Interim Update to Sierra Vista Subwatershed Pumping and Artificial Recharge Rates in the Upper San Pedro Basin Groundwater Model

Prepared for

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By

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Executive Summary

This study incorporates the best available pumping and recharge data into the U.S. Geological Survey's 2007 published groundwater model for the Upper San Pedro Basin (Pool & Dickinson, 2007). This interim update to the model comes six years after the last pumping update (Lacher, 2011), and provides a more accurate accounting of both actual pumping and artificial recharge in the Sierra Vista subwatershed (SVS) over the 2003 to 2015 period, and of projected pumping from 2016 to 2100. These improvements are designed to make simulated impacts to baseflows and groundwater elevations as accurate as possible to inform water management decisions, but they do not include any new model calibration or changes to the historic model period (1902-2003). Additional updates are anticipated in future years as new data become available.

Artificial recharge is the sum of both *managed* aquifer recharge, such as projects designed to recharge treated effluent and/or storm water runoff, and *incidental* recharge, which results from human uses of groundwater without any deliberate intention to recharge, such as seepage from septic systems or excess irrigation. This study updates simulated pumping and incidental recharge rates for public water supply, domestic, golf course, and stock wells in the SVS for the period 2003 to 2015 using the best available data as of 2017. After 2015, the most recent sub-county level population projections from the U.S. Census were used to project public water supply (municipal and water company) and domestic (rural) pumping rates to 2100. Except for a few specific wells where details of discontinued use are available, simulated pumping for wells supplying water for large agriculture and other irrigation, mining, and commercial, industrial, and institutional uses was held constant at 2002 levels throughout the 2003 to 2100 simulation period in lieu of more current information. Managed aquifer recharge (MAR) at the City of Sierra Vista's Environmental Operations Park (EOP) was updated to 2015, then increased slightly to 2030 before being held constant through 2100. This same distribution was applied in the 2011 model in order to provide a clear comparison of the effects of updated pumping. MAR at Greenbush Draw near Naco was added to the current study using existing data through 2015 and then held constant to 2100.

The results of this study's pumping and recharge updates were compared with the last similar update conducted by Lacher in 2011. Lower-than-expected population growth and declining per-capita water use rates in the SVS resulted in projected public water supply and domestic pumping rates on the order of 4,000 acre-feet per year (AFA) less for the period 2016 to 2100 in this study compared to the previous model update (Lacher, 2011). Domestic pumping in this study was based on recent research by Plateau

Resources, LLC (2013) and Western Resources Advocates (2012) to estimate actual unmetered-well water use in the SVS. This method marks a departure from previous modeling efforts by Goode and Maddock (2000) and Pool and Dickinson (2007) where unmetered-well pumping was based largely on well dimensions rather than actual estimated per-household water use for the local area. Total SVS simulated pumping minus incidental recharge, referred to as net pumping in this study, increased from a low in 2015 of about 37,350 acre-feet per year (AFA) to a maximum of about 44,850 AFA by 2100. In the 2011 model update, Lacher simulated net SVS pumping values of 43,295 AFA in 2015 and 53,760 AFA by 2100. The lower net pumping projections in the current study relative to the 2011 study produced smaller pumping-related depletions of simulated evapotranspiration (ET) and stream baseflow, as well. However, the roughly 6,000 to 9,000 AFA reduction in simulated net pumping over most of the simulation period resulted in just a 930 AFA benefit to the riparian system (in the form of increased simulated baseflow plus ET) by the year 2100 relative to the 2011 model update. After accounting for the long-term MAR from the EOP near the Charleston stream-flow gaging station on the San Pedro River, simulated pumping-induced capture of riparian water (ET and baseflow) reached a maximum of 2,964 AFA in 2100 in this study compared with 3,893 AFA in the 2011 study.

The capture analysis in this study demonstrates that simulated natural recharge and existing MAR are insufficient to meet the net pumping demand in the model area, even at the reduced pumping rates in this study compared with the 2011 model update by Lacher. Evidence of this imbalance is provided by the fact that simulated riparian water (baseflow and ET – the primary sources of pumping-induced capture) decreases steadily throughout the simulation period. Because of the large distance between the surface and the groundwater system across most of the SVS, the only mechanisms for reducing the rate of capture (from the riparian system) are increasing MAR or decreasing pumping. Conservation efforts over the past 15 years in the SVS have pushed per-capita water use downward. Efforts to continue that trend and to increase near-stream MAR may further protect San Pedro River baseflows in future.

ACRONYMS AND ABBREVIATIONS

ADWR – Arizona Department of Water Resources

AF – acre-feet

AFA – acre-feet per annum

AMA – Active Management Area

AOEO – Arizona Office of Economic Opportunity

AZWSC – Arizona Water Science Center

CDP – Census Designated Place

cfs – cubic feet per second

CWS – Community Water System

EOP – Environmental Operations Park

ET - evapotranspiration

gpcd – gallons per capita per day

MAR – managed aquifer recharge

SPR – San Pedro River

SPRNCA – San Pedro National Riparian Conservation Area

SVS – Sierra Vista subwatershed

USGS – United States Geological Survey

USPB – Upper San Pedro Basin

WWTF – Waste Water Treatment Facility

Disclaimer

Groundwater modeling is a subjective undertaking. Although the pumping values used in this study were derived from the best publicly available data at the time of the study, some judgment on behalf of the modeler is always involved in developing pumping data sets. In some cases, missing pumping data, well construction details, and/or the use of the pumped water were estimated based on reasonable assumptions. The author acknowledges that the data used in this study do not perfectly represent real conditions, but asserts that the values are reasonable and representative of the best information available at the time of the study.

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Introduction

Background

The U.S. Geological Survey (USGS) published the groundwater model used in this study in 2007 (Pool & Dickinson, 2007). The geographic extent of the published model, titled "Ground-Water Flow Model of the Sierra Vista Subwatershed and Sonoran Portions of the Upper San Pedro Basin, Southeastern Arizona, United States, and Northern Sonora, Mexico," is shown in Figure 1. The published model included steady-state calibration and transient calibration periods from 1902 to 2003. In 2009, Lacher extended the simulation period to 2105 by updating municipal pumping rates in the Sierra Vista subwatershed (SVS) using the Arizona Department of Water Resources (ADWR) well registry (Arizona Department of Water Resources, 2017) and extending the pumping record by generalizing census growth rates in Cochise County census block areas to the entire SVS using Arizona Department of Commerce population estimates for the 2003 to 2009 period, and population projections from 2009 to 2055 (App. B. in GeoSystems Analysis, Inc., 2010). A subsequent model update by Lacher (2011) included 2010 municipal and Fort Huachuca pumping rates and improvements in the model's representation of managed aquifer recharge (MAR) at the City of Sierra Vista's Environmental Operations Park (EOP). The 2011 updates were reviewed and deemed reasonable and valid by the U.S. Geological Survey's (USGS) Arizona Water Science Center (Leake, S.A and B. Gungle, 2012).

Following the 2008 national economic crisis, the SVS population declined after years of significant growth (AZ Office of Economic Opp., 2017). Because groundwater is the sole source of water for most of the SVS, pumping is generally closely tied to population. Lacher's method of projecting pumping utilized the most recent pumping estimates available, so projecting these rates with population projections based on several recent years of high growth would lead to overestimated pumping if population experienced a significant decline after the initial year of projections. In this case, the 2011 model update by Lacher utilized census growth rate projections that were based on the early 2000's rapid growth in the SVS and Cochise County, producing pumping projections that were too high, as determined by 2010-2015 pumping data now available.

Scope of Study

Although the boundary of the 2007 USGS MODFLOW model (Pool & Dickinson, 2007) incorporates the entire Upper San Pedro River Basin (USPB) (see Figure 1), about half of which is in Mexico, this study updates pumping, incidental recharge, and MAR[1] in the SVS only. Updating pumping and artificial recharge in the Mexican portion of the USPB is among efforts recommended for future work at the end of this report.

Purpose of Study

This study is intended to provide a more accurate accounting of actual pumping in the SVS over the 2003 to 2015 period, and projected pumping from 2016 to 2100, such that simulated impacts to baseflows and groundwater elevations can be the most useful to inform water management decisions. This involves updating pumping, incidental recharge, and MAR estimates based on available data for the 2003 to 2015 period, then developing projections for the 2016 to 2100 period based on the most recent US Census projections for population growth in the SVS.

Methods

This study updates pumping and incidental recharge[2] in the SVS across all water-use sectors as well as MAR associated with the two largest wastewater treatment facilities in the region. Municipal and water-company pumping were updated in the previous studies described in the Introduction above. This study incorporates recent pumping data through 2015 for those water providers. Previous studies by Lacher also projected pumping for private, unmetered wells (or "exempt wells") based on growth rate projections in nearby census block areas, but without any direct estimates of actual exempt-well water use. This study applies more spatially representative census growth rate projections to rural wells and incorporates recent estimates for domestic water use in rural areas developed by Western Resource Advocates (2012)

[1] Incidental recharge is inadvertent, human-caused recharge (eg, from septic tank seepage and excess irrigation). MAR is intentional recharge (eg, treated effluent basins). Together, incidental recharge and MAR make up all artificial recharge.

[2] Incidental recharge for domestic and irrigation wells is calculated as a fixed percentage of pumping.

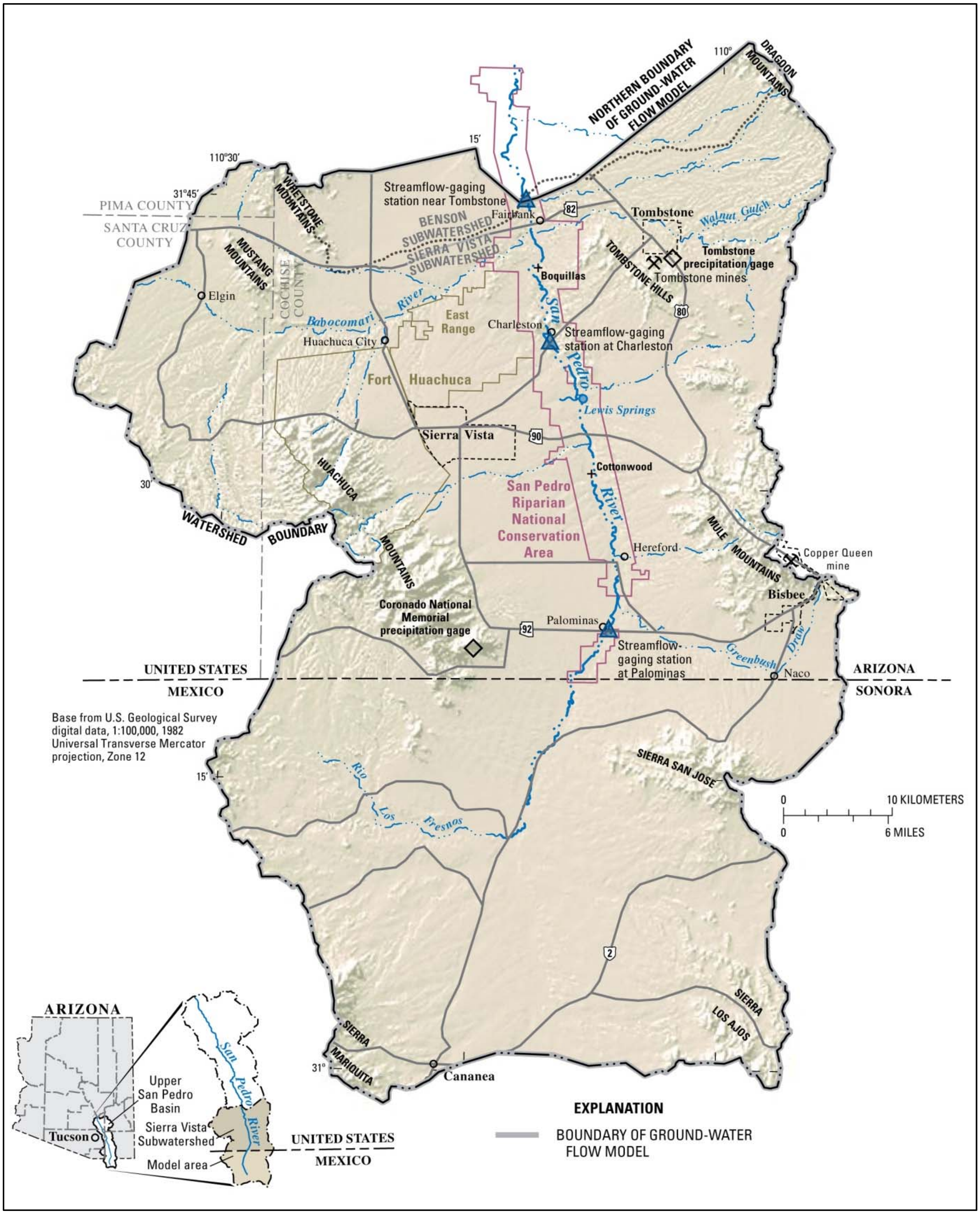

Figure 1. Map of the Upper San Pedro Basin showing the extent of the USGS groundwater flow model (Pool & Dickinson, 2007) and the San Pedro Riparian National Conservation Area. The Sierra Vista subwatershed is the area north of the United States – Mexico boundary. After Figure 1 in Pool and Dickinson (2007)

and Plateau Resources, LLC (2013) for the Upper San Pedro Partnership (USPP).

This study also incorporates the recently established MAR in Greenbush Draw. The San José Wastewater Treatment Facility (WWTF) near Naco, Arizona, replaced three old treatment facilities serving the City of Bisbee, Arizona. Since 2006, excess treated effluent from the San José WWTF has been discharged to Greenbush Draw and allowed to infiltrate through the streambed in a passive recharge system. Lacher (2016) made a detailed study of the Greenbush Draw recharge and that information is incorporated in this model update.

Like the USGS model (Pool & Dickinson, 2007), this study holds natural recharge constant, with no assumption of climate-induced changes throughout the 2003 to 2100 simulation period. Simulation of climate change scenarios are recommended in the "Recommendations for Future Work" section at the end of this report. Finally, the newest model updates are compared with the last model update (2011) to determine the impact of updating simulated pumping and related incidental recharge.

Estimating Water Use for Model Update

Historically, agricultural irrigation, stock watering, and mining made up the largest groundwater uses in the SVS. In recent decades, municipal and domestic water use have far exceeded all other groundwater use categories in the SVS. Figure 2 illustrates the estimated relative proportions of groundwater use by category in the SVS in 2002 (a) and 2015 (b). Estimated (and simulated) total water use declined from about 22,570 acre-feet per year (AFA) in 2002 to 16,840 AFA in 2015. This large decline reflects generally low or negative population growth in various areas of the SVS, a near elimination of agricultural irrigation, and active conservation efforts in the subwatershed. Simulated water use for the Bisbee Copper Queen mine is maintained at 2002 levels in the model, even though the mine is currently inactive, as a conservative measure in the event that the mine reactivates. Simulated water use for stock and other undetermined water uses decreases significantly from 2002 based on more current stock water use estimates from the Hereford Natural Resources Conservation District as well as the most recent estimates of rural water use in the SVS (Plateau Resources, LLC, 2013).

Declining water use in the SVS over the past 15 to 20 years is in line with a national trend, especially in the western states. (Maupin, M.A., Kenny, J.F., Hutson, S.S., Lovelace, J.K., Barber, N.L., Linsey, K.S, 2014). This study's analysis of *residential* per-capita water use across all water service providers serving 98% or more residential water users within the study area indicates that per-capita water use declined by about

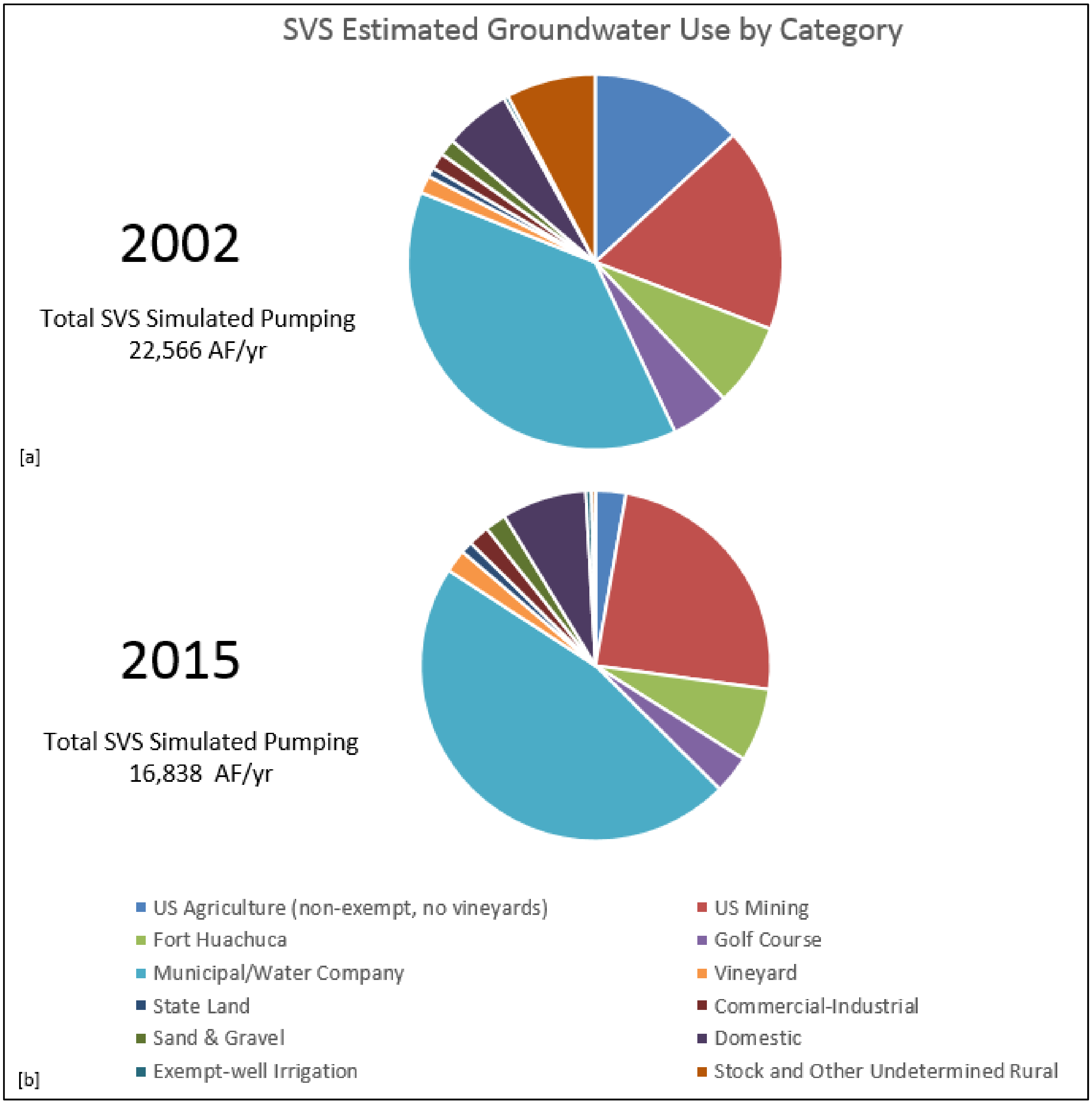

Figure 2. Groundwater use in the SVS by category for: a) 2002 and b) 2015.

1.2 gallons per capita per day (gpcd) from 2006 to 2015, which equates to about 1% per year relative to the 10-year mean.[3] While this model reflects changes in per-capita water use in the SVS for years when actual pumping is available (through 2015), this study makes no assumptions about future changes in per capita water-use rates. Instead, actual and estimated pumping rates for 2015 are used as the starting

[3] Data derived with some estimates for missing data from Community Water System annual reports (Arizona Dept. of Water Resources, 2006-2015).

point for projections of pumping based solely on the projected rate of population change from 2016 to 2050. After 2050, all simulated municipal and domestic pumping, and associated incidental recharge from septic systems, is increased annually by 0.8%, which is the average estimated population growth rate for both incorporated and unincorporated areas of the SVS for the 2016 to 2050 period (AZ Office of Economic Opportunity, 2017).

Figure 3 shows US Census block areas in the SVS. These include incorporated cities and towns (Sierra Vista, Tombstone, Huachuca City, and Bisbee) and Census Designated Places (CDPs) in the unincorporated portion of the subwatershed (Whetstone, Sierra Vista Southeast, Miracle Valley, Palominas, and Naco).

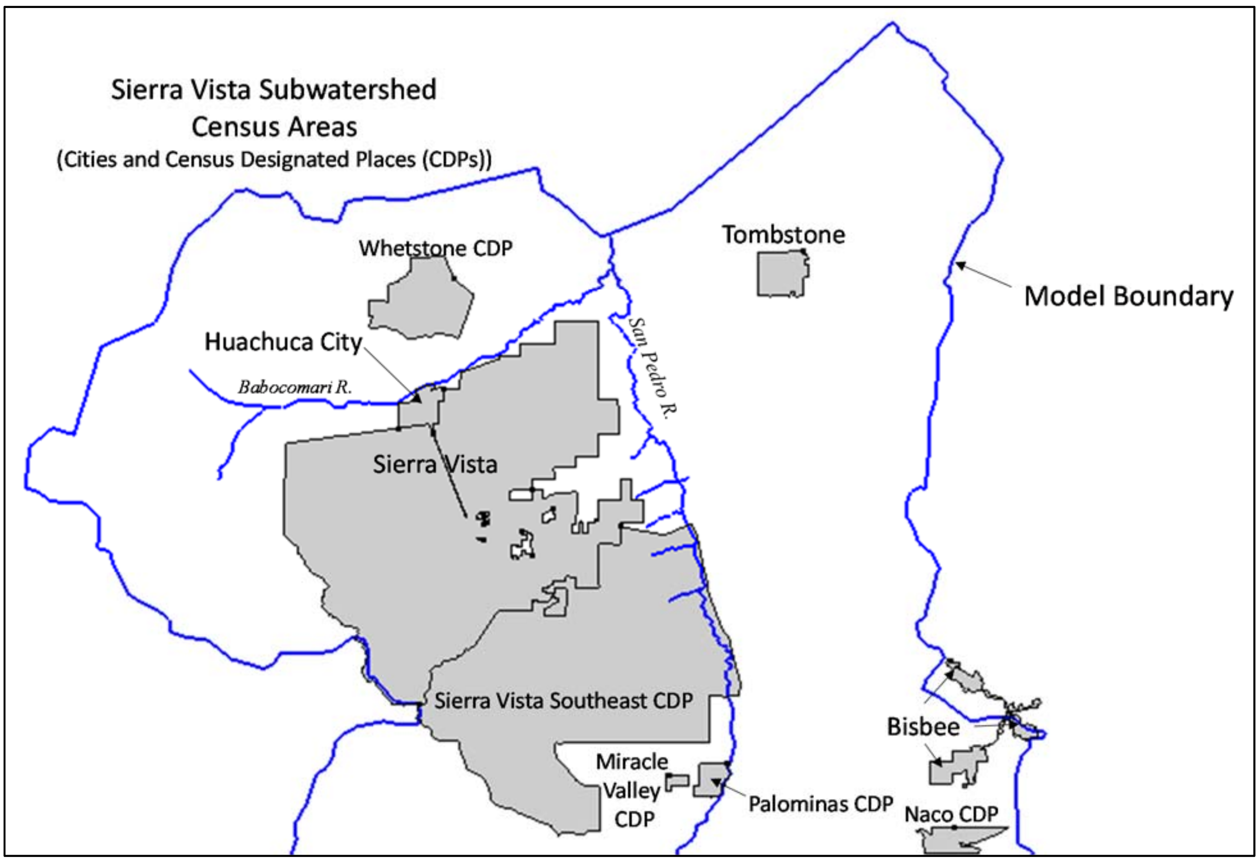

Figure 3. Incorporated areas and unincorporated Census Designated Places in the SVS.

Figure 4 plots US Census-based population projections for incorporated areas in the SVS for 2010 (Arizona Dept. of Commerce, 2010) and 2017 (AZ Office of Economic Opportunity, 2017). Figure 5 plots the 2010 and 2017 projections for unincorporated "Census Designated Places" in the SVS. These graphs reflect discrete geographic areas of the SVS where census counts occur. The remainder of the SVS population is included in a category of "Unincorporated Remainder of County" (AZ Office of Economic Opportunity, 2017). Thus, because census counts are not done specifically for the SVS, but for all of Cochise County,

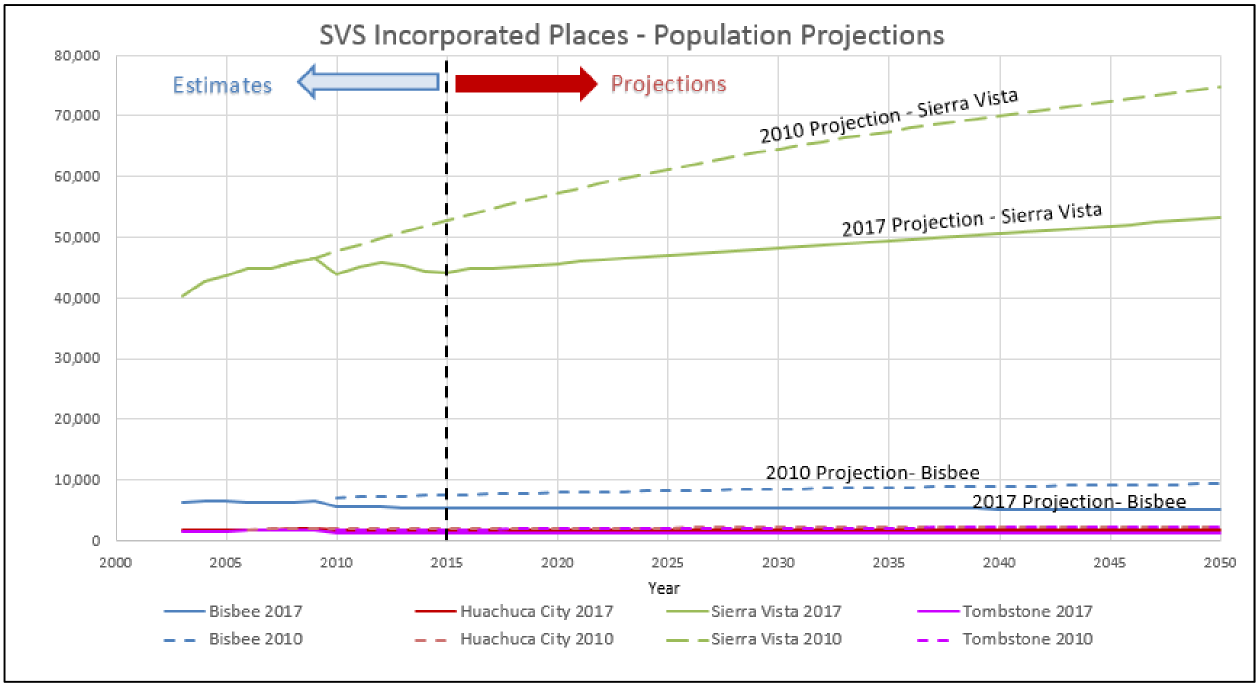

Figure 4. 2010 (Arizona Dept. of Commerce, 2010) and 2017 population projections for incorporated areas in the SVS (AZ Office of Economic Opportunity, 2017).

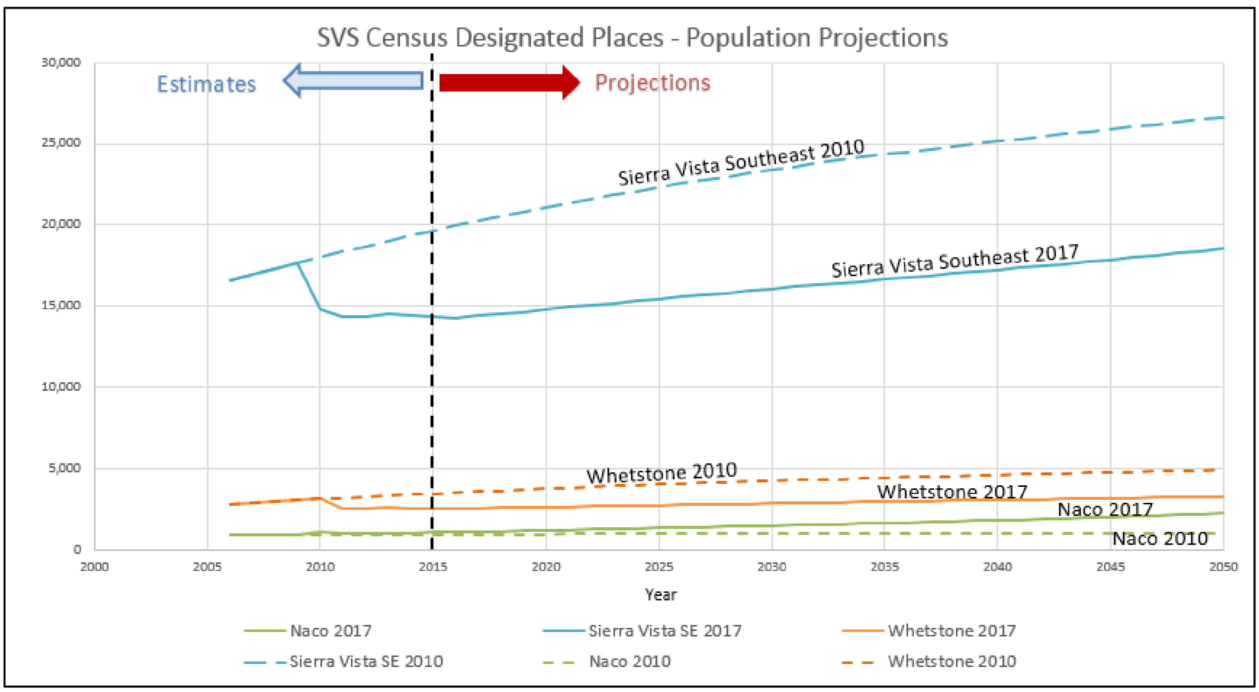

Figure 5. 2010 (Arizona Dept. of Commerce, 2010) and 2017 population projections for unincorporated Census Designated Places in the SVS (AZ Office of Economic Opportunity, 2017).

the SVS population must be estimated. Western Resource Advocates (2012) estimated that roughly 20% of the SVS population is served by private wells, while the remaining 80% is served by private or municipalities or water companies, collectively known as "water service providers" and/or "community water systems." The U.S. Environmental Protection Agency defines a Community Water System (CWS) as "a public water system that supplies water to the same population year-round," so some water service providers who serve small, transient populations (such as seasonal trailer parks) may not be classified as a CWS. CWSs have specific monitoring and reporting requirements under the federal Safe Drinking Water Act. Figure 6 shows the water provider service area boundaries in the SVS as of 2012 (Mott-LaCroix, 2013).

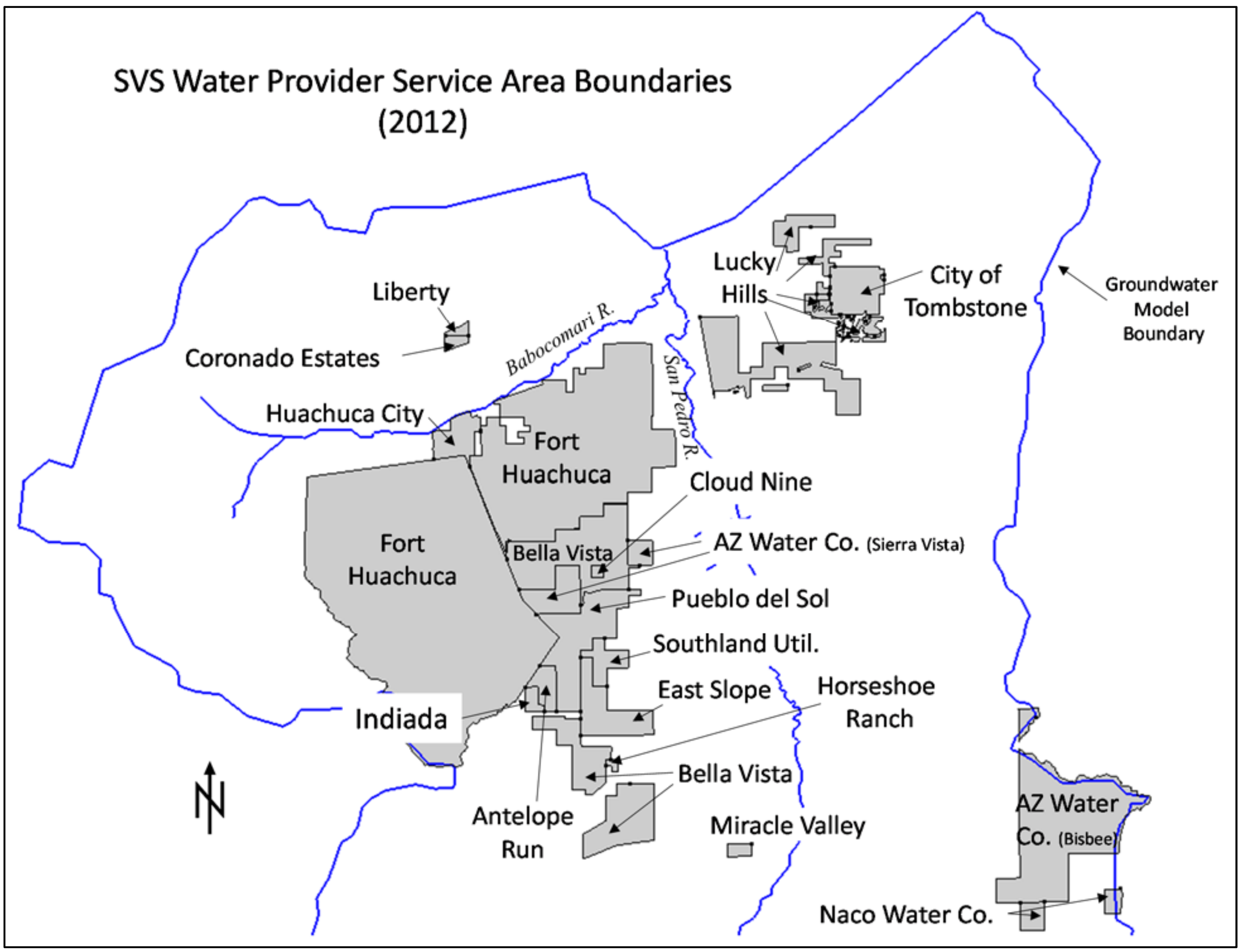

Figure 6. SVS water provider service area boundaries (email comm., K. Mott-LaCroix, 2013).

Water Service Providers

Pumping

Of the four incorporated cities and towns in the SVS, only Huachuca City and Tombstone own public water utilities. Fort Huachuca and the unincorporated town of Naco also operate their own water utilities. All of the other communities rely on private water companies for their municipal water service (Figure 6). Most of these companies produce their water with "non-exempt" wells in the SVS.[4] Non-exempt wells are designated by the Arizona Department of Water Resources (ADWR). Generally, they have a pumping capacity of more than 35 gallons per minute (gpm), and their pumping is regulated inside Active Management Areas (AMAs) of Arizona. Non-exempt well pumping in the state of Arizona outside of AMAs is unregulated and, except in the case of public water systems, has no reporting requirement. The USGS Arizona Water Science Center (AZWSC) began polling water service providers and other non-exempt well users in the SVS annually in 2002 to support the development of the USGS's groundwater model (Pool & Dickinson, 2007), but they have continued annual polling since that time, in part to support the annual reporting requirements of Public Law 108–136, Section 321[5] (Arizona Water Sci. Center, 2017). Prior to 2006, public water systems were required to report their pumping to the Arizona Corporation Commission. Starting in 2006, Arizona CWSs were also required to report their annual pumping to the ADWR as part of the state's drought planning policy initiative (Arizona Dept. of Water Resources, 2017). These data, combined with the CWS reports, were the primary sources for recent municipal and water company pumping values used in this study. In contrast to the original USGS MODFLOW model (Pool & Dickinson, 2007), this study uses volume of water pumped, rather than volume sold, for simulated pumping rates in the model. While volume sold accounts for system losses (leaks) between the well and the customer which, theoretically, could return to the aquifer as incidental recharge, pumped volume is more conservative since many system losses in water system infrastructure may occur near or above the ground surface, and result in little or no groundwater recharge.

This model update includes all active non-exempt wells in the ADWR Wells-55 and GWSI databases (Arizona Department of Water Resources, 2017) within the SVS, as well as some unidentified wells (mostly mining and agricultural) that were included in the USGS groundwater model (Pool & Dickinson, 2007). Most of these are public water supply wells owned by private water companies or municipalities, though some other commercial, industrial, and agricultural wells are also in use within the SVS. Some non-exempt commercial/industrial well uses in the SVS include a sand and gravel processing facility in Sierra Vista, military operations at Fort Huachuca, and stock and irrigation on both State Land Department and private lands.

[4] The City of Tombstone also uses some spring water from the Miller Canyon area of the Huachuca Mountains for its municipal supply.
[5] National Defense Authorization Act for Fiscal Year 2004, Cooperative Water Use Management Related to Fort Huachuca, Arizona, and Sierra Vista subwatershed.

Incidental Recharge

Because most customers of public water providers live within sewered areas, no incidental septic tank recharge is applied to wells pumping inside sewered areas. For public water supply wells outside sewered areas, an incidental recharge rate of 14%[6] was applied in the form of an injection well in the top-most layer in the groundwater model at that location. Figure 7 shows the active public water supply wells and sewered area boundaries within the SVS.

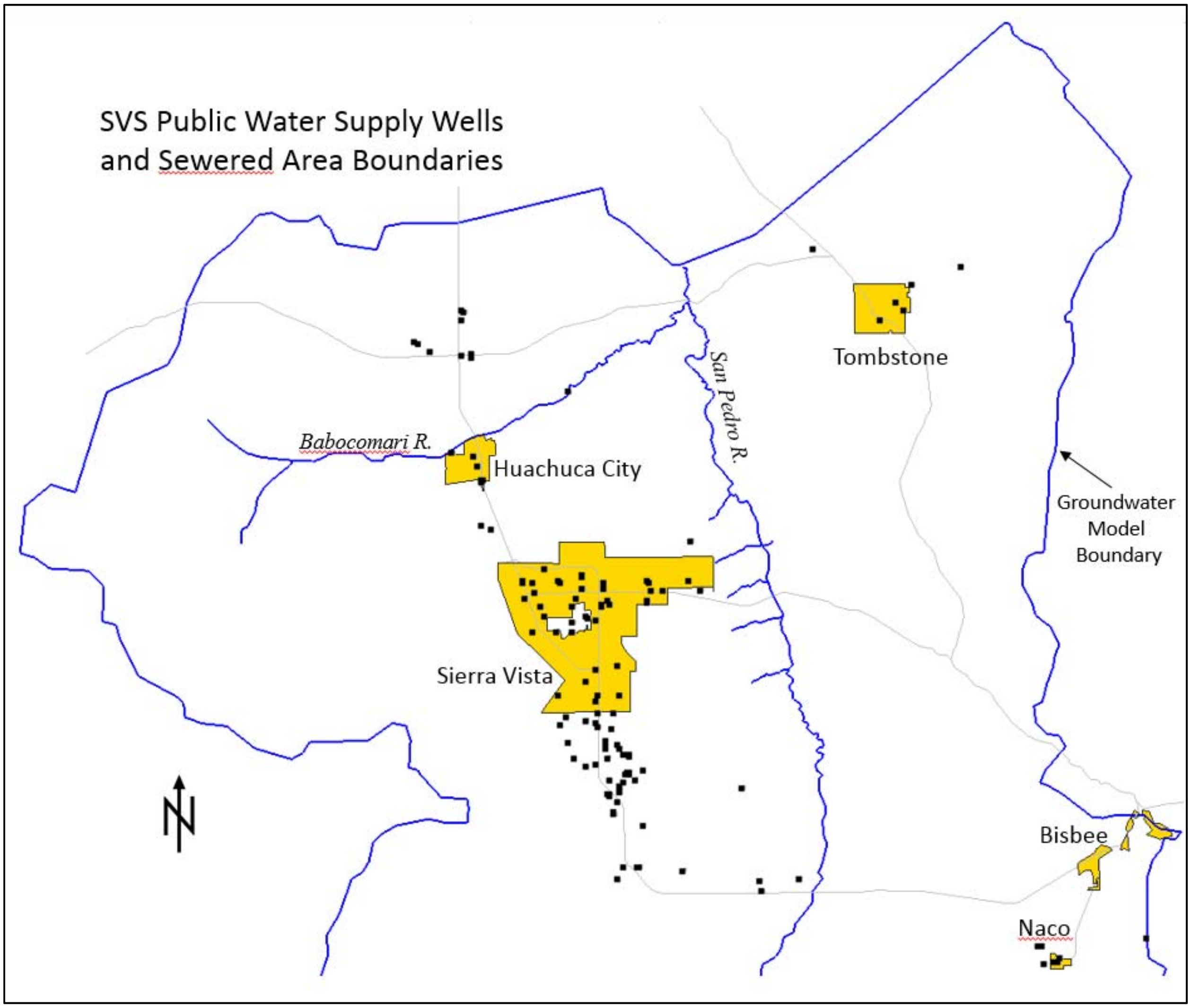

Figure 7. Public water supply system wells (black dots), sewered areas (yellow), and major highways (grey) in the SVS. Does not include Fort Huachuca's wells or sewered area.

Wells that were originally included in the USGS groundwater model but are no longer active (according to ADWR and CWS reports) were removed from the model.

[6] The same rate used by Pool and Dickinson (2007) in the USGS groundwater model.

Unmetered Wells

Pumping

The SVS population living outside of water provider service areas depends on private wells for its water use. Most of these private "domestic" (household) wells are categorized as "exempt" by the ADWR. Exempt wells have a pumping capacity of 35 gallons per minute (gpm) or less, and their use is completely unregulated in the State of Arizona. In addition to these domestic wells, many other wells in the SVS used for purposes other than public water supply, are unmetered and not required to report their pumping, irrespective of their pumping capacity. Many unmetered wells (both exempt and non-exempt) in the SVS are used for irrigation, stock, and commercial/industrial purposes, including golf courses. Some domestic wells may serve more than one home or some homes may have more than one well.

In a previous groundwater modeling effort in the Upper San Pedro Basin (Goode, T. and Maddock, T. III, 2000), modelers estimated unmetered well pumping based on well construction details (depth, casing size, screened interval, etc.), assuming a correlation between physical well characteristics and pumping rate when no pumping or water use data were available. Pool and Dickinson (2007) applied the same methodology to distribute the estimated unmetered-well demand across the SVS. Other studies in the southwest have estimated domestic water use rates of 0.24 to 0.48 AF per household (Western Resource Advocates, 2012). This study uses estimated water consumption by private well users in the SVS (Western Resource Advocates, 2012; Plateau Resources, LLC, 2013) as the basis for estimating unmetered well pumping, irrespective of well construction details. Recent research based on direct observations and locally based estimates of water use suggest that rural, domestic water use ranges from 0.18 AFA for homes built in or after 1997 to 0.26 AFA per household for homes built before 1997 (Plateau Resources, LLC, 2013). In this case, the term "domestic" means typical rural household indoor and outdoor water use (no turf, ponds, orchards, or other large outdoor water uses). With an estimated per-household population of 2.4 in SVS (Western Resource Advocates, 2012, p.4), that estimate translates to a per-capita water use of 0.08 to 0.1 AFA (mean 0.092 AFA). Plateau Resources (2013) estimated outdoor water use by non-metered exempt and non-exempt wells by direct observation, interviews, and satellite imagery. For rural residential homes, about 27% of annual water consumption is for outdoor (consumptive) uses (Plateau Resources, LLC, 2013, p. 10).

Although Pool and Dickinson (2007) do notspecifically identify domestic wells among other "unincorporated" wells in their model documentation, most unincorporated wells in the model are assigned 2002 pumping rates of 0.7 AFA or less. After removing wells labeled as "unused" in the ADWR well registry (Arizona Department of Water Resources, 2017), assigning all remaining “unincorporated” model wells with 2002 simulated pumping rates of 0.9 AFA or less to the “domestic” category yielded a total simulated domestic pumping rate of 1,234 AF in 2002, as shown in Table 1.

The USGS AZWSC published its most recent water budget for the SVS in its 2012 report titled, “Hydrological Conditions and Evaluation of Sustainable Groundwater Use in the Sierra Vista Subwatershed, Upper San Pedro Basin, Southeastern Arizona” and referred to as the “Sustainability Report” (Gungle, et. al, 2016). These estimates generally follow the same water budget methodology used in the Section 321 reports to Congress until 2011 (Upper San Pedro Partnership, 2010). Table 1 compares 2002 estimates of exempt-well demand in the SVS from the published USGS groundwater model (Pool & Dickinson, 2007), and 2012 estimated values from the unmetered well study (Plateau Resources, LLC, 2013) and the Sustainabilty Report (Gungle, et. al, 2016). Table 1 also lists the simulated 2012 values for each water-use category developed for this study. The values for annual domestic well use in Table 1 range from about 1,200 to 1,400 AF in 2012, with a mean estimated value[7] of 1,325 AF and a simulated value of 1,216 AF in this study.

Plateau Resources (“Plateau”) estimated 2012 domestic well use in the range of 1,135 to 1,366 AF with a mean of 1,250 AF based on the number of parcels with homes outside of water service provider areas and homes inside water provider service areas that continued to use their own wells. Plateau broke down water use by home age based on the fact that older homes generally have older, less water-efficient appliances and plumbing (Western Resource Advocates, 2012). This study analyzed 2012 data from Cochise County (Mott-LaCroix, Parcels Built Outside Water Service Provider Areas (shapefile), 2012) parcels developed before and after 1997 and found 2,022 parcels (49%) built before 1997 and 2,131 parcels (51%) built in or after 1997 (Figure 8). Applying Plateau’s water-use rates of 0.18 AFA for homes built in or since 1997, and 0.26 AFA for older homes, yields approximately 909 AFA for domestic well use outside of water provider service areas. Plateau (2013) reports mean values of 1,018 AFA and 231 AFA for unmetered residential well water use outside and inside water service provider areas, respectively,

[7] Mean of Plateau Resources (2013) and Gungle, et. al (2016) estimates.

Table 1. Comparison of Recent Simulated and Estimated Unmetered Pumping in the SVS.

Unmetered Well Category	**Pool & Dickinson (2007) Simulated 2002 Values**	**Plateau Resources (2013) Estimated 2012 Values**[1]		**Gungle, et. al (2016) Estimated 2012 Values**		**Mean of Estimated 2012 Values**	**Lacher (2017) Simulated 2012 Values**
		mean	***range***	**mean**	***range***		
Domestic	1234[2]	1,250	*1135 to 1366*	1400[3]	*700 to 2100*	1,325	1,216
Commercial-Industrial (including golf courses)	1,388	1,056	*1065 to 1070*[4]	983[5]	*900 to 1500*[6]	1,026	978
Large Outdoor/Irrigation (excluding golf courses)[7]	413	505	*425 to 584*	50	*0 to 150*	317	414
Stock and Other Undefined	1,657	57[8]	n/a	57[9]	n/a	57	57
Subtotal	3,607	2,880	*1823.3 to 2042.5*	2,650	*1600 to 3750*	2,725	2,664
State Trust Land	171			n/a			171
Sand & Gravel	307			160			307

Notes:

1-All estimates from Plateau Resources (2013) except "Stock" value, which is from Hereford NRCD (Upper San Pedro Partnership Tech. Comm., Apr 2014)
2 - USGS value includes 1180 for "Domestic" and 53 AF of "Undetermined" category in ADWR Well Registry
3- values include stock estimate of 12 AF
4- 1200 minus 57 for stock and 160 for sand & gravelIncludes all rural/exempt-well pumping (stock, comm-industrial, and other outdoor uses)
5- turf (including golf courses)
6 - range includes stock plus sand & gravel
7 - USGS value includes 265 for vineyards and 83 for other irrigation
8 - Plateau Res. (2013) figure is 12 AF for 1 cattle ranch with 900 head
9 - included in "Commercial-Industrial" in report.
n/a = not applicable

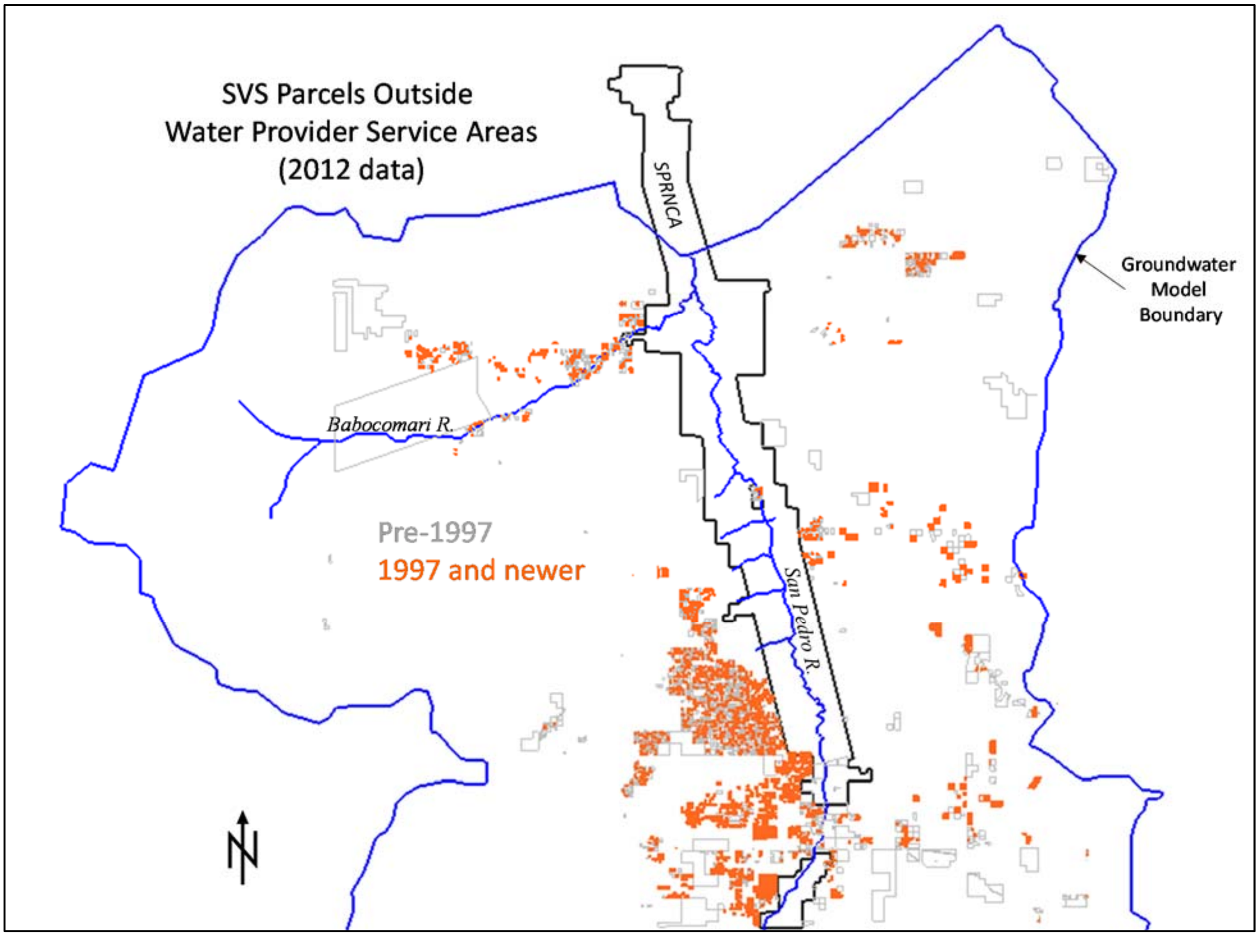

Figure 8. Developed parcels outside of water provider service areas in the SVS as of 2012 (Mott-LaCroix, Parcels Built Outside Water Service Provider Areas (shapefile), 2012). Parcels built on before 1997 shown in grey; parcels built in 1997 or more recently shown in orange. San Pedro Riparian National Conservation Area (SPRNCA) boundaries shown in black.

yielding a total mean water use of about 1,250 AFA for unmetered residential wells in the SVS (see Table 1). The 1,216 AF simulated domestic 2012 pumping value used in this study was developed based on population projections from 2002 to 2015 (see discussion in "SVS Pumping and Recharge Projections" below).

The "commercial-industrial" category in Table 1 is defined in various ways by different authors, but the values in Table 1 include golf courses and, except in the case of the Gungle, et. al (2016) study, other small business operations, churches, schools, etc. (sometimes referred to as "institutional" water users). This study's simulated value of 978 AF in 2012 derives from what is interpreted as commercial-industrial well pumping in the 2002 USGS model (Pool & Dickinson, 2007) based on well size, pumping rates, and institutional ownership (303 AF) plus 674 AF of golf course pumping derived from Arizona Water Science

Center water company polling data (Arizona Water Sci. Center, 2017) and ADWR pumping records (Arizona Department of Water Resources, 2017).

Simulated and estimated values for the "large outdoor/irrigation" category in Table 1 vary from 50 (Gungle et. al, 2016) to 505 (Plateau Resources, LLC, 2013) because of differences in category definitions. The simulated values used in this study maintain the 2002 levels for exempt-well irrigation and vineyards for this category (refer to Table A- 1), for a total of 414 AF in 2012. The widest divergence in simulated and estimated values is for stock water use and other undefined unincorporated well pumping. Pool and Dickinson's (2007) value for this pumping is estimated at 1,657 AF for 2002 based on simulated pumping rate (higher than 0.7 AFA criterion for domestic wells defined in this study) and a "stock or "undetermined" designation by ADWR. However, recent information from the Hereford Natural Resources Conservation District (Upper San Pedro Partnership Technical Committee, 2014) estimates SVS stock water use since 2008 at about 57 AFA, which is the simulated value used in this study for 2012 to 2100. This large difference between this estimate and the 2002 simulated value may result from a combination of changes in estimated stock demand and erroneous estimates of unincorporated well pumping based on well size. This study interpolated simulated pumping values linearly between the 2002 value (1,657 AF) and the 2012 simulated value (57 AF) shown in Table 1 to derive simulated pumping values between these two extremes for the years 2003 through 2011.

Wells associated with a sand and gravel processing facility in Sierra Vista (as determined by satellite imagery) were assigned 2002 simulated pumping rates of 307 AF (Pool & Dickinson, 2007). Two Arizona State Land Department wells were assigned simulated pumping rates of 171 AF in 2002 by Pool and Dickinson (2007). Neither of these categories of pumping were estimated by Plateau, but Gungle, et. al (2016) estimated sand and gravel pumping at 160 AF in 2012. This study maintained the simulated 2002 values for these categories.

In general, the 2002 total simulated pumping for unmetered wells in the SVS was about 730 to 960 AF greater than the 2012 estimates listed in Table 1 excluding State Trust Land and sand and gravel pumping. The total 2012 simulated pumping for the first four categories in Table 1 in this study is 2,664 AF, compared to 2,880 and 2,650 AF mean estimates by Plateau (2013) and Gungle, et. al (2016).

Incidental Recharge

All homes with residential wells, whether inside or outside of sewered area boundaries, were assumed to have septic tanks. In keeping with the method used by Pool and Dickinson (2007), 14% of all simulated domestic pumping was returned to the aquifer via hypothetical injection wells in the uppermost aquifer layer in the groundwater model at the location of the pumping well. Incidental recharge from golf course irrigation was maintained at the aerial recharge rate of 0.005 feet per day applied by Pool and Dickinson (2007) in the 2002 groundwater model.

Excess turf watering generates a small quantity of recharge, which was held constant at 2002 simulated rates (0.005 feet per day) throughout the 2003 to 2100 simulation period. Recharge from agricultural irrigation (except drip irrigation) and stock watering was applied at 18% of the pumping rate, which is the ratio used by Pool and Dickinson (2007) in the original model. All public supply and domestic wells outside of sewered areas were assigned a recharge rate of 14%, as specified in the original model. Figure 15 plots simulated incidental (hypothetical injection-well) recharge for each water-use category. This study identified several new municipal/water company wells outside sewered areas, so the 2017 simulated recharge value for this category is larger than the 2011 value. As discussed earlier, the “stock and undetermined rural” simulated pumping is much lower in the current model update than in 2011, so recharge associated with that pumping is also much lower than in the 2011 model update. Domestic well incidental recharge is lower in 2017 than in 2011 in proportion to the lower pumping rates.

Pumping in Mexico

Pumping in Mexico is dominated by industrial demand for the Cananea Copper Mine and agricultural irrigation, mostly near the SPR, but increasingly, near the town of Naco, Sonora. Simulated Mexican pumping constitutes about 50% of the total simulated pumping in the USPB in the groundwater model (Pool & Dickinson, 2007). This model update does not address the simulated pumping in Mexico, but updating this component of basin pumping is suggested in the “Recommendations for Future Work” section at the end of this report.

SVS Pumping and Recharge Projections, 2016 to 2100

Population *estimates* for the years 2003[8] to 2015 and population *projections* for the years 2016 to 2050 formed the basis for developing domestic SVS pumping rates from 2003 to 2015, and all SVS projected public supply and domestic pumping rates in this study from 2016 to 2100. The Arizona Office of Economic Opportunity (AZOEO) provides US Census Bureau population estimates for Arizona counties for the years 2003 to 2015 (https://population.az.gov/population-estimates). For the period 2016 to 2050, the AZOEO provides US Census-based sub-county level population projections for incorporated and unincorporated

[8] 2003 is the first year following the published USGS model’s transient calibration period.

areas of each county (https://population.az.gov/population-projections). Since the census data for unincorporated areas outside of census blocks (which are incorporated) and census designated places (CDPs) (which are unincorporated) are developed for the entire county, determining growth rates for the SVS unincorporated population outside CDPs requires estimation. Using the weighted average annual growth rate of the four CDPs with 2000 to 2015 population estimates available (Miracle Valley, Naco, Sierra Vista Southeast, and Whetstone) and applying that annual rate of growth (most of which is negative) to the 2002 estimated domestic pumping in the groundwater model (1,234 AFA) yielded a 2012 domestic well production rate estimate of 1,216 AF. Because this falls near the mean of the range of Plateau's (2013) 1,135 to 1,355 AF for 2012 residential well use, this pumping rate estimate was considered acceptable. The average estimated growth rate for all four CDPs in the SVS over the 2016 to 2050 period is 0.8%. This happens to equal the 2016-2050 projected growth rate for incorporated areas of the SVS, as well (AZ Office of Economic Opportunity, 2017). Thus, for the 2050 to 2100 period, this study projects all domestic and munipal/water company public supply pumping based on an annual growth rate of 0.8% after the year 2050.

Because CWS (exempt and non-exempt) wells are mostly metered, their water use is fairly well known and, since 2006, available online (Arizona Dept. of Water Resources, 2006-2015). Non-exempt well water use for purposes other than public water supply is often difficult to discern. For this study, the AZWSC's annual polling of water providers in the SVS provided guidance that, when coupled with the CWS reports, allowed a reasonably complete accounting of non-exempt water use for golf courses and public supply. Non-exempt and exempt wells used for commercial, institutional, and industrial purposes, as well as stock watering and irrigation, are often not metered and their water production is not required to be reported to ADWR, so those estimates are more difficult. In general, unless estimated or actual pumping rates were reported by another source, the values for these uses that were in the original groundwater model (Pool & Dickinson, 2007) were held constant for the 2003-2100 simulation period in this update. Specifically, simulated SVS pumping for the following water use categories was held constant from 2002 to 2100:

- Mining
- All agricultural and irrigation
- All commercial, industrial, and institutional (including golf courses)
- Livestock (corrected from 2002 to 2012, then held constant to 2100)

Figure 9 plots simulated SVS pumping by category for the current model update. Comparison with 2011 updates for municipal/water company and domestic well production shows the impact of declining population after the economic recession of the early 2000's and modified census growth projections. The 2017 model update curve (solid bright blue) drops to a minimum in 2015, then climbs at a rate nearly equal the rate of increase of the 2011 model update curve (2011). Starting pumping projections at the new 2015 low point (about 7,300 AF) results in a projected 2100 pumping value of about 14,350 AF. By contrast, the 2011 model update started projections in 2010, near the peak in pumping values since 2003, resulting in a projected municipal/water company pumping rate of 17,740 AF in the year 2100.

Figure 10 shows the same data without the large municipal/water company data to highlight the smaller water-use categories. The 2011 model update and 2017 model cuves for domestic pumping mimic the shape of the municipal/water company curves in Figure 9. Simulated domestic pumping in this study (solid dark blue curve) is nearly level at about 1,200 AFA from 2010 to 2016, when projections begin to increase slope of the curve. By 2100, simulated domestic pumping is about 2,400 AF in this study compared with 2,900 AF in the 2011 model update.

Fort Huachuca's simulated values were updated to 2015 then held constant in this study. The biggest change from the 2011 model update is in the water use category of "Stock and Undetermined Rural" water use. As described in the "Unmetered Wells – Pumping" section above, stock wells were not identified separately among the other "unincorporated" category wells in the original model (Pool & Dickinson, 2007). The 2011 update attempted to hold agricultual and mining pumping flat, but simulated pumping for all other "unincorporated" wells in the 2002 model were projected 2003 to 2100 period at the same rate as other wells in the same geographic area based on the nearest census block. In this model update, the most recent estimate of stock water demand (57 AFA) (Upper San Pedro Partnership Technical Committee, 2014) was applied for the simulation period 2012 to 2100, and domestic and other unincorporated water uses were estimated separately. Thus, the "excess" simulated pumping in the 2002 (Pool & Dickinson, 2007) "Stock and Undetermined Rural"[9] use category was gradually zeroed out from 2003 to 2012. A complete listing of simulated pumping by category for the 2017 and 2011 model updates is provided in Table A- 1 and Table A- 2, respectively.

[9] This category was defined for this study, and was not used by Pool & Dickinson (2007).

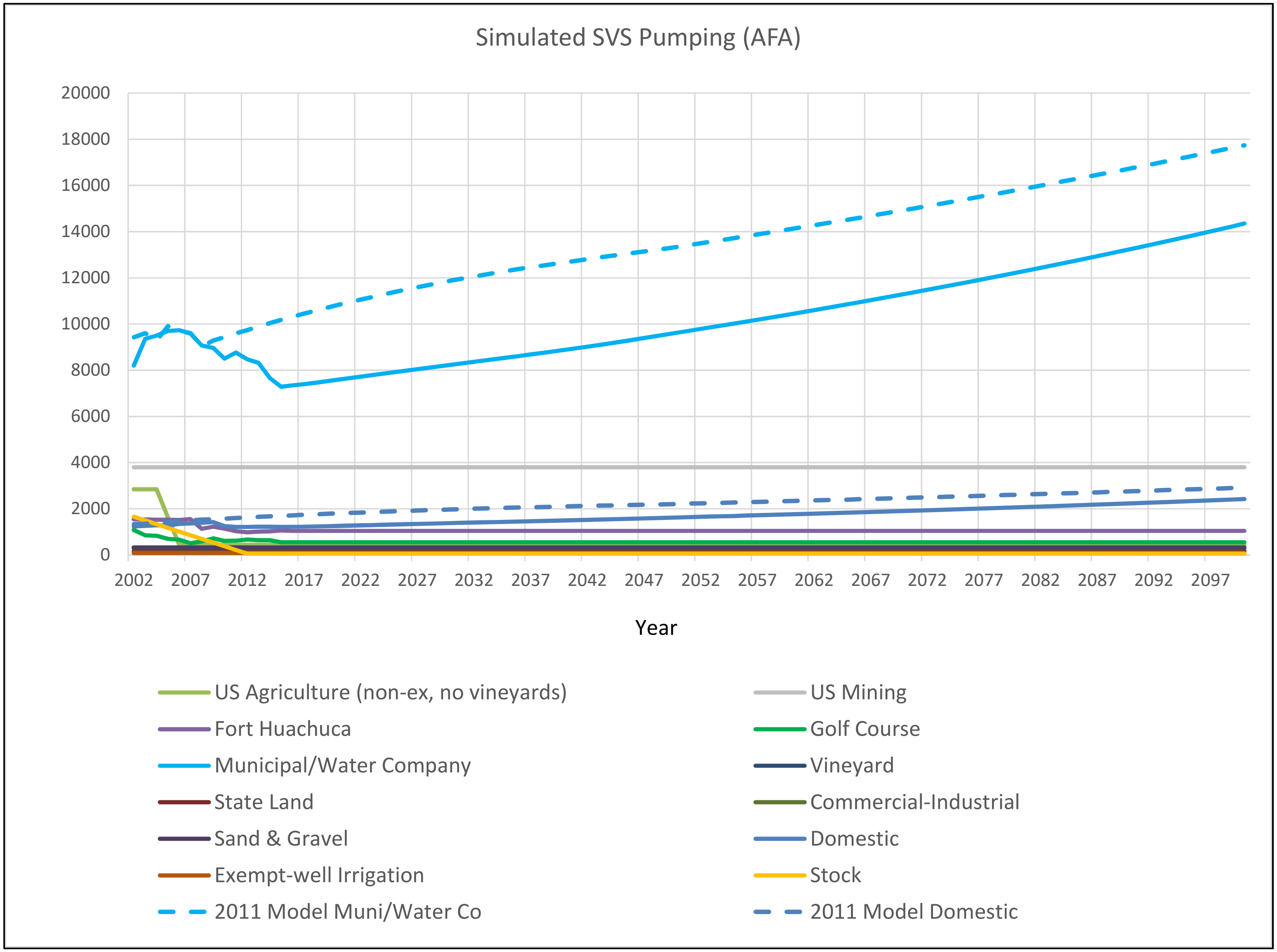

Figure 9. Simulated pumping in the SVS by water use category. Dashed curves show 2011 projections for municipal/water company and domestic pumping.

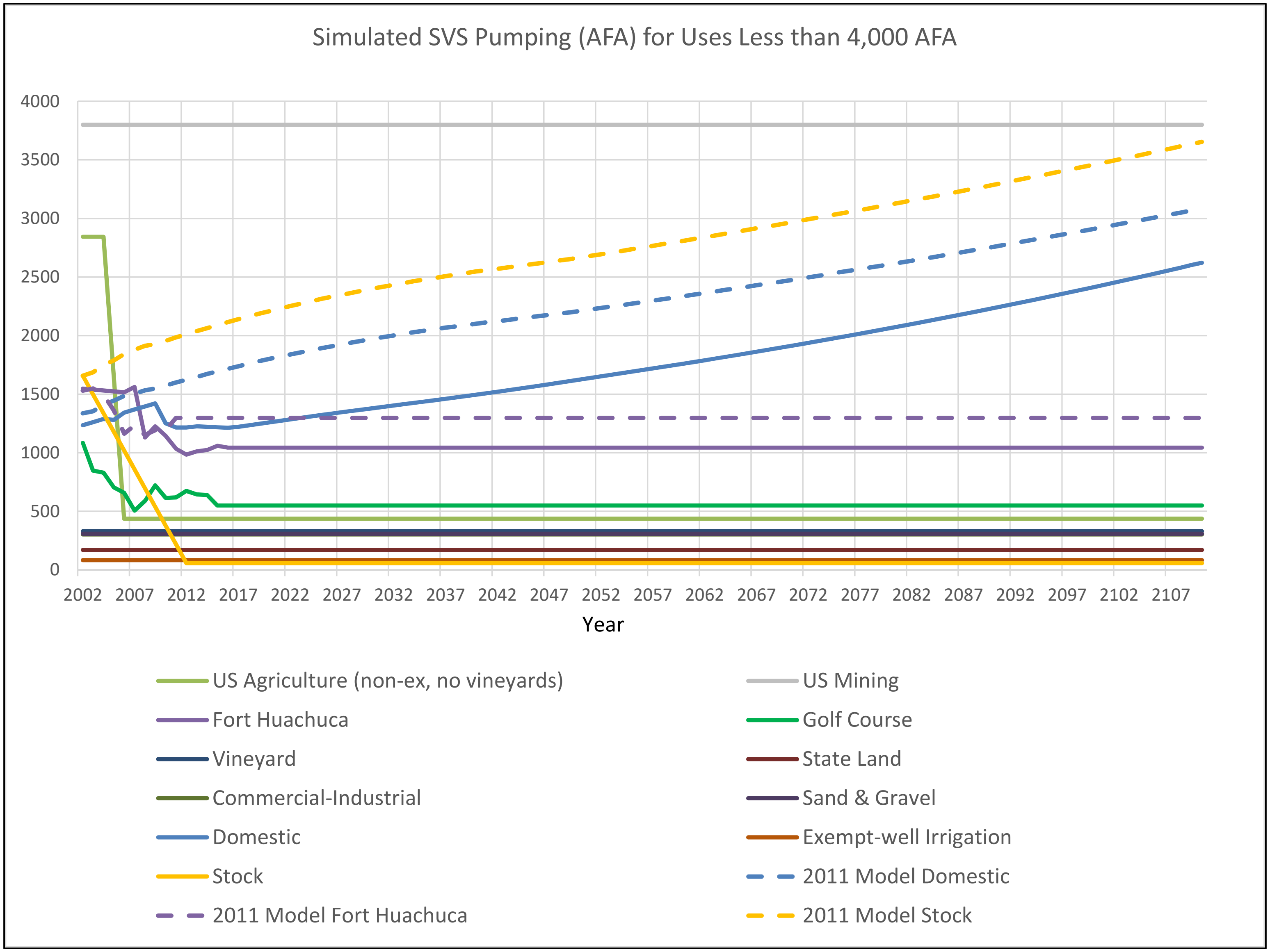

Figure 10. Updated simulated pumping in the SVS for categories totaling less than 4,000 AFA.

Managed Aquifer Recharge (MAR)

Managed recharge of treated municipal effluent occurs at three locations in the SVS, as indicated by the yellow square markers in Figure 11. The City of Sierra Vista recharges Class A+ treated effluent through recharge basins and artificial wetlands at its Environmental Operations Park (EOP). The method and volume of simulated EOP recharge has been updated several times since 2002 (Brown and Caldwell, Inc., 2099; Lacher, 2011). Long-term total recharge for this facility is simulated at about 2800 AF/yr, as shown in Figure 12. Because of its significant impact on simulated baseflows in the SPR, the EOP recharge distribution used in this study (Figure 12) was also applied in the 2011 model, for comparison purposes, in order to clearly isolate the effects of the pumping update from other factors.

Fort Huachuca recharges treated effluent to its basins east of Highway 90 between Huachuca City and Sierra Vista, with a long-term simulated rate of 675 AF/yr (Figure 13). The San José WWTF near Naco has been discharging treated effluent (permitted as Class B+) to Greenbush Draw, where a portion of the discharge infiltrates through the streambed, since 2006. Sumer, winter, and total simulated recharge in Greenbush Draw is shown in Figure 14, with total recharge varying from about 100 to 400 AF/yr.

The Greenbush Draw recharge (Figure 14), after accounting for streambed evapotranspiration (ET), was added as part of a separate study for The Nature Conservancy in 2016 (Lacher, 2016), and was maintained at 2015 levels in this model update through 2100. While this recharge was not incorporated into the 2011 model update, it is far enough from the San Pedro River (SPR) as to have minimal, if any, measurable effect on the simulated flows on the mainstem of the river over the simulation period.

Incidental Recharge

Simulated incidental recharge for septic tanks associated with public and domestic water supply wells outside of sewered areas and for excess irrigation and stock-water infiltration was is calculated as a fixed percentage of pumping for each water-use category throughout the simulation period 2003 to 2100. Figure 15 shows simulated incidental recharge by water-use category for the 2017 and 2011 model updates. The large gap between 2017 and 2011 incidental recharge for municipal/water company wells reflects the identification of several water company wells outside of sewered areas that had no previous septic-system incidental recharge attributed to them.

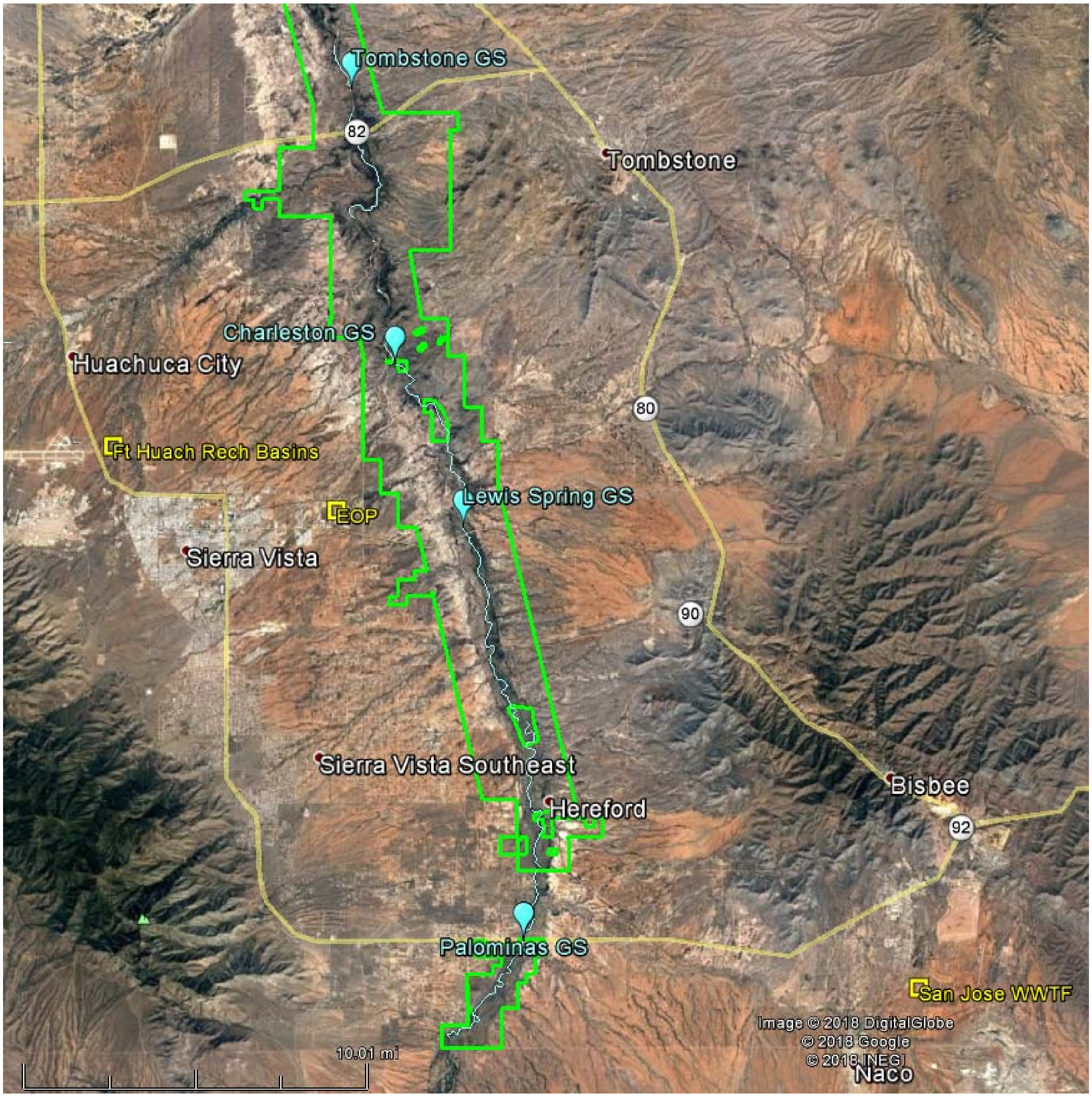

Figure 11. Map showing the Palominas, Lewis Spring, and Charleston stream-flow gaging stations (blue markers) on the Upper San Pedro River within the model area. The SPRNCA is outlined in green. Effluent recharge sites indicated with white boxes.

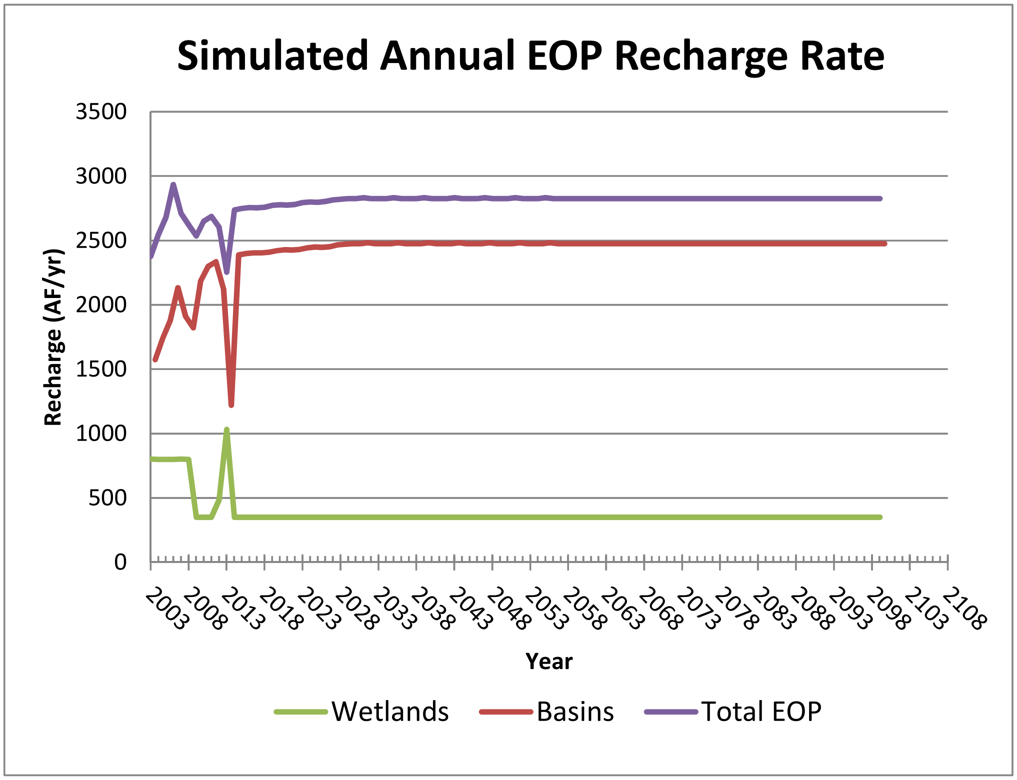

Figure 12. Simulated recharge at the City of Sierra Vista's EOP.

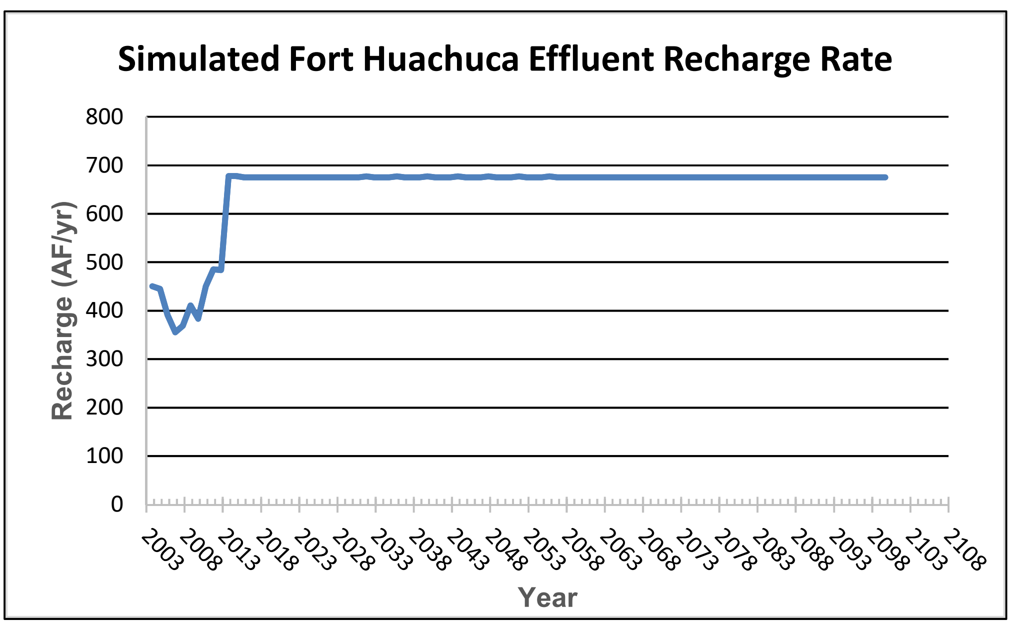

Figure 13. Simulated recharge at the Fort Huachuca WWTF recharge basins.

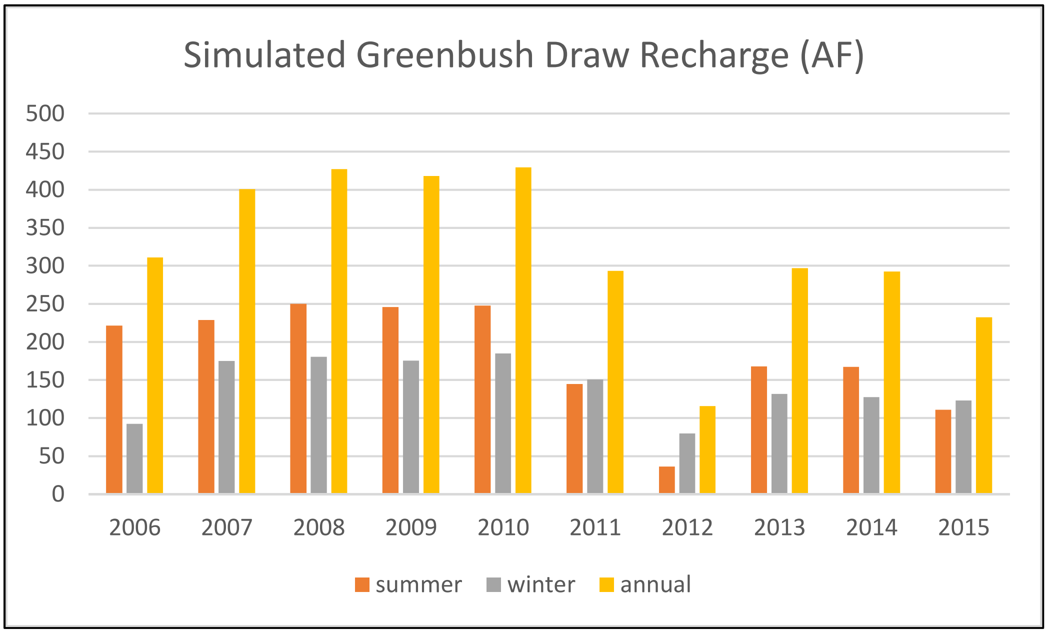

Figure 14. Simulated recharge of treated effluent in Greenbush Draw 2006 to 2015 (Lacher, 2016).

Simulation Results

Water Budget

Figure 16 plots major water budget components from the model output[10] – *net* pumping (extraction minus recharge), stream baseflow, aquifer storage depletion, and ET – for the 2011 model update (Lacher, 2011) and this (2017) model update. As the graph shows, the difference in simulated *net* pumping between the two model updates mirrors the simulated pumping data input shown in Figure 9 and Figure 10. The 2003 values are nearly identical, but the 2017 model update curve for simulated *net* pumping (green line in Table A- 1) quickly drops below the 2011 curve, reaching a minimum of about 37,380 AF for the entire model area in the year 2015 compared to 43,300 AF in the 2011 model update. This difference of about 6,000 AFA of simulated *net* pumping between the two model updates grows to about 9,000 AFA by the end of the simulation period in 2100 when the current model update predicts 44,900 AFA and the 2011 model update predicted 53,900 AFA.

[10] Model output may vary slightly from model input based on number rounding and slightly different accounting for leap years.

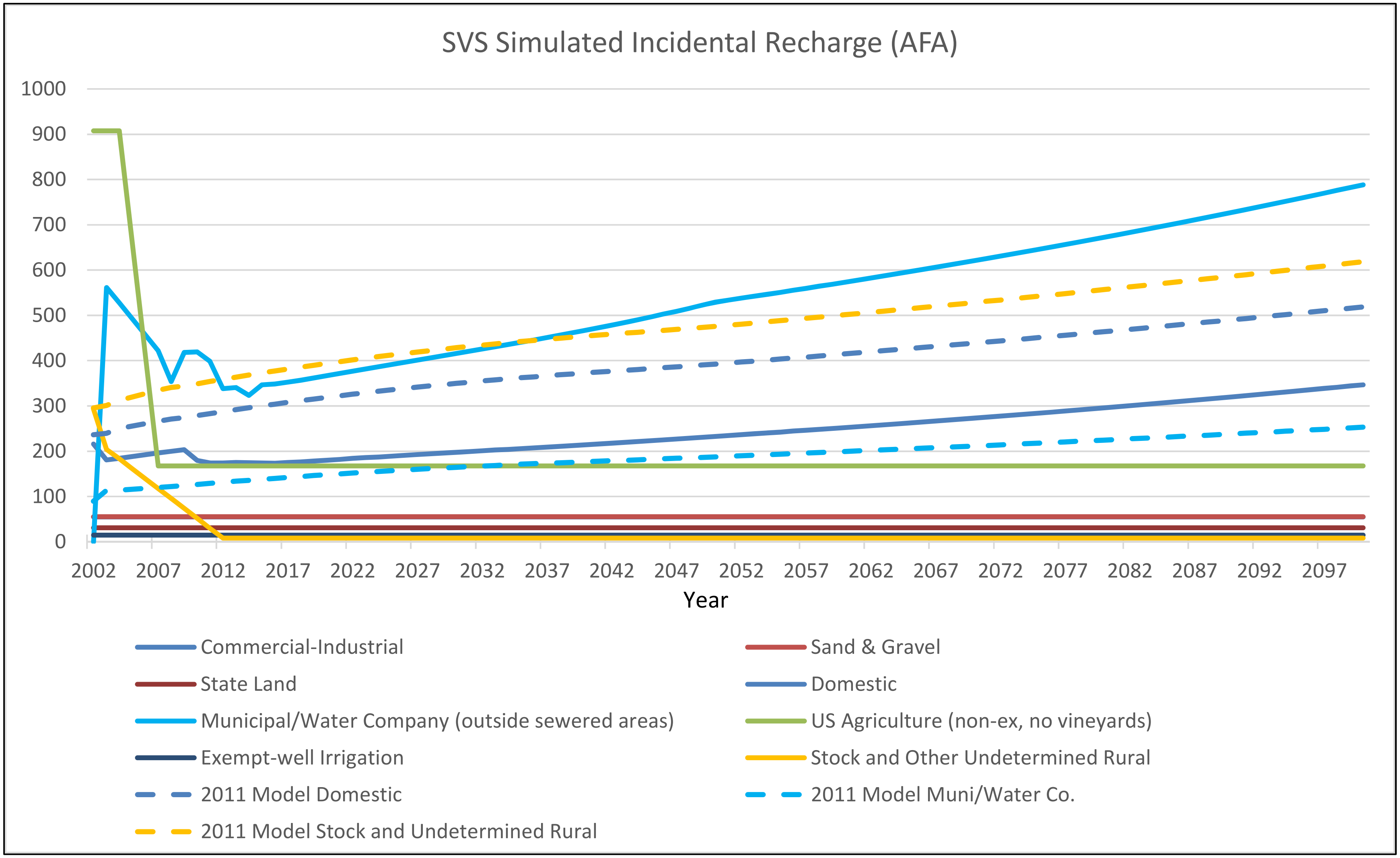

Figure 15. Simulated model recharge by category.

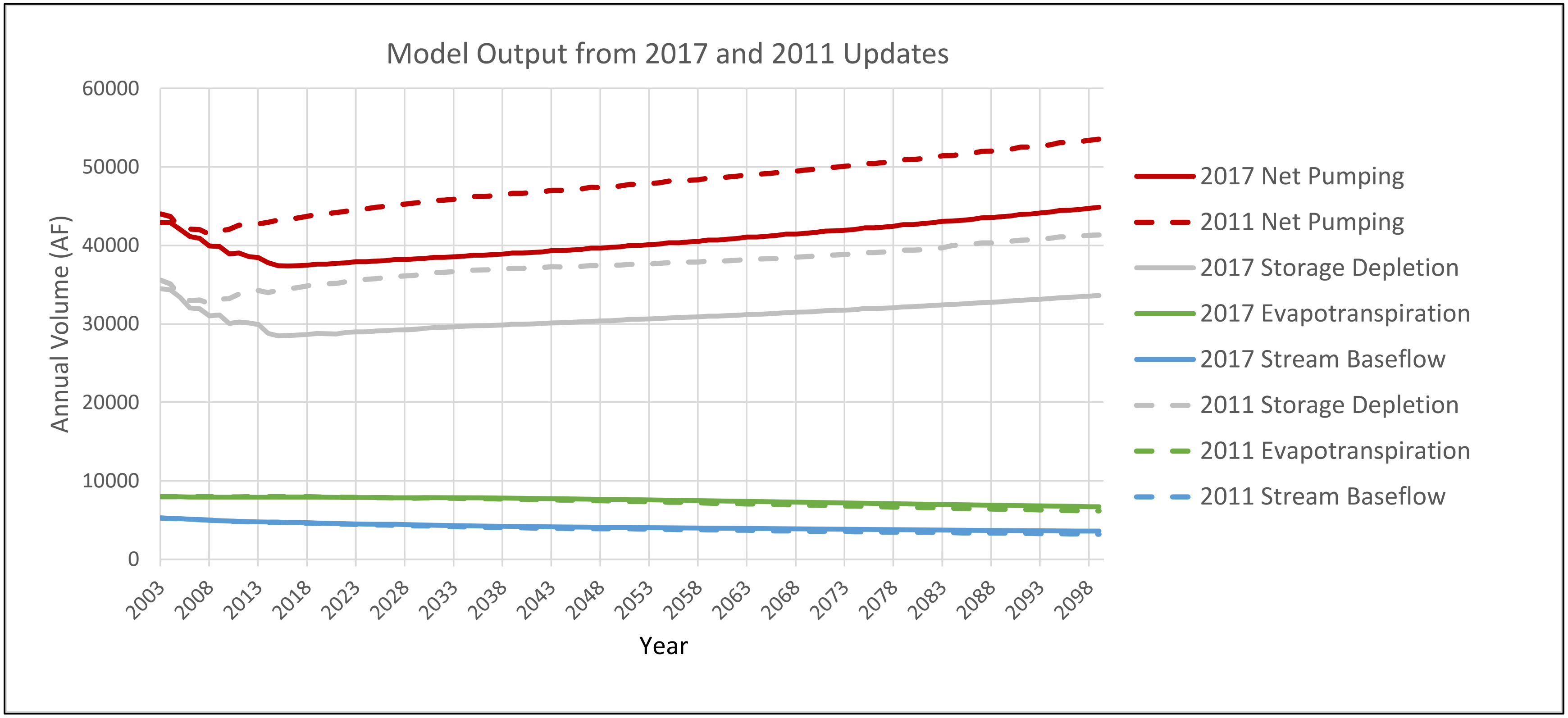

Figure 16. Comparison of water budget components from 2017 and 2011 groundwater model updates by Lacher.

The simulated storage depletion curves for the two model updates (grey solid and dashed lines in Figure 16) almost exactly mirror the trends in net pumping but are about 10,000 AFA less in both model updates. The fact that net pumping exceeds aquifer storage depletion indicates that about 25% of all the water extracted in the model area is being produced from sources other than aquifer storage. These sources include natural recharge and MAR (about 22,000) and capture (pumping induced losses). Possible sources of groundwater capture in the model area include: 1) trans-basin groundwater flow on the downstream (northern) end of the model area; 2) evapotranspiration, and 3) stream baseflow.

Figure 17 illustrates the simulated water budget components as output from the 2017 model update. This figure includes the natural recharge and MAR component, which varies from about 20,000 to 22,000 during the simulation period. The increases in this component reflect changes in recharge at the Sierra Vista EOP and in Greenbush Draw. Natural, incidental, and managed aquifer recharge are the only inputs to the model water budget each year, and they are sources of supply for ET and stream baseflow, which, in addition to pumping, are abstractions from the water budget.

Capture

As net pumping increases over time from 37,400 AFA in 2015 to about 45,000 AFA (a 7,600 AFA increase) in 2100, aquifer storage depletion increases from about 28,500 AFA to 33,500 AFA (a 5,000 AFA increase). The difference between net pumping and aquifer depletion must derive from either recharge or capture. The natural groundwater system is characterized by an equilibrium between natural recharge (R) and natural discharge out of the basin (D) which can be expressed as:

$$R = D \qquad (1)$$

Under steady-state equilibrium conditions, change in aquifer storage (ΔS) is zero, so:

$$\Delta S = R - D = 0 \qquad (2)$$

When pumping (P) is imposed on a system, aquifer storage is the first source of water extracted by pumping wells. Thus,

$$P = \Delta S \qquad (3)$$

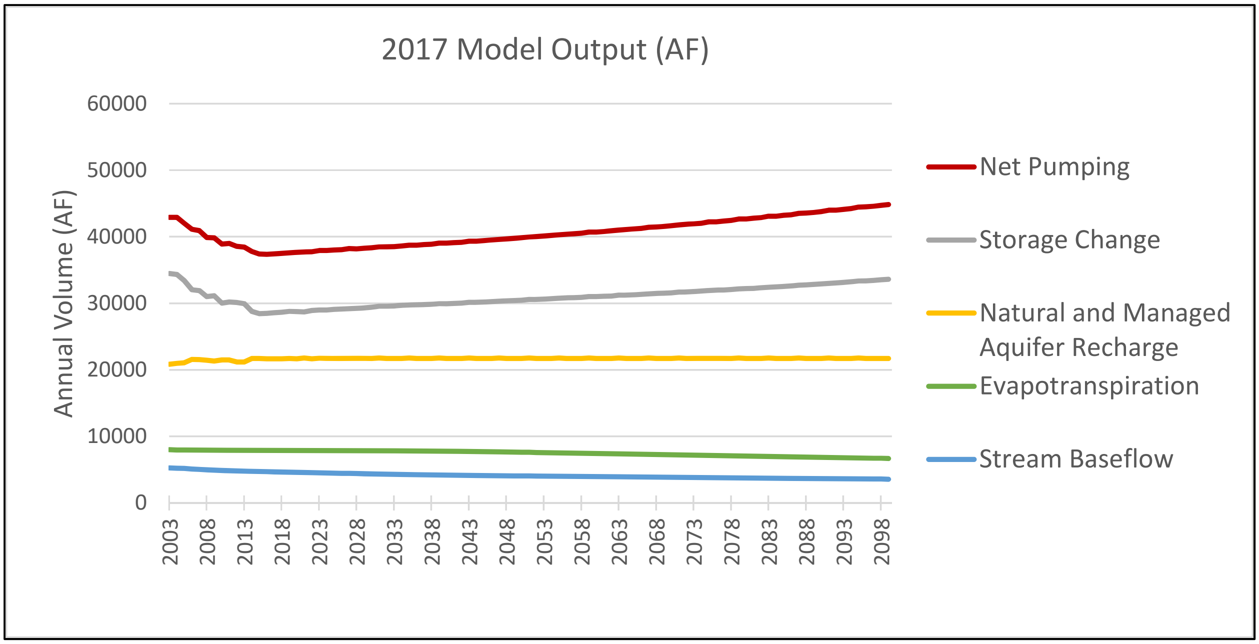

Figure 17. Model output of water budget components from the 2017 model update.

But in order for change in storage to be nonzero, R and D must eventually change. These changes can be written as ΔR and ΔD, and now

$$P = \Delta S + \Delta R + \Delta D \tag{4}$$

Or, if capture (C) is defined as ΔR + ΔD, then equation (4) may be rearranged to:

$$C = P - \Delta S \tag{5}$$

Since the only possible change in recharge comes from MAR, [11] then MAR = ΔR and equation (4) becomes:

$$P - \Delta S = MAR + \Delta D \tag{6}$$

Substituting equation (5) into equation (6) gives:

$$C = MAR + \Delta D \tag{7}$$

In the case of the USPB, ΔD consists primarily of <u>declining ET and stream baseflows (eg, riparian water)</u>, but also includes a small amount of reduced groundwater flow through the north end of the basin.[12] From equation (6), if P exceeds ΔS, then either MAR or ΔD, or both, must increase.[13] This is the situation in the

[11] Pumping cannot induce a change in natural recharge when the groundwater table is far below the surface as it is in the USPB.

[12] Simulated groundwater outflow from the basin declines by about 22 AFA from 2003 to 2100 in this study.

[13] Increasing ΔD means less water leaving the basin.

USPB. As pumping increases, aquifer storage can only partially meet the groundwater demand. Even though significant MAR occurs at the Sierra Vista EOP (approximately 2,800 AFA), evidence that this MAR is insufficient to supply all of the pumping-induced capture is provided by the fact that simulated discharge leaving the basin – primarily in the form of ET and stream baseflow – is decreasing (i.e., ΔD is increasing). Beyond what MAR is able to supply, additional capture is essentially limited to declines in ET and baseflow, as expressed in equation (8):

$$C - MAR = \Delta D \quad (8)$$

Figure 18 illustrates this concept by plotting simulated riparian water (declining baseflow and ET are the main components of ΔD) and capture (P-ΔS) minus MAR, which equals ΔD. The two sets of curves in Figure 18 illustrate how the increasing *change*[14] in discharge (ΔD) is exactly matched by decreasing riparian water. Note that this capture does not include any capture that occurred in the previous century. Thus, compared to the 2011 model update, this study finds that reducing simulated net pumping across the SVS by roughly 6,000 to 9,000 AFA over the 2016 to 2100 period yields an increase in simulated riparian water (baseflow plus ET) of about 919 AFA by 2100, where 384 AFA is baseflow and 535 AFA is ET.

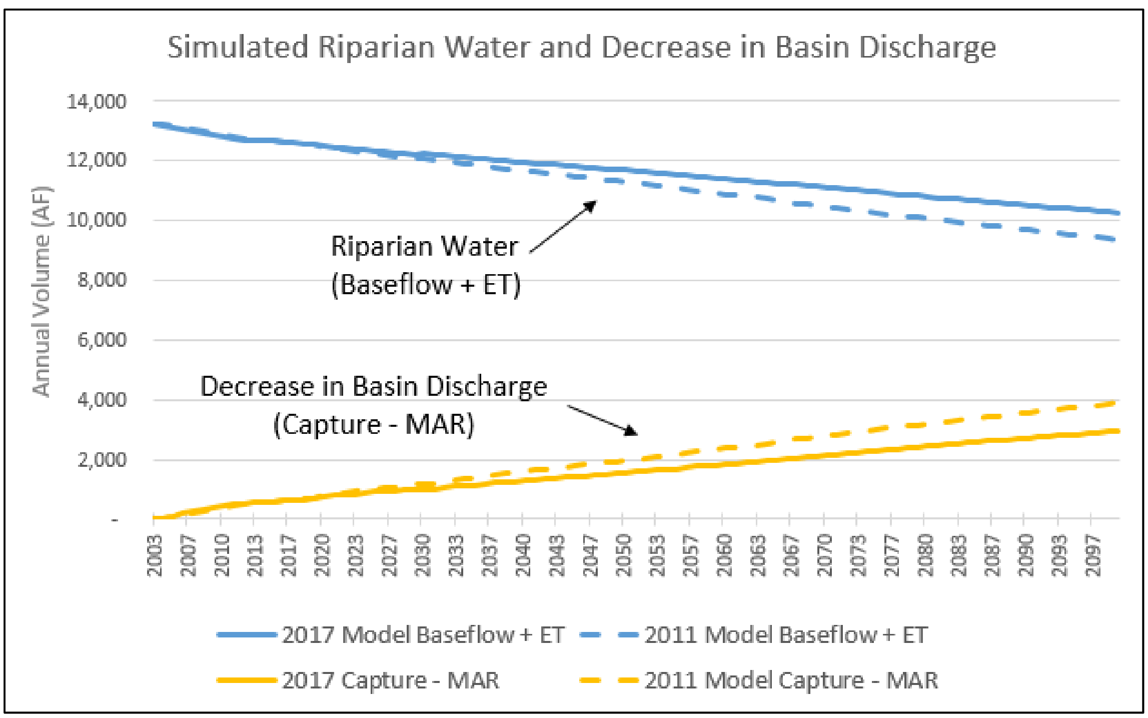

Figure 18. Simulated riparian water (baseflow plus ET) and decrease in basin discharge (pumping-induced capture minus MAR) over the 2003 to 2100 simulation period for the 2017 and 2011 model updates.

[14] In this case, increasing change in discharge from the basin means less water leaving the basin.

Baseflow

The lower net pumping projections over the 21st century in this study compared to the 2011 model update reduced the simulated pumping-related declines in stream baseflow in the USPB. Simulated baseflow for the 2011 and 2017 model updates at the three stream-flow gaging stations along the SPR shown in Figure 11 are plotted in Figure 19, Figure 20, and Figure 21. In each case, the 2017 model simulated baseflows are higher than the 2011 model update values. Despite the higher simulated baseflows relative to the 2011 model update, all of the simulated baseflow curves in this study show declining trends starting before 2040. For Palominas, the decline starts immediately in the new (2017) model, in contrast to a brief increase in flow followed by a steep decline in the 2011 model. The initial increase in the 2011 model reflects a recovery in the hydrologic system after the cessation of pumping from several large agricultural wells in the area from the 1980's to early 2000's. While this recovery is still present in the new model update, its impact on baseflows is more subdued because of updated domestic pumping rates in the area. Simulated baseflows at Lewis Spring and Charleston are influenced by the development of a groundwater mound under the EOP. This mound produces a simulated rise in baseflows until about 2030 before they begin to decline at both locations.

The curves in Figures Figure 19 through Figure 21 are plotted at different vertical scales for visibility, but the biggest absolute difference between simulated baseflows in this study and the 2011 model update occurs at the Charleston location (Figure 21). The average simulated baseflow at the Charleston site was 2,269 AFA in the 2011 model, and 2,461 AFA in the 2017 model update. By 2100, the 2017 model values exceed the 2011 model values by 408 AFA (0.56 cubic feet per second (cfs)), which is about 17% of the average simulated baseflow over the 2003 to 2100 period in this study (Table 2). The gap between the 2011 and 2017 model simulated baseflows at Lewis Spring in 2100 was 34 AFA (0.05 cfs), or about 13% of the average simulated baseflow in the 2017 model update. In the case of the Palominas stream-gaging station, the 2011 model predicted that baseflows would drop to zero by 2083 (Figure 19). However, the 2017 model predicts that flows will remain at about 117 AFA (0.16 cfs) by the year 2100, which is roughly 39% of the average simulated baseflow of 300 AFA for the entire simulation period (Table 2). Simulated average baseflows at Charleston, Lewis Spring and Palominas for both model updates are provided in Table 2.

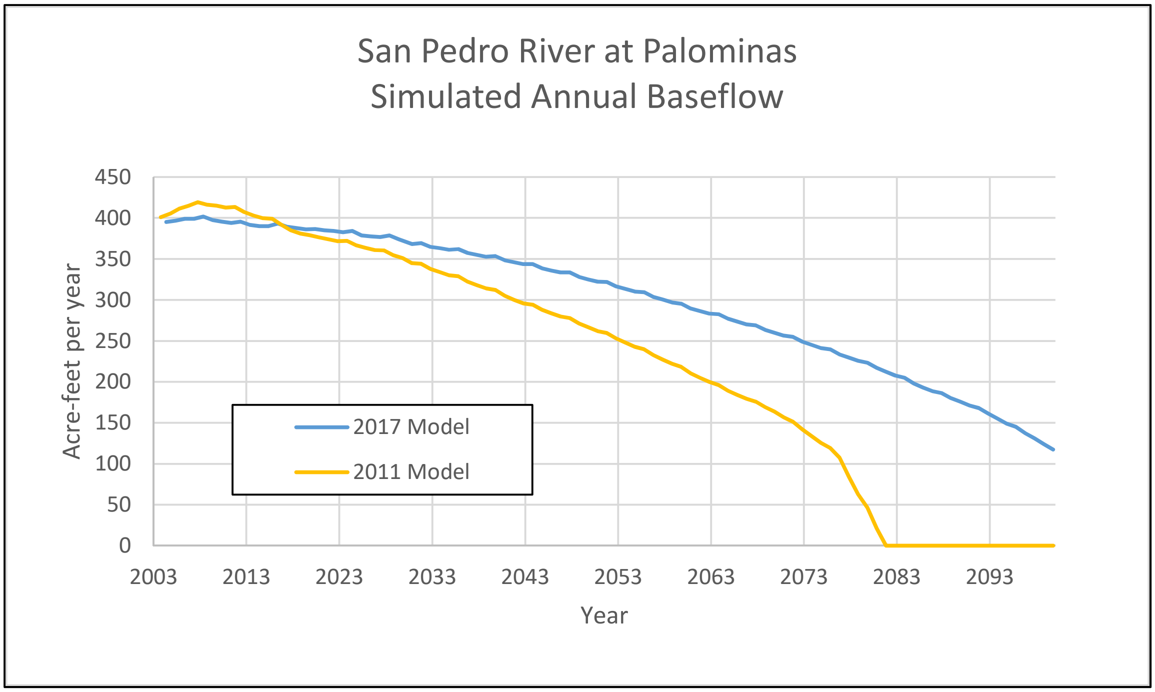

Figure 19. Simulated baseflow at the Palominas stream-gaging station.

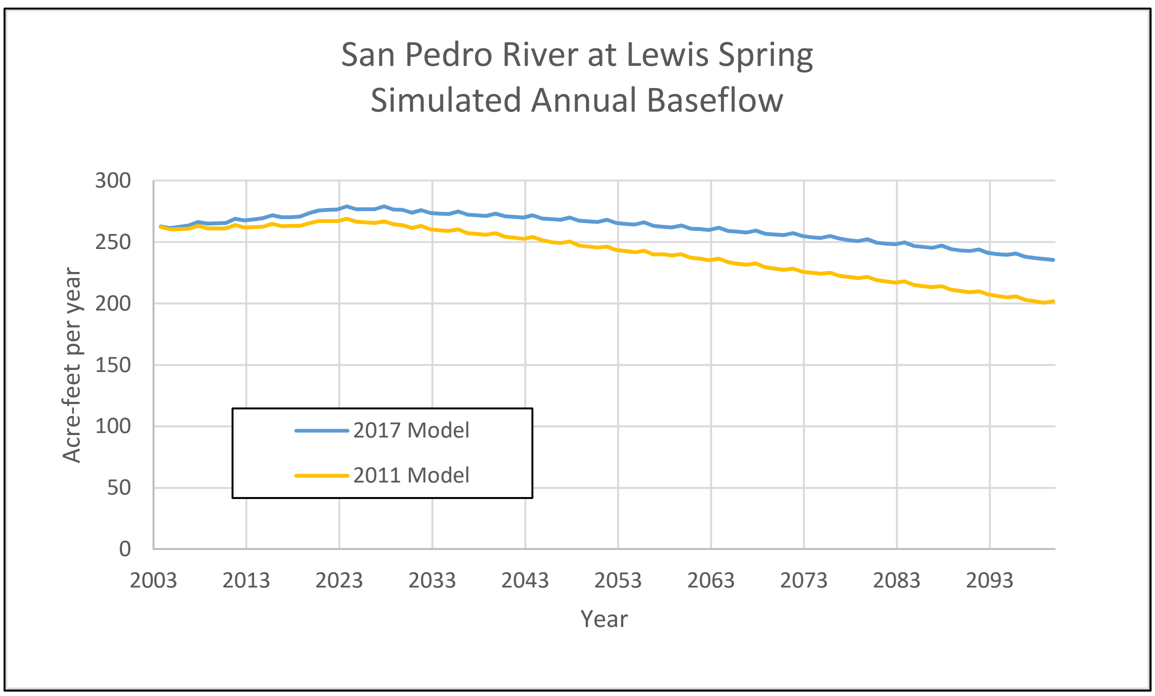

Figure 20. Simulated baseflow at the Lewis Spring staff-gage location.

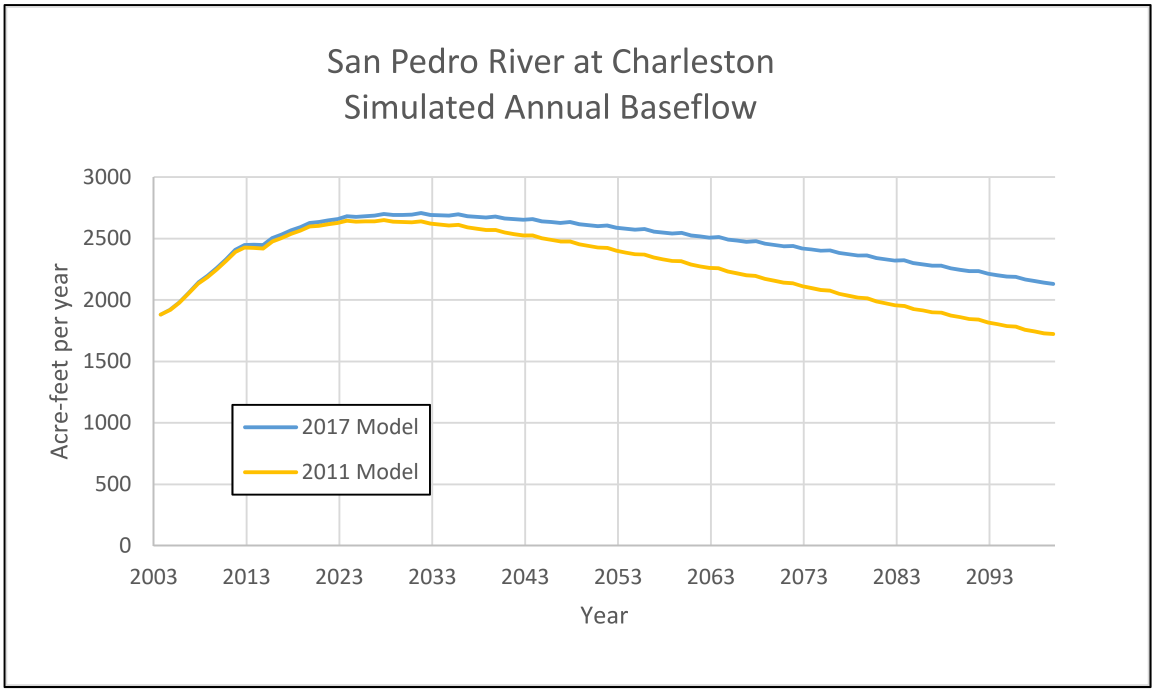

Figure 21. Simulated baseflow at the Charleston stream-gaging station.

Table 2. Simulated Average Baseflow, 2003-2100, for 2011 and 2017 Model Updates (AFA).

Location	**2011 Model Update**		**2017 Model Update**	
	AFA	cfs	AFA	Cfs
Charleston	2269	3.1	2461	3.4
Lewis Spring	241	0.33	262	0.36
Palominas	228	0.31	300	0.41

Figure 22 and Figure 23 show maps of the change in simulated baseflow in cfs from 2003 to the years 2025, 2050, 2075 and 2100 for the 2017 and 2011 model updates, respectively. Comparison of the two figures shows a much stronger persistence in positive baseflow changes (above 2003 levels) in the lower (northern) portion of the mainstem of the SPR in the 2017 model compared to the 2011 model. The cool blue and green colors indicate positive change from 2003, while the warm red and yellow colors indicate a decline in flow rates from 2003 levels. The cool colors persist on the lower (northern) part of the mainstem of the SPR (below the EOP almost to the Babocomari confluence) through 2100 in this study (Figure 22), but in the 2011 model (Figure 23), all mainstem SPR flows are below 2003 levels by the year 2100. Despite the higher simulated baseflows on the mainstem of the SPR in the 2017 model, simulated

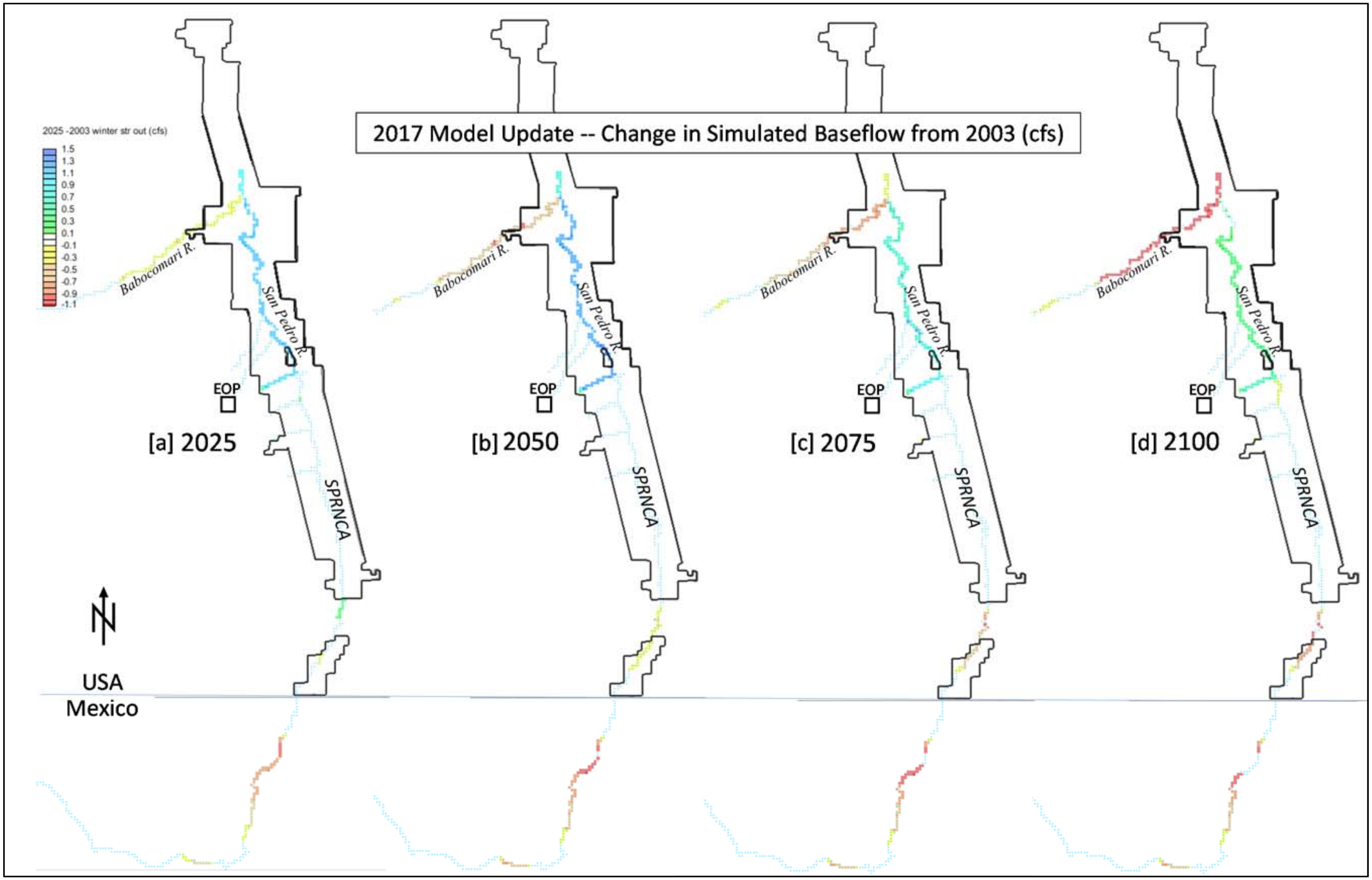

Figure 22. Change in simulated baseflow compared to 2003 in 2025, 2050, 2075, and 2100 for this study. River location shown by light blue dots.

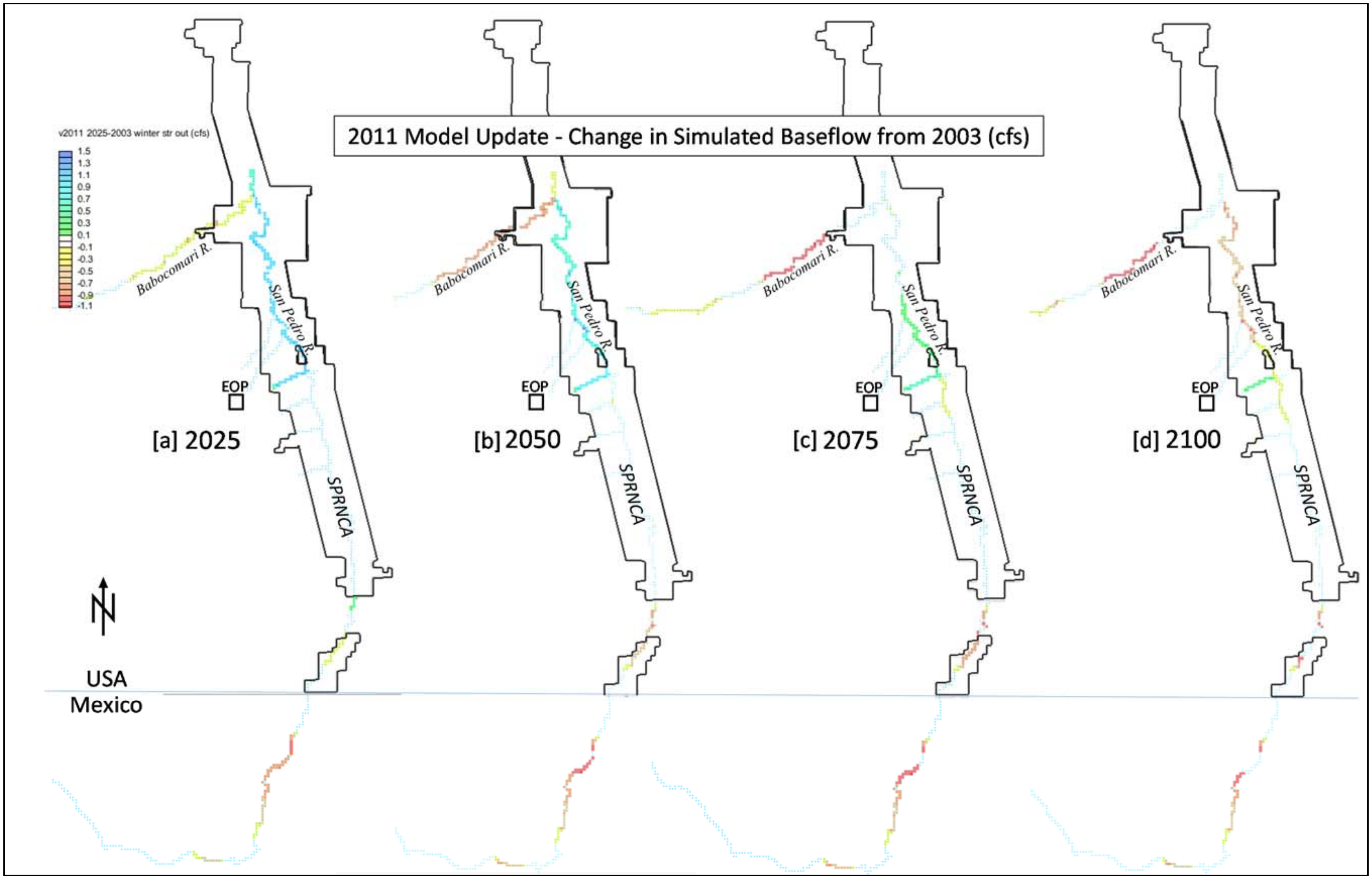

Figure 23. Change in simulated baseflow compared to 2003 in 2025, 2050, 2075, and 2100 for the 2011 model update by Lacher. River location shown by light blue dots.

baseflow losses (relative to 2003 conditions) on the Babocomari and south of the main SPRNCA boundary in the SVS and in Mexico persist in both sets of simulations. These results reinforce the ongoing need to use both modeling and monitoring results to inform future MAR efforts over the next century in order to maintain the groundwater conditions that are capable of supporting both streamside forests and baseflows.

Figure 24 plots the difference in simulated baseflow between the 2017 and 2011 model updates for simulation years 2050 (a) and 2100 (b). The 2050 plot (Figure 24[a]) shows that this study's simulated baseflows on the mainstem of the SPR and the lower reaches of the Babocomari River exceed the 2011 model update values by about 0.6 and 0.5 cfs (434 and 362 AFA), respectively, above the confluence, but that the two models diverge by more than 1 cfs (724 AFA) below the confluence, near the north end of the model area. By 2100 (Figure 24[b]), the 2017 model simulates baseflows of 0.7 to 0.8 cfs (507 to 579 AFA) higher than the 2011 model on the mainstem SPR between the EOP and the Babocomari confluence. The difference between the two models is only about 0.1 cfs (72 AFA) on the Babocomari by the year 2100, and below the confluence, the 2017 model predicts baseflow of just under 1 cfs (724 AFA) more than the 2011 model predicted for the same time period. Because artificial recharge at the EOP, which has a strong influence on the mainstem SPR below the EOP, is held constant in the two simulations, all of the difference between the two models results solely from updates to pumping.[15] The simulated Palominas-area baseflows in this study are 0.2 to 0.4 cfs (145 to 290 AFA) higher than those in the 2011 study in 2050 (Figure 24[a]), and over 0.5 cfs (362 AFA) greater than the 2011 model values by the year 2100 (Figure 24[b]), as noted in the discussion of Figure 19 above.

Summary and Conclusions

This study updated simulated pumping and incidental recharge rates for public water supply, domestic, golf course, and stock wells in the SVS for the period 2003 to 2015 using the best available data as of 2017. After 2015, the most recent sub-county level population projections from the U.S. Census were used to project public water supply (municipal and water company) and domestic (rural) pumping rates to 2100. Simulated pumping for wells supplying water for large agriculture and other irrigation, mining, and commercial, industrial, and institutional uses was held constant at 2002 levels throughout the 2003 to 2100 simulation period in lieu of more current information. Simulated MAR at the City of Sierra Vista's

[15] MAR at the San José WWTF was not included in the 2011 model update but its effect on SPR flows in these simulations is negligible.

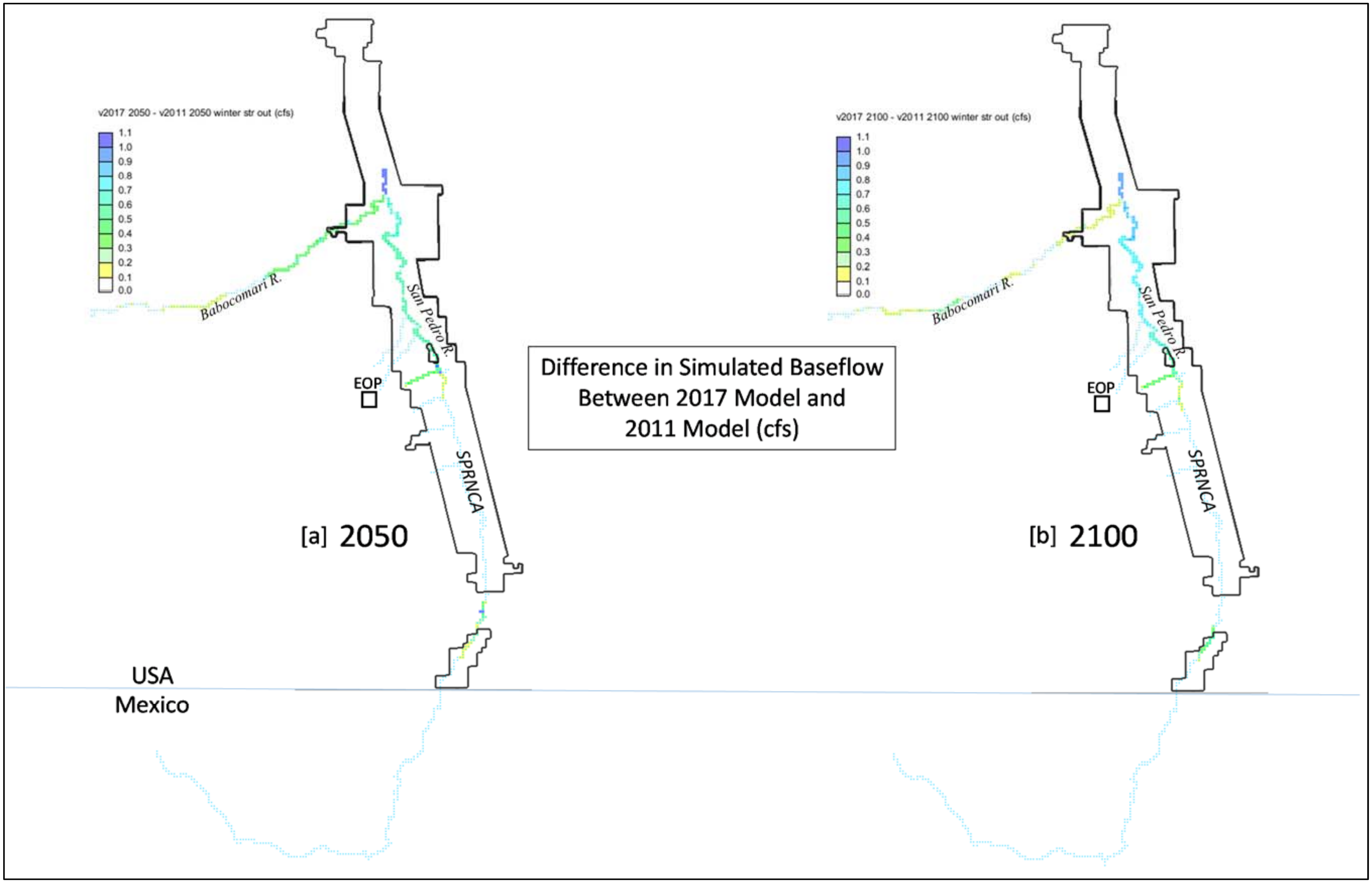

Figure 24. Difference in simulated baseflow between the 2017 and the 2011 model updates for the years 2050 and 2100. River location shown by light blue dots.

Environmental Operations Park (EOP) was updated to 2013 then increased slightly to 2030 before being held constant for the remainder of the simulation period in both the 2011 and 2017 model updates. Simulated MAR in Greenbush Draw near Naco was updated to 2015 and then held constant to 2100 in the 2017 model update and was not included in the 2011 model.

The results of this study's pumping and recharge updates were compared with the last similar update conducted by Lacher in 2011. Lower-than-expected population growth and declining per-capita water use rates in the SVS resulted in projected public water supply and domestic pumping rates on the order of 4,000 AFA less for the period 2016 to 2100 in this study compared to the previous model update (Lacher, 2011). Domestic pumping in this study was based on recent research by Plateau Resources, LLC (2013) and Western Resources Advocates (2012) to estimate actual unmetered-well water use in the SVS. This method marks a departure from previous modeling efforts by Goode and Maddock (2000) and Pool and Dickinson (2007) where unmetered-well pumping was based largely on well dimensions rather than actual estimated per-household water use for the local area. Total net SVS pumping in this study increased from a low in 2015 of about 37,350 AFA to a maximum of about 44,850 AFA by 2100. In the 2011 model update, Lacher simulated net SVS pumping of 43,300 AFA in 2015 increasing to 53,760 AFA in 2100. The lower net pumping projections in the current study relative to the 2011 study produced smaller simulated pumping-related depletions of riparian water (simulated ET and stream baseflow). However, the nearly 6,000- to 9,000-AFA reduction in simulated net pumping over most of the simulation period resulted in just a 930-AFA benefit to the riparian system (in the form of increased simulated baseflow plus ET) by the year 2100 relative to the 2011 model update. After accounting for the long-term MAR from the EOP near the Charleston stream-flow gaging station on the SPR, simulated pumping-induced capture of riparian water (ET and baseflow) reached a maximum of 2,964 AFA in 2100 in this study compared with 3,893 AFA in the 2011 study.

The lower pumping rates in this study resulted in a 408-AFA (0.56-cfs; 17% of mean) higher simulated baseflow rate in the SPR at Charleston by 2100 compared to the 2011 study. The simulated 2100 baseflow rates for this study at Lewis Spring and Palominas exceeded those of the 2011 study by roughly 33 AFA (.05 cfs; 13% of mean) and 117 AFA (0.16 cfs; 39% of mean), respectively.

The capture analysis in this study demonstrates that simulated natural recharge and existing MAR are insufficient to meet the net pumping demand in the model area, even at the reduced pumping rates in this study compared with the 2011 model update by Lacher. Evidence of this imbalance is provided by the fact that simulated riparian water (baseflow and ET – the primary sources of pumping-induced capture) decreases steadily throughout the simulation period. Because of the large distance between the surface and the groundwater system across most of the SVS, the only mechanisms for reducing the rate of capture (from the riparian system) are increasing MAR or decreasing pumping. Conservation efforts over the past 15 years in the SVS have pushed per-capita water use downward. Efforts to continue that trend and to increase near-stream MAR may further protect SPR baseflows in future.

Recommendations for Future Work

This study addressed pumping in the SVS over the period 2003 to 2100. Additional efforts that could improve on the work in this study include:

1. Updating pumping in Mexico;
2. Assessing and updating turf watering practices and re-estimating incidental recharge rates based on current irrigation practices;
3. Updating Fort Huachuca pumping and recharge values;
4. Running climate-change scenarios with varied natural recharge.

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APPENDIX A

SIMULATED ANNUAL PUMPING AND RECHARGE FOR 2017 AND 2011 MODEL UPDATES

Table A- 1. Simulated Pumping and Incidental Recharge (2003-2100) for 2017 Model Update

Water Budget (AF) -2017 Model Update																
	USGS Model	2017 Model Update														
PUMPING - By Category	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
US Agriculture (non-exempt, no vineyards)	-2,844	-2,844	-2,844	-1,640	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436
Mexico	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591
US Mining	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799
Fort Huachuca	-1,547	-1,539	-1,531	-1,523	-1,515	-1,560	-1,129	-1,225	-1,145	-1,033	-985	-1,012	-1,024	-1,059	-1,043	-1,043
Golf Course	-1,085	-848	-830	-703	-658	-505	-588	-722	-614	-620	-674	-644	-637	-549	-549	-549
Municipal/Water Company	-8,205	-9,358	-9,502	-9,696	-9,729	-9,590	-9,062	-8,966	-8,504	-8,766	-8,476	-8,319	-7,654	-7,285	-7,346	-7,392
Vineyard	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330
State Land	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171
Commercial-Industrial	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303
Sand & Gravel	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307
Domestic	-1,234	-1,261	-1,288	-1,280	-1,341	-1,369	-1,395	-1,422	-1,252	-1,215	-1,216	-1,224	-1,220	-1,217	-1,212	-1,222
Exempt-well Irrigation	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83
Stock and Other Undetermined Rural	-1,657	-1,497	-1,337	-1,177	-1,017	-857	-697	-537	-377	-217	-57	-57	-57	-57	-57	-57
Total Pumping	**-44,158**	**-44,934**	**-44,918**	**-43,605**	**-42,282**	**-41,903**	**-40,894**	**-40,893**	**-39,913**	**-39,872**	**-39,430**	**-39,279**	**-38,614**	**-38,188**	**-38,228**	**-38,284**
SVS only	-21,566	-22,342	-22,327	-21,014	-19,691	-19,311	-18,302	-18,301	-17,322	-17,281	-16,838	-16,687	-16,023	-15,596	-15,637	-15,692
RECHARGE																
Commercial-Industrial	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
Sand & Gravel	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
State Land	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Domestic	216	181	184	183	192	196	200	204	179	174	174	175	175	174	174	175
Municipal/Water Company (outside sewered areas)	0	562	528	501	451	422	354	418	419	398	338	341	323	346	348	352
US Agriculture (non-exempt, no vineyards)	907	907	907	537	167	167	167	167	167	167	167	167	167	167	167	167
Exempt-well Irrigation	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Stock and Other Undetermined Rural	293	204	183	161	140	118	96	74	52	30	8	8	8	8	8	8
Total Recharge	**1,572**	**2,009**	**1,959**	**1,539**	**1,106**	**1,058**	**972**	**1,018**	**973**	**925**	**843**	**847**	**829**	**852**	**853**	**858**
Net Pumping	-42,586	-42,924	-42,959	-42,066	-41,176	-40,844	-39,922	-39,875	-38,940	-38,947	-38,586	-38,432	-37,786	-37,336	-37,376	-37,426

Table A-1 (cont'd)

	2017 Model Update																			
PUMPING - By Category	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**
US Agriculture (non-exempt, no vineyards)	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436
Mexico	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591
US Mining	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799
Fort Huachuca	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043
Golf Course	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549
Municipal/Water Company	-7,451	-7,517	-7,585	-7,653	-7,720	-7,786	-7,852	-7,917	-7,982	-8,046	-8,109	-8,172	-8,236	-8,299	-8,362	-8,426	-8,489	-8,553	-8,617	-8,682
Vineyard	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330
State Land	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171
Commercial-Industrial	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303
Sand & Gravel	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307
Domestic	-1,233	-1,246	-1,259	-1,272	-1,284	-1,297	-1,309	-1,321	-1,333	-1,345	-1,357	-1,368	-1,380	-1,392	-1,403	-1,414	-1,426	-1,437	-1,449	-1,460
Exempt-well Irrigation	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83
Stock and Other Undetermined Rural	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57
Total Pumping	**-38,355**	**-38,433**	**-38,514**	**-38,594**	**-38,674**	**-38,753**	**-38,831**	**-38,909**	**-38,985**	**-39,061**	**-39,136**	**-39,211**	**-39,285**	**-39,361**	**-39,435**	**-39,510**	**-39,585**	**-39,660**	**-39,736**	**-39,812**
SVS only	-15,763	-15,842	-15,923	-16,003	-16,083	-16,162	-16,240	-16,317	-16,394	-16,470	-16,545	-16,619	-16,694	-16,769	-16,844	-16,919	-16,993	-17,069	-17,144	-17,221
RECHARGE																				
Commercial-Industrial	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
Sand & Gravel	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
State Land	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Domestic	177	178	180	182	184	186	187	189	191	193	194	196	198	199	201	203	204	206	207	209
Municipal/Water Company (outside sewered areas)	357	362	367	372	377	382	387	391	396	401	406	411	416	421	426	430	436	441	446	451
US Agriculture (non-exempt, no vineyards)	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167
Exempt-well Irrigation	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Stock and Other Undetermined Rural	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Total Recharge	**864**	**871**	**878**	**885**	**891**	**898**	**905**	**912**	**918**	**925**	**931**	**938**	**944**	**951**	**957**	**964**	**971**	**977**	**984**	**991**
Net Pumping	-37,490	-37,562	-37,636	-37,710	-37,783	-37,855	-37,926	-37,997	-38,067	-38,137	-38,205	-38,273	-38,341	-38,410	-38,478	-38,546	-38,614	-38,683	-38,752	-38,821

Table A-1 (cont'd)

Water Budget (AF) -2017 Model Update

	2017 Model Update																			
PUMPING - By Category	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**	**2051**	**2052**	**2053**	**2054**	**2055**	**2056**	**2057**
US Agriculture (non-exempt, no vineyards)	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436
Mexico	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591
US Mining	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799
Fort Huachuca	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043
Golf Course	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549
Municipal/Water Company	-8,748	-8,814	-8,881	-8,949	-9,019	-9,090	-9,162	-9,236	-9,312	-9,389	-9,469	-9,550	-9,633	-9,710	-9,788	-9,866	-9,945	-10,025	-10,105	-10,186
Vineyard	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330
State Land	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171
Commercial-Industrial	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303
Sand & Gravel	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307
Domestic	-1,472	-1,484	-1,496	-1,508	-1,520	-1,532	-1,545	-1,558	-1,571	-1,584	-1,598	-1,612	-1,626	-1,639	-1,652	-1,665	-1,678	-1,692	-1,705	-1,719
Exempt-well Irrigation	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83
Stock and Other Undetermined Rural	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57
Total Pumping	**-39,890**	**-39,968**	**-40,047**	**-40,127**	**-40,208**	**-40,292**	**-40,377**	**-40,464**	**-40,552**	**-40,643**	**-40,736**	**-40,831**	**-40,929**	**-41,019**	**-41,110**	**-41,201**	**-41,294**	**-41,387**	**-41,480**	**-41,575**
SVS only	-17,298	-17,376	-17,455	-17,535	-17,617	-17,700	-17,785	-17,872	-17,961	-18,052	-18,145	-18,240	-18,337	-18,428	-18,518	-18,610	-18,702	-18,795	-18,889	-18,983
RECHARGE																				
Commercial-Industrial	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
Sand & Gravel	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
State Land	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Domestic	211	212	214	216	218	219	221	223	225	227	229	231	233	235	237	238	240	242	244	246
Municipal/Water Company (outside sewered areas)	456	462	467	473	478	484	490	496	503	509	516	522	529	534	538	542	546	551	555	560
US Agriculture (non-exempt, no vineyards)	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167
Exempt-well Irrigation	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Stock and Other Undetermined Rural	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Total Recharge	**998**	**1,005**	**1,012**	**1,019**	**1,027**	**1,035**	**1,042**	**1,050**	**1,058**	**1,067**	**1,075**	**1,084**	**1,093**	**1,099**	**1,105**	**1,111**	**1,118**	**1,124**	**1,130**	**1,137**
Net Pumping	-38,892	-38,963	-39,034	-39,107	-39,181	-39,257	-39,335	-39,413	-39,494	-39,576	-39,661	-39,747	-39,836	-39,920	-40,004	-40,090	-40,176	-40,262	-40,350	-40,438

Table A-1 (cont'd)

Water Budget (AF) -2017 Model Update																				
	2017 Model Update																			
PUMPING - By Category	**2058**	**2059**	**2060**	**2061**	**2062**	**2063**	**2064**	**2065**	**2066**	**2067**	**2068**	**2069**	**2070**	**2071**	**2072**	**2073**	**2074**	**2075**	**2076**	**2077**
US Agriculture (non-exempt, no vineyards)	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436
Mexico	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591
US Mining	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799
Fort Huachuca	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043
Golf Course	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549
Municipal/Water Company	-10,267	-10,349	-10,432	-10,516	-10,600	-10,685	-10,770	-10,856	-10,943	-11,031	-11,119	-11,208	-11,297	-11,388	-11,479	-11,571	-11,663	-11,757	-11,851	-11,946
Vineyard	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330
State Land	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171
Commercial-Industrial	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303
Sand & Gravel	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307
Domestic	-1,733	-1,747	-1,761	-1,775	-1,789	-1,803	-1,818	-1,832	-1,847	-1,862	-1,876	-1,891	-1,907	-1,922	-1,937	-1,953	-1,968	-1,984	-2,000	-2,016
Exempt-well Irrigation	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83
Stock and Other Undetermined Rural	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57
Total Pumping	**-41,670**	**-41,766**	**-41,863**	**-41,960**	**-42,059**	**-42,158**	**-42,258**	**-42,358**	**-42,460**	**-42,562**	**-42,665**	**-42,769**	**-42,874**	**-42,980**	**-43,086**	**-43,193**	**-43,302**	**-43,411**	**-43,521**	**-43,631**
SVS only	-19,079	-19,175	-19,271	-19,369	-19,467	-19,566	-19,666	-19,767	-19,868	-19,971	-20,074	-20,178	-20,283	-20,388	-20,495	-20,602	-20,710	-20,819	-20,929	-21,040
RECHARGE																				
Commercial-Industrial	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
Sand & Gravel	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
State Land	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Domestic	248	250	252	254	256	258	260	262	264	267	269	271	273	275	277	280	282	284	286	289
Municipal/Water Company (outside sewered areas)	564	569	573	578	582	587	592	597	601	606	611	616	621	626	631	636	641	646	651	656
US Agriculture (non-exempt, no vineyards)	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167
Exempt-well Irrigation	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Stock and Other Undetermined Rural	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Total Recharge	**1,143**	**1,150**	**1,156**	**1,163**	**1,169**	**1,176**	**1,183**	**1,190**	**1,197**	**1,204**	**1,211**	**1,218**	**1,225**	**1,232**	**1,239**	**1,246**	**1,254**	**1,261**	**1,268**	**1,276**
Net Pumping	-40,527	-40,616	-40,706	-40,797	-40,889	-40,981	-41,075	-41,169	-41,263	-41,359	-41,455	-41,552	-41,649	-41,748	-41,847	-41,947	-42,048	-42,150	-42,252	-42,355

Table A-1 (cont'd)

Water Budget (AF) -2017 Model Update

PUMPING - By Category	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099
US Agriculture (non-exempt, no vineyards)	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436
Mexico	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591
US Mining	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799
Fort Huachuca	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043	-1,043
Golf Course	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549	-549
Municipal/Water Company	-12,041	-12,137	-12,235	-12,332	-12,431	-12,530	-12,631	-12,732	-12,834	-12,936	-13,040	-13,144	-13,249	-13,355	-13,462	-13,570	-13,678	-13,788	-13,898	-14,009	-14,121	-14,234
Vineyard	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330	-330
State Land	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171	-171
Commercial-Industrial	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303	-303
Sand & Gravel	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307	-307
Domestic	-2,032	-2,048	-2,065	-2,081	-2,098	-2,115	-2,132	-2,149	-2,166	-2,183	-2,201	-2,218	-2,236	-2,254	-2,272	-2,290	-2,308	-2,327	-2,346	-2,364	-2,383	-2,402
Exempt-well Irrigation	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83
Stock and Other Undetermined Rural	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57
Total Pumping	**-43,743**	**-43,856**	**-43,969**	**-44,084**	**-44,199**	**-44,315**	**-44,432**	**-44,550**	**-44,669**	**-44,789**	**-44,910**	**-45,032**	**-45,155**	**-45,279**	**-45,404**	**-45,530**	**-45,657**	**-45,785**	**-45,914**	**-46,043**	**-46,174**	**-46,307**
SVS only	-21,152	-21,264	-21,378	-21,492	-21,607	-21,724	-21,841	-21,959	-22,078	-22,198	-22,319	-22,441	-22,564	-22,688	-22,813	-22,938	-23,065	-23,193	-23,322	-23,452	-23,583	-23,715
RECHARGE																						
Commercial-Industrial	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
Sand & Gravel	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
State Land	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Domestic	291	293	296	298	300	303	305	308	310	313	315	318	320	323	325	328	331	333	336	339	341	344
Municipal/Water Company (outside sewered areas)	662	667	672	678	683	688	694	700	705	711	716	722	728	734	740	746	752	758	764	770	776	782
US Agriculture (non-exempt, no vineyards)	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167
Exempt-well Irrigation	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Stock and Other Undetermined Rural	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Total Recharge	**1,284**	**1,291**	**1,299**	**1,307**	**1,314**	**1,322**	**1,330**	**1,338**	**1,346**	**1,354**	**1,363**	**1,371**	**1,379**	**1,387**	**1,396**	**1,404**	**1,413**	**1,422**	**1,430**	**1,439**	**1,448**	**1,457**
Net Pumping	-42,460	-42,565	-42,670	-42,777	-42,885	-42,993	-43,102	-43,212	-43,323	-43,435	-43,548	-43,662	-43,776	-43,892	-44,008	-44,125	-44,244	-44,363	-44,483	-44,604	-44,726	-44,849

Table A- 2. Simulated Pumping in 2011 Model Update.

Water Budget (AF) -2011 Model Update																
	USGS Model	2011 Model Update														
PUMPING - By Category	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
US Agriculture (non-ex, no vineyards)	-2,844	-2,844	-2,844	-1,640	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436
Mexico	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591
US Mining	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799
Fort Huachuca	-1,530	-1,548	-1,493	-1,362	-1,164	-1,233	-1,151	-1,192	-1,193	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296
Golf Course	-1,085	-1,105	-1,065	-962	-916	-753	-808	-866	-866	-866	-866	-866	-866	-866	-866	-866
Municipal/Water Company	-9,428	-9,605	-9,284	-9,909	-9,715	-9,603	-9,027	-9,282	-9,438	-9,591	-9,739	-9,889	-10,036	-10,177	-10,314	-10,447
Vineyard	-330	-338	-348	-356	-368	-378	-384	-386	-392	-397	-401	-406	-411	-416	-420	-424
State Land	-171	-171	-181	-185	-190	-189	-194	-197	-202	-206	-210	-215	-219	-223	-227	-231
Commercial-Industrial	-303	-309	-321	-327	-333	-337	-343	-346	-351	-357	-362	-367	-372	-377	-382	-386
Sand & Gravel	-307	-307	-325	-332	-341	-340	-349	-354	-363	-371	-378	-386	-394	-402	-409	-416
Domestic	-1,337	-1,355	-1,412	-1,443	-1,484	-1,505	-1,533	-1,549	-1,574	-1,600	-1,624	-1,648	-1,672	-1,694	-1,717	-1,738
Exempt-well Irrigation	-83	-85	-88	-90	-93	-95	-97	-98	-99	-100	-101	-103	-104	-105	-106	-107
Stock and Other Undetermined Rural	-1,657	-1,686	-1,749	-1,787	-1,842	-1,879	-1,911	-1,927	-1,956	-1,984	-2,011	-2,038	-2,065	-2,090	-2,115	-2,139
Total Pumping	**-45,467**	**-45,743**	**-45,501**	**-44,782**	**-43,272**	**-43,140**	**-42,623**	**-43,023**	**-43,260**	**-43,594**	**-43,816**	**-44,040**	**-44,261**	**-44,473**	**-44,679**	**-44,877**
SVS Only	-22,876	-23,151	-22,910	-22,191	-20,680	-20,549	-20,031	-20,432	-20,668	-21,002	-21,225	-21,448	-21,669	-21,881	-22,088	-22,286
RECHARGE	USGS Model	2011 Model Update														
Commercial-Industrial	55	56	58	59	60	61	62	62	63	64	65	66	67	68	69	70
Sand & Gravel	55	55	59	60	62	61	63	64	65	67	68	70	71	72	74	75
State Land	31	31	33	33	34	34	35	35	36	37	38	39	39	40	41	42
Domestic	237	240	250	255	263	266	271	274	279	283	287	292	296	300	304	308
Municipal/Water Company (outside sewered areas)	90	114	114	116	118	120	122	124	127	129	131	134	136	138	140	142
US Agriculture (non-ex, no vineyards)	907	907	907	537	167	167	167	167	167	167	167	167	167	167	167	167
Exempt-well Irrigation	15	15	16	16	17	17	17	18	18	18	18	18	19	19	19	19
Stock and Other Undetermined Rural	296	301	312	319	329	335	341	344	349	354	359	363	368	373	377	382
Total Recharge	**1,685**	**1,719**	**1,748**	**1,395**	**1,049**	**1,062**	**1,078**	**1,088**	**1,104**	**1,119**	**1,134**	**1,149**	**1,163**	**1,177**	**1,191**	**1,204**
NET PUMPING	-43,782	-44,024	-43,753	-43,387	-42,223	-42,078	-41,544	-41,935	-42,156	-42,474	-42,682	-42,891	-43,097	-43,295	-43,488	-43,673
2017 Update Minus 2011 Model Update	**1,196**	**1,100**	**793**	**1,320**	**1,047**	**1,234**	**1,623**	**2,061**	**3,216**	**3,528**	**4,096**	**4,459**	**5,312**	**5,959**	**6,112**	**6,247**

Table A-2 (cont'd)

Water Budget (AF) -2011 Model Update

	USGS Model	2011 Model Update																			
PUMPING - By Category	2002	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**
US Agriculture (non-ex, no vineyards)	-2,844	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436
Mexico	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591
US Mining	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799
Fort Huachuca	-1,530	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296
Golf Course	-1,085	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866
Municipal/Water Company	-9,428	-10,574	-10,703	-10,825	-10,942	-11,058	-11,170	-11,281	-11,387	-11,491	-11,591	-11,691	-11,784	-11,877	-11,969	-12,055	-12,141	-12,227	-12,304	-12,382	-12,460
Vineyard	-330	-429	-433	-437	-441	-445	-448	-452	-455	-459	-462	-465	-468	-472	-474	-477	-480	-483	-485	-488	-490
State Land	-171	-235	-238	-242	-245	-249	-252	-255	-258	-262	-264	-267	-270	-273	-275	-278	-280	-283	-285	-288	-290
Commercial-Industrial	-303	-391	-396	-400	-404	-408	-412	-416	-419	-423	-426	-430	-433	-437	-440	-443	-446	-449	-452	-454	-457
Sand & Gravel	-307	-422	-429	-436	-442	-448	-454	-460	-465	-471	-476	-481	-486	-491	-496	-500	-505	-509	-513	-517	-521
Domestic	-1,337	-1,759	-1,780	-1,800	-1,819	-1,838	-1,857	-1,874	-1,892	-1,909	-1,925	-1,941	-1,957	-1,973	-1,987	-2,001	-2,016	-2,030	-2,042	-2,054	-2,067
Exempt-well Irrigation	-83	-108	-109	-110	-111	-112	-113	-114	-115	-116	-117	-118	-118	-119	-120	-121	-121	-122	-123	-123	-124
Stock and Other Undetermined Rural	-1,657	-2,162	-2,186	-2,208	-2,230	-2,252	-2,272	-2,292	-2,312	-2,330	-2,348	-2,366	-2,384	-2,402	-2,418	-2,434	-2,450	-2,466	-2,479	-2,493	-2,507
Total Pumping	**-45,467**	**-45,070**	**-45,264**	**-45,447**	**-45,623**	**-45,798**	**-45,966**	**-46,133**	**-46,294**	**-46,448**	**-46,598**	**-46,748**	**-46,890**	**-47,031**	**-47,169**	**-47,298**	**-47,427**	**-47,558**	**-47,673**	**-47,789**	**-47,905**
SVS Only	-22,876	-22,478	-22,673	-22,856	-23,031	-23,207	-23,375	-23,541	-23,703	-23,857	-24,006	-24,157	-24,298	-24,439	-24,578	-24,706	-24,836	-24,966	-25,081	-25,197	-25,314
RECHARGE	USGS Model																				
Commercial-Industrial	55	70	71	72	73	74	74	75	76	76	77	77	78	79	79	80	80	81	81	82	82
Sand & Gravel	55	76	77	78	80	81	82	83	84	85	86	87	88	88	89	90	91	92	92	93	94
State Land	31	42	43	44	44	45	45	46	47	47	48	48	49	49	50	50	51	51	51	52	52
Domestic	237	312	315	319	322	326	329	332	335	338	341	344	347	350	352	355	357	360	362	364	367
Municipal/Water Company (outside sewered a	90	144	146	148	150	152	153	155	157	158	160	162	163	164	166	167	169	170	171	172	174
US Agriculture (non-ex, no vineyards)	907	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167
Exempt-well Irrigation	15	20	20	20	20	20	20	21	21	21	21	21	21	21	22	22	22	22	22	22	22
Stock and Other Undetermined Rural	296	386	390	394	398	402	405	409	412	416	419	422	425	428	431	434	437	440	442	445	447
Total Recharge	**1,685**	**1,217**	**1,230**	**1,242**	**1,254**	**1,266**	**1,277**	**1,288**	**1,299**	**1,309**	**1,319**	**1,329**	**1,338**	**1,348**	**1,357**	**1,365**	**1,374**	**1,383**	**1,390**	**1,398**	**1,406**
NET PUMPING	-43,782	-43,852	-44,034	-44,205	-44,369	-44,533	-44,690	-44,845	-44,995	-45,140	-45,279	-45,420	-45,552	-45,683	-45,812	-45,932	-46,053	-46,175	-46,282	-46,391	-46,500
2017 Update Minus 2011 Model Update	**1,196**	**6,362**	**6,472**	**6,569**	**6,659**	**6,750**	**6,835**	**6,919**	**6,998**	**7,073**	**7,143**	**7,215**	**7,278**	**7,342**	**7,402**	**7,454**	**7,507**	**7,561**	**7,600**	**7,639**	**7,678**

Table A-2 (cont'd)

Water Budget (AF) -2011 Model Update

PUMPING - By Category	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057
US Agriculture (non-ex, no vineyards)	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436
Mexico	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591
US Mining	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799
Fort Huachuca	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296
Golf Course	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866
Municipal/Water Company	-12,529	-12,600	-12,670	-12,739	-12,808	-12,878	-12,948	-13,012	-13,076	-13,141	-13,206	-13,271	-13,344	-13,419	-13,494	-13,570	-13,646	-13,722	-13,799	-13,877
Vineyard	-493	-495	-498	-500	-502	-504	-506	-508	-510	-512	-514	-516	-518	-521	-524	-526	-529	-532	-534	-537
State Land	-292	-294	-296	-298	-300	-302	-304	-306	-308	-310	-312	-314	-316	-318	-320	-322	-325	-327	-329	-332
Commercial-Industrial	-459	-462	-465	-467	-469	-471	-473	-475	-477	-480	-482	-484	-486	-489	-491	-494	-497	-499	-502	-504
Sand & Gravel	-525	-529	-533	-536	-540	-544	-548	-551	-554	-558	-561	-564	-568	-572	-576	-580	-584	-588	-592	-597
Domestic	-2,078	-2,090	-2,102	-2,112	-2,123	-2,134	-2,145	-2,155	-2,166	-2,177	-2,187	-2,198	-2,211	-2,223	-2,235	-2,248	-2,260	-2,273	-2,285	-2,298
Exempt-well Irrigation	-125	-125	-126	-126	-127	-127	-128	-129	-129	-130	-130	-131	-131	-132	-133	-133	-134	-135	-135	-136
Stock and Other Undetermined Rural	-2,520	-2,533	-2,547	-2,558	-2,570	-2,582	-2,593	-2,605	-2,617	-2,628	-2,640	-2,652	-2,666	-2,680	-2,694	-2,708	-2,722	-2,737	-2,751	-2,765
Total Pumping	**-48,011**	**-48,117**	**-48,224**	**-48,326**	**-48,428**	**-48,530**	**-48,633**	**-48,729**	**-48,826**	**-48,923**	**-49,020**	**-49,118**	**-49,229**	**-49,342**	**-49,456**	**-49,570**	**-49,685**	**-49,801**	**-49,918**	**-50,035**
SVS Only	-25,419	-25,526	-25,633	-25,734	-25,836	-25,939	-26,042	-26,138	-26,235	-26,331	-26,429	-26,527	-26,638	-26,751	-26,865	-26,979	-27,094	-27,210	-27,326	-27,444
RECHARGE																				
Commercial-Industrial	83	83	84	84	84	85	85	86	86	86	87	87	88	88	89	89	89	90	90	91
Sand & Gravel	95	95	96	97	97	98	99	99	100	100	101	102	102	103	104	105	105	106	107	107
State Land	53	53	53	54	54	54	55	55	55	56	56	56	57	57	58	58	58	59	59	60
Domestic	369	371	373	375	377	379	381	382	384	386	388	390	392	395	397	399	401	403	406	408
Municipal/Water Company (outside sewered areas)	175	176	177	178	179	180	181	182	183	184	185	187	188	189	190	191	192	193	194	196
US Agriculture (non-ex, no vineyards)	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167
Exempt-well Irrigation	22	23	23	23	23	23	23	23	23	23	23	24	24	24	24	24	24	24	24	25
Stock and Other Undetermined Rural	450	452	454	456	458	461	463	465	467	469	471	473	476	478	481	483	486	488	491	493
Total Recharge	**1,413**	**1,420**	**1,427**	**1,433**	**1,440**	**1,447**	**1,453**	**1,460**	**1,466**	**1,473**	**1,479**	**1,486**	**1,493**	**1,501**	**1,509**	**1,516**	**1,524**	**1,531**	**1,539**	**1,547**
NET PUMPING	-46,598	-46,697	-46,797	-46,892	-46,988	-47,084	-47,180	-47,270	-47,360	-47,450	-47,541	-47,632	-47,736	-47,841	-47,947	-48,054	-48,162	-48,270	-48,379	-48,488
2017 Update Minus 2011 Model Update	**7,707**	**7,735**	**7,763**	**7,785**	**7,806**	**7,826**	**7,846**	**7,856**	**7,866**	**7,873**	**7,880**	**7,885**	**7,900**	**7,922**	**7,943**	**7,964**	**7,986**	**8,007**	**8,029**	**8,050**

Table A-2 (cont'd)

Water Budget (AF) -2011 Model Update	2011 Model Update																					
PUMPING - By Category	**2078**	**2079**	**2080**	**2081**	**2082**	**2083**	**2084**	**2085**	**2086**	**2087**	**2088**	**2089**	**2090**	**2091**	**2092**	**2093**	**2094**	**2095**	**2096**	**2097**	**2098**	**2099**
US Agriculture (non-ex, no vineyards)	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436	-436
Mexico	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591	-22,591
US Mining	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799	-3,799
Fort Huachuca	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296	-1,296
Golf Course	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866	-866
Municipal/Water Company	-15,629	-15,719	-15,809	-15,900	-15,991	-16,083	-16,175	-16,268	-16,362	-16,456	-16,551	-16,647	-16,743	-16,840	-16,937	-17,035	-17,134	-17,233	-17,333	-17,434	-17,535	-17,637
Vineyard	-596	-599	-602	-605	-608	-611	-614	-617	-620	-624	-627	-630	-633	-636	-639	-642	-646	-649	-652	-655	-659	-662
State Land	-384	-387	-389	-392	-395	-397	-400	-403	-406	-409	-412	-414	-417	-420	-423	-426	-429	-432	-435	-438	-441	-444
Commercial-Industrial	-563	-566	-569	-572	-575	-578	-581	-585	-588	-591	-594	-597	-600	-603	-607	-610	-613	-616	-620	-623	-626	-630
Sand & Gravel	-691	-696	-700	-705	-710	-715	-720	-725	-730	-735	-741	-746	-751	-756	-762	-767	-772	-778	-783	-789	-794	-800
Domestic	-2,582	-2,596	-2,610	-2,625	-2,639	-2,654	-2,669	-2,684	-2,699	-2,714	-2,729	-2,744	-2,759	-2,775	-2,790	-2,806	-2,821	-2,837	-2,853	-2,869	-2,885	-2,901
Exempt-well Irrigation	-151	-152	-153	-153	-154	-155	-156	-157	-157	-158	-159	-160	-161	-161	-162	-163	-164	-165	-165	-166	-167	-168
Stock and Other Undetermined Rural	-3,088	-3,104	-3,120	-3,137	-3,153	-3,170	-3,187	-3,203	-3,220	-3,237	-3,254	-3,272	-3,289	-3,306	-3,324	-3,341	-3,359	-3,376	-3,394	-3,412	-3,430	-3,448
Total Pumping	**-52,673**	**-52,807**	**-52,942**	**-53,079**	**-53,215**	**-53,353**	**-53,492**	**-53,631**	**-53,772**	**-53,913**	**-54,055**	**-54,198**	**-54,342**	**-54,487**	**-54,633**	**-54,779**	**-54,927**	**-55,075**	**-55,225**	**-55,375**	**-55,527**	**-55,679**
SVS Only	-30,081	-30,216	-30,351	-30,487	-30,624	-30,762	-30,900	-31,040	-31,180	-31,322	-31,464	-31,607	-31,751	-31,896	-32,041	-32,188	-32,336	-32,484	-32,633	-32,784	-32,935	-33,087
RECHARGE																						
Commercial-Industrial	102	102	103	103	104	104	105	105	106	106	107	108	108	109	109	110	110	111	112	112	113	113
Sand & Gravel	124	125	126	127	128	129	130	131	132	133	133	134	135	136	137	138	139	140	141	142	143	144
State Land	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77	77	78	78	79	80	80
Domestic	459	461	464	466	469	472	474	477	480	482	485	488	490	493	496	499	502	504	507	510	513	516
Municipal/Water Company (outside sewered areas)	222	223	225	226	227	229	230	231	233	234	236	237	238	240	241	243	244	246	247	249	250	252
US Agriculture (non-ex, no vineyards)	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167
Exempt-well Irrigation	27	27	28	28	28	28	28	28	28	28	29	29	29	29	29	29	30	30	30	30	30	30
Stock and Other Undetermined Rural	551	554	557	560	563	566	569	572	575	578	581	584	587	590	593	596	599	602	606	609	612	615
Total Recharge	**1,721**	**1,730**	**1,739**	**1,748**	**1,757**	**1,766**	**1,775**	**1,784**	**1,793**	**1,802**	**1,812**	**1,821**	**1,831**	**1,840**	**1,850**	**1,859**	**1,869**	**1,878**	**1,888**	**1,898**	**1,908**	**1,918**
NET PUMPING	-50,952	-51,077	-51,204	-51,331	-51,459	-51,587	-51,717	-51,847	-51,979	-52,111	-52,243	-52,377	-52,512	-52,647	-52,783	-52,920	-53,058	-53,197	-53,337	-53,477	-53,619	-53,761
2017 Update Minus 2011 Model Update	**8,492**	**8,513**	**8,533**	**8,554**	**8,574**	**8,595**	**8,615**	**8,635**	**8,655**	**8,676**	**8,696**	**8,716**	**8,736**	**8,755**	**8,775**	**8,795**	**8,815**	**8,834**	**8,854**	**8,873**	**8,892**	**8,911**