4 WATER BUDGETS

Surface and groundwater budgets have been developed for the KRGSA Plan Area to quantify historical changes in the amount of groundwater in storage and to identify the amount of sustainable groundwater available for future use. In particular, reductions of groundwater in storage are estimated to assess the potential for undesirable results.

The water budget analysis presented herein allows the response of the physical groundwater system to be correlated to current and historical groundwater use. This analysis also provides the foundation for identifying potential future deficits of groundwater based on future projections of surface water supplies and demands. A primary objective of the groundwater budget analysis is to quantify historical, current, and projected groundwater deficits so that management actions can be identified to mitigate undesirable results attributable to potential groundwater deficits.

The groundwater budgets for the KRGSA Plan Area quantify inflows and outflows to the groundwater system and illustrate how these flows change over time. The annual difference between inflows and outflows represents the annual change of groundwater in storage beneath the Plan Area[20]. The analysis considers average historical conditions, current conditions, and future projections of these flows, incorporating GSP requirements and DWR guidance. Although the water budget balance is focused on the groundwater system, surface water supplies are also tabulated for the analysis.

4.1 WATER BUDGET APPROACH

The KRGSA Plan Area contains the largest urban area (Metropolitan Bakersfield) within the Subbasin, almost 15 percent of the Subbasin total irrigated agricultural acres, a major supplier of imported water, the largest natural water supply in the Subbasin (Kern River), and several of the large groundwater banking projects on the Kern Fan. KRGSA member agencies cooperatively manage a broad portfolio of water sources including imported water (SWP and CVP), Kern River water, stormwater, recycled water, and groundwater for beneficial use.

The approach to a water budget analysis for this large, multi-faceted area begins with an understanding of the local management operations that either recharge (inflow) or extract (outflow) groundwater in the KRGSA Plan Area. These and other inflows and outflows to the groundwater system were tabulated monthly to create a hydrologic inventory over the 20-year historical Study Period WY 1994 through WY 2014 and the one-year current Study Period WY 2015. These data were also used to support integrated surface water-groundwater modeling of historical, current, and future projected groundwater budgets.

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[20] Multiple methods of analyzing the groundwater budget are employed in this analysis. One method conservatively excludes subsurface flows for planning purposes; this is more relevant to local deficits in supplies compared to demands than to physical changes of groundwater in storage.

4.1.1 Methods of Analysis

These and other data were used to analyze the KRGSA GSP water budgets. The approach to this analysis incorporates three independent methods to compare and corroborate water budget results, as summarized below.

1. ***Checkbook groundwater budgets*** were prepared to provide a detailed accounting of inflows and outflows for historical and current study periods. These data also support the development and analysis of projected future water budgets and are used to identify potential future deficits in sustainable groundwater supply. For planning purposes, this analysis does not consider subsurface flows and allows groundwater managers to focus on the inventory of water supplies that they each control and manage.
2. ***C2VSimFG-Kern model water budgets*** were developed using the DWR regional C2VSim model, which has been revised with Subbasin-specific water budget data to represent a local Subbasin model. Data from the checkbook method described above was used as input for model revisions and analysis of the KRGSA Plan Area. This analysis provided estimates of subsurface flows, which had not been included in the Checkbook method. Water budgets were analyzed on both a Subbasin-wide and Plan Area basis for historical and current study periods and over a 50-year planning horizon, which included climate change analyses for 2030 and 2070 climate change conditions, as required by GSP regulations. The Subbasin modeling was supported by all GSAs in the Subbasin for a coordinated and consistent analysis, which incorporated the same data and methodologies.
3. ***Electronic subtraction of annual groundwater elevation contour maps*** was conducted for the KRGSA Plan Area to provide an independent check of the changes in groundwater in storage over the historical and current study periods. Maps prepared in spring of each year by KCWA were used in the analysis to provide a consistent approach and incorporate similar data sets from year to year over the KRGSA Plan Area. This method allows for documentation of overdraft, if any, on an annual basis for a 20-year period as required by the GSP regulations for a critically over-drafted Subbasin. This analysis of change in groundwater in storage was described previously in **Section 3.3.3**, illustrated on **Figure 3-28**, and is referenced, but not repeated in this section on water budgets.

4.1.2 Water Budget Study Periods and Analysis Considerations

As discussed in **Section 3.1**, the historical Study Period (WY 1995 – WY 2014) was selected based on average hydrologic conditions (precipitation and Kern River flows), 20 years of satellite image-based evapotranspiration (ET) data, at least 10 years of coverage (as required by the regulations), overlap with the time period of the C2VSimFG-Kern model, and other criteria (see **Section 3.1**). WY 2015 was selected as the Study Period for current conditions as it represents the most recent available year in the C2VSimFG-Kern numerical model and immediately follows the historical Study Period.

As discussed previously (**Section 3.1**), it is recognized that the historical and current study periods end in the drought of record when then-current water levels were at or near historic lows. Ending a study period in the drought of record will almost always result in a cumulative decline of groundwater in storage from the beginning to the end of the period. However, such a cumulative decline does not necessarily indicate overdraft conditions. Regardless of when a study period begins or ends, the sustainable yield is more closely represented by average annual conditions rather than any one year or years that are analyzed sequentially and cumulatively. The annual, cumulative, and annual average change in groundwater in storage are all presented for the historical study period, with a focus on the average annual change in groundwater in storage for the sustainability analysis.

The initial development of the checkbook water budget focused on changes to the physical groundwater system within Plan Area boundaries to better link water budgets to local water levels. A complicating factor to that approach involved operations by both KRGSA and non-KRGSA agencies that recharge and recover groundwater inside the Plan Area for use outside the Plan Area. Although these actions affect the physical groundwater system in the Plan Area, not all inflows and outflows are available for local Plan Area use. Similarly, KRGSA member agencies also take advantage of groundwater banking opportunities adjacent to but outside the KRGSA for future use within the Plan Area. To make the water budgets more reflective of the Plan Area agencies' water portfolio, the checkbook water budget was adjusted to remove water attributable to others and to include outside water attributable to KRGSA. This alternative checkbook water budget is presented with other water budgets in this section.

It is recognized that the checkbook water budget approach does not account for subsurface flows into and out of the KRGSA Plan Area. KRGSA Plan managers, coordinating with KGA GSA managers, generally agreed that reliance on subsurface inflows by others – especially when it occurs from groundwater banking projects operated for the benefit of others – would not adequately reflect which areas were sustainable on their own. KGA, KRGSA, and other GSA managers have noted that the checkbook approach would be more suitable for local sustainability planning purposes.

Notwithstanding the need for the checkbook water budget approach, It is recognized that subsurface flows occur almost everywhere across the complex KRGSA Plan Area perimeter; furthermore, these flows are dynamic and change significantly over space and time. A more sophisticated method than the analytical checkbook approach is needed to quantify these flows. As such, the local C2VSimFG-Kern model is used to estimate these subsurface flows over time. Water Budgets, including subsurface flows, have been developed for the KRGSA Plan Area using the C2VSimFG-Kern model and are described in this section. A technical report describing model documentation, revisions, application, and the basin-wide water budget analysis is being incorporated into all GSPs for the Kern County Subbasin; that report is incorporated by reference herein as **Attachment 1**.

Types and sources of data used to develop the checkbook water budgets and also to provide input for the C2VSimFG-Kern local model are described in the sections below. The data descriptions are followed by an analysis of changes in groundwater in storage for historical and current Study Periods using the checkbook method and C2VSimFG-Kern model. Finally, future projected water budgets over a 50-year period are summarized including a projected baseline and projected conditions of climate change for 2030 and 2070 scenarios.

4.2 INFLOWS FOR HISTORICAL AND CURRENT GROUNDWATER BUDGET

Surface inflows to KRGSA Plan Area groundwater occur primarily from conjunctive management of Kern River water, imported water (primarily SWP water), stormwater, and recycled water. Managed recharge in the river channel, unlined canals, and banking recharge facilities account for about two thirds of average groundwater inflows using the checkbook method. Additional recharge occurs over a broader area and includes deep percolation from precipitation, stormwater conservation, infiltration from irrigation with recycled water and wastewater percolation and return flows from agricultural and municipal uses. As explained above, subsurface inflows are quantified separately using the groundwater model and discussed in **Section 4.4**.

Annual average inflows of the checkbook method are summarized in **Table 4-1** for the historical Study Period (WY 1995 – 2014) and the current Study Period (WY 2015). As shown, average annual inflows to the groundwater system (excluding subsurface inflows) total 319,893 AFY. During the historical Study Period, inflows ranged from about 153,000 AFY in 2014 up to about 558,000 AFY in 2011. As shown in **Table 4-1**, inflows for the drought year of 2015 total 163,104 AFY, only about one-half of the average annual inflow.

Table 4-1: Groundwater Inflows, KRGSA Plan Area – Checkbook Method

Inflow Component	Historical Study Period (WY 1995 – 2014) Average Annual Inflows, AFY	Current Study Period (WY 2015) Annual Inflows AFY
Kern River Channel Recharge	69,779	8,447
Unlined Canal Recharge	77,820	60,145
Municipal Return Flows	9,949	8,773
Applied Irrigation Infiltration	33,133	31,151
Agricultural Return Flows	34,162	26,207
Deep Percolation of Precipitation	4,243	4,434
Stormwater Conservation	20,786	17,827
Wastewater Percolation	4,142	4,600
Groundwater Banking	65,879	1,520
TOTAL INFLOWS	**319,893**	**163,104**

Information on data and methodology used to estimate each inflow component is described in the following sections.

4.2.1 Kern River Channel and Canal Operational Recharge

The Kern River channel and local unlined canals are used for both conveyance and recharge of surface water resources in the KRGSA Plan Area including Kern River water, imported water, and stormwater runoff diverted to the channel and canals. The City of Bakersfield operates the river channel and has agreements with other agencies for banking directly in the permeable sands of the unlined channel, including through conveyance of water to more formal banking areas. Unlined canals are also maintained and used for recharge and are purposefully kept unlined to allow recharge to occur over a broad area of the KRGSA. During the non-irrigation season, river water is often released into canals for recharge only, which serves to supplement recharge basins and banking projects. This strategy has been implemented by KRGSA agencies and is a key component of the KDWD Water Allocation Plan (WAP), adopted in 2018 (KDWD, 2011), along with City polices and projects (**Sections 7.1.1** and **7.1.2**). The Kern River channel and unlined canals in the KRGSA Plan Area are shown on **Figures 3-11** and **3-12**.

As discussed previously, flows are measured along the river channel, at diversion points, and along canals. Seepage losses in the channel and canals are calculated and recorded monthly in each Kern River Annual Hydrographic Report. Additional daily documentation is used by the City of Bakersfield to provide historical monthly flows attributable to each agency using the channel for conveyance and recharge. For this project, flow data from the City were summed and compared to measured monthly and annual totals in the Annual Hydrographic Reports to avoid double counting.

During the historical and current Study Periods, the City, ID4, KDWD, KCWA and other agencies recorded operational losses in the Kern River channel involving regulated flows between First Point and Second Point. Measured losses were corrected for water use by riparian vegetation along the river channel to estimate groundwater recharge. Riparian water use amounts for various hydrologic conditions (wet, dry, and average years) were derived from a separate study by Daniel B. Stephens and Associates (DBS&A, 2012) for defined reaches along the Kern River. These factors were used to estimate a percentage of total flow per reach consumed by riparian vegetation ET and were applied based on water year type to the measured flow of each reach.

As shown on **Table 4-1** above, the annual average recharge in the Kern River channel for the KRGSA is estimated at 69,779 AFY for historical conditions. About 86 percent of this recharge was attributable to KRGSA member agencies, mostly to ID4 and the City. An additional 12 percent was recharged in the channel by KCWA and the remaining 2 percent represented conveyance recharge by other agencies. This total does not include recharge in the banking projects located along the river channel, such as the COB 2800 recharge facilities or Berrenda Mesa, which are evaluated separately in **Section 4.2.7**.

Some of the recharge associated with the channel involves imported water. For example, KCWA may use the river channel to recharge and store excess imported water outside of designated banking projects. Recharge in the Kern River channel by ID4 represents both local storage of imported water and conveyance of Kern River water to the Henry C. Garnett Water Purification Plant (HCG WPP) through exchanges with Kern River interests. Monthly recharge in the Calloway Pool and along the Calloway

Canal attributable to ID4 exchange water is summarized separately in the Kern River Annual Hydrographic Reports beginning in 1997. For 1995 and 1996, recharge attributable to ID4 was estimated from the Calloway Operations Report in the hydrographic reports.

Data on operational recharge along unlined canals were obtained from the Kern River Annual Hydrographic Reports, the annual Report of Water Conditions (ROWC) developed by ID4, and supplemental sources provided by KDWD, the City, and ID4. Canal recharge occurring in the KRGSA Plan Area was estimated monthly for the Calloway Canal (portions in the KRGSA only), Carrier Canal, Kern Island Canal, Eastside Canal, Stine Canal, Famers Canal, Buena Vista Canal, and unlined portion of the Cross Valley Canal (CVC). As shown on **Table 4-1** above, the annual average recharge along unlined canals in the KRGSA Plan Area is estimated at 77,820 AFY.

4.2.2 Municipal Return Flows

A portion of municipal water applied as urban irrigation (e.g., lawns, parks, urban landscaping) and for other outdoor purposes infiltrates below the root zone and results in groundwater recharge; because most of this water is sourced from the groundwater system, this recharge component is referred to as municipal return flows. Although some portion of this water represents deep percolation of irrigation sourced from either imported or local surface water, all municipal uses resulting in recharge are included in municipal return flows to simplify the calculations.

The percent of municipal water used outdoors, average ET rates, and the resulting return flows were estimated on a monthly basis over the historical and current study periods. Consistent with information from the Bakersfield area, 50 to 70 percent of municipal supply is assumed to be used outdoors for some purpose. Further, it is assumed that 12 to 16.8 percent of the outdoor use (or 6 to 8.4 percent of total applied irrigation depending on the month) recharges the aquifer as return flow. Municipal return flows were estimated for the City and Cal Water Service Areas as well as the smaller water systems including ENCSD, OMWC/NORMWD, Vaughn MWC (portions in the KRGSA Plan Area), Greenfield CWD, and portions of Lamont PUD. Additional return flows from other smaller water systems, MWCs, and private pumpers in the ID4 service area (except for agricultural pumping which is considered separately) were also included in this water budget category based on pumping estimates reported to ID4. Total municipal return flows are estimated at 9,949 AFY on an average annual basis (see **Table 4-1** above).

4.2.3 Applied Surface Water Infiltration and Agricultural Return Flows

Both applied surface water infiltration and agricultural return flows refer to the portion of agricultural irrigation that is applied in excess of the evapotranspiration (ET) of the crop (overapplication) and subsequently percolates to the groundwater system. Applied irrigation infiltration occurs with overapplication of local surface or imported water (primarily the Kern River or SWP water); agricultural return flow refers to overapplication of groundwater. Although these two inflow components result from the same process in the same area, they are calculated separately because the deep percolation of local surface or imported water represents a new water source to the groundwater system.

Overapplication of groundwater simply returns some component of groundwater back to the groundwater system.

The amount of irrigation that is applied in excess of the crop ET is related to both the irrigation method and the permeability of the soils. This overapplication is also referred to as irrigation efficiency. An irrigation efficiency of 80 percent indicates that an extra 20 percent is applied above the crop ET to ensure that crop ET is satisfied. For the purposes of this checkbook water budget, these inflow components also incorporate any natural precipitation in the agricultural irrigation areas that percolates to groundwater.

The ET crop demand in agricultural areas was estimated based on monthly satellite imagery processed with METRIC, a procedure developed at the University of Idaho and applied by the Irrigation Training and Research Center (ITRC) of California Polytechnic State University (Cal Poly) (Burt, 2016). METRIC ET data were developed for the entire Kern County Subbasin from 1993 through 2016 (Howes, 2018) and have been incorporated into the C2VSimFG-Kern local surface water-groundwater model. For the checkbook method, average ET data were analyzed for the KRGSA independent of the local model.

Parcels with an ET of more than 20 inches per year were assumed to be irrigated lands and incorporated into the analysis. Areas near the City of Bakersfield were reviewed to remove any large parcels irrigated by municipal sources (cemeteries, golf courses, parks, etc.) and already incorporated in municipal return flows.

Parcel ET values for agricultural irrigated lands were summed monthly for the KRGSA Plan Area and an irrigation efficiency of 80 percent was applied to develop agricultural irrigation infiltration/agricultural return flows. As such, these inflow components are estimated at approximately 20 percent of the METRIC crop demand. Although actual irrigation efficiencies are unknown and expected to vary throughout the KRGSA Plan Area and over time, an average irrigation efficiency of 80 percent was determined to be sufficient for the checkbook water budget. Previous analyses by KDWD suggest average efficiencies of about 80 percent for the southern Plan Area where most of the irrigated agriculture occurs (see **Figure 2-9** for irrigated agriculture in the Plan Area).

It is recognized that return flows do not recharge groundwater immediately upon application of irrigation and require variable transport times through the unsaturated zone based on sediment permeability and depth to groundwater. For simplification, no transport time is assumed for the checkbook water budget and the infiltration/return flows are assumed to recharge groundwater within the same month as the associated crop ET.

This approach resulted in an estimate of 33,133 AFY of applied local surface water/imported water providing groundwater recharge on an average annual basis (**Table 4-1** above). The analysis of agricultural return flows indicates about 34,162 AFY of applied groundwater returning to the groundwater system (**Table 4-1**).

4.2.4 Recharge from Rainfall (Non-agricultural areas)

Deep percolation of precipitation on undeveloped, non-irrigated lands was estimated at eight percent of monthly precipitation. These undeveloped areas were identified using monthly METRIC satellite imagery and included natural areas with a total ET of less than 20 inches per year. Deep percolation on these areas is estimated at about 4,243 AFY on an average annual basis (**Table 4-1**). Percolation of precipitation in irrigated agricultural areas is included in agricultural return flows discussed above. Precipitation in the urban areas is incorporated into the estimates of stormwater runoff and conservation described below.

4.2.5 Stormwater Conservation

The City of Bakersfield and Kern County operate a storm drainage system that serves urbanized areas of the City and County enclosed within or surrounding the City limits. The system includes open storm drain channels, closed pipes, and stormwater basins (referred to in local stormwater plans as sumps). This storm drainage system serves an area designated as the Bakersfield Urbanized Area (which also includes some undeveloped lands) and is operated under a RWQCB Waste Discharge permit (December 2013).

The Bakersfield Urbanized Area covers about 88,576 acres and includes 322 stormwater basins (RWQCB, 2013). The stormwater basins are dispersed throughout the area and collectively cover approximately 534 acres. Locations of the larger stormwater basins are shown on **Figure 3-12**. Stormwater runoff from this area is conveyed either to the stormwater basins, to the East Side, Carrier, Stine, or Kern Island canals, or to the Kern River channel (RWQCB, 2013). Stormwater flows into the canals either directly or indirectly via detention basins/outfalls. KDWD works cooperatively with the City and County to direct local stormwater to nearby unlined canals to maximize recharge.

As indicated in the RWQCB Permit (2013), approximately 80 percent of the Bakersfield Urbanized Area discharges stormwater runoff to the stormwater basins. The remaining 20 percent of the area drains to the Kern River or nearby canals. The City has estimated that approximately 90 percent of the average annual stormwater runoff is retained in these stormwater basins for groundwater recharge (Carollo, 2015). The remaining 10 percent is discharged directly to a receiving water (Kern River and/or groundwater) or is detained in a basin and then discharged (RWQCB, 2013). These unlined stormwater basins are generally located on highly permeable soils and are maintained to function as recharge basins.

These conditions predict that approximately 72 percent of the runoff from the Bakersfield Urbanized Area would infiltrate to groundwater. Once in a stormwater basin, any standing stormwater would be subject to some evaporation, but given the nature of the soils, the maintenance of the basins, and the assumption that stormwater is generated during relatively low ET conditions, evaporation is assumed to be small. Accordingly, this methodology assumes that 72 percent of the Bakersfield Urbanized Area runoff is available for groundwater recharge (i.e., 80% of runoff to stormwater basins x 90% retained for recharge = 72% of the runoff is recharged).

To estimate the amount of stormwater runoff, it was assumed that about 50 percent of the area connected to the storm water system is impervious and that all of the rainfall on this impervious area runs off into the storm water system. The remaining rainfall either infiltrates or is lost to evapotranspiration or evaporation. To estimate monthly recharge from the stormwater basins, monthly rainfall measured at the Bakersfield Airport station (#040442) was multiplied by the percentage of rainfall on the Bakersfield Urbanized Area that is estimated to runoff to the basins and recharge (i.e., 72 percent x 50 percent).

Applying this methodology results in about 16,514 AFY of stormwater runoff being recharged in stormwater basins on an average annual basis. With 20 percent of the stormwater runoff being directed to the river and canals, an additional 4,272 AFY is estimated to be conserved in the river and unlined canals. These two components indicate a total of 20,786 AFY of stormwater from the urbanized areas is being recharged in the KRGSA Plan Area on an average annual basis (see **Table 4-1** above).

4.2.6 Wastewater Discharge

Discharge operations and WWTP activities within the KRGSA Plan Area were reviewed for potential re-use and/or inflows pertinent to the groundwater budget. Multiple wastewater treatment plants (WWTP) are located in the KRGSA, two of which are owned and operated by the City (see information in **Section 2.4.4** and **Table 2-1**). Effluent from the Kern Sanitation Authority and North of the River Sanitary District is recycled for crop irrigation in portions inside and outside of the KRGSA; these flows already are accounted as recharge from surface water application for irrigation as described in **Section 4.2.3** and are not double-counted here. Wastewater collected by CSA-71 is conveyed to other WWTPs for treatment. Wastewater infiltration from individual septic systems occurs in the Plan Area; amounts are unknown but are likely to be negligible compared to the other water balance components and have not been estimated.

The water budget focuses on the two city-owned wastewater treatment plants – Wastewater Treatment Plant No. 2 (WWTP No. 2) and Wastewater Treatment Plant No. 3 (WWTP No. 3) – which generally serve areas east of Highway 99 and west of Highway 99, respectively (City of Bakersfield, 2018). Until 2017, all wastewater flows from East Niles CSD were also treated at WWTP No. 2; up to about 10 percent of these flows are now diverted to Kern Sanitation Authority (KSA) with the remainder continuing to be treated at WWTP No. 2. Monitoring of WWTP discharges and quality is regulated by the Central Valley Water Board.

4.2.6.1 City of Bakersfield WWTP No. 2

WWTP No. 2 has a design capacity of 25 million gallons per day (mgd) with a current average daily flow of 13.7 mgd (City of Bakersfield, 2018). Secondary effluent is discharged to nine plant reservoirs for subsequent irrigation of about 447 acres of City-owned fields leased for agricultural use. The leased lands are located south of the WWTP and extend into KDWD. For the water budget, wastewater effluent from WWTP No. 2 already is accounted as an additional surface water source for irrigation, consistent with the methodology described in **Section 4.2.3** above. The plant reservoirs are lined and are not associated with groundwater recharge.

4.2.6.2 City of Bakersfield WWTP No. 3

WWTP No. 3 provides primary, secondary, and tertiary treatment. The plant has a design capacity of 32 mgd and a current average daily flow of 17.3 mgd (City of Bakersfield, 2018). Beginning in 2010, tertiary effluent has been used for landscape irrigation at the plant and at the adjacent State Farm Sports Village, a local soccer and football complex. Secondary treated, denitrified effluent is discharged to four onsite ponds for groundwater recharge. In addition, the City exports recycled water to agricultural lands outside its service area for irrigation. The irrigated lands, referred to as Green Acres Farm, are owned and operated by the City of Los Angeles, and are located partially inside and partially outside the KRGSA Plan Area. When irrigation demands are low in the winter, the recycled water is discharged into the four onsite ponds for storage and percolation.

The City provided monthly effluent flow data for 2000 through 2016. Annual effluent flows for 1986 through 1999 were estimated using population growth trends and a typical per capita effluent flow rate. The estimated annual flows were divided evenly over each 12-month period.

For 1989 through 2016, all effluent discharged between February and September was provided to Green Acres Farm for irrigation. From October through January, effluent was stored first in onsite ponds (up to a percolation rate of 900 AF/month) and then provided to Green Acres Farm. For the water budget, irrigation was prorated to reflect the approximately 28 percent of the farm that lies within the KRGSA Plan Area and this prorated portion was accounted in the applied surface water infiltration component described in **Section 4.2.3**. Pond recharge was calculated on a monthly basis less a six percent evaporation loss to determine remaining wastewater provided to the farm.

In sum, effluent used for surface water irrigation is already accounted in the applied surface water infiltration component described in **Section 4.2.3**. The remaining water budget component is the amount of recharge occurring in the unlined recharge ponds at WWTP No. 3. An analysis of the total effluent data indicates an annual average recharge of approximately 4,142 AFY in the ponds (**Table 4-1**).

4.2.7 Additional Managed Recharge and Groundwater Banking Projects

As discussed throughout this GSP, managed recharge and conjunctive use represent core operations of the KRGSA member agencies. In addition to the ongoing recharge associated with the Kern River channel and canals, more formal groundwater banking projects occur throughout the KRGSA Plan Area.

Over the last four decades, the City of Bakersfield has operated its COB 2800 Recharge facility along a 5.5 mile reach of the Kern River above Second Point (see **Figure 3-11**). The facility has 13 recharge basins with a total capacity of more than 150,000 AFY. Over the 20-year historical Study Period, recharge in this facility alone has averaged 37,606 AFY. The City, ID4, and KCWA have all banked water in the 2800 Recharge facility during the 20-year Study Period.

An additional groundwater banking project, Berrenda Mesa, lies just upstream of the 2800 Facility and consists of six recharge basins (see **Figure 3-11**). Managed by KCWA, pursuant to an agreement with Berrenda Mesa Water District, the recharge project provides storage and recovery of primarily imported water for use by participants in the northwestern Subbasin outside the KRGSA Plan Area. Over the historical Study Period, water was recharged in Berrenda Mesa 13 of 20 years; recharge events have ranged up to about 29,000 AFY with a 20-year annual average of 9,221 AFY. Nearby Wilson Ditch, located just upstream of Berrenda Mesa, is located in a wide portion of the Kern River channel and used to convey water to these two banking projects. The sandy river bottom along the Wilson Ditch provides for excellent recharge and this area is considered part of the KRGSA banking facilities.

In addition to the managed recharge along the Kern River Channel, the City also operates smaller recharge facilities, generally consisting of lakes in City parks, for groundwater banking and other purposes. Three small lakes south of the river along the Kern River Parkway and Truxtun Avenue, referred to as Truxtun Lakes, are used by both the City and ID4 for groundwater recharge and operational purposes. During the 20-year historical Study Period, the lakes were used to recharge up to about 6,000 AFY (1998), with additional capacity added since that time. Small recreational lakes are also used by the City and ID4 for recharge at Aera Park (Rio Vista Lake) and The Park at River Walk, both located along Stockdale Highway, north and south of the river, respectively. Collectively these lakes are capable of recharging up to about 1,000 AFY. The City also operates the Kern River Canal and Irrigation (KRC&I) canal for recharge of about 1,500 AFY in areas north of the Kern River.

In the southern KRGSA Plan Area, KDWD operates groundwater banking facilities for banking partners including Metropolitan Water District of Southern California (Metropolitan) and San Bernardino Valley Municipal Water District (Valley). KDWD facilities include more than 1,000 acres of recharge basins throughout and adjacent to the KDWD service area. The Metropolitan banking agreement allows the agencies to store up to 50,000 AFY beneath KDWD with a maximum storage amount of 250,000 AF. The Valley agreement allows for a one-time delivery of 30,000 AF with a maximum recovery of 5,000 AFY (about 11,300 AF remaining in the account). An 11 percent conveyance loss is retained by KDWD in both agreements. Since the program began in 2003, KDWD has stored approximately 160,000 AF for banking partners.

The City, ID4 and KCWA provided groundwater banking data for use in the checkbook water budget. Banking of Kern River water by the City and ID4 were also available in the Kern River Hydrographic Reports. KDWD provided monthly data on the banking operations in the southern KRGSA Plan Area. Additional small amounts of recharge by Kern Sanitation Agency, Rosedale Ranch and others are also grouped into this inflow component. Those data were provided by the individual agencies. Additional duplicate sources were checked to avoid double counting of the large amounts of recharged water including the river channel (**Section 4.2.1**), canals (**Section 4.2.1**), and groundwater banking facilities.

As shown on **Table 4-1** above, groundwater banking recharge results in about 65,879 AFY on an annual average basis. During the Study Period, recharge associated with the groundwater banking facilities ranged up to about 200,000 AFY. The additional banking capacity that has been added to the KRGSA in recent years would allow for much more water to be banked during future wet years.

4.3 OUTFLOWS FOR HISTORICAL AND CURRENT GROUNDWATER BUDGET

Outflows from the groundwater system beneath the KRGSA Plan Area include groundwater pumping and subsurface outflows. Consistent with the checkbook water budget method, subsurface outflows are not quantified and not discussed in this section. Rather, subsurface flows are estimated with the C2VSimFG-Kern numerical model and provided in **Section 4.4**. Outflows quantified in this section include pumping for municipal, agricultural, banking recovery, industrial/domestic, and other water supply purposes.

Average annual outflows for KRGSA Plan Area using the checkbook method are summarized in in **Table 4-2** for the historical Study Period (WY 1995 – 2014) and current conditions (represented by 2015). As shown in the table, the average annual outflows (pumping) for the KRGSA Plan Area checkbook total about 321,871 AFY. Outflows during the critically dry year of 2015 total 401,177 AFY - about 25 percent higher than the average – reflecting an overall increase in agricultural and recovery pumping to supplement a decrease in surface water supplies.

Agricultural pumping is estimated at 175,668 AFY and represents about 55 percent of the total groundwater production. Municipal pumping of about 109,966 AFY is about 34 percent of the total. An additional 8 percent of pumping is conducted to recover banked groundwater. Remaining outflows include pumping from small water systems and private industrial and domestic wells (**Table 4-2**).

Table 4-2: Groundwater Outflows, KRGSA Plan Area – Checkbook Method

Outflow Component	Average Outflows, AFY (WY 1995 – 2014)	Annual Outflows AFY (WY 2015)
Agricultural Pumping	175,668	196,859
Municipal Pumping	109,966	96,390
Small Water Systems/Private Pumping	9,038	7,201
Banking Recovery Pumping	27,199	100,727
TOTAL AVERAGE OUTFLOWS	**321,871**	**401,177**

Data and methodologies for estimating the pumping components listed above are described in the following sections.

4.3.1 Agricultural Groundwater Pumping

This outflow component includes pumping for irrigation of agricultural crops in the KRGSA Plan Area and totals 175,668 AFY on an average annual basis (**Table 4-2**). Agricultural crop lands for the KRGSA Plan

Area in 2016 are shown on **Figure 2-9**. Although groundwater pumping for agricultural irrigation occurs throughout the KRGSA Plan Area, about 87 percent occurs in the KDWD Service Area; the remaining 13 percent occurs mostly in the northwestern Plan Area (e.g., in Rosedale Ranch ID) but also occurs on smaller isolated parcels in Greenfield CWD, Lamont PUD, and other areas. In general, these smaller irrigated areas have declined over the historical Study Period. For example, during the first 10 years of the historical Study Period (WY 1995 – 2004), agricultural pumping in the KRGSA Plan Area outside of KDWD averaged about 26,000 AFY, with several years exceeding 30,000 AFY. Since 2009, annual average pumping for non-KDWD areas has decreased to about 16,000 AFY (data through 2016).

Pumping for agricultural irrigation was estimated by first calculating the total crop demand for irrigated acres in the Plan Area. Crop demand (ET) was estimated analytically from the monthly METRIC data from satellite imagery provided by the ITRC, Cal Poly (see **Section 4.2.3**). A total ET threshold of more than 20 inches per year was used to differentiate parcels with agricultural irrigation from parcels of native vegetation.

The total crop ET demand was corrected using an irrigation efficiency of 80 percent to estimate the total applied irrigation water needed to satisfy the crop demand (i.e., the volume of water applied in excess of the crop ET; see discussion on irrigation efficiency in **Section 4.2.3** above). This correction increased the total crop demand value by 20%, resulting in an applied water demand of 120% of the analytically-derived crop ET.

Precipitation was used to first satisfy the applied water demand if rainfall occurred in sufficient amounts during the irrigation season. For the purposes of the water budget, precipitation that satisfied a portion of the applied water demand is referred to as effective precipitation. It was recognized that daily precipitation and evaporation needed to be considered to make sure that the precipitation event was sufficient to be effective. A separate evaluation of precipitation and evaporation over the Study Period determined that about 20 percent of the monthly precipitation occurred in small rainfall events that would not likely contribute to crop demand. Therefore, 80 percent of the monthly precipitation data was compared to each month of the crop applied water demand.

Surface water used for agricultural irrigation was then subtracted from the remaining applied water demand. In addition to precipitation, surface water sources used to offset the total applied water in the KRGSA Plan Area include Kern River water, imported water, and recycled water (from the City, LPUD, dairies, and others). Almost all Kern River water and imported water (SWP water) delivered for agricultural irrigation was used in KDWD. Wastewater/recycled water was available for irrigation both inside and outside KDWD.

Dairy wastewater is an additional source of water reused for agricultural irrigation in the KRGSA Plan Area. For the checkbook water budget calculation, the pumping and irrigation application by dairies was included in the agricultural private pumping calculation so that all of the METRIC calculations could be conducted collectively. A separate estimation of consumptive use by dairies was calculated and included in the outflow component for private industrial pumping. This consumptive use calculation is explained in **Section 4.3.3**.

With the subtraction of surface water deliveries, all remaining monthly applied water demands were assumed to be satisfied through groundwater pumping for agricultural irrigation. KDWD pumping for in-district use was tabulated separately and included in the groundwater banking recovery pumping (**Section 4.3.4**). After adjusting applied water for surface water deliveries and KDWD pumping, the remaining applied water demand is assumed to be satisfied by private agricultural pumping. Although estimated separately, KDWD pumping was a relatively small amount and is combined with the private agricultural pumping to total 175,668 AFY on an average annual basis.

4.3.2 Municipal Groundwater Pumping

For the purposes of the checkbook water budget, this outflow category includes pumping for Metropolitan Bakersfield by Cal Water and the City, along with five relatively large purveyors in the Plan Area including ENCSD, NORMWD/OMWC, Vaughn Water Company, Greenfield CWD, and Lamont PUD. Service areas for these purveyors within the KRGSA Plan Area[21] are shown on **Figure 2-4**. For these systems, metered pumping records were provided from each purveyor for at least a portion of the historical and current study periods. Collectively, this municipal groundwater pumping totals 109,966 AFY on an average annual basis (**Table 4-2**).

Pumping at smaller water systems throughout the KRGSA Plan Area was estimated based on either pumping records (for systems in ID4 service area) or population. Data for these smaller water systems are excluded from municipal pumping and tabulated separately as discussed in **Section 4.3.3**. The arbitrary division between pumping by municipalities and pumping by smaller public or private water systems was based more on the type of available data rather than a strict definition of municipal or non-municipal pumping.

In addition to groundwater, municipal water supplies also include local surface water and imported water sources. Data presented herein refers only to groundwater pumping and does not include all of the urban demand in the KRGSA Plan Area.

4.3.2.1 California Water Service Company (Cal Water)

Cal Water is the largest municipal water supplier in Bakersfield. Their system serves a large portion of the City and segments of unincorporated lands adjacent to the City encompassing about 49 square miles and a population of about 225,000 (see **Figure 2-4**). Groundwater has historically supplied up to 80 percent of the Cal Water demands with about 20 percent supplied by Kern River and imported SWP water. In 2011, Cal Water operated about 115 active wells with a design capacity of 142,000 AFY.

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[21] Some purveyors overlap only portions of the KRGSA Plan Area with service areas both inside and outside of the KRGSA (see **Figure 2-4**). Only pumping from wells inside the KRGSA Plan Area are included in this groundwater budget.

Cal Water provided monthly production by well for 2000 through 2016 in electronic format. Data from 1994 through 1999 were provided as handwritten monthly well production sheets, which were hand-entered into the KRGSA database. During the historical Study Period, Cal Water pumped 57,588 AFY on an annual average basis.

4.3.2.2 City of Bakersfield Water System (City Water System)

The City's Water System service area covers about 35 percent of western Bakersfield (about 38 square miles) and provides water to a population of about 118,600 (**Figure 2-4**). Similar to Cal Water, the City relies on a variety of water sources including groundwater, Kern River water, and imported SWP water. By an agreement with the City, Cal Water operates the City's domestic water system, including approximately 50 active groundwater wells and local surface water treatment plants. Metered monthly production data were provided by well from 1994 through 2016 to support this water budget analysis.

City wells located within the COB 2800 Recharge Facility are referred to as the Olcese wells and can be pumped by the City for municipal supply and/or recovery of banked groundwater. These wells are also available for pumping by KCWA for banking recovery. For this water budget, production from Olcese Wells No. 1 and 2 is included in the City totals as municipal pumping. In order to prevent double counting of shared facilities and provide a more accurate use of production wells, a separate water budget pumping category has been designated specifically for recovery of banked groundwater. This recovery pumping category, described in **Section 4.3.4**, includes production from the Olcese Wells No. 3 through No. 8, which are typically pumped for groundwater recovery. Recovery pumping also includes pumping of any Olcese wells by KCWA.

Over the historical Study Period, municipal pumping from City wells averaged 34,085 AFY (including production from Olcese No. 1 and No. 2 wells as discussed above).

4.3.2.3 East Niles Community Services District (ENCSD)

ENCSD is a member agency of the KRGSA covering about 6,202 acres in the northeastern Plan Area and serving a population of about 35,364 (see **Figures 1-2** and **2-4**). (MKN, 2016). The District provided monthly pumping data for its seven groundwater wells from 2000 through 2017. Pumping from 1995 to 1999 was estimated based on an approximate 4 percent decrease in 2000 monthly pumping. Over the historical Study Period, ENCSD has pumped about 4,081 AFY on an average annual basis.

4.3.2.4 North of the River Municipal Water District (NORMWD) / Oildale Mutual Water Company (OMWC)

NORMWD and OMWC are located on the north-central boundary of the KRGSA Plan Area. The two entities previously operated separately but they merged operations in 2013. Collectively, they serve a population of about 32,000 from about 14 wells with a combined service area located both inside and outside KRGSA. Both entities rely on both groundwater and imported SWP water from ID4. Production in the KRGSA Plan Area is reported to ID4 on a semi-annual basis. These amounts were distributed evenly on a monthly basis for the purposes of the water budget. Combined production for NORMWD and OMWC of about 1,000 AFY has been estimated on an average annual basis for the KRGSA Plan Area.

4.3.2.5 Vaughn Water Company (Vaughn WC)

Vaugh Water Company covers about 17,280 acres located both inside and outside of the KRGSA Plan Area. Vaugh WC is reliant solely on groundwater and participates in local recharge projects through property taxes and pumping fees to ID4 (Dee Jaspar, 2016c). Vaughn WC provided monthly pumping data by well from 1995 through 2017. Only wells located in the KRGSA Plan Area (about 10 wells) were used for this water budget category. The annual average pumping for these wells during the historical Study Period was about 6,721 AFY.

4.3.2.6 Greenfield County Water District (Greenfield CWD)

Greenfield CWD supplies groundwater to a population of about 8,500 from five wells. In support of the GSP, Greenfield CWD provided monthly pumping data for 2005 through 2011 and 2015 through 2017. Annual pumping totals were provided for 2003 and 2004. Annual water use data were available for 1998 through 2001 in annual Water Supply Reports prepared by KCWA (KCWA 2002; 2003; 2005; 2008). Available data were used to develop estimates for the incomplete data sets. For 1995 through 1997, pumping was estimated based on observed pumping increases over time. Annual pumping in 2002 was estimated to be the mid-point between 2001 and 2003 data; pumping for 2012-2014 was estimated by averaging the monthly data for 2011 and 2015. Monthly pumping averages from 2005 through 2010 were used to distribute the annual 1995 through 2004 pumping on a monthly basis. Based on this analysis, the average annual pumping total for Greenfield CWD during the historical Study Period was about 1,810 AFY.

4.3.2.7 Lamont Public Utilities District (Lamont PUD)

Lamont PUD is located along the east-central KRGSA Plan Area boundary and provides water and sewer services to the communities of Lamont and Weedpatch. Its service area consists of about 2,000 acres, most of which (about two-thirds) is included inside KRGSA Plan Area. The district relies solely on groundwater for its water supply and operates about nine wells within the KRGSA Plan Area. Lamont PUD provided monthly pumping data by well from 2000 through 2017 in support of this GSP. Monthly pumping data from 2001 were extrapolated to fill in missing data for 1995 to 1999. Based on the information provided, the average annual pumping for Lamont PUD during the historical Study Period was about 4,804 AFY in the KRGSA Plan Area.

4.3.3 Small Water Systems and Additional Private Groundwater Pumping

Additional pumping occurs in the KRGSA Plan Area that is not accounted for in other water budget pumping components discussed above. This pumping is associated with the smaller Community Water Systems and mutual water companies, and private wells used for industrial or domestic purposes. As indicated in **Table 4-2**, this additional groundwater pumping is estimated at 9,038 AFY on an average annual basis. Estimates have been developed separately in the northern (7,558 AFY) and southern KRGSA Plan Area (1,480 AFY) based on data types and availability, as summarized below.

4.3.3.1 Additional Pumping in the Northern KRGSA Plan Area

Groundwater pumping in the ID4 Service Area is reported to ID4 and compiled on semi-annual basis. As shown on **Figure 2-4**, ID4 covers most of the northern Plan Area and provides the best available data for pumping by public water systems, mutual water companies, and private well owners for agricultural, industrial, and domestic supply. Metered pumping data for the larger purveyors in the ID4 service area were obtained from each agency and tabulated separately including the City of Bakersfield, Cal Water, ENCSD, NORMWD/OMWC, and Vaughn WC (**Section 4.3.2** above). Remaining pumping data as reported to ID4 were reviewed, divided into monthly data, and incorporated into the water budget. Due to the large number of well owners and the relatively small amount of pumping per party, data are combined and categorized collectively in this water budget as small water systems and private industrial and domestic pumping for the northern KRGSA Plan Area.

4.3.3.2 Additional Pumping in Southern KRGSA Plan Area

As shown on **Figure 2-24**, there are about 26 small water systems in the southern KRGSA Plan Area and also multiple systems along the eastern boundary. These systems are outside the area where pumping is reported to ID4 (as described above), and production data are generally unavailable. However, the data reported to ID4 provided a methodology for estimating this unreported pumping in the southern KRGSA Plan Area.

Water use totals reported to ID4 for the northern small water systems were divided by reported population for each system's service area to estimate a water demand per capita for small water systems in the KRGSA. This estimate, 0.2442 AFY per capita, was applied to the populations associated with the 26 water systems within the KDWD service area as obtained from the SWRCB. Greenfield CWD and Lamont PUD were excluded from this analysis because these water systems provided more accurate metered pumping data by well to support the water budget (see Section 4.3.2.4 above).

4.3.3.3 Dairies Consumptive Use

About 25 dairies are located in the southern KRGSA Plan Area (in KDWD service area), all of which are assumed to rely on groundwater for water supply. Known historical dairies are included in the confined animal category shown on **Figure 2-7**; more accurate locations of dairies in the KRGSA Plan Area were provided by KDWD and are shown on **Figure 2-9**. These dairies are regulated by the Central Valley RWQCB and have developed water management plans that provide for re-use and recharge of dairy wastewater. In the Plan Area, re-use typically includes irrigation of nearby agricultural fields. Pumping estimates for agricultural irrigation and irrigation return flows are already accounted for in the water budget based on METRIC ET data and estimated pumping of irrigated lands. However, there is some additional consumption of groundwater associated with dairy water management, primarily associated with watering and cooling the cows, evaporation, and subsequent export of water in the milk products.

To estimate this consumptive use, local dairy practices and published information were reviewed. A 2013 study in the western U.S. conducted by researchers at the University of Arizona and Kansas State University provided a scientific analysis of dairy water budgets (Harner, et al., 2013). Although it is recognized that there is a wide variety of information on how much water is used per dairy cow and that each dairy may be different in how water is applied and managed, the 2013 study provides recent data developed in a western U.S. study for use on an average basis. That study suggests that approximately 71 gallons/day/cow (0.08 AFY) is needed for drinking, cooling, and milking the herd. Herd size was compiled for the 25 dairies in the KRGSA Plan Area to assess the amount of groundwater that is likely required; for the KRGSA dairies, herd size averaged about 2,800 cows. Because most of this water is re-used and included in other water budget components (i.e., re-use for irrigation described above), consumptive use was estimated. Using reasonable assumptions for the amount of water in milk products to be sold, a consumptive use of about 10.2 percent of the total groundwater pumped is estimated. This calculation resulted in a combined total of 581.65 AFY for all 25 dairies in the Plan Area (average about 23 AFY/dairy); this consumptive use is included in the Smaller Water Systems and Additional Private Pumping outflow component.

4.3.3.4 Ski Lakes

The southeastern KRGSA Plan Area contains man-made lakes, constructed as a private recreational water skiing resort. The general location of the largest lake area is shown by the Ski West Village Water System on **Figure 2-4**. A more detailed view of the constructed lakes is shown on the aerial photograph on **Figure 3-48c** (with a location map provided on **Figure 3-45**). The lakes extend up to about one-half mile long, 300 feet wide, and 5 feet deep. The water surface of the combined lakes covers about 11.5 acres. Lakes are replenished with groundwater from a private well system for each lake.

Although domestic water use for the Ski West Village Water System is already incorporated into the water budget based on population, groundwater pumping to keep the lakes filled is not included. Leakage beneath the lakes is estimated to be minimal, given that they have been sited on clay soils and in the area where perched water has been observed. Therefore, the estimated evaporation from the lake surface is considered a reasonable estimate for the groundwater pumping to maintain the lakes.

Historical aerial imagery (Google Earth) dating back to at least 1992 indicates that approximately 9 to 12 lakes have been filled at any given time. CIMIS evapotranspiration data (Arvin-Edison Station) was collected and converted to evaporation from open water surfaces using a lake evaporation factor of 1.1 inches of evaporation for every inch of reference ET (University of California, Davis, 1982). Based on the surface area and monthly reference evaporation, the evaporative loss of the lakes (and therefore the groundwater replenishment) is calculated to range from 54 AFY to 68 AFY. Given the small amount of this pumping compared to other outflow components, the extra groundwater pumping associated with lake filling is combined with groundwater pumping estimates from the small water systems.

4.3.4 Groundwater Pumping for Banking Project Recovery

Managed aquifer recharge in the KRGSA as described in **Section 4.2**[22] above is recovered either from dedicated recovery wells or from production wells for municipal or agricultural supply. Most of the recovery occurs from the latter because most of the managed recharge in the KRGSA is conducted to benefit water levels and water supply wells. Recognizing that recovery pumping for water supply is already incorporated into the water supply pumping categories above, recovery pumping tabulated for this category involves only pumping of dedicated recovery wells. Monthly pumping data were provided for all recovery wells by each agency that owns and/or uses the wells. As shown on **Table 4-2**, recovery pumping has averaged about 27,199 AFY over the historical 20-year Study Period. Recovery pumping during the drought year of 2015 was about 100,727 AFY, more than three times the average (**Table 4-2**).

For the COB 2800 Recharge facility, the City, KCWA, and ID4 all share the City's facility recovery wells (also referred to as the Olcese wells). These wells function as both municipal wells and banking recovery wells. To avoid double counting, production from Olcese 1 and 2 is included in municipal pumping (**Section 4.3.2.2** above) and production from Olcese 3 through 8 is included in this water budget category, consistent with the primary use of each well.

ID4 operates 18 recovery wells, 7 of which are shared with RRBWSD for the Joint Use Groundwater Recovery Project. The remaining 11 wells are used to recover ID4 recharge/banking in the COB 2800 recharge facility, along the unlined portion of the CVC, and other in-district recharge conducted by ID4.

KCWA is active in the KRGSA, sharing recharge facilities and groundwater banking recovery wells with KRGSA member agencies through agreements. Because of the close proximity of multiple Kern Fan groundwater banking facilities (i.e., COB 2800, Berrenda Mesa, Pioneer Project), recharge and recovery for the same project may occur both inside and outside of the KRGSA. For example, fourteen wells are used to recover water recharged on behalf of Berrenda Mesa groundwater banking project for project participants (outside of the KRGSA). Of the 14 wells, only 9 are located inside KRGSA boundaries.

Because the first approximation of the water budget is to define inflows and outflows from the physical groundwater system, only recovery occurring within the KRGSA boundaries is included in this section. As discussed previously, the checkbook water budget is further modified in subsequent sections of this GSP to facilitate KRGSA planning for sustainable management using only its own water supplies.

In the southern KRGSA, KDWD recovers water for the Metropolitan and SBVMWD banking program from 18 district wells. KDWD pumping for in-district use is also included in this water budget category.

As mentioned previously, recovery pumping occurs primarily in dry years to supplement decreases in surface water supplies. Accordingly, the amount varies widely from year to year from 0 AFY to more

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[22] Although all inflow categories in Section 4.2 involve some management of groundwater recharge, the two primary categories applicable to this discussion include *Kern River Channel and Canal Operational Recharge* (**Section 4.2.1**) and *Additional Managed Recharge and Groundwater Banking Projects* (**Section 4.2.7**).

than 100,000 AFY. No recovery pumping occurred during 8 years of the 20-year historical Study Period. Further, more than one-third of all of the water recovered during the 20-year Study Period (about 189,000 AF) was produced during the last 2 years (2013 – 2014) of the period, commensurate with the recent drought. The drought continued through WY 2015 with recovery pumping totaling about 100,727 AFY, the second highest annual total in more than 20 years of KRGSA banking (**Table 4-2**).

4.4 CHANGE IN GROUNDWATER IN STORAGE - CHECKBOOK METHOD

The inflows and outflows listed in **Tables 4-1** and **4-2**, respectively, and described above are used to estimate the change in groundwater in storage for the KRGSA Plan Area as summarized below:

Inflows – Outflows = Change in Groundwater in Storage

This simple equation provides a first approximation of the change in groundwater in storage over time based solely on recharge and extraction in the Plan Area. Because the checkbook method does not incorporate subsurface flows, it allows GSA managers to link surface supplies directly to demand. Subsurface flows are incorporated into the water budget in subsequent analyses.

4.4.1 Annual Inflows, Outflows, and Change in Groundwater in Storage – Checkbook Method

Monthly inflow (recharge) and outflow (pumping) data were compiled by water year to develop the change in groundwater in storage over the historical Study Period WY 1995 – WY 2014 and the current Study Period WY 2015. Annual inflows, outflows, and changes in groundwater in storage for the 20-year historical Study Period are presented in **Table 4-3** and displayed graphically on **Figure 4-1**. The two columns on the far right side of the table summarize the cumulative and average annual amounts for each component and the overall change in groundwater in storage.

As shown in **Table 4-3** and **Figure 4-1**, inflows and outflows vary significantly from year to year during the historical Study Period. Inflows range from 153,128 AFY in the critically dry year of 2014 to more than 550,000 AFY in the wet year of 2011. Outflows (pumping) are highest in 2014 when surface supplies are scarce, and groundwater is needed to fulfill more of that year's demand. Similarly, outflows (pumping) are smallest in 2011, when surface supplies were more plentiful (as evidenced by significant increases in recharge). Using the Kern River annual index as an indication of the changes in surface water supplies, the indices for 2011 and 2014 were 201 percent and 24 percent of the long-term average flow, respectively.

WY 2011 and WY 2014 also represent the largest gain (395,347 AFY) and loss (-328,106 AFY), respectively, of groundwater in storage (see bottom row in **Table 4-3**). Over the 20-year period, a cumulative net loss of approximately -39,570 AF is indicated. The average annual change in groundwater in storage is approximately -1,978 AFY on an average annual basis (**Table 4-3**). These data suggest a relatively small amount of overdraft for the groundwater system beneath the KRGSA Plan Area, representing less than one percent of the average annual inflows or outflows.

Table 4-3: Historical Groundwater Budget, KRGSA Plan Area

All values presented in acre-feet; Years are Water Years.

Groundwater Budget Component	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Cumulative	Average Annual
Inflows																					**Inflows**	
Kern Channel Recharge	87,965	96,671	85,684	85,199	77,064	79,546	25,899	48,425	84,473	77,891	140,139	101,716	32,858	17,210	19,536	81,921	155,341	58,570	24,465	14,999	1,395,572	69,779
Canal Operational Recharge	100,022	104,016	114,105	93,284	96,061	79,700	61,328	71,299	70,656	63,787	91,316	92,961	52,340	54,328	47,130	88,703	114,336	68,504	45,425	47,091	1,556,392	77,820
Municipal Return Flows	9,110	10,041	9,523	7,953	10,094	9,847	10,011	10,252	9,874	9,853	8,799	8,894	10,457	10,796	9,858	9,567	10,273	12,204	10,519	11,065	198,989	9,949
Applied Water Infiltration (Agriculture)	37,218	41,754	42,389	30,511	34,506	36,421	27,665	29,085	31,768	33,288	41,328	42,515	27,742	35,004	30,799	34,760	34,439	31,493	20,891	19,087	662,665	33,133
Agriculture Pumping Return Flows	32,183	37,420	30,278	24,668	28,672	30,085	38,669	43,501	33,954	48,197	33,376	17,936	52,932	42,445	39,169	15,756	7,190	32,098	50,950	43,766	683,245	34,162
Precipitation Percolation	4,309	3,913	4,780	6,999	4,931	4,147	4,186	3,428	3,689	3,810	4,425	5,691	3,070	3,353	3,649	6,182	5,681	2,532	2,462	3,630	84,866	4,243
Stormwater Conservation	34,083	21,975	21,574	50,138	22,510	16,958	19,466	11,840	20,135	15,185	31,073	22,610	10,670	7,526	16,590	23,714	34,551	16,556	10,469	8,094	415,718	20,786
Wastewater Percolation	3,578	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,470	3,600	3,600	3,600	3,600	8,506	7,528	5,726	3,632	82,841	4,142
GW Banking Recharge	162,607	124,060	87,624	141,045	49,511	48,200	10,260	8,125	7,621	20,623	169,255	115,334	31,387	2,032	3,058	31,264	187,670	92,135	23,994	1,764	1,317,570	65,879
TOTAL INFLOWS	**471,074**	**443,450**	**399,556**	**443,397**	**326,948**	**308,504**	**201,085**	**229,556**	**265,770**	**276,235**	**523,310**	**411,127**	**225,057**	**176,293**	**173,389**	**295,467**	**557,988**	**321,621**	**194,903**	**153,128**	**6,397,859**	**319,893**
Outflows																					**Outflows**	
Agricultural Pumping	(165,633)	(192,328)	(154,647)	(126,458)	(146,404)	(154,191)	(197,215)	(221,238)	(173,255)	(245,680)	(170,955)	(104,774)	(268,938)	(215,766)	(198,745)	(95,887)	(39,773)	(162,330)	(257,739)	(221,399)	(3,513,353)	(175,668)
Municipal Pumping	(94,400)	(109,169)	(107,031)	(91,572)	(108,133)	(105,563)	(110,093)	(114,274)	(110,698)	(111,213)	(104,060)	(106,528)	(117,330)	(120,460)	(109,263)	(104,628)	(115,232)	(130,838)	(109,043)	(119,794)	(2,199,321)	(109,966)
Small Water System/Private Pumping	(12,861)	(12,029)	(1,913)	(8,611)	(11,820)	(11,485)	(11,728)	(10,902)	(9,292)	(8,696)	(5,012)	(8,150)	(9,821)	(9,867)	(8,303)	(7,958)	(7,636)	(7,645)	(7,776)	(9,259)	(180,765)	(9,038)
Banking Recovery	-	-	-	-	-	-	(52,034)	(15,820)	(19,190)	(10,632)	(8,845)	-	(51,583)	(73,466)	(72,150)	(31,055)	-	(19,949)	(58,484)	(130,782)	(543,990)	(27,199)
TOTAL OUTFLOWS	**(272,894)**	**(313,526)**	**(263,591)**	**(226,640)**	**(266,356)**	**(271,238)**	**(371,069)**	**(362,233)**	**(312,435)**	**(376,221)**	**(288,872)**	**(219,452)**	**(447,673)**	**(419,559)**	**(388,461)**	**(239,528)**	**(162,641)**	**(320,762)**	**(433,042)**	**(481,234)**	**(6,437,429)**	**(321,871)**
Change in Groundwater in Storage																					**Totals**	
INFLOWS minus OUTFLOWS	**198,180**	**129,923**	**135,965**	**216,757**	**60,592**	**37,265**	**(169,984)**	**(132,678)**	**(46,665)**	**(99,985)**	**234,438**	**191,675**	**(222,616)**	**(243,266)**	**(215,072)**	**55,939**	**395,347**	**859**	**(238,139)**	**(328,106)**	**(39,570)**	**(1,978)**

A similar presentation of inflows, outflows, and change in groundwater in storage is provided in **Table 4-4** and **Figure 4-2** for the current Study Period, represented by WY 2015. The critically dry year of 2015 is associated with decreased recharge and relatively high levels of pumping, resulting in a negative change in groundwater in storage of -238,072 AFY. This loss of groundwater in storage over a one-year period is consistent with the lack of surface water supplies in a dry year and cannot be used solely as an indication of long-term overdraft conditions.

Table 4-4: Current Groundwater Budget, Checkbook Method, KRGSA Plan Area

Groundwater Budget Component	WY 2015 AFY
INFLOWS	
Kern Channel Recharge	8,447
Canal Operational Recharge	60,145
Municipal Return Flows	8,773
Applied Water Infiltration (Ag)	31,151
Agricultural Pumping Return Flows	26,207
Precipitation Percolation	4,434
Stormwater Conservation	17,827
Wastewater Percolation	4,600
GW Banking Recharge	1,520
Total Inflows	163,104
OUTFLOWS	
Agricultural Pumping (METRIC)	(196,859)
Municipal Pumping	(96,390)
Small Water System/Private Pumping	(7,201)
Banking Recovery	(100,727)
Total Outflows	(401,177)
Change in GW in Storage	
Inflows minus Outflows	(238,072)

The annual changes in groundwater in storage discussed above and summarized in **Tables 4-3** and **4-4** are shown graphically on **Figure 4-3** for the historical and current study periods. **Figure 4-3** more clearly illustrates the annual gains and losses of groundwater in storage through drought and wet cycles over the study periods.

Figure 4-3 also includes the cumulative change in groundwater in storage over time. The cumulative curve (in orange) illustrates the -39,570 AF cumulative decline by 2014 at the end of the historical Study Period (see also last row, right side of **Table 4-3**). The curve continues to decline in 2015 to -277,642 AFY as the -238,072 AFY change in groundwater in storage from the current Study Period (**Table 4-4**) is added to the cumulative value from the historical Study Period.

The overall trend of the cumulative curve compares reasonably well with the cumulative curve derived from the change in groundwater in storage analysis using water level contour maps as shown on **Figure 3-28** and discussed in **Section 3.3.3**. Although these represent two independent methods of analyzing the groundwater budget, both methods provide overall consistent results over the average hydrologic conditions of the historical Study Period. For example, the average annual change in groundwater in storage from the checkbook method is -1,978 AFY compared to -2,912 AFY from the water level contour map method as shown on **Figures 4-3** and **3-28**, respectively. The cumulative loss of groundwater in storage of -39,570 AF from the checkbook method also compares reasonably well with -55,325 as estimated from the water level contour map analysis.

The cumulative loss of groundwater in storage is due, in part, to the timing of the study periods, which begin during normal to wet periods and end in the drought of record. The average annual change in groundwater in storage of -1,978 AFY is a better indicator for evaluating overdraft and sustainability for average hydrologic conditions (**Figure 4-3**).

4.4.2 Adjustments for Groundwater Banking Obligations and Water Attributable to Others

The water budget analysis using the checkbook method described above incorporated all of the physical recharge (inflows) and pumping (outflows) for the Plan Area to account for all KRGSA groundwater-related activities and to better link aquifer response to ongoing management. This approach did not consider ownership of the water or management activities for and by others within the KRGSA Plan Area. For example, groundwater banking occurs within the Plan Area for ultimate export out of the Plan Area. Examples of these banking obligations include the Berrenda Mesa project, KDWD-Metropolitan banking project, and recharge operations along the Kern River channel, unlined canals, and in the COB 2800 recharge facility by KCWA and other parties outside of the KRGSA. This recharge also included operational loss along the Carrier and Calloway canals as others have conveyed water attributable to them across the KRGSA Plan Area.

KRGSA Plan Managers determined that the checkbook method required adjustment for water that had been recharged in the KRGSA Plan Area but was attributable to others. Accordingly, recharge by/for others was removed from the checkbook water budget along with any associated recovery pumping. Additionally, water banked outside of the KRGSA Plan Area for use within the Plan Area was added back to the checkbook budget. These adjustments facilitated improved accounting of KRGSA water supplies.

Adjustments for the groundwater banking obligations and water attributable to others are summarized in **Table 4-5**. Recharge for and by others has been removed from the Inflows; banking recovery pumping for and by others has been removed from the Outflows (**Table 4-5**). Banking balances outside of the KRGSA have been added to the checkbook.

Table 4-5: Historical and Current Checkbook Water Budget Adjusted for Banking Obligations and Water Attributable to Non-KRGSA Entities

All values presented in acre-feet; Years are Water Years.

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	1995 - 2014 Cummlative	Average Annual	2015
Inflows																					**Historical**		**Current**
Kern Channel Recharge	62,877	62,315	72,537	78,731	75,838	73,555	25,760	45,312	75,050	50,595	105,701	95,115	32,550	17,120	19,536	81,921	134,871	51,476	24,447	14,999	1,200,307	60,015	8,447
Canal Operational Recharge	72,644	80,334	105,264	75,595	65,756	71,209	59,853	66,285	69,849	62,798	68,057	67,391	52,334	54,770	47,645	69,549	72,167	62,414	45,383	46,751	1,316,048	57,683	37,782
Municipal Return Flows	9,110	10,041	9,523	7,953	10,094	9,847	10,011	10,252	9,874	9,853	8,799	8,894	10,457	10,796	9,858	9,567	10,273	12,204	10,519	11,065	198,989	8,737	8,773
Applied Water Infiltration (Ag)	37,218	41,754	42,389	30,511	34,506	36,421	27,665	29,085	31,768	33,288	41,328	42,515	27,742	35,004	30,799	34,760	34,439	31,493	20,891	19,087	662,665	36,151	31,151
Ag Pumping Return Flows	32,183	37,420	30,278	24,668	28,672	30,085	38,669	43,501	33,954	48,197	33,376	17,936	52,932	42,445	39,169	15,756	7,190	32,098	50,950	43,766	683,245	21,671	26,207
Precipitation Percolation	4,309	3,913	4,780	6,999	4,931	4,147	4,186	3,428	3,689	3,810	4,425	5,691	3,070	3,353	3,649	6,182	5,681	2,532	2,462	3,630	84,866	6,712	4,434
Stormwater Conservation	34,083	21,975	21,574	50,138	22,510	16,958	19,466	11,840	20,135	15,185	31,073	22,610	10,670	7,526	16,590	23,714	34,551	16,556	10,469	8,094	415,718	18,162	17,827
WW Percolation	3,578	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,470	3,600	3,600	3,600	3,600	8,506	7,528	5,726	3,632	82,841	5,213	4,600
GW Banking Recharge	97,667	89,897	62,595	79,404	25,048	12,722	7,721	6,645	8,606	9,280	43,454	34,943	3,102	2,077	3,058	31,264	127,987	68,043	18,244	1,764	733,522	4,420	1,520
Input Total	**353,669**	**351,249**	**352,538**	**357,599**	**270,954**	**258,544**	**196,932**	**219,949**	**256,525**	**236,607**	**339,812**	**298,565**	**196,458**	**176,690**	**173,904**	**276,313**	**435,666**	**284,345**	**189,093**	**152,788**	**5,378,201**	**268,910**	**140,741**
Outflows																							
Agricultural Pumping (METRIC)	(165,633)	(192,328)	(154,647)	(126,458)	(146,404)	(154,191)	(197,215)	(221,238)	(173,255)	(245,680)	(170,955)	(104,774)	(268,938)	(215,766)	(198,745)	(95,887)	(39,773)	(162,330)	(257,739)	(221,399)	(3,513,353)	(175,668)	(196,859)
Municipal Pumping	(94,400)	(109,169)	(107,031)	(91,572)	(108,133)	(105,563)	(110,093)	(114,274)	(110,698)	(111,213)	(104,060)	(106,528)	(117,330)	(120,460)	(109,263)	(104,628)	(115,232)	(130,838)	(109,043)	(119,794)	(2,199,321)	(109,966)	(96,390)
Small Water System/Private Pumping	(12,861)	(12,029)	(1,913)	(8,611)	(11,820)	(11,485)	(11,728)	(10,902)	(9,292)	(8,696)	(5,012)	(8,150)	(9,821)	(9,867)	(8,303)	(7,958)	(7,636)	(7,645)	(7,776)	(9,259)	(180,765)	(9,038)	(7,201)
Banking Recovery	-	-	-	-	-	-	(4,350)	(4,464)	(10,073)	(5,956)	(2,137)	-	(13,020)	(23,817)	(21,041)	(5,327)	-	(4,833)	(33,848)	(83,891)	(212,757)	(10,638)	(61,929)
TOTAL OUTFLOWS	**(272,894)**	**(313,526)**	**(263,591)**	**(226,640)**	**(266,356)**	**(271,238)**	**(323,385)**	**(350,877)**	**(303,318)**	**(371,545)**	**(282,164)**	**(219,452)**	**(409,110)**	**(369,910)**	**(337,352)**	**(213,800)**	**(162,641)**	**(305,646)**	**(408,406)**	**(434,343)**	**(6,106,196)**	**(305,310)**	**(362,379)**
Change in Groundwater in Storage																							
INFLOWS MINUS OUTFLOWS	80,775	37,723	88,947	130,959	4,597	(12,694)	(126,453)	(130,929)	(46,793)	(134,937)	57,648	79,114	(212,652)	(193,220)	(163,448)	62,513	273,025	(21,301)	(219,313)	(281,555)	(727,995)	(36,400)	(221,637)

Banking Adjustments*

	1995 - 2014 Cummlative	Average Annual	2015
Banking balances in KDWD for Others (Metropolitan, SBVWD):	-155,782		-123,806
Banking balances by KCWA for KDWD in KRGSA:	2,877		2,995
Banking balance by KCWA for ID4 in KRGSA:	37,662		29,288
Banking balances outside KRGSA for KDWD (Pioneer, KWB):	70,194		70,244
Banking balances outside KRGSA for ID4 (Pioneer, KWB):	189,981		172,146
TOTAL BANKING ADJUSTMENTS	144,932		150,867
Adjusted Change in Groundwater in Storage	-583,063	(29,153)	(70,770)

***1. Inflows and outflows above have been adjusted to remove recharge and recovery operations in KRGSA for and by others**

***2. Adjustments made in this section account for banking balances to be exported from (subtract) or imported to (add) the KRGSA Plan Area**

A comparison of the adjusted checkbook to the initial checkbook indicates a greater annual decline in groundwater in storage from -1,978 (**Table 4-3**) to -36,400 AFY (**Table 4-5**). The annual change for the 2015 Study Period indicates a slight gain of groundwater in storage from -238,072 AFY in **Table 4-4** to -221,637 AFY in **Table 4-5** because of the removal of recovery pumping delivered outside of the KRGSA.

Additional adjustments are made to the checkbook to incorporate other banking obligations as well as banking balances outside of the KRGSA attributable to KRGSA agencies. For KDWD, the banking balance owed to out-of-basin banking partners is subtracted from the cumulative change in storage for the historical Study Period and also for the current Study Period. By making these one-time adjustments using the then-current banking balance, the annual amounts dedicated to the KRGSA as "leave-behind" are already in the checkbook. The remaining banking adjustments are additive and account for water banked outside of the KRGSA for Plan Area use. For example, ID4 routinely banks excess SWP water in the Kern Water Bank or Pioneer Project (and other areas) for dry-year storage if needed at the Henry C. Garnett Treatment Plant. Banking balances for KRGSA agencies were provided by KCWA.

The results of the adjusted checkbook water budget indicate a deficit of about -29,153 AFY on an average annual basis for the KRGSA Plan Area and a deficit of about -70,770 AFY for the current WY 2015 (**Table 4-5**).

4.5 C2VSIMFG-KERN MODEL WATER BUDGET ANALYSIS

The primary goal of the C2VSim-Kern local model is to analyze historical, current, and projected water budgets for the entire Kern County Subbasin. Development of the Subbasin model is described in more detail in **Attachment 1**. In brief, the water budget data in the DWR regional C2VSim-FG model were revised with local water budget data provided by water and irrigation districts, municipalities, and GSAs in the Subbasin. To facilitate review of the revised input data in the model, the modeling team produced numerous local water budgets for distinct zones within the Subbasin, typically on a District- or GSA-basis, using the Z-Budget tool in the model (described in **Attachment 1**).

As part of this data-checking process, two separate zone budgets were developed for the KRGSA Plan Area, including the southern Plan Area generally aligning with the KDWD boundaries and the northern KRGSA Plan Area approximately aligned with the City/ID4 outer boundaries. These two zone budgets do not align perfectly with the KRGSA Plan Area boundaries due to model cell configuration and some simplifying assumptions required for analyzing urban demand in the Subbasin-wide model. However, overall area differences are relatively small and do not adversely impact the analysis. Model water budget areas are overlain on the KRGSA boundaries on **Figure 4-4a** and **4-4b**.

4.5.1 Application of the C2VSimFG-Kern Model to the KRGSA Plan Area

In general, input data for the C2VSimFG-Kern Model were revised for the KRGSA Plan Area based on the historical and current inflows and outflows described above in **Sections 4.3** and **4.4**, respectively. Because the model simulates the physical groundwater system, data from the initial checkbook method (see **Section 4.4.1**) were used instead of the adjusted checkbook method (see **Section 4.4.2**). Specifically, all recharge in the Plan Area was included in the model, even the managed recharge that was conducted by or on behalf of non-KRGSA agencies. Any recovery pumping that occurred in the KRGSA Plan Area for or by others was also included in the model. The recovered water was either routed to other Subbasin areas by the model or removed from the model to account for export out of the Subbasin. By representing all flows associated with the physical groundwater system, the model develops results that are more directly comparable to changes in groundwater in storage estimated by both the checkbook and the water level contour map methods. Collectively, these three methods serve as independent checks for estimating changes in groundwater in storage for the KRGSA Plan Area.

Although the C2VSimFG-Kern numerical model was based on the inflows and outflows from the checkbook method, the model analysis differs significantly from the checkbook analysis. Some of the more significant differences are summarized below:

- The model estimates urban pumping by populations and per capita water use rather than the metered pumping by well used by the checkbook method. The per capita water use was modified within reasonable and documented ranges to better match metered pumping data, as needed.
- Urban pumping from adjacent areas (e.g., pumping in RRBWSD by Vaughn Water Company) was combined with municipal pumping in the northern KRGSA Plan Area to facilitate model setup for estimating urban demand throughout continuously developed urban lands.
- The Independent Demand Calculator (IDC) module of the model was used to conduct a soil moisture balance in the unsaturated zone, providing estimates of deep percolation of precipitation and applied water return flows based on current monthly surface water deliveries, soil properties, and antecedent soil moisture conditions. The checkbook method employed simplified assumptions for these estimates, using a percentage of rainfall for deep percolation and an average overall agricultural efficiency of 80 percent to estimate return flows (20 percent of applied water).
- The model calculated effective precipitation and agricultural pumping based on METRIC ET crop demand and the estimated mix of crop types by model cell. The checkbook method calculated the METRIC ET for the Plan Area independent of crop type and used an analytical approach for developing monthly estimates of effective precipitation and agricultural pumping.
- The model simulated the Kern River as an active stream with channel seepage calculated directly by the model independent of measurements at stream gages or weirs. Stream gage and weir data were used to check and adjust model seepage estimates, as needed.

These differences highlight many of the model features being used to simulate various water budget components directly rather than “hard-wiring” the model with historical measured data (metered pumping, for example). By allowing the model to generate these components independently, the C2VSimFG-Kern model is preserved as a planning and management tool capable of predicting water budget components for future simulations.

Finally, as mentioned previously, the model water budget areas for the KRGSA Plan Area are based on boundaries of model cells, which do not precisely align with the Plan Area boundaries (**Figure 4-4**). Accordingly, the water budgets either include areas outside of the Plan Area or omit some areas within the Plan Area; these small differences in area prevent a direct comparison of some model water budget metrics to similar metrics in the checkbook. Notwithstanding these limitations, the model serves to corroborate the changes of groundwater in storage from the other methods and links aquifer response to historical and current groundwater management activities in the Plan Area.

4.5.2 Model Results for the KRGSA Plan Area

The results of the groundwater budget from the C2VSimFG-Kern model are presented for the northern and southern portions of the KRGSA Plan Area in **Tables 4-6** and **4-7**, respectively. Each table provides a summary of the groundwater budget for both historical (WY 1995 – WY 2014) and current (WY 2015) study periods. Results for the historical Study Period are also presented graphically on **Figure 4-5a**. and **4-5b.** for the northern and southern KRGSA Plan Area, respectively.

Although model input files are based on detailed checkbook data, the model output is organized a bit differently. Annual inflows (positive numbers) and outflows (negative numbers) are presented in **Tables 4-6** and **4-7** below and illustrated on **Figure 4-5**. Inflows associated with the deep percolation of precipitation and applied water (including surface water infiltration and pumping return flows) are combined in the second column of each table (orange on **Figure 4-5**). Inflows associated with managed recharge and operational recharge in unlined canals are combined in column 3 of each table (purple on **Figure 4-5**). Recharge in the river channel is presented separately in column 4 because the model calculates this separately based on river flows (light blue on **Figure 4-5**). Groundwater pumping, presented in column 5 of each table (dark blue on **Figure 4-5**), represents the largest outflow and combines data from all pumpers including municipal, industrial, agricultural, small water systems, and domestic/other private pumping occurring in the northern (**Tables 4-6**) and southern Plan Area (**Table 4-7**).

Subsurface inflows (positive numbers) and outflows (negative numbers) are shown in column 6 of each table and represent the net subsurface flow for each water year. Net annual subsurface flows are shown in yellow on **Figure 4-5** and vary from net inflows to net outflows based on then current water level conditions. Subsurface flows from the model (unavailable for the checkbook) account for the dynamic conditions around the complex KRGSA Plan Area boundary over time. Some subsurface flow originates from the adjacent bedrock of the Sierra Nevada foothills along the Plan Area perimeter where the model water budget area abuts the Subbasin boundary in the northeast (see **Figure 4-4a**). These basin inflows are presented in column 7 on **Table 4-6** and shown by the thin red bar as an inflow in **Figure 4-5a**. This inflow does not occur in the southern KRGSA Plan Area as indicated by the 0s in column 7 of **Table 4-7**.

Table 4-6: Historical and Current Groundwater Budget from C2VSimFG-Kern Model Northern KRGSA Plan Area

(1) Water Year	(2) Deep Percolation (precipitation, applied water return flows)	(3) Managed Recharge and Canal Operational Recharge	(4) River Channel Recharge	(5) Groundwater Pumping	(6) Net Subsurface Flows	(7) Basin Inflow	(8) Change in Groundwater in Storage
Units	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft	Acre-ft
HISTORICAL STUDY PERIOD WY 1995 - WY 2014							
1995	88,051	183,107	86,672	-142,689	-14,016	195	201,321
1996	79,906	125,137	12,391	-153,176	27,440	196	91,895
1997	68,113	88,080	45,404	-156,476	16,739	195	62,056
1998	97,059	168,050	15,365	-147,154	18,338	197	151,855
1999	65,509	74,945	9,912	-145,513	24,019	199	29,071
2000	38,448	61,711	46,793	-149,991	-7,631	198	-10,473
2001	32,278	28,643	33,692	-205,909	-23,853	198	-134,951
2002	27,912	21,836	39,828	-174,248	-13,502	197	-97,977
2003	32,736	25,492	68,331	-166,873	-3,701	196	-43,818
2004	31,274	31,306	49,961	-182,544	-4,300	196	-74,107
2005	83,027	200,919	88,207	-136,920	-3,125	196	232,304
2006	90,903	164,011	4,609	-131,961	23,480	196	151,238
2007	39,119	50,394	2,106	-210,177	-26,580	195	-144,942
2008	27,293	14,443	30,553	-233,663	-41,981	194	-203,161
2009	25,136	25,980	34,340	-220,742	-24,198	194	-159,289
2010	38,965	62,484	76,765	-163,908	-10,278	193	4,220
2011	100,336	199,248	122,441	-134,712	28,486	195	315,994
2012	54,370	68,659	34,604	-169,938	-6,880	196	-18,990
2013	36,097	20,510	28,207	-189,200	-35,813	195	-140,005
2014	24,212	12,072	24,233	-237,293	-39,068	194	-215,651
Total	**1,080,744**	**1,627,029**	**854,413**	**-3,453,088**	**-116,424**	**3,914**	**-3,413**
Average	**54,037**	**81,351**	**42,721**	**-172,654**	**-5,821**	**196**	**-171**
CURRENT STUDY PERIOD WY 2015							
2015	**21,186**	**20,608**	**17,169**	**-221,748**	**-30,709**	**193**	**-193,301**

Finally, column 8 of **Tables 4-6** and **4-7** presents the annual change in groundwater in storage for the northern and southern Plan Area, respectively. The average annual inflows, outflows, and change in groundwater in storage for the historical Study Period are shown at the bottom of each table above the Current Study Period. An annual tabulation of inflows and outflows is presented on **Figure 4-5** for the northern (**Figure 4-5a**) and southern (**Figure 4-5b**) Plan Area.

As indicated in **Table 4-6** and shown on **Figure 4-5a**, the average annual change in groundwater in storage is about -171 AFY for the northern KRGSA Plan Area. This change is relatively small and, given the magnitude of the inflows and outflows, is within the margin of error of flow measurements. As indicated in **Table 4-7** and shown on **Figure 4-5b**, the average annual change in groundwater in storage is about 4,226 AFY for the southern Plan Area. When these estimates are combined, the C2VSimFG-Kern model indicates that the change in groundwater in storage for the entire KRGSA Plan Area is about 4,055 AFY on an average annual basis.

Table 4-7: Historical and Current Groundwater Budget from C2VSimFG-Kern Model Southern KRGSA Plan Area

(1) Water Year	(2) Deep Percolation (precipitation, applied water return flows)	(3) Managed Recharge and Canal Operational Recharge	(4) River Channel Recharge	(5) Groundwater Pumping	(6) Net Subsurface Flows	(7) Basin Inflow	(8) Change in Groundwater in Storage
Units	**Acre-ft**	**Acre-ft**	**Acre-ft**	**Acre-ft**	**Acre-ft**	**Acre-ft**	**Acre-ft**
HISTORICAL STUDY PERIOD WY 1995 - WY 2014							
1995	100,173	60,330	3,799	-90,415	-16,821	0	57,066
1996	106,571	65,704	0	-135,400	-5,466	0	31,409
1997	103,925	70,665	121	-132,462	2,607	0	44,856
1998	127,735	63,157	5,152	-104,747	15,968	0	107,266
1999	104,118	53,227	0	-150,039	28,278	0	35,584
2000	87,397	56,971	0	-165,322	28,622	0	7,668
2001	79,301	46,696	0	-188,998	34,251	0	-28,750
2002	58,867	47,836	0	-211,118	29,157	0	-75,257
2003	63,392	65,042	452	-144,702	17,429	0	1,612
2004	75,702	54,373	0	-201,175	15,866	0	-55,234
2005	103,497	68,705	3,717	-109,726	8,332	0	74,525
2006	96,209	57,588	513	-143,503	19,181	0	29,989
2007	65,234	41,606	0	-219,142	31,546	0	-80,755
2008	50,194	43,547	0	-194,060	23,030	0	-77,290
2009	47,026	36,554	0	-207,959	10,861	0	-113,518
2010	75,414	75,325	2,040	-116,260	-5,879	0	30,641
2011	208,665	142,454	5,170	-90,215	-24,486	0	241,588
2012	135,260	112,351	0	-103,737	-14,852	0	129,021
2013	114,803	52,249	0	-261,221	-2,382	0	-96,551
2014	36,592	39,505	0	-257,385	1,947	0	-179,341
Total	**1,840,075**	**1,253,886**	**20,964**	**-3,227,585**	**197,190**	**0**	**84,530**
Average	**92,004**	**62,694**	**1,048**	**-161,379**	**9,859**	**0**	**4,226**
CURRENT STUDY PERIOD WY 2015							
2015	**34,712**	**33,554**	**0**	**-253,654**	**-3,570**	**0**	**-188,958**

4.5.3 Historical and Current Subsurface Flows

The C2VSimFG-Kern model provides the best available estimates of subsurface groundwater flows into and out of the KRGSA Plan Area. The model accounts for monthly dynamic conditions governing subsurface inflows and outflows over the entire historical and current study periods. Because these data are not included in the checkbook method, details of the subsurface flows are presented here.

For the northern Plan Area, an average annual net subsurface outflow of -5,821 AFY is estimated by the model (Column 6, **Table 4-6**). A detailed examination of these subsurface flows on an average annual basis indicates a net inflow of groundwater from the east-northeast and a net outflow of groundwater to the north, west, and south (**Table 4-8**). The predominance of a net outflow of groundwater from the northern Plan Area is consistent with historical groundwater elevations along the Kern River, which are generally higher than surrounding areas, especially in downgradient areas to the north. The amount of groundwater outflow to the west is the net result of both inflows and outflows associated with recharge and recovery events at the large Kern Fan banking projects. The outflow of groundwater beneath the northern KRGSA Plan Area to the south (-5,073 AFY) serves as an inflow to the southern KRGSA Plan Area from the north (5,073AFY) (**Tables 4-8** and **4-9**).

Table 4-8: Net Subsurface Flows In/Out of Northern KRGSA Plan Area

Net Subsurface Flows	Average Annual Flow (AFY)	Adjacent Agency Areas
Inflow from East	12,660	AEWSD, Olcese WD, other eastern lands
Outflow to North	-10,413	NKWSD, Cawelo WD, other northern lands
Outflow to West	-2,995	RRBWSD, Pioneer, Kern Water Bank
Outflow to South	-5,073	Southern KRGSA Plan Area
Net Total Subsurface Flows:	-5,821	

Table 4-9: Net Subsurface Flows In/Out of Southern KRGSA Plan Area

Net Subsurface Flows	Average Annual Flow (AFY)	Adjacent Agency Areas
Inflow from North	5,073	Northern KRGSA Plan Area
Inflow from West	13,272	Kern Water Bank, Henry Miller WD, BVWSD-Maples, other western lands
Inflow from East	1,989	Arvin-Edison WSD
Outflow to South	-10,475	Wheeler Ridge-Maricopa WSD
Net Total Subsurface Flows:	9,859	

For the southern KRGSA Plan Area, the model indicates an overall net inflow of 9,859 AFY on an average annual basis. Subsurface inflows occur from the northern KRGSA Plan Area, the east, and also from the west where water levels are relatively high near the Kern Fan banking projects (**Table 4-9**). The model suggests a net outflow to the south, although perched water conditions are not well-simulated in this area; accordingly, the model may be overestimating flow through the clay deposits beneath the Kern lakebed.

Combining the northern and southern net subsurface flows, an average annual inflow of approximately 4,038 AFY is estimated for the KRGSA Plan Area. As with all subsurface flows discussed herein, the flows vary substantially on a monthly basis and are typically associated with both inflows and outflows over time. Net subsurface flows are expected to diverge from these estimates as water level conditions change in the Subbasin over time in response to GSP implementation by the KRGSA and other GSAs.

4.5.4 Estimated Sustainable Yield

The detailed water budget, developed using three independent methods of analysis, indicates that, in general, the KRGSA has experienced only relatively small changes in groundwater in storage on an average annual basis over the 20-year Study Period. **Table 4-10** presents a summary of these groundwater in storage changes.

Table 4-10: Method Comparison, Change in Groundwater in Storage, KRGSA Plan Area

Water Budget Method	Change in Groundwater in Storage (AFY)[1]	Comments
Checkbook	-1,978 AFY	Tabulates recharge and pumping for the physical groundwater system beneath the KRGSA (**Table 4-3**, **Figure 4-1**)
C2VSimFG-Kern Model	4,055 AFY	Simulated inflows and outflows including subsurface flows (**Tables 4-6** and **4-7**, **Figure 4-5**)
Groundwater Elevation Contour Maps	-2,912 AFY	Subtraction of spring groundwater elevation contour maps (**Figure 3-28**)
Adjusted Checkbook	-29,153 AFY	Removes recharge and pumping attributable to non-KRGSA parties. Adds banking outside of KRGSA attributable to KRGSA agencies (**Table 4-5**)

[1]Average Annual Change over Historical Study Period (WY 1995 – WY 2014) for the KRGSA Plan Area

Table 4-10 shows that the first three methods of analysis, while different in many aspects, provide similar average annual changes in groundwater in storage over a 20-year period, ranging between -2,912 AFY and 4,055 AFY. Given the magnitude of inflows and outflows, which average more than 300,000 AFY (**Tables 4-1** and **4-2**), the results for the first three methods are within about one percent of the estimated flows. Collectively, these results indicate that there has not been a significant and unreasonable reduction in groundwater in storage historically beneath the KRGSA. Any small deficits (indicated by negative numbers) for the first three methods could be readily eliminated with minor management actions, thereby establishing a sustainable water budget.

This sustainable water budget for the KRGSA physical groundwater system suggests that groundwater outflows could be sustained at historical averages without significant overdraft and thus represents an initial estimate of a sustainable yield for groundwater beneath the KRGSA Plan Area[23]. This is considered only an initial estimate, in part, because the SGMA definition of sustainable yield is broader than just a sustainable water budget. Specifically, SGMA defines sustainable yield as follows:

> "…the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result (§10721(w))."

As indicated above, the sustainable yield is linked directly to the analysis of undesirable results, which includes a comprehensive analysis of sustainability indicators other than the reduction of groundwater in storage. Undesirable results are analyzed in **Section 5** of this GSP. Accepting this qualification for the purposes of an initial estimate only, the average annual sustainable yield is approximately 321,871 AFY and assumes average annual groundwater inflows of about 319,893 AFY as itemized on **Table 4-1**. The sustainable yield also assumes that the average annual surface water supplies available for the historical Study Period remain available to meet demands (presented in **Section 4.6**).

The adjusted checkbook method (row 4 on **Table 4-10**) indicates a more significant decline in groundwater in storage than the water budget analysis of the physical groundwater system provided above. As discussed in **Section 4.4.2**, a change in groundwater in storage of about -29,153 AFY is being considered by KRGSA Plan Managers for planning purposes (**Table 4-10**). As discussed previously, this method removes recharge and pumping attributable to others outside of the KRGSA (e.g., banking projects within the KRGSA such as Berrenda Mesa or banking by outside parties in the COB 2800 facility). Even though this decline may be offset, in part, by subsurface flows and/or maintenance of positive banking balances, the KRGSA Plan Managers have decided to address this deficit in the GSP for future sustainable groundwater management. Using these adjustments for the checkbook method, the sustainable yield of the KRGSA Plan Area would be reduced to about 290,740 AFY, assuming historical adjusted inflows presented in **Table 4-10**.

The initial sustainable yield estimates discussed above of about 290,000 AFY to 320,000 AFY are considered sufficiently accurate for planning purposes. However, this GSP recognizes that the actual sustainable yield of a groundwater basin is not a fixed number; rather, the sustainable yield will change based on changes in water supplies and demands for the future. Future projected demands are expected to increase while future projected supplies may be adversely impacted due to climate change and other factors. Therefore, the GSP is being developed to eliminate this and future projected deficits, as reasonable. The projected water budgets are described in more detail in the following sections.

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[23] It is recognized that a simple comparison of inflows and outflows may not equate to a sustainable yield if the inflows cannot be adequately captured (Bredehoft,2002). However, results of the change in storage analysis using the groundwater elevation contour maps and the numerical groundwater modeling both corroborate the checkbook method and support the use of this water budget analysis for planning purposes.

4.5.5 Native Safe Yield Estimates for the Kern County Subbasin

The Kern County Subbasin GSAs have been coordinating on a Subbasin-wide checkbook-type water budget analysis (Subbasin Checkbook) for planning purposes. Specifically, the Subbasin Checkbook has been developed to ensure that GSAs are not double-counting water supplies and to estimate a consistent range for a native safe yield in the Subbasin. Ranges of values were developed and selected primarily for application to non-managed lands in the Subbasin.

In developing estimates, the Subbasin GSAs considered results from the C2VSim-FG Kern model and other local information. Recognizing the uncertainty associated with spatial variation and other factors affecting the analysis, a range of numbers was developed and evaluated. After discussions with the Kern Subbasin Policy Committee, it was determined that a preliminary estimate of 0.15 AF/acre represented a reasonable approach for a native safe yield to be applied to currently-undeveloped Subbasin lands. For lands that are currently irrigated, an estimate of 0.2 AF/acre was selected for the amount of effective precipitation that would satisfy a portion of the crop ET. Therefore, for currently irrigated lands, the Subbasin-wide estimates indicate a safe yield of 0.35 AF/acre (0.15 AF/acre plus 0.2 AF/acre). This range of 0.15 AF/acre to 0.35 AF/acre will continue to be evaluated and revised, as needed.

4.6 SURFACE WATER SUPPLIES

KRGSA agencies have a long history of conjunctive use in the Plan Area. Local surface water sources (primarily the Kern River) and imported water sources (mostly SWP) are managed for direct use and groundwater recharge. These actions serve to decrease reliance on groundwater and to replenish it for times when surface water supplies are limited. In this manner surface water and groundwater are managed conjunctively to optimize water supply for beneficial uses in the KRGSA Plan Area.

Almost all surface supplies available to the KRGSA are managed by the City of Bakersfield, ID4, and KDWD. The surface water supplies used in the KRGSA Plan Area by these agencies over the historical and current study periods are shown graphically on **Figure 4-6**; average annual supplies from the historical Study Period are summarized in **Table 4-11**.

Table 4-11: Historical Average Annual Surface Water Use, KRGSA Plan Area, WY 1995 – 2014

Agency	Average Annual Surface Water Use WY 1995 – WY 2014	Sources
City of Bakersfield	59,770 AFY	Kern River
Improvement District No. 4	74,035 AFY	SWP, Kern River (right or exchange), CVP by exchange
Kern Delta Water District	192,517 AFY	Kern River (right or exchange), SWP, CVP
East Niles CSD	1,464 AFY	CVP from AEWSD; average deliveries 1996-2003
TOTAL	327,786 AFY	

Note: Does not include surface supplies banked outside KRGSA for future use in the KRGSA, which represents significant quantities that vary over time and can be extracted as a reserve supply, when needed.

During this period, additional surface water supplies were available for use but were not always optimized for a variety of reasons. Some water was available during wet years prior to the completion of current recharge facilities. During wet periods, some agencies within the KRGSA did not use their full SWP allocation because water levels were high and groundwater pumping was determined to be less expensive. For the City, a portion of its Kern River supplies was obligated to long-term contracts that have since expired. For KDWD, its Water Allocation Plan (WAP), which resulted in more effective use of its Kern River entitlement, had not yet been adopted. A primary goal of this GSP is optimize surface water supplies available to the KRGSA Plan Area to eliminate undesirable results and promote sustainable groundwater management for the future.

4.6.1 Current Surface Water Supplies

Descriptions of the various surface water supplies available to the KRGSA are summarized in **Section 2.4.5** for KRGSA Water Purveyors and are not repeated here. Surface water supplies to be optimized in this GSP are listed in **Table 4-12**. Average supplies are based on either current availability or actual historical availability over hydrologic conditions (WY 1995 – WY 2014), as applicable. Using guidance from DWR and data from the ID4 UWMP, available SWP supplies have been reduced from actual historical use to current availability. In addition, DWR has provided guidance for further reductions to SWP supplies for the purposes of Climate Change planning. These reductions are not included below but are incorporated as 2030 and 2070 Climate Change baselines in the projected future water budget analysis using the C2VSimFG-Kern local model and discussed in subsequent sections.

Table 4-12: Current Available Surface Water Supplies in the KRGSA Plan Area

Agency	Average Annual Surface Water Supplies	Description
City of Bakersfield	163,139 AFY[1]	Kern River entitlement (incl. KRC&I and South Fork)[1]
	29,171	Recycled water and stormwater conservation
Kern Delta Water District	201,943 AFY	Kern River entitlement[2]
	15,765 AFY	SWP, Table A SWP Allocation – Current Conditions[3]
	1,257 AFY	11% “leave behind” from Groundwater Banking Program
Improvement District No. 4	51,281 AFY	SWP Table A Allocation – Current Conditions[3]
	1,432 AFY	SWP Article 21 Allocation – Current Conditions[3]
	9,000 AFY	Kern River, Lower River Water Right (KCWA)[4]
		Additional miscellaneous surface supplies not quantified[5]
		Not all water budget components included in table[6]
TOTAL	437,780 AFY	

[1] Pre-1914 water rights, average annual conditions; see **Section 2.4.5.** Total amount includes current obligations to others both inside and outside of the KRGSA.

[2] Pre-1914 water rights; KDWD average annual entitlement adjusted for Court-imposed restrictions, Todd Engineers, 2011.

[3] Availability of SWP supplies based on Table A and Article 21 allocations and current DWR operations imposed on average hydrologic conditions; annual amounts provided directly from DWR.

[4] KCWA water rights on the Lower Kern River below 2nd Point; the first 40,000 AFY is provided to ID4, when available. The right only occurs in wet years when excess river water is available. Based on available amounts over the 20-year average hydrologic study period, an average annual 9,000 AFY is estimated for the ID4 Lower River right.

[5] KDWD has rights on the Lower River but water is available only in very wet years and in relatively small quantities; supply not quantified for purposes of this table. In addition, both the City and KDWD have used Kern River water released by other water rights holders. For example, the City has used an average of 20,000 AFY of released water over the historical Study Period. Because the use of this release water is uncertain for future river flows, it is acknowledged as an additional supply but not quantified for purposes of this table.

[6] Return flows from pumping, effective precipitation, and other water budget components are not included in **Table 4-12.**

As noted above, **Table 4-12** is not meant to be a full accounting of water budget components. Although groundwater contributes to surface supplies when extracted, the purpose of **Table 4-12** is to capture the primary surface water supplies available to use conjunctively with groundwater.

In addition, **Table 4-12** lists most but not all surface water supplies that have been available to the KRGSA from year to year. For example, the table does not include historical banking balances for water currently banked outside of the KRGSA for use by KRGSA agencies, even though significant amounts of banked water are available for recovery as needed and represent an important water supply. Previously banked water is viewed as a reserve source of water and, similar to surface water stored in Isabella Reservoir, provides a buffer for periods of limited supplies. Any excess water associated with the current supplies in **Table 4-12** will also be available for banking and recovery for future use. Finally, each of the KRGSA agencies listed above have coordinated the use of available supplies among Subbasin entities and obtained additional water through purchases, exchanges, or releases of supply to others.

4.6.2 Surface Water Storage in Lake Isabella

Isabella Dam and Reservoir were completed in 1953 to control the unregulated flows of the Kern River. Although built primarily for flood control, the reservoir facilitates delivery of regulated flows for water supply and also provides surface water storage. The reservoir was designed to hold 570,000 AF of water, but since 2006 the capacity has been operated at about 340,860 AF (about 60 percent of capacity) due to issues concerning seepage, earthquakes, and floods. The US Army Corps of Engineers (USACE) initiated the Isabella Dam Safety Modification project in 2012 to address these and other concerns. The project involves both design improvements to the existing dams and relocation of U.S. Forest service buildings in the excavation footprint. The ongoing project is expected to be completed in 2022 (USACE, 2012).

The reservoir has a minimum pool volume of 30,000 AF; the remaining storage capacity in the reservoir is reserved for downstream water rights holders to conserve water (Kern County, 2011) and is referred to as the conservation storage space. As explained previously, the USACE releases water from the dam as requested by the City on behalf of the Kern River Watermaster as long as the integrity of the dam is not jeopardized. Hydroelectric power generators have diversion rights that are also considered in the timing and amounts of releases from the dam.

KRGSA agencies have various rights associated with storing water in Lake Isabella. The City can use up to 34% of the total conservation storage space in the reservoir. KDWD is also allowed to store water within and as a part of the City's 34% conservation space with storage rights varying from month to month based on a rule curve (KDWD, 2015). KDWD can store a maximum of 44,000 AFY in Lake Isabella with a maximum carryover amount of 7,000 AFY (KDWD, 2015). The Kern County Water Agency also has the right to store water in Lake Isabella during years when Kern River flows are approximately 125% of the long-term average or greater. As mentioned previously, KCWA has Kern River rights for the Lower River and allocates a portion of this to ID4.

The ability to store water in Lake Isabella for subsequent use and the ability to carry-over storage to the following year are important water management tools for securing long-term sustainability in the KRGSA Plan Area. Primary sustainability benefits of conserving water in Lake Isabella are summarized below:

- Regulates the timing of surface water deliveries to better match demands by storing winter and spring runoff for use in the summer. This practice provides water managers with more flexibility to satisfy demands while also optimizing groundwater recharge.
- Allows Carry-Over of stored water from one year to the next, which can be especially valuable when the following year is dry. Reliance on the stored water in dry years allows groundwater pumping to be reduced when water levels are likely declining, while still meeting water demands.
- Optimizes capture and management of runoff for beneficial use when climate change results in less snowpack and earlier snow melt runoff.

4.7 PROJECTED WATER BUDGETS

Although the historical water budgets provide useful water budget deficits representing average hydrologic conditions, changes in projected water supplies are anticipated to impact future water budgets. To better understand potential future deficits, the C2VSimFG-Kern local model was modified to simulate baseline and GSP conditions over a 50-year Planning and Implementation horizon incorporating 50 years of hydrologic data in the Subbasin. Model set-up and baseline development is described in **Attachment 1** and summarized below with an emphasis on conditions in the KRGSA.

4.7.1 Baseline Development

The 50-year planning and implementation horizon begins in WY 2021 after GSP submittal and review and extends through WY 2070. This 50-year sequence was developed using actual hydrologic data and water management practices documented in the 20-year historical Study Period WY 1995 – WY 2014, which represents average hydrologic conditions. These years were re-combined/repeated into a 50-year sequence, which also represented average hydrologic conditions in terms of average precipitation and the long-term mean flow on the Kern River. In addition, the intervening years between the last year of water budget data (Current Condition Study Period of WY 2015) and the beginning of GSP implementation (2021) had to be "bridged" to represent WY 2016 through 2020.

The sequence of the 20 years from the historical Study Period was re-ordered slightly to prevent the sequence from ending in the drought of record and to equal 50 years of average hydrologic data. The model set-up of the 50-year sequence based on historical data is summarized in **Table 4-13**.

Table 4-13: C2VSimFG-Kern Model Set-Up for the Planning and Implementation Horizon

Planning and Implementation Horizon (Water Year)	Based on Historical Study Period (Water Year)
2021 - 2032	2003 - 2014
2033 - 2052	1995 - 2014
2053 - 2070	1995 - 2012

Using this sequencing, three separate 50-year baselines were developed as described below.

1. **Baseline Conditions**: represented by current land use and projected water supply and demand. For current land use, conditions from WY 2013 were selected. Land use for the more recent years of WY 2014 and 2015 contained abnormal conditions associated with the drought of record including agricultural land fallowing and mandatory conservation measures. As such, these recent years would likely under-estimate projected future demands. Increases in urban demand for the KRGSA were simulated using projections of population and per capita water use from local KRGSA UWMPs including the City of Bakersfield, Cal Water, NORMWD/OMWC, Vaughn WC, Lamont PUD, and ENCSD. Using data from the UWMPs and County population projections, an area-weighted average population growth rate of 1.17 percent annually through 2040 and a 0.8 percent increase for subsequent years was incorporated into the model. Using targets of per capita water use from the UWMPs, a weighted average of 248 gallons per capita per day (gpcd) was developed and applied over the entire Planning and Implementation horizon. Reductions in SWP availability provided by KCWA/DWR for ID4 and KDWD were incorporated into the analysis.

2. **2030 Climate Change Conditions**: represented by reductions in water supply and increases in water demand using DWR climate change factors and guidance. For the KRGSA, further reductions in SWP water availability provided by KCWA/DWR (2070 climate change tables) for ID4 and KDWD were incorporated. Increases in urban demand were estimated using the same methodology as applied in baseline conditions (see description above). Agricultural demand was increased by an average of about four percent based on decreases in effective precipitation and higher estimates of potential ET as provided by DWR. DWR climate change guidance also includes a change in the timing of Kern River flows, with more winter/early spring flows and less summer flows. However, the total volume of the Kern River does not change.

3. **2070 Climate Change Conditions:** represented by further reductions to the 2030 Climate Change conditions for water supply and additional increases in water demand using DWR climate change factors and guidance. For the KRGSA, reductions in SWP amounts for ID4 and

KDWD were incorporated from KCWA/DWR 2070 SWP availability data as summarized and distributed by KGA (Erlwine, 2019). Increases in urban demand were estimated using the same methodology as applied in baseline conditions. Increases in agricultural demand of approximately seven percent were based on DWR guidance for 2070 conditions of precipitation and potential ET.

4.7.2 Projected Water Budget Deficits

Based on the increases in demand and decreases in water supplies, additional water budget deficits are projected for future conditions. The primary changes to the checkbook water budget are summarized in **Table 4-14** for planning purposes. A more detailed assessment of projected water budgets has been developed for both the Subbasin and the KRGSA using the C2VSimFG-Kern local model. These Subbasin-wide analyses are described in **Attachment 1** and summarized for the KRGSA in **Section 4.7.3**.

Table 4-14: Comparison of Selected Historical and Projected Water Budget Components (Checkbook Method)

Water Budget Component	Historical Average Annual Amounts (AFY)	Baseline Conditions (AFY)	2030 Climate Change Conditions (AFY)	2070 Climate Change Conditions (AFY)
SWP[1] – ID4	74,035	52,758	51,182	48,759
SWP - KDWD	18,655	15,765	15,294	14,537
TOTAL SWP	92,690	68,523	66,476	63,296
Net decrease in SWP from historical:		**24,167**	**26,214**	**29,394**
Agriculture Demand	261,019	261,019	271,460	281,460
Urban Demand[2]	167,970	182,290	178,115	254,117
TOTAL DEMAND	428,989	443,309	449,575	535,577
Net increase in demand from historical:		**14,320**	**20,586**	**106,588**
Potential Future Water Budget Deficits:		-38,487	-46,800	-135,982

[1] *Table A Allocation and Article 21 water*

[2] *Baseline Conditions urban demand from WY 2013. Urban demand for 2030 based on area-weighted population growth (average 1.1% annually) and per capita water demand estimates from UWMPs (average 248 gpcd). Population growth rates for the County (0.8% annually) used for years 2040 through 2070.*

As shown in **Table 4-14**, SWP water availability is projected to decline under baseline and both climate change conditions. Agricultural demand increases under climate change conditions as a result of higher potential evaporation and lower precipitation (i.e., hotter and drier conditions). Urban demand is projected to increase based on an increase in population and changes in per capita water demand, as documented in the individual UWMPs of the primary water purveyors. A decline in urban demand from baseline to 2030 conditions is due to a decrease in per capita water demand for future conditions as indicated in the UWMPs. Collectively, these projected supplies indicate potential water budget deficits of -38,487 AFY (Baseline), -46,800 AFY (2030 Climate Change), and -135,982 AFY (2070 Climate Change).

The methodology used to develop the projected increases in demand is conservative in that current land use is unchanged. The increases in demand associated with **Table 4-14** are associated in part with climate change conditions, but urban demand in particular is controlled by population growth projections and per capita water use. If these projections actually occur, current undeveloped or agricultural land uses would likely be converted to urban use. Such a conversion of land use from agricultural to urban would decrease the total projected demand shown in **Table 4-14**. Urbanization of a portion of agricultural lands is included as a project in this GSP and represents an estimated demand reduction of about 27,000 AFY (see **Section 7.1.3**).

In addition, these water budget deficits for projected supplies/demands are considered with a previously-identified checkbook deficit. In particular, a deficit of about -29,153 AFY was estimated for an adjusted checkbook analysis that considered banking, recharge, and other activities in the KRGSA Plan Area that are attributable to others (see **Section 4.4.2** and **Table 4-5**). When this deficit is added to the 2030 and 2070 Climate Change deficits of -46,800 AFY and -135,982 AFY in **Table 4-14**, combined potential future water budget deficits of -75,953 AFY and -165,135 AFY, are indicated. Again, these deficit estimates are computed on a checkbook basis and do not account for subsurface flows or banking in the KRGSA conducted by others. Nonetheless, they represent maximum estimated future deficits for planning purposes only.

Kern River supply is not included in **Table 4-14** because it is not associated with a significant potential future deficit. Although there are projected changes in the monthly timing and flows for the Kern River under both 2030 and 2070 Climate Change conditions, the total average annual flows in the river are not expected to decline. Specifically, GEI consultants analyzed projected future changes in the monthly unregulated river flows at First Point to assist with setting up the climate change analysis in the C2VSimFG-Kern model. GEI used DWR monthly and annual runoff change factors for the contributing watersheds and re-calculated local runoff. These estimates predict a significant decrease in summer flows between April and September and a corresponding projected increase in flows from October through March. However, overall projected changes in the total annual flow volumes are less than one percent (99.6 percent for 2030 condition and 99.4 percent for 2070 conditions). Further, the change in timing of flows can be managed by KRGSA diverters for optimal Kern River use.

The potential decreases in supply and increases in demand in **Table 4-14** are used to develop appropriate projects and management actions that target a more sustainable water budget. Projects and management actions are described in **Section 7** of this GSP.

The potential deficits projected in **Table 4-14** for the 2030 Climate Change conditions occur only 10 years after GSP implementation in 2020 and are within the window for achieving sustainability. Accordingly, those conditions are the focus of the priority GSP projects. It is recognized that the 2070 Climate Change conditions are less certain, given the long-term 50-year implementation and planning horizon. As part of the GSP, future Annual Reports and five-year GSP evaluations will be used to update these potential projected deficits when much more detailed information from the KRGSA water budgets will be available. During those re-evaluations, the GSP will be adapted as needed to maintain sustainable groundwater management.

4.7.3 Projected Water Budget Results for the KRGSA Plan Area

Projected water budgets were analyzed based on the conditions described above for baseline, 2030 Climate Change, and 2070 Climate Change scenarios. Based on the checkbook estimate of water budget deficits described above, two water supply GSP projects and one demand reduction project were developed to erase those deficits. Those three projects – the KDWD Water Allocation Plan, the City Kern River Conjunctive Use Optimization, and Urbanization of Agricultural Lands – are described in more detail in **Sections 7.1.1**, **7.1.2**, and **7.1.3**, respectively.

4.7.3.1 Projected Water Budget Change in Groundwater in Storage

Model input files were developed for those projects and simulated with the C2VSimFG-Kern model for each of the three baseline/climate change scenarios. Model results demonstrate the ability for GSP projects to offset deficits and avoid future overdraft conditions. Model results were also used to demonstrate avoidance of undesirable results after GSP projects are implemented. In total, six model simulations were developed, as summarized in **Table 4-15**.

Table 4-15: Future Projected Water Budget Model Results

Water Budget Scenario	Change in Groundwater in Storage	Adjustments for Model Limitations		Adjusted Change in Groundwater in Storage
		Excess Kern River Outflow from Model	Banking Obligations for Export from Subbasin*	
AFY	**AFY**	**AFY**	**AFY**	**AFY**
Baseline	-10,852	0	-6,714	-17,566
Baseline with Projects	44,930	8,100	-6,714	46,316
2030 Climate Change	-13,962	3,589	-6,548	-16,921
2030 with Projects	42,658	14,858	-6,548	50,968
2070 Climate Change	-30,821	7,662	-6,217	-29,376
2070 with Projects	26,561	20,520	-6,217	40,864

** Only water banked for export from the Subbasin is included in this adjustment to preserve the overall Subbasin water budget simulated in the model. As explained in **Section 4.4.2**, additional banking obligations, as well as credits, are applicable for adjustments in the KRGSA using the checkbook method.*

Model results for the change in groundwater in storage are summarized for each of the six runs in the second column of **Table 4-15**. Model output listed in this column requires adjustments due to some limitations with the model. Specifically, the model does not simulate recharge conditions on the Kern

River accurately and indicates baseflow beneath the western banking projects where no baseflow occurs. Accordingly, more water recharges the groundwater system than is indicated by the model. This excess Kern River outflow requires manual adjustment of the portion of the river recharge that is lost from the model; those amounts are tabulated and summarized in the third column of **Table 4-15**.

An additional adjustment is made in the fourth column of **Table 4-15** involving a correction for the banking obligations in the KRGSA that are dedicated for subsequent export out of the Subbasin. Such obligations will add to water budget deficits when exported. This adjustment has to be made outside of the model to preserve the physical inflows and outflows to the groundwater system. By adjusting for only the banked water that will be exported from the Subbasin, the overall Subbasin water budget is preserved. (As indicated by the footnote below **Table 4-15**, this banking adjustment does not account for all of the banking complexities within the KRGSA; these are discussed in more detail later in this section).

The resulting adjusted change in groundwater in storage is provided in the last column of **Table 4-15**. Adjusted model results are shown graphically on **Figure 4-7** for the 70-year implementation and planning horizon. Changes of groundwater in storage are illustrated on a cumulative basis for the six model runs summarized on **Table 4-15**. Note that the units on **Figure 4-7** are in thousands of AF. Results in **Table 4-15** and **Figure 4-7** demonstrate the ability of the GSP projects to achieve sustainability within the KRGSA during the implementation period and to maintain sustainability throughout the planning horizon.

As shown in **Table 4-15**, the baseline/climate change deficits (i.e., -17,566 AFY, -16,921 AFY, and -29,376 AFY) are smaller than estimated previously in **Table 4-14**. This is due to the differences in a numerical model method (**Table 4-15**) versus a checkbook method (**Table 4-14**). First, subsurface flows occur dynamically in the groundwater model and are not included in the checkbook approach. Further, banking recharge conducted within the KRGSA by others is included in the model; this is appropriate because the model represents the physical groundwater system, yet this inclusion of banked water for others can add an average of -65,000 AFY to the checkbook deficits. By adjusting only for water to be exported, the Subbasin balance is preserved.

Notwithstanding these banking complications, GSP projects clearly provide sufficient increased water supply and decreased demand to eliminate both checkbook and adjusted model deficits and fully mitigate potential future overdraft. Volumes of water associated with GSP projects are documented in **Sections 7.1.1** and **7.1.2**.

4.7.3.2 Future Projected Model Hydrographs

Model results also indicate that GSP projects are sufficient to eliminate undesirable results during the implementation period and avoid them throughout the planning horizon. This was tested by the model using preliminary representative monitoring well locations as shown on **Figure 4-8**. Initial sustainable management criteria (including minimum thresholds and measurable objectives[24]) were selected for these wells (as described in **Section 5**). As described in more detail in **Attachment 1**, the model was set up to predict water level response to GSP projects at these wells and predict whether levels could be maintained above the selected minimum thresholds[25].

Eight model hydrographs were selected to illustrate how water levels are predicted to respond to GSP projects; four hydrographs were selected in the northern Plan Area and four in the southern Plan area as highlighted on **Figure 4-8**. Hydrographs from the northern and southern Plan Area are presented on **Figures 4-9** and **4-10**, respectively. Rather than showing all six model runs, hydrographs are simplified to include only the baseline and 2070 runs as end members of the analysis. This provides four color-coded lines on each graph with dark and light blue lines representing the Baseline and 2070 Climate Change scenarios, respectively; magenta and yellow lines represent the Baseline with Projects and the 2070 Climate Change with Projects, respectively. The initial minimum threshold is shown as a red line and labeled on each hydrograph; the measurable objective is shown in green.

Hydrographs from the northern Plan Area on **Figure 4-9** includes a northern well in agricultural areas (**Figure 4-9a**), two wells near the municipal wellfields of north-central Plan Area (**Figures 4-9b** and **4-9d**), and a well in the banking area (**Figure 4-9c**) (see locations on **Figure 4-8**). With the exception of the banking area hydrograph (**Figure 4-9c**), all hydrographs show the overall declining trend in the baseline/2070 climate change scenarios and an overall positive trend when the GSP projects are simulated. The banking area hydrograph doesn't illustrate these trends because of the banking operations whereby recharge occurs in wet years followed by pumping of an equal or lesser amount in dry years. Given this operation, local KRGSA banking projects do not contribute to overdraft. Although water levels fluctuate more significantly in response to these operations, model results indicate that water levels can be maintained above the minimum threshold to avoid undesirable results. Only in one of the urban wells (**Figure 4-9b**) are project-related water levels below the minimum threshold. In that well, the *2070 with Projects* scenario indicates water levels below the minimum threshold during drought years of 2047-2049 and 2052-2054. Given the uncertainty associated with the 2070 conditions and the ability to re-distribute urban pumping under project conditions (**Section 7.1.2**), this potential indication of undesirable results can be readily managed, as needed.

In the southern KRGSA Plan Area, four wells (**Figures 4-10a** through **4-10d**) also illustrate the declining trends of the projected baselines and the rising water levels associated with GSP projects. In this area, both baseline and project model runs remain above the minimum thresholds for all wells. This is likely due to lower projected deficits in this area compared to the increase in growth and urban demand in the northern Plan Area.

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[24] These thresholds are defined and discussed in detail in **Section 5**.

[25] Some minimum thresholds have been adjusted slightly since modeling was completed but adjustments are not sufficient to change the conclusions of the model results.

Collectively, these model scenarios indicate that the KRGSA projects described in **Section 7** are sufficient to address future water budget deficits and to meet GSP minimum thresholds as described in **Section 5**.

4.8 DATA AND KNOWLEDGE GAPS FOR THE WATER BUDGET ANALYSIS

As described above, surface water and groundwater components of the water budget analysis represent measured, estimated, and/or inferred amounts of water, each associated with an increasing level of uncertainty. Some uncertainty associated with missing or incomplete historical data cannot be addressed simply due to an absence of information; however, these missing data may not represent significant levels of "uncertainty" or a "data gap" as defined by SGMA. Both of these terms are defined in the regulations as representing significant unknowns that would affect the ability to assess whether a basin is being sustainably managed. For the water budget, the data gap analysis focuses on the larger water budget components that would likely affect the efficacy of Plan implementation or the ability to assess future sustainable management.

Surface water inflows represent mostly measured and well-documented values including Kern River flow, diversions, and deliveries, importation of SWP water, and wastewater deliveries. Groundwater banking amounts are also based on measured deliveries.

Municipal pumping, including several small water systems, is also measured via well meters. Although some estimates were required to fill incomplete historical data, these estimates are considered reasonable because they are based on other relatively accurate datasets such as population, water demands, and metered data covering similar time intervals. Pumping totals within the ID4 service area represent both metered and estimated data but are reported and recorded semi-annually by a public agency; accordingly, these data are considered reasonably accurate for the purposes of the water budget. The largest pumpers in ID4 have metered data, as do some smaller industrial pumpers and other water users. Most of the private and domestic pumping in the northern Plan Area is estimated, however, amounts are relatively small and would not significantly affect the water budget analysis.

Evaporative loss along the river is estimated based on measured reference evapotranspiration and observed vegetative conditions and considered sufficient for the water budget purposes. Estimates of stormwater conservation are based on previous studies and are regulated by the Central Valley Water Board through a stormwater permit. Estimates of municipal return flows are less certain, but the amounts are relatively small and based on established methods of estimation of indoor and outdoor water use for the region.

The most significant data gaps for the water budget analysis involve agricultural pumping and associated return flows. Private agricultural pumping is inferred based on estimated crop ET, surface water deliveries, and effective precipitation. Although the METRIC ET dataset provides a reasonable estimate for the cumulative agricultural pumping in the Plan Area, pumping details are unknown for any specific location across the large Agricultural MA. Private agricultural wells are located throughout the southern Plan Area (**Figure 2-14**), but there is no information on which wells are pumping when and how much.

Well completion reports are a source of general information on pumping depths within the Principal Aquifer but are difficult to match to each active agricultural identified by KDWD staff.

Because METRIC ET data are available for the historical study period, estimates are considered sufficient for the historical water budgets. However, future pumping will require either ongoing ET analysis or an alternative method to estimate pumping. In addition, the ability of rainfall to satisfy ET is also uncertain due to the difficulty of applying daily (or hourly) rainfall intensity and duration to then-current crop needs. This uncertainty in effective precipitation contributes to the uncertainty of how much water needs to be pumped to satisfy the total crop demand.

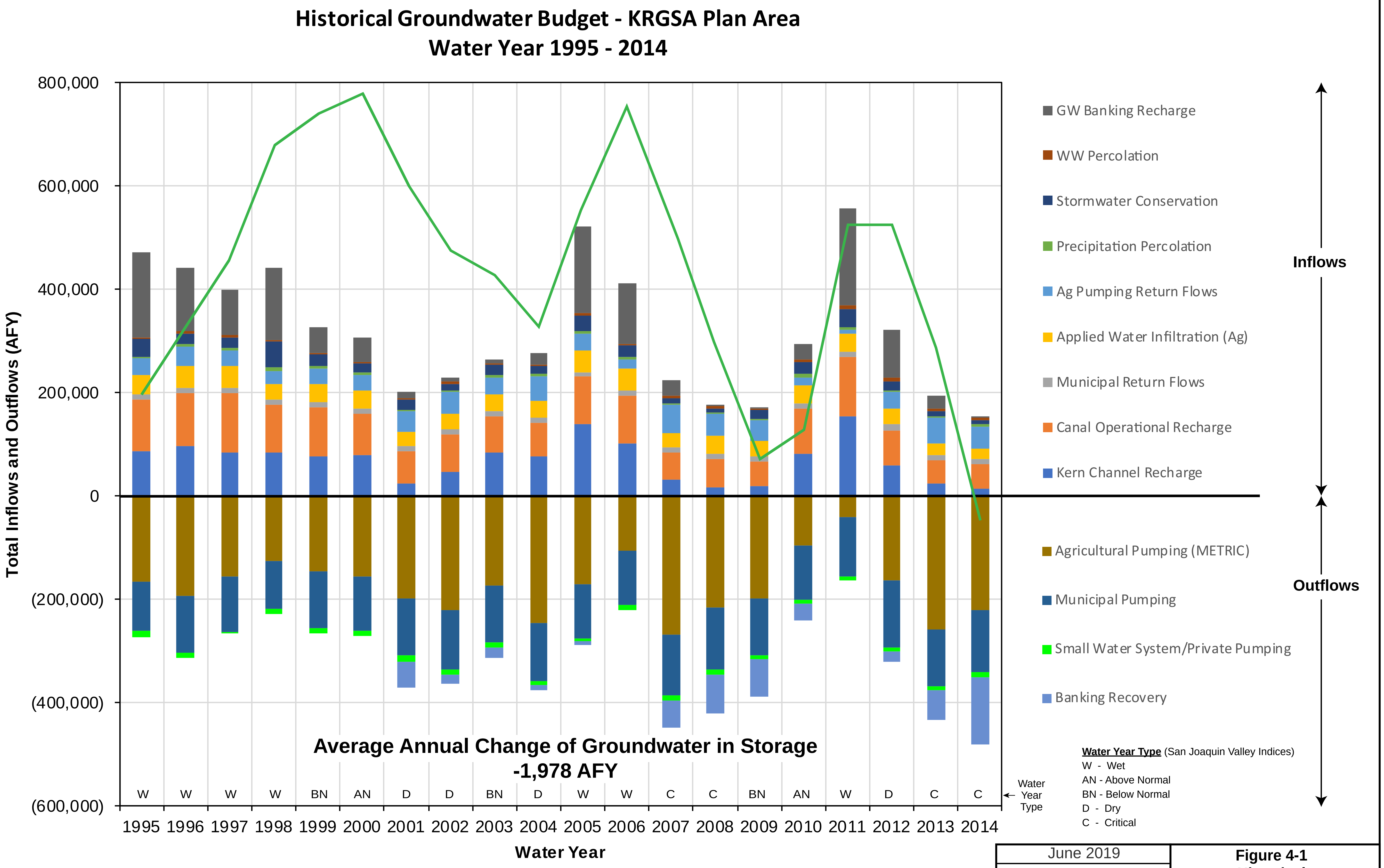
Even if ET and effective precipitation are better known, return flows associated with agricultural pumping are unknown and are qualitatively based on past KDWD analyses and general soil and irrigation assumptions. In the absence of actual values, an irrigation efficiency of 80 percent was applied evenly throughout the KRGSA Plan Area. However, the perched water conditions in the southern Plan Area clearly represent an area where return flows are expected to be much lower than in other parts of the KRGSA; any over-irrigation in these areas could be lost to evaporation. Even outside of the perched water zone, infiltration rates are expected to vary, and the amount of deep percolation is not well-quantified.

Finally, subsurface flows around the Plan Area perimeter are associated with significant uncertainty. Depending on Kern River flows, the activities at nearby Kern Fan banking projects, and other factors, these flows are highly dynamic and change seasonally and with wet/drought cycles. The C2VSimFG-Kern model is the best available tool for analysis of subsurface flows, but this component of the water budget will be more difficult to manage in the future. As GSP implementation projects occur at various times and rates in areas surrounding the KRGSA MAs, the ability to store and capture recharged water will depend on local hydraulic gradients, which are affected by water levels outside of the Plan Area and the resultant subsurface flows.

A summary of these data gaps, including the impact on groundwater management and potential management actions to address the issue are shown on **Table 4-16**.

Table 4-16: Data Gaps / Knowledge Gaps for the Water Budget Analysis

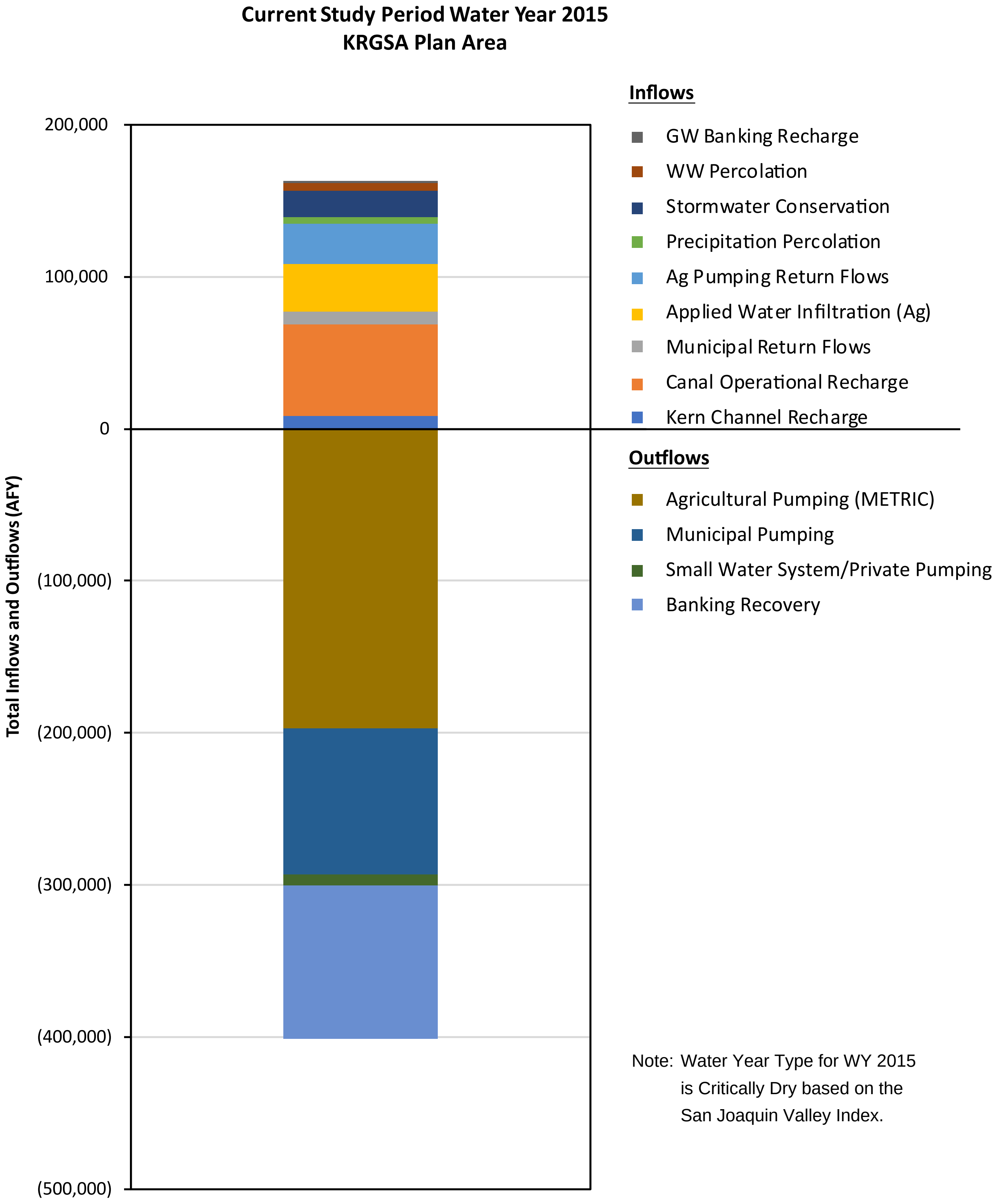
Issue	Area	Groundwater Management	Actions to Address
Agricultural Pumping	KRGSA Plan Area	Future pumping as crop ET changes over time.	Consider well metering. Consider use of METRIC or other ET estimating methods in future.
Agricultural Return Flows and Deep Percolation of Precipitation	KRGSA Plan Area	Affects the amount, timing, and location of groundwater recharge.	Consider well metering. Continue to monitor and analyze perched water conditions in the southern Plan Area. Document irrigation methods, as needed. Incorporate local infiltration rates into the water budget analysis.
Subsurface Flows	KRGSA Plan Area	Potential to affect the ability to meet Minimum Thresholds and understand water level changes.	Coordinate with adjacent MAs and GSAs to manage water levels across MA boundaries. Continue to document recharge/banking in the KRGSA by others.



June 2019

TODD GROUNDWATER

Figure 4-1
Historical
Groundwater Budget
Checkbook Method

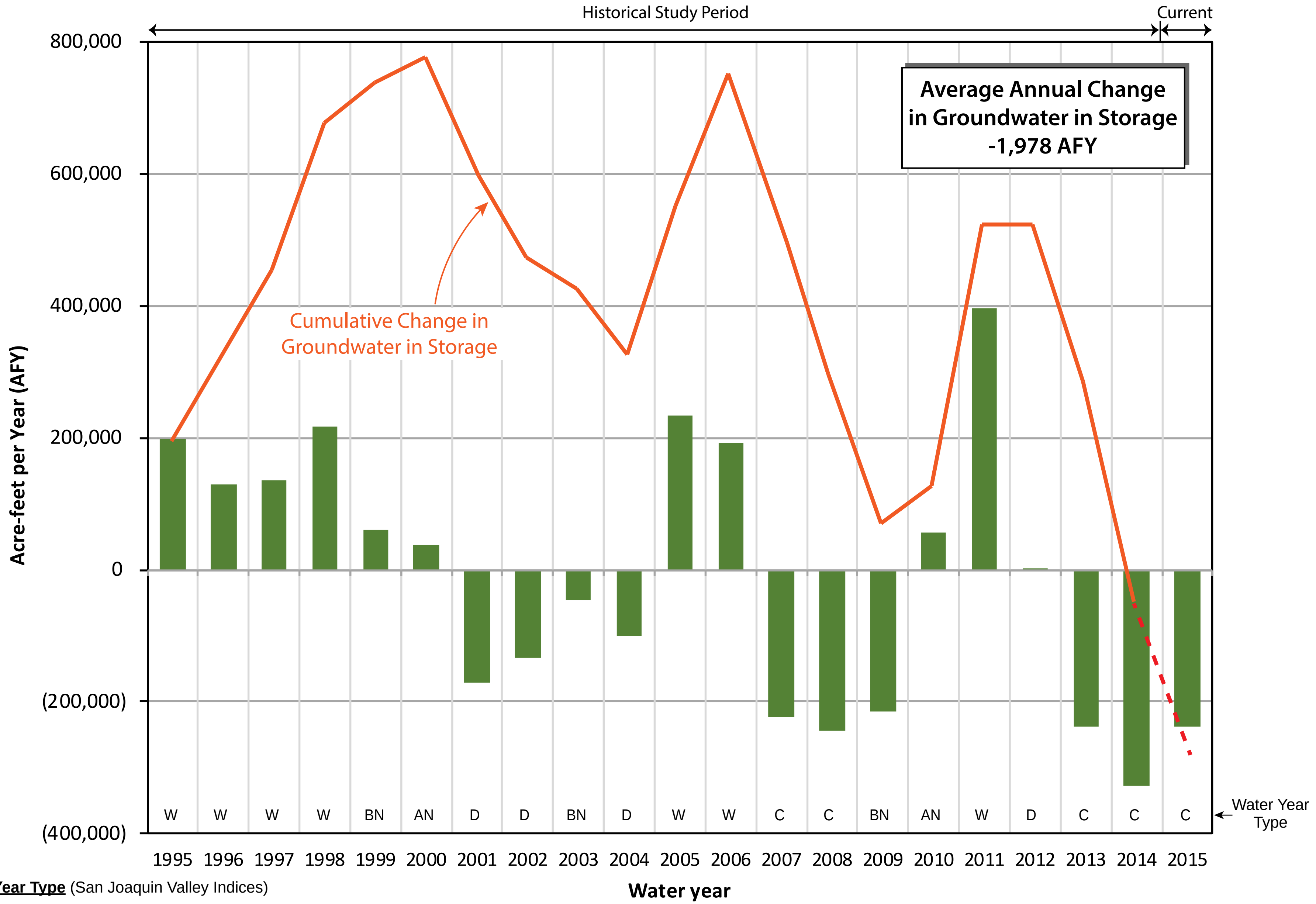


Note: Water Year Type for WY 2015
is Critically Dry based on the
San Joaquin Valley Index.

June 2019

TODD GROUNDWATER

Figure 4-2
Groundwater Budget
Current Study Period
Checkbook Method



Average Annual Change in Groundwater in Storage -1,978 AFY

Water Year Type (San Joaquin Valley Indices)

W - Wet
AN - Above Normal
BN - Below Normal
D - Dry
C - Critical

June 2019

TODD GROUNDWATER

Figure 4-3
Changes in Groundwater in Storage Checkbook Method

Figure 4-4a

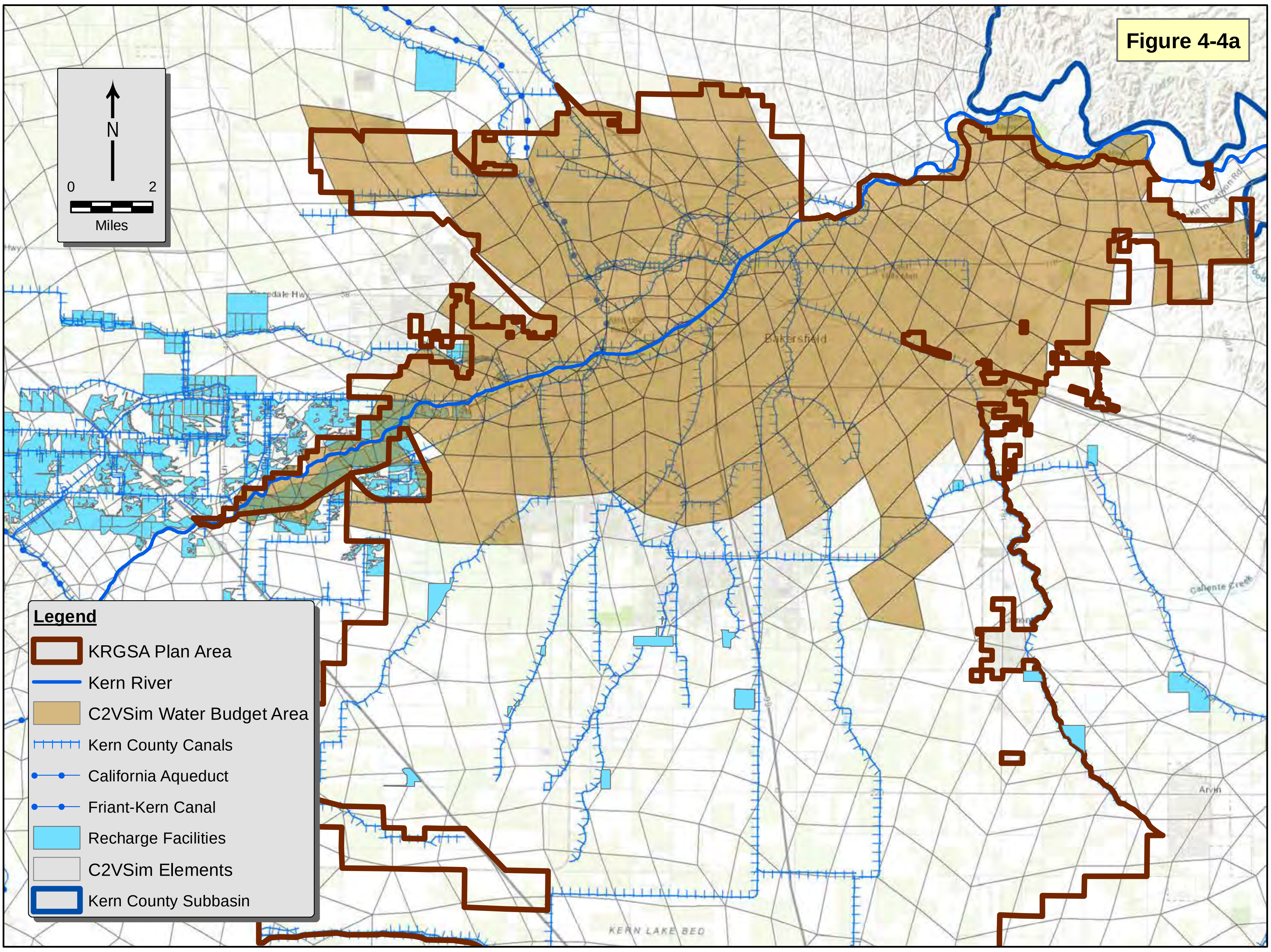
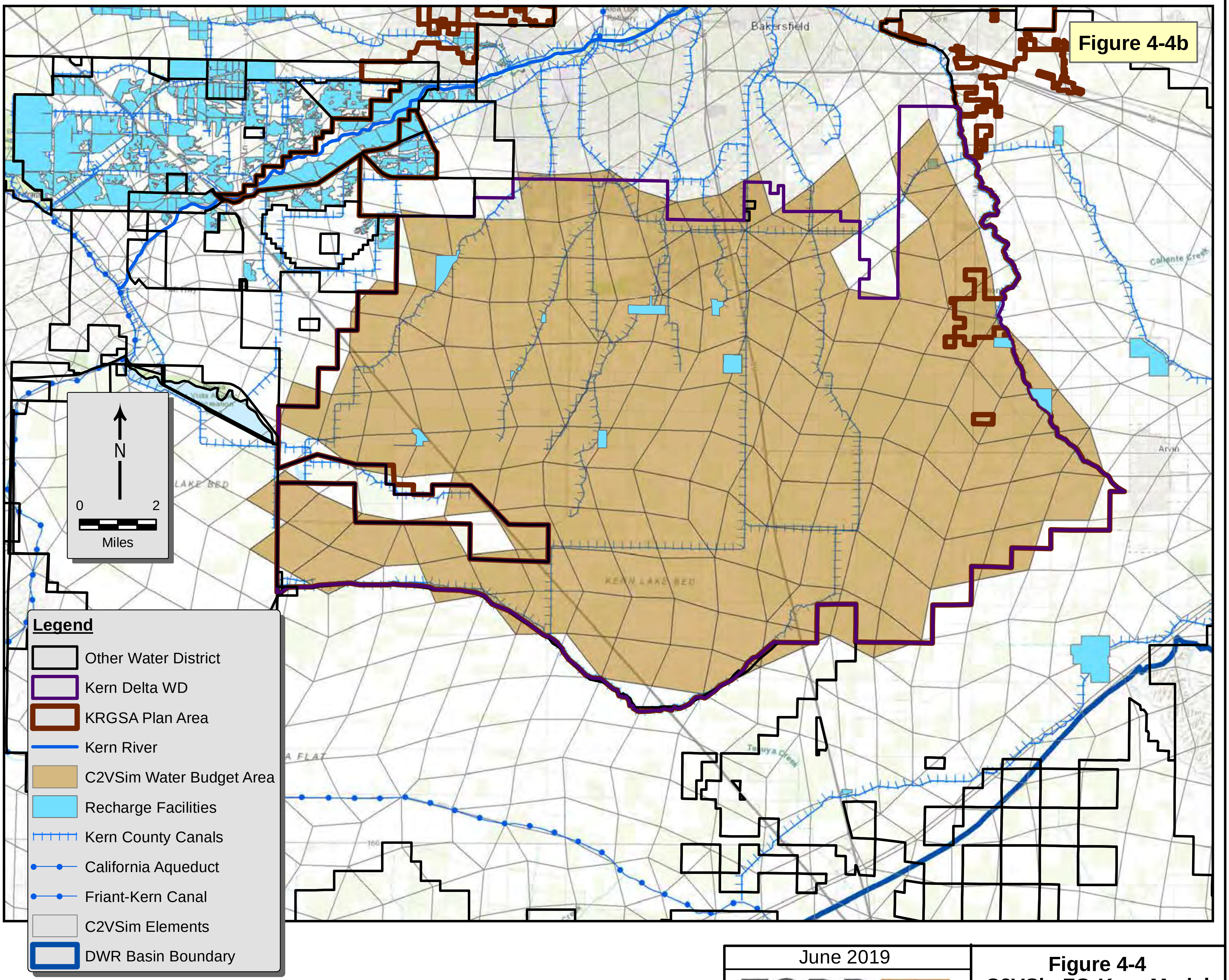


Figure 4-4b



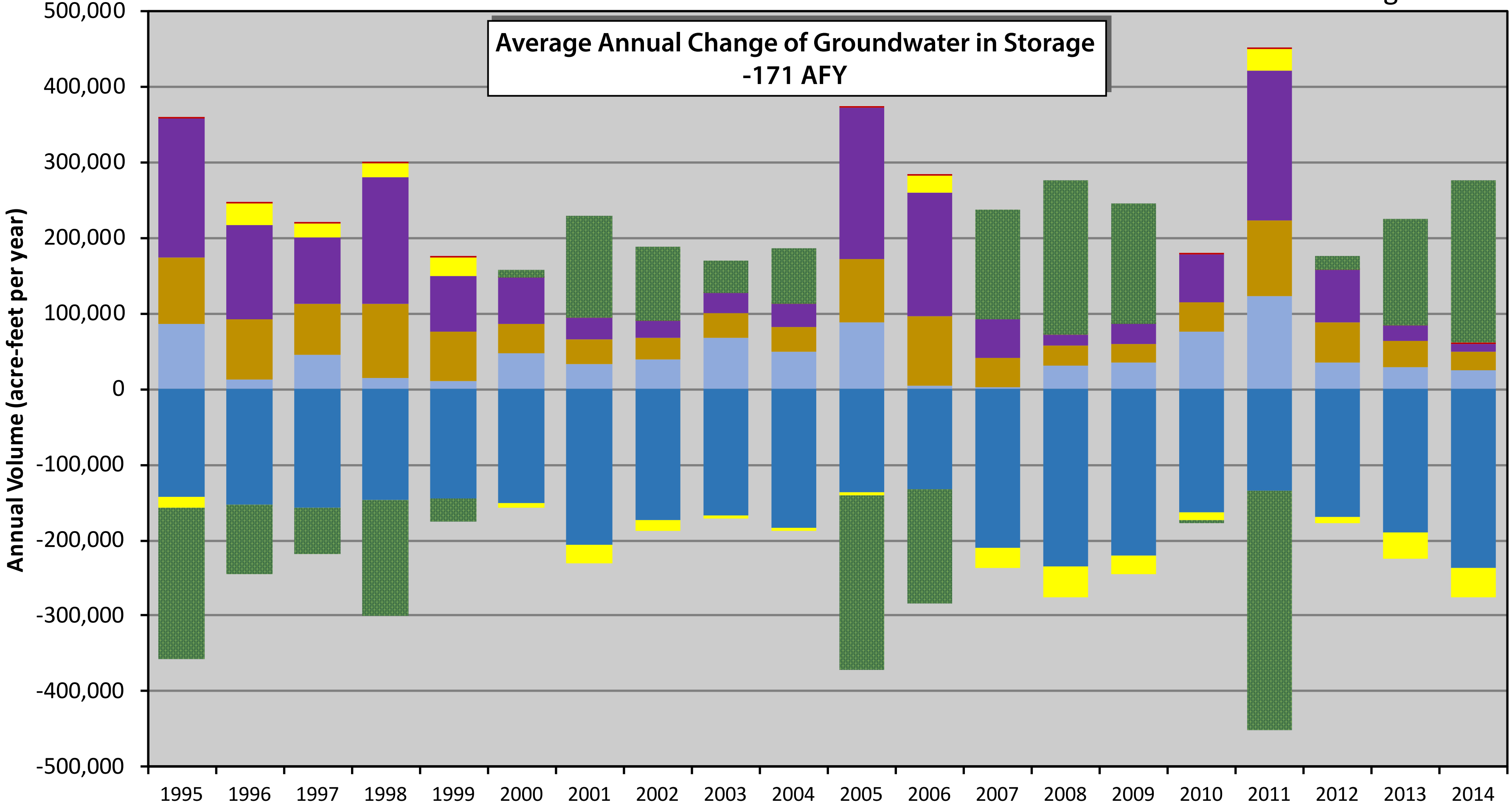
June 2019

TODD GROUNDWATER

Figure 4-4
C2VSimFG-Kern Model
Water Budget Areas
KRGSA Plan Area

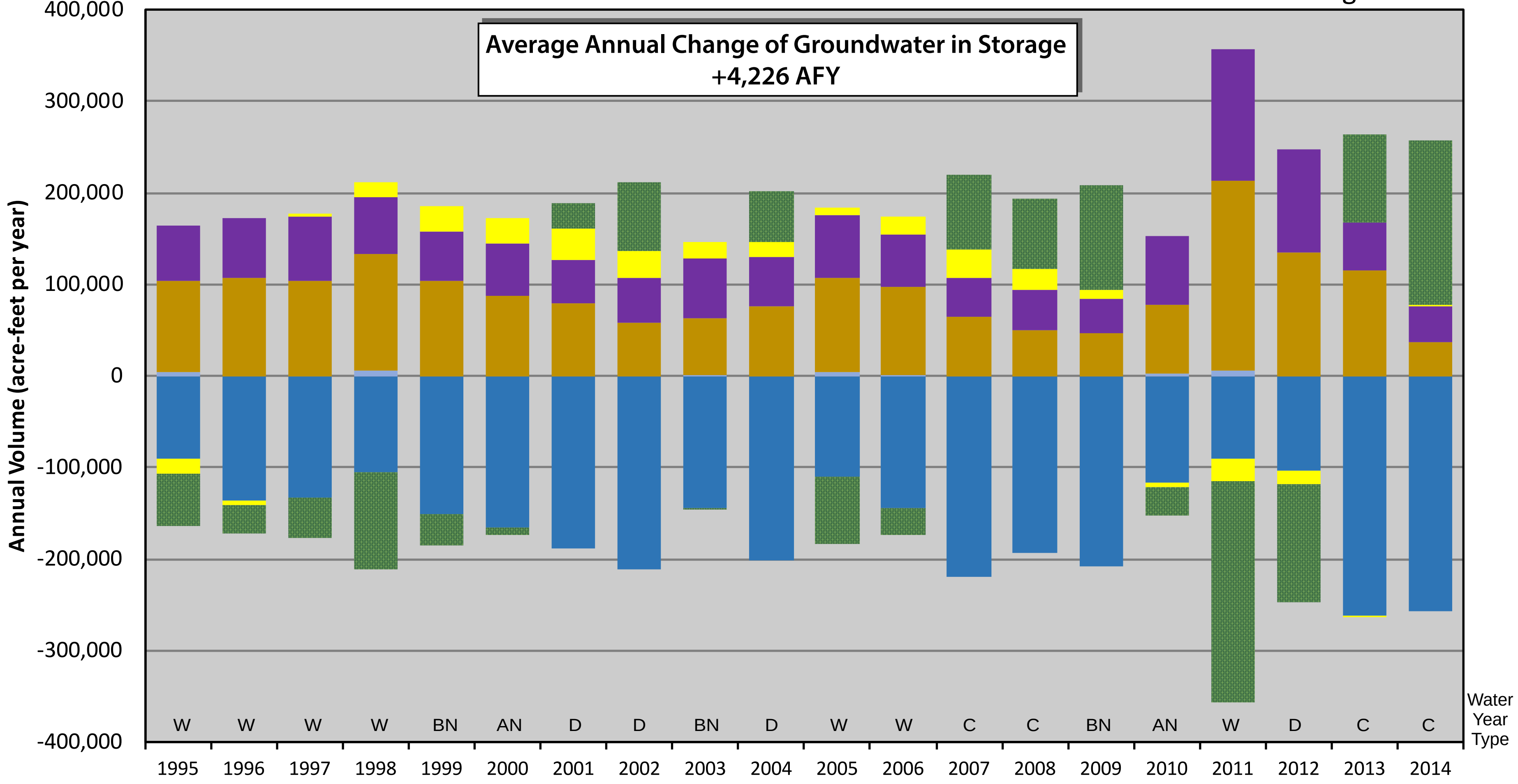
Historical Groundwater Budget for Northern KRGSA Plan Area (WY 1995 - WY 2014)

Figure 4-5a



Historical Groundwater Budget for Southern KRGSA Plan Area (WY 1995 - WY 2014)

Figure 4-5b



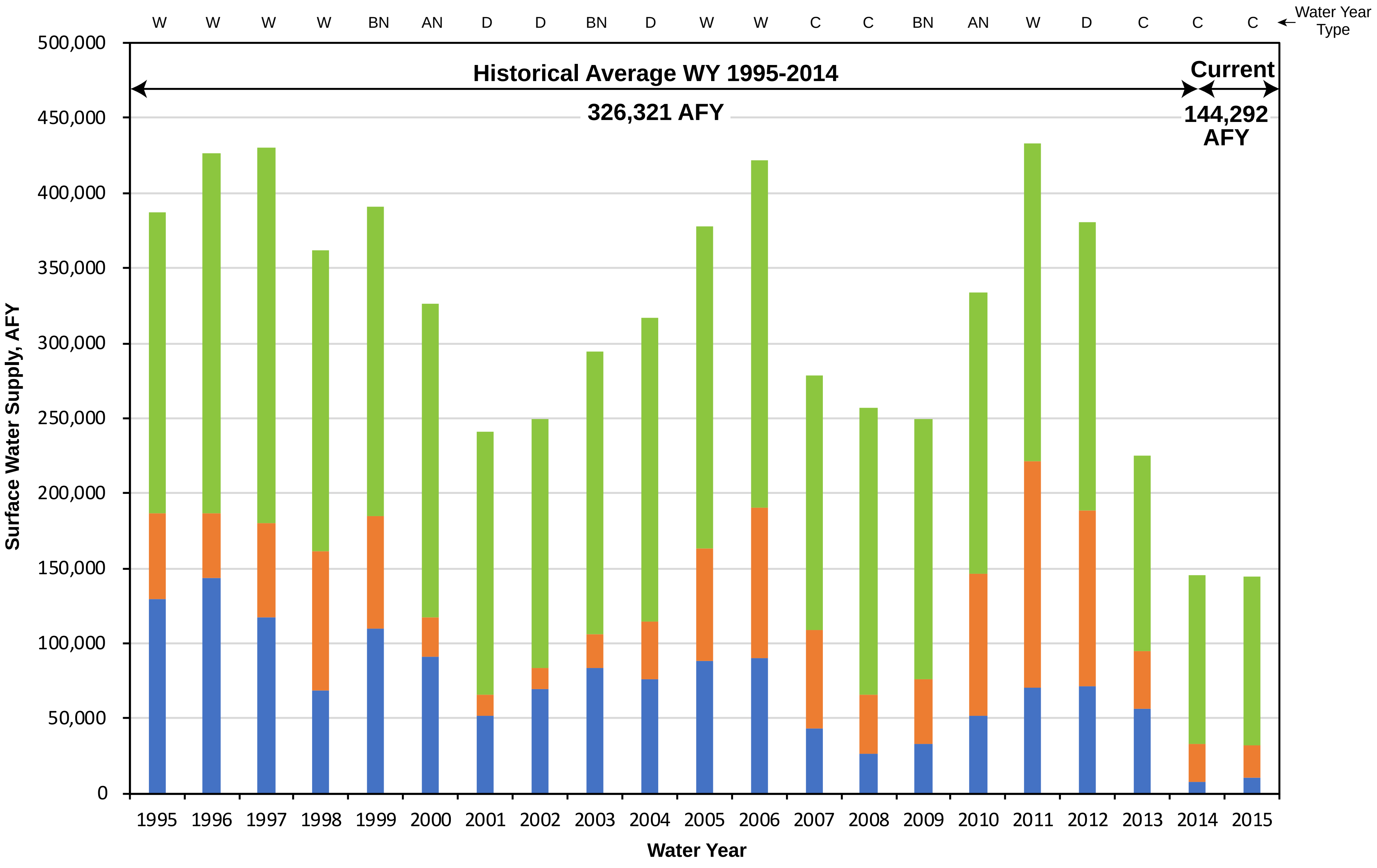
- 🟦 River Channel Recharge
- 🟧 Percolation of Precipitation, Return Flows, and Applied SW Infiltration
- 🟦 Groundwater Pumping
- 🟪 Managed Recharge; Canal Operational Recharge
- 🟨 Net Subsurface Flows
- 🟥 Basin Inflow
- 🟩 Change in Groundwater in Storage

<u>**Water Year Type**</u> (San Joaquin Valley Indices)
W - Wet
AN - Above Normal
BN - Below Normal
D - Dry
C - Critical

June 2019

TODD GROUNDWATER

Figure 4-5
Historical Groundwater Budget
C2VSimFG - Kern Model
KRGSA Plan Area



Water Year Type (San Joaquin Valley Indices)

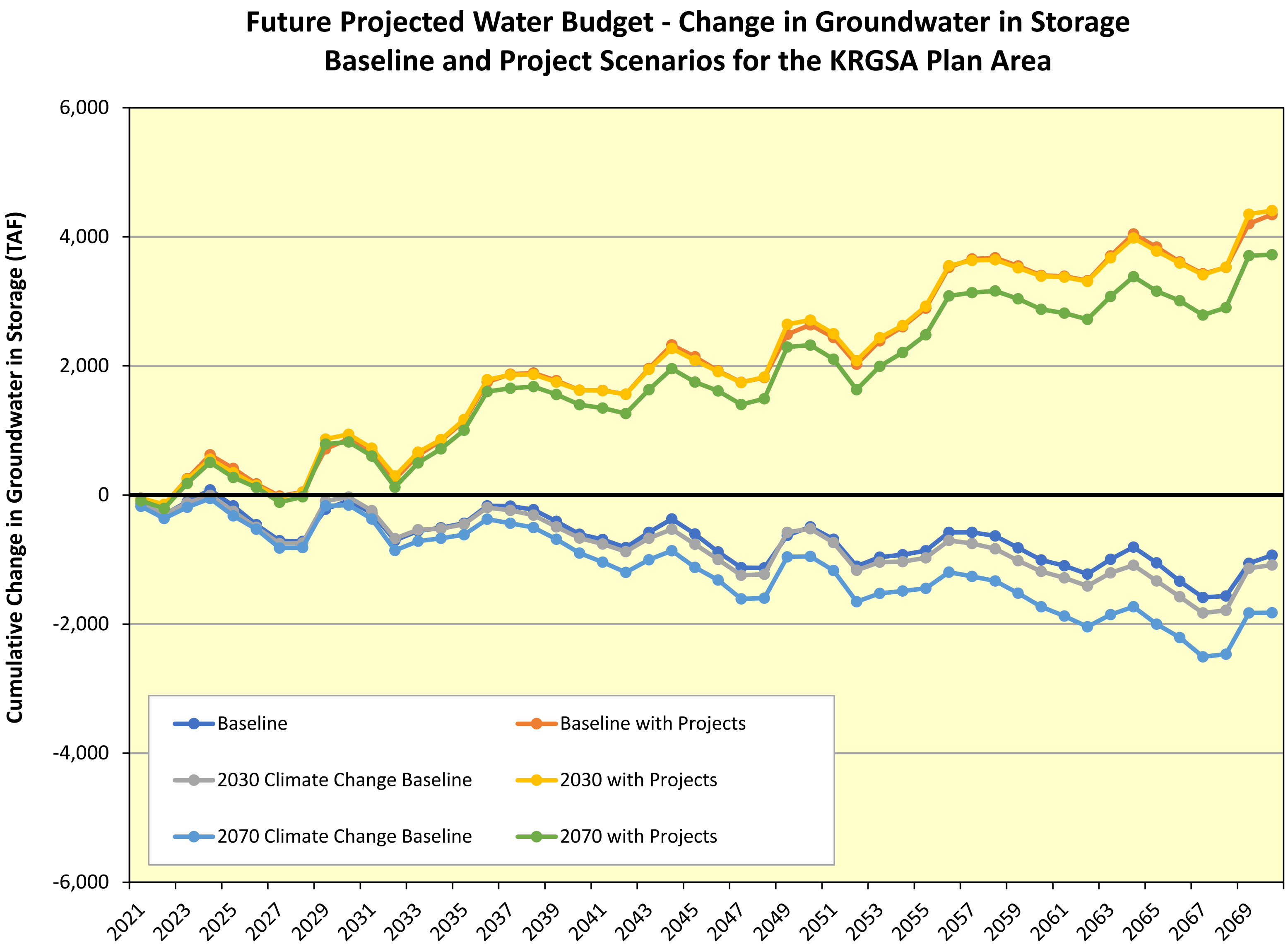
W - Wet
AN - Above Normal
BN - Below Normal
D - Dry
C - Critical

🟦 ID4 - SWP or Kern River and/or CVP by Exchange
🟧 City of Bakersfield - Kern River
🟩 KDWD - Kern River or SWP/CVP via Kern River by Exchange

June 2019

TODD GROUNDWATER

Figure 4-6
Historical and Current Surface Water Supplies KRGSA Plan Area

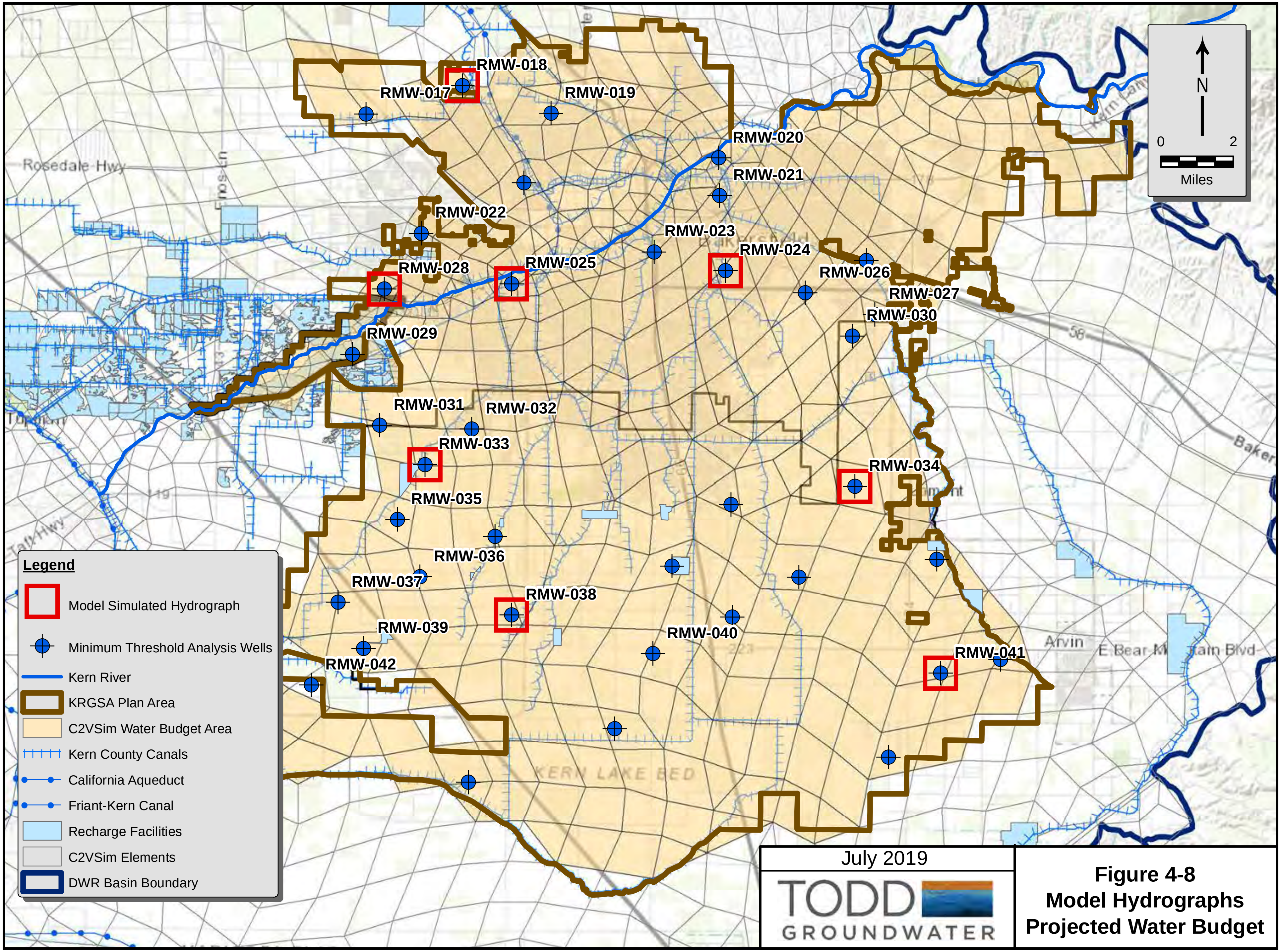


Future Projected Water Budget as simulated with C2VSimFG-Kern model and adjusted for excess river outflow and banking obligations for Subbasin export.

August 2019

TODD GROUNDWATER

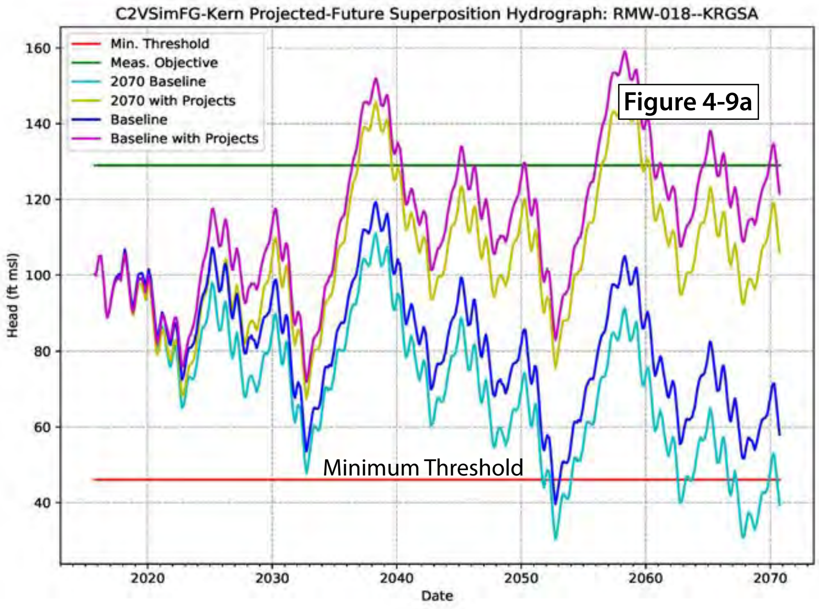
Figure 4-7
Future Projected Change in Groundwater in Storage

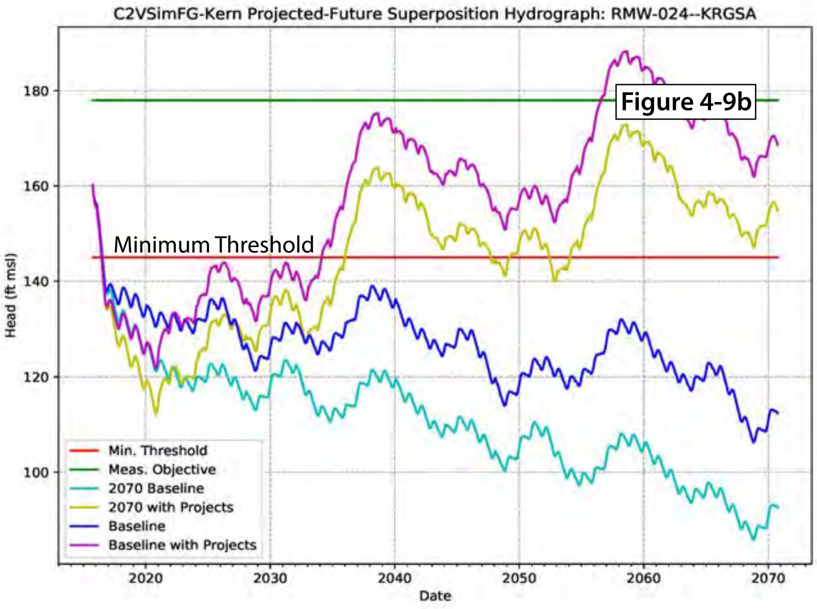


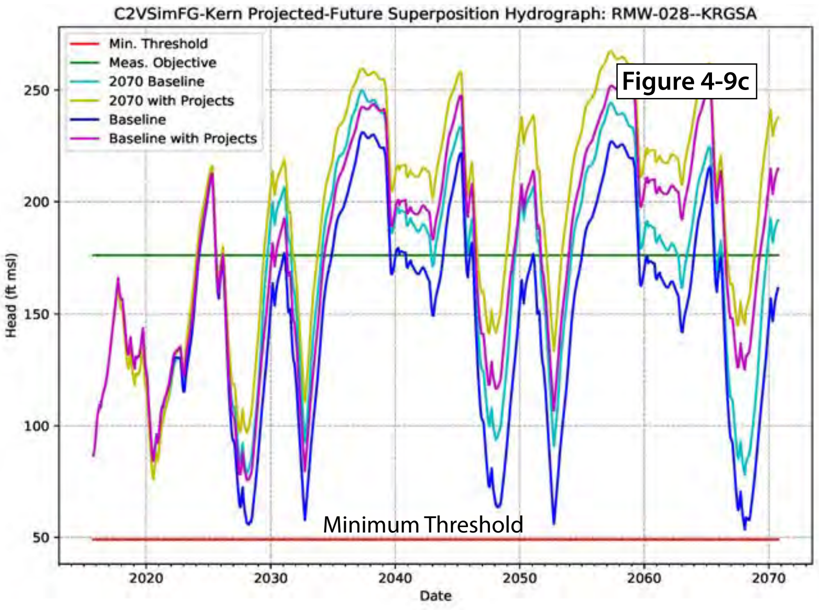
July 2019

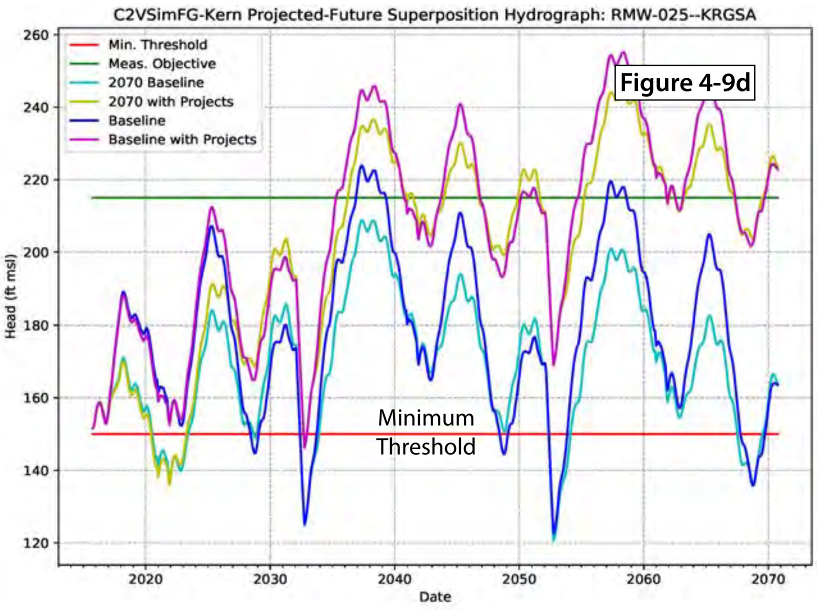
TODD GROUNDWATER

Figure 4-8
Model Hydrographs
Projected Water Budget





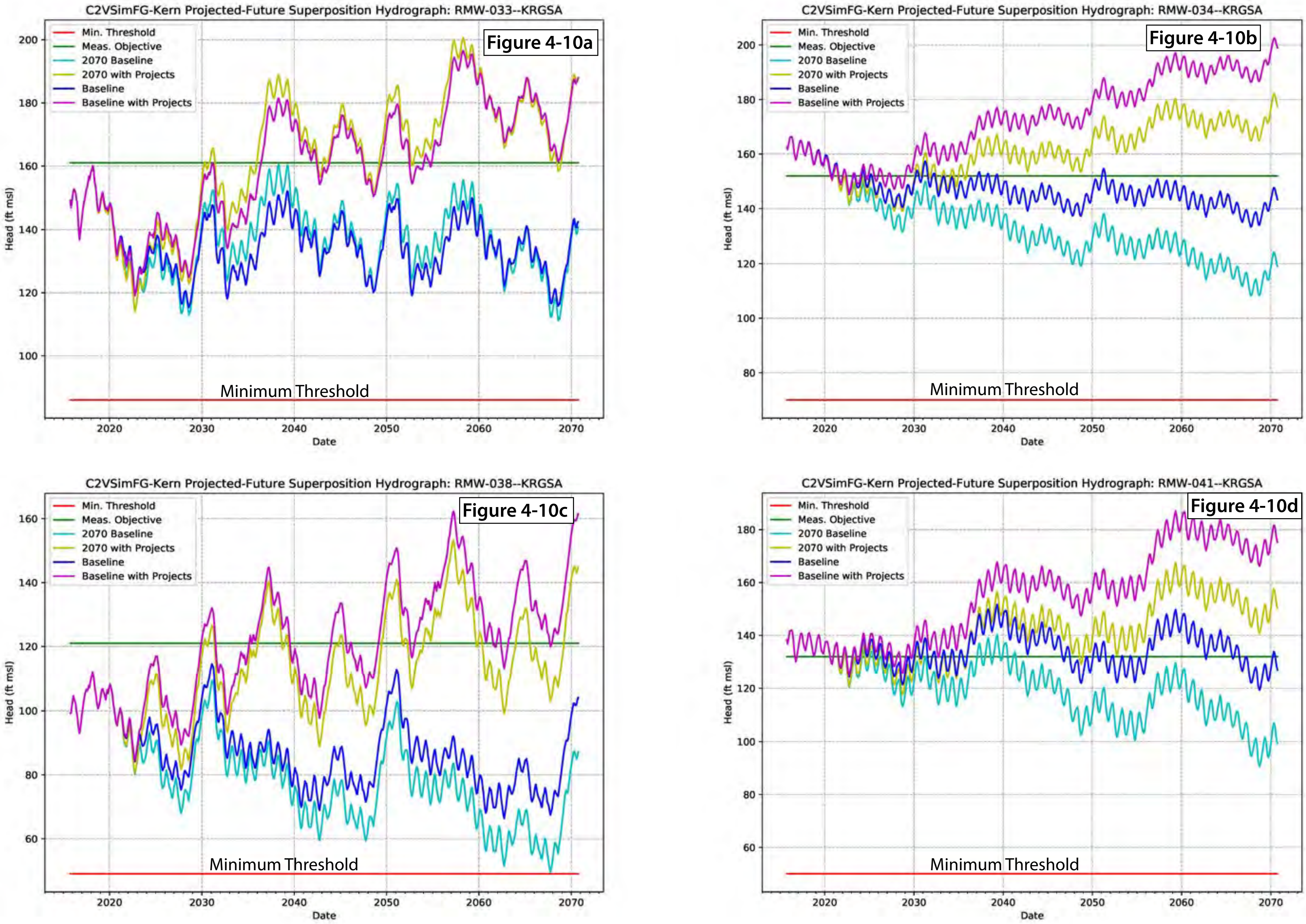




August 2018

TODD GROUNDWATER

Figure 4-9
Projected Water Levels
Northern Plan Area



August 2018

TODD GROUNDWATER

Figure 4-10
Projected Water Levels
Southern Plan Area