Water Use by Single-Family Residences in the Tucson Water Service Area in 2009 & 2010

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Tucson Water
Tom Arnold

Pima County Regional Flood Control District
Akitsu Kimoto
Evan Canfield

Executive Summary

In April 2008 the City of Tucson and Pima County initiated a joint effort for sustainable water resource planning known as the "City/County Water and Wastewater Infrastructure, Supply and Planning Study" (WISP). The Water Study was a multi-year effort to identify ways the City and County, which respectively own and operate the region's primary water and wastewater utilities, could work together to advance more cooperative and sustainable water planning.

After two years of intensive study under the guidance of a joint City/County Citizens Advisory Committee, City and County staff prepared the Phase 2 Water Study Report. The Phase 2 Report establishes a framework for sustainable water resources planning including 19 goals and 56 recommendations within four interconnected elements: Water Supply, Demand Management, Comprehensive Integrated Planning and Respect for Environment. This study addresses Demand Management Goal 1 – Collect Uniform Data on Water Use Patterns to Identify Conservation Potential.

The City of Tucson Mayor and Council and the Pima County Board of Supervisors adopted the Phase 2 Report through City and County resolutions (No. 21478 and 2010-16 respectively), and directed staff to work together to create an Action Plan for implementing the Phase 2 goals and recommendations.

http://www.tucsonpimawaterstudy.com/AP/ActionPlan_web.pdf

Water use patterns need to be understood in order to project demand and target conservation efforts. For this reason, a foundational effort in addressing Demand Management was to simply understand how water is used, and Demand Management Action Workplan 1.1. focused specifically on water use in single-family residential housing with an aim to identify management strategies for more efficient water use in the residential sector (Attachment A).

The Phase 2 effort recognized that this effort to understand water use in the residential sector was foundational to managing Demand Management. A project team of Tom Arnold from Tucson Water, Evan Canfield and Akitsu Kimoto, from Regional Flood Control District studied water use in single-family residential housing.

The team used monthly water use data for approximately 70,000 single-family residences in over 1200 subdivisions in the Tucson Water service area for calendar years 2009 and 2010. The characteristics of these residences were derived from two datasets: the GIS parcel data from the Pima County GIS library and tabular data on those parcels, including property value, from the Pima County Assessor's office. Household size came from the 2010 census block data.

While the workplan for Demand Management 1.1 described two reports, one to address how to modify building and zoning codes to reduce demand in new construction, and one to address how to implement demand management in existing construction, the project team ultimately decided that the results of the study were best described by reports in three separate chapters as follows:

Chapter A. Per-Household Water Use Study – a "big picture" story about how construction pattern and household water use differ between homes built before 2000 and homes built after. (Arnold lead author)

Chapter B. Per-Capita Water Use Study – ties in the census data and describes some of the nuances in water use and some of the surprising findings (water use in "green" subdivisions is actually a little higher). (Kimoto lead author)

Chapter C. Subdivision Water Use Study – a look at larger trends including subdivision water use characteristics and potential factors affecting the water use pattern. (Kimoto lead author)

The project team decided to proceed with these chapters rather than the original two because the analysis had shown that the underlying assumptions about what reports were needed were flawed. For example, the project team expected to see that one new subdivision would have significantly different water use from another allowing us to describe what building and zoning codes would be better for reducing water use in future development. However, the study found that newer subdivisions tended to use less water than older subdivisions, and parcel area provided a useful way to understand water use.

The study indicated that current building and zoning codes operating within the market demand produced single-family residential homes that use substantially less water than homes built before 2000. Therefore, the project team did not believe that it was necessary to identify individual building and zoning code changes that should be promoted for water efficiency

Some of the findings of the reports are as follows:

Chapter A. Household Water Use Study – shows that homes built after 2000 use less water than homes built before 2000, and that there are structural differences that may be the reason for this lower use including:

- *Smaller parcels:* The most common parcel area in homes built before 2000 is 7,500 to 12,500 sq ft, while the most common parcel area of homes built after is 5,250 to 7,500 sq ft.

- *More livable area on a typical parcel:* Even though the most common parcel area of homes built after 2000 was smaller, the home on that parcel had an average indoor area of 1,735 sq ft, which is about 200 sq ft larger than the home on the most common parcel area for home built before 2000.

- *More garage bays:* About 40% of all homes built before 2000 had one or no garage bays, while only about 5% of homes built after 2000 had none or one garage bay – meaning that 95% of all homes built after 2000 had two or more garage bays.

- *Fewer pools:* About 15% of homes built after 2000 have pool(s), while about 25% of homes built before 2000 have pools.

- *Transition to air conditioning from evaporative cooling:* Over 50% of all homes built before 2000 have evaporative cooling, while less than 1% of all homes built after 2000 have evaporative cooling.

Overall, *Chapter A. Household Water Use Study* shows that there are structural reasons for homes built after 2000 to use less water. Newer homes built after 2000 are likely to be on smaller parcels, and more of that parcel is likely to be covered by home or garage space leaving less space for landscaping. Furthermore, they are less likely to have pools and evaporative coolers. These structural differences also tend to reduce the difference between summer and winter water use because landscaping, pools, and evaporative coolers will use more water in the summer.

Chapter B. The Per-Capita Water Use Study –showed that the average household size in homes built after 2000 was slightly larger than homes built before 2000. Coupled with the lower water use per household noted in *Chapter A. Household Water Use Study*, this chapter showed substantially lower water use per person in homes built after 2000. In particular:

- *Lower gallons per capita per day (GPCD:* In homes built after 2000 the average per-capita water use is about 90 GPCD, while it is 114 GPCD in homes built before 2000).

- *Larger household size:* In homes built after 2000, the average household size (number of people living in houses) is 2.77, while it is 2.55 in homes built before 2000.

- *Smaller seasonal difference in summer and winter water:* The average summer water use in homes built after 2000 was about 19 GPCD more than winter, while the summer water use in homes built before 2000 was about 44 GPCD more than winter.

- *Smaller water use in winter:* Winter water use in homes built after 2000 averages 78 GPCD, while it is 88 GPCD in homes built before 2000.

- *More water use in "Green" homes:* "Green" homes use 87 GPCD on average, while "Non-Green" homes use 78 GPCD on average. The analysis showed that "Green" homes" may use more water on average than "Non-Green" homes on per capita (GPCD) basis on comparable parcel sizes, particularly in summer. In part, this higher per-capita water use in "Green" homes can be attributed to smaller household size with average number of residents of 2.5 compared to 2.9 in "Non-Green" or traditional construction. However, it should be noted that sample size for "Green" homes is significantly smaller than the one for "Non-Green", which could affect the results.

Chapter C. Subdivision Water Use Study – showed the larger trend of subdivision water use characteristics. This study considered both household water use in per-household use in Ccf and per-capita use in GPCD for subdivisions. Because the original goal was to consider before and after 2000, it

considered subdivisions built entirely before or after 2000. Some of the findings are as follows:

- *Average per-household water use (Ccf) and per-capita water use (GPCD) are relatively high in the foothills area.* The average subdivision per-household water use in the foothills was 20 Ccf or greater. The average subdivision per-capita water use in the foothills was 150 GPCD or greater with some subdivisions exceeding 300 GPCD.

- *Average per-household water use (Ccf) is relatively low in central and southern Tucson, while average per-capita water use (GPCD) is relatively low in southern and southwestern Tucson.* In central and southern Tucson, per-household water use in most subdivisions is less than 12.5 Ccf. In central and southwestern Tucson, per-capita water use is 100 GPCD or less with some subdivisions using less than 50 GCPD.

- *The lower per-capita water use in southern and southwestern Tucson can be caused by a larger household size living in newer and more water efficient housing in southern and southwestern Tucson.* In this area, the average household size is about four, while it is three or less in most of the Tucson Water service area.

- *Water use increases with both property size and property value.* However, the relationship between property value and water use has a stronger statistical significance. Furthermore, the relationship between water use and property size approaches a constant, while water use continues to increase with property value.

- *There is significant variability in water use within a newer subdivision, even if the subdivision appears to be similar in parcel and house sizes.* In the newer subdivision studied, the per-capita water use ranges from less than 5 Ccf to greater than 20 Ccf.

Overall, this study indicated that property characteristics, such as age of a house, parcel area and property values influence water use. Furthermore lower per-capita water use is impacted by the number of residents living in a property. Newer homes use less water overall, and the difference between summer and winter water use is substantially less, suggesting a decline in consumptive uses such as landscaping, pools and evaporative coolers.

Because one of the objectives of the task that provided the focus for this study (presented in Attachment A) was to develop a uniform data collection methodology, a methodology is proposed and summarized in Attachment B.

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Chapter A - Assessing the Impact of New Construction Patterns on Single Family Household Water Demand

1. Summary:

During the 2000s, single family parcel sizes decreased and homes grew. With ever larger garages, there was little space left for swimming pools and landscaping. Newer homes no longer use evaporative coolers and instead rely on air conditioning. The result is lower water usage in single-family residential homes in the Tucson Water Service Area. These changes in the housing stock were due largely to the market forces as opposed to regulatory requirements. To the extent these conditions persist, new residential housing will use considerably less water than homes constructed earlier.

The water use of single-family homes constructed in the 2000s can be treated as a baseline from which future zoning and building codes or other requirements can be measured. There is no guarantee the development patterns of the 2000s will continue. We may find that parcel sizes increase as the market for mid and down market homes is reduced and credit requirements tighten. If the region begins to grow again, instead of a booming single-family housing market, we may see a return to multifamily construction. Thus while the average parcel size may increase to satisfy a higher end, single-family housing market than we had in the 2000s, the percent of all new housing that is single-family may fall. From a total residential water demand perspective, if there is a shift from single-family housing to multifamily, the result will be lower demand, similar to the effect smaller parcel sizes had in the 2000s.

2. Scope:

In this chapter, we examine differences in single-family residential water use in the Tucson Water Service Area between those homes constructed before 2000 and those constructed after 2000. This is a convenient, though arbitrary division, because it is likely that a home constructed in 1999 is not substantially different from one constructed in 2002. Much of the nuance of the trends is lost by creating a simple dichotomy of before and after 2000, but this division lends itself to the relatively straightforward bivariate analysis used in this paper. That said, the 2000s did represent a period of unprecedented growth in a relatively short period of time. While not perfect, it does give us insight into the characteristics of new construction and the impact it has had on demand and provides a reasonable baseline for assessing the efficacy of additional zoning and building requirements to achieve a greater reduction in demand.

The analysis used data from over 60,000 parcels with homes built before 2000 in the Tucson Water Service Area, and about 9,000 parcels with homes built after 2000. A description of the data used for this analysis is presented in Appendix A-1. For water use, we used monthly usage from 2009 and 2010 and selected homes with a construction year before 2008. This removed homes that did not have time to establish a “normal” level of demand by 2009 and 2010. There weren’t many homes constructed after 2007, as the housing bubble had largely burst by that point.

Water use data in Tucson Water Service Area (TWSA) for 2009 and 2010 was used for this study. Both 2009 and 2010 were dry years, though 2009 was exceedingly dry and 2010 approached normal conditions. In 2010, annual rainfall of 11.13 inches was just under the long-term average of 11.59 inches with 5.45 inches of Monsoon rainfall, just below the long-term average of 6.06 inches. In contrast, 2009, was the 4th driest year recorded at the Tucson airport with only 5.67 inches of annual rainfall and 2.86 inches of Monsoon rainfall. Because water use data was from these two dry years, water would have been required to supply outside water needs, especially in the hotter months of 2009.

The following variables were used in this chapter to help explain why water use per home decreased after 2000.

1. Parcel size
2. House size
3. Garage capacity
4. Pools
5. Cooling

3. Water Use in Single-Family Residential Housing before 2000 versus after 2000:

3.1 Overall Reduction in Water Use in Homes Built After 2000

As can be seen in Figure A-1, the average per-household water use of newer homes is less than those homes constructed before 2000, except during the winter months. The difference is noticeable for the summer months where there is a 1.3 Ccf per month difference in usage.[1]

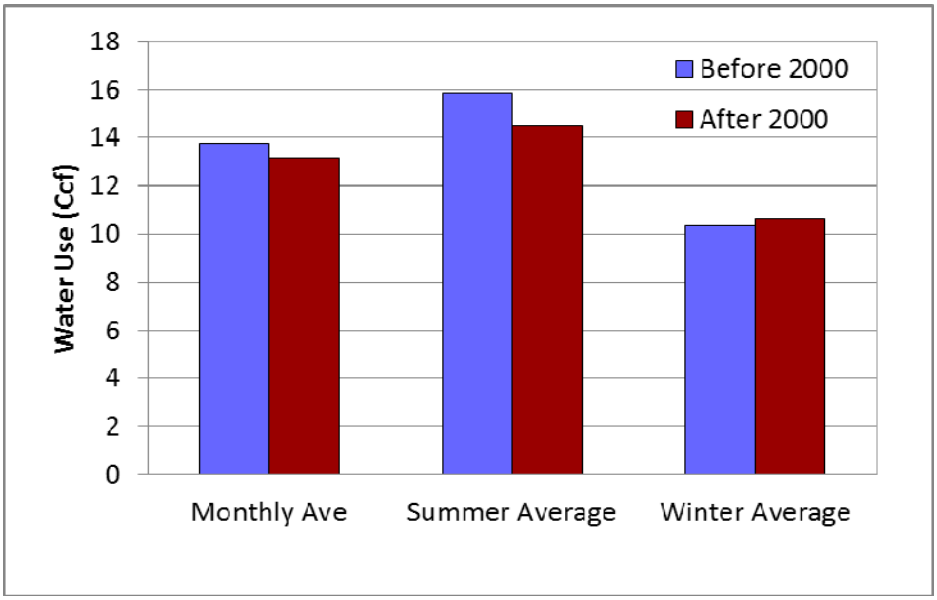

Figure A-1: Per-Household Monthly Water Use Before and After 2000.

[1] By the 2009 and 2010 period, the difference in water use between before and after 2000 homes had fallen significantly, primarily because pre 2000 homes water use had fallen dramatically in the latter part of the decade.

3.2 Reduction in Water Use for All Parcel Size Classes

Figure A-2 shows that water use increases significantly with parcel size for both “Before 2000” and “After 2000.” The water use is lower for “After 2000” across all parcel sizes.

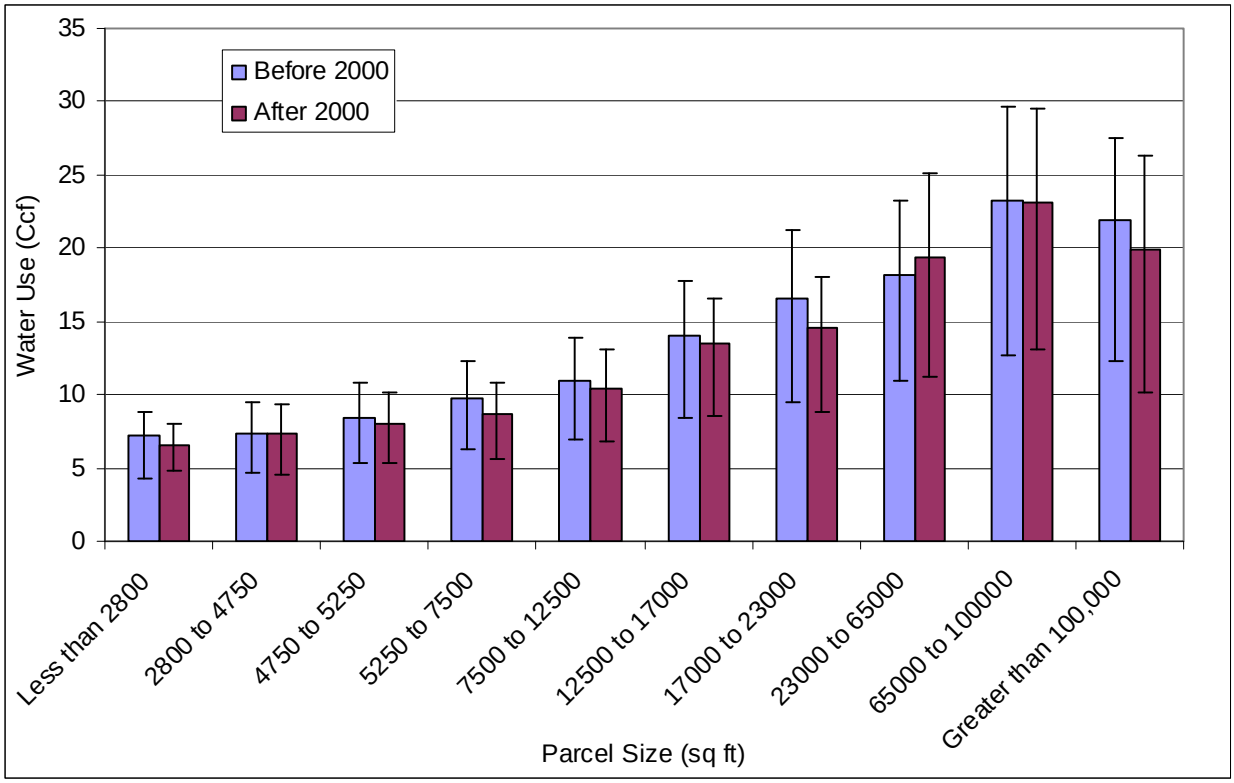

Figure A-2. Average Per-Household Monthly Water Use in Ccf by Parcel Size. (Error Bar Shows 50% of the Central 50% of the Data.)

Table A-1 Monthly Water Use per Household in Parcel Classes

		Household Monthly Water Use (Ccf)									
		Less than 2800	**2800 to 4750**	**4750 to 5250**	**5250 to 7500**	**7500 to 12500**	**12500 to 17000**	**17000 to 23000**	**23000 to 65000**	**65000 to 100000**	**Greater than 100,000**
Number of Parcels	Before 2000	100	1,445	1,225	12,115	32,191	2,988	1,233	8,189	484	530
	After 2000	83	1,031	1,201	3,213	2,294	214	85	699	54	48
Average Use	Before 2000	7.2	7.4	8.4	9.7	10.9	14	16.6	18.1	23.3	21.9
	After 2000	6.6	7.3	8	8.6	10.5	13.5	14.5	19.3	23.1	19.9
Summer Use	Before 2000	7.9	7.9	9.2	11.1	12.9	16.5	19.5	21.2	26.4	25.9
	After 2000	6.3	7.6	8.5	9.3	11.5	15.1	16.4	21.9	25.5	23.1
Winter Use	Before 2000	6.3	6.6	7.3	8	8.4	10.2	11.8	12.9	16.9	15.1
	After 2000	6.8	6.8	7.3	7.6	8.8	10.9	11.6	14.3	17.5	14.7

3.3 Smaller Parcel Sizes

In order to understand better housing stock differences between houses built before 2000 and those built after, the parcel data for single-family residences in the Tucson Water Service Area were divided into discreet parcel sizes. As can been seen in Figure A-3, parcel sizes for "After 2000" are skewed to the left, the low end, with about 1/3 of all houses being built on 5,250 to 7,500 square feet. In fact, 60% of the parcels were less than 7,500 square feet for "After 2000" compared to under 30% for "Before 2000." More than half of all "Before 2000" parcels were in the next larger parcel size, 7,500 to 12,000 square feet. As shown in Figure A-2, there is a about a 2 Ccf per month decrease in usage between parcels of 7,500 to 12,500 sq ft and parcels of 5,250 to 7,500 sq ft. This general downward shift in parcel sizes appears to be an important explanatory variable in why new homes use less water.

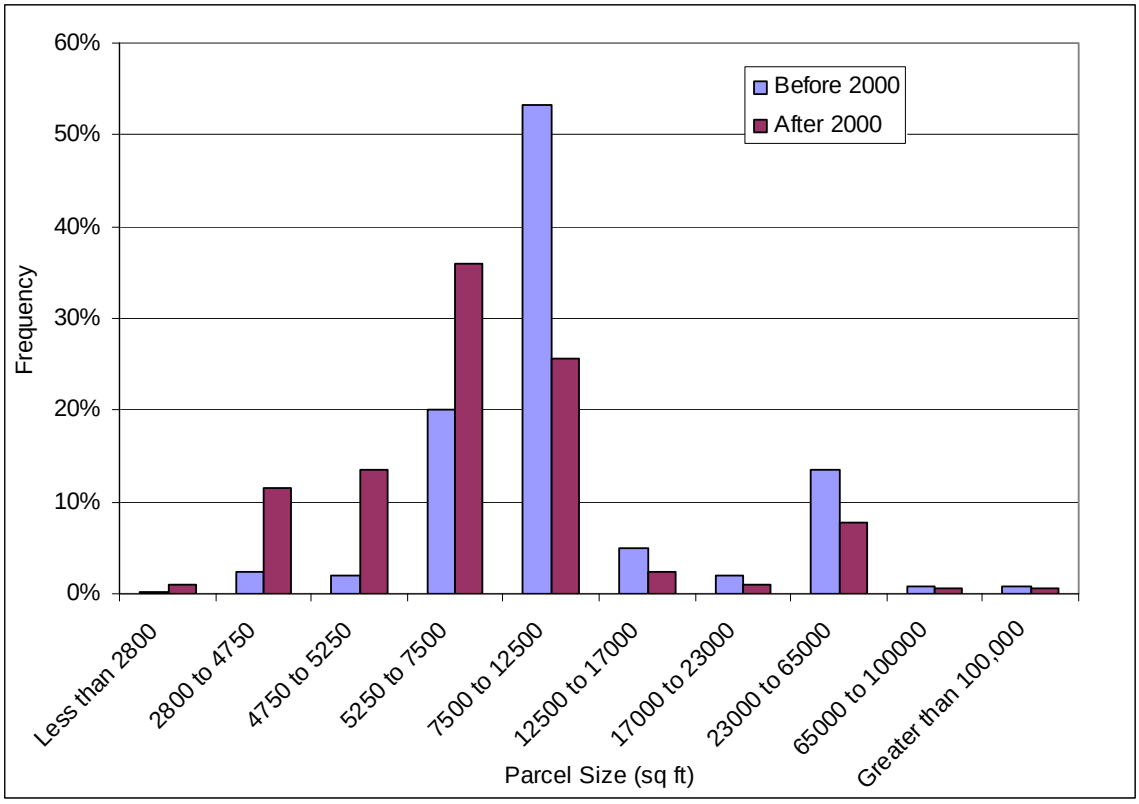

Figure A-3. Parcel Size by Year of Construction

3.4 Larger Homes on Smaller Parcels

While parcel sizes of single-family homes are smaller after 2000, the indoor area of houses is larger across all parcel sizes (Figure A-4). With a general trend toward larger homes on smaller parcels there is less area available for landscaping or pools.

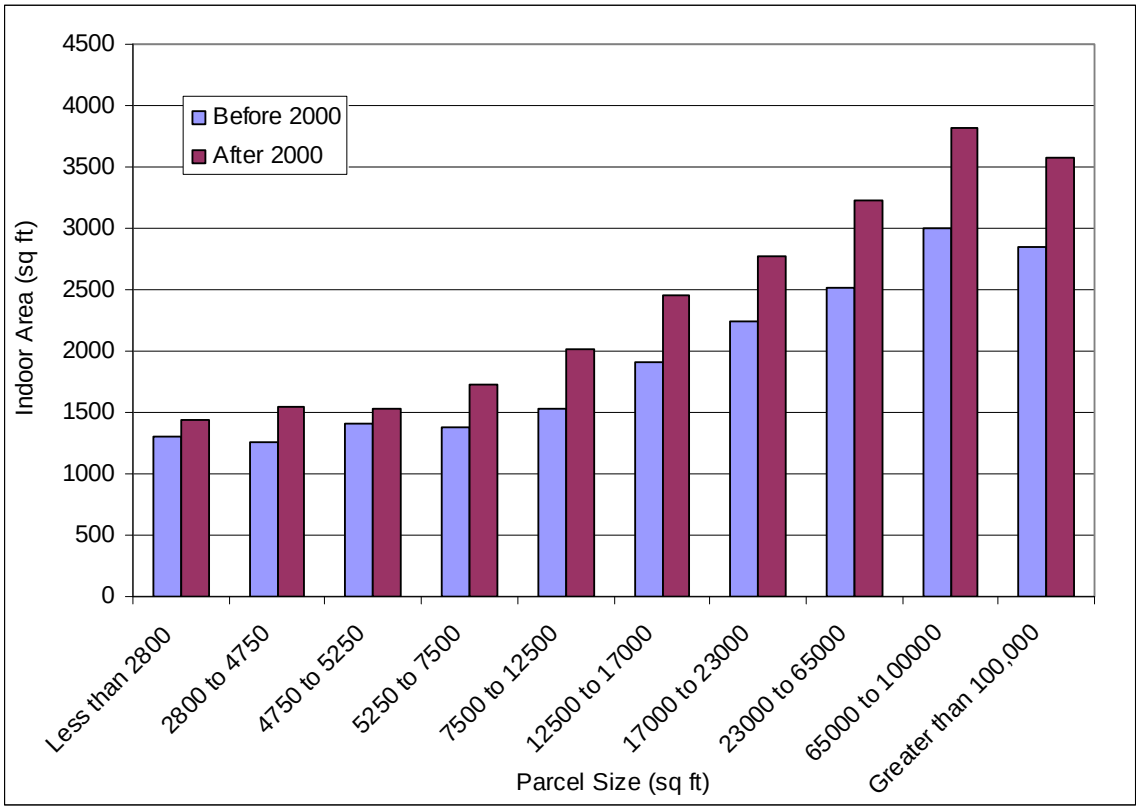

Figure A-4. Parcel Size by Living Area by Year of Construction

3.5 More Garage Bays

In addition to the fact that parcels became smaller and the indoor area of houses became larger, homes built after 2000 have more garage bays than houses built before 2000 (Figure A-5). Among homes built after 2000, about 95% had 2 or more bays compared to around 60% for houses built before 2000. Around 20% had three or more bays in homes built after 2000. As shown in Figure A-3, the parcel size of "After 2000" homes tend to be smaller than "Before 2000" homes. The results of smaller parcels and more garage bays indicate that adding larger garages on smaller parcels allows less of the remaining area for landscaping and pools in homes built after 2000.

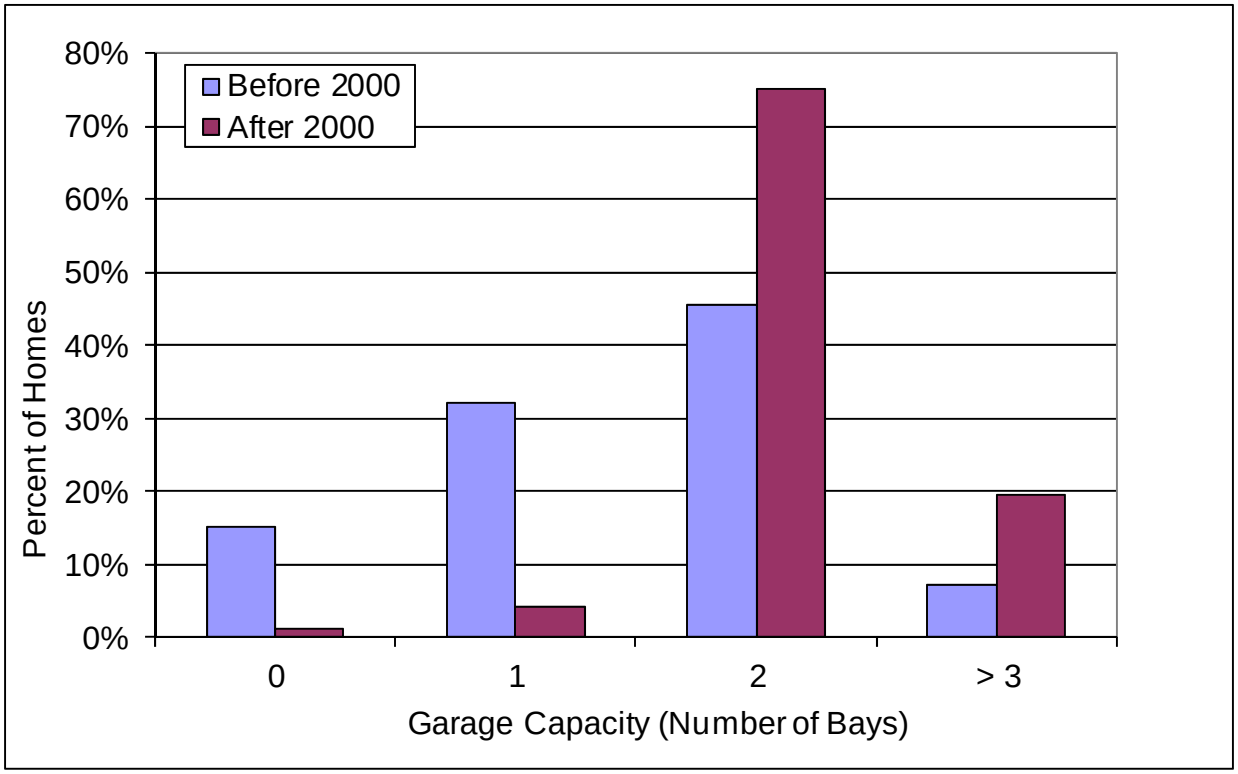

Figure A-5. Garage Spaces by Year of Construction

3.6 Fewer Pools

Approximately 15% of houses built after 2000 have pools, compared to about 25% of all houses built before 2000 (Figure A-6). Much of this decrease in homes with pools among newer homes comes from the fact the percent of homes with pools increases dramatically once parcel sizes exceed 7,500 sq ft. There are a fewer percentage of homes with pools on parcels larger than 7,500 sq ft built after 2000. Nearly 60% of the homes built after 2000 are on parcel sizes of less than 7,500 sq ft, compared to 30% of the homes built before 2000. As shown in Figures A-3 and A-4, smaller parcels with larger homes present access problems, making it difficult to add pools in future years.

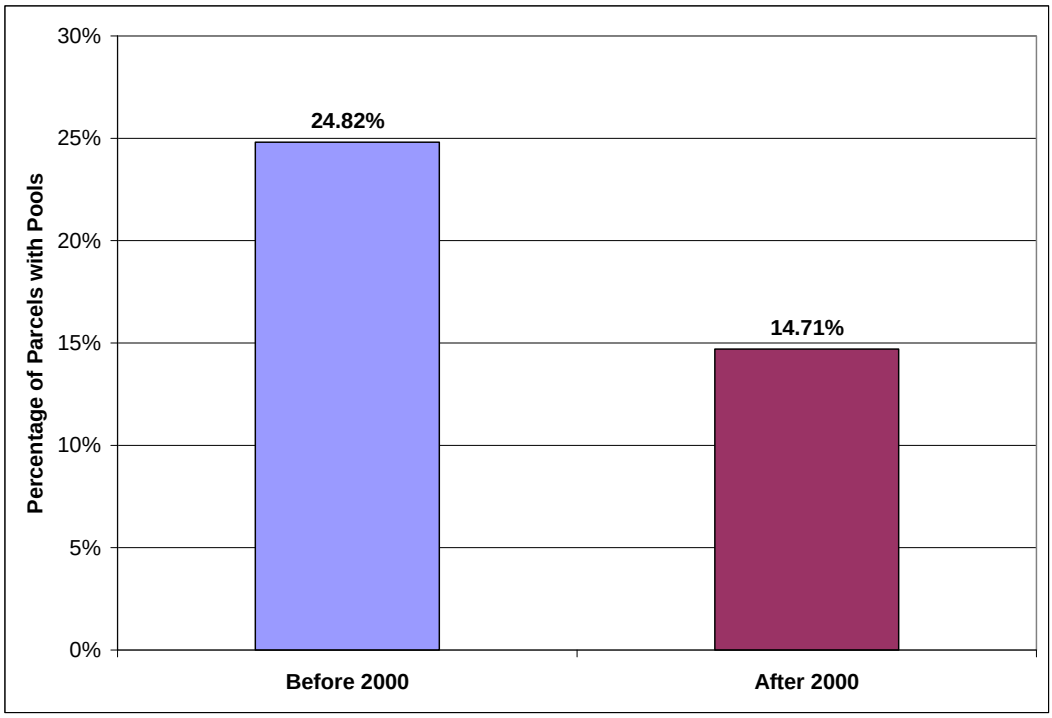

Figure A-6. Percent of Homes with Pools by Age of Construction

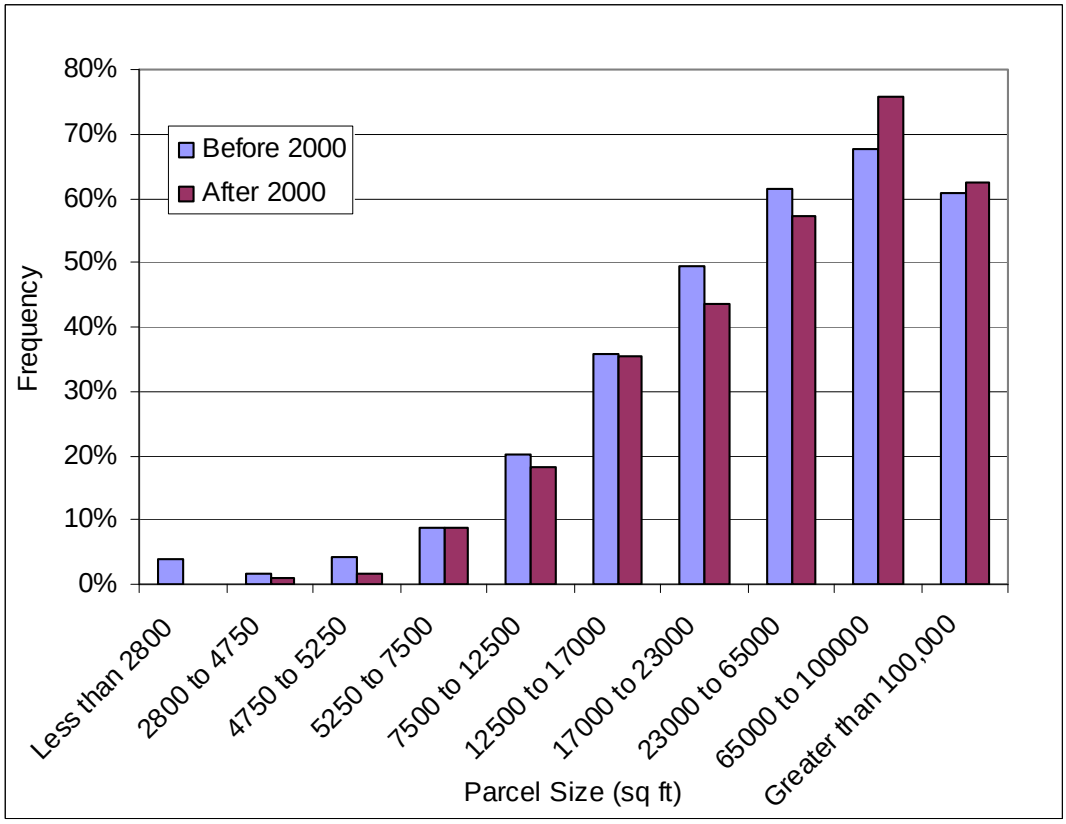

Figure A-7. Percentage of Homes with Pools by Parcel Size and Age of Construction

4. Transition from Evaporative Cooling to Air Conditioning

Another phenomenon of newer construction is the almost complete absence of evaporative coolers. Over half of homes built before 2000 (54%) were found to have evaporative cooling. This change could be a result of regulatory changes regarding construction and energy performance of air conditioners as opposed to simply changes in customer preference for convenience and comfort.[2]

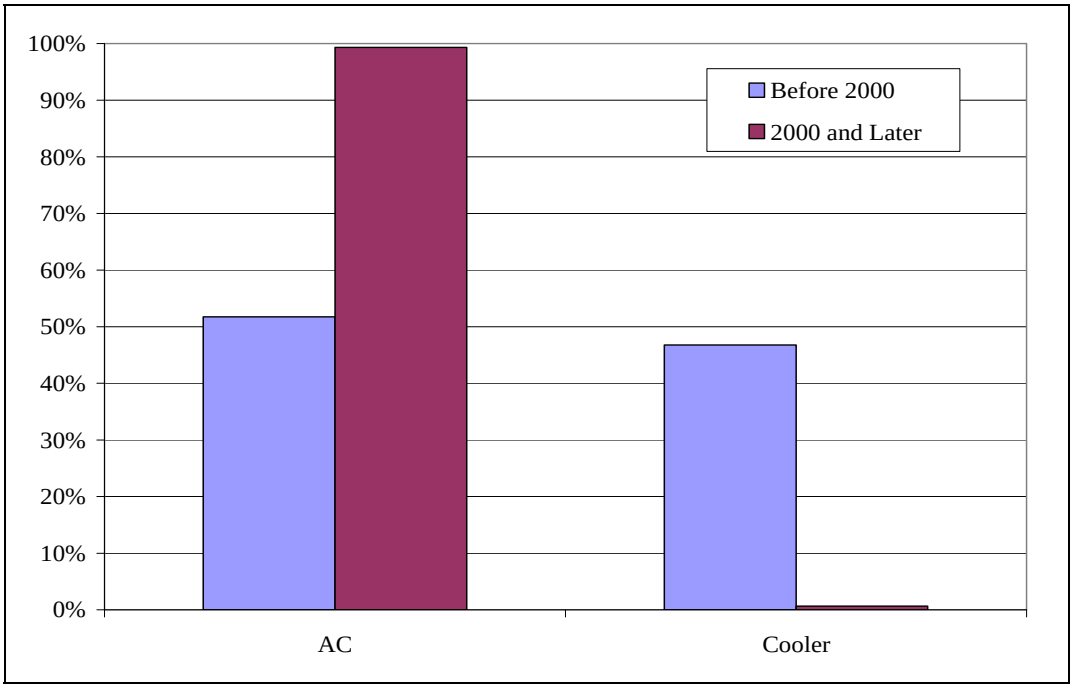

Figure A-8. Frequency of All Homes Having Evaporative Coolers by Year of Construction

[2] In addition to new construction, there is a fairly active conversion market from evaporative cooling to air conditioning driven by improvements in the overall performance of air conditioners, and in recent years, utility and tax incentives

5. Conclusions:

Evaluation of water use patterns and construction patterns of homes in the Tucson Water Service Area shows that homes built after 2000 use less water than homes built before 2000. The reduction in water use can be attributed to significant differences in land use and construction patterns of homes built after 2000 in comparison with homes built before 2000. Homes built after 2000 tend to be built on smaller parcels than homes built before 2000. Across all parcel sizes, the homes built after 2000 have more living space and more garage bays. The overall effect of these differences is that homes built after 2000 have more of the parcel covered with hardscape than homes built before 2000, which will reduce the amount of land available for landscaping and outside water use[3]. Homes built after 2000 are also far less likely to have pools, which may be a secondary effect of the overall reduction in available space on parcels.

The changes in construction and development patterns before and after 2000 are summarized in Table A-2.

In addition to the parcel-size, there are other factors affecting water use. Evaporative cooling, the dominant cooling type in homes built before 2000 is virtually non-existent in homes built after 2000. There are other structural effects that we didn't track in this study, which will also contribute to lower water use. We know that plumbing fixtures in homes built after 2000 are more efficient than those built before 2000. For example, since 1992 all toilets must use 1.6 gal/flush or less, while 3.5 gal/flush was the standard prior to that point. We know that the newer homes are more likely to have appliances (dishwashers, clothes washers) that are more water efficient. Landscapes in newer developments tend to use xeriscape rather than turf. Home Owners Associations (HOAs), which are increasingly common, may restrict the landscaping a homeowner may use, thus reducing the overall use of landscaping.

[3] One consequence of the increase in hardscape is increased stormwater runoff. This is an example of the fact that the built environment is a complex system and beneficial changes in one part of the system may aversely affect other parts of the system.

Table A-2 Summary of Construction and Development Patterns in Parcel Classes

	Parcel Size in Square Feet									
	Less than 2800	**2800 to 4750**	**4750 to 5250**	**5250 to 7500**	**7500 to 12500**	**12500 to 17000**	**17000 to 23000**	**23000 to 65000**	**65000 to 100000**	**Greater than 100,000**
Number of Parcels										
Before 2000	100	1,445	1,225	12,115	32,191	2,988	1,233	8,189	484	530
After 2000	83	1,031	1,201	3,213	2,294	214	85	699	54	48
Percent of Parcels										
Before 2000	0.2%	2.4%	2.0%	20.0%	53.2%	4.9%	2.0%	13.5%	0.8%	0.9%
After 2000	0.9%	11.6%	13.5%	36.0%	25.7%	2.4%	1.0%	7.8%	0.6%	0.5%
Cumulative										
Before 2000	0.2%	2.6%	4.6%	24.6%	77.8%	82.8%	84.8%	98.3%	99.1%	100.0%
After 2000	0.9%	12.5%	25.9%	62.0%	87.7%	90.1%	91.0%	98.9%	99.5%	100.0%
Indoor Area										
Before 2000	1301	1264	1404	1377	1537	1903	2238	2513	3001	2854
After 2000	1437	1548	1537	1735	2022	2448	2774	3223	3818	3579
Pool										
Before 2000	4	25	51	1,050	6,520	1,071	611	5,033	328	322
After 2000	0	11	20	278	420	76	37	399	41	30
Percent										
Before 2000	4.0%	1.7%	4.2%	8.7%	20.3%	35.8%	49.6%	61.5%	67.8%	60.8%
After 2000	0.0%	1.1%	1.7%	8.7%	18.3%	35.5%	43.5%	57.1%	75.9%	62.5%
Evaporative cooling										
Before 2000	44	446	275	7,495	20,836	1,301	375	1,513	46	125
After 2000	1	2	6	11	18	2	0	1	0	0
Percent										
Before 2000	44.0%	30.9%	22.4%	61.9%	64.7%	43.5%	30.4%	18.5%	9.5%	23.6%
After 2000	1.2%	0.2%	0.5%	0.3%	0.8%	0.9%	0.0%	0.1%	0.0%	0.0%

Appendix A- 1

Data Review/Discussion:

1. Introduction:

The source data is available to any water provider in the area. It is largely a matter of being able to join customer address to a parcel address to obtain a parcel number. Once this is accomplished, the user can get to all of the housing characteristics data, such as pool, garage etc., in what is commonly called the MAS file series. It is available on the Assessor's Office web site. Parcel size data in square feet is in a files series named EDNP## (## for the year).

The data are not perfect as it is almost impossible for the Assessor's Office to know all the changes that are made to homes throughout Pima County. It is, however, more likely that the characteristics of new housing will be more accurate as there has been less opportunity to make changes to the homes.

Year of Construction:

The year of construction is not a static number and may not be the original year of construction. If the living area of a home has increased, the age of the home will increase as well. For example, if a home built in 1980 was 1,000 sf and another 1,000 sf were added in 2000, the age of the home would then be 1990 in the Assessors records. The Assessor should have been notified that the change has occurred. It is possible that there are houses in the Assessor's records that are smaller and younger than they really are. For newer homes, this is unlikely to present a problem.

It is unlikely that a home constructed before 2000 would be classified as year 2000 home. And, the older the original construction date, the more difficult it becomes. For example, for a home built in 1980 to get a 2000 year of construction would require the home triple in size in 2010. So, dividing homes between pre 2000 and 2000 and later should not introduce any significant problems into the analysis.

Square Footage of Home:

It is implied in this paper that the living area is a proxy for the footprint of the house. There is some evidence that homes are also getting taller, meaning that the living area of the homes may overstate the footprint of the home. This is particularly true for homes on smaller parcels – homes get shorter as parcel size increases. It should be noted that it appears that Assessor's data does not reflect the number of stories in older parcels.

Garages:

It has not uncommon for older homes to convert their garages to living area. Again, to the extent the Assessors Office has reflected this, the Assessors Office data would underestimate the living area and over estimate the number of garages. This would commonly apply to older homes rather than new homes because newer homes are already quite large and there is little need to convert their garages to dens. See the figures A-1 and A-2 for the detail. However, this would not likely change the overall hardscape.

Air Conditioning:

There has been a fair amount of activity converting older homes to air conditioning. It is very likely that the Assessors data underestimates the number of older homes with air conditioning as not all conversions are picked up. This would have the effect of reducing the difference in water use between old and new homes. For all intents and purposes, there are no new homes with installed evaporative coolers. See the Figure A-3 for the detail.

2. Data Preparation and Analysis:

ArcGIS 10.0 was used to extract information from the database for parcels within the Tucson Water Service Area (TWSA).

Water use data in Tucson Water Service Area (TWSA) for 2009 and 2010 was used for this study. Both 2009 and 2010 were dry years, though 2009 was exceedingly dry and 2010 approached normal conditions. In 2010, annual rainfall of 11.13 inches was just under the long-term average of 11.59 inches with 5.45 inches of Monsoon rainfall, just below the long-term average of 6.06 inches. In contrast, 2009, was the 4th driest year recorded at the Tucson airport with only 5.67 inches of annual rainfall and 2.86 inches of Monsoon rainfall. Because water use data was from these two dry years, water would have been required to supply outside water needs, especially in the hotter months of 2009.

Selection of Parcels:
The "USE" code of MAS 2011 was used to select only single-family residences since this study focuses only on single-family water use. Parcels in subdivisions were used in this study. Subdivision data was used to select parcels in subdivisions within TWSA. Data from approximately 70,000 single-family homes (approximately 88% of single-family residences within Tucson Water Service Area) were used for analysis. The housing stock was then divided into two groups, "Before 2000" and "After 2000." While the year 2000 was selected somewhat arbitrarily, the expectation was to identify building practices that contribute to efficient water use by comparing the water use of homes built since 2000 with the larger population of homes built before 2000. Water use records from 2009 and 2010 were used for the analysis. Parcels with "After 2000" homes that were built after 2008 were removed from the analysis in order to remove homes that did not establish a "normal" level of demand by 2009.

Newer homes built since 2000 ("After 2000") were classified into two groups, "Green" homes in model communities such as Civano and "Traditional" or "Non-Green" homes.

Single-Family Water Use:
Parcels were merged with water use records from 2009 and 2010. Parcels were removed from the analysis if monthly water use is zero during the study period from 2009 and 2010. This is because temporal vacancy (zero water use) could skew the average water use calculation. In other words, it is necessary to use water use data for homes that are occupied. We assessed water use by using monthly average per household (Ccf) and daily average per capita (GPCD). Per-capita water use was calculated by dividing water use by average number of household. Average water use within subdivisions was calculated using single-family water use (Ccf and GPCD).

Property Value:
Property value was estimated using "Actual" from MAS 2011.

Parcel Area:

Parcel area was obtained using the attribute table of a “Parcel shape file.”

Parcels were classified into 10 classes based on the size of parcel area.

Table A-1 Parcel Classification

Class #	Class Name	Square Feet of Parcel
1	Small 1	< 2800
2	Small 2	2800-4750
3	Standard 1	2750-5250
4	Standard 2	5250-7500
5	Medium 1	7500-12500
6	Medium 2	12500-17000
7	Large 1	17000-23000
8	Large 2	23000-65000
9	Rural 1	65000-100000
10	Rural 2	>100000

Household Size:
In order to obtain representative data on per-capita water use, both water use data and number of residents in a home must be determined. Census data is available for a collection of parcels, called a block, rather than at individual parcels. As mentioned previously, this study focuses on single-family water use. When multi-family residences occupy more than 20% of an entire area of census blocks, the blocks were removed from the analysis. The “USE” code of MAS 2011 (Pima County Assessor’s Office) was used to select single-family residences. Census block 2010 data includes different types of household size. “Average Household Size of Occupied Housing Units” (H0120001 of Census Blocks 2010) was selected in this study. Because we eliminated vacant properties for water use analysis, “Average Household Size of Occupied Housing Units” is a reasonable household size to estimate average water use per capita (GPCD).

Subdivision Water Use:
In order to obtain representative data of average water use within subdivisions, subdivisions including less than five parcels were removed from the analysis. Subdivisions with a mixed age of construction (some homes were built before 2000 while the others were built since 2000) were also removed from the analysis. Newer subdivisions include only homes built entirely since 2000, while older subdivisions include homes built before 2000. Total number of older subdivisions used for the analysis is 1073, while the one for newer subdivisions is 146.

3. Unit of Analysis: Parcel versus Subdivision:

The unit of analysis in Chapter A and B is parcel. We can imply from parcel size data that newer subdivisions have smaller parcels, but the development framework occurs at the subdivision level. Characterizing subdivisions is much more difficult and requires GIS skills. It is common for there to be homeowners associations (HOA) which often provide for offsite amenities such as community pools and common landscaped areas. By focusing on the parcels only, we are likely underestimating the water usage for the parcel. To the extent newer

subdivisions are associated with HOAs that provide irrigation and other water demanding amenities, we may be underestimating the water demand in new homes. Preliminary data suggests, however, that this does not result in a significant difference in usage – it is a small volume spread over many homes – and would not change the effects of smaller parcels, large homes and garages, resulting in fewer pools and less landscaped areas and the lack of evaporative coolers.

4. Garage Space and Evaporative Coolers:

Additional information of garage space and evaporative coolers is shown in Figures A1-1-1-3.

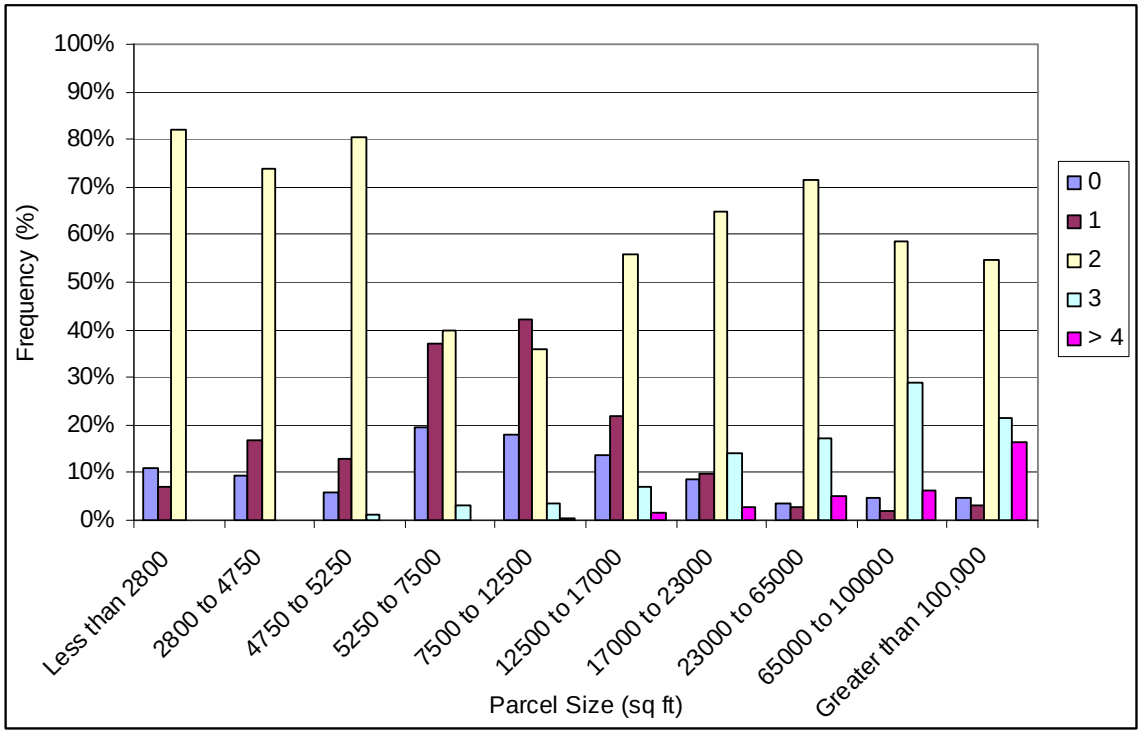

Figure A1-1. Garage Spaces at Homes Built Before 2000

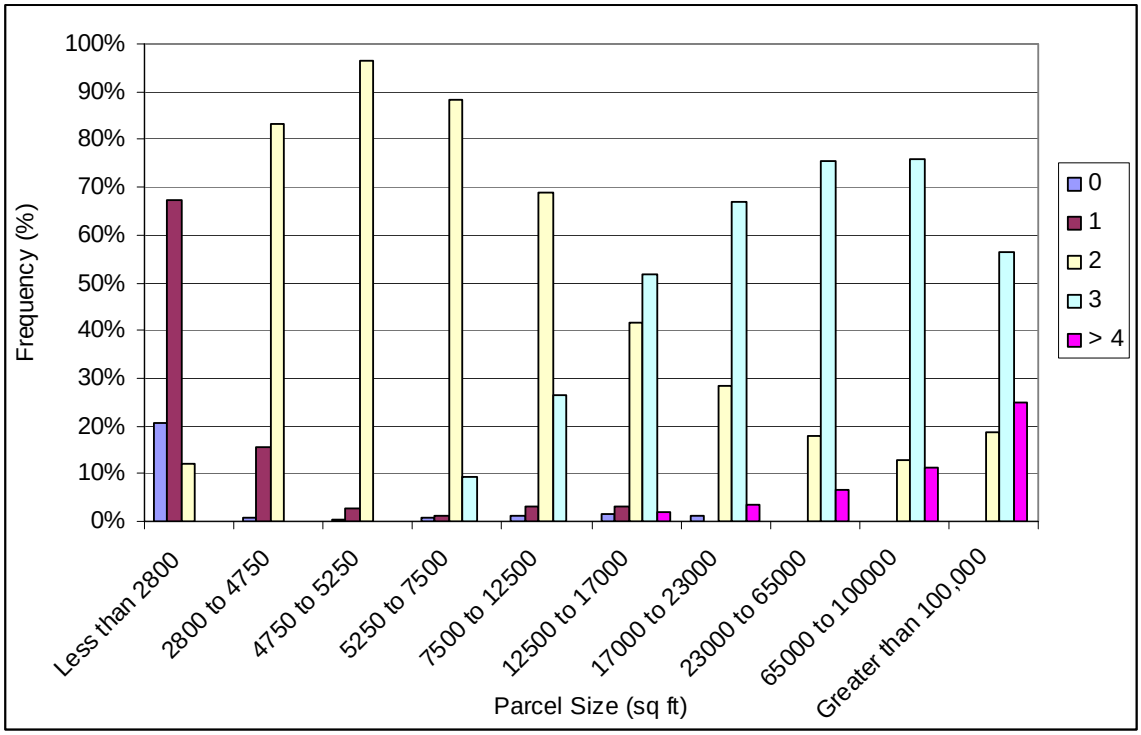

Figure A1-2. Garage Spaces at Homes Built After 2000

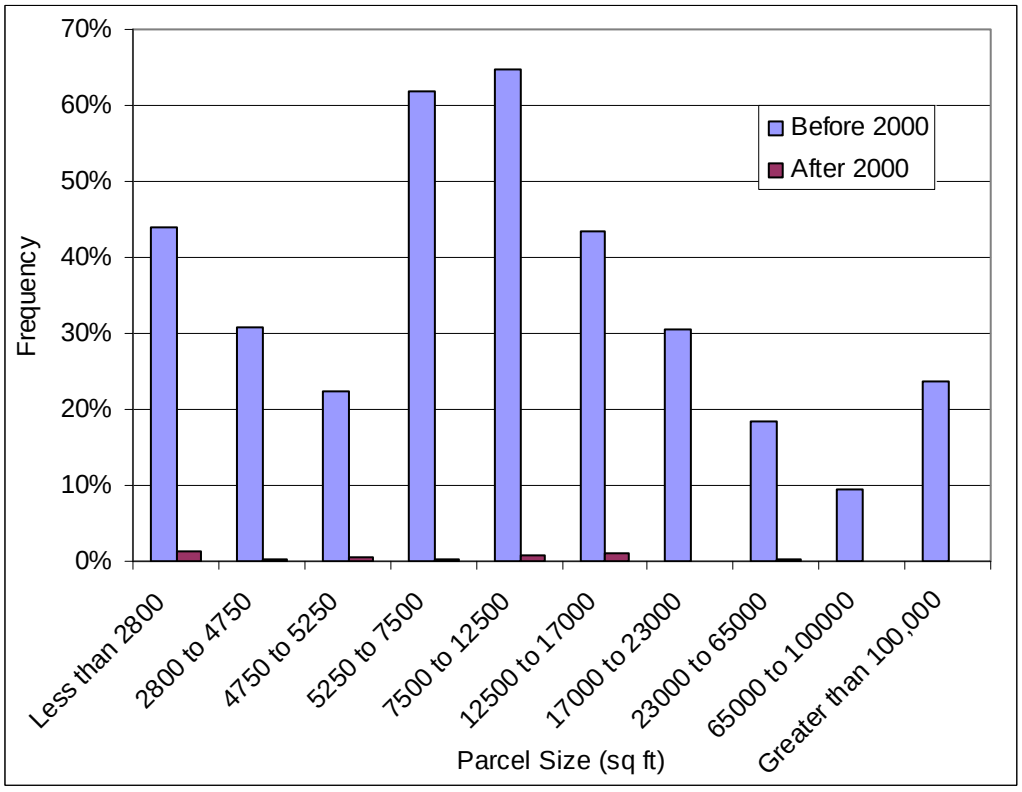

Figure A1-3. Frequency of All Homes Having Evaporative Coolers

Chapter B - Assessing Single Family Water Demand per Capita in the Tucson Water Service Area

1. Introduction

1.1 Background

A previous chapter (*A. Household Water Use Study*) assessed the impact of changes in construction patterns on household water use for single–family residences. The results of the previous chapter are summarized below.

- Newer homes built since 2000 ("After 2000") were built on smaller parcels, while house size is relatively large on a given parcel area. This indicates that newer homes have less outdoor space for landscape.
- Newer homes have larger garage spaces regardless of parcel size. This also indicates less outdoor space.
- Newer homes were less likely to have a backyard pool.
- Newer homes were mostly constructed with AC.
- Average water use generally increases with the size of parcels.
- Average water use of newer homes is less than older homes regardless of parcel size.
- Summer water use of newer homes is less than older homes.

The lower water use of newer homes ("After 2000") can be explained by the following changes in construction patterns:

1. Newer homes have less outdoor area because they tend to be built on smaller parcels but have larger house footprints with larger garage spaces.
2. Newer homes virtually have no evaporative coolers and are less likely to have pools. This could be one reason that summer water use at newer homes is less than older homes.

The previous chapter addressed construction differences between older homes ("Before 2000") and newer homes ("After 2000") and how these construction differences impacted water use. Although the previous chapter did not investigate the impacts of newer appliances and plumbing on water use, more water-efficient appliances and plumbing can also be expected to contribute to lower water use in newer homes.

Water resources projections are often made using per-capita water use as the basis for making water resources policy decisions such as securing water supplies for the expected populace. The previous chapter did not consider per-capita differences in water use. This chapter focuses on per-capita water use for single-family residences in the Tucson Water Service Area.

1.2 Purpose

In this chapter, we determine how per-capita water use differs in older and newer homes ("Before 2000" and "After 2000"). A secondary objective is to determine how per-capita water use in a subset of the newer homes, the self-proclaimed "Green" subdivisions, differs from water use in traditional newer homes. For example, the Civano development has requirements based on re-zoning to use less than 28 gallons per day, per capita exterior and 53 gallons per day, per capita interior[4]. The Civano development identified water conservation as a founding principal and uses alternative water supplies such as reclaimed and water harvesting to offset potable demand.

The specific objectives of this chapter are as follows:

1. to determine if there is a difference in single-family household size between older homes and newer homes;
2. to determine if there is a difference in daily water use per capita (gallons per capita per day - GPCD) between older homes and newer homes; and
3. to determine if water use at "Green" homes differs from water use in "Non-Green" or "Traditional" newer homes.

2. Method

2.1 Data Collection

The analysis focused on single-family residences within Tucson Water Service Area (TWSA). The following data was used for the analysis. The source of the data is listed below.

Spatial Datasets

- Parcel data (Pima County GIS library)
- Subdivision data (Pima County GIS library)
- Tucson Water Service Area boundary (Pima County GIS library)
- Census Block 2010 data (Pima County GIS library)

Tabular Data

- MAS 2011 (Pima County Assessor's Office)
- Water usage record in 2009 and 2010 (Tucson Water)

2.2 Data Preparation and Analysis

ArcGIS 10.0 was used to extract information from the database for parcels within the Tucson Water Service Area (TWSA).

Water use data in Tucson Water Service Area (TWSA) for 2009 and 2010 was used for this study. Both 2009 and 2010 were dry years, though 2009 was exceedingly dry and 2010 approached normal conditions. In 2010, annual rainfall of 11.13 inches was just under the long-

[4] http://www.civanoneighbors.com/docs/environment/Civano_Energy_Water_2007.pdf

term average of 11.59 inches with 5.45 inches of Monsoon rainfall, just below the long-term average of 6.06 inches. In contrast, 2009, was the 4th driest year recorded at the Tucson airport with only 5.67 inches of annual rainfall and 2.86 inches of Monsoon rainfall. Because water use data was from these two dry years, water would have been required to supply outside water needs, especially in the hotter months of 2009.

Selection of Parcels:
The "USE" code of MAS 2011 was used to select only single-family residences since this study focuses only on single-family water use. Parcels in subdivisions were used in this study. Subdivision data was used to select parcels in subdivisions within TWSA. Data from approximately 70,000 single-family homes (approximately 88% of single-family residences within Tucson Water Service Area) were used for analysis. The housing stock was then divided into two groups, "Before 2000" and "After 2000." While the year 2000 was selected somewhat arbitrarily, the expectation was to identify building practices that contribute to efficient water use by comparing the water use of homes built since 2000 with the larger population of homes built prior to 2000. Water use records from 2009 and 2010 were used for the analysis. Parcels with "After 2000" homes that were built after 2008 were removed from the analysis in order to remove homes that did not establish a "normal" level of demand by 2009.

Newer homes built since 2000 ("After 2000") were classified into two groups, "Green" homes in model communities such as Civano and "Traditional" or "Non-Green" homes.

Single-Family Water Use:
Parcels were merged with water use records from 2009 and 2010. Parcels were removed from the analysis if monthly water use is zero during the study period from 2009 and 2010. This is because temporal vacancy (zero water use) could skew the average water use calculation. In other words, it is necessary to use water use data for homes that are occupied. We assessed water use by using monthly average per household (Ccf) and daily average per capita (GPCD). Per-capita water use was calculated by dividing water use by average number of household.

Property Value:
Property value was estimated using "Actual" from MAS 2011.

Parcel Area:
Parcel area was obtained using the attribute table of a "Parcel shape file."

Indoor Area:
Indoor Area was obtained from "SQFT" of MAS 2011.

Household Size:
In order to obtain representative data on per-capita water use, both water use data and number of residents in a home must be determined. Census data is available for a collection of parcels, called a block, rather than at individual parcels. Since this study focuses on single-family water use, only census blocks where the majority of parcels are single-family residences were used. The "USE" code of MAS 2011 (Pima County Assessor's Office) was used to select only single-family residences. When multi-family residences occupy more than 20% of an entire area of census blocks, the blocks were removed from the analysis. Census block 2010 data includes different types of household size. "Average Household Size of Occupied Housing Units" (H0120001 of Census Blocks 2010) was selected in this study. Because we eliminated vacant properties for water use analysis, "Average Household Size of Occupied Housing Units" is a reasonable household size to estimate average water use per capita (GPCD).

Parcels were classified into 10 classes based on the size of parcel area, which is the same method used in the previous chapter ("*A. Household Water Use Study* ").

Table B-1 Parcel Classification

Class #	Class Name	Square Feet of Parcel
1	Small 1	< 2800
2	Small 2	2800-4750
3	Standard 1	2750-5250
4	Standard 2	5250-7500
5	Medium 1	7500-12500
6	Medium 2	12500-17000
7	Large 1	17000-23000
8	Large 2	23000-65000
9	Rural 1	65000-100000
10	Rural 2	>100000

3. Results

3.1 Comparison of Household Size between "Before" and "After" 2000

Using the 2010 census data, average household size was compared between "Before 2000" and "After 2000." As shown in Figure B-1, the number of people per household for "After 2000" is larger than "Before 2000" regardless of parcel size. The trend is clear especially in parcel classes less than 5,250 square feet.

While the reason for this difference was not determined, it may be related to the fact that homes on smaller parcels tend to be larger after 2000 ("*A. Household Water Use Study*"). Larger homes on smaller parcels built after 2000 may have more bedrooms, and be able to accommodate more people. The difference could also be attributed to the observation that many new homes are sold to young families with children, while older neighborhoods may have a more mature population with no children living in the home.

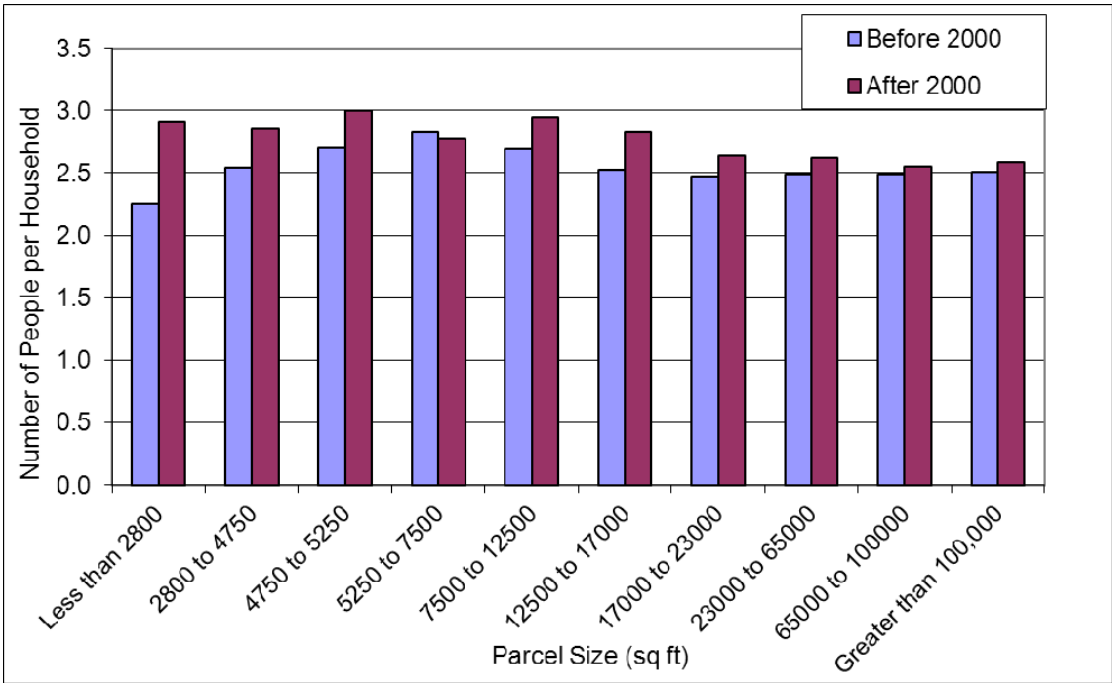

Figure B-1 Average Household Size for "Before 2000" and "After 2000"

3.2 Comparison of Water Use between "Before" and "After" 2000

Figure B-2 shows average daily water usage per capita for "Before 2000" and "After 2000" in parcel classes. Table B-2 summarizes the water use in parcel classes.

Water use generally increases with the size of parcels (Figure B-2). Water use for "Before 2000" is more than "After 2000" in every parcel size class, except one class with the parcel area ranging from 23,000 to 65,000 square feet (Figure B-2) (i.e. homes on ½ acre to 1-acre parcels). These results are consistent with monthly average water use per household (*A. Household Water Use Study*).

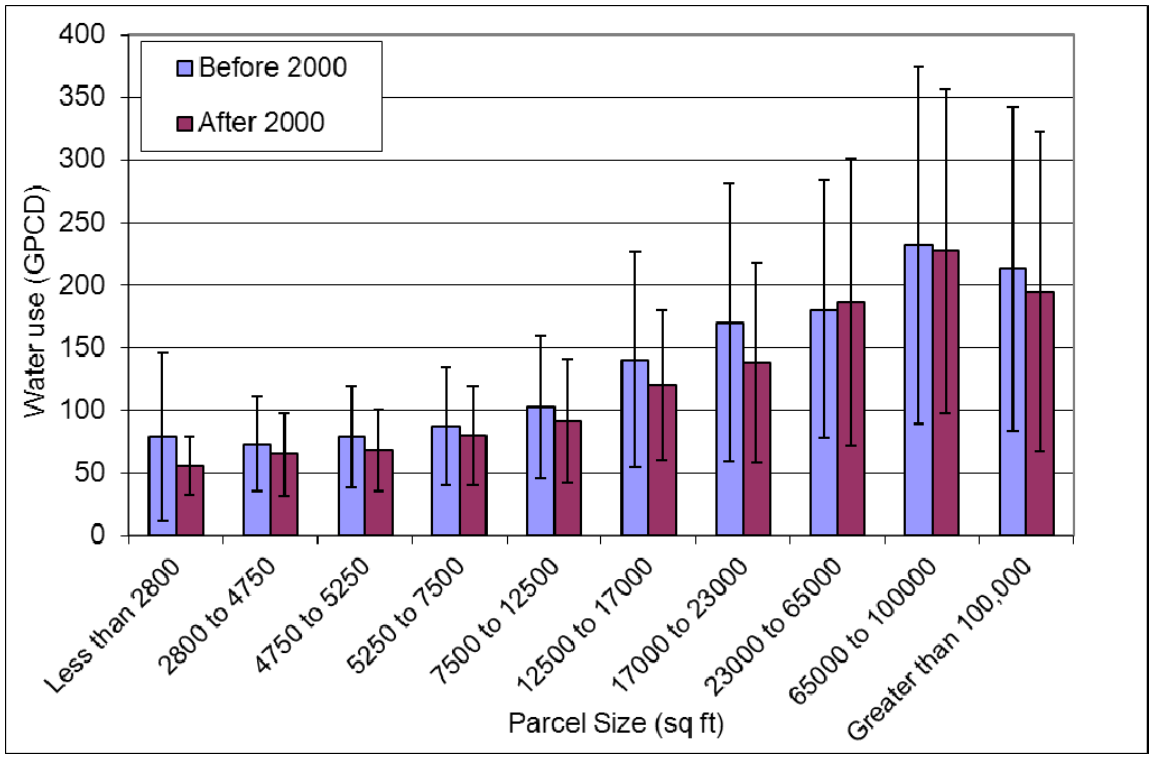

Figure B-2 Average Water Use for "Before 2000" and "After 2000." Error Bar Shows 50% of the Central 50% of the Data.

Table B-2 Average Water Use per Capita in Parcel Classes

		Household Monthly Water Use (Ccf)									
		Less than 2800	**2800 to 4750**	**4750 to 5250**	**5250 to 7500**	**7500 to 12500**	**12500 to 17000**	**17000 to 23000**	**23000 to 65000**	**65000 to 100000**	**Greater than 100,000**
Number of Parcels	Before 2000	100	1,445	1,225	12,115	32,191	2,988	1,233	8,189	484	530
	After 2000	83	1,031	1,201	3,213	2,294	214	85	699	54	48
Summer Water Use (GPCD)	Before 2000	84.4	77.9	85	99.1	121.1	164.2	196.3	209.8	261.2	250.8
	After 2000	53.2	66.6	71.6	84.6	99.4	133.4	155.1	209.6	248.6	202.1
Winter Water Use (GPCD)	Before 2000	70.7	66.7	69.6	73	80.2	103.3	122.1	130.9	166.9	149
	After 2000	58.8	61.1	62.8	71.4	78.2	99.5	112.6	139.3	173.2	145
Difference (%)	Before 2000	16.2	14.5	18.2	26.3	33.8	37.1	37.8	37.6	36.1	40.6
	After 2000	-10.6	8.4	12.3	15.7	21.4	25.4	27.4	33.6	30.3	28.3

Average water use in each month was evaluated in order to assess a seasonal pattern of water use. Figures B-3.1 and B-3.2 show average water use per capita in each month.

In relatively small parcel sized classes less than 12,500 square feet, the differences in monthly average water use tend to be smaller in “After 2000” homes than “Before 2000” homes (Figures B-3.1 and B-3.2). This indicates that seasonal differences in water use are smaller in “After 2000” homes than “Before 2000” homes, particularly in parcels smaller than 12,500 square feet.

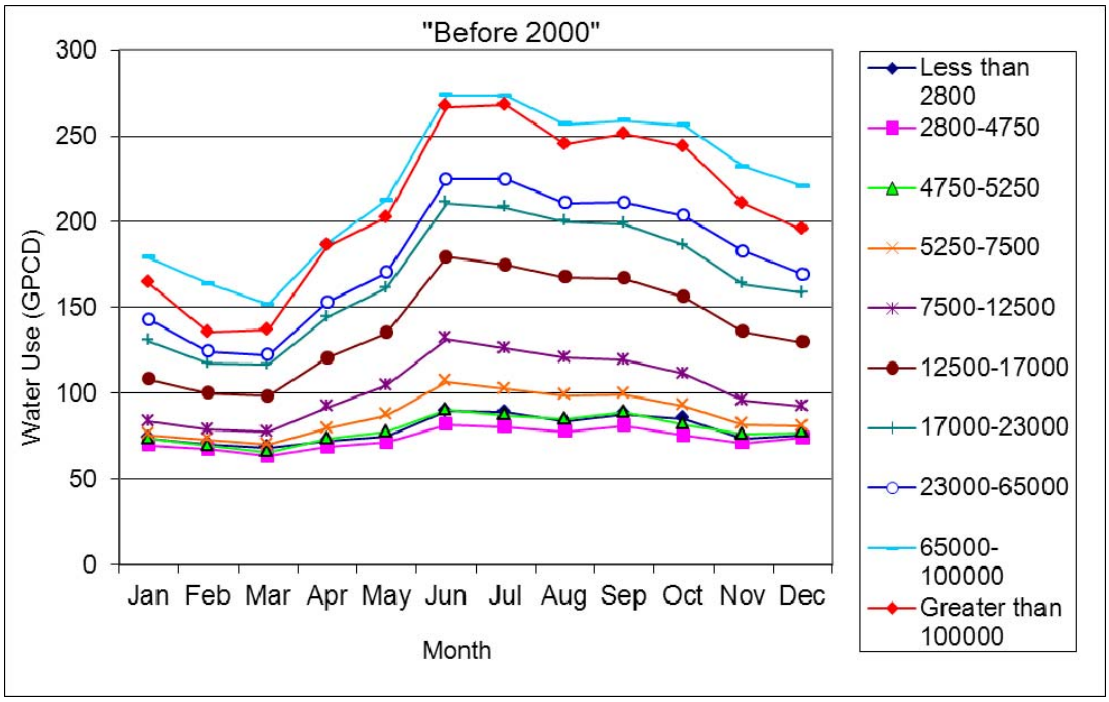

Figure B-3.1 Average Water Use in “Before 2000” homes.

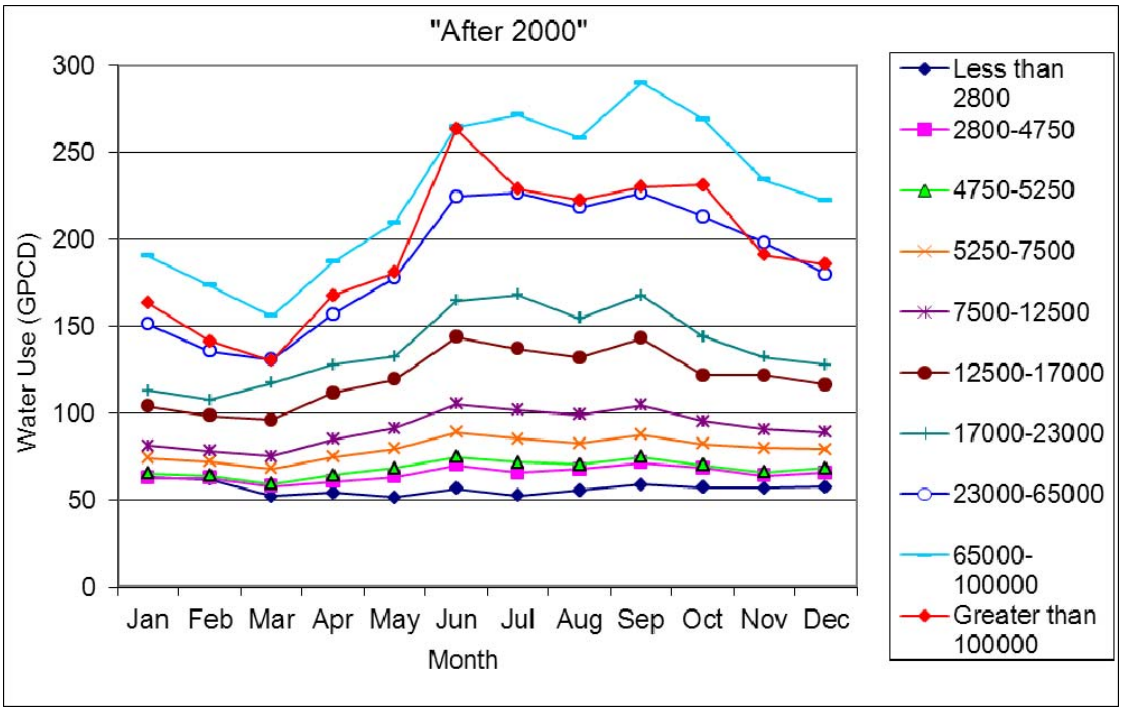

Figure B-3.2 Average Water Use in "After 2000" homes.

Seasonal average of water use is shown in Figure B-4 and Table B-3. Summer represents May through July while winter represents January through March. According to the historical record of water use in Tucson Water Service Area (TWSA), "Summer" months are the highest water demand period in TWSA, while "Winter" months are lowest water demand period. Table B-3 also summarizes the differences between summer and winter water use. The reduced seasonal variability in smaller parcels (e.g. less than 12,500 sq ft) on homes built since 2000 is consistent with the conclusion of the water use study (Arnold et al, 2011), which found that the increased amount of hardscape in newer homes reduces the amount that can be used for landscaping.

Summer water usage for both "Before" and "After" 2000 is generally higher than winter water usage except in the parcel class smaller than 2,800 square feet (Figure B-4). The seasonal difference of water use is larger in larger parcel classes (Table B-3). The difference is negative in parcel class less than 2,800 square feet for "After 2000," indicating that summer water use is less than winter water use in the smallest parcel class. It is unclear why the summer water use is less than winter use in the smallest parcel class. Table B-3 also shows that seasonal difference of water use for "After 2000" is generally smaller than "Before 2000." This suggests that older homes use more water in summer than winter, compared to newer homes.

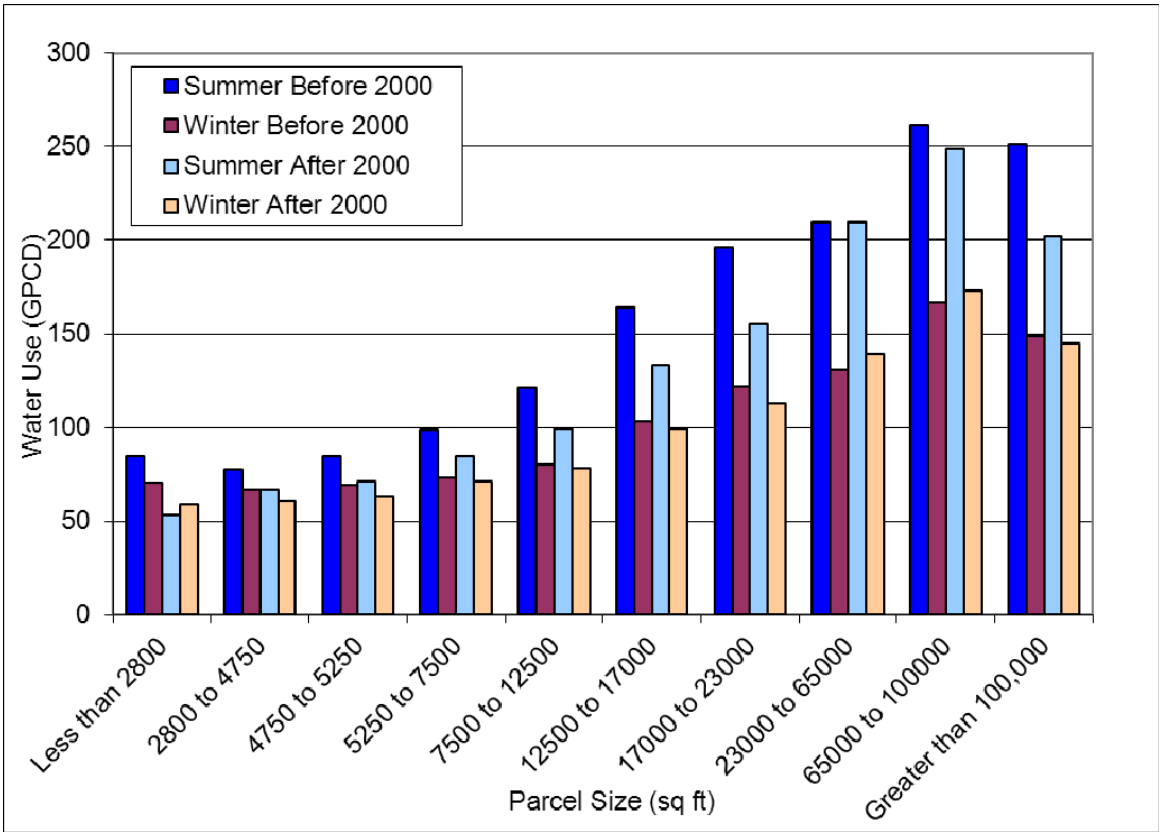

Figure B-4 Average Daily Water Use per Capita in Summer and Winter

Table B-3 Difference between Summer Water Use and Winter Water Use

		Household Monthly Water Use (Ccf)									
		Less than 2800	**2800 to 4750**	**4750 to 5250**	**5250 to 7500**	**7500 to 12500**	**12500 to 17000**	**17000 to 23000**	**23000 to 65000**	**65000 to 100000**	**Greater than 100,000**
Number of Parcels	Before 2000	100	1,445	1,225	12,115	32,191	2,988	1,233	8,189	484	530
	After 2000	83	1,031	1,201	3,213	2,294	214	85	699	54	48
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Winter Water Use (GPCD)	Before 2000	70.7	66.7	69.6	73	80.2	103.3	122.1	130.9	166.9	149
	After 2000	58.8	61.1	62.8	71.4	78.2	99.5	112.6	139.3	173.2	145
Difference (%)	Before 2000	16.2	14.5	18.2	26.3	33.8	37.1	37.8	37.6	36.1	40.6
	After 2000	-10.6	8.4	12.3	15.7	21.4	25.4	27.4	33.6	30.3	28.3

3.3 Comparison of Water Use between "Green" and "Non-Green" Homes

Daily water use per capita was compared between "Green" and "Non-Green" homes (Figure B-5). . Monthly water use per household was shown in Figure B-6. "Green" homes came from the different phases of the Civano development and Mercado District of Menlo Park All "Green" and Non-Green" homes used in the analysis were constructed since 2000.

"Non-Green" and "Green" homes were classified into 5 sizes, < 4,000, 4,000-5,000, 5,000-6,000, 6,000-7,000, 7,000-11,000 square feet. This is partially because all of the "Green" homes fall in the three parcel size classes from 4750 to 12,500 sq ft (4,750 to 5,250, 5,250 to 7,500 and 7,500 to 12,500 sq ft). The water use data for "Green" and "Non-Green" homes is further summarized in Appendix B-1.

The study found that per-capita water use for "Green" homes is higher than "Non-Green" homes (Figure B-5), while per-household water use for "Green" homes is less than "Non-Green" homes in smaller parcel sized classes less than 5,000 square feet (Figure B-6). This suggests that more people live in smaller "Non-Green" homes, compared to smaller "Green" homes.

It should be noted that the sampling size of "Green" homes are substantially smaller than the sampling size of "Non-Green" homes (Table B-4). It is possible that the substantial difference in sampling numbers could affect the results of the water use in "Green" homes.

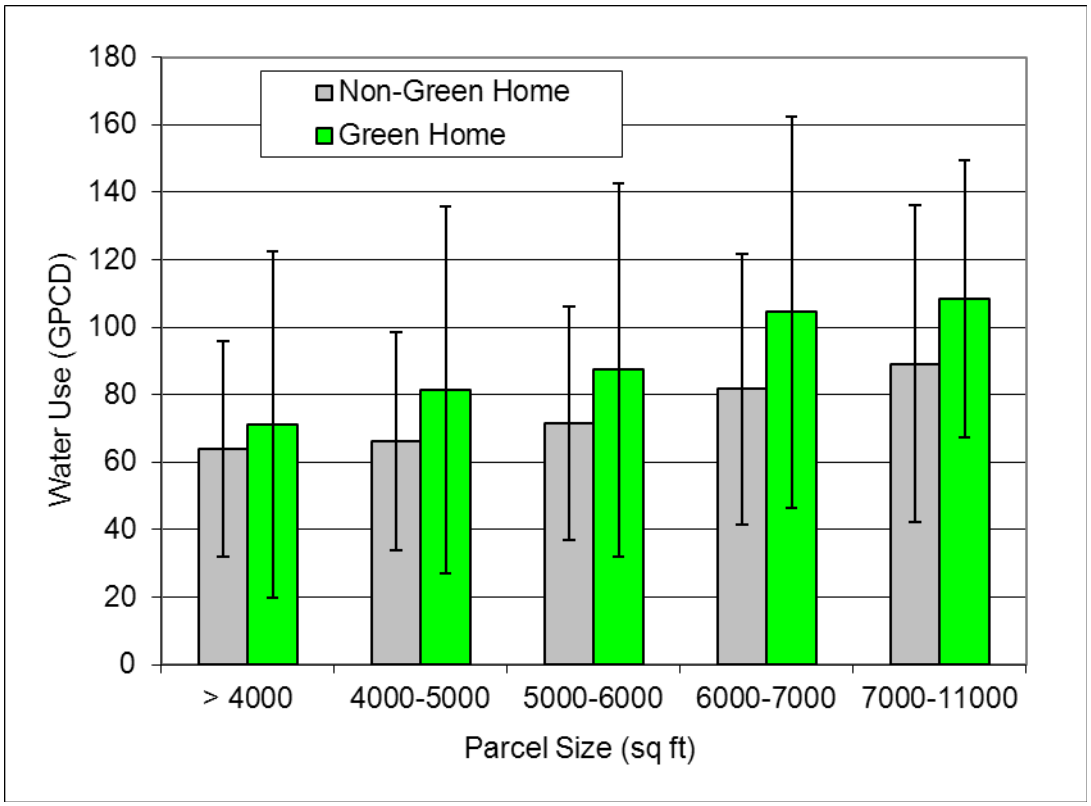

Figure B-5 Average Daily Water Use in "Non-Green" and "Green" Parcel Classes. Error Bar Shows Standard Deviation.

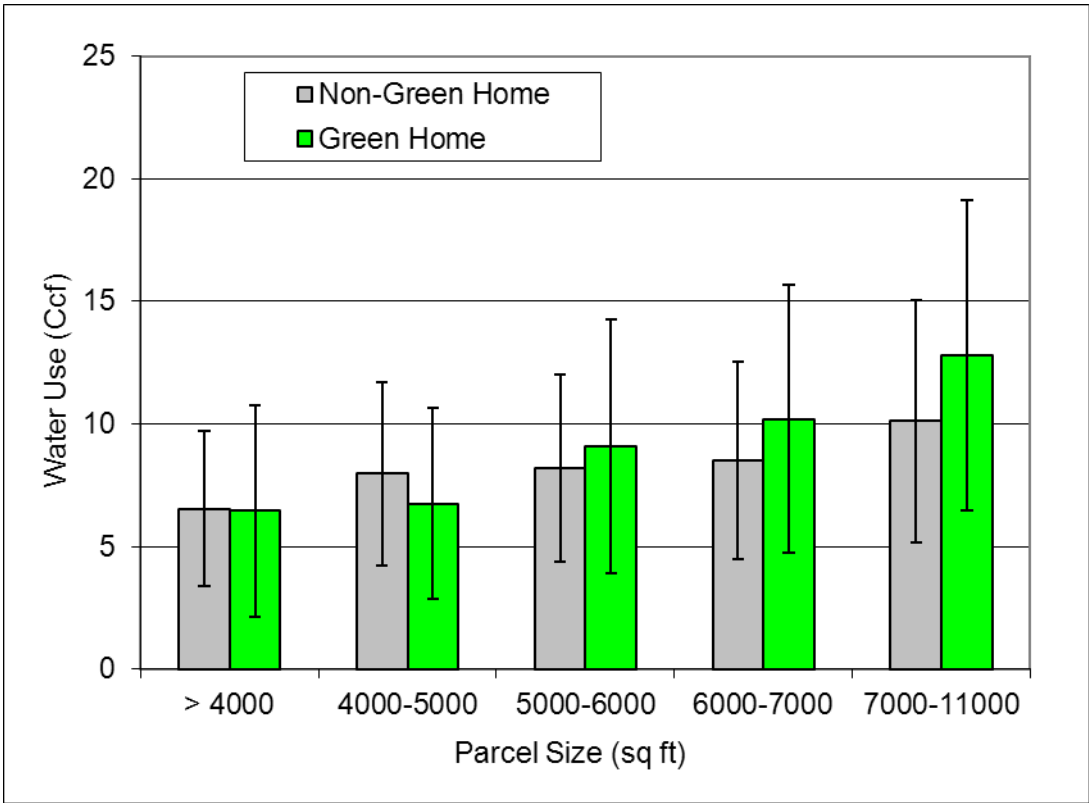

Figure B-6 Average Monthly Water Use in "Non-Green" and "Green" Parcel Classes. Error Bar Shows Standard Deviation.

Table B-4 shows average indoor area and average household size for "Non-Green" and "Green" homes. As shown in Table B-4, "Green" homes tend to have a larger indoor space with smaller household size. This suggests that less people live in "Green" homes while the houses are larger than "Non-Green" houses.

Table B-4 Indoor Area and Household Size for "Non-Green" and "Green" Homes

Parcel Size (sq ft)	Sample Size (Number of Samples)		Indoor Area (sq ft)		Household Size (Number of People)	
	Non-Green	Green	Non-Green	Green	Non-Green	Green
> 4000	500	12	1594.8	1948.3	2.6	2.4
4000-5000	1171	7	1505.7	1438.1	3.1	2.2
5000-6000	1762	19	1589.0	1704.4	2.9	2.7
6000-7000	1351	5	1736.3	1789.8	2.7	2.4
7000-11000	2799	7	1990.6	2012.4	2.9	2.8

The evaluation of 2006 water use provided by Civano showed that Civano I and II developments used less water on average (82-92 Ccf/year) than residential water users in Tucson (131 Ccf/year) (http://www.civanoneighbors.com/docs/environment/Civano_Energy_Water_2007.pdf#page=11). Our result indicated that per-capita water use (GPCD) in "Green" homes, such

as Civano, may not be less than “Non-Green” homes built after 2000 (Figure B-6). This could be related to the fact that we targeted only newer homes (“After 2000”) built after 2000 to compare water use with “Green” homes. Most likely, the residential water use in Tucson used in the report provided by Civano includes water use in older homes (“Before 2000”) that generally use more water than newer homes. It should be noted that Civano uses reclaimed water for outside irrigation. According to their monitoring data in 2006, Civano used 34.4 Ccf/residence per year for site landscaping (not including the community pools) in addition to potable water use of 82-92 Ccf/year.

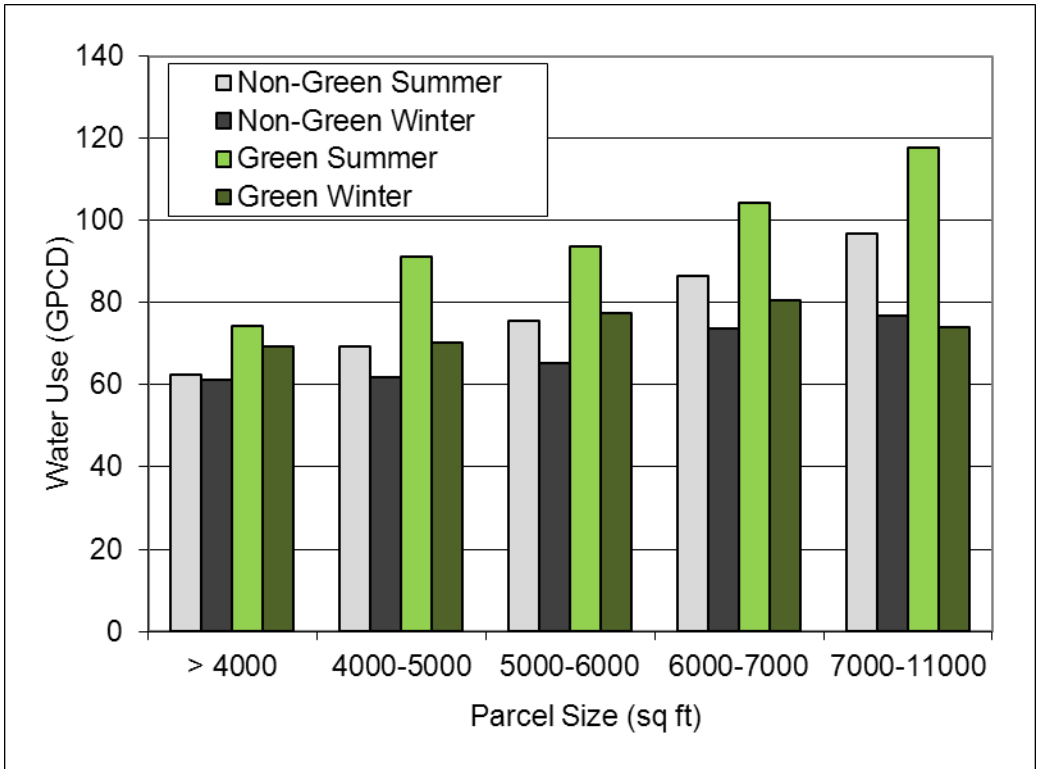

Figure B-7 Average Summer and Winter Water Use in “Non-Green” and “Green” Parcel Classes.

Figure B-7 shows average summer and winter per-capita water use in “Green” and “Non-Green” homes. The difference in water use between summer and winter in “Non-Green” homes is smaller than the difference in “Green” homes. It appears that “Green” homes use more water in summer than “Non-Green” homes.

While it is somewhat surprising that per-capita water use in “Green” homes was higher than “Non-Green” homes, this may indicate that newer “Non-Green” homes built since 2000 have close or possibly higher water efficiency, compared to “Green” homes. It may be related to using potable water for locally grown food or gardening. It may have to do with having fewer people living in “Green” homes or conflicting “Green” ethics. It is unclear why water use in “Green” homes is higher than “Non-Green” homes.

Summary and Conclusions

This study showed that average water use at newer homes ("After 2000") is less than older homes ("Before 2000") in all parcel classes. This can be a result of the changes in construction patterns, water efficient appliances, and/or plumbing fixtures reported in the previous chapter (*A. Household Water Use Study*). Newer homes were built on smaller parcels, while the size of the house and garage is larger than older homes on comparable parcel sizes. Therefore, newer homes have less outdoor space for landscaping, suggesting less outdoor water use at newer homes. Other major factors contributing to less water use at newer homes are the absence of backyard pools and virtually no evaporative coolers.

This study indicated that seasonal difference in water use for newer homes is smaller than older homes. In addition to the fact that there is less outdoor space that can be used for pools or landscaping in newer homes, there is another known change in the housing stock which should help explain why the difference in water usage between summer and winter at newer homes is smaller than older homes. That is the wholesale installation of air conditioning (AC) in all new homes. There are few new homes that have evaporative cooling as their primary source of cooling. From 1995 to 2005, we have added nearly 46,000 new single-family residential services (*A. Household Water Use Study*). An estimated 97% of the homes added during this period had AC as their primary source of cooling. According to MAS 2011 data, 46% of older homes ("Before 2000") have evaporative coolers (*A. Household Water Use Study*). Studies vary on the amount of water used in a cooler. A study by the University of Arizona found homes with evaporative coolers use 150 gallons per day on a hot dry day (http://www.climas.arizona.edu/feature-articles/september-2007). On hot dry days, homes with evaporative coolers can use around 6 Ccf per month, with much of that coming in the dry month of June. A cooler is estimated to use about 25 Ccf per cooling season.

We assume that homes with coolers use more water in summer. The findings of this study, the difference in water use at newer homes is less than older homes and there are few homes with evaporative coolers as their primary source of cooling, support the assumption that homes with evaporative coolers use more water. However, water use patterns could be more complicated than the simple assumption. Figures B-8.1 and B-8.2 show per-capita summer water use in homes with cooler or AC. Since there is a small percentage of homes built with evaporative coolers after 2000, we used only homes built before 2000 for the analysis in Figures B-8.1 and 8.2. Figure B-8.1 shows summer water use in homes with no pools, while Figure B-8.2 shows summer water use in homes with pools. Data used for those figures are summarized in Table B-3 in Appendix B. It appears that homes with AC tend to use more water in summer than homes with a cooler. It is unclear why homes with AC use more water on average (Table B-3, Appendix B), particularly in summer (Figures B-8.1 and B-8.2). The more water use at homes with AC might be related to efficient appliances and plumbing or increased efficiency of newer coolers.

This study also indicated that "Green" homes may use more water on average than "Non-Green" homes on a per capita (GPCD) basis on comparable parcel sizes, particularly in summer. It is unclear why these "Green" homes tend to use more water than "Non-Green" homes on a per capita basis. It may have to do with having fewer

people living in “Green” homes or conflicting “Green” ethics, such as gardening and growing fruit trees, that result in more water outside use.

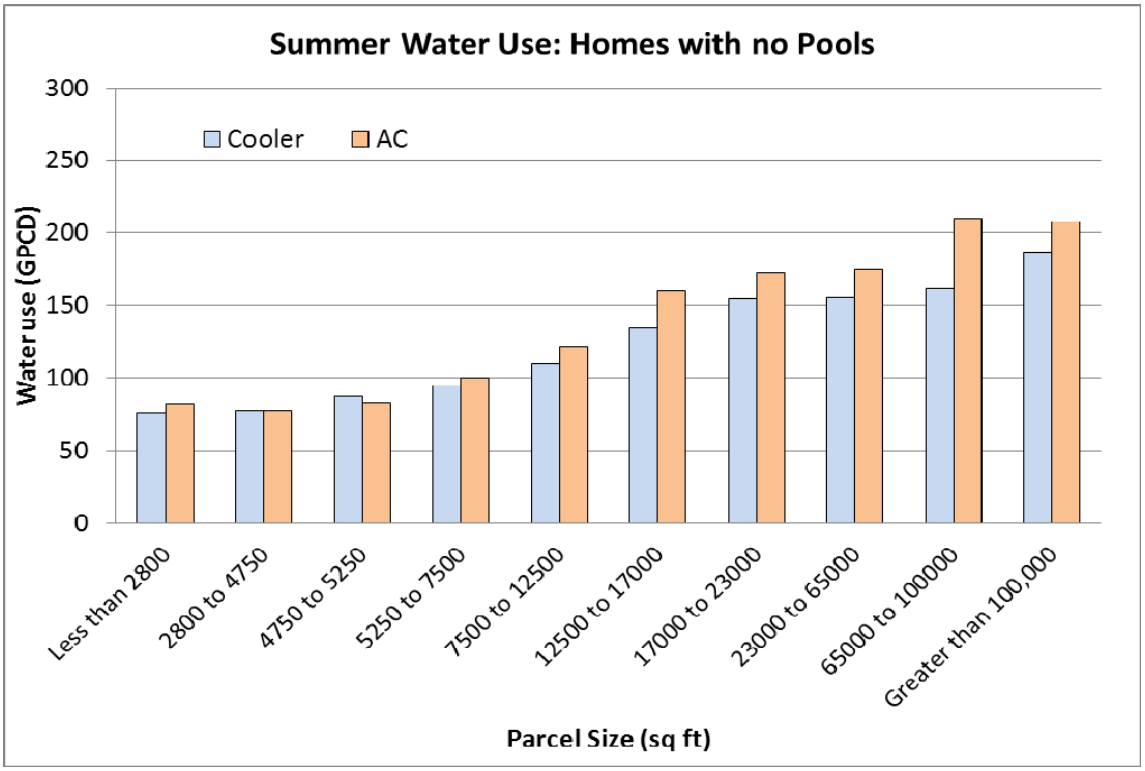

Figure B-8.1 Summer Water Use in Homes without Pools

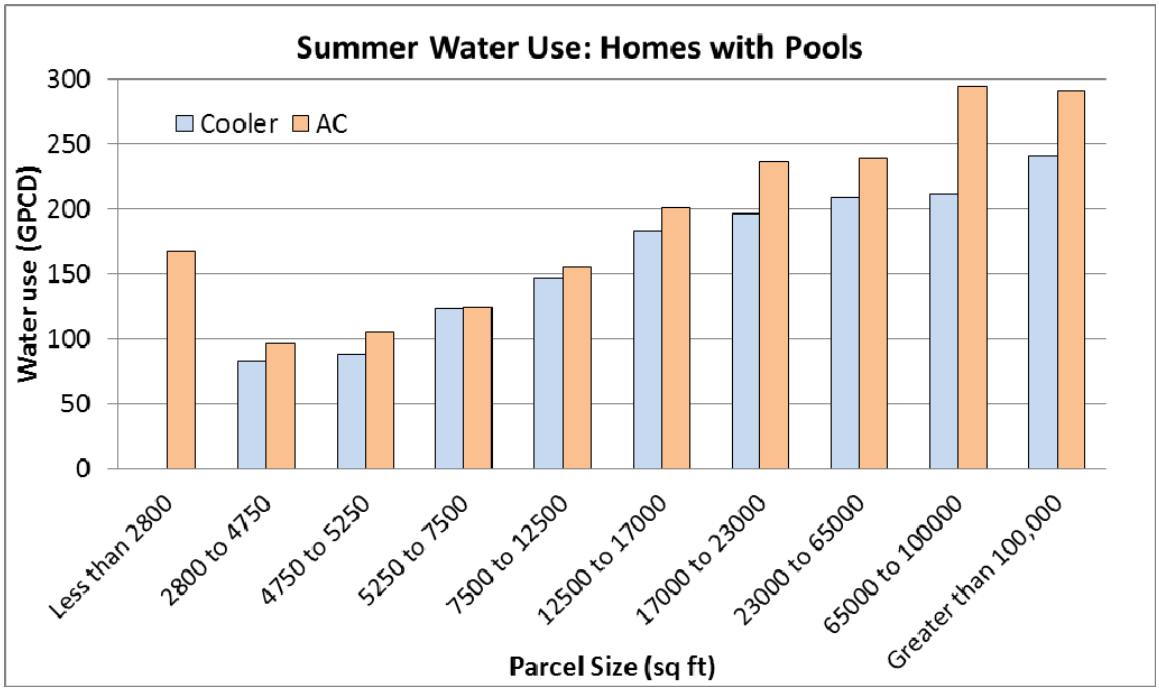

Figure B-8.2 Summer Water Use in Homes with Pools

4. References

A. *Household Water Use Study*

http://www.climas.arizona.edu/feature-articles/september-2007

Fiske and Associates. 2006. *Tucson Water Conservation Plan – Draft Final Report*.

Karpisak, M and Marion, M.H. 1994. Evaporative Cooler Water Use. University of Arizona Cooperative Extension Consumer Publication #9145

Appendix B-1

Table B1.1 Average Monthly Water Use for "Before 2000"

	Water Use (GPCD)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Less than 2800	73.8	70.2	68.2	72.1	74.9	89.6	88.8	83.7	88.0	85.1	73.6	75.9
2800 to 4750	69.6	67.3	63.1	68.6	71.5	81.8	80.6	77.8	81.1	75.5	71.1	74.2
4750 to 5250	73.5	69.4	65.7	73.2	77.4	90.3	87.3	84.8	88.9	81.9	76.2	77.2
5250 to 7500	75.9	72.9	70.1	79.5	87.2	106.7	102.5	98.8	99.3	92.7	81.8	81.0
7500 to 12500	83.4	79.0	77.5	92.0	104.5	131.8	126.2	120.7	119.2	111.2	95.7	92.2
12500 to 17000	108.3	100.2	98.5	120.9	135.2	179.5	174.7	167.6	167.0	156.2	135.8	129.8
17000 to 23000	130.5	117.2	116.6	144.3	161.4	211.1	208.1	200.0	198.7	186.2	163.8	158.7
23000 to 65000	143.0	124.3	122.2	153.3	170.4	225.0	224.9	210.8	211.2	203.6	183.0	169.5
65000 to 100000	179.1	163.8	151.9	187.5	212.6	273.9	273.5	256.9	258.9	256.2	232.2	220.8
Greater than 100,000	164.5	135.7	136.9	186.0	202.4	267.1	268.3	244.9	251.1	243.9	210.7	195.5

Table B1.2 Average Monthly Water Use for "After 2000"

	Water Use (GPCD)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Less than 2800	63.2	62.0	52.0	54.1	51.3	56.5	52.5	55.5	58.8	57.0	56.7	57.6
2800 to 4750	62.5	62.5	57.7	60.4	63.3	70.2	65.8	67.6	71.3	68.3	64.1	65.7
4750 to 5250	65.2	64.0	59.3	64.2	68.2	74.9	71.6	70.3	74.6	70.0	65.9	68.5
5250 to 7500	74.1	72.0	67.8	74.7	79.4	89.0	85.1	82.5	87.6	82.2	79.7	79.2
7500 to 12500	81.2	78.3	75.1	84.8	91.2	105.2	101.7	98.9	104.6	95.5	90.8	88.8
12500 to 17000	103.9	98.3	96.2	111.7	119.3	143.8	136.9	131.7	142.9	121.7	121.6	116.3
17000 to 23000	113.0	107.7	117.3	128.0	132.6	164.7	168.1	154.5	167.6	143.9	132.1	127.9
23000 to 65000	151.2	135.7	130.9	157.0	177.9	224.3	226.7	218.0	226.6	213.1	198.2	180.0
65000 to 100000	190.3	173.5	155.9	187.1	209.5	264.9	271.6	258.4	290.1	269.1	234.3	222.1
Greater than 100,000	163.5	141.4	130.0	167.7	180.8	263.5	228.9	222.5	230.2	231.3	191.2	185.7

Table B1.3 Water Use in Homes with AC or Cooler

Parcel Size (sq ft)	Cooler /AC	Pool	Frequency	Daily Water Use per Capita (GPCD)			Monthly Water Use per Household (Ccf)			Property Value (USD)	Household Size
				Average	Summer	Winter	Average	Summer	Winter		
Less than 2800	Cooler	No	48	70.7	75.9	61.8	7.5	8.2	6.4	72,951	2.5
	Cooler	Yes	0	NA	NA	NA	NA	NA	NA	NA	NA
	AC	No	45	80.6	82.5	76.8	6.3	6.6	5.9	144,286	2.0
	AC	Yes	4	125.9	167.4	87.1	11.7	16.2	7.7	410,613	2.3
2800 to 4750	Cooler	No	461	71.0	77.9	61.8	7.8	8.6	6.7	77,729	2.8
	Cooler	Yes	5	70.7	83.1	57.7	8.6	10.1	7.0	84,585	3.2
	AC	No	939	74.5	77.6	69.0	7.1	7.5	6.5	126,550	2.4
	AC	Yes	20	86.3	96.7	76.2	9.6	10.9	8.3	134,109	2.7
4750 to 5250	Cooler	No	273	77.5	87.2	65.5	9.5	10.7	8.0	84,015	3.1
	Cooler	Yes	4	84.0	88.5	64.8	10.0	10.6	7.6	137,071	2.9
	AC	No	899	78.2	83.1	70.1	8.0	8.5	7.1	131,333	2.6
	AC	Yes	47	97.6	105.8	83.1	10.4	11.4	8.7	152,792	2.7
5250 to 7500	Cooler	No	7132	82.8	95.0	68.5	9.7	11.2	8.0	88,865	3.0
	Cooler	Yes	470	102.0	124.0	78.8	11.7	14.3	8.9	107,149	2.9
	AC	No	3827	91.5	100.0	78.6	9.2	10.2	7.8	146,693	2.6
	AC	Yes	579	109.7	124.9	89.1	11.4	13.1	9.1	178,728	2.6
7500 to 12500	Cooler	No	17497	93.4	109.7	73.6	10.2	12.1	8.0	104,809	2.8
	Cooler	Yes	3443	119.0	146.8	86.5	12.7	15.7	9.1	129,746	2.7
	AC	No	8071	106.8	122.0	84.6	10.8	12.4	8.5	149,239	2.6
	AC	Yes	3076	131.4	155.6	99.5	13.5	16.1	10.1	174,942	2.6
12500 to 17000	Cooler	No	959	112.5	134.2	84.5	11.5	13.8	8.6	136,495	2.6
	Cooler	Yes	346	153.2	182.8	105.3	15.4	18.8	10.5	174,695	2.5
	AC	No	955	139.8	159.8	104.1	13.7	15.8	10.1	199,638	2.5
	AC	Yes	724	172.9	200.8	126.1	16.8	19.7	12.1	258,642	2.4

Parcel Size (sq ft)	Cooler /AC	Pool	Frequency	Daily Water Use per Capita (GPCD)			Monthly Water Use per Household (Ccf)			Property Value (USD)	Household Size
				Average	Summer	Winter	Average	Summer	Winter		
17000 to 23000				Average	Summer	Winter	Average	Summer	Winter		
	Cooler	Yes	124	161.3	196.9	112.9	15.8	19.4	10.9	207,593	2.4
	AC	No	363	151.4	172.8	109.4	14.9	17.5	10.7	257,732	2.5
	AC	Yes	487	207.3	236.1	146.4	20.3	23.5	14.1	339,843	2.5
23000 to 65000											
	Cooler	No	844	133.0	155.7	96.8	13.2	15.7	9.5	209,743	2.5
	Cooler	Yes	672	171.2	209.4	116.4	17.1	21.0	11.4	244,468	2.5
	AC	No	2309	153.8	174.8	114.6	15.3	17.5	11.2	314,272	2.5
	AC	Yes	4361	206.1	238.9	148.4	20.7	24.2	14.6	384,653	2.5
65000 to 100000											
	Cooler	No	22	138.7	161.1	105.6	14.2	16.5	10.6	281,741	2.6
	Cooler	Yes	24	174.7	211.6	128.8	17.5	21.3	12.8	326,507	2.5
	AC	No	134	189.7	209.7	137.9	18.9	21.0	14.8	394,990	2.5
	AC	Yes	304	261.5	295.1	187.1	26.4	29.9	18.6	481,662	2.5
Greater than 100,000											
	Cooler	No	73	154.5	186.8	102.8	15.8	19.2	10.4	287,550	2.5
	Cooler	Yes	52	208.5	241.4	147.8	20.4	23.7	14.3	330,961	2.4
	AC	No	135	169.4	208.0	116.2	18.2	21.4	12.5	379,807	2.5
	AC	Yes	270	250.7	291.4	178.1	25.7	30.4	17.8	506,157	2.5

Chapter C - Assessing the Spatial Pattern of Water Use in the Tucson Water Service Area

1. Introduction

1.1 Background

While water providers like Tucson Water must make policy based on water use considerations on a connection-by-connection basis, the aggregate patterns of larger groups of water users, such as subdivisions, can inform policy makers on how the similarities and differences of these aggregates affect water use. The City of Tucson/Pima County Water and Wastewater Study (WISP) developed a task to evaluate water use in newer and older construction with the assumption that meaningful comparisons of water use could be derived at the subdivision scale (Exhibit A).

Previous chapters of this study (*A. Household Water Use Study*; B*.The Per-Capita Water Use Study*) focused on single-family water demand at a parcel scale in the Tucson Water Service Area (TWSA). The main goal of the previous chapters was to evaluate the changes in construction patterns and single-family water use at a parcel scale.

This chapter focuses on water use at a subdivision scale. We evaluated a spatial pattern of subdivision water use. We also assessed possible factors affecting the spatial pattern of water use. Various factors could affect the local water use pattern. The previous chapters (*A. Household Water Use Study*; *B.The Per-Capita Water Use Study*) showed that, in general, water use increases with parcel area. Aiken et al. (1991), Mayer et al. (1999) and Harlan et al. (2009) have shown that water use can be related to property value and income. Another studies found that there are strong relationships among neighborhood economic status, vegetation pattern and Urban Heat Island (Jenerette et al., 2011). Those studies suggest that water use patterns could be impacted by household wealth. In this chapter, we used property value as an indicator of household wealth in order to assess the impact of household wealth on water use.

1.2 Purpose

The purpose of this chapter is to evaluate water use at a subdivision scale, particularly focusing on:

- Spatial pattern of household size
- Spatial patterns of subdivision water use
- Relationship between Parcel area, property value and subdivision water use
- Variability of water use within an individual subdivision.

2. Method

2.1 Data Collection

The analysis focused on single-family residences within Tucson Water Service Area (TWSA). Following data was used for the analysis. The source of the data is listed below.

Spatial Datasets

- Parcel data (Pima County GIS library)
- Subdivision data (Pima County GIS library)
- Tucson Water Service Area boundary (Pima County GIS library)
- Census Block 2010 data (Pima County GIS library)

Tabular Data

- MAS 2011 (Pima County Assessor's Office data)
- Water usage record in 2009 and 2010 (Tucson Water)

2.2 Data Preparation and Analysis

The primary method of analysis was to develop a database of characteristics for each parcel in a Geographic Information System (GIS), and then aggregate this data at the subdivision scale. ArcGIS 10.0 was used to extract information from the database for parcels within the Tucson Water Service Area (TWSA).

Water use data in TWSA for 2009 and 2010 was used for this study. Both 2009 and 2010 were dry years, though 2009 was exceedingly dry and 2010 approached normal conditions. In 2010, annual rainfall of 11.13 inches was just under the long-term average of 11.59 inches with 5.45 inches of Monsoon rainfall, just below the long-term average of 6.06 inches. In contrast, 2009, was the 4th driest year recorded at the Tucson airport with only 5.67 inches of annual rainfall and 2.86 inches of Monsoon rainfall. Because water use data was from these two dry years, water would have been required to supply outside water needs, especially in the hotter months of 2009.

Selection of Parcels:
The "USE" code of MAS 2011 was used to select only single-family residences since this study focuses only on single-family water use. Parcels in subdivisions were used in this study. Subdivision data was used to select parcels in subdivisions within TWSA. Data from approximately 70,000 single-family homes (approximately 88% of single-family residences within Tucson Water Service Area) were used for analysis. The housing stock was then divided into two groups, "Before 2000" and "After 2000." While the year 2000 was selected somewhat arbitrarily, the expectation was to identify building practices that contribute to efficient water use by comparing the water use of homes built after 2000 with the larger population of homes built before 2000. Water use records from 2009 and 2010 were used for the analysis. Parcels with "After 2000" homes that

were built after 2008 were removed from the analysis in order to remove homes that did not establish a “normal” level of demand by 2009.

Single-Family Water Use:
Parcels were merged with water use records from 2009 and 2010. Parcels were removed from the analysis if monthly water use is zero during the study period from 2009 and 2010. This is because temporal vacancy (zero water use) could skew the average water use calculation. In other words, it is necessary to use water use data for homes that are occupied. We assessed water use by using monthly average per household (Ccf) and daily average per capita (GPCD). Per-capita water use was calculated by dividing water use by average number of household. Average water use within subdivisions was calculated using single-family water use (Ccf and GPCD).

Property Value:
Property value was estimated using “Actual” from MAS 2011.

Parcel Area:
Parcel area was obtained using the attribute table of a “Parcel shape file.”

Household Size:
In order to obtain representative data on per-capita water use, both water use data and number of residents in a home must be determined. Census data is available for a collection of parcels, called a block, rather than at individual parcels. Since this study focuses on single-family water use, only census blocks where the majority of parcels are single-family residences were used. The “USE” code of MAS 2011 (Pima County Assessor’s Office) was used to select only single-family residences. When multi-family residences occupy more than 20% of an entire area of census blocks, the blocks were removed from the analysis. Census block 2010 data includes different types of household size. “Average Household Size of Occupied Housing Units” (H0120001 of Census Blocks 2010) was selected in this study. Because we eliminated vacant properties for water use analysis, “Average Household Size of Occupied Housing Units” is a reasonable household size to estimate average water use per capita (GPCD).

Subdivision Water Use:
In order to obtain representative data of average water use within subdivisions, subdivisions including less than five parcels were removed from the analysis. Subdivisions with a mixed age of construction (some homes were built before 2000 while the others were built after 2000) were also removed from the analysis. Newer subdivisions include only homes built entirely after 2000, while older subdivisions include homes built before 2000. Total number of older subdivisions used for the analysis is 1073, while the one for newer subdivisions is 146.

3. Results and Discussion

3.1 Spatial Pattern of Household Size

In proceeding with the analysis of water use, it is important to understand how the average number of people living in a home varies spatially. Figure C-1 shows a spatial pattern of average household size in a census block. As shown in Figure C-1, there are areas with no data (e.g. Speedway/Kolb area, around Cloud Rd, Grant/Kolb area). As mentioned previously, blocks in those areas could be removed because multi-family residences are dominant, or blocks include vacant parcels (zero water use) between 2009 and 2010, or blocks include subdivisions with a mixture of newer and older construction (i.e. “Before 2000” and “After 2000”).

Figure C-1 shows that more people tend to live in a house in southern and southwestern Tucson than in central Tucson. Furthermore, homes outside central Tucson tend to have more residents, which may indicate a tendency of families with children to live in more suburban neighborhoods, outside the central part of town.

The per-capita water use study (*B. The Per-Capita Water Use Study*) showed that more people tend to live in newer homes, which is consistent with the spatial pattern of household size shown in Figure C-1. Many houses on the southwest and southeast sides were constructed since 2000, and homes further from the center on the east and northwest sides tend to be newer as well.

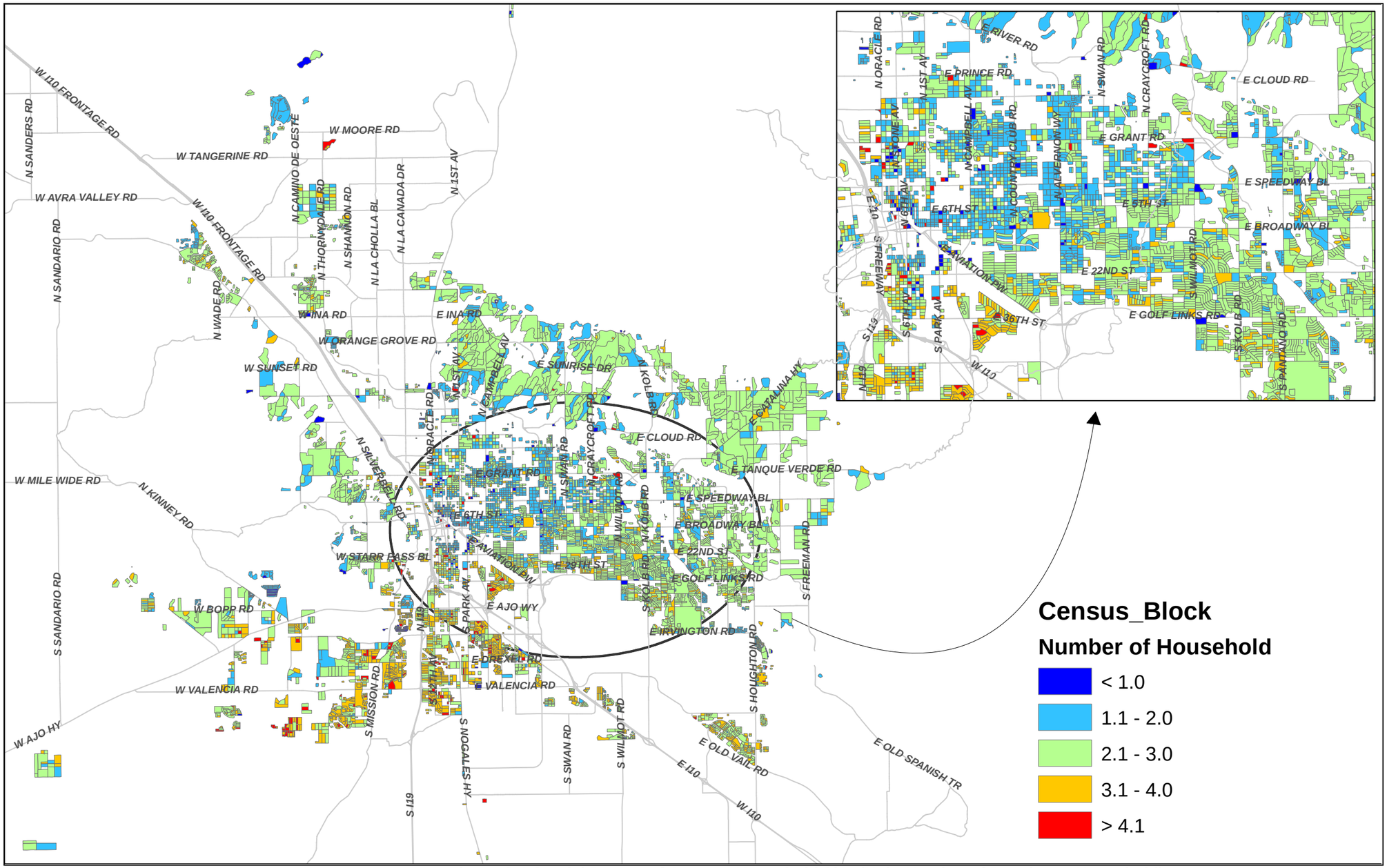

Figure C-1 Spatial Pattern of Average Household Size (Unit: Number of People per Household)

3.2 Spatial Pattern of Water Use

The spatial patterns of average subdivision water use in TWSA are shown in Figures C-2 and C-3. Both older (homes built before 2000) and newer subdivisions (homes built after 2000) were shown in the figures. Both per-capita and per-household water uses are higher in the foothills area, exceeding 15 Ccf and 150 GPCD across much of this area (Figures C-2 and C-3). Household water use is relatively small in central, southern and southwestern Tucson (Figure C-2), while per-capita water use in southern and southwestern Tucson is less than central Tucson (Figure C-3). This could be related to household size shown in Figure C-1. By factoring in household size, it is reasonable that per-capita water use is less in the south, particularly in the southwest (~ 75 GPCD), in central Tucson (~ 100-150 GPCD).

Because the per-capita water use study (*B.The Per-Capita Water Use Study*) showed that winter and summer water use can vary significantly from mean water use, especially for homes on larger parcels, it is instructive to look at how water use varies spatially between the summer and the winter. Figures C-4 and C-5 show a spatial pattern of summer and winter daily water use per-capita in subdivisions. Summer represents May through July while winter represents January through March. According to the historical record of water use in TWSA, "Summer" months are the highest water demand period in a year, while "Winter" months are lowest water demand period in a year.

Per-capita water use in summer or winter is relatively high in the foothills area while it is low in southern and southwestern Tucson (Figures C-4 and C-5), which is similar to the pattern of average per-capita water use (Figure C-3). The overall trends are amplified so that there is even higher water use in the summer in the foothills with a preponderance of > 200 GPCD subdivisions, and even lower water use in the winter with a preponderance of < 75 GPCD subdivisions in the southwest in the wintertime.

The overall trends indicate i) homes in central and southern Tucson use less water than homes in the foothills, ii) more people tend to live in a home in the south and southwest, and iii) per-capita water use is lowest in the south and southwest.

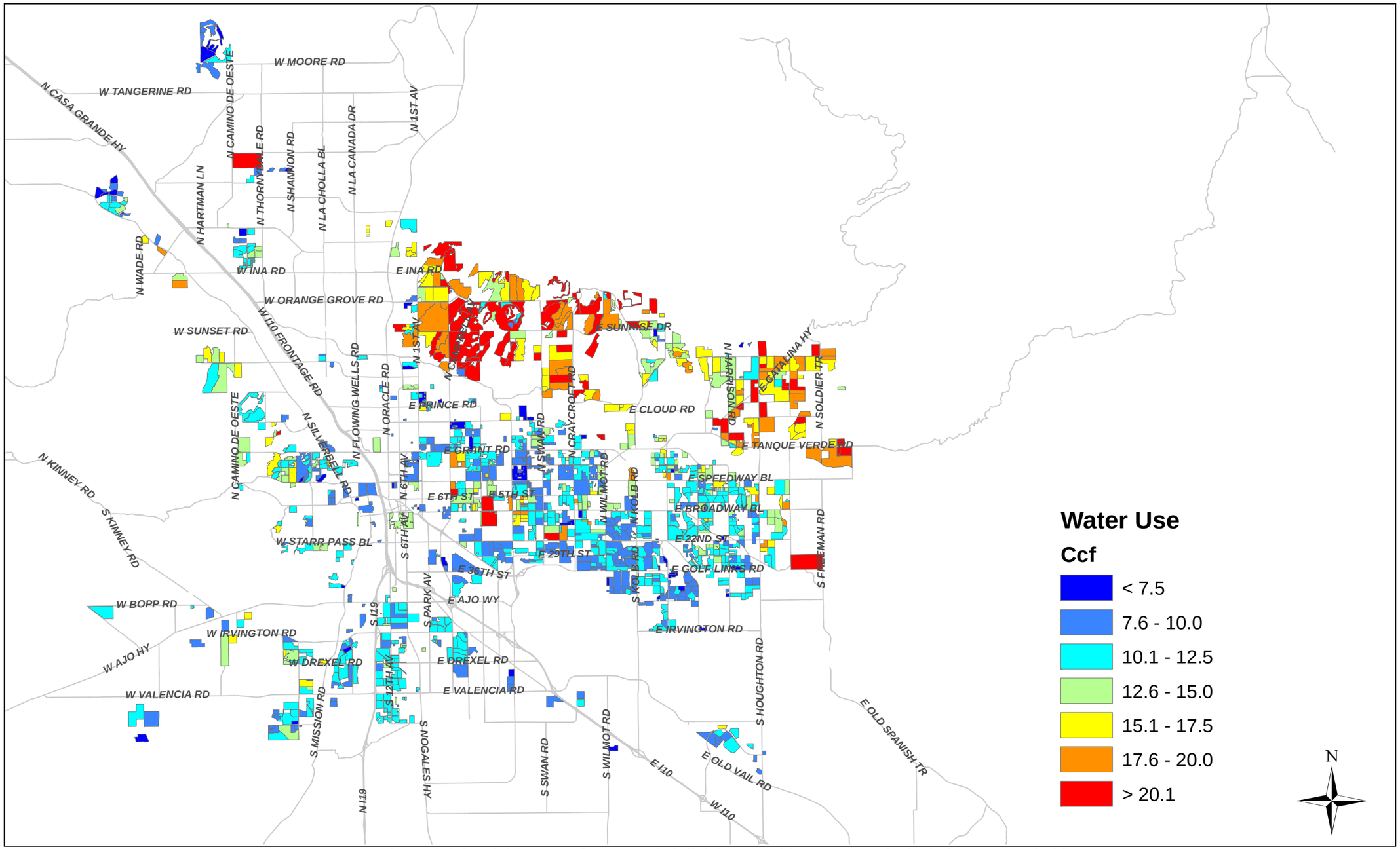

Figure C-2 Spatial Pattern of Average Subdivision Monthly Water Use (unit: Ccf; per Household)

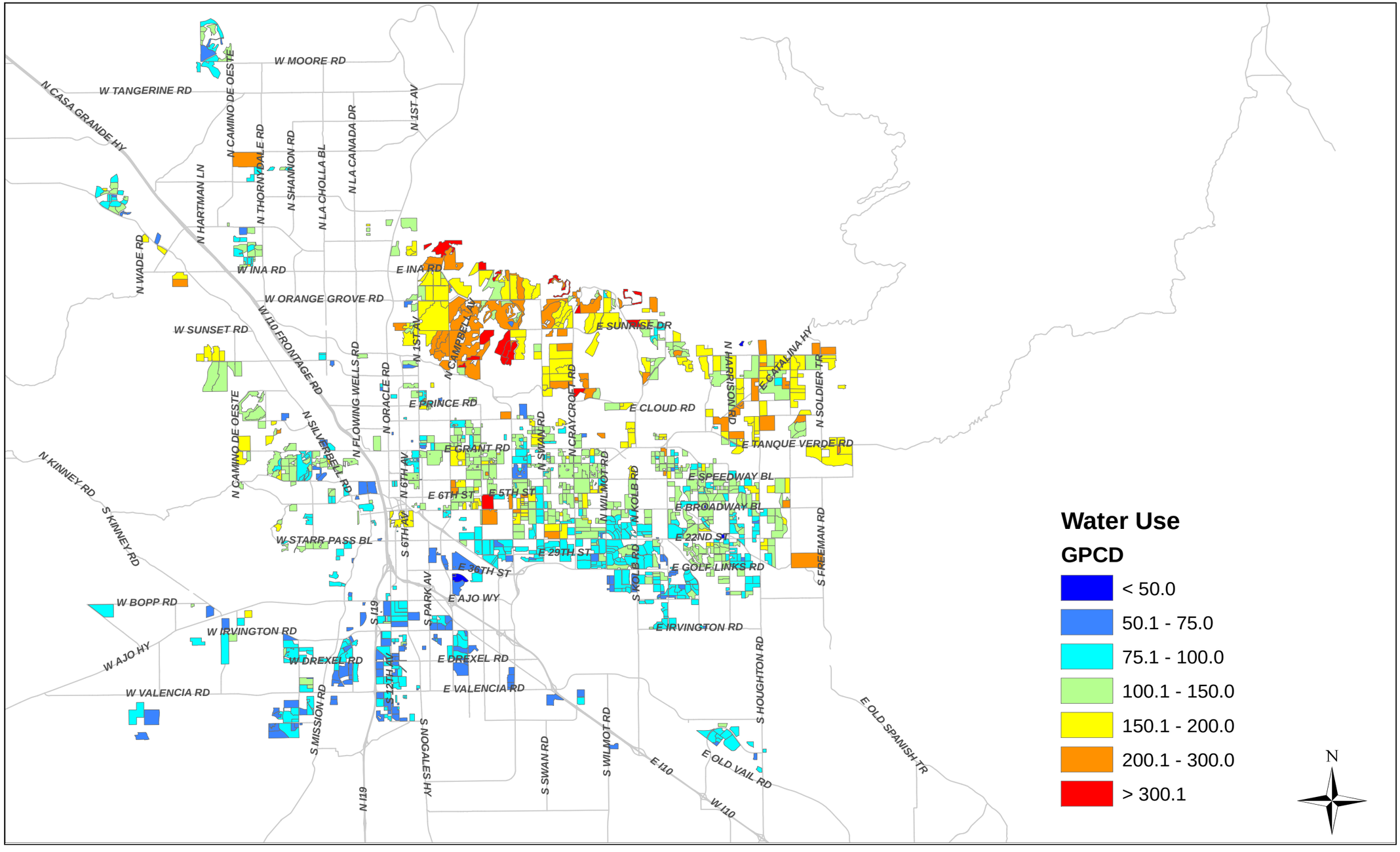

Figure C-3 Spatial Pattern of Average Subdivision Daily Water Use (unit: GPCD)

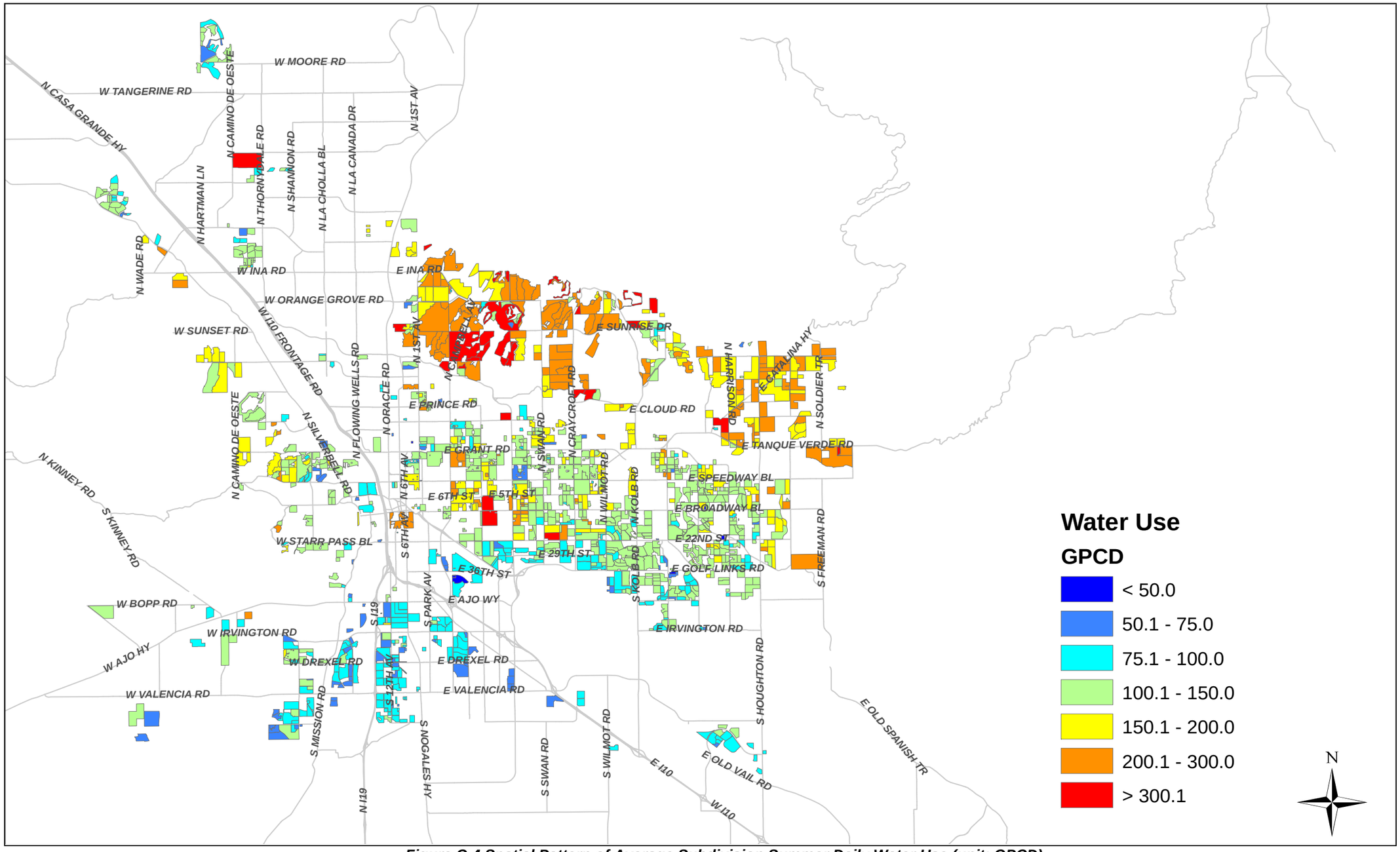

Figure C-4 Spatial Pattern of Average Subdivision Summer Daily Water Use (unit: GPCD)

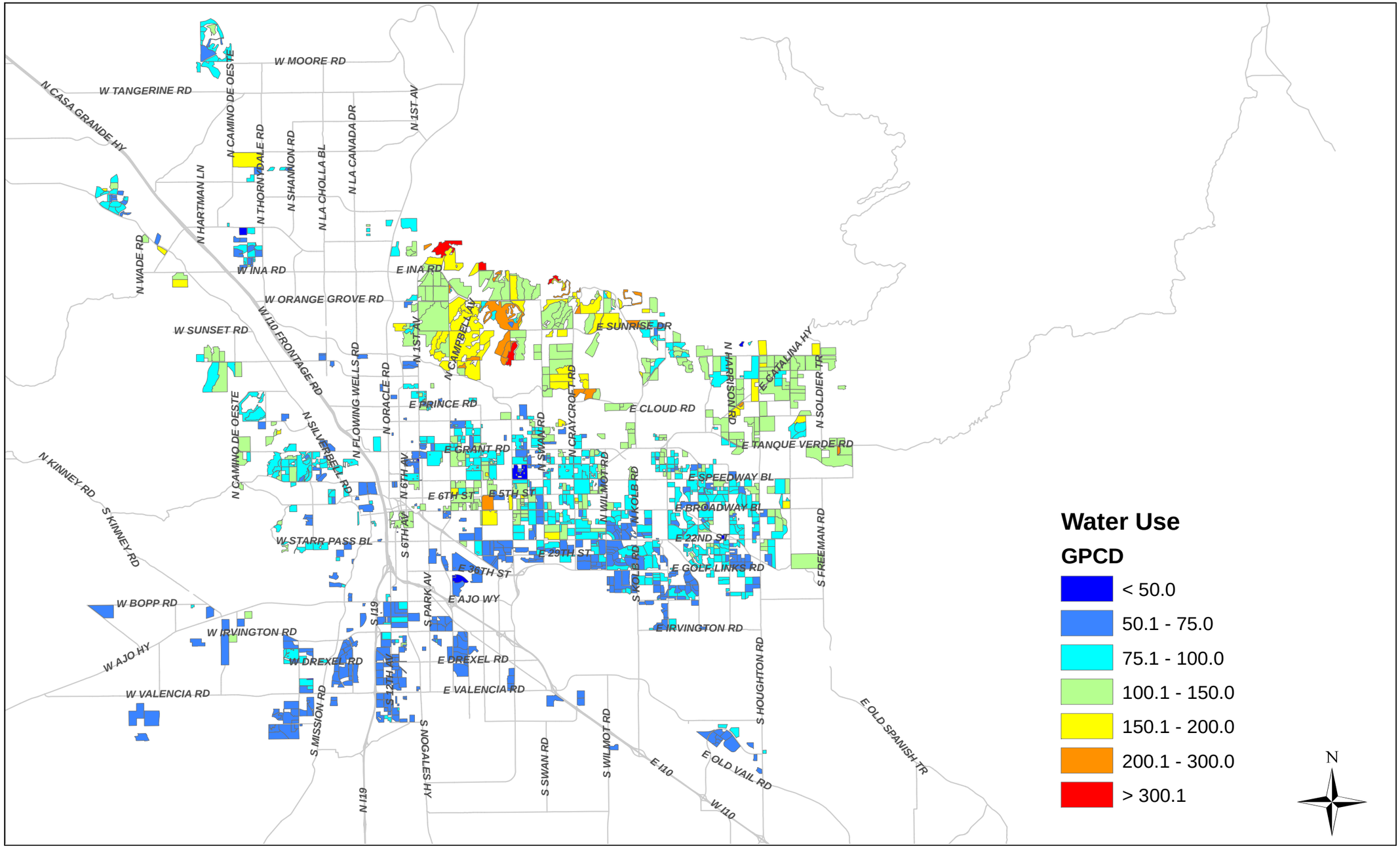

Figure C-5 Spatial Pattern of Average Subdivision Winter Daily Water Use (unit: GPCD)

3.3 Parcel Area, Property Value and Water Usage

Figure C-6 shows a spatial pattern of property value. Both older and newer subdivisions were shown in the figures. Property values in the foothills area tend to be higher than central or southern Tucson (Figure C-6). In general, water use increases with parcel area (*A. Household Water Use Study*; *B.The Per-Capita Water Use Study*), and water use tends to be higher in foothills (Figures C-2 to C-5). These results suggest that the amount of water use can be affected by property value as well as parcel area. The trend that residential water use is closely related to household wealth has been found in Phoenix, AZ (Aikent et al., 1991; Harlan et al., 2009).

Average monthly water use in a subdivision was plotted vs average parcel area (Figure C-7a) and average property value (Figure C-7b). Average per-capita water use was plotted vs average subdivision parcel area (Figure C-8a) and average property value (Figure C-8b). Subdivisions were divided into two groups, older subdivisions (“Before 2000”) and newer subdivisions (“After 2000”) in the figures.

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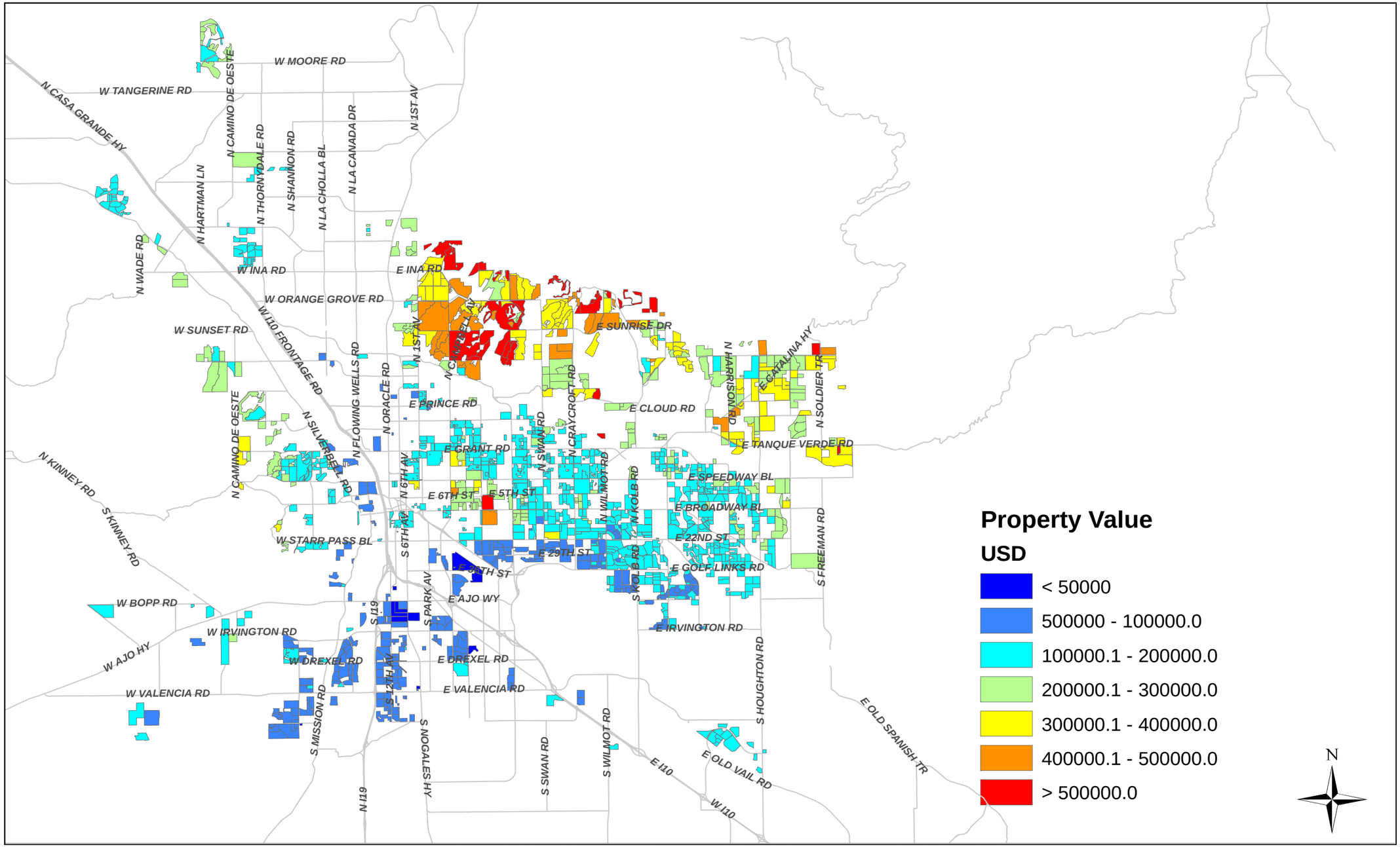

Figure C-6 Spatial Pattern of Average Subdivision Property Value (US Dollar)

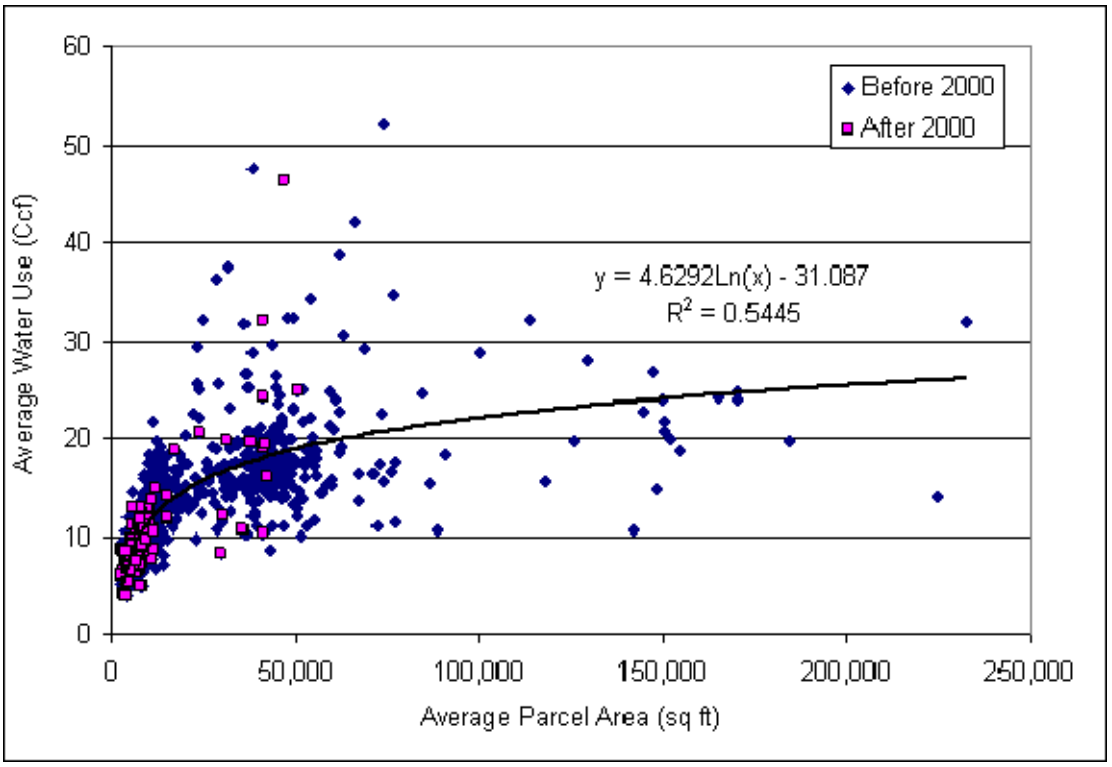

Figure C-7a Average Subdivision Parcel Area and per-Household Water Use (Ccf)

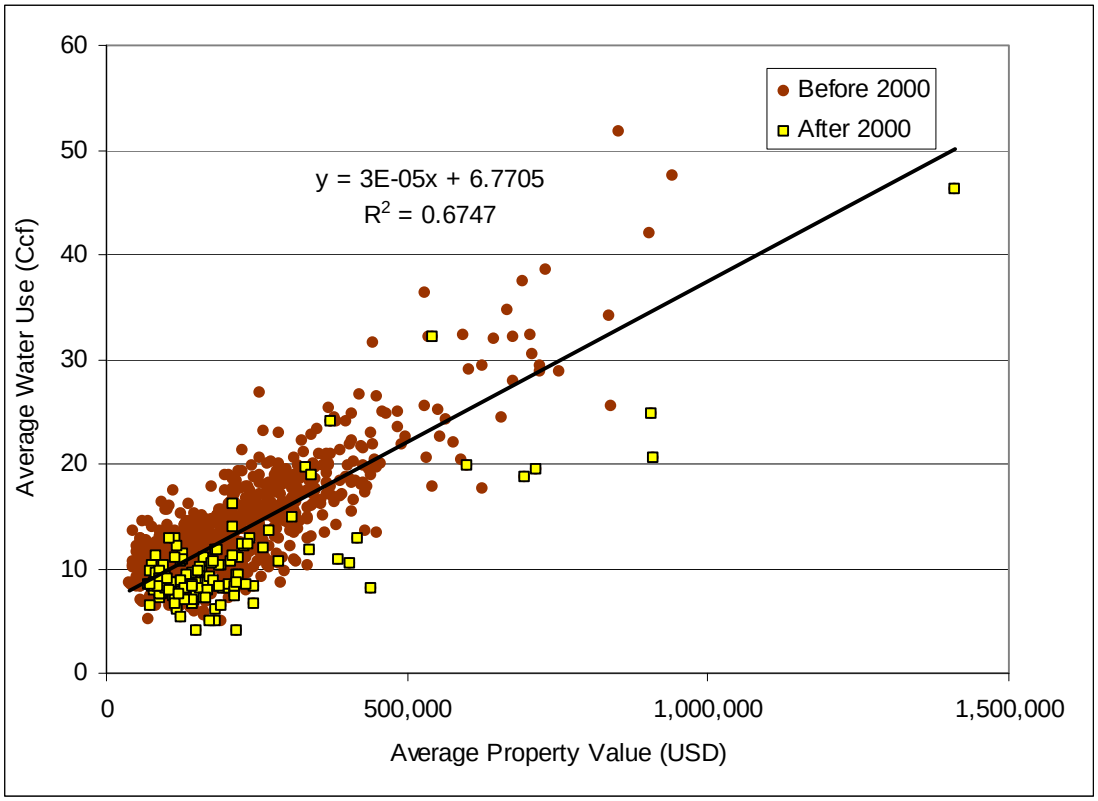

Figure C-7b Average Subdivision Property Value and per-Household Water Use (Ccf)

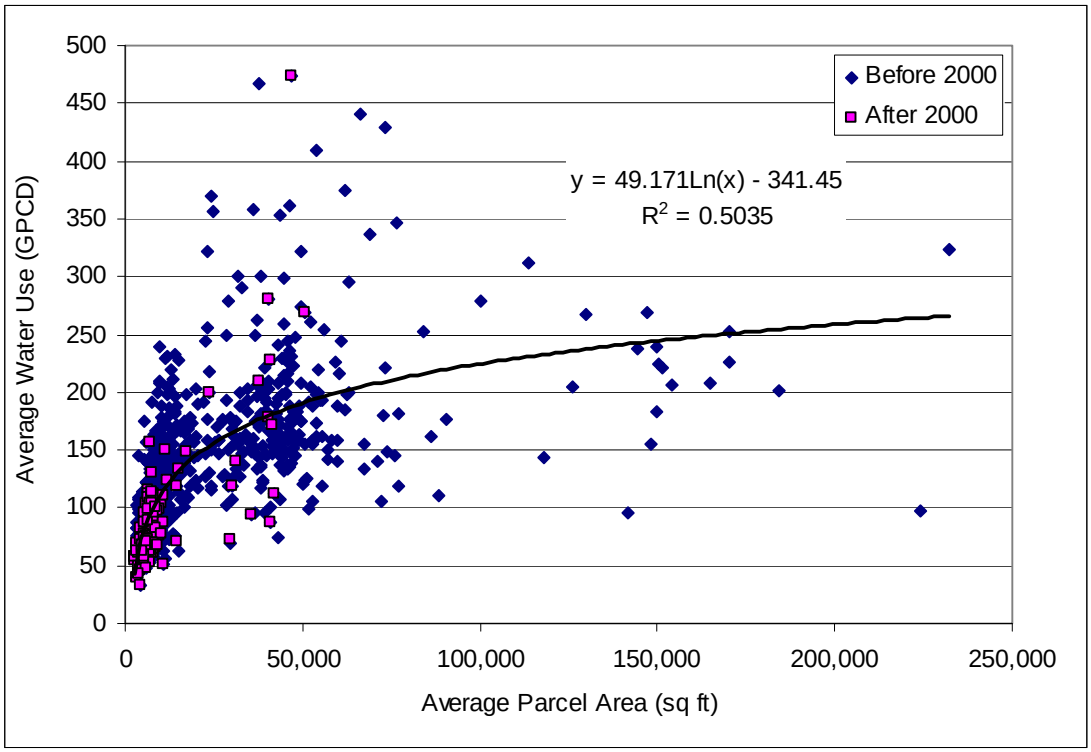

Figure C-8a Average Subdivision Parcel Area and per-Capita Water Use (GPCD)

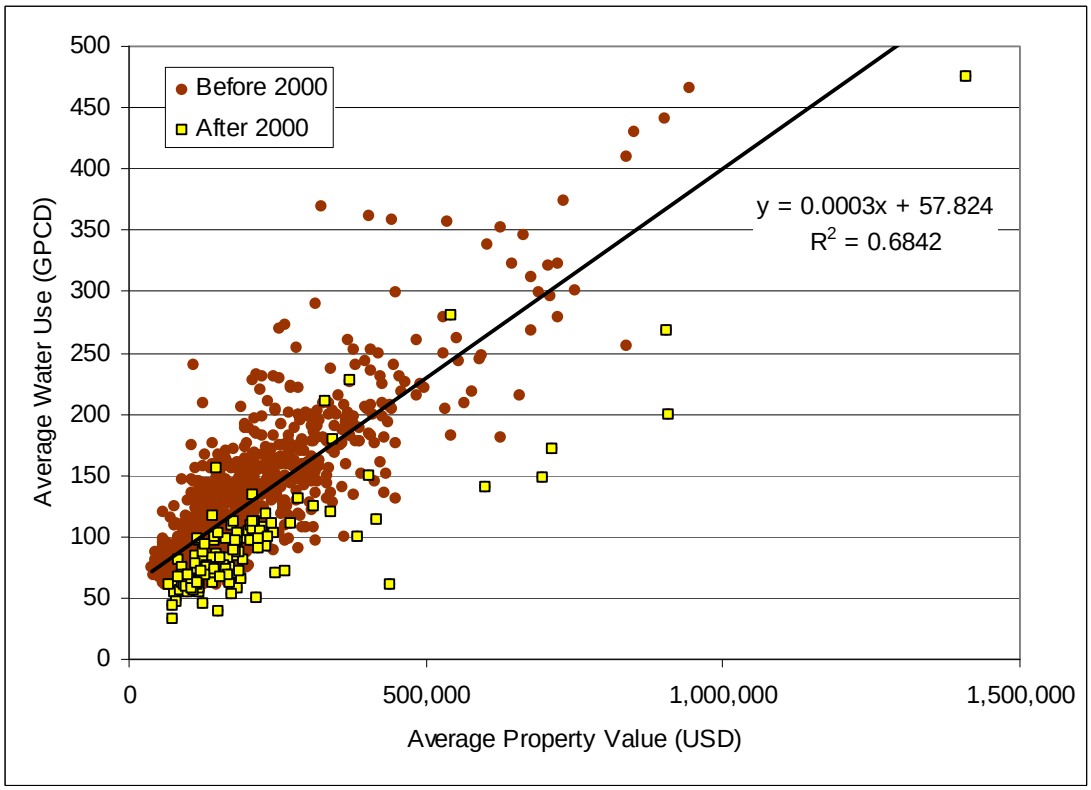

Figure C-8b Average Subdivision Property Value and per-Capita Water Use (GPCD)

Per-household water use (Figures 7-A and 7-B) and per-capita water use (Figures 8-A and 8-B) show the same trends with water use increasing with both parcel area and property value. While water use by parcel area tends to level off with increasing parcel area and is best fit with a logarithmic trend line (Figures 7-A and 8-A), water use as a function of average property value in the subdivision is linear (Figures 7-B and 8-B). Furthermore, there is a stronger correlation between water use and property value (R^2 of ~0.68) than water use and parcel area (R^2 of ~0.55).

The reason why water use would tend to level off with larger parcel areas could be explained by areas for landscaping. Typically, only land near a home site will be landscaped. This indicates that a home on a 2-acre parcel may use about the same amount of irrigated landscape as a home on a 5-acre parcel, and the livable area might not be much different. Understanding why water use increases with property value is less easy to explain except to note that amenities resulting from higher water use (pools landscaping, etc.) may contribute to higher overall property appeal and value.

3.4 Water Use Variability within a Subdivision

There is a trend that homes in a newer subdivision have smaller parcel areas with fairly similar house size. Because homes in a newer subdivision appear to be similar in parcel area and house size, we might assume that within a new subdivision, water use would be fairly uniform. In this section, we assess the water use in a small newer subdivision with similar-sized houses in order to determine if the similarity in parcel area and house size results in similar water use.

An example of a typical newer subdivision is Rancho Paraiso, a subdivision built after 2000 (Figure C-9). Around 75% of parcels in the subdivision are smaller than 6,000 square feet and houses in the subdivision are similar in size.

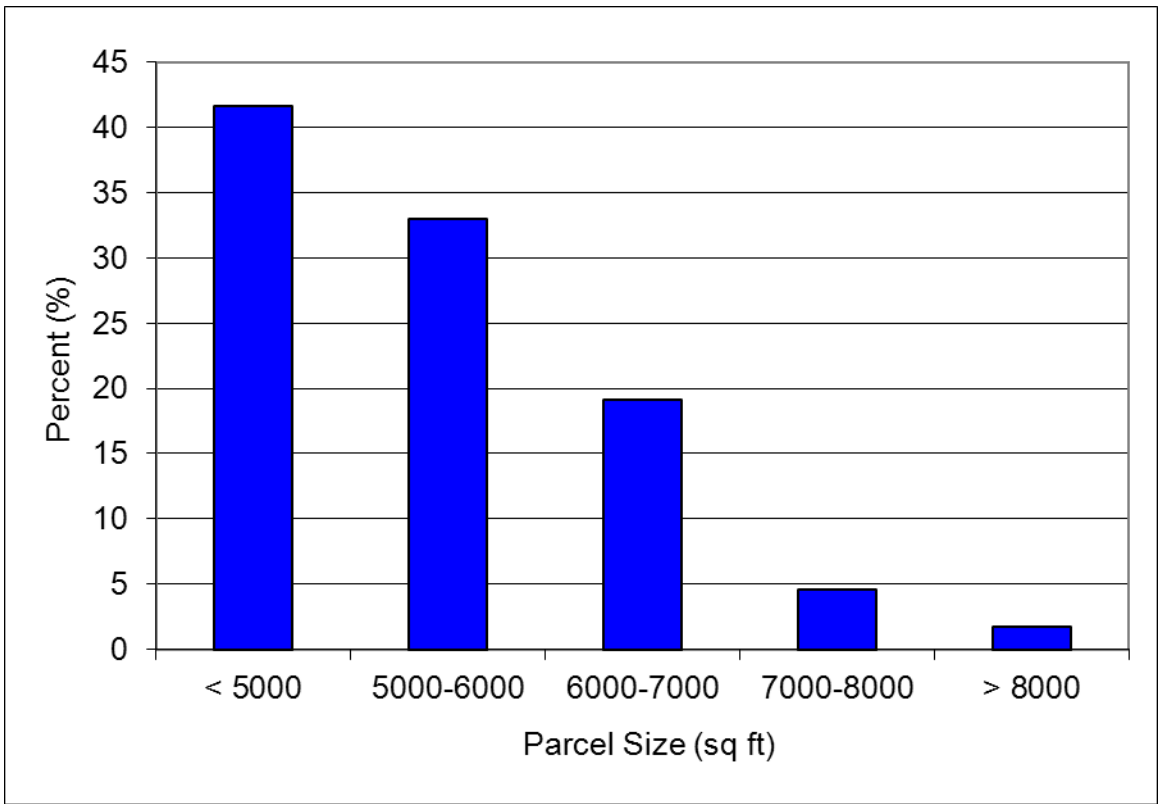

Figure C-9 Range of Water Use in a Newer Subdivision (Rancho Paraiso)

Although the size of parcels and houses in the subdivision looks similar, per-household water use varies from less than 5 Ccf to over 20 Ccf (Figure C-10). This suggests that water use at individual homes is highly variable even when houses and parcels are similar in size. This may be resulted from a difference in household size and/or having a pool. As shown on Figure C-9, there are several homes with pools. This might be one of the reasons that water use between similar houses is highly variable.

We evaluated water use at a subdivision scale in previous sections (3.1-3.3). The result of this section indicated that there can be substantial variability of water use in subdivisions that is not captured in the analysis of water use at a subdivision scale.

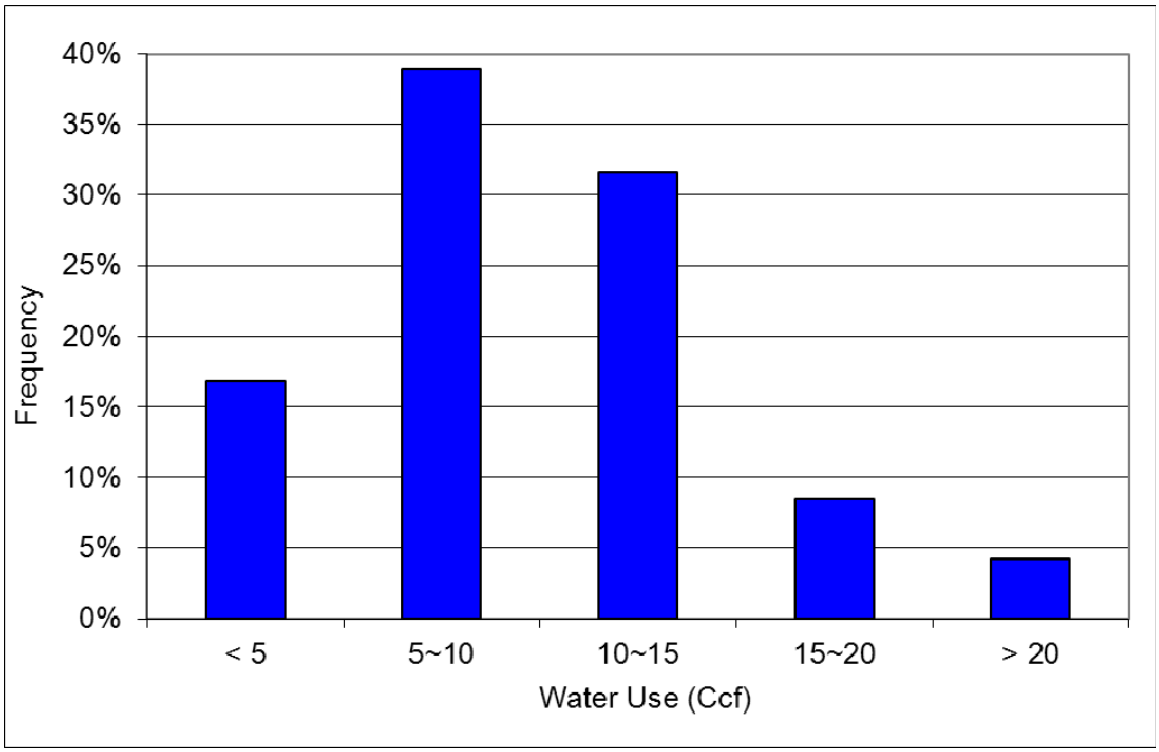

Figure C-10 Water Use a Newer Subdivision (Rancho Paraiso)

4. Summary and Conclusions

The study of water use at a subdivision scale showed the following:

- Average per-household water use and per-capita water use are relatively high in the foothills area.
- Average per-household water use is relatively low in central, southern and southwestern Tucson, while average per-capita water use is relatively low in southern and southwestern Tucson.
- The lower per-capita water use in southern and southwestern Tucson can be caused by a larger household size living in newer and more water efficient housing in southern and southwestern Tucson.

- Water use increases with both parcel area and property value. However, the relationship between property value and water use has a stronger statistical significance. Furthermore, the relationship between water use and property size approaches a constant, while water use continues to increase with property value.
- There is a high variability in water use within a given subdivision, even if homes within the subdivision appear to be similar in parcel areas and house sizes.

The findings of chapters A, B and C show that newer homes located in southern and southwestern Tucson, which often were built on smaller parcels, use less water compared to similar sized parcels with older houses. According to the City of Tucson and Pima County (2009), 45% of water supplied to single-family residences is used outdoors. As discussed in chapters A and B, the less water use at newer small homes is mainly a result of smaller outdoor space for landscaping and may be due to more efficient appliances and plumbing. Similar findings were reported by Wentz and Gober (2007). They found that new-home construction with fewer pools, less irrigation and smaller parcels reduce average water demand in single-family neighborhoods in Phoenix.

In terms of water saving, there is an advantage to build small and high-density homes that were typically seen in southern and southwestern Tucson. Those small and high-density developments with little landscape areas for irrigation are highly efficient in terms of water use. However, other factors should be considered for future development and planning. Halper et al. (2011) studied the relationship between vegetation, water use and surface temperature in Tucson. They found that reduced landscape irrigation in high-density residential areas with little vegetation cover amplifies the urban heat island. Developments with little vegetation cover most likely create urban heat island issues due to the lack of evaporative cooling from vegetation. Policy makers should be aware of the secondary effects of water use, e.g. water use may contribute to property value increase and urban heat island mitigation.

While not specifically identified in the objectives of this study, the results of the three chapters can be useful in planning. For future use they may be helpful in revising the 'Planning Factors' used by Tucson Water, or other local water providers, to estimate water use of future subdivisions. At the Service Area scale, they may also be useful projecting water use of future build out, such as estimating the water use within Tucson Water's Obligated Service area under different kinds of residential construction. And at the regional scale, such as the planning being done by Imagine Greater Tucson, they may be used to project regional water demands under different build-out scenarios that can be used to evaluate regional water security and determine whether additional supplies may need to be secured. The spatial water use patterns presented in this chapter may provide a means to target high water use subdivisions for conservation initiatives, such as education or targeted rebate programs.

5. References

A. Household Water Use Study

B. The Per-Capita Water Use Study

Aiken, C., Duncan, H., McMahon, T.A. (1991). A cross-sectional regression-analysis of residential water demand in Melbourne, Australia. Applied Geography 11 (2), 157-165.

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Halper, E., Scott, C., Yool, S. (2011). Correlating vegetation, water use and surface temperature in a semi-arid city: A multi-scale analysis of the impacts of irrigation by single-family residences. Paper submitted to Geographical Analysis.

Harlan, S.L., S. Yabiku, L. Larsen, and A. Brazel. Household Water Consumption in an Arid City: Affluence, Affordance, and Attitudes. Society and Natural Resources (2009).

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Mayer, P.W., DeOreo, W.B., Opitz, E., Kiefer, J., Dziegielewski, B., Dacus W., Nelson, J.O. (1999). Residential end uses of water. American Water Works Association Research Foundation, Denver, CO.

Wentz, E. A., and P. Gober. (2007). "Determinants of Small-Area Water Consumption for the City of Phoenix, Arizona." Water Resource Management 21 (11), 1849-63.

Attachment A

Action Plan Worksheet: Demand Management 1.1

Project Information		
Activity Title: Collect uniform data on water use patterns to identify conservation potential	**Related Phase 2 Goal and Recommendation:** Goal 1:INCREASE THE EFFECTIVENESS OF CONSERVATION PROGRAMMING THROUGH COORDINATED PLANNING AND EVALUATION Recommendation 1 Collect data on current conditions to provide a foundation for assessing potential to reduce the water/energy footprint of new development and work with regional water utilities to identify opportunities for uniform data collection. (1.1)	
City Staff (lead): Tom Arnold	**Title/Department:** **Tucson Water**	**Phone/email: 837-2114** **tom.arnold@tucsonaz.gov**
County Staff (Lead): Evan Canfield	**Title/Department:** **Pima County Regional Flood Control**	**Phone/email: 243-1836** **evan.canfield@rfcd.pima.gov**
Brief Activity Description: Collect and develop data that will support analysis of water use by age and size of structure and housing densities.		
Estimated funding impact: $20,000		
Start Date: 09-2010	**End Date: 12-2011**	**Priority Level: X H ❑ M ❑ L**

Background Information

Problem statement: Describe the issue or needs that will be addressed by the project, program or activity. Why is it critical to address this issue now?

Water use patterns need to be understood in order to target conservation efforts. Furthermore, construction methods and development patterns have changed through the years so that different water use patterns can be expected based on age and development type.

While conservation efforts must target all construction types, newer construction is potentially more informative, because they represent the status-quo in terms of existing building and zoning codes, and therefore may provide a greater understanding of how these building and zoning codes can be updated to achieve higher water use efficiency.

Project scope & vision: List main activities to be undertaken and end product or service.

This project will have the following components:

- Merging water use data from Tucson Water with other spatial classifications, such as zoning or a range of calculated densities, and subdivision ages. This effort will focus primarily on establishing baseline water use for newer housing (e.g. post 2000) under current codes, recent market conditions and housing preferences.
- Evaluating existing case studies of model communities such as Civano and Armory Park Del Sol.
- Evaluating case studies of water use of subdivisions of different ages (e.g. WaterCASA evaluation of indoor and outdoor water use in Sewell, Sagewood and other neighborhoods).
- Evaluation of other studies of water use in Pima County (e.g. by researchers at U of A).
- Comparing water use with water use targets (e.g. ADWR GPCD water use).

- Prepare a report on how building and zoning codes could be modified to reduce potable water use for new construction.
- Prepare a second report on potential for programmatic changes to reduce potable water use in existing construction.
- Prepare recommendation for developing a methodology of collecting uniform data on water use for water utilities in Pima County.

Project Benefits: How will this project, program or activity help achieve Phase 2 goals for securing a sustainable water future? Also describe other potential positive impacts
Evaluation of baseline conditions for newer construction will provide a starting point for revision of building, zoning and land use codes to achieve reduced water use in future construction.

Evaluation of baseline conditions for older construction will provide a basis for utilities to target conservation efforts

Comparison with accepted targets such as ADWR.

Development of a framework for uniform data collection by water utilities.

Who Are the Potential Stakeholders and Partners? What entities or individuals will be impacted by this activity and/or wish to partner in implementing the activity?

Potential Stakeholder	**Potential Partner**
SAWUA	SAWUA
PAG	WaterCASA
ADWR	U of A
Other Providers Statewide	
SAHBA	
State Blue Ribbon Panel	
Economic Development Community (TREO, SALC, IGT)	

How will you know if this project or activity is successful?

ACTIVITY PRIORITIZATION

Scoring:
High ranking (H): 5 pts Moderate ranking (M): 3 pts Low ranking (L): 1 pt

Instructions: Rank the activity described above according the following 4 prioritization criteria.

Prioritization Criteria	H	M	L
What is the level of importance of this project in securing a sustainable water future? Explain: We need to understand water use and savings potential.	X		
What is the level of feasibility to implement? (Resources, Policy/legal implications are factors to consider). Explain:	X		
What is the level of cost effectiveness of this project to implement? (low initial costs, existing programs with funding in place, can be linked to future budgets are factors to consider). Explain:		X	
To what degree is this activity “low hanging fruit” or a “quick win”? (Length of time to implement is a factor to consider) Explain: It may take a couple years to modify building codes to improve water use efficiency of new construction.		X	

Attachment B

Recommendations for Uniform Data Collection

Going forward into the future, there will be a need to gather data on water use and compare it with previous studies such as this one. Therefore, a uniform data collection strategy needs to be laid out. Furthermore, Demand Management 1.1, which was the basis of this study, included developing means of collecting uniform data. This study includes recommendations on uniform data collection.

In Pima County, the regional parcel data covers the county, which means it provides a uniform data set, the individual traits of which can serve as a basis for characterizing single-family residences.

The analysis in this report demonstrated that residential water use is strongly correlated with parcel size. Furthermore, the ten parcel size classes used in this analysis proved to capture the range of parcel sizes in both homes built after 2000 and homes built before that time. Therefore, the following parcel size classes used in this study and re-iterated in Table 4 should be used:

Table B.1 Proposed Parcel Size Classes for Uniform Data Collection

Class #	Square Feet
1	< 2800
2	2800-4750
3	2750-5250
4	5250-7500
5	7500-12500
6	12500-17000
7	17000-23000
8	23000-65000
9	65000-100000
10	>100000

In addition to parcel size, the following characteristics of housing stock were found to be relevant to water use and should be collected:

- Livable Space (sq. ft)
- Age of Housing (as determined by construction year)
- Presence of a Pool
- Presence of an Evaporative Cooler
- Garage Spaces
- Number in Household

Water use data should also be collected:

- Annual Average Water Use (Ccf)
- Average Summer Water Use (mean Ccf of May to July water bill)
- Average Winter Water Use (mean Ccf of January to March water bill)
- Peak Summer Water Use (June use in Ccf)

- Low Winter Water Use (January use in Ccf)
- Indoor/Outdoor Water Use if available

These data sets should allow characterizing water using the available water use and spatial data sets.