Estimated Water Demand and Conservation Potential of Domestic Wells in the Sierra Vista Subwatershed, Arizona

Prepared for

WESTERN RESOURCE ADVOCATES

by

Plateau Resources, LLC

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1.0 INTRODUCTION

The effect of domestic wells on aquifers and streams in Arizona is not well quantified. Because these wells do not require metering, estimates of their pumpage can vary (see Section 3). Nonetheless, the total demand from domestic wells is potentially large and important to water providers, cities and counties as they plan and develop strategies to meet future water needs, including water conservation programs.

Due to the uncertainty in demand, Western Resource Advocates (WRA) contracted Plateau Resources LLC (Plateau) to develop a methodology to estimate the conservation potential of domestic wells in the Sierra Vista Subwatershed (SVS). While this study does not report a total domestic well demand for the region, it does present recent and new household estimates and identifies areas with water conservation potential. Such information may help water managers in the SVS better understand domestic well use characteristics and design and implement appropriate water conservation programs. The methodology developed here is likely also transferable to other areas of Arizona and the western United States.

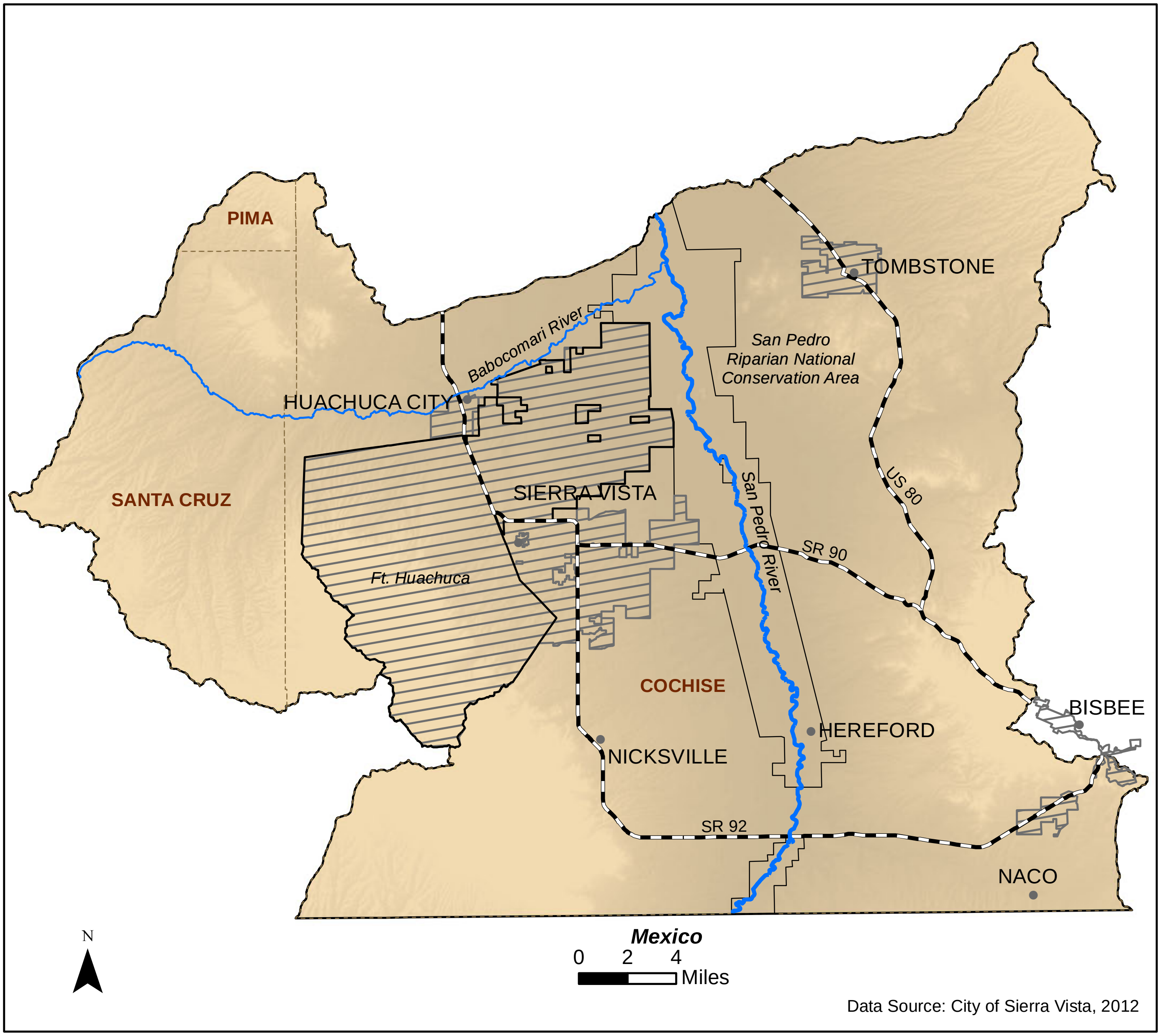
1.1 BACKGROUND

The SVS is located in the San Pedro River Watershed of southeastern Arizona and contains one of the nation's two riparian conservation areas. Sustained by the San Pedro River, the San Pedro Riparian National Conservation Area (SPRNCA) was recognized by the United Nations as a World Heritage Natural Area. Also located in the SVS are the communities of Sierra Vista, Huachuca City, Tombstone, Naco and much of the town of Bisbee as well as Fort Huachuca, the area's economic engine (Figure 1).

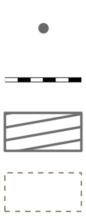
To preserve the SPRNCA and local economy, area stakeholders formed the Upper San Pedro Partnership (USPP), a consortium of 21 member agencies and organizations, to "monitor and manage our water, build projects to enhance our water resources, and provide education and public policy recommendations in an effort to help state and local governments better manage water resources" (USPP, 2011). In addition, Public Law 108-136, the 2004 National Defense Authorization Act, requires that the USPP submit an annual report to Congress (ending in 2011) describing its progress toward restoring and maintaining the regional aquifer system. Flows in the San Pedro River are supported by this aquifer.

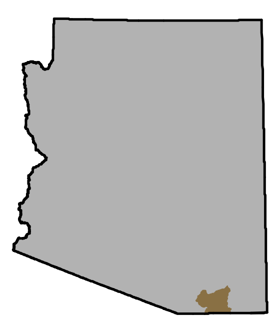
Numerous scientific studies and several hydrologic models have been completed for the SVS. These investigations include estimates of municipal, industrial and agricultural water demands as well as an analysis of aquifer sustained yield. Well pumpage in the SVS currently exceeds aquifer recharge, a condition known as overdraft. The most recent overdraft estimate was published by the U.S. Geological Survey (USGS) in its 2010 Section 321 Report to Congress (DOI, 2012) and totaled approximately 6,100 acre-feet for 2009. Better understanding components of the region's water demands enables local decision makers to develop strategies to mitigate this overdraft and reduce potential impacts from well pumpage on the river.

Figure 1
Sierra Vista Subwatershed



Legend





Plateau Resources, LLC

Domestic wells may serve as much as 20% of the SVS population (see Section 2) and were estimated to have a total annual demand of 4,680 acre-feet (afa) during 2009 (DOI, 2012). Pumpage of this magnitude represents an important component of the regional water demand, but domestic wells statewide are exempt from metering and reporting requirements. Moreover, most water conservation programs have been focused within water provider service areas where water rates and bills provide a convenient means of communicating information.

Domestic well owners may lack detailed knowledge of their water demand and how these demands vary during the year and from year to year. This report provides an approach to informing these well owners of their conservation opportunities and bringing their demands into a regional water management strategy that preserves both the San Pedro River and the local economy.

1.2 SCOPE OF WORK

On behalf of WRA, Plateau completed the following tasks during this project:

- Task 1 – Researched and compiled existing data and information;
- Task 2 – Identified areas within the SVS that are currently not served by a water provider (i.e. are supplied by domestic wells) or a sewer system and those areas in close proximity where service could be extended outside of incorporated areas;
- Task 3 – Categorized the age of homes with domestic wells based on county parcel records;
- Task 4 – Used aerial imagery to initially identify which of these homes have outdoor water use;
- Task 5 – Further analyzed the imagery and mapped several types of outdoor water use and their acreage;
- Task 6 – Estimated the watering requirements for these outdoor uses;
- Task 7 – Toured the study area and ground-truthed features noted in the aerial imagery;
- Task 8 – Refined, as necessary, our outdoor water use estimates using results from ground-truthing;
- Task 9 – Developed a relationship between home age and indoor water use;
- Task 10 – Using the above relationship, estimated indoor household water uses in the study area;
- Task 11 – Researched which areas in the SVS have the greatest potential to impact the San Pedro River from domestic well pumpage; and
- Task 12 – Determined the conservation potential of homes in the study area served by domestic wells and how the methodology developed here could be applied elsewhere in Arizona and the western United States.

2.0 STUDY AREA

Figure 2 shows the current location of water providers in the SVS based on Geographic Information System (GIS) data from Cochise County (2011) that were supplemented with 2010 Community Water System records from ADWR (2011a). As described in the introduction, the study area for this project covers those portions of the SVS not currently served by a water provider. More specifically, we evaluated the water conservation potential of private residences in the SVS supplied by domestic wells in unincorporated areas. While domestic wells also exist within incorporated areas and even within water company service areas, the largest concentration is located in unincorporated areas where their uniform distribution makes it more effective to target conservation programs. Further, conservation outreach by municipalities such as the City of Sierra Vista may already extend to domestic well owners within their incorporated area.

Population and parcel data for the SVS are summarized in Table 1. USGS (2011) estimated that the total SVS population in 2010 was approximately 77,300. Using available water provider records and U.S. Census (2011) tract data, we estimated that about 62,100 people in the SVS are currently served by a water provider. Subtracting these two estimates, 15,200 people or about 20% of the total SVS population is calculated to be supplied water by domestic wells.

The number of private residences in the study area supplied by domestic wells was evaluated separately using Cochise County (2011) assessor files and GIS parcel data. Table 1 lists the approximate number of private parcels in the study area not served by a water provider (8,515) and divides these parcels into improvement categories. Almost 60% of the parcels have single family residences or mobile homes. Other parcel improvements include multi-family homes (2), commercial and public buildings (30), and yard and other improvements such as barns, sheds, stables, etc. (173).

Nearly 4,000 parcels in the study area are listed by the county with no improvements. Plateau randomly checked these parcels using 2010 aerial imagery and found that about 17% have a single family residence or mobile home. To address this potential undercounting, Table 1 also includes an estimated number of households in the study area by assuming that 17% of the vacant parcels actually have occupied homes and these are equally divided between single family residences and mobile homes. Based on that assumption, the total number of homes in the SVS that are supplied water by domestic wells and outside of water service areas and incorporated areas is estimated at approximately 5,020. However, for our analysis of demand and conservation potential we used the unadjusted parcel data because this was the only data source that included housing age, a key component in our methodology.

Using U.S. Census data, we calculate that the current occupancy rate for homes in the study area is about 2.4 persons per household (pph). Multiplying this rate by our parcel-based estimate of the total number of households gives a total population served by domestic wells of 12,050 – a figure that would be higher if

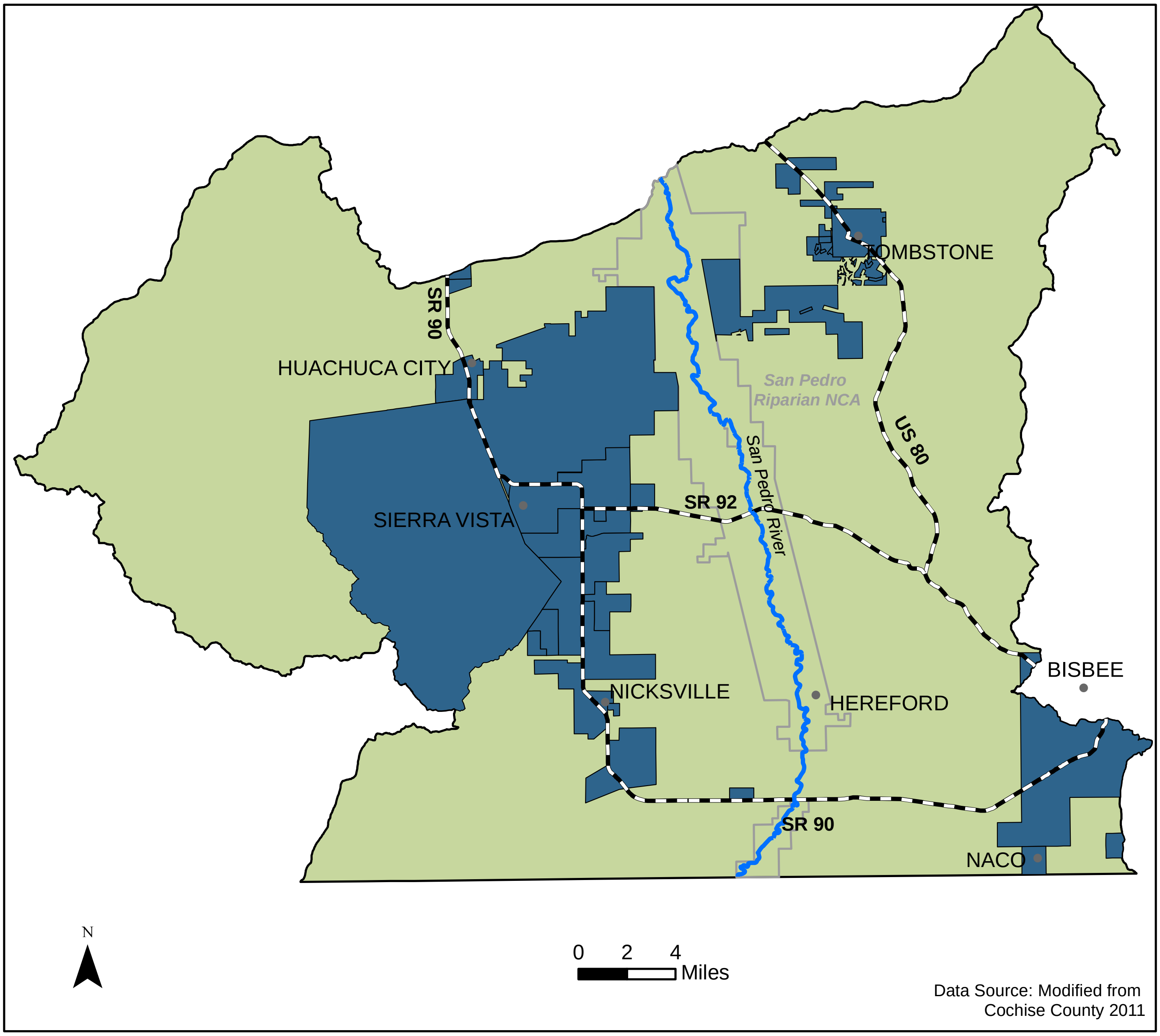
TABLE 1 – POPULATION AND PARCEL DATA

Area	2010 Population
Sierra Vista Subwatershed (SVS)	77,300[1]
Portion of SVS Served by Water Providers	62,100[2]
Portion of SVS Not Served by Water Providers	15,200[3] (12,050)[7]
Type of Parcel Improvement	**Approximate Number of Private Parcels in Study Area Not Served by Water Providers[4]**
Single Family Residence	2,150[5] (2,490)[6]
Mobile Home (includes affixed and park models)	2,180 (2,530)[6]
Multi-Family Residence	2
Commercial	20
Public	10
Yard	3
Other	170
None	3,970 (3,290)[6]
Total	*8,515*

Notes:
[1] Estimated by USGS (2011) based on 2010 census block data from the U.S. Bureau of Reclamation.
[2] Estimated by Plateau Resources using U.S. Census (2011) tract data and Cochise County (2011) water provider records supplemented with ADWR (2011a) Community Water System files.
[3] Calculated by subtracting the SVS population served by water providers from the total SVS population.
[4] Based on Cochise County (2011) assessor 'cost file' and GIS data from this study.
[5] Includes approximately 30 parcels with an "unknown" improvement.
[6] A random check of parcels reported by Cochise County with no improvements showed that about 17% had a single family residence or mobile home on the 2010 aerial imagery. The numbers in parentheses are estimates that correct for this potential undercounting.
[7] Calculated by adding the number of single family residences and mobile homes in unincorporated areas corrected for potential undercounting (see footnote 6) and multiplying the total by an occupancy rate of 2.4 persons per household based on census data.

we had included domestic wells located within incorporated areas. This compares to 15,200 people in the SVS that we independently estimated were not served by a water provider during 2010. Because of data uncertainties and the different methodologies used, it should not be assumed that the difference in these estimates represents the population served by domestic wells within incorporated areas. While outside the scope of this study, further comparison of U.S. Census data with service area boundaries may yield a more accurate estimate of the population served by domestic wells.

Figure 2
Areas Within the Sierra Vista Subwatershed Not Served by a Water Provider



Legend

- Water Provider Service Areas
- Area Outside of Water Provider Serivce Area
- City or Town
- Roads

3.0 DOMESTIC WELL PUMPAGE

Before analyzing domestic water demands in the study area (Section 4) and associated conservation potential (Section 5), it is useful to review rates of domestic well pumpage reported locally and for the region. Table 2 summarizes the data we found and includes information on well location, average annual water use per household and per capita, year of water use and number of homes metered, if applicable, and data sources.

Recent data from eight metered domestic wells in the SVS and 250 metered domestic wells near Santa Fe, New Mexico indicate an average annual water use of 0.24 to 0.30 acre-feet per household (afh), respectively. This quantity of use is consistent with delivery records from a local water company (Liberty Water - Southern Sunrise system) that served 799 homes near Sierra Vista during 2010 at an average rate of 0.21 afh. Data from the metered domestic wells are also consistent with the rate of domestic well pumpage cited by the United States Fish and Wildlife Service (USFWS) in its 2007 Biological Opinion for Fort Huachuca. The USFWS rate of 118 gallons per capita day (gpcd) was taken from a Prescott Active Management Area report (GUAC, 2006) and represents an estimate of average domestic well pumpage in the AMA foothills. This rate equates to an annual usage of 0.31 afh if an occupancy rate of 2.4 persons per household (pph) is assumed for the study area.[1]

Water use by the metered SVS and Santa Fe domestic wells is lower than the domestic use rates that ADWR allows applicants to assume when filing for state water rights. The standard domestic use when filing an application to appropriate surface water is 180 gpcd and the suggested domestic use when filing claims in the Gila River and Little Colorado River Adjudication areas is 150 gpcd. Assuming the aforementioned occupancy rate in the study area, these rates equate to an annual domestic well use of 0.48 afh and 0.41 afh, respectively. Water use by the metered wells is also lower than the 312 gpcd assumed for domestic well pumpage by DOI (2010) in its 2009 321 Report to Congress on management of the SVS regional aquifer. Their assumed pumpage rate was based on data presented in the ADWR (2005) San Pedro AMA Review Report.

Although limited, the data presented above suggest that annual water use by domestic wells in the study area may average about 0.3 afh or less, equivalent to about 112 gpcd.

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[1] Santa Fe and Prescott have similar, but cooler, climates than Sierra Vista suggesting that their outdoor watering requirements would be somewhat less than the study area (WRCC, 2011). From 1981-2010, the mean annual precipitation, maximum temperature and minimum temperature in Santa Fe (Station 298085) and Prescott (Station 026796) were 14.18 inches and 17.95 inches, 65.1°F and 69.7°F, and 35.0°F and 40.1°F, respectively, compared to 14.20 inches, 77.3°F, and 49.7°F in Sierra Vista (Station 027880). Other factors that can affect domestic use rates such as lot size, occupancy rate, home age and median income were not compared but probably explain differences between the metered domestic uses cited here.

TABLE 2 – REPORTED DOMESTIC WELL USE

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Year</th><th rowspan="2">Number of Homes</th><th colspan="2">Average Annual Use (acre-feet)</th><th rowspan="2">Data Source</th></tr>
<tr><th>Per capita</th><th>Per household</th></tr>
<tr><td colspan="6">Metered</td></tr>
<tr><td>Sierra Vista Subwatershed[1]</td><td>Between 2005 and 2007</td><td>8</td><td>0.12 (107 gallons per day)</td><td>0.24</td><td>Daily (2011a)</td></tr>
<tr><td>Sierra Vista, AZ[2]</td><td>2010</td><td>799</td><td>0.09 (76 gallons per day)</td><td>0.21</td><td>Liberty Water Company (2011)</td></tr>
<tr><td>Near Santa Fe, NM[3]</td><td>2009</td><td>250</td><td>---</td><td>0.30</td><td>Chavez (2010)</td></tr>
<tr><td colspan="6">Estimated or Assumed Values</td></tr>
<tr><td rowspan="2">Sierra Vista Subwatershed</td><td rowspan="4">Current</td><td rowspan="4">---</td><td>0.13 (118 gallons per day)[4]</td><td>0.31[5]</td><td>USFWS (2007)</td></tr>
<tr><td>0.35 (312 gallons per day)[6]</td><td>0.84[5]</td><td>USGS (2010)</td></tr>
<tr><td>Statewide (‘standard’ domestic use when filing an application to appropriate water)</td><td>0.20 (180 gallons per day)</td><td>0.48[5]</td><td rowspan="2">ADWR (2011b,c)</td></tr>
<tr><td>Adjudication Areas (suggested domestic use when filing adjudication claims)</td><td>0.17 (150 gallons per day)[7]</td><td>0.41[5]</td></tr>
</table>

Notes:

[1] Includes homes with a complete year of well pumpage (meter) data recorded by Water Wise staff. One month of water use data was missing for one home and estimated based on prior metered months.

[2] Delivery data listed in the Community Water System report for the Southern Sunrise system, which may be representative of domestic well use in the study area.

[3] Homes with very low (<0.045 acre-feet per year) metered water use or wells with one meter that supply multiple homes are not included in this table.

[4] Estimate from a 2006 GUAC report for the Prescott Active Management Area (AMA) that approximates the average domestic well usage in the AMA foothills.

[5] Calculated using the per capita value listed in this table and an assumed 2.4 persons per household in the study area based on U.S. Census (2011) data.

[6] Based on information presented in ADWR’s 2005 San Pedro AMA Review Report which, in turn, was based on metered water use data from a relatively low water use, rural large lot service area in the Tucson AMA and an assumed 572 acres of deficit irrigation associated with domestic wells in the SVS.

[7] According to ADWR (1991), this rate represents the average interior and exterior water use in the Phoenix AMA which ADWR suggested be used by adjudication claimants when estimating their domestic water usage.

4.0 ANALYSIS OF DOMESTIC WATER DEMANDS

This section presents an analysis of domestic water demands in the study area. Indoor and outdoor water uses were evaluated separately and methodologies, findings, and study limitations are described below for each. Results from these analyses are used in the next section to assess the water conservation potential of homes in the area.

4.1 INDOOR

4.1.1 Methodology

Due to limited data on domestic well pumpage (see Section 3), indoor residential water use in the study area was estimated by assuming a relationship between home age and fixture use efficiency. Several recent studies (Aquacraft, 2011; Friedman and others, 2011; Great Western Institute, 2010; Rashid and others, 2010; and WRA, 2011) have evaluated changes in indoor water use across the United States and each notes the importance of higher efficiency fixtures in reducing the water demands in newer homes. For this study, per capita indoor water use was assumed to be higher in homes constructed before 1997 and lower in newer homes based on fixture use rates reported by AWWA (1999) and Aquacraft (2011).

Plateau's use of 1997 to distinguish homes with higher and lower water use fixtures primarily reflects passage of the U.S. Energy Policy Act (EPA) in 1992. This legislation mandated that only water efficient plumbing fixtures (toilets, showerheads, and faucets) could be manufactured from January 1994 onward. Accounting for the use of existing plumbing stocks, it was probably not until 1995 or 1996 that only lower water use fixtures were being installed in new homes and older fixtures in existing homes began to be replaced with more efficient models. In the AWWA (1999) study, data on indoor water use was collected between May 1996 and March 1998 from 1,200 existing homes in 14 towns and cities. For purposes of this report, AWWA's data are considered representative of the current indoor water use of pre-1997 homes in our study area. The Aquacraft (2011) study looked at the indoor water uses of 1,000 homes built after 2001 in 9 cities. These data are considered representative of the current indoor water use in our newer study area homes.

The age of homes in the study area was determined using Cochise County (2011) assessor records. As described in Section 2, assessor "cost files" were initially reviewed to identify private parcels with single family residences and mobile homes. Construction dates were included in these files and were used to group study area homes into three age categories – before 1997, 1997 to 2005, and 2005 to present.

Homes in the most recent age category (2005 to present) are expected to have more fixtures that meet the EPA standards and, as further discussed in Section 5, probably have the least conservation potential. GWI (2010) reported that, beginning in 2005, higher efficiency clothes and dish washers became more readily available in response to legislation passed by the California Energy Commission. The legislation increased water efficiency standards and, due to the size of California's economy, reportedly affected the manufacture and distribution of appliances across the western United States. Participation in the Environmental Protection Agency Energy Star and WaterSense programs was also cited for the increased water use efficiencies during this period.

4.1.2 Findings

Table 3 lists indoor water use estimates for the study area, by fixture type, assuming an occupancy rate of 2.4 pph. For pre-1997 homes, daily indoor water use is estimated to average about 166 gallons per household (gph) or 0.19 afa based on the AWWA (1999) study. The fixtures that account for the greatest daily water use in these older homes include toilets (44.4 gph), clothes washers (36.0 gph), showers (27.8 gph), faucets (26.2 gph) and leaks (22.8 gph).

Daily indoor water use is estimated to be lower in newer study area homes and average about 115 gph or 0.13 afa based on the Aquacraft (2011) study. The same fixtures account for the greatest indoor water uses in these homes but their relative importance has changed to showers (24.6 gph), clothes washes (23.8 gph), toilets (22.6 gph), faucets (20.7 gph) and leaks (16.2 gph).

Available data suggest that mandatory use of low-flow toilets and improved clothes washer efficiencies explain much of the reductions in indoor water use in newer homes. However, data from Aquacraft (2011) suggest that further water savings are possible by retrofitting existing homes with higher efficiency fixtures. As listed in Table 3, retrofits could potentially lower the average daily indoor water use in the study area to 99 gph or 0.11 afa.[2]

The number of homes in the study area that could potentially benefit from improved fixture efficiencies is also listed in Table 3 and their locations are shown in Figure 3. Assessor data indicate that approximately 2,190 residences were constructed in the study area before 1997 and approximately 2,140 residences were constructed since that time. Figure 3 shows the distribution of these older and newer homes. Older homes are located throughout the study area while newer homes are more concentrated northeast of Nicksville and north of Huachuca City.

[2] Work by Vickers (2001) showed toilet replacement savings for the newer (1980-1994) homes in her study that are similar to those reported by AWWA and Aquacraft. She estimated savings of 9.7 to 11.3 gallons per capita day (gpcd) depending on toilet efficiency (1.6 and 1.28 gallons per flush or gpf). This is equivalent to a maximum savings of 27.1 gph in our study area. She also reported toilet replacement savings equivalent to 45.6 gpcd for houses constructed between 1950 and 1980 if high efficiency toilets (1.28 gpf) were installed. While toilets may last for many years if aging parts are replaced, there is evidence that a typical "life expectancy" is between 20 to 30 years (City of Tampa, 2012). Vickers also estimated yields from high efficiency clothes washer replacement in post 1990 homes that equates to a savings of 4.4 gph.

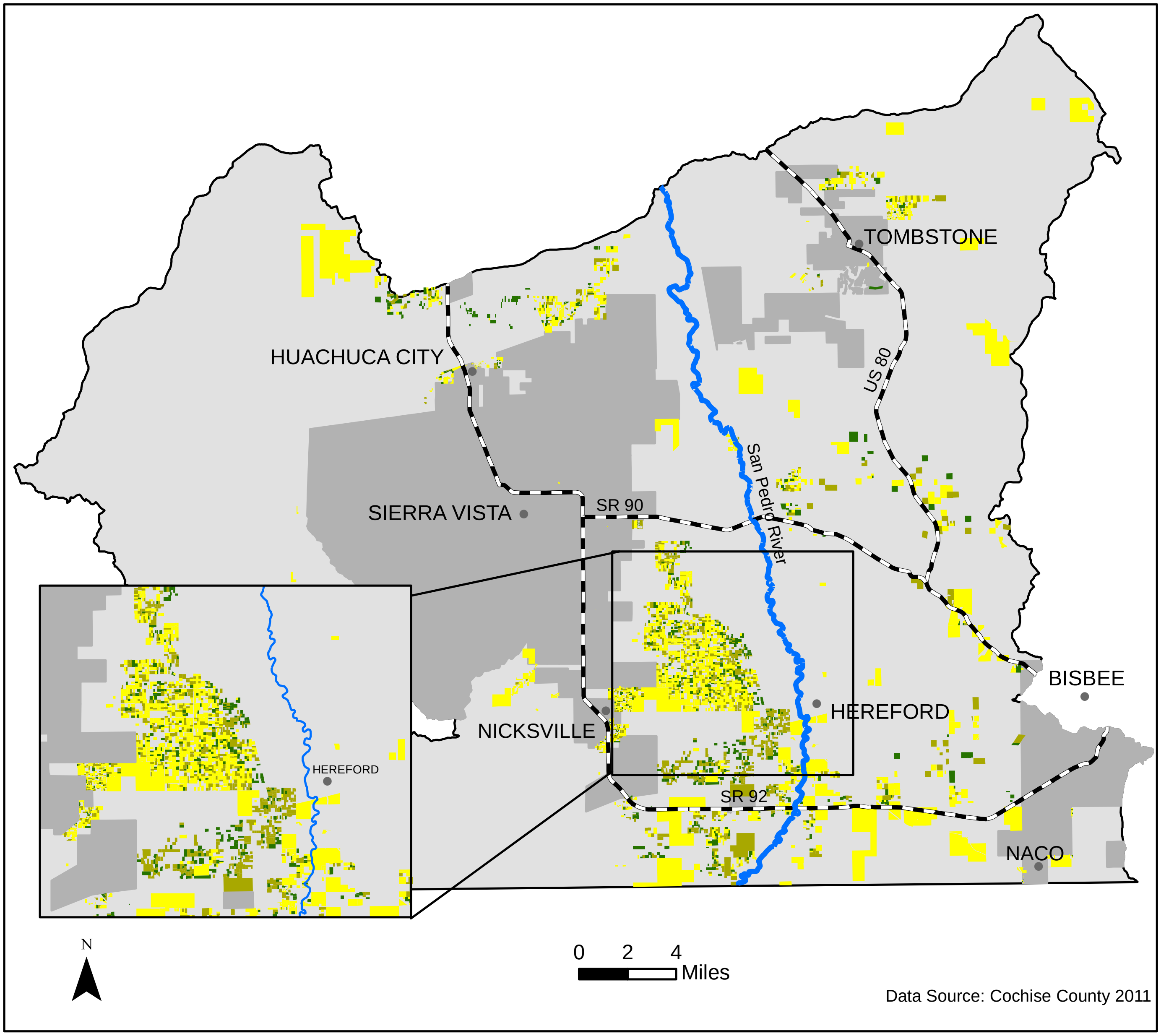
TABLE 3 – ESTIMATED INDOOR WATER USE BASED ON HOME AGES IN THE STUDY AREA

Home Age[1]	Number (Percentage) of Households in SVS Not Served by Water Provider[2]	Estimated Average Daily Indoor Water Use Per Household (gallons)[3]									Estimated Total Annual Indoor Water Use by Homes in Study Area (acre-feet)
		Toilets	Clothes Washer	Showers	Faucets	Leaks	Other	Bathtubs	Dishwasher	Total[4]	
Before 1997	2,190 (51%)[5]	44.4	36.0	27.8	26.2	22.8	3.8	2.9	2.4	166.3 (0.19 AFA)	408
1997 to Present	2,140 (49%)	22.6	23.8	24.6	20.7	16.2	2.5	2.9	1.6	114.9 (0.13 AFA)	275
Retrofit Existing Homes with High Efficiency Fixtures[6]	---	18.4	21.1	21.6	18.2	10.1	1.4	6.3	1.8	98.9 (0.11 AFA)	---

Notes:

[1] Home age from construction dates listed in the Cochise County (2011) Assessor cost file.
[2] Includes single family residences and mobile homes with construction data (see Table 1).
[3] Assumes 2.4 people per household based on U.S. Census (2011) data for the study area. Fixture rates taken from AWWA (1999) for pre-1997 homes and from Aquacraft (2011a,b) for newer homes. Aquacraft (2011a,b) also provided fixture rates for retrofitted existing homes.
[4] AFA = Acre-feet per year
[5] Includes approximately 50 households with no reported date of construction.
[6] High efficiency fixtures include 1.28 gallons per flush toilets, 12 to 15 gallons per load clothes washers, 1.5 gallon per minute (gpm) shower heads and 0.5 gpm sink aerators.

Figure 3
Age of Single-Family and Mobile Homes within the Study Area Served by Domestic Wells



Legend

- City or Town
- Water Provider Service Areas

Year Built

- Before 1997 (~2,190 parcels)
- 1997 to 2004 (~1,330 parcels)
- 2005 to Present (~810 parcels)

4.1.3 Limitations

Our main assumption when analyzing indoor water use in the study area is that a relationship exists between home age and fixture efficiency. Although several studies have documented lower water use in newer homes with more efficient fixtures, these studies were primarily conducted in large metropolitan areas served by water providers. Without surveying home owners in the study area, the rate of fixture replacement in older homes and the use of high efficiency fixtures in newer homes can only be assumed but seems reasonable. In addition, the number of homes in the study area that have already participated in local toilet retrofit programs is unknown. As discussed further in Section 6, recent data on the number of toilet retrofits completed by Cochise County and their locations were not available.

In addition, we did not evaluate indoor water use by multi-family residences and commercial and public buildings. Such properties were outside the project scope, but site visits would be effective in determining their conservation potential. The number of these properties in the study area is limited and their expected water use relatively small.

4.2 OUTDOOR

4.2.1 Methodology

We estimated outdoor water use in the study area by remote sensing. Several types of aerial imagery are readily available for the study area covering the time period between 2007 and 2010. Table 4 lists the imagery identified and several factors that determined its suitability for the project. Ideally, the imagery should (a) be recent and cover the entire study area; (b) have high (1-foot) resolution to allow detection of small areas of vegetation around homes; (c) include multi-spectral bands to better distinguish natural from planted vegetation; (d) be flown in late spring/early summer when watering needs in the study area are high but before monsoon rains begin and (e) not be flown after a period of unusually high rainfall. Based on these factors, the 1-meter, 4-band imagery flown by the National Agricultural Imagery Program (NAIP) in

TABLE 4 – AERIAL IMAGERY EVALUATED FOR PROJECT

Flight Date	Resolution	Number of Spectral Bands	Study Area Coverage	Source/Type
June-July 2007	1-meter	4	Complete	National Agriculture Imagery Program (NAIP)
September 2008	30-meter	6	Complete	Landsat ETM
Fall 2008	1-foot	3	Complete	National Geospatial Data Agency (NGA)
September 2009	1-foot	4	Partial (west of San Pedro River)	Ft. Huachuca
June 2010	1-meter	4	Complete	NAIP

June 2010 was selected for analysis. Precipitation records for Tombstone indicate that the 3-month period prior to the June 2010 flight date was not unusual with rainfall equaling the long-term (over 100-year) average for this period (WRCC, 2011).

After importing this imagery into GIS, a supervised classification was initially performed whereby certain areas of obvious outdoor water use were identified by eye and other areas with a similar spectral signature were located using computer software.[3] Several areas of potential outdoor water use were eventually recognized this way and grouped into six categories – pasture, orchards, turf, ponds, landscape plants, and pools. Each area was also coded based on our certainty in its classification.

To improve the accuracy of these initial classifications, we toured the study area on December 1-2, 2011. A total of 29 parcels with potential outdoor water use were visited including 12 in the Palominas-Hereford area, eight near Sierra Vista, five near Tombstone and four outside Huachuca City. This ground-truthing verified each of our outdoor water use categories and, as described further below, indicated that aerial imagery alone may not be sufficient in distinguishing irrigated turf from turf watered by rainfall.

The quantity of outdoor water use in the study area was calculated by multiplying the total acreage mapped for each use category by its annual watering requirement. Table 5 lists estimated watering requirements for several local outdoor uses, not all of which were observed in the study area. Most of these estimates were made using published crop coefficients and monthly reference evapotranspiration (ETo) rates from regional climate stations. Other estimates were made using data provided by Water Wise, a University of Arizona Cooperative Extension public education outreach program that promotes local water conservation. Further discussion of this program is presented in Section 5.1.3. To account for watering requirements met by rainfall, consumptive use values were reduced by effective or total precipitation measured in the Sierra Vista area. Further details on the water requirement estimates are found in footnotes to Table 5.

Finally, to account for potential losses in water during application, the watering requirements were divided by an application efficiency. Table 6 lists assumed application efficiencies for each category of water use in the study area. These efficiencies are based on data from Daily (2011c) and Tadayon (2011) and apply to a variety of irrigation methods including flood and drip irrigation and sprinkler and landscape irrigation systems. Table footnotes further explain the types of vegetation assumed in each water use category.

4.2.2 Findings

Table 6 summarizes our analysis of outdoor water use in the study area during 2010 and Figures 4A through 4D show several areas where these uses were mapped. A total of 372 areas of possible outdoor

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[3] Plateau also considered applying the Normalized Difference Vegetation Index (NDVI) to identify irrigation in the study area. However, after reviewing the methodology used by GSA (2010) to map turf in the region and discussions with Runyon (2011) of Ft. Huachuca, it was decided that a supervised classification based first on visual examination of the imagery followed by computer processing with ESRI's ArcGIS Spatial Analyst would be most efficient and yield reliable results.

TABLE 5 – LOCAL OUTDOOR WATERING REQUIREMENTS

Type	Watering Requirement	
	(inches/year)	(gallons/ft^2 /year)
Open water (ponds, pools and fountains)[1]	50.1	31.3
Cool season grasses[2]	49.2	30.8
Overseeded grasses (warm and annual cool)[2]	46.4	29.0
Pasture (low to high)[1]	27.4 – 39.7	17.1 – 24.8
Deciduous orchard (low to high)[1]	16.0 – 33.7	10.0 – 21.0
Ground covers and vines (low to high)[3]	14.8 – 32.3	9.2 – 20.2
Warm season grasses[2]	31.2	19.5
Shrubs (low to high)[3]	8.5 – 27.8	5.3 – 17.4
Evergreens and other landscape trees (low to high)[3]	3.5 – 25.8	2.2 – 16.1
Vegetable gardens (low to high)[1]	19.6 – 24.0	12.2 – 15.0
Mesquite (low to high)[4]	1.6 – 19.9	1.0 – 12.5
Xeriscape[2]	3.2	2.0

Notes:
[1] Calculated using crop coefficients (K_c) from Allen and others (1998) and reference evapotranspiration (ETo) rates reported by Brown (2011) based on AZMET station data and Yitayew (1990). Crop consumptive use values were reduced by effective precipitation using USDA (1970) methodology for semi-arid environments and average rainfall data reported by WRCC (2011) for Sierra Vista Station #027880 from 1981 to 2010. Low to high values account for potential variations in growing season length from year to year and physical variations in plant species that affect water consumption. For pools and fountains, total precipitation was subtracted from annual evaporation rates since nearly all rainfall that falls into open water is assumed effective.
[2] Data from Daily (2011b) and Water Wise, University of Arizona, Cooperative Extension, Cochise County (http://cals.arizona.edu/cochise/waterwise/wateringturf.html). Calculations were reportedly performed separately by Brown using AZMET methodology.
[3] Low to high water requirements were derived using Water Wise information and AZMET methodology, respectively. The Water Wise estimates represent average water needs for common plants in a given category based on a percentage of cover area, the volume of water required to reach a specific depth in sandy loam soil (the dominant soil in the region) and the recommended watering frequency according to the Sunset Western Garden Book (2008) correlated with regional ET data. Differences reflect assumed cover area and plant types.
[4] The low watering requirement is based on Water Wise information, as described in Footnote 3, and assumes it is used for xeriscaping. The high water requirement value is from Leenhouts and others (2006) and represents trees along the San Pedro River that have access to perennial surface water.

irrigation were identified covering approximately 73.1 acres. The most common category was turf (165 areas) but pastures covered the most area (31.6 acres) and probably used the most water. Note that the estimated range of water use by turf in Table 6 reflects the growth of natural grasses in some yards with apparently little or no supplemental watering and irrigation of warm season grasses in other yards. Both practices were observed during ground truthing but were difficult to distinguish by remote sensing. Note also that some homeowners may actually apply more water than is required to meet the local outdoor

TABLE 6 – ESTIMATED OUTDOOR WATER USE IN THE STUDY AREA DURING 2010

Type	Number of Areas Mapped[1]	Total Area (acres)	Annual Watering Requirement (feet)[2]	Assumed Application Efficiency	Estimated Annual Outdoor Water Use (acre-feet)[3]
Pasture[4]	10	31.6	2.3 to 3.3	70 to 85%[7]	86 to 149
Orchards	18	20.1	1.3 to 2.8	70 to 90%[7]	29 to 80
Turf	165	12.4	0.0 to 2.6[5]	40 to 75%[8]	0 to 81
Landscape Plants	115	8.5	0.3 to 2.7[6]	40 to 95%[8]	3 to 57
Pools	64	0.5	4.2	Near 100%	2
Total	*372*	*73.1*	---	---	*120 to 369*

Notes:
[1] Areas of outdoor water use were originally mapped using June 2010 aerial photography and later revised after ground-truthing in December 2011.
[2] See Table 5 for data sources and additional information.
[3] Calculated by multiplying total area by average annual watering requirement and dividing by assumed application efficiency.
[4] Includes areas of turf that exceed 0.5 acres.
[5] Lower watering requirement reflects the local practice of letting natural grasses grow in yards with little or no supplemental irrigation. Higher watering requirement represents warm season grasses which were observed in some yards.
[6] Represents a variety of vegetation including evergreens and other landscaping trees, shrubs, and ground covers and vines.
[7] Assumed by Tadayon (2011) to estimate water use in the project area; includes efficiencies for flood irrigation (70 to 75%), sprinkler systems (80 to 85%), and drips (90%).
[8] Reported by Daily (2011c) based on the Irrigation Association's *Drip Irrigation in the Landscape*; includes efficiencies for spray (40 to 65%), rotor (50 to 75%) and drip (80 to 95%) landscape irrigation systems.

watering requirements. This possibility is not reflected in Table 6 and was not noted during the December 2011 ground truthing when most outdoor water uses had ceased.

Considering the range of potential watering requirements and application efficiencies, we estimate that the total outdoor water use was between 120 and 369 afa. This total includes both residential and non-residential private parcels but most of the outdoor uses identified were associated with households. Based on parcel data, the older (pre-1997) homes were found to be more likely to have outdoor water use than newer homes, with irrigation of landscape plants largely making up the difference.

4.2.3 Limitations

The main limitation in our estimate of outdoor water use in the study area is a lack of high resolution imagery. Although the imagery we analyzed had an adequate (1-meter) resolution, it is likely that small-scale uses such as some gardens were missed and deficit-irrigated and xeriscaped areas may have been mistaken for natural vegetation. Conversely, areas watered only by rainfall may have been mistaken for irrigation. Higher resolution imagery and/or detailed field surveys would be required to reduce these potential errors.

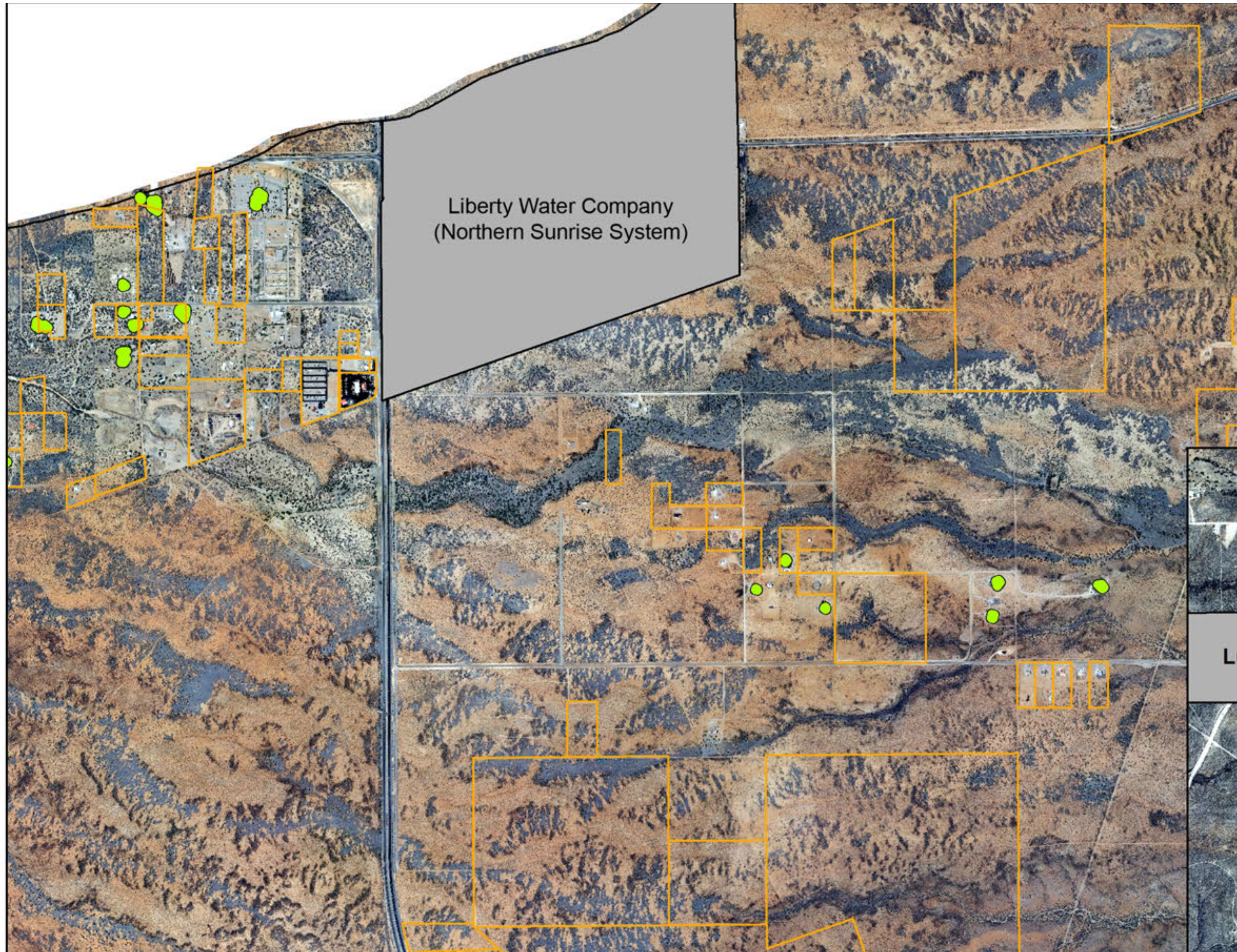
Another limitation was not being able to assess potential water use by evaporative coolers.[4] The California Energy Commission (2011) estimates that evaporative coolers can use from 3 to 15 gpd which, over a 4-month cooling season, could total 1,800 gallons. However, distinguishing evaporative coolers from air conditioners is difficult even with higher-resolution imagery and these data are not available from the county assessor. Use of evaporative coolers would best be determined through homeowner surveys.

We also did not evaluate outdoor water use by livestock. Four of the 19 homes we visited in the study area during December 2011 had livestock, so this type of use is not uncommon. However, the daily water use by livestock is relatively low, ranging from 0.25 gallons per chicken to 12 gallons per horse or cow based on standard use quantities from ADWR (2011b).

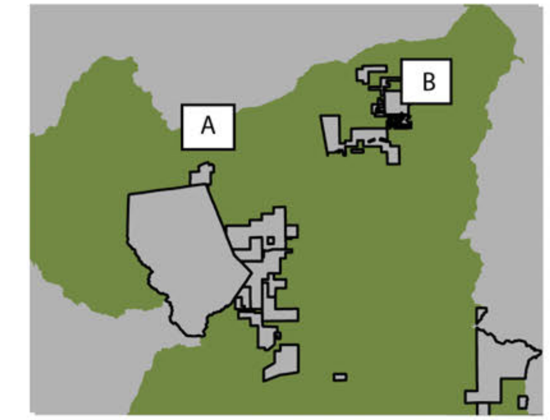
Finally, we did not consider other potential outdoor water uses including car and equipment washing, dust control, and cleaning of hardscapes which are difficult to quantify but normally are relatively small. We also did not attempt to evaluate how many home owners in the study area are potentially over irrigating.

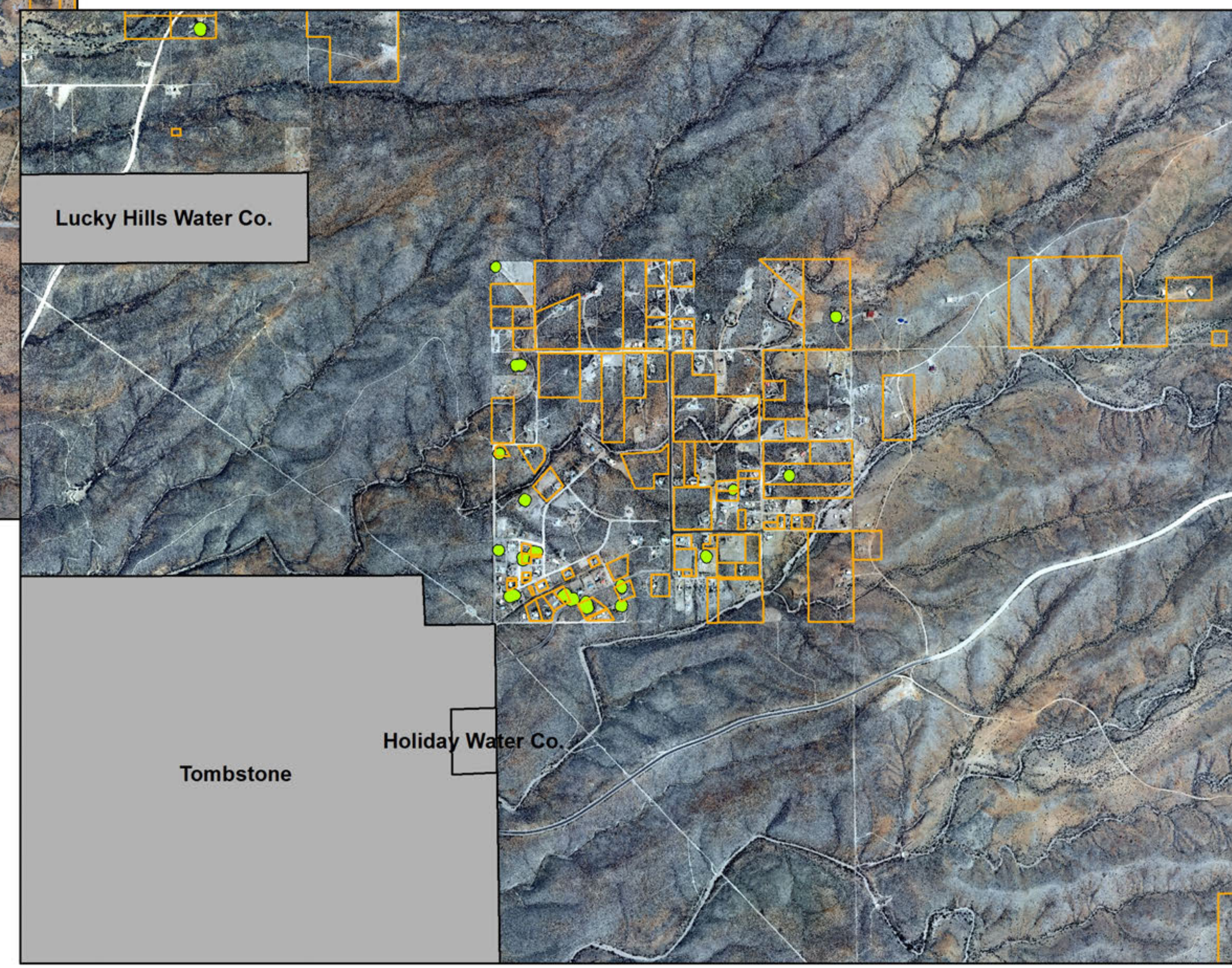
[4] For purposes of this study, evaporative coolers are considered an outdoor water use. This is consistent with exterior water use models used in AMA management plans and accounts for the outdoor disposal of cooler bleed off water.

Figure 4 A-B
Outdoor Water Use in the Study Area
Mapped During June 2010



A - Huachua City Area





B - Tombstone Area

Legend

- Water Provider Service Areas
- Parcels
- Outdoor Water Use

Note: Includes potential irrigation of pastures, orchards, turf and landscape plants and

N

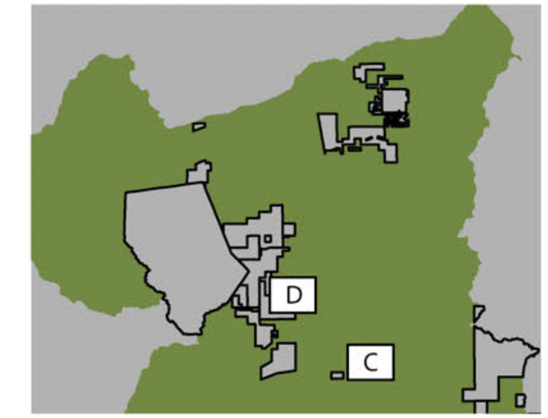
0 0.25 0.5 1 Miles

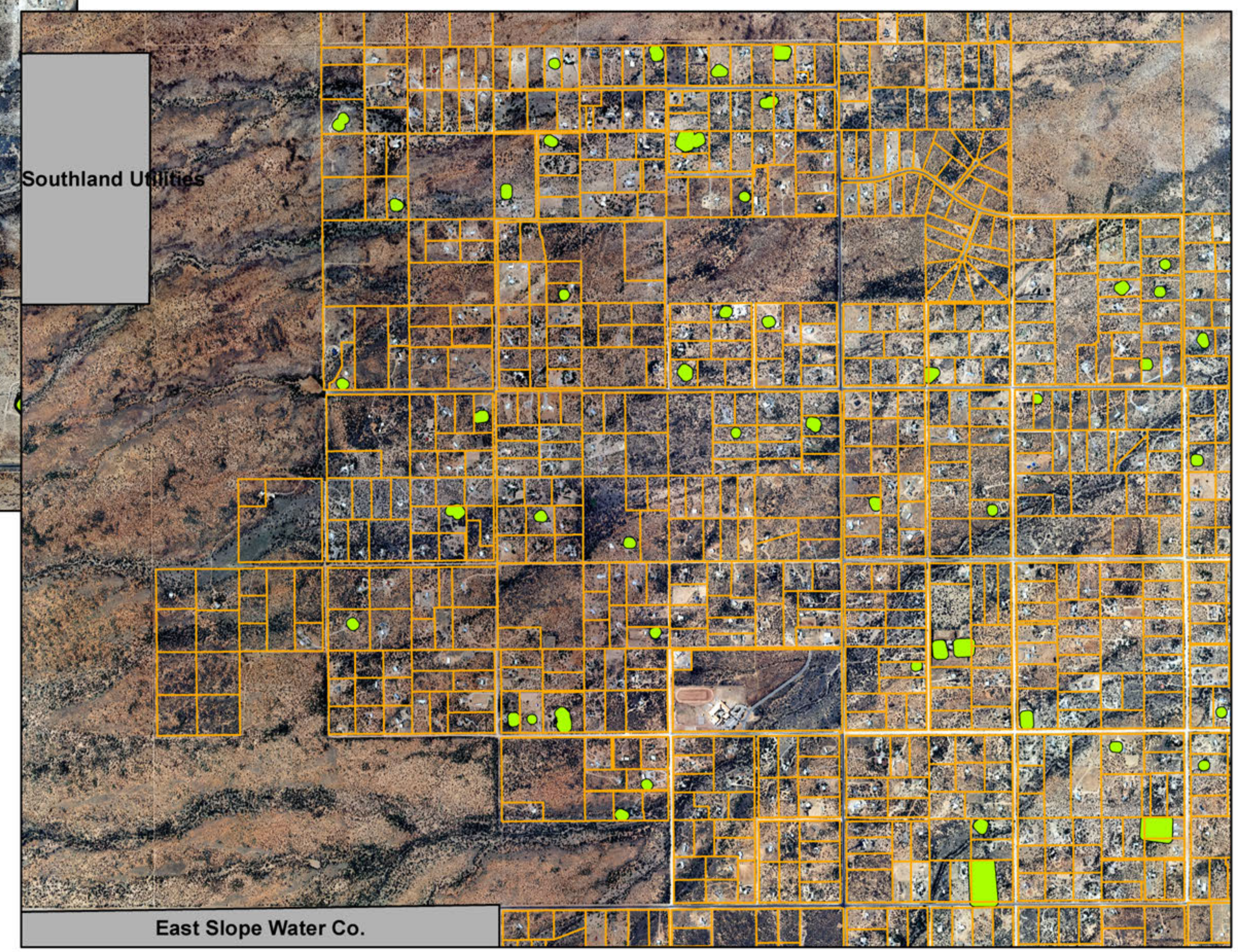
Data Source: Analysis of 2010 NAIP imagery and December 2010 ground truthing

Plateau Resources, LLC

Figure 4 C-D
Outdoor Water Use in the Study Area
Mapped During June 2010

C - Hereford Area





D - Sierra Vista Area

Legend

- Water Provider Service Areas
- Parcels
- Outdoor Water Use

Note: Includes potential irrigation of pastures, orchards, turf and landscape plants and water use by pools.

Plateau Resources, LLC

N

0 0.25 0.5 1 Miles

Data Source: Analysis of 2010 NAIP imagery and December 2010 ground truthing

5.0 WATER CONSERVATION

This section describes recent efforts to conserve water in the study area and methods to further reduce indoor and outdoor water demand by domestic well users. Also discussed are opportunities to recycle wastewater and extend the service area of existing water providers. All of these water conservation measures are ultimately aimed at reducing domestic well pumpage and thereby limiting potential impacts from pumping on the San Pedro River.

Figure 5 shows areas in the SVS with an increased potential to impact the river from pumpage of shallow wells. Most domestic wells in the study area are assumed to be shallow and completed in the uppermost water-bearing zone. Using USGS groundwater model data (Pool and Dickinson, 2007), Leake and others (2008) estimated the quantity of water that would otherwise flow to the San Pedro River if a well is not pumped. This 'capture' of groundwater by well pumpage would eventually impact the ecosystem of the river by reducing stream flow, spring discharge and riparian ET. The capture map presented in Figure 5 represents the potential effects of pumping a shallow well at a constant rate for 25 years.[5]

As expected, the modeling shows that the greatest fraction of capture by shallow wells is for areas closest to the river (the red areas in Figure 5). In several areas, after 25 years of pumping, more than half of the groundwater removed from a shallow well is estimated to be capture that would otherwise flow to the river, springs or riparian vegetation. Recent and future conservation efforts described below may have a greater impact on river ecology if focused on domestic wells in these areas of highest capture.

5.1 RECENT EFFORTS

Recent efforts to conserve water in the study area include city and county toilet rebate programs, revisions to county building codes, public education outreach through the Water Wise program and conservation grants to businesses. Each of these efforts is discussed further below.

5.1.1 Toilet Rebates

Since 2001, the City of Sierra Vista has offered a toilet rebate program that provides homeowners with a financial incentive to replace their older, inefficient toilets. The program is available to city residents who replace 3.5 gallons per flush (gpf) toilets with 1.6 gpf or better toilets. In late 2011 or early 2012 (?), the program began requiring toilet replacement with only high efficiency models that use 1.28 gpf or less.

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[5] This map is based on the computed increase in streamflow, spring discharge and riparian ET that Leake and others (2008) simulated would result from artificial recharge of water to the uppermost model layer. USGS provided their model output files at 5-year time steps for 100 years and Plateau selected the 25-year period to display in Figure 5. To represent well capture from shallow wells, the inverse of the simulated effects of recharge was calculated and the superposition principle applied.

Figure 5
Simulated Ground-water Capture Zones in the Sierra Vista Subwatershed

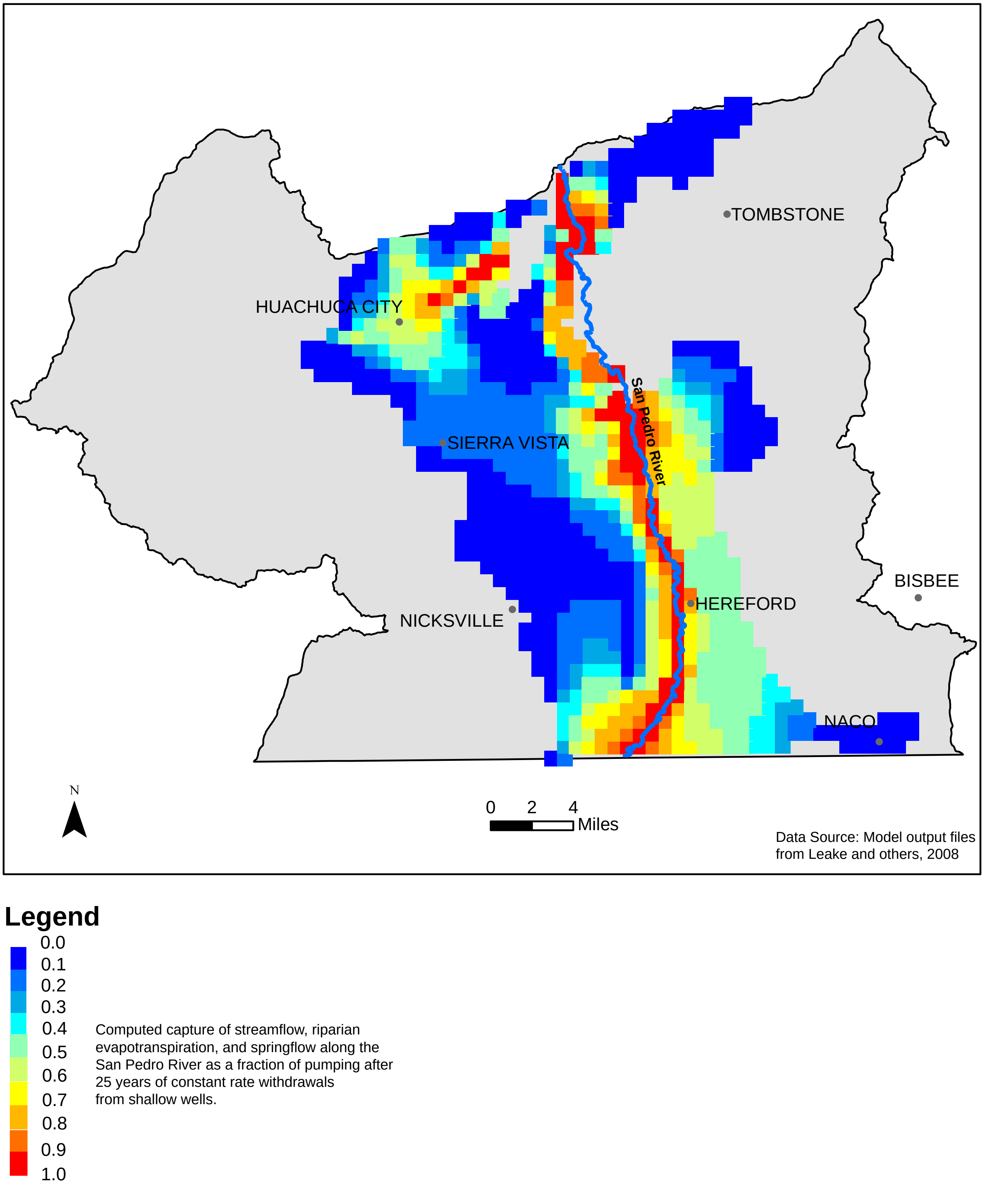

TABLE 7 – RESULTS FROM REGIONAL TOILET REBATE PROGRAMS

Fiscal Year	Number of Participating Households	Number of Toilets Replaced	Cost Per Unit Replaced	Total Expenditure
City of Sierra Vista (2011)				
2001/2002	176	197	$125	$24,625
2002/2003	at least 100	200	$125	$25,000
2003/2004 (Grant)	253	260	$121	$31,500
2003/2004		156	$121	$18,900
2004/2005	109	158	$120	$18,950
2005/2006	149	150	$120	$18,750
2006/2007	151	228	$124	$28,214
2007/2008	132	218	$124	$26,950
2008/2009	220	344	$125	$43,000
2009/2010	243	367	$125	$44,623
2010/2011	195	281	$122	$30,779
Total	**1,728**	**2,559[1]**	**$122 (avg)[2]**	**$311,291**
Cochise County (2009c)				
2004-2009	NP	600[3]	NP	NP
More recent data requested but not received in time for publication.				

NP = Data not provided.
Notes:
[1] As of August 15, 2011, the city estimates that its toilet rebate program is annually saving 73.6 acre-feet of water.
[2] Includes an assumed administrative cost of $25 per unit recovered for scheduling, pick-up, disposal and finance processing fees.
[3] As of 2009, the county estimates that its toilet rebate program is annually saving 30 acre-feet of water.

As of August 15, 2011, 1,728 Sierra Vista households had reportedly replaced a total of 2,559 toilets with an estimated water savings of 73.6 afa (Table 7). The city calculates its average cost per toilet replaced is about $125 which includes a $100 rebate check and an assumed $25 administrative fee. This compares to an estimated total cost by the homeowner of between $200 and $260 to purchase and install a new toilet (HomeWyse, 2011).

Cochise County has offered a similar toilet rebate program since 2004. This program is available to SVS homeowners that live in residences built before 1994 and located outside of incorporated areas. As of 2009, 600 toilets had reportedly been replaced at an estimated savings of 30 afa (Cochise County, 2009c). We were unable to obtain more recent toilet rebate information or locational data from the County.

5.1.2 Building Codes

In 2007, to further conserve water in the SVS, the Cochise County Board of Supervisors adopted more stringent standards for new residential and non-residential construction (Cochise County, 2009a). Within the Sierra Vista Subwatershed Water Conservation Overlay Zone, building permits for new homes must now include:

- Gray water lines plumbed to at least two fixtures and capped for optional future use;
- Hot water on demand systems for sinks and showers;
- No single-pass evaporative coolers; and
- Outdoor sprinkler systems, if installed or replaced, that include rain or humidity sensors to override the irrigation system after rainfall occurs.

In addition to its overlay zone, the county has developed a voluntary residential green building program to guide developers and owners on the design and construction of more energy efficient and water-conserving homes. The incentive-based program awards credits for construction measures that increase water efficiency and those homes with more credits receive a higher green rating. Credits are given for installation of the following water conservation measures (Cochise County, 2009b):

- Rainwater harvesting systems;
- Point of use tankless hot water heaters supplied by cold water or solar-assisted pre-heating;
- Low flow (1.5 gpm or less) bathroom faucets and showerheads and high-efficiency (1.28 gpf) toilets;
- Pervious driveway materials;
- Drought-tolerant plants that require little or no watering; and
- High efficiency irrigation systems that include moisture sensors, high efficiency nozzles, timing systems, and drip irrigation for all planting beds.

5.1.3 Public Outreach

Water Wise is a public education outreach program run by the University of Arizona's Cooperative Extension for Cochise County working in partnership with Cochise County, the City of Sierra Vista, Fort Huachuca, the USPP, Sulphur Springs Valley Electric Cooperative and the City of Bisbee. It promotes water conservation by providing local homeowners, including those served by domestic wells, with strategies to reduce their indoor and outdoor water demand. Free on-site consultations are offered to assess household water use ("water audits") as well as advice and resources to improve water use efficiency. Many educational materials are also available through the Water Wise website (www.waterwise.arizona.edu) on topics ranging from gray water systems, replacement of toilets and other water-use fixtures, and use of evaporative coolers. To reduce outdoor water use, information is provided on using alternative waters for irrigation such as rainwater and 'gray water', the use and replacement of pools, landscape watering requirements and RainScapes (established landscapes that rely entirely on rain and stormwater) and Xeriscape design. In addition, Water Wise provides information on available rebate programs and tax credits and hosts numerous education events throughout the year.

The City of Sierra Vista also offers public outreach through its "All About Water" website (www. sierravistaaz.gov/water). This website provides information on the city's toilet rebate program, local stormwater and effluent recharge projects, a link to EPA's WaterSense, an events calendar, and various data on the hydrology, water resources and sustainability in the SVS.

5.1.4 USPP Water Conservation Grant Program

The USPP currently offers businesses in the SVS, including those served by domestic wells, up to $2,000 to reduce their water use. To receive a water conservation grant, businesses must schedule an on-site visit with a Water Wise representative and then decide which conservation measure to implement. Several options exist such as:

- Replacing inefficient toilets and washing machines;
- Installing waterless urinals;
- Removing turf and replacing with Xeriscape;
- Installing a rainwater harvesting system; and
- Replacing swimming pool sand filters with cartridge filters.

5.2 INDOOR WATER CONSERVATION POTENTIAL

There are approximately 2,190 older (pre-1997) and 2,140 newer single family residences and mobile homes in the study area. Based on data presented in Table 3, the older homes may use, on average, about 51 gallons per day (gpd) more water indoors than the newer homes and about 67 gpd more than a home retrofitted with high efficiency fixtures. The difference in indoor water use between the newer and retrofitted homes would be less (about 16 gpd) but still substantial.

Studies by Aquacraft (2011) using flow trace analysis found that the largest interior water savings generally result from replacing inefficient toilets, clothes washers and, to a lesser extent, faucets. Water savings are also possible through installation of on-demand hot water circulation systems which may reduce per capita use by at least 2.5 gpd (James City, 2011).

Given the present level of assumed water use in study area homes, if all were eventually retrofitted with high efficiency fixtures and leaks reduced, the potential water savings could total over 200 afa[6]. Figure 6 shows the relationship between home ages in the study area and potential groundwater capture from domestic wells. Conservation efforts should be focused, as feasible, on the older homes that have the greatest potential to capture river water (light gray dots within red squares in Figure 6). The newest homes (2005 to present) that are located furthest from the river would generally have the lowest priority (black dots within blue squares).

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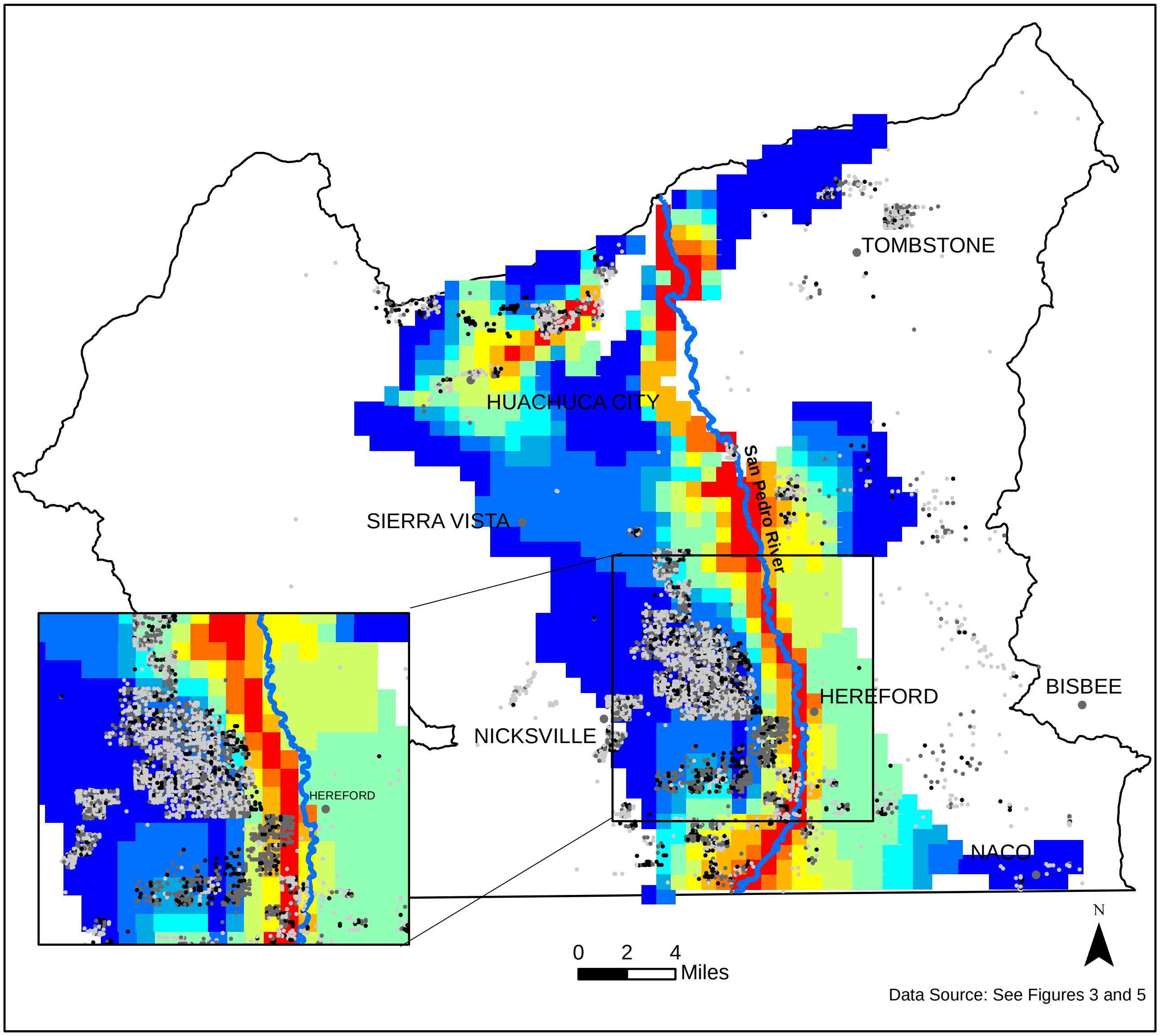
[6] Calculated by assuming that daily indoor water use is reduced from 166.3 to 98.9 gallons for 2,190 pre-1997 homes (a savings of 165 afa) and reduced from 114.9 to 98.9 for 2,140 newer homes (a savings of 38 afa). See Table 3 for further details.

Figure 6
Comparison of Ground-water Capture Zones to Assumed Indoor Water Use Efficiencies in the Study Area



Legend

0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Computed capture of streamflow, riparian evapotranspiration, and springflow along the San Pedro River as a fraction of pumping after 25 years of constant rate withdrawals from shallow wells.

Age of Single-Family Homes Served by Domestic Wells

- Before 1997 (~2,190 parcels)
- 1997 to 2004 (~1,330 parcels)
- 2005 to Present (~810 parcels)

Water audits, which are locally free to homeowners through Water Wise, can assess which home fixtures are least efficient, identify leaks, and educate homeowners on reducing waste. Such audits may also accelerate installation of new fixtures that would have otherwise occurred at a later date as fixtures age and need replacement or homes are renovated.

Fixture replacement is the preferred means of indoor water conservation since significant water savings can be realized with little effort or change in behavior. However, since domestic well owners in the study area do not pay for their water other than costs associated with well operation and maintenance, it may be difficult to convince them of the benefits of conducting a water audit and/or implementing audit recommendations. A changing water-use ethic in the SVS could, nonetheless, result in more audits and indoor water savings.

Financial incentives, either through fixture rebate or give-away programs, offer the best chance of reducing indoor water use in the study area through replacement of inefficient fixtures with quality fixtures that ensure savings. As described above, the Sierra Vista and Cochise County toilet rebate programs have been a success. As a further incentive, the City of Austin, Texas gives their replacement toilets away for free, but still makes the owner responsible for installation. The city reportedly keeps its costs down by purchasing units in bulk (The Statesman, 2010). Such programs can be very effective in reducing indoor water use. In the study area, an older home that replaces its high flow toilets with a good quality, high efficiency model may save up to 26 gpd or over 9,000 gallons in a year.

Some cities have also implemented clothes washer rebate programs, typically offering about $150 to offset the $500 or more cost of purchasing a high-efficiency (HE) front loading machine. Although more costly than replacing a toilet, the water savings from a clothes washer can also be significant. An older home in the study area that replaces its washing machine with a HE model may save more than 15 gpd or nearly 5,500 gallons over the year (see Table 3).

Installation of on-demand hot water recirculation systems could also offer both water and energy savings. Assuming an occupancy rate of 2.4 pph in the study area and a per capita savings of at least 2.5 gpd (James City Water Authority, 2011), these systems could save a household an average of 6 gpd or 2,190 gallons in a year with a potential annual energy savings of $100 to $200. If all homes in the study area were retrofit, this would result in nearly 30 afa of additional water savings. The systems can cost from $200 to $350 to install (James City Water Authority, 2011) and, in Arizona, the cities of Peoria and Scottsdale offer system rebates of $100 and $200, respectively. As described in Section 5.1.2, Cochise County now requires that hot water on demand systems be included in new homes built in the SVS.

While it is not reasonable to assume that all homes in the study area can be retrofit, the estimated savings from installation of high efficiency fixtures listed in Table 3 plus hot water recirculation systems could total over 230 afa.

5.3 OUTDOOR WATER CONSERVATION POTENTIAL

We identified approximately 73 acres of outdoor water use in the study area during 2010 based on remote sensing and ground-truthing. Over 70% of this acreage consisted of relatively large tracts of orchards and irrigated pastures. Water use by orchards could potentially be reduced by replacing sprinklers and flood irrigation with drip irrigation systems. Similarly, water use by pastures could potentially be reduced by using sprinklers instead of flood irrigation. Depending on current irrigation practices, these upgrades could result in a water savings of 15 to 20%. Further ground truthing is required to verify these potential savings.

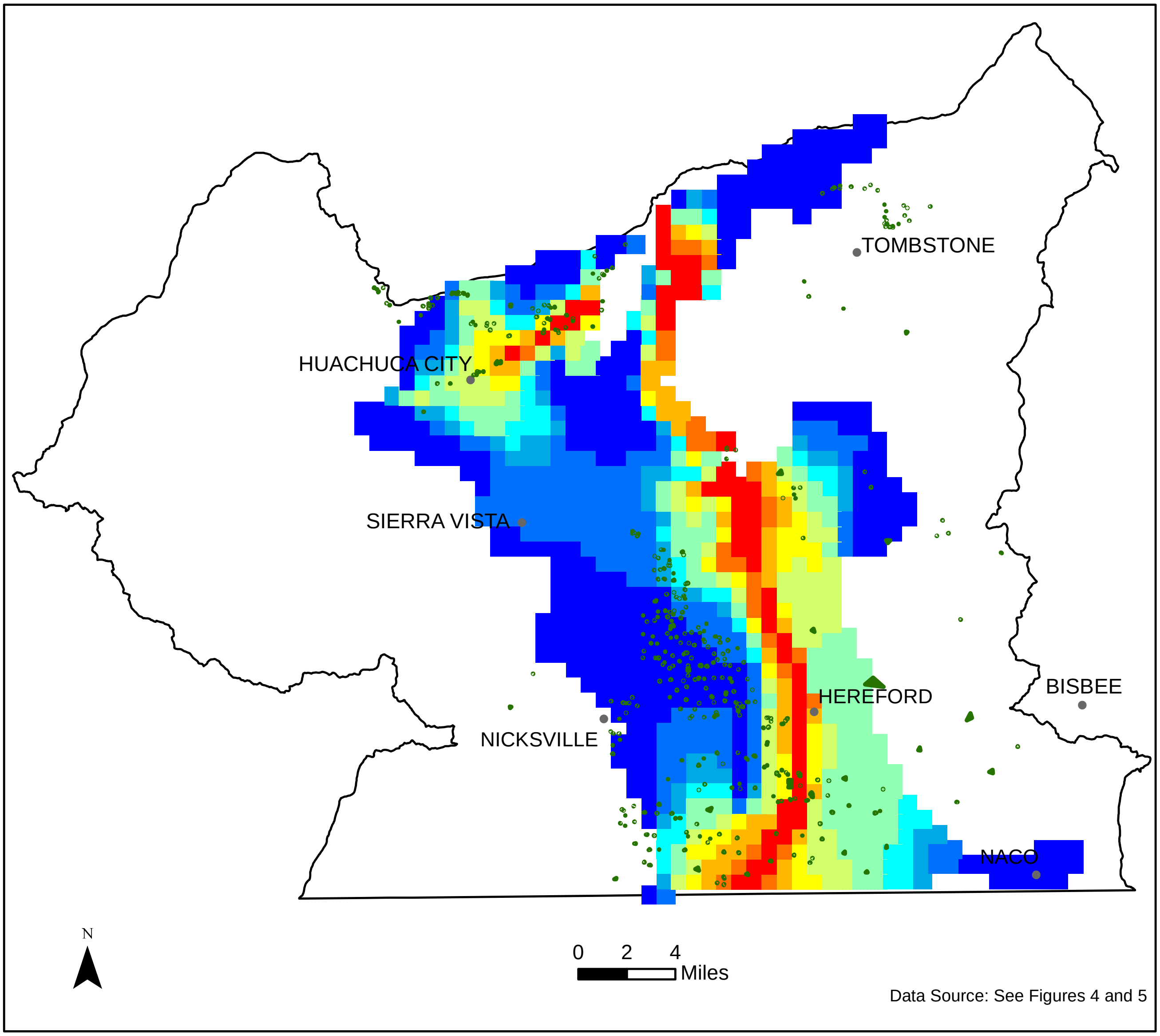
Other outdoor water uses (turf, landscape plants, and pools and fountains) were more common in the study area but covered smaller, individual plots. Due to their size, these areas would be amenable to water conservation strategies such as residential rainwater harvesting.

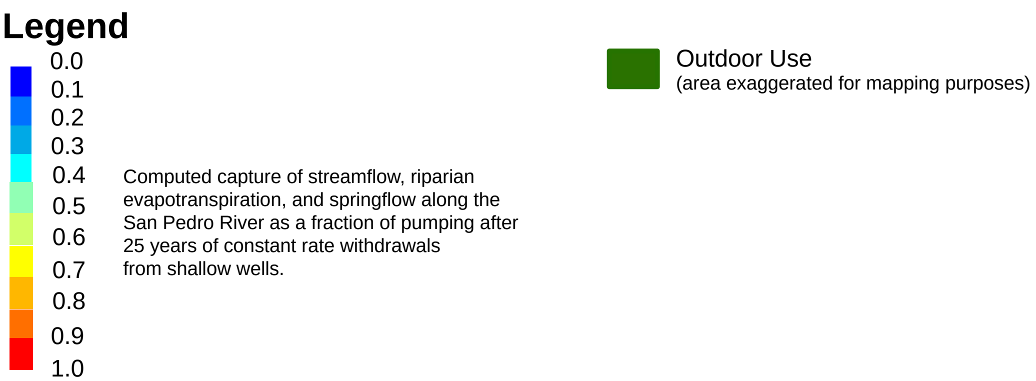
Rainwater harvesting could supply many residential outdoor water uses including some that we did not evaluate during this project (i.e. livestock watering, small-scale landscapes, dust control, and cleaning of hardscapes). It may also benefit homeowners by reducing on-site flooding and erosion and improving plant health due to the low salt and high nitrogen content of rainfall. Moreover, with additional investment, it could replace some indoor non-potable uses such as toilet flushing and provide an emergency water supply to homeowners in the event of power outages or well failure. In their evaluation of water augmentation alternatives for the SVS, BOR (2007) concluded that rainwater harvesting could indeed support toilet flushing in a housing development.

Rainwater harvesting systems can range from simple berms and dikes that divert storm runoff to planted areas to more sophisticated systems that store and distribute the rainwater at a later time. All of these systems require a catchment such as a roof, patio or driveway and generally produce about 600 gallons of runoff for every 1-inch of rain falling over a 1,000 square-foot area. For many homes in the study area, this yield would satisfy most, if not all, of their outdoor water demand.

Other outdoor water conservation measures include RainScapes, xeriscaping and installation of smart irrigation systems. Conversion of turf and high water use landscape plants to RainScapes and Xeriscape could result in local savings, particularly if combined with water harvesting. As listed in Table 3, the average supplemental watering requirement for Xeriscape in the study area is about 3 inches per year compared to over 30 inches per year for warm season grasses and over 25 inches per year for certain ground covers, shrubs and landscape trees. Smart irrigation systems could further reduce outdoor water use by automatically updating outdoor watering schedules based on local climatic conditions. Based on the type of application system and landscape plants, these systems can result in a range of water savings.

Figure 7
Comparison of Ground-water Capture Zones to Mapped Outdoor Water Uses in the Study Area





As with indoor water conservation measures, financial incentives offer the best chance of reducing outdoor uses in the study area. Some cities, notably Las Vegas, pay homeowners to remove turf and replace it with Xeriscape (Las Vegas Review Journal, 2011). Incentives for turf replacement have included rebates of $0.75 to $1.50 for each square foot of turf replaced, lump sum credits of $50 to $600, and $100 nursery gift certificates to purchase low-water use plants (WSJ, 2009). Free water audits, as presently performed by Water Wise, are also effective in identifying leaks in watering systems and educating homeowners on more efficient outdoor water use (Center for Resource Conservation, 2007). GSA (2010) describes in detail how a landscape conversion rebate program could be designed for Cochise County and the Sierra Vista area.

Regardless of the conservation measure, reductions in domestic well outdoor water use should be focused where the largest uses are occurring closest to the San Pedro River. Figure 7 shows the relationship between outdoor water uses mapped in the study area during 2010 and potential groundwater capture from domestic wells. Based on this figure, outdoor conservation efforts should be focused on areas northeast of Huachuca City and southeast of Hereford.

5.4 RECYCLE/REUSE

Domestic well users typically discharge their household wastewater (effluent) to a septic system. The quantity of effluent discharged into a septic system relates to the amount of indoor water use. For example, in central Yavapai County, USBOR and others (2011) estimated that an average of 69 gpcd is discharged into local septic systems, a rate that equals the estimated indoor rate of water use for older homes in our study area. However, the volume of effluent produced from a septic system is likely less since some indoor water use is consumed or taken off-site and some is retained within the septic tank itself. EEC (2002) estimated that about 80% of interior water use is discharged to the ground via a septic tank leach field.

The portion of this effluent that eventually returns to the local aquifer can vary due to septic system design and local hydrogeologic conditions. For a leach field to operate properly, the effluent must be in contact with air to prevent formation of a biomat that can inhibit downward percolation. For this reason, trench-type tile fields (pipes) are typically set no deeper than 3 to 3.5 feet (ADEQ, 2012). EEC (2002) estimated that if the tile field is less than 5 feet deep, the rate of recharge to the underlying aquifer is approximately 40% of the effluent discharged, with the remainder lost to evapotranspiration. The misconception that virtually all indoor water use replenishes the aquifer via septic tank recharge has been used to argue against the effectiveness of indoor water conservation. Clearly there are still benefits, both from a hydrologic and economic (pumping cost) perspective.

With an estimated domestic well population of at least 12,000 (see Table 1), the volume of effluent reporting to septic systems in the study area is relatively large. The USBOR study mentioned above identified septic system recharge as a potential future water supply. Recovery of this effluent could represent an important new source of water for mitigating potential impacts from well pumpage on river health in the region. Lacher (2012) recently simulated three recharge sites, two along the San Pedro River and one along the Babocomari River, where managed recharge could enhance stream flows.

To utilize effluent from domestic well owners, existing sewer lines would need to be extended and/or small package plants locally constructed. Such measures would be most cost effective where the density of septic systems is high and existing sewer lines are located nearby. The City of Bisbee recently consolidated and upgraded its waste water treatment system and is extending service to residents still on septic systems. Similarly, Sierra Vista has plans to connect existing septic systems in the city limits to sewer lines and thereby augment its recharge of effluent to the regional aquifer system.

The cost to extend sewer system services into the study area is difficult to determine without detailed engineering studies that address, among other factors, the current capacity of local treatment plants and sewer lines. And even if such costs were known, it may be difficult to convince homeowners to participate in a program that requires them to pay a sewer hook-up and monthly service fee. Figure 8 shows some existing wastewater service areas in the SVS relative to the density of homes served by septic systems. Sewer system expansion could be targeted for those areas where high home density is close to existing service areas.

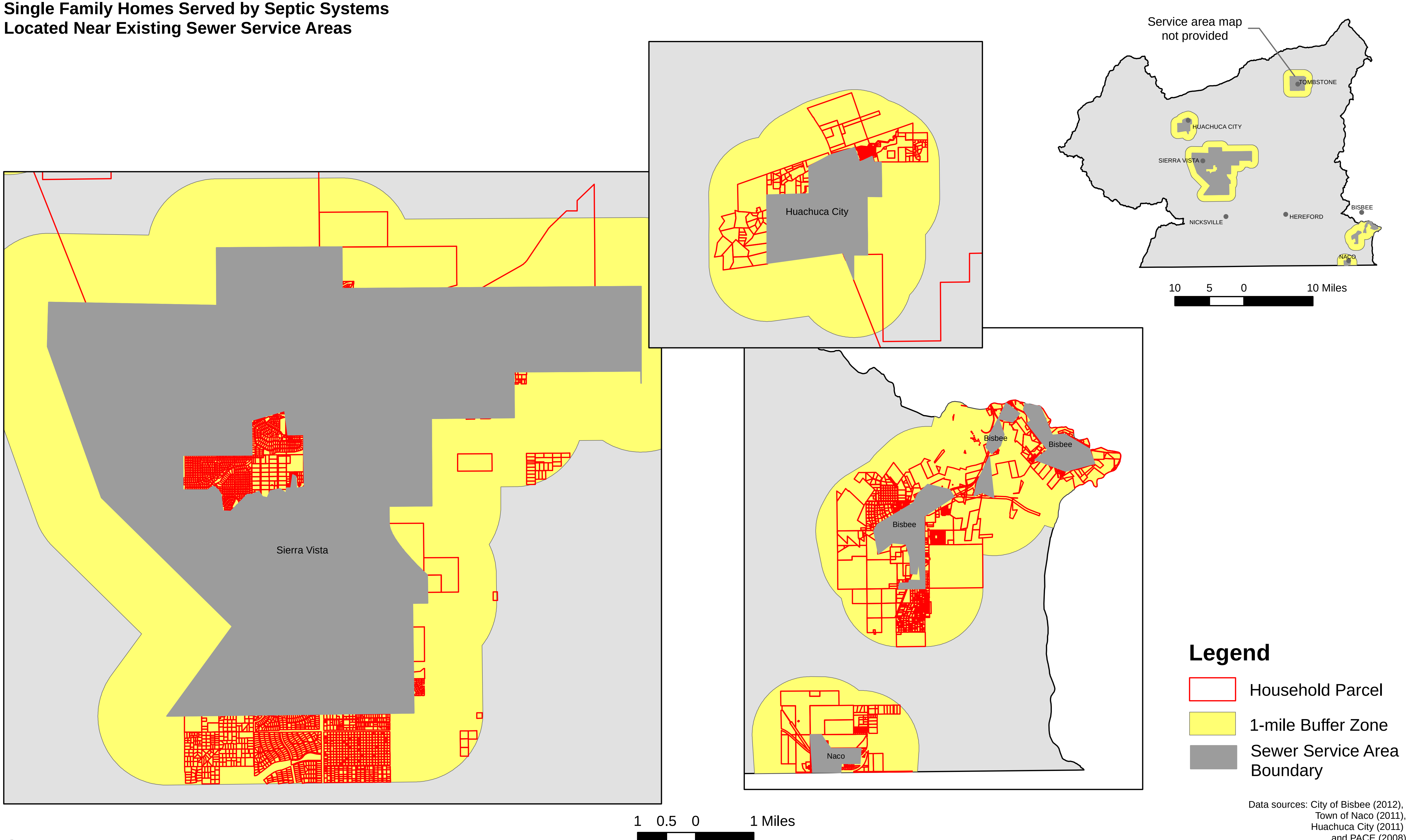
As an alternative to connecting to a sewer line, some homeowners in the study area could utilize their effluent as gray water to supplant groundwater for certain outdoor uses. ADEQ (2011) has developed 13 Best Management Practices (BMPs) to comply with Arizona's rules for gray water use. Gray water can include waste water from clothes washers, bathtubs, showers and sinks, but not from kitchen sinks, dishwashers and toilets. Other restrictions include only using gray water on-site, the water must be applied using a drip or flood irrigation system (not spray), and no more than 400 gallons can be used each day.

5.5 EXTEND WATER PROVIDER SERVICE AREA

There would be several benefits from extending water provider service areas into the study area. For existing well owners, a water provider can offer a reliable supply of water, regularly monitored water quality, and relatively low-cost delivery. In addition, there would be no further costs for well operation, maintenance and deepening. From a conservation perspective, customers could track their monthly water usage and would probably receive information on conservation in their water bills and on-line. Most domestic well owners are probably generally aware of their water use through energy bills or well-share arrangements but, since their wells are unmetered, it is likely difficult for them to determine if they are using water efficiently.

Notwithstanding the above benefits, domestic well owners have made substantial investments in their water systems and probably enjoy not having to pay a monthly water bill. Extending water provider services into unserved areas may, therefore, prove both unpopular and cost prohibitive given the relatively low housing density of most rural areas. It may only be feasible (a) where higher density areas are immediately adjacent to existing water providers; (b) if financial incentives are offered; and/or (c) if water levels are locally declining and wells require expensive deepening. Figure 3 shows the location of existing water providers in the SVS relative to homes served currently by domestic wells.

Figure 8
Single Family Homes Served by Septic Systems
Located Near Existing Sewer Service Areas



Data sources: City of Bisbee (2012),
Town of Naco (2011),
Huachuca City (2011)
and PACE (2008)

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6.0 TRANSFERABILITY OF STUDY

The methodologies described in this report could be used to estimate the conservation potential of domestic wells in other areas. In addition to assisting local water managers in designing and implementing more effective water conservation programs, such efforts could shed further light on unmetered domestic well use in Arizona and increase our understanding of potential impacts to rivers from well pumpage. The most critical information needed for methodology transfer includes:

- Water provider service area maps;
- Population data;
- Parcel maps and files including construction dates;
- Aerial imagery; and
- Climate records.

Most water providers have accurate maps of their service areas but note that some maps may only be available in hard copy and would have to be digitized. ADWR has a current list of water providers in each groundwater basin who can be contacted for these maps. Additional water provider information is summarized in Community Water System Reports, also available from ADWR and posted on-line.

2010 census block data should be available soon for most areas and is needed to estimate the number of persons potentially served by domestic wells and the average number of persons served per household. For this study, block data were unavailable so tract data were used instead. Domestic well populations are determined by overlaying the census data on service area maps using GIS software and persons per household is calculated by comparing this population to the number of parcels in the area with single and multi-family residences and mobile homes.

Parcel maps and database files can be obtained from county assessor offices and are critical for identifying the location and address of households. As described further in Section 7, addresses are particularly important if contacting homeowners is necessary. However, this information may not be free and could contain inaccuracies and/or be incomplete. Cochise County charges a fee for an electronic copy of their parcel maps and database and our review of their database found that some homes did not have a date of construction. The construction date was necessary in assessing which households are likely to have inefficient indoor water uses based on home age. Several other parcels coded in the database with no improvements ("none") actually have homes when we compared these against recent aerial imagery. Unfortunately, due to the relatively large number of parcels in our study area, it was impractical to verify whether each of these parcels was indeed vacant so a random sampling was performed. Such verification of parcel information is recommended, particularly in rural counties where home improvements may initially go undocumented.

Aerial imagery is readily available for most areas however, to evaluate outdoor domestic water uses, the imagery should be recent, have at least 1-meter resolution, include multi-spectral bands, and be collected at a time of year when irrigation is occurring. Higher (1-foot) resolution is preferable and would allow identification of smaller outdoor uses such as gardens and fountains. Multi-spectral bands are helpful in distinguishing natural from irrigated vegetation and for identifying deficit irrigation. Any imagery that was collected during the wet season or a particularly wet year should be used with caution as it may not be representative of local outdoor water demands. And, regardless of which imagery is selected for analysis, ground-truthing is necessary to verify the types of outdoor water use identified and which irrigation methods are being utilized.

Finally, climate records are needed to estimate local watering requirements and evaporation rates from open water bodies. Agricultural extension offices can be a good source for this information and serve many rural areas where domestic wells are common. In Arizona, detailed weather data are also available in larger farming districts through a network of meteorological (AZMET) stations. Data from these stations can be used to calculate evapotranspiration rates for a variety of crop types.

7.0 STUDY LIMITATIONS

Listed below are several limitations of this study as well as recommendations on how these could be addressed in future studies:

- Due to limited data on domestic well pumpage, indoor residential water use in the study area was estimated by assuming a relationship between home age and fixture efficiency. A survey of homeowners and/or metering in the area would confirm this relationship;
- The county assessor did not have dates of construction for about 50 homes listed in the study area. To estimate the water conservation potential of these homes, we assumed that all were constructed before 1997. This assumption could be verified through site visits or homeowner surveys;
- Over 600 parcels in the study area identified by the county as unimproved are estimated to have a household based on our random check of recent aerial imagery. All of these ‘vacant’ parcels (nearly 4,000) should be checked and dates of home construction determined;
- The current number and location of homes in the study area that have already participated in the County toilet retrofit program is unknown, so the actual indoor conservation potential is probably somewhat less than described. Since participation in this program is kept confidential, a homeowner survey would be required to obtain this information;
- All relatively large outdoor water use areas (orchards and pastures) should be visited to determine which irrigation systems are in use. This information would be useful in identifying areas of greater outdoor water conservation potential;
- Higher (1-foot) resolution aerial imagery is needed to identify potential small-scale outdoor water uses in the study area such as gardens and fountains and avoid mistaking some deficit irrigation and xeriscaping for natural vegetation;
- Other types of outdoor water use were not evaluated in the study area including evaporative coolers, livestock, car and equipment washing, dust control and cleaning of hardscapes. It is also unknown

how many homeowners are potentially over irrigating. Detailed on-site visits, homeowner surveys and/or metering are necessary to quantify these additional uses; and

- We did not assess domestic well use by multi-family homes or commercial and public buildings. Fortunately, their number is relatively low in the study area (see Table 1), so on-site visits would be practical.

8.0 CONCLUSIONS

This study developed methodologies to estimate the indoor and outdoor water demands of domestic wells in the SVS and evaluate their conservation potential. These methodologies may assist local water managers in designing and implementing more effective water conservation programs and be transferable to other areas. While well metering, homeowner surveys, detailed site visits and higher resolution aerial imagery could all improve estimates of domestic well use, such options are often unavailable or impractical. The methodologies we employed are relatively inexpensive and easy to implement and provide a first approximation of domestic well pumpage and conservation potential.

Almost 20% of the SVS population is served by domestic wells. Our study focused on the domestic wells in unincorporated areas. Based on metered well data from other studies, estimates of domestic water use and results from this project, the annual water use by these wells may average about 0.3 afh or less, equivalent to a daily use of 112 gpcd. Actual use may be higher and while this demand is relatively low compared to some reported residential demands, additional water savings are possible through targeted conservation programs.

Assuming a relationship exists between housing age and the efficiency of a home's water fixtures and appliances, we estimate that the approximately 2,200 older (pre-1997) homes in the study area could, on average, each save up to about 67 gpd indoors if retrofitted with higher efficiency models. The 2,100 newer homes in the study area could, on average, each save up to about 16 gpd indoors if similarly retrofitted. Using studies by AWWA (1999) and Aquacraft (2011a,b), the current interior domestic well demand for homes in the study area is estimated to total nearly 700 afy, with a water savings potential of about 200 afy. Large-scale fixture and appliance retrofit programs, installation of on-demand hot water recirculating systems, and leak reduction (often associated with older fixtures) show promise for reducing this interior water demand.

Using 1-meter aerial imagery collected in June 2010, we identified approximately 73 acres of outdoor water uses in the SVS supplied by domestic wells. These uses included pasture, orchards, turf, landscape plants and pools. Accounting for local watering requirements and assumed irrigation efficiencies, we estimated a total outdoor water demand of between 120 and 369 afy. Additional, lower water use landscaping would likely have been identified if higher resolution imagery had been available. We did not quantify evaporative cooler, livestock or incidental outdoor water demands. Improving irrigation efficiency may be a conservation option for some irrigated pasture and orchards, which comprised over 70% of the irrigated acreage, while rainwater harvesting could be suitable for a range of other outdoor uses as well as non-potable indoor use.

The fraction of groundwater captured by domestic wells that would otherwise flow to the San Pedro River was evaluated using USGS (2008) groundwater model data. As expected, wells located closer to the river typically capture a greater fraction of this flow than wells further away over a given period. Such capture could eventually impact the ecosystem of the river by reducing streamflow, spring discharge and riparian ET. We recommend that conservation efforts be initially focused where areas of greatest groundwater capture coincide with higher domestic well use (e.g. parcels with older homes and/or substantial outdoor water use).

Wastewater generated by homes supplied by domestic wells is a potential resource in the SVS. When discharged to septic systems, some wastewater is lost to evapotranspiration and the remainder eventually reaches the underlying aquifer. To support regional water management goals, this effluent could be captured and reused, either directly or by recharge at critical, target areas. We mapped the location of parcels served by domestic wells in proximity to existing municipal sewer systems to identify areas for potential sewer system expansion. Although such expansions would be an expensive undertaking, there may be areas in the SVS where this alternative is attractive. For example, the Sierra Vista Sulger Sewer Project is currently expanding service to neighborhoods where lots are too small to comply with current state septic tank siting requirements and where septic system failures have occurred. Funded through grants, the connection cost for these homeowners can be spread over 20 years to reduce the economic impact. Alternatively, programs that promote gray water capture from clothes washers, bathtubs, showers and bathroom sinks could be considered.

Extending the service area of water providers in the SVS could also provide conservation benefits. However, because domestic well owners have already invested significant resources in their wells, this alternative may only be attractive in areas experiencing significant water level declines.

All residents of the SVS have a stake in using the regional aquifer system in a sustainable manner, both to preserve the local economy and the San Pedro River. Acknowledging its limitations, our study provides information that may help local water managers and hopefully will further their efforts to engage domestic wells owners in meeting this goal. Success will be best achieved by identifying those homes supplied by domestic wells with the greatest conservation potential and accounting for their proximity to the river.

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