the other MAs, watershed inflows and valley floor runoff are smaller in the future period than in the prior periods because of less average annual rainfall combined with the nonlinear relationship between rainfall and runoff. Future CVP imports are expected to be similar to those during the recovery period due to SBCWD's increased ability to use more M&I CVP water when it is available.

Total surface water inflows equal outflows because of lack of surface water storage in the San Juan MA.

Table 5-4. Average Annual Surface Water Balances, San Juan Management Area (AFY)

Water Balance Items	Historical		Current	Future[1]
	Pre-CVP 1975-1988	Recovery 1989-2014	2015-2017	
Surface Water Inflows				
Local watershed inflows	6,220	6,004	7,950	4,491
Valley floor runoff	2,413	2,240	2,948	1,744
Inflow from Hollister MA	17,492	16,298	10,880	14,113
Inflow from Bolsa MA	51,125	56,768	62,926	43,369
CVP imports	*261*	*4,950*	*2,549*	*4,801*
Seepage from groundwater	80	637	835	1,170
Total	**77,591**	**86,898**	**88,088**	**69,688**
Surface Water Outflows				
Outflow from San Juan MA to Pajaro River	-67,873	-75,626	-79,483	-59,314
Percolation to groundwater	-9,456	-6,321	-6,056	-5,573
Total	**-77,329**	**-81,947**	**-85,539**	**-64,887**
Net Inflow				
Inflows (except CVP) - outflows	**0**	**0**	**0**	**0**

1. Average for 1925-1953 and 1982-2002 combined (50 years total).

5.5.3.4. Bolsa MA

As shown in **Table 5-5**, the surface water balance of the Bolsa MA is dominated by inflows from the Hollister MA (Pacheco Creek and Tequisquita Slough). The water balance does not include surface inflows from the Llagas Subbasin, which would be large but tend to simply pass through the Bolsa MA as flow in the Pajaro River. Groundwater discharge to streams occurs primarily east of the Calaveras Fault; this increased from the historical to the recovery period as a result of regional recovery of groundwater levels. Discharge was lower during the current period due to drought-depressed groundwater levels and during the future period due to generally drier conditions (less rainfall on average). Lower average annual rainfall in the future scenario resulted in lower values of almost all surface inflows and outflows relative to the three prior periods.

Total surface water inflows equal outflows because of lack of surface storage in Bolsa MA.

Table 5-5. Average Annual Surface Water Balances, Bolsa Management Area (AFY)

Water Balance Items	Historical		Current 2015-2017	Future[3]
	Pre-CVP 1975-1988	Recovery 1989-2014		
Surface Water Inflows				
Local watershed inflows	0	0	0	0
Valley floor runoff[1]	3,603	3,374	4,377	2,347
Inflow from Hollister MA	46,803	49,961	59,370	41,736
CVP imports	0	0	0	0
Seepage from groundwater[2]	4,463	6,293	3,761	2,683
Total	**54,869**	**59,628**	**67,508**	**46,765**
Outflows				
Outflow from Bolsa to San Juan MA	-51,125	-56,768	-62,926	-43,369
Percolation to groundwater	-3,744	-2,860	-4,582	-3,396
Total	**-54,869**	**-59,628**	**-67,508**	**-46,765**
Net Inflow				
Inflows (except CVP) - outflows	**0**	**0**	**0**	**0**

1. For Bolsa MA, valley floor runoff includes runoff from the northern slopes of the Lomerias Muertas and from a small strip of land in the Llagas Basin between the Pajaro River and the northwestern model boundary.
2. For Bolsa MA, groundwater discharge to streams includes flow modeled as discharge to hypothetical drains along the lower reaches of Pacheco Creek and Tequisquita Slough.
3. Average for 1925-1953 and 1982-2002 combined (50 years total).

5.6. GROUNDWATER BALANCE

Annual groundwater inflows and outflows for each Management Area for the entire historical and current model period (1975-2017) are shown as stacked bars in **Figures 5-8 through 5-11**. Inflows are stacked in the positive (upward) direction and outflows are stacked in the negative (downward) direction. Average annual water budgets (including inflows, outflows, and change in groundwater storage) for each MA are presented in Section 5.6.3 for the Pre-CVP Historical, Historical Recovery, Current and Future analysis periods. This section describes groundwater inflows and outflows, while section 5.7 discusses groundwater balance variations by water year type and section 5.8 discusses cumulative change in groundwater storage.

5.6.1. Inflows to Groundwater

Inflows to the groundwater flow system can be conceptualized as dispersed recharge through the land surface (such as rainfall recharge and irrigation return flow), linear sources of recharge (such as percolation from creeks and subsurface inflow along the Basin boundary) and point sources of recharge (such as wastewater percolation facilities). Most groundwater inflows to the basin are controlled by hydrologic conditions. Natural stream percolation and deep percolation from rainfall are related to the volume and distribution of rainfall. The availability of imported water similarly reflects wet and dry conditions in the source area, which for CVP water is the Sierra Nevada. Because they are related to rainfall, almost all Basin inflows are higher in wet years and lower in dry years. The water balance analysis includes several categories of inflow to the North San Benito Basin, each of which is described below.

5.6.1.1. Dispersed Recharge from Rainfall and Irrigation

Dispersed recharge from rainfall and applied irrigation water is estimated by the rainfall-runoff-recharge model. The model simulates soil moisture storage in the root zone, with inflows from rainfall infiltration and irrigation, and outflows to evapotranspiration and deep percolation. Simulation is on a daily basis. In recharge zones with irrigated crops, irrigation is assumed to be applied when soil moisture falls below a certain threshold. When soil moisture exceeds the root zone storage capacity, the excess becomes deep percolation. Rainfall and irrigation water comingle in the root zone and in deep percolation. For the purposes of displaying an itemized water balance, the amount of deep percolation derived from irrigation is estimated as a percentage of the simulated irrigation quantity, and the remainder of the dispersed recharge is attributed to rainfall. In urban recharge zones, pipe leaks are included in the amount shown as rainfall recharge. Deep percolation of applied irrigation water (irrigation return flow) is generally similar from year to year, whereas rainfall percolation varies significantly on an annual basis. The one-dimensional dispersed recharge rates are multiplied by the surface area of each recharge zone (2,768 zones in total) to obtain volumetric flow rates, and those are subtotaled by Management Area. The dispersed rainfall estimates are calculated using the rainfall-runoff-recharge model and were adjusted slightly to match the total model inflow as some recharge zones overlapped Basin or management area boundaries. This allowed a more detailed itemization of the water balance but introduced minor discrepancies in the totals. In the water balance bar charts, dispersed recharge from rainfall and irrigation are shown in light blue and light green, respectively.

5.6.1.2. Percolation from Streams

Inflows to the stream network in the surface water module of the groundwater model include a combination of gauged flows (for the San Benito River at the upstream end of the Southern MA only), simulated runoff from tributary watersheds and valley floor areas obtained from the rainfall-runoff-recharge model, and historical amounts of CVP water percolated in local streams. The effects of Hernandez Reservoir operation on San Benito River flows are included in the gauged flows, and the effects of Pacheco Reservoir on Pacheco Creek inflows were estimated by applying simple rules for seasonal storage and release. The effects of storage in the small Paicines Reservoir on San Benito River flows in the Southern MA were not considered. The surface water module simulates percolation from streams reach by reach along each stream that crosses the basin. Percolation is affected by groundwater levels. When groundwater levels are high there is less storage space available to receive stream percolation and overall percolation goes down. This phenomenon is known as "rejected recharge" and has been observed in field data as well as model results. It means that streams can provide high rates of recharge during the recovery period following a drought but not overfill the groundwater basin.

5.6.1.3. Reclaimed Water Percolation

Percolation of reclaimed water in wastewater disposal ponds occurs in two Management Areas (San Juan and Hollister) at facilities operated by the City of Hollister, SSCWD, and Tres Pinos County Water District (see **Figure 3-11 or 5-3** for locations). Discharges from the San Juan Bautista wastewater treatment plant flow are not included. These discharges occur to a small channel along the southwestern edge of San Juan Valley. That channel has little interaction with groundwater because it is southwest of the San Andreas Fault over much of its length. The remaining reach to San Juan Creek and the Pajaro River is underlain by clay soils that also do not support significant seepage fluxes to or from the channel. Wastewater releases to the City, SSCWD and Tres Pinos ponds are measured directly. Percolation is assumed to be the plant inflow less net evaporation and amounts of wastewater recycled for irrigation use. Additional percolation may occur around rural residential septic systems. For the numerical model, it is assumed to be negligible as the volumes would be small and spread out all over the basin.

In the groundwater model, reclaimed water percolation and percolation of CVP water as incidental leakage from San Justo Reservoir are both simulated as shallow injection wells. Percolation of CVP water in off-channel recharge ponds has occurred in Hollister and San Juan MAs. The amounts have been relatively small and are not included in the groundwater model or water balance tables.

5.6.1.4. Subsurface Groundwater Inflow

Three types of subsurface inflow are listed separately in the water balance tables. Subsurface inflow from external basins occurs only in the Bolsa MA, where flow enters from the adjacent Llagas Subbasin. This is simulated as a head-dependent flow that varies depending on simulated groundwater levels near the boundary (lower water levels increase the simulated inflow rate). Along the rest of the Basin perimeter, small amounts of subsurface inflow results from recharge percolating through fractured bedrock in tributary watershed areas. This process is simulated by the rainfall-runoff-recharge model. Bedrock inflow is simulated as shallow injection wells along the perimeter of the Basin. Finally, subsurface flow occurs across the management area boundaries within the Basin. These flows are extracted from the groundwater model using the ZoneBudget post-processing utility program. In the water balance bar charts, Llagas inflow, bedrock inflow and inflow from other Management Areas are shown in yellow, gray and dark green, respectively.

5.6.2. Outflows from Groundwater

Major outflows from the Basin are pumping (agricultural, municipal, industrial, and domestic), groundwater seepage into streams, subsurface outflow and evapotranspiration by riparian vegetation.

5.6.2.1. Pumping by Wells

Agricultural. Agricultural pumping is much larger than the other types and is listed separately in the water balance tables and shown in green on the water balance bar charts. Agricultural pumping is dependent not only on cropping patterns and irrigation practices, but also on the volume of CVP imports and the amount and timing of rainfall. Spring rains decrease total irrigation demand, and growers adjust pumping to compensate for wet weather and the availability of CVP imports. Agricultural groundwater pumping in the model and water balance tables is simulated by the rainfall-runoff-recharge model. When simulated soil moisture falls below a specified threshold in a recharge zone with irrigated crops, irrigation is assumed to be applied and to refill soil moisture to capacity. Irrigation not derived from CVP water or recycled water is assumed to be from groundwater. In the groundwater model, the agricultural pumping associated with each zone is located at the center of the zone.

Agricultural pumping in Zone 6 is also monitored by SBCWD by recording the operating time of pump motors and multiplying that by a measured discharge rate. Previous studies have found that the pumping estimates obtained by this method are significantly smaller than the estimates obtained by simulating crop water demand and soil moisture. The simulation approach improved model calibration during the 2014 model update, and that approach is retained in the current model.

Reliable measurements of agricultural pumping are a recognized data gap. Given the large range or uncertainty and the model sensitivity to the volume and location of agricultural pumping, evaluation is needed of alternative methodologies for accurately evaluating agricultural pumping.

Municipal, Industrial and Domestic. Municipal pumping by City of Hollister and SSCWD is in the Hollister MA, with additional pumping by San Juan Bautista in San Juan MA. Pumping by major municipal providers is measured, as is pumping by smaller community water systems and self-supplied commercial and industrial facilities within Zone 6. Actual pumping and well locations are used in the numerical model. Additional pumping for potable use at rural residences and agricultural buildings was estimated by inventorying the number and locations of those buildings on aerial photos. This domestic pumping is assigned to 200 hypothetical wells near building locations. This pumping is shown in the charts as pink.

5.6.2.2. Subsurface Outflow

Subsurface outflows were calculated using the groundwater model by the same methods used to simulate subsurface inflows. In the water balance tables and charts subsurface outflow to external basins (dark blue) is shown separately from outflow to other Management Areas (orange).

5.6.2.3. Groundwater Discharge to Streams

Discharges from the groundwater basin to surface water bodies are simulated by the groundwater model based on stream bed wetted area and permeability and on the amount by which the simulated groundwater elevation in a model stream cell is higher than the simulated surface water elevation. This occurs in all Management Areas, but notably where Pacheco Creek and Tequisquita Slough approach the Calaveras Fault, where the Pajaro River approaches the downstream end of the Bolsa MA, and along the San Benito River at the downstream end of the San Juan MA. The relatively large amounts of simulated groundwater discharge to streams in the Southern MA is balanced by high amounts of percolation from streams. The San Benito River and Tres Pinos Creek transition from gaining to losing at various locations in the Southern MA. This outflow is shown in the water balance charts in a red color.

5.6.2.4. Riparian Evapotranspiration

The presence of dense, vigorous trees and shrubs along a stream channel is often a sign that the roots of the vegetation extend to the water table and have access to groundwater throughout the dry season. Plants that draw water directly from groundwater are called phreatophytes. Stream reaches with this type of vegetation were mapped from Google Earth air photos, and the width of the vegetation corridor was used to obtain the total area of phreatophyte evapotranspiration (ET). The rate of groundwater withdrawal was estimated as the difference in simulated ET when the vegetation was assumed to be non-irrigated (subsisting only on rainfall) versus irrigated (accessing all water needed to meet potential ET). In the groundwater model, riparian ET is a function of water table depth, decreasing from unrestricted water use when the water table is at the ground surface to zero when it is 15 feet or more below the ground surface. This reflects a reasonable range of root depth distribution for a mix of riparian shrub and tree species. Riparian ET is shown with a blue color on the water balance bar charts.

5.6.3. Summary by Management Area

5.6.3.1. Southern MA

Figure 5-8 and **Table 5-6** summarize groundwater balances for the Southern MA. The Southern MA includes long reaches of the San Benito River and Tres Pinos Creek as they first enter the groundwater basin. The dominant land use is natural grassland and shrubs. Given that, the major inflows to and outflows from groundwater are dominated by percolation from streams and groundwater discharge into streams. As shown on **Figure 5-8** and **Table 5-6**, percolation from surface water accounts for more than 70 percent of inflow and discharge to streams represents more than 50 percent of outflow. Percolation from stream channels into the Southern MA is significantly higher in wet years than dry years. As illustrated in **Figure 5-6**, wet-year inflow from streams can average four times more than in critically dry years. Similarly, outflow to streams varies substantially. Agricultural pumping in the Management Area remains steady at approximately 6,700 AFY. The small amount of inflow from the Hollister MA is an artifact of local deviations in the boundary alignment relative to the prevailing flow gradient, which is from the Southern MA to the Hollister MA. The relatively large increase in groundwater storage during the current period reflects groundwater recovery following the 2013-2015 drought and concurrent decrease in groundwater discharge to streams. Under future baseline conditions average annual rainfall is less than during the prior periods (reflecting the difference between historical measured or estimated rainfall during 1922-1974 versus 1975-2017). Stream flow and rainfall recharge are both nonlinear functions of rainfall, such that a percentage decrease in rainfall will produce a larger percentage decrease in runoff and recharge. However, the reduction in recharge from streams and rainfall is balanced by changes in other inflows and outflows so that the average annual storage change for the future baseline scenario is close to zero.

Table 5-6. Average Annual Groundwater Balance, Southern Management Area (AFY)

	Historical			
Water Balance Items	**Pre-CVP 1975-1988**	**Recovery 1989-2014**	**Current 2015-2017**	**Future[2]**
Groundwater Inflow				
Subsurface inflow from external basins	0	0	0	0
Percolation from streams	28,241	24,454	25,556	24,526
Bedrock inflow	1,601	1,693	684	1,119
Dispersed recharge from rainfall[1]	5,810	5,954	8,595	4,439
Irrigation deep percolation	597	576	659	624
Reclaimed water percolation	0	0	0	0
Inflow from Hollister MA	940	954	941	822
Total inflow	**37,189**	**33,632**	**36,434**	**31,530**
Groundwater Outflow				
Subsurface outflow to external basins	0	0	0	0
Wells - M&I and domestic	(53)	(126)	(143)	(142)
Wells - agricultural	(6,626)	(6,396)	(7,157)	(6,911)
Groundwater discharge to streams	(20,482)	(18,851)	(12,911)	(19,297)
Riparian evapotranspiration	(1,675)	(1,572)	(1,563)	(1,587)
Outflow to Hollister MA	(3,328)	(3,357)	(3,215)	(2,991)
Total outflow	**(32,163)**	**(30,304)**	**(24,988)**	**(30,928)**
Net Change in Storage	**5,026**	**3,328**	**11,446**	**603**

1. Dispersed recharge volumes adjusted from pre-processor to match model inflows
2. Average for 1925-1953 and 1982-2002 combined (50 years total)

5.6.3.2. Hollister MA

Groundwater balances for the Hollister MA are summarized in **Figure 5-9** and **Table 5-7**. As shown on **Figure 5-9**, inflows to the Hollister MA are largely from deep percolation of precipitation and percolation of surface water (i.e., San Benito River and others). Both sources are much larger (more than double) in wet years than in normal or dry years. Percolation from streams is relatively high and groundwater discharge to streams is relatively low when groundwater levels are low, such as in the Historical and Current periods (due to prior overdraft and to drought, respectively). As shown in **Table 5-7**, groundwater inflow from bedrock in tributary watersheds was considerably lower during the current period than the other periods. This was because bedrock inflow is relatively slow and reflects average hydrologic conditions over the preceding several years. During the three-year current period it was still depressed from the 2013-2015 drought.

The outflow from Hollister is dominated by agricultural pumping (more than 65 percent of total outflow), followed by outflow to other MAs (more than 15 percent). Agricultural pumping was relatively high in the Current period due to reduced allocations of CVP water during the 2013-2015 drought (see **Figure 5-9**). Future agricultural groundwater pumping is expected to be about the same as it was during the Recovery period. M&I pumping increased from the Pre-CVP Historical to Recovery period reflecting a growing population but decreased in the current period reflecting the new treatment capacity to replace groundwater with CVP water for M&I uses. Future M&I pumping is higher than current pumping because of reduced long-term average CVP allocations, but wastewater percolation remains about the same. Outflow to other MAs was relatively low during the Current period, probably because the drought-related reduction in CVP use caused a greater increase in groundwater pumping (and hence decrease in groundwater levels) in the Hollister MA relative to the Bolsa MA. This would decrease the water level gradient and reduce the flow. The average annual decline in storage in the Future period is small relative to total inflows and outflows and is probably within the range of uncertainty of the overall water balance. For example, simulated storage change for the overall 1922-2007 period was positive (see Section 5.8).

Table 5-7. Average Annual Groundwater Balances, Hollister Management Area (AFY)

Water Balance Items	Historical		Current 2015-2017	Future[2]
	Pre-CVP 1975-1988	Recovery 1989-2014		
Groundwater Inflow				
Subsurface inflow from external basins	0	0	0	0
Percolation from streams	30,021	24,831	28,192	21,671
Bedrock inflow	4,075	4,115	427	3,143
Dispersed recharge from rainfall[1]	19,455	18,336	23,709	17,414
Irrigation deep percolation	4,747	4,511	5,132	4,761
Reclaimed water percolation	1,250	1,841	2,603	2,486
Inflow from Southern MA	7,033	6,455	6,371	6,043
Total inflow	**66,580**	**60,089**	**66,434**	**55,517**
Groundwater Outflow				
Subsurface outflow to external basins	0	0	0	0
Wells - M&I and domestic	(3,885)	(6,905)	(4,424)	(5,627)
Wells - agricultural	(39,049)	(38,278)	(45,458)	(38,411)
Groundwater discharge to streams	(844)	(2,541)	(635)	(2,203)
Riparian evapotranspiration	(173)	(174)	(118)	(158)
Outflow to Bolsa and San Juan MAs	(10,294)	(9,439)	(8,717)	(10,176)
Total outflow	**(54,245)**	**(57,337)**	**(59,351)**	**(56,575)**
Net Change in Storage	**12,336**	**2,752**	**7,083**	**(1,058)**

1. Dispersed recharge volumes adjusted from pre-processor to match model inflows
2. Average for 1925-1953 and 1982-2002 combined (50 years total).

5.6.3.3. San Juan MA

The groundwater balances for San Juan MA are shown on **Figure 5-10** and **Table 5-8**. Inflow to San Juan MA is mostly deep percolation of rainfall and irrigation water (31-39 percent) and percolation from the San Benito River and San Juan Creek (25-36 percent) followed by inflow from the Hollister MA (16-22 percent). As illustrated in **Figure 5-10**, wet-year percolation from surface water and rainfall can average almost 30,000 AFY compared to only 3,000 AFY in critically dry years.

Relative to inflow, groundwater outflow is relatively steady and consists mainly of agricultural pumping (80-86 percent). As in the Hollister MA, average pumping decreased from the Pre-CVP Historical to the Recovery period due to CVP imports and increased in the Current period due to drought-related reductions in CVP supplies. Groundwater discharge to the San Benito River increased from the Historical to the Current periods as groundwater levels recovered. This discharge is important as a means of removing salts from the basin and limiting long-term increases in groundwater salinity. Average annual storage change was positive during the Historical and Current periods due to long-term recovery of groundwater levels. Future storage change is expected to average around zero.

Table 5-8. Average Annual Groundwater Balances, San Juan Management Area (AFY)

Water Balance Items	Historical Pre-CVP 1975-1988	Historical Recovery 1989-2014	Current 2015-2017	Future[2]
Groundwater Inflow				
Subsurface inflow from external basins	0	0	0	0
Percolation from streams	9,456	6,321	6,056	5,573
Bedrock inflow	774	1,328	1,110	1,140
Dispersed recharge from rainfall[1]	8,239	7,703	9,585	7,039
Irrigation deep percolation	2,151	1,924	1,942	2,161
Reclaimed water percolation	609	1,441	1,843	1,734
Inflow from Hollister and Bolsa MAs	5,239	4,188	4,026	4,910
Total inflow	**26,469**	**22,904**	**24,563**	**22,557**
Groundwater Outflow				
Subsurface outflow to external basins	0	0	0	0
Wells - M&I and domestic	(581)	(917)	(476)	(652)
Wells - agricultural	(17,936)	(16,588)	(17,490)	(18,364)
Groundwater discharge to streams	(80)	(637)	(835)	(1,170)
Riparian evapotranspiration	(740)	(959)	(1,065)	(1,042)
Outflow to Bolsa MA	(1,451)	(1,546)	(1,578)	(1,686)
Total outflow	**(20,790)**	**(20,645)**	**(21,444)**	**(22,914)**
Net Change in Storage	**5,679**	**2,259**	**3,118**	**(357)**

1. Dispersed recharge volumes adjusted from pre-processor to match model inflows
2. Average for 1925-1953 and 1982-2002 combined (50 years total).

5.6.3.4. Bolsa

The annual groundwater inflows and outflows for the Bolsa MA are shown on **Figure 5-11** and **Table 5-9**. The largest source of inflow is rainfall recharge, but it varies greatly by year type: accounting for over half of total inflow during a wet year like 2017 and only 7 percent during a dry year like 2013. Rainfall recharge is relatively low in the Future period because average annual rainfall is smaller and the nonlinear relationship between rainfall and recharge causes an even larger decrease in recharge on a percentage basis. Subsurface inflow from the Hollister MA is relatively stable at around 5,000 AFY.

As described in the Management Area section, Bolsa does not receive CVP imported water and thus relies on groundwater pumping, which is 64-81 percent of total outflow. The area of irrigated cropland increased in the past decade, resulting in the increase in pumping from the Recovery to the Future period. The even higher amount during the Current period is the result of drought conditions. The recent increase in irrigated area combined with minor changes in parameters used to estimate irrigation demand resulted in agricultural pumping estimates in the current model that are larger than estimates previously presented in annual groundwater reports. The next largest outflow is discharge to streams (including water from tile drains and flowing wells listed in the table as "shallow discharge to streams"), which accounts for 11-26 percent of total outflow. This outflow increases noticeably in wet years.

Table 5-9. Average Annual Groundwater Balances, Bolsa Management Area (AFY)

	Historical			
Water Balance Items	**Pre-CVP 1975-1988**	**Recovery 1989-2014**	**Current 2015-2017**	**Future[2]**
Groundwater Inflow				
Subsurface inflow from external basins	4,176	3,761	5,940	5,088
Percolation from streams	3,744	2,860	4,582	3,396
Bedrock inflow	0	0	71	0
Dispersed recharge from rainfall[1]	11,756	11,088	16,184	8,431
Irrigation deep percolation	1,427	1,395	2,257	2,863
Reclaimed water percolation	0	0	0	0
Inflow from Hollister and San Juan MAs	4,560	4,740	4,415	4,954
Total inflow	**25,662**	**23,844**	**33,448**	**24,733**
Groundwater Outflow				
Subsurface outflow to external basins	(34)	(42)	(17)	(21)
Wells - M&I and domestic	(9)	(22)	(24)	(24)
Wells - agricultural	(15,860)	(15,467)	(24,017)	(19,958)
Groundwater discharge to streams	(4,463)	(6,293)	(3,761)	(2,683)
Riparian evapotranspiration	(251)	(256)	(192)	(213)
Outflow to San Juan MA	(2,699)	(1,995)	(2,350)	(1,877)
Total outflow	**(23,315)**	**(24,076)**	**(30,362)**	**(24,775)**
Net Change in Storage	**2,347**	**(232)**	**3,087**	**(42)**

1. Dispersed recharge volumes adjusted from pre-processor to match model inflows
2. Average for 1925-1953 and 1982-2002 combined (50 years total).

5.7. VARIATION IN WATER BUDGET BY WATER YEAR TYPE

In each Management Area, the contribution from each source of inflow varies in response to hydrological conditions. Accordingly, **Table 5-10** shows the average annual water balance during the historic and current analysis (1975-2017) based on water year type (wet, above average, normal, dry, and critically dry). In general, inflows respond to changes in hydrological conditions, but outflows remain dominated by pumping that is fairly consistent across all water year types. In all Management Areas, inflow varies greatly from high volumes of inflow in wet years to minimal volumes of inflow during critically dry years. The result is that the basin gains groundwater storage in wet years and loses storage in dry years.

Table 5-10. Inflows and Outflows by Water Year Type (AFY)

	Water Year Type				
	Wet Year	**Above Normal**	**Normal**	**Dry**	**Critically Dry**
Southern					
Inflow	63,081	37,081	27,131	21,120	13,260
Outflow	(32,601)	(32,234)	(27,040)	(30,576)	(27,319)
Change in Storage	30,480	4,847	92	(9,456)	(14,059)
Hollister					
Inflow	96,071	68,817	51,562	45,374	33,891
Outflow	(51,522)	(54,785)	(58,933)	(58,394)	(62,151)
Change in Storage	44,549	14,032	(7,371)	(13,020)	(28,260)
San Juan					
Inflow	40,008	26,688	17,776	15,978	12,018
Outflow	(18,178)	(20,105)	(21,943)	(21,774)	(23,388)
Change in Storage	21,831	6,584	(4,167)	(5,796)	(11,369)
Bolsa					
Inflow	35,787	26,246	21,417	19,395	17,488
Outflow	(28,731)	(25,193)	(21,595)	(21,931)	(21,177)
Change in Storage	7,056	1,054	(178)	(2,536)	(3,689)

5.8. Change in Groundwater Storage

The water balance tables show two estimates of storage: the difference between total inflows and total outflows, and the amount simulated by the groundwater model.

Figure 5-12 shows the cumulative change in storage from the model for the four Management Areas for the historical and current periods, 1975-2017. The amount of groundwater in storage fluctuated over the simulation period. Groundwater storage was at its lowest near the beginning of the simulation because of overdraft during the preceding decades and an intense drought during 1976-1977. For Hollister and San Juan MAs, groundwater storage increased significantly when imported water deliveries begin in 1988. With decreased groundwater pumping, managed aquifer recharge, and several wet years in the 1990s, groundwater storage increased rapidly in these two MAs and has remained relatively steady since 1998. As discussed in Section 4.1.3, the recovery of groundwater levels and storage in those Management Areas provided a buffer for the recent drought of 2013-2015, allowing local groundwater users to pump groundwater without severe declines.

Evaluation of storage change in the Southern MA is less certain because of the scarcity of hydrogeologic and monitoring data to correctly estimate the initial storage in 1975. The rapid increase in storage during the 1990s resulted primarily from wet years during that decade (no CVP water is delivered to this MA), but the overall long-term increasing trend is likely the result of having underestimated the 1975 water levels. The model gradually added water to storage until the simulated water-level surface in upland areas achieved a balance between recharge rates and estimated aquifer permeability and storativity.

Groundwater storage in the Bolsa MA remained relatively steady during 1975-2017. In wet years, high rainfall recharge tended to be balanced by greater groundwater discharge to streams. There were also some compensating effects among different parts of the Management Area. East of the Calaveras Fault, some hydrographs showed water levels rising several tens of feet until intersecting the land surface elevation in the mid-1990s, then leveling out. In contrast, hydrographs west of the fault declined through about 1988, rose to the mid-1990s, then generally leveled out. A few hydrographs in that area have exhibited slight long-term declining trends, and the model calibration slightly overestimated some of those declines.

Figure 5-13 shows cumulative storage changes in each of the Management Areas under simulated future conditions. These are the results of a continuous 86-year simulation corresponding to hydrologic conditions during 1922-2007. As indicated on the figure, fifty years were extracted from the simulation results to represent future baseline conditions for water balance calculations. Imported CVP water was assumed to be available throughout the future period in amounts simulated by DWR's CalSim2 model. Average availability over the future period was less than during the Recovery period, but the results indicated sufficiency to prevent overdraft.

Conjunctive operation of local groundwater with CVP imports nevertheless resulted in substantial groundwater storage declines during droughts followed by recovery in wet years. This can be seen during the simulation intervals corresponding to historical hydrology during 1922-1934 and 1987-1992. Those droughts produced large cumulative deficits in local rainfall and CVP deliveries and large cumulative decreases in groundwater storage. CVP allocations to agricultural users in the Basin dropped to about 8,900 AFY and 4,600 AFY during the two droughts, respectively, compared to the long-term average of 17,600 AFY. There was a large simulated increase in groundwater pumping to compensate for the decreased CVP deliveries. This caused cumulative storage declines of 173,000 AF in the Hollister MA and 68,000 AF in the San Juan MA during the 1922-1934 drought (121,000 AF and 52,000 AF during 1987-1992). However, simulated storage in both of those areas recovered to pre-drought levels within 6-10 years.

The Southern MA and to a lesser extent the Bolsa MA also experienced cumulative storage declines during the drought periods, but those were due solely to decreased rainfall and stream recharge. In those Management Areas, simulated storage also recovered during the 6-10 years following the droughts.

5.9. Estimate of Sustainable Yield

The sustainable yield is defined as the volume of pumping that the basin can sustain without causing undesirable effects. It is not a fixed or inherent natural characteristic of a groundwater basin. Rather, it is influenced by land use activities, importation of water, wastewater and stormwater management methods, and the locations of wells with respect to interconnected streams. The estimate of sustainable yield presented in this section reflects the current status of those variables and evaluates whether there would be a long-term increase or decrease in basin storage if those conditions continued over a 50-year future period with local hydrology and CVP imports (per CalSim 2) corresponding to 1925-1953 and 1982-2002..

A long analysis period is needed to evaluate yield because of changes in the relative amounts of recharge and pumping from normal or wet conditions to droughts and back again. In basins like this one where groundwater and surface water supplies are used conjunctively, groundwater storage is expected to decline during droughts and recover afterwards. In a dry year when imported supplies are generally limited, the volume of groundwater pumped is generally higher. This increased pumping can be sustained for limited periods of time as long as the basin is subsequently replenished. In wet years when rainfall recharge is relatively high, imported supplies are more available and groundwater pumping is generally reduced, recharge exceeds pumping and storage recovers. Therefore, the evaluation of long-term storage trends needs to span one or more complete wet-dry-wet climate cycles. The two-part period of years selected for the future baseline simulation includes complete drought and recovery cycles for the 1923-1935 drought and 1987-1992 drought, which were the two largest droughts in terms of effect on simulated water levels.

The estimate of sustainable yield was based on the future baseline simulation. It is a forward-looking estimate that incorporates current land use, CVP operating rules, and other management activities. To evaluate a sustainable yield, the average pumping that occurred during the 1925-1953 and 1982-2002 periods of the future baseline simulation was calculated. Average annual pumping by Management Area and type of use in the future baseline simulation is as shown in **Table 5-11** and totals 100,486 AFY.

If the simulation showed a net decline in groundwater storage over the simulation period, the sustainable yield would be less than the amount of pumping in the simulation, and vice versa. In the future baseline simulation, net change in groundwater storage was essentially zero (see **Tables 5-6** through **5-9**). Specifically, average annual storage change was +/- 1% for Hollister, San Juan and Bolsa MAs and 3% for Southern MA, which is within the range of uncertainty in the modeled water balance. Therefore, average annual groundwater pumping in the future baseline simulation is the best available estimate of sustainable yield.

This long-term average sustainable yield reflects a continuation of existing conditions. Significant changes in management (e.g., the recent completion of additional treatment capacity for imported water) or significant climate changes (e.g., reduction in precipitation) would affect the yield of the basin. Accordingly, sustainable yield is not a fixed number.

Moreover, the definition of sustainable yield refers to undesirable results, which are quantified through the sustainability criteria (i.e., minimum thresholds and measurable objectives) and have important ramifications for overall sustainable yield. Accordingly, this sustainable yield value is a broad indicator. It indicates no overdraft based on the water budget, but it must be interpreted through evaluation of undesirable results.

Table 5-11. Average Annual Pumping (AFY) by Management Area, Future Baseline

	Future Baseline		
Management Area	**Agricultural Pumping**	**M&I Pumping**	**TOTAL**
Southern	6,911	142	7,053
Hollister	39,043	5,627	44,670
San Juan	18,350	652	19,002
Bolsa	29,737	24	29,761
TOTAL	**94,041**	**6,445**	**100,486**

References Cited

Yates, G. and C-M. Zhang, May 11, 2001, Groundwater flow and solute transport models for the San Benito County portion of the Gilroy-Hollister groundwater basin. Draft. Prepared for San Benito County Water District, Hollister, CA.

Todd Groundwater, June 12, 2015, Northern San Benito County groundwater model update and enhancement. Prepared for San Benito County Water District, Hollister, CA.

Clark, William, 1924, Groundwater in Santa Clara Valley, California, USGS Water Supply Paper 519, https://pubs.er.usgs.gov/publication/wsp519

FIGURES

Please note that the figures in this section include maps that are designed for printing at 11x17 inches.

We recommend printing the pdf through Adobe Acrobat and selecting *Actual Size* and *Choose paper source by PDF page size*.

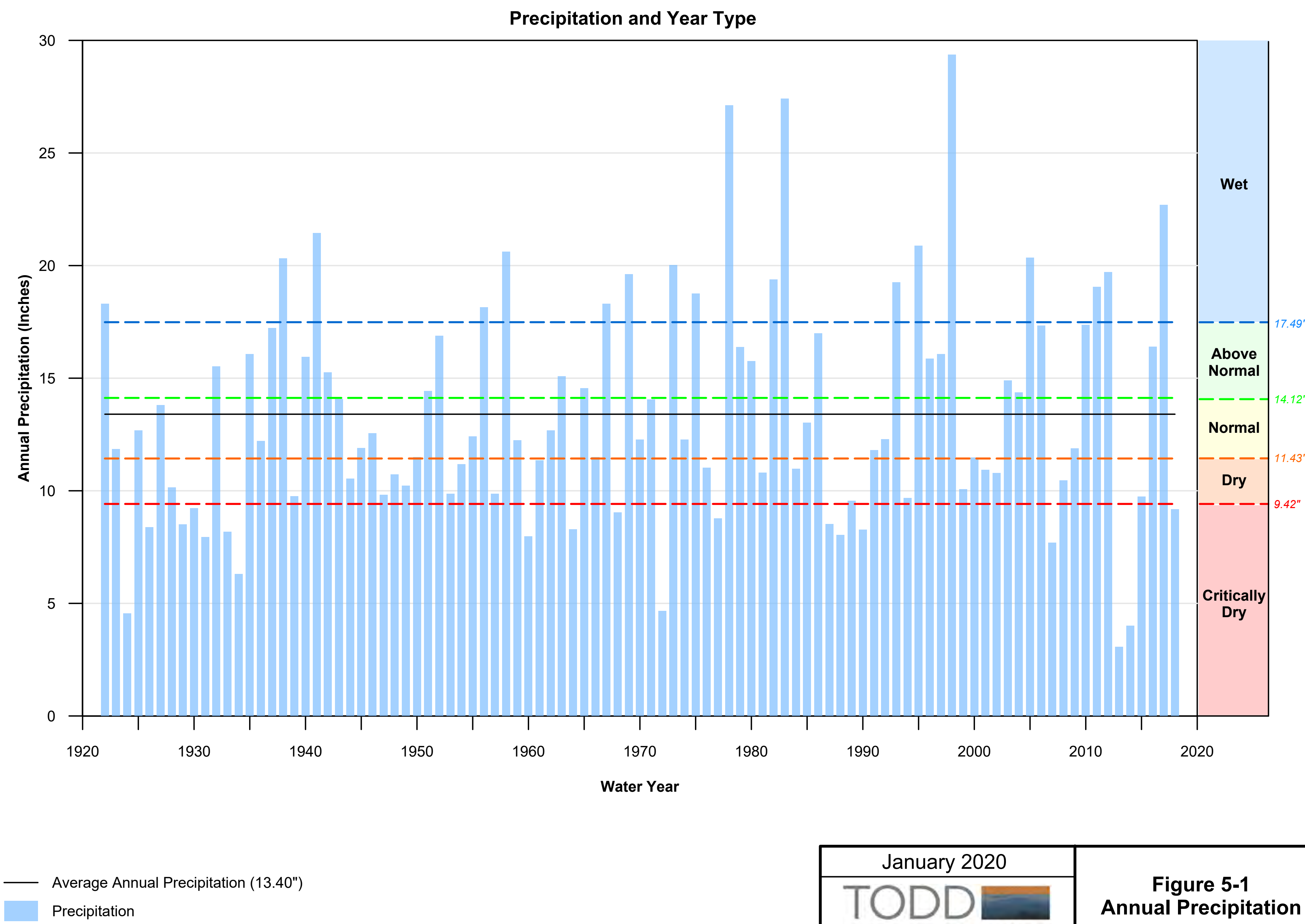

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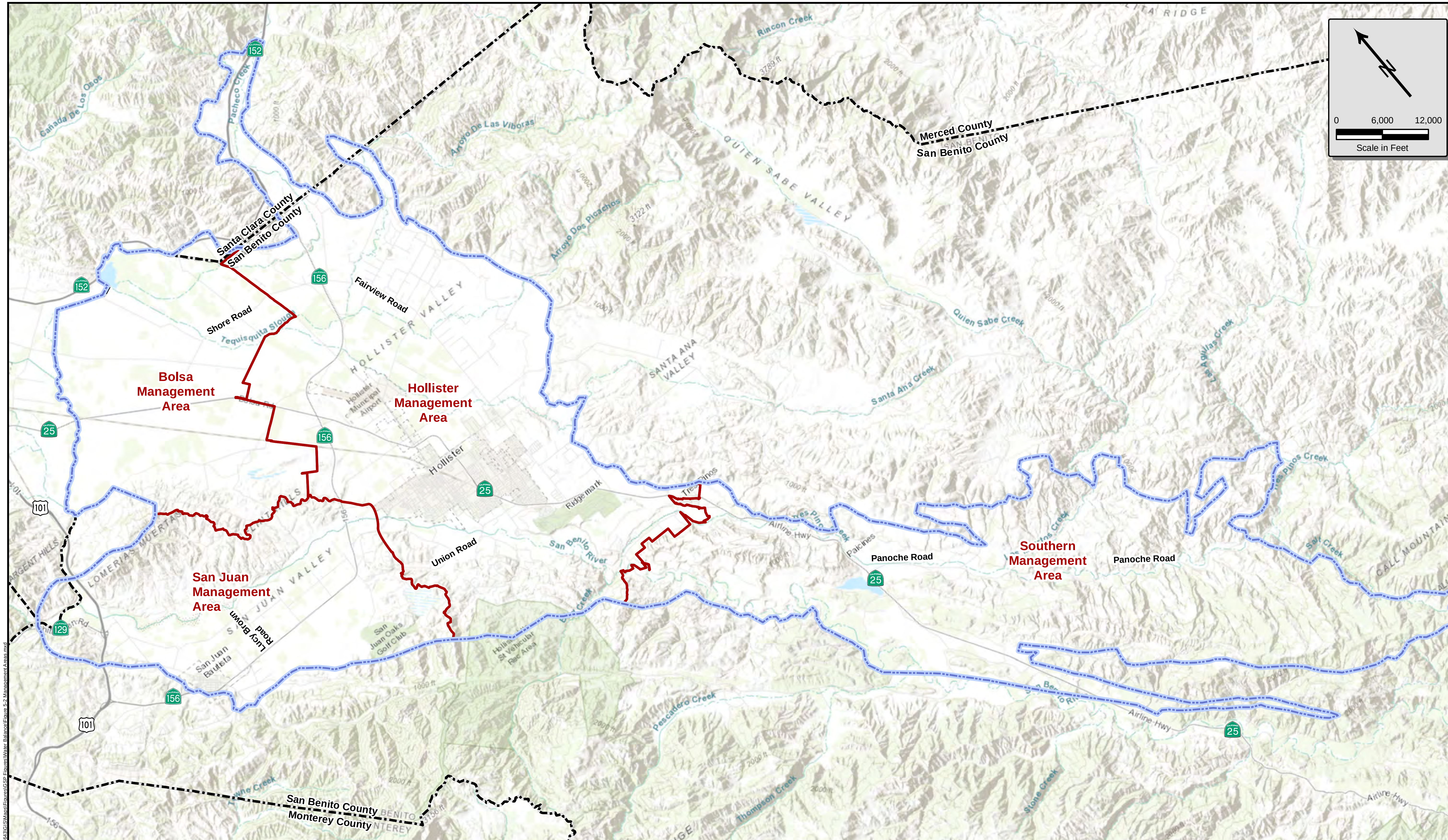
Figure 5-1
Annual Precipitation



Management Areas

North San Benito Basin

San Benito County

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Figure 5-2
Management Areas

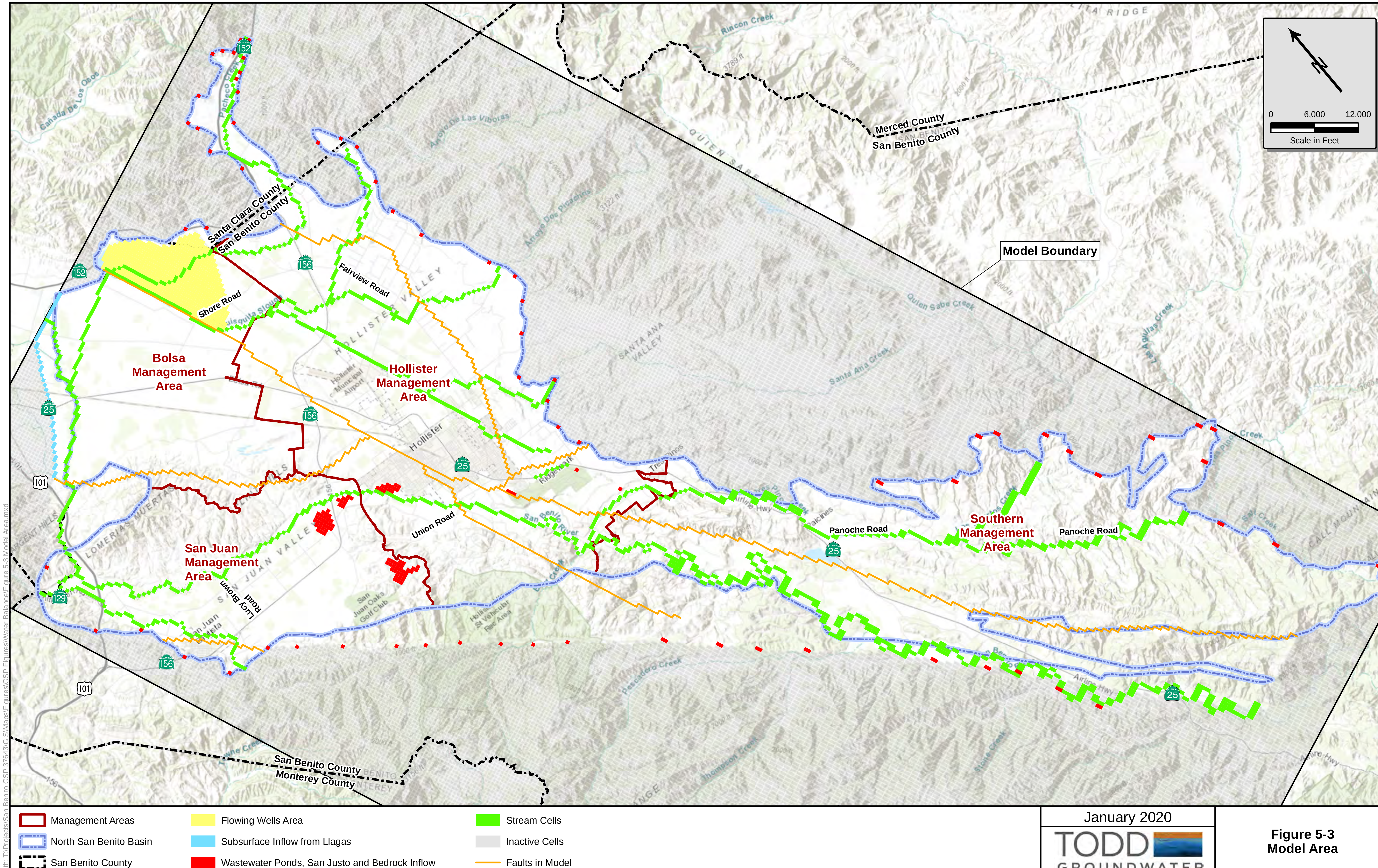

Figure 5-3
Model Area

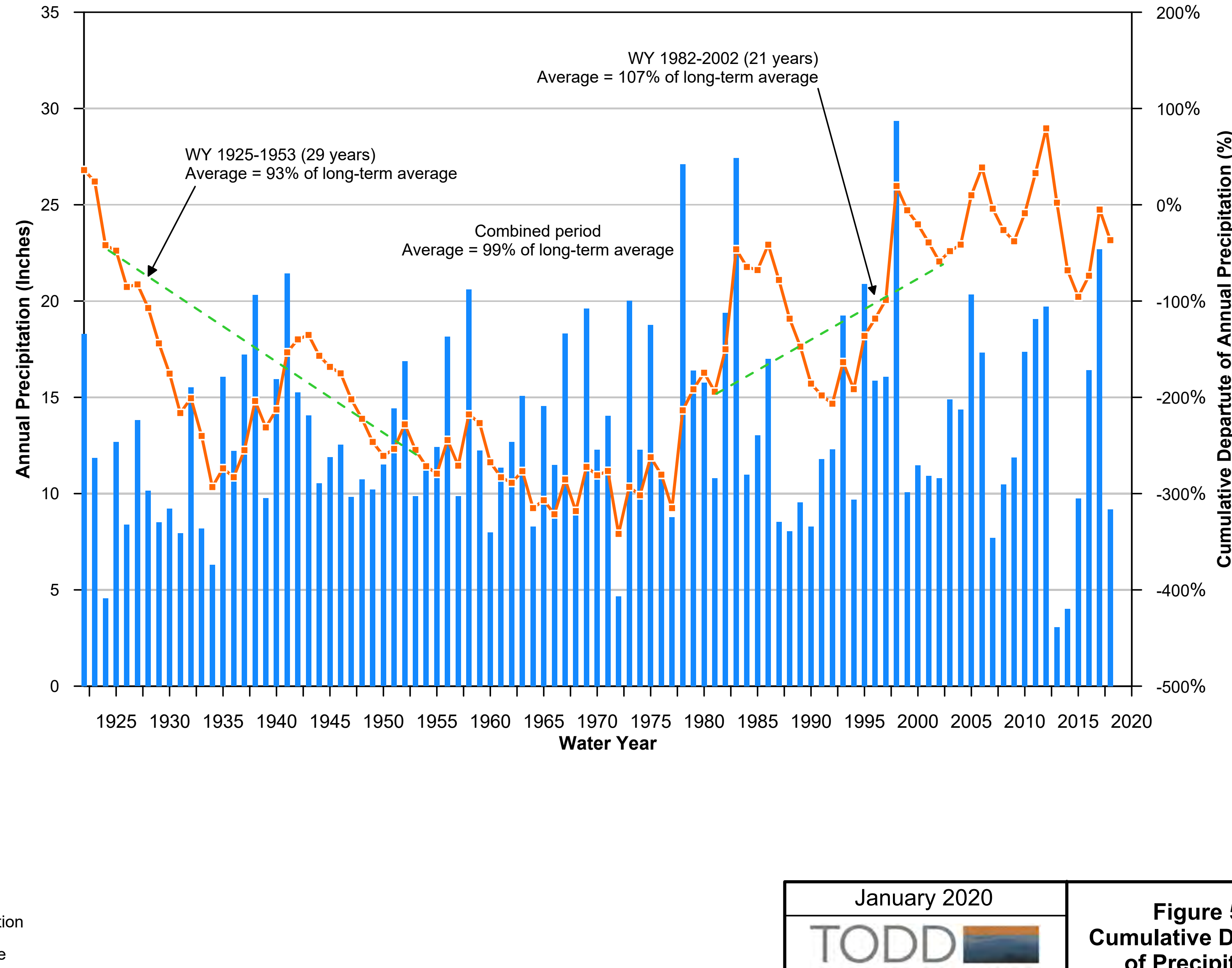

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Figure 5-4
Cumulative Departure of Precipitation

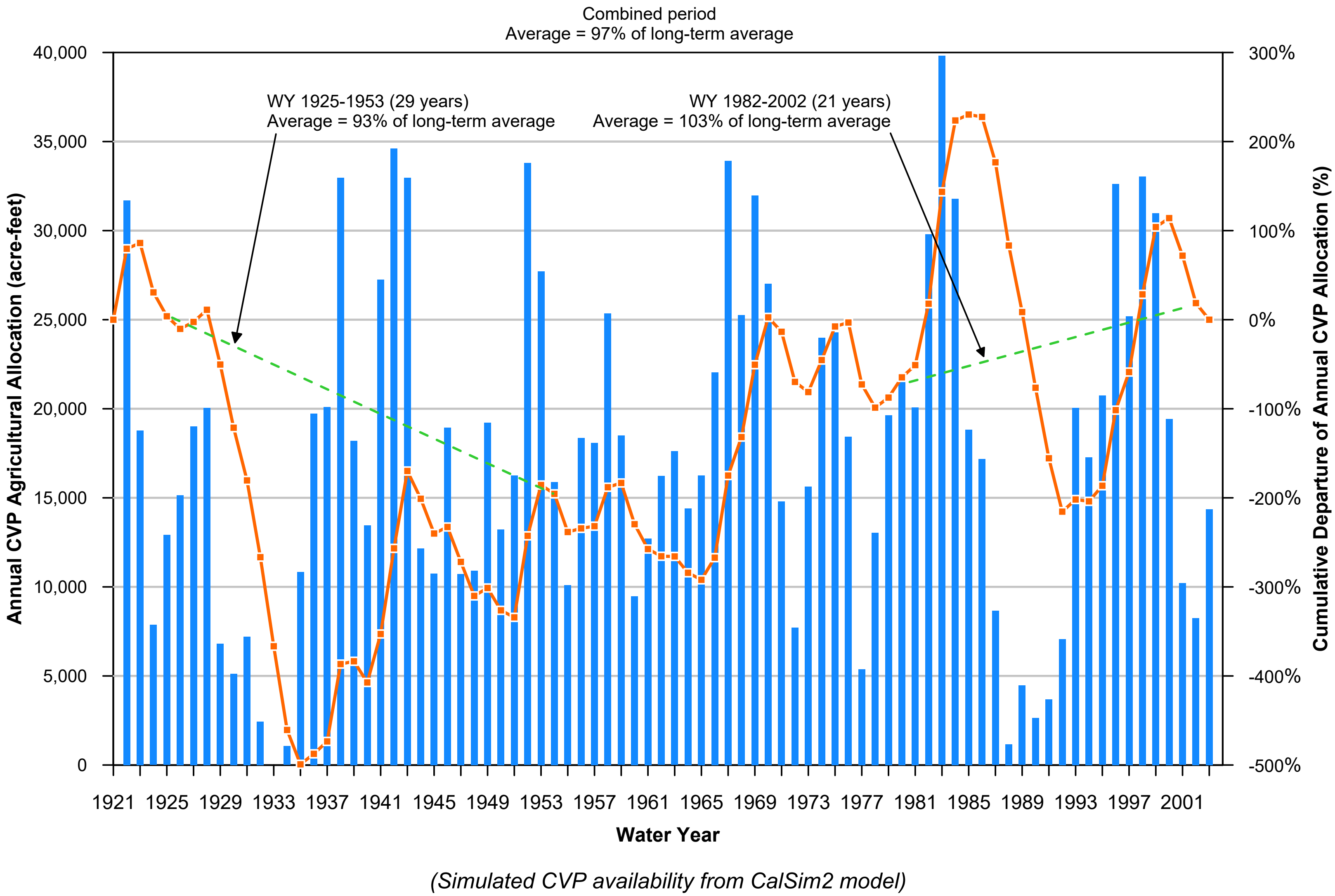

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Figure 5-5
Cumulative Departure of CVP Availability

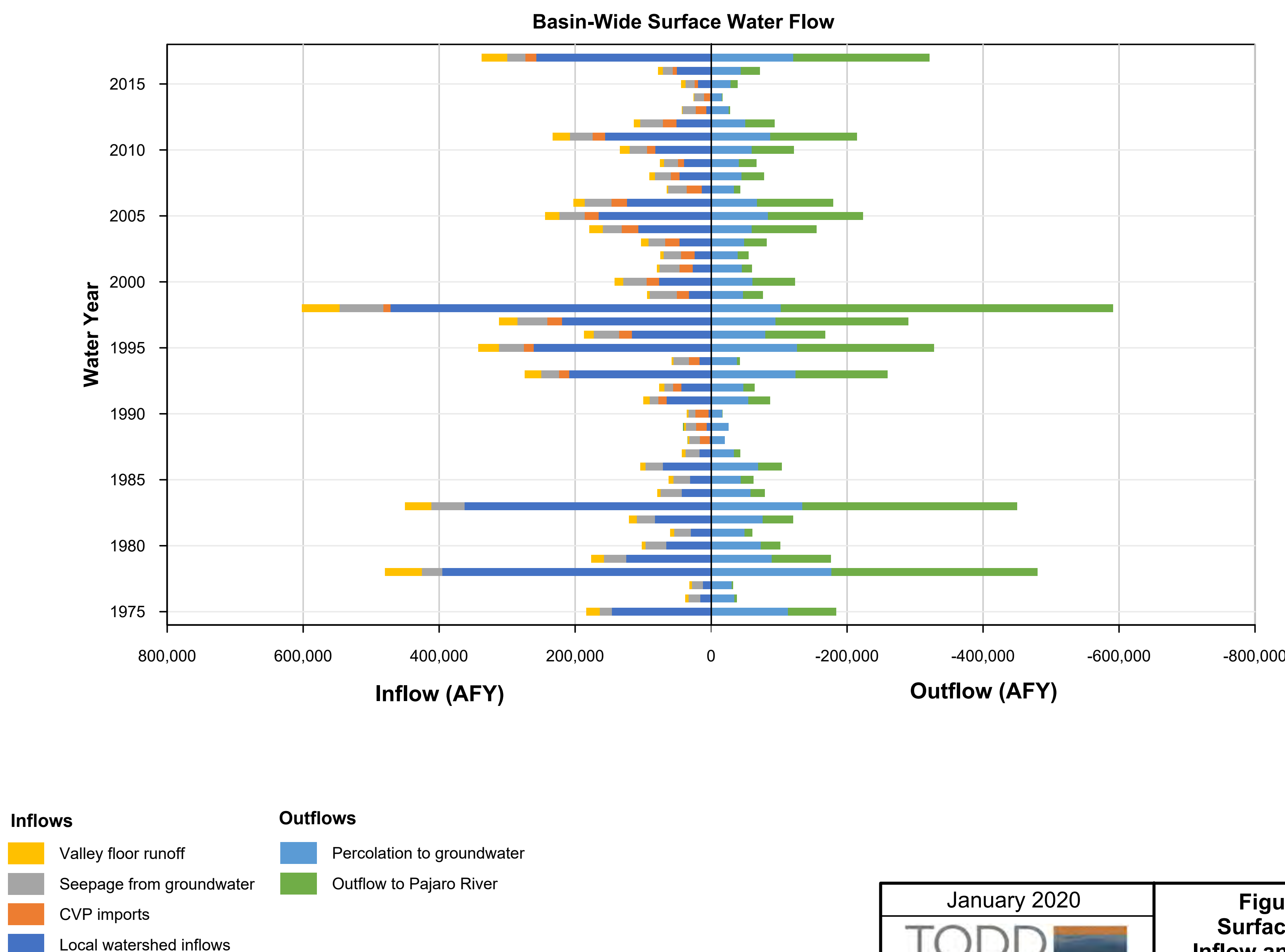

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Figure 5-6
Surface Water Inflow and Outflow of the Basin

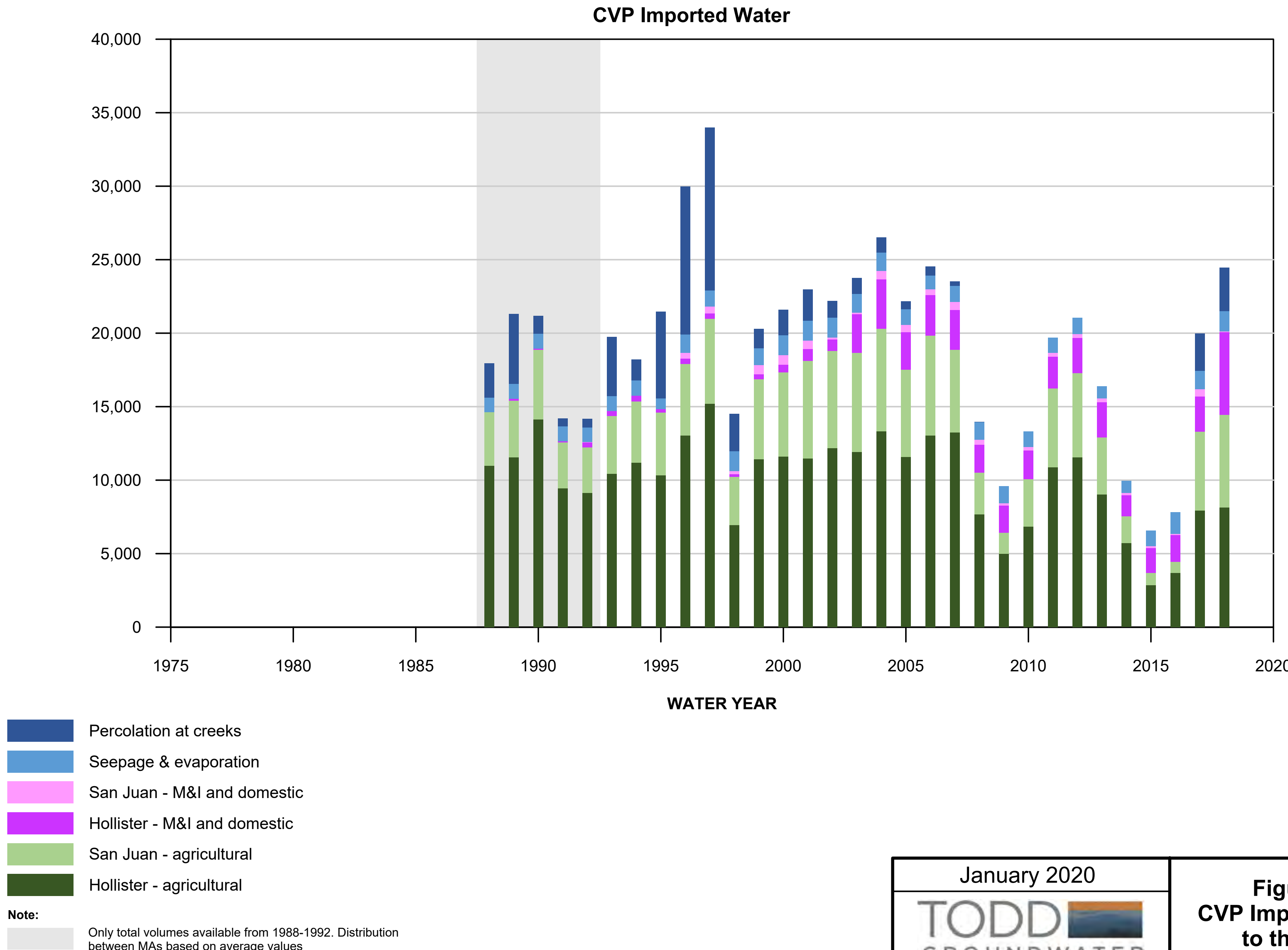

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Figure 5-7
CVP Imported Water to the Basin

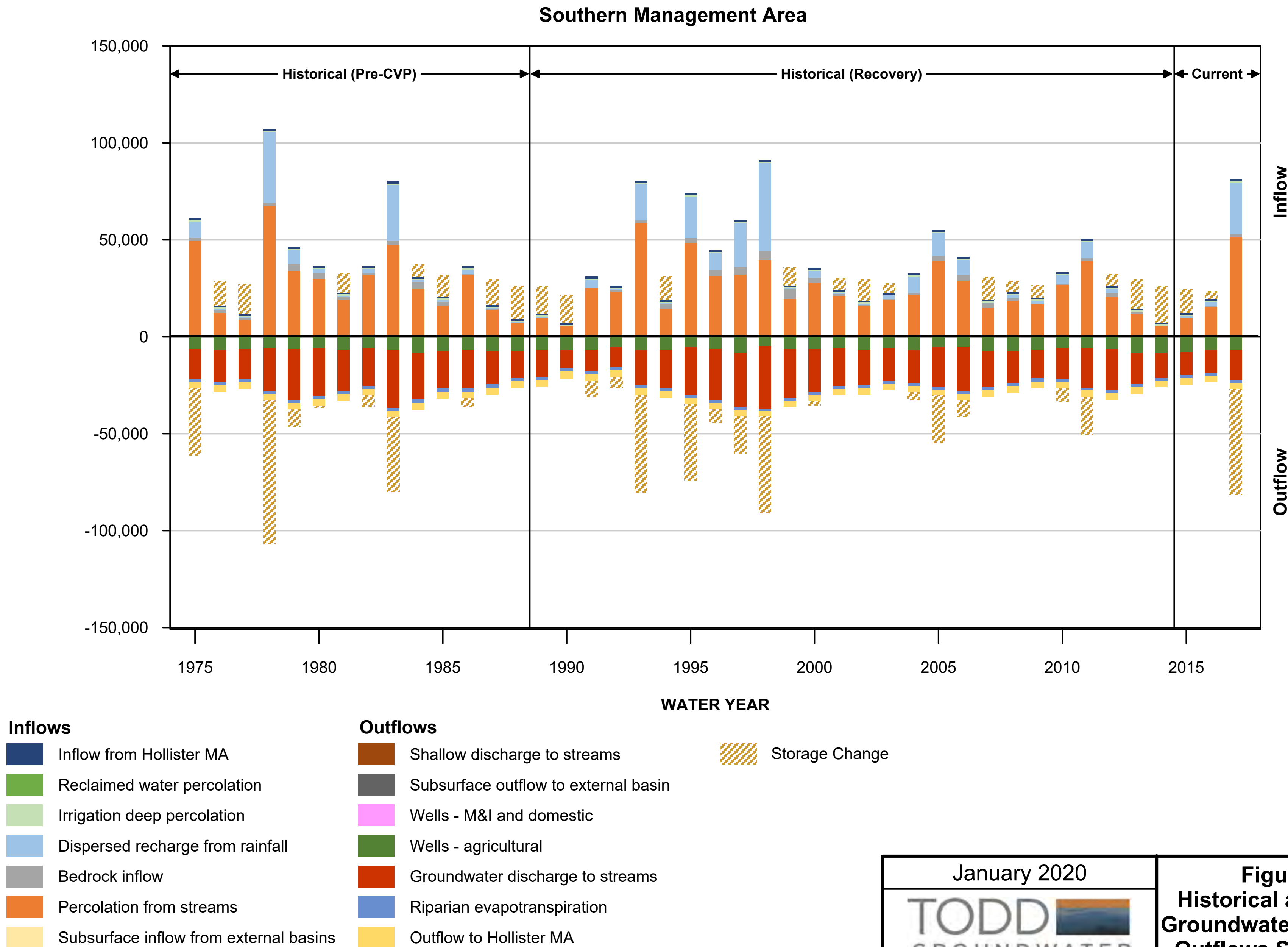

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Figure 5-8
Historical and Current Groundwater Inflows and Outflows Southern MA

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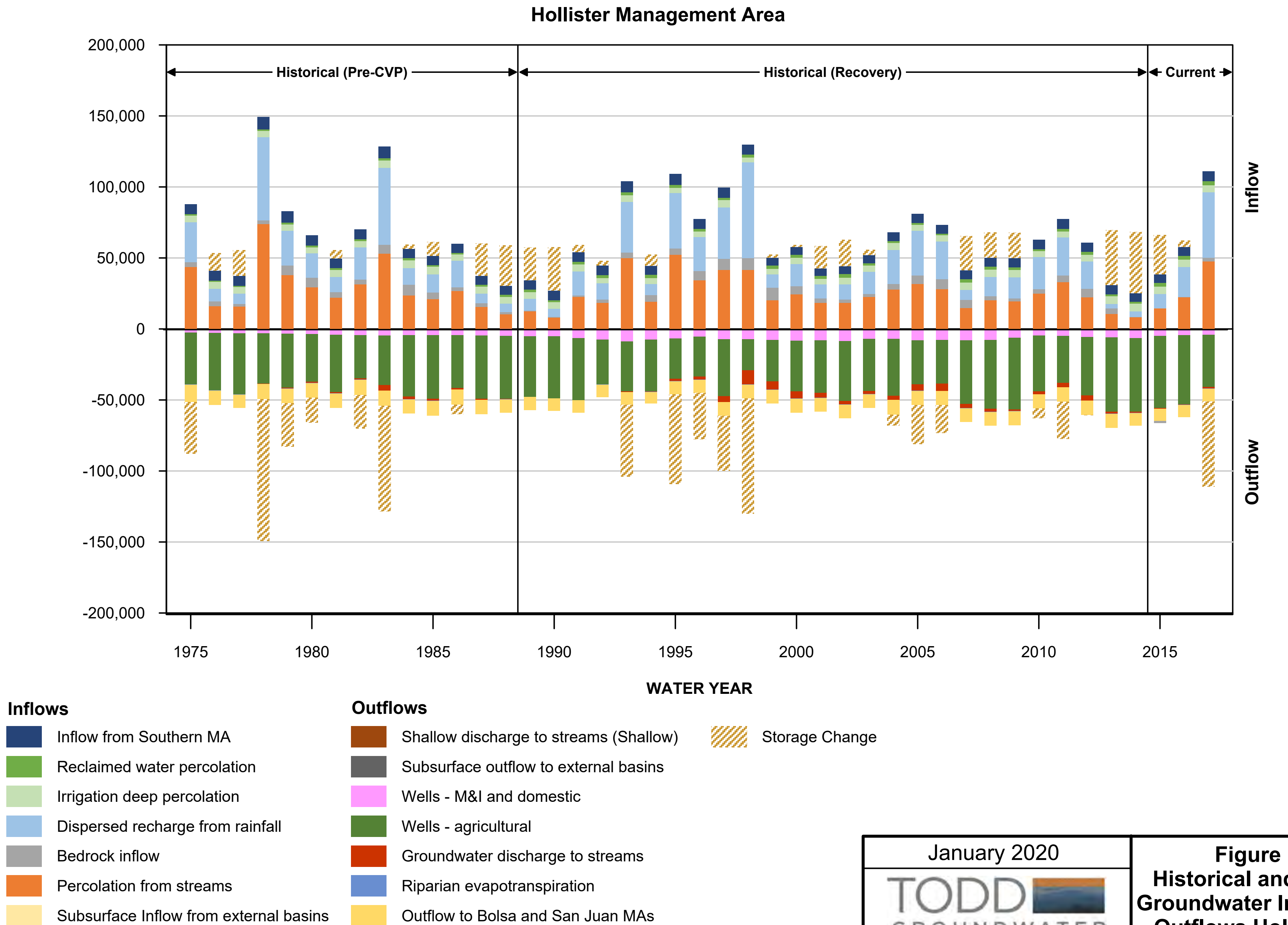

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Figure 5-9
Historical and Current Groundwater Inflows and Outflows Hollister MA

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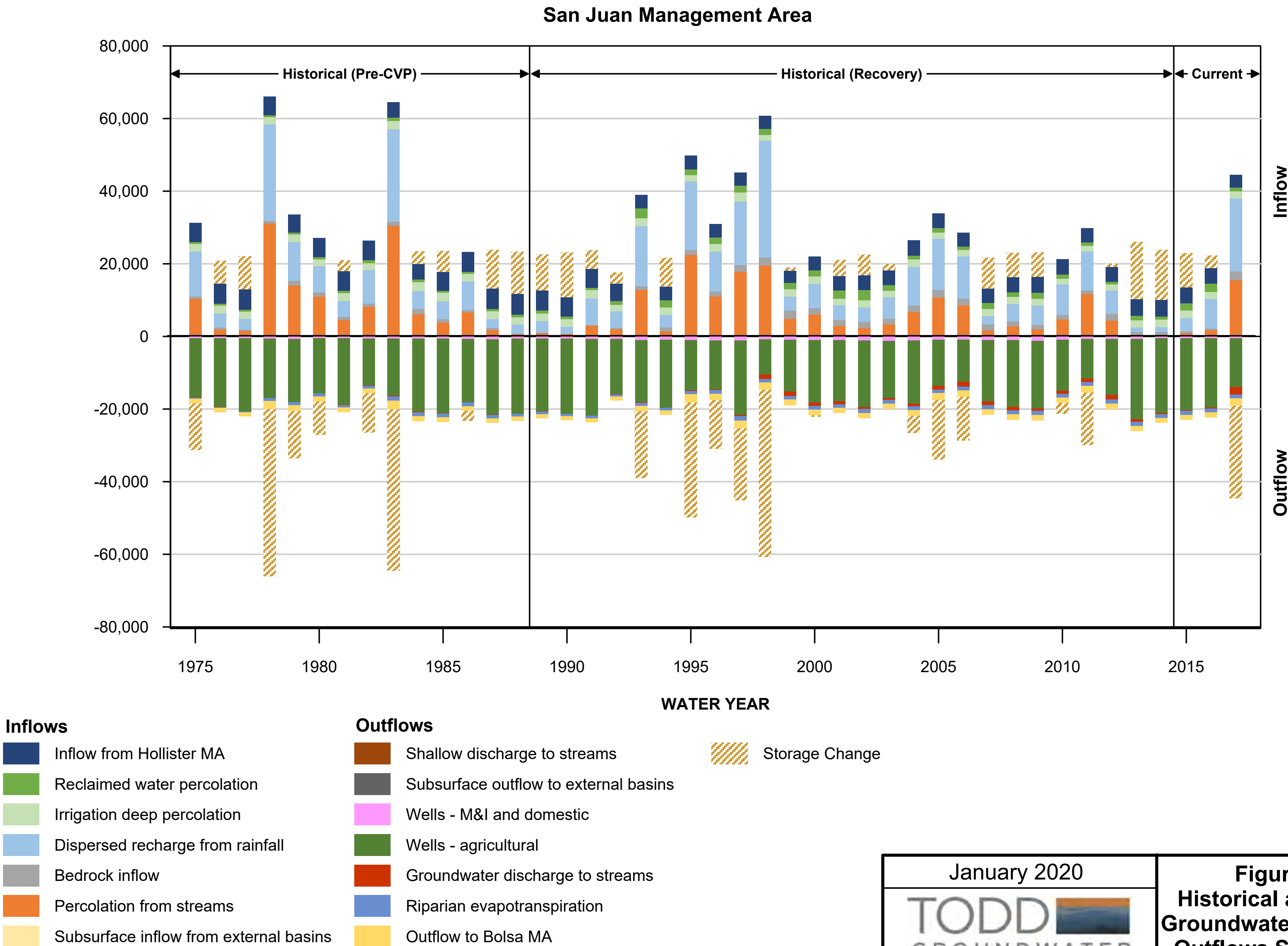

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Figure 5-10
Historical and Current Groundwater Inflows and Outflows San Juan MA

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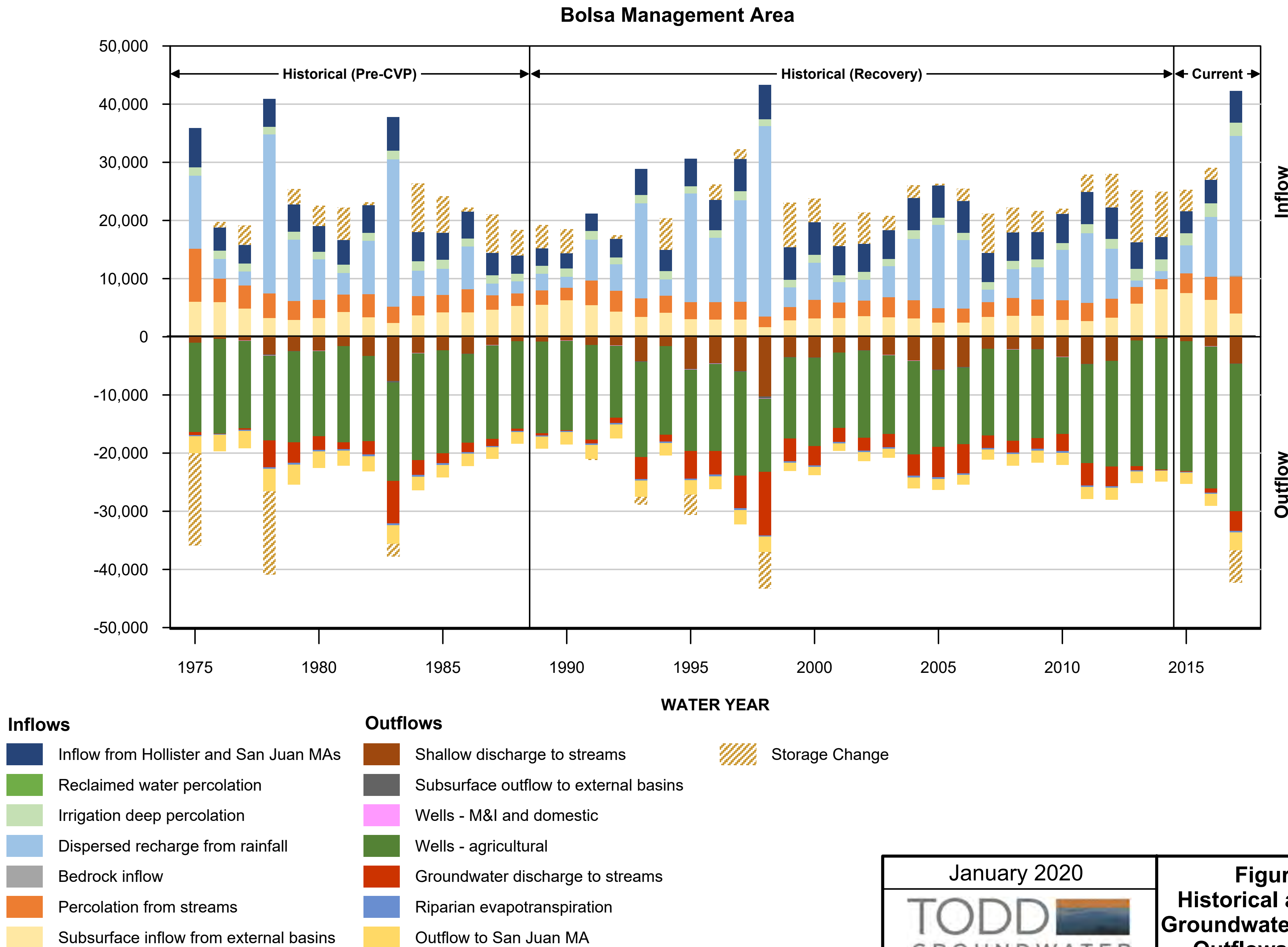

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Figure 5-11
Historical and Current Groundwater Inflows and Outflows Bolsa MA

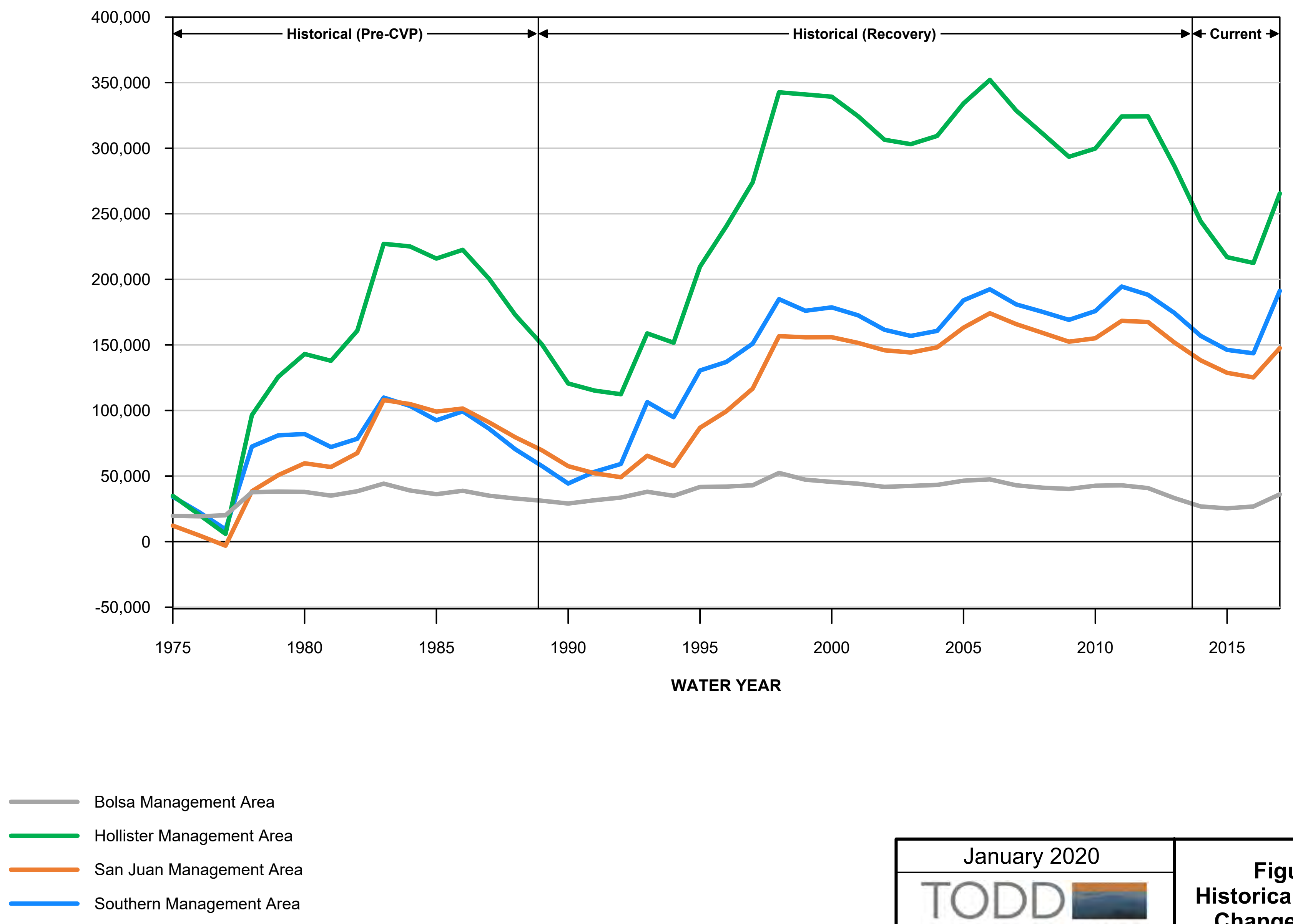

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Figure 5-12
Historical and Current Change in Storage

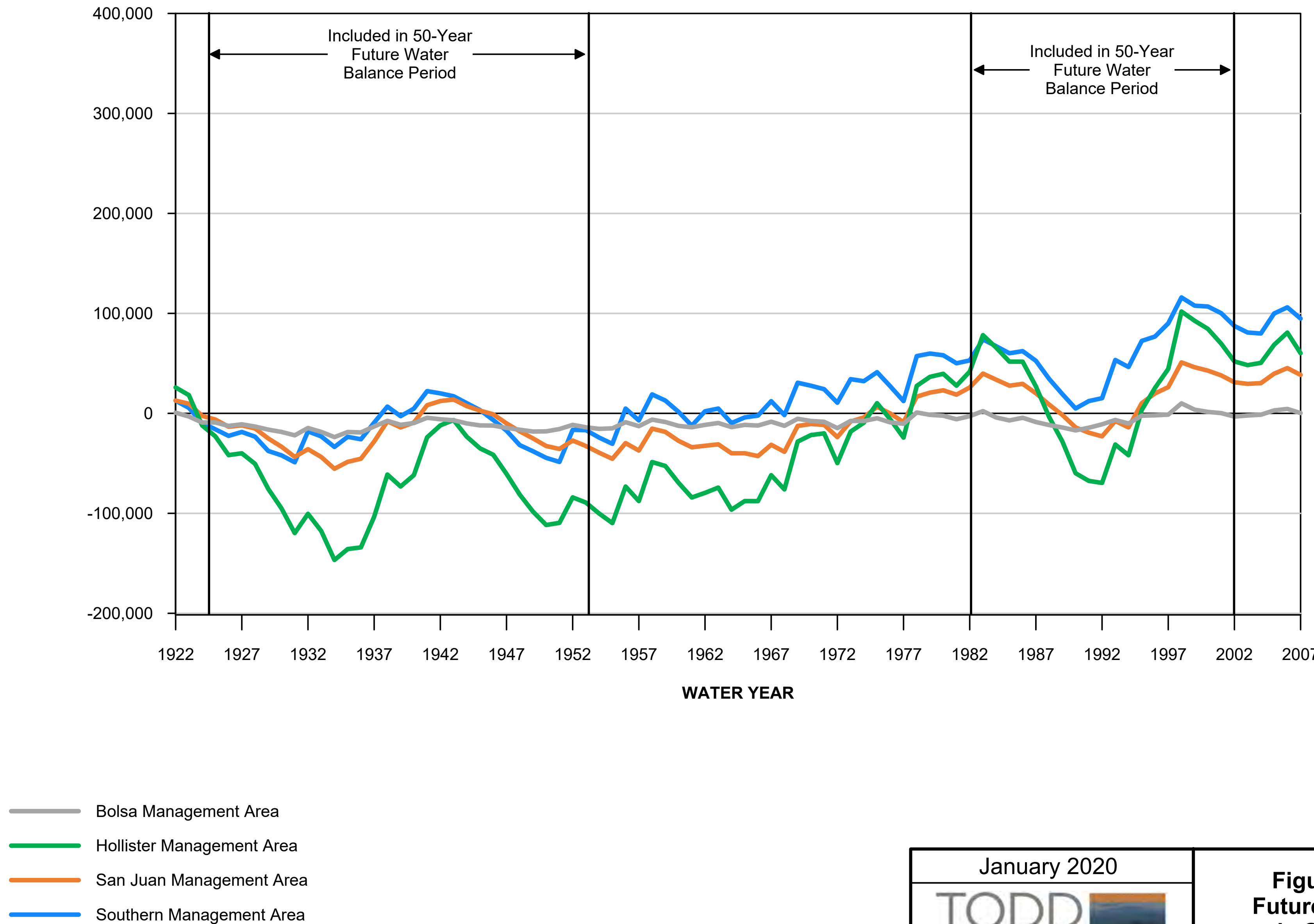

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Figure 5-13
Future Change in Storage