ANALYSIS OF WATER USE PATTERNS IN MULTI-FAMILY RESIDENCES

FINAL REPORT

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Prepared for;
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EXECUTIVE SUMMARY

There are over 48,000 multi-family households served by the Irvine Ranch Water District (IRWD), and they account for approximately 10% of all water deliveries from the system, or 8307 acre feet of treated water deliveries. Fortunately, over 26,000 (54%) of these customers are individually metered. This provides an excellent opportunity to study the water use patterns of the multi-family customers in detail. The IRWD wished to undertake a study of multi-family water use in order to improve their methodology of setting indoor water budgets for multi-family accounts, and contracted with Aquacraft, Inc. to undertake the project.

The billing data showed that existing multi-family accounts could be divided into a series of categories according to the type of housing, the presence of sub-metering or master metering and the age of construction. The percentiles of annual water use for each of the billing groups is shown in Figure ES 1. The median water use (50th percentile) ranged from a low of 58 ccf to a high of 98 ccf, which is a difference of over 80%. There were many factors that explained this variability.

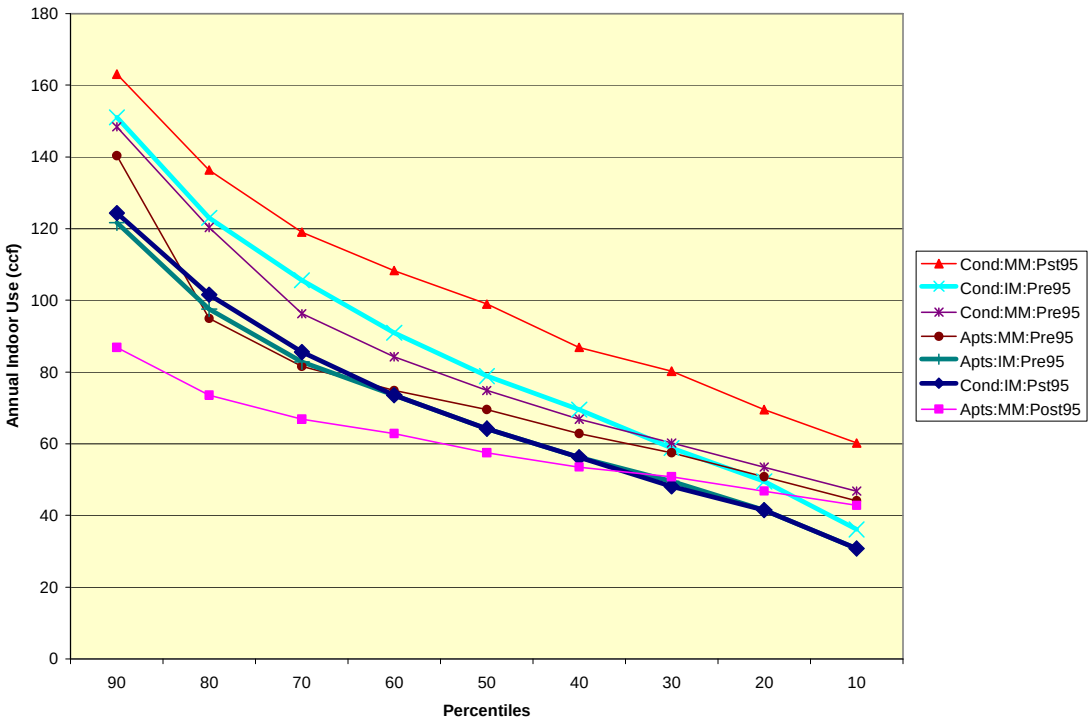


Figure ES 1: Percentiles of annual water use for IRWD Multi-family customers

Using a combination of water billing and survey data obtained from a sample of multi-family customers a series of mathematical models were developed to explain variations in water use as a function of a number of relevant variables. While there were a number of factors for which a relationship with water use was suggested, these were often tenuous. The clearest and most consistent factor explaining water use was the number of

occupants in residence. Then there were a series of categorical parameters that were significant. These were:

- Whether the unit was an apartment or a condo,
- If an apartment, whether it was equipped with a clothes washer in the unit
- If it was a condo, if it included irrigation use,
- If it was a condo, if it was built prior or after 1995.

From these parameters a series of six predictive models were developed that explain annual water use.

Table ES 1: Models of multi-family water use

Group No.	Group Name	Model
1	Apartments w/CW	$39.59 * Res^{0.44} * 1.24 = 49.09 * Res^{0.44}$
2	Apartments wo/CW	$39.59 * Res^{0.44}$
3	Condos w/Irr and Pre 95	$45.41 * Res^{0.56} * 1.22 = 55.4 * Res^{0.56}$
4	Condos w/Irr and Post 95	$45.41 * Res^{0.56} * 1.22 * 0.79 = 43.76 * Rex^{0.56}$
5	Condos wo/Irr and Pre 95	$45.41 * Res^{0.56}$
6	Condos wo/Irr and Post 95	$45.41 * Res^{0.56} * 0.79 = 35.9 * Res^{0.56}$

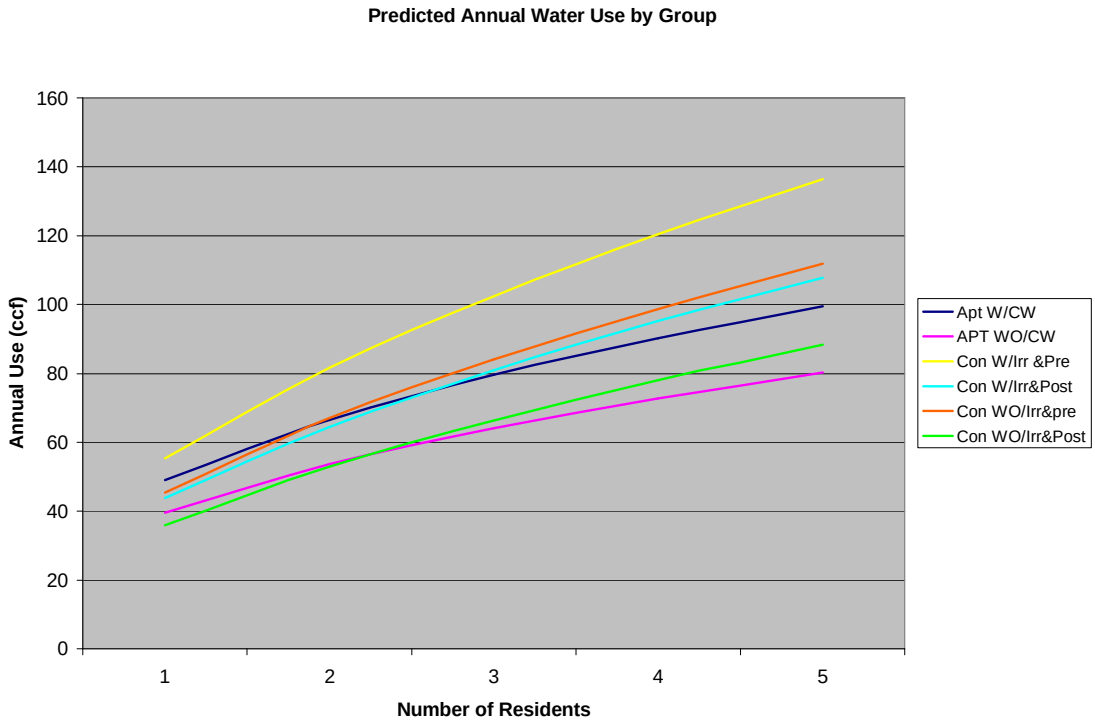


Figure ES 2: Annual water use verses residents for multi-family groups

This data collected as part of this study showed that the existing method used by IRWD for calculating multi-family water budgets over estimates the required amount of water for each unit. The existing system assumes a linear relationship of 75 gpd per person for indoor uses and allows 100% of ET for outdoor allocation. Figure ES 3 shows the percentages of customers that fall into each tier of the water budget system using the current system. In the current system only 1.4% of customers fall into the top two tiers of water use, while 87% are in the bottom two tiers.

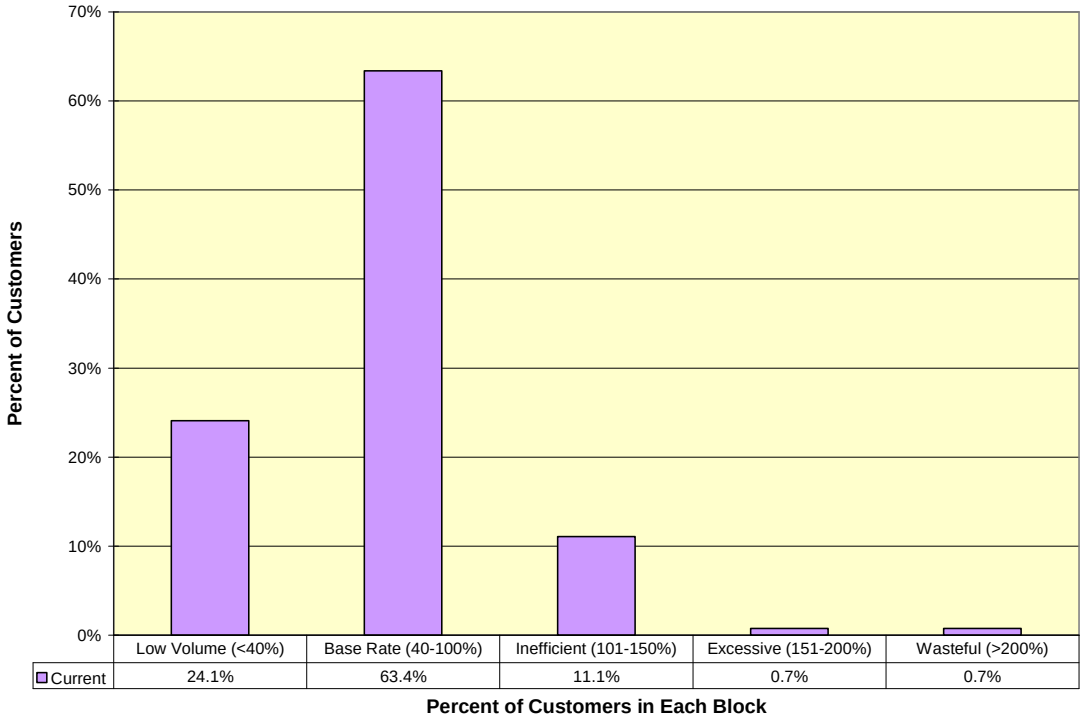


Figure ES 3: Percentages of customers by tier for current water budget structure.

In order to encourage water conservation IRWD is considering trimming the budgets to 50 gpcd for indoor uses and allowing only 80% of ET for the outdoor allocation. Using the sample group from this study, which is representative of the population of individually metered single family customers, shows that this would be an effective and reasonable conservation step. Figure ES 4 shows the distribution of customers into the five budget tiers based on their annual water use. This shows that 10% of the accounts would fall into the top two tiers using this approach to budget setting. This is the recommended approach.

The adoption of the recommended water budget approach has the potential to reduce the multi-family water use significantly. There are 28% of the customers that exceed the budgets derived from this system. If their use was reduced to the budget levels the average annual use of the group would drop from 80 ccf to 71 ccf. This represents a reduction of 9 ccf or a 11% reduction in overall multi-family water use. If this percent

reduction were achieved for the entire multi-family sector the potential savings would be approximately 913 acre feet per year of treated water demand.

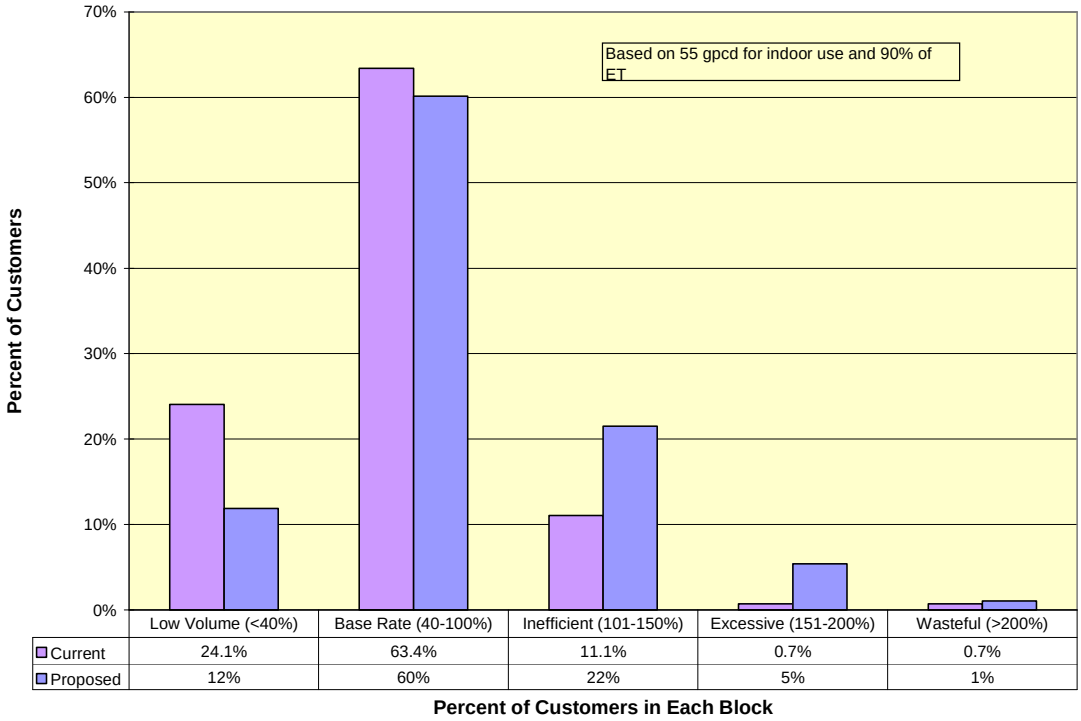


Figure ES 4: Distribution of customers among tiers for proposed budget approach

INTRODUCTION

As of the date of this report there a total of 48,080 multi-family units served by approximately 28,000 multi-family accounts in the IRWD system. These include both apartments and condominiums (condos). There were a total of 1667 master-metered and 26,357 individually metered accounts . The number of units served by the master metered accounts is tracked by the District for wastewater billing, which makes it possible to determine the total number of units in the system.

A total of 2,706 million gallons (8307 acre feet)[1] of water were delivered to all multi-family units during 2006, which is an average delivery of 75.2 ccf/unit (56.3 kgal/unit). This represented approximately 10% of the total metered deliveries in 2006 by the District[2].

The IRWD currently employs a water budget rate structure, outlined in Table 1, that allocates water for each customer based on the sum of their indoor and outdoor uses. Multi-family indoor allocations use a default of 3 residents per unit for attached single family (e.g. condos) and 2 residents/unit for apartments x 75 gpd/resident. Outdoor allocations are based on the landscape area served by the meter, the ET and 1.25 times the lot specific crop coefficient, which is currently set at 0.8 for turf.

Table 1: Base allocation formula

Account Type	Base Allocation number of Residents	Landscape Area (LA)	Base Allocation Indoor	Base Allocation Outdoor	Total Allocation
Residential Detached	4	1300 sq. ft (0.03 acres)	# Residents x 75 gpd	ET x Kc x 1.25 x LA	(Indoor + Outdoor) x # days in bill service period
Residential Attached*	3	435 sq. ft	# Residents x 75 gpd	ET x Kc x 1.25 x LA	(Indoor + Outdoor) x # days in bill service period
Apartments*	2	N/A	# Residents x 75 gpd		Indoor x # days in bill service period

*For master-metered apartments and condominiums, the base allocation is multiplied by the number of dwelling units.

The procedure for setting outdoor allocations is well documented and objective. IRWD adopted water-budget based rated in 1991, and is in the process of conducting a review of the allocations and basis for establishment. These budgets must be based on parameters that are easily determined and have a good correlation with the anticipated water use by the customer. In an effort to establish a procedure for establishing fair indoor water budgets for its multi-family account the Irvine Ranch Water District contracted with Aquacraft, Inc to perform an analysis of the water use patterns of apartment and condominium customers.

[1] 1 million gallons (MG)= 3.07 acre feet (AF) = 1337 CCF
[2] The total metered deliveries by IRWD in 2006 were 79,657 AF, per IRWD staff

IRWD MULTI-FAMILY BILLING DATA

The goal of this study was to examine the current indoor use patterns of the multi-family group with respect to the parameters available for setting budgets obtained from both billing data and customer surveys. Information was also desired on the level of efficiency of use by multi-family customers and the potential for savings in this group. In order to assess multi-family water use trends, information was generated on several aspects of the indoor water use per unit:

1. The mean annual use
2. The median annual use
3. The maximum and minimum monthly use for seasonal use estimation
4. The mean and median monthly use
5. The 90th through 10th percentile annual water use

Most of the billing data for the multi-family groups represents indoor use, but there are a significant number of condo accounts with irrigated landscape. Consequently, the water use from the billing data can not be considered representative of solely indoor use.

Grouping of Multi-family Accounts

The multi-family accounts in the IRWD service area are grouped in the billing data in several ways. Having the ability to group the customers allowed the water use statistics to be determined both as a group and for specific sub-sets. Both the aggregate water use and the statistics on how water use varies across distinctions in residential characteristics was of interest in the study. Table 2 indicates parameters from the billing database that are internal to IRWD.

Table 2: Data associated with each account

Database field	Useful values
Account sequence number	Surveys are organized by this unique identifier, but unless indicated otherwise account sequence is not present in analysis.
Billing section and UWT number	Only billing sections “apartment” and “condominium” are present.
Street address, city and "village" subdivision name	All accounts are considered, regardless of this field. Unless indicated otherwise it is not present in analysis.
Date service established	Dates aggregated into years, with 1995 chosen to test for effects of the Energy Policy act of 1992. (This assumes that the date that service was established is a good estimate of the date of construction for the unit.)
Individual units	Number of units is used as a weight for master-metered accounts. Individually metered accounts are indicated by 0, or less-often by 1.

IRWD established three useful factors associated with grouping accounts: whether the units are apartments or condos, built before or after 1995 (used as a kick-in date for the Energy Policy act of 1992), or whether the units are master or individually metered. Table 3 summarizes the number of accounts and dwelling units within these groups. The individually metered units represent 94% of all multi-family accounts and 55% of all multi-family units. Because they represent the majority of multi-family customers, and they are directly accessible for mail surveys, the decision was made to focus on the individually metered accounts for this analysis.

Table 3: Eight groups of multi-family accounts evident from IRWD billing data

Section	Year	Metering type	Total Accounts	Total Units	Mean Annual CCF
Apartment	Pre 95	Master metered	309	5375	84.2
Apartment	Post 95	Master metered	772	11779	60.9
Apartment	Pre 95	Individually Metered	4657	4657	73.2
Apartment	Post 95	Individually Metered	3	3	85.3
Condo	Pre 95	Master metered	324	3102	89.2
Condo	Post 95	Master metered	262	1377	106.1
Condo	Pre 95	Individually Metered	16043	16043	88.9
Condo	Post 95	Individually Metered	5654	5654	71.9

Year Established

Figure 1 shows year-to-year trends in the number of accounts and number of units (respectively) established in these groups.

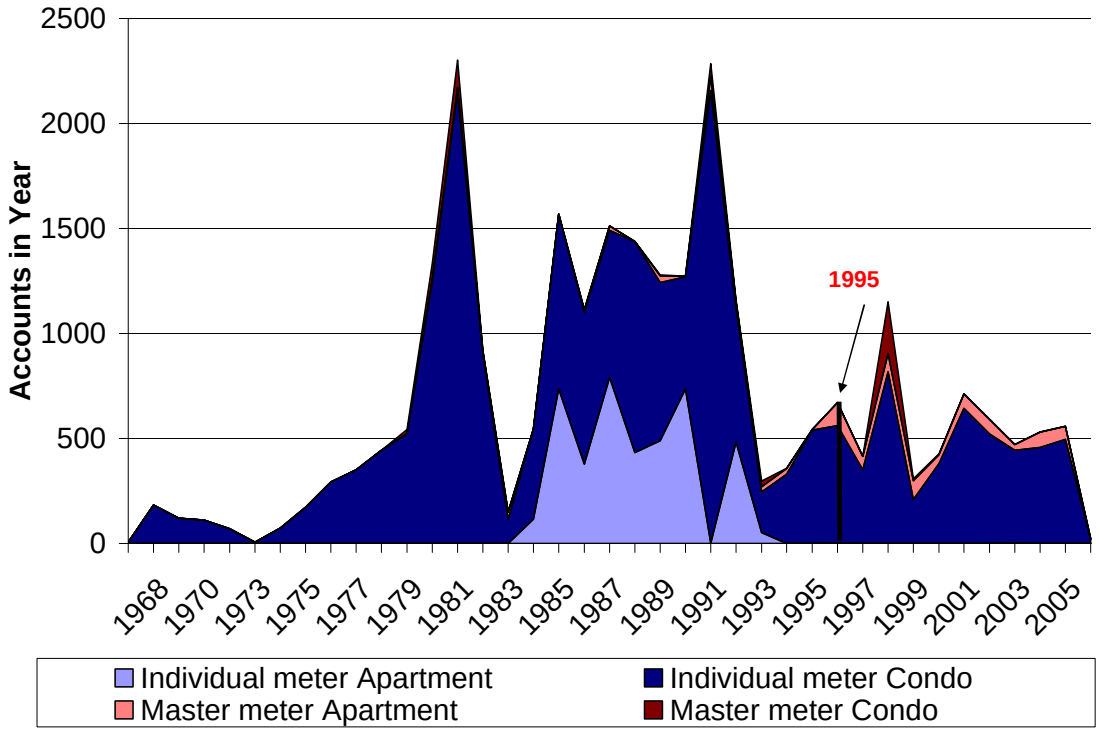


Figure 1: Accounts Established per year

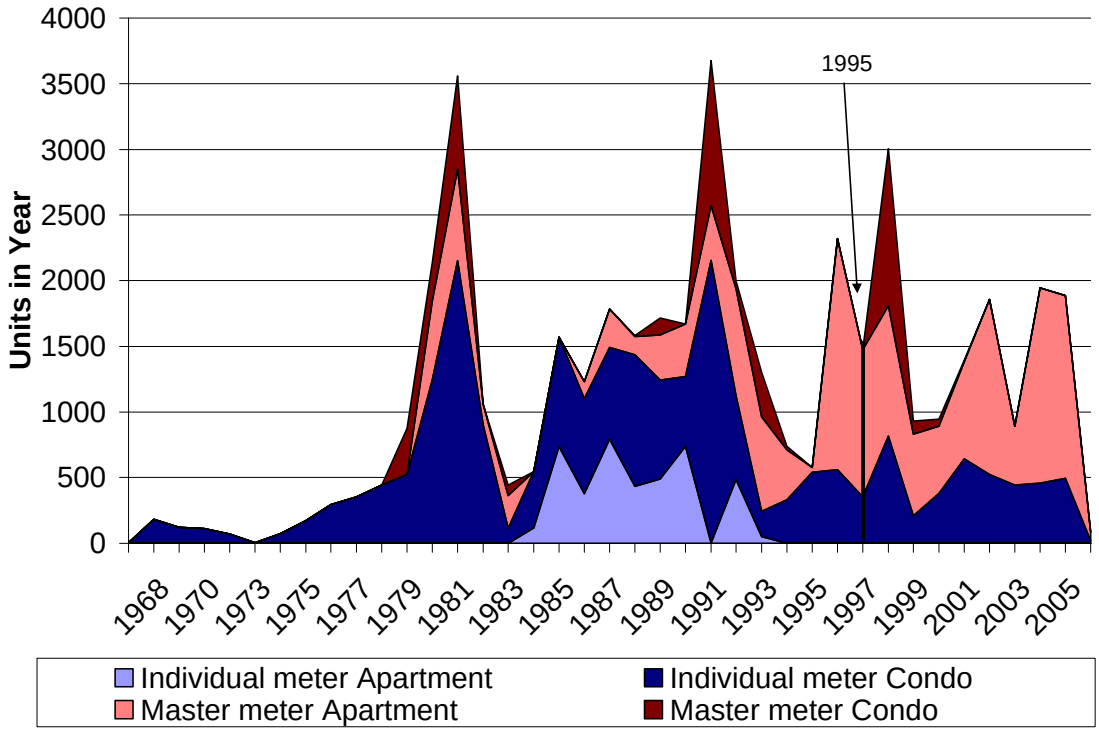


Figure 2: Units established per year

Volumetric Data

Along with characteristics used for grouping, the database provided by IRWD contains monthly water consumption in hundreds of cubic feet (CCF) for 2006. Having this information allowed separate water use statistics to be determined for each group of customers shown above. Comparisons of water use among individually metered accounts were made using both the means and confidence intervals in order to determine statistical significance of differences observed in the average water use. For master-metered accounts individual statistics are replaced with average use per unit for the entire property. This lack of precision in the master metered accounts is the main reason for using the individually metered accounts for the analyses.

Volumetric Units

Several units of volume have been used in this report. For large volumes of water units of million gallons or acre feet have been used. For typical account consumption values of hundreds of cubic feet (CCF) and thousands of gallons (Kgal) have been used. To assist with making conversions among units a set of conversion multipliers are provided in Table 4.

Table 4: Conversion multipliers

	GAL	CF	CCF	KGAL	AF	MG
GAL	1	0.1337	1.337 x 10-3	1.0 x 10-3	3.069 x 10-6	1.0 x 10-6
CF	7.48	1	0.01	7.48 x 10-3	2.296 x 10-5	7.48 x 10-6
CCF	748	100	1	0.748	2.296 x 10-3	7.48 x 10-4
KGAL	1000	133.7	1.337	1	3.069 x 10-3	1.00 x 10-3
AF	325,851	43,560	435.6	325.852	1	0.326
MG	1,000,000	13,370	133.7	1000	3.069	1

Note: multiply number of units in column 1 by the number in the body of the table to convert to units shown in row 1.

ANNUAL WATER USE PATTERNS

Copies of the billing data for the multi-family accounts provided by IRWD were assembled into a database in order to perform the statistical analyses required for the billing analysis portion of the study.

According to the billing data provided by the District, there were a total of 48,080 multi-family households served by the system in 2006. Of these, 21,723 were served by master meters, and 26,357 were individually metered. Figure 3 shows the total number of units contained in each of the 8 multi-family groups. This figure shows that the three major groups of individually metered multi-family customers in the system are: individually metered apartments built before 1995, individually metered condos built before 1995 and individually metered condos built after 1995. Together, these three groups account for 55% of all of the multi-family households served by the system.

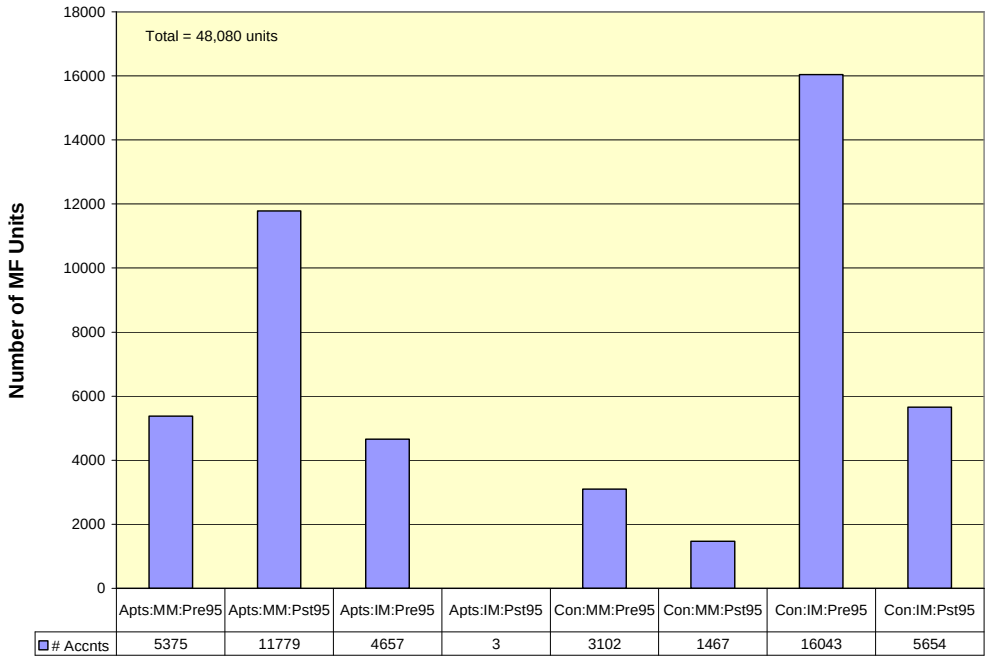


Figure 3: Number of multi-family units served by group (2006)

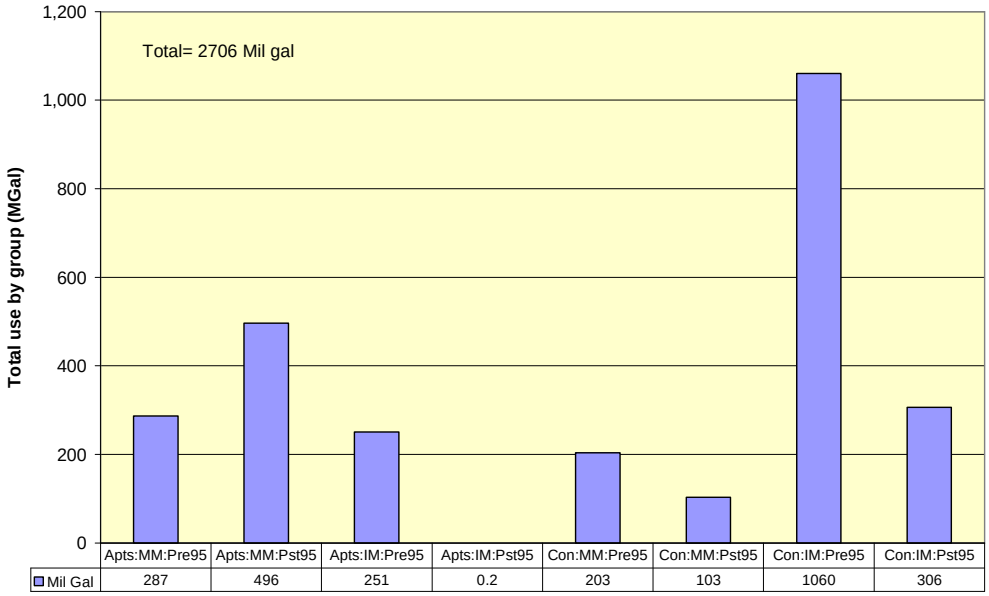


Figure 4: Total water use (MG) by multi family groups (2006)

The total annual deliveries of water to the multi-family customers equaled 2706 million gallons (8307 af) of water in 2006, and the pattern of water use closely mirrored the number of accounts, as shown in Figure 4. The individually metered units comprise 60% of the water use for the multi-family group.

Table 5 shows the mean and median annual indoor water use for each customer group in 2006 in CCF. The 95% confidence interval and number of accounts in each group is shown as well. Remember that the water use for the master metered accounts represents average use for all units in each building. Figure 5 and Figure 6 show the mean and medians in graphic form.

Table 5: Annual indoor water use statistics for multi-family customers (CCF)

	Average Annual Use (ccf)				
	Mean	Median	Stdev	Units	CI 95%
Apartments:MM:Pre 95	84.6	69.2	63.58	5375	1.70
Apartments:MM:Post 95	61.6	57.5	19.42	11779	0.35
Apartments:IM:Pre 95	71.9	64.0	45.49	4657	1.31
Apartments:IM:Post 95	74.7	74.0	40.00	3	45.27
Condos:MM:Pre 95	89.3	74.7	50.12	3102	1.76
Condos:MM:Post 95	102.3	97.3	41.35	1467	2.12
Condos:IM:Pre 95	88.4	79.0	48.40	16043	0.75
Condos:IM:Post 95	72.4	64.0	40.15	5654	1.05
Total				48080	

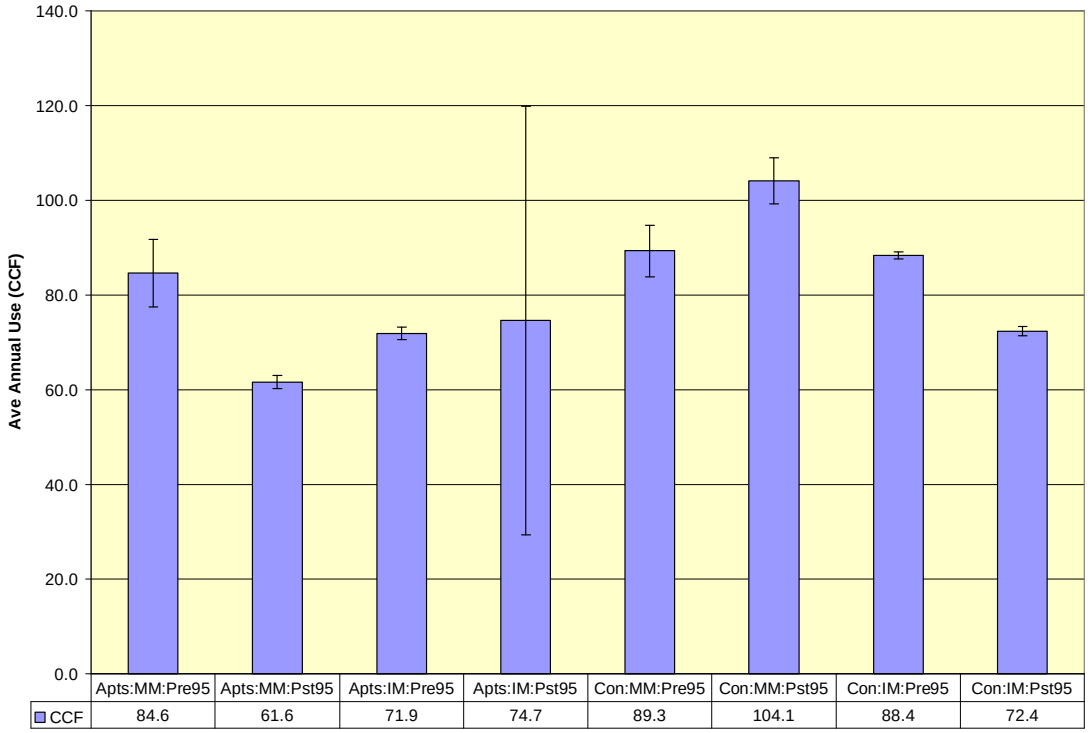


Figure 5: Average annual water use for multi-family customers, CCF

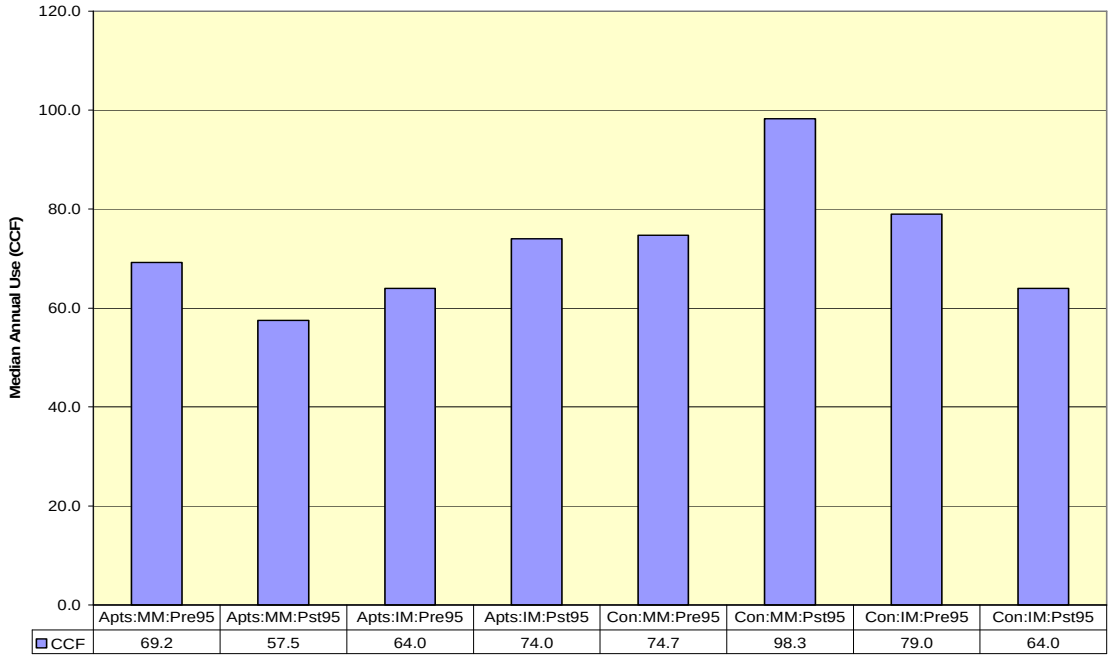


Figure 6: Median annual use (CCF)

Comparison with National Submetering Study

In 2004 Aquacraft conducted a study of water use in multi-family units across the United States. One main objective of that study was to determine whether there was a difference between indoor use in master-metered units and individually metered (and billed) units. Figure 7 shows a comparison of the master-metered units in Irvine to those from the national sample of master-metered multi-family dwellings. All of the Irvine groups (except for the apartments built after 1995) showed significantly higher indoor water use than the national sample.

Figure 8 compares the indoor water use in the individually metered units in Irvine to those from the national sample. All of the individually metered multi-family units in Irvine show indoor water use above that of the national sample. The difference in the average use for the condos and pre-1995 apartments is significant, while that for the post-1995 apartments is not statistically significant due to the small number in that group.

There are several reasons why water use in the IRWD multi-family properties is greater than that observed in the national sample. Many of the IRWD condos use water for landscape irrigation, which was not the case in the national study. The national sample tended to contain more apartments than condos, and this would tend to bias the national study towards lower water use found in apartments. There are also many significant socio-economic differences between the IRWD and the National group.

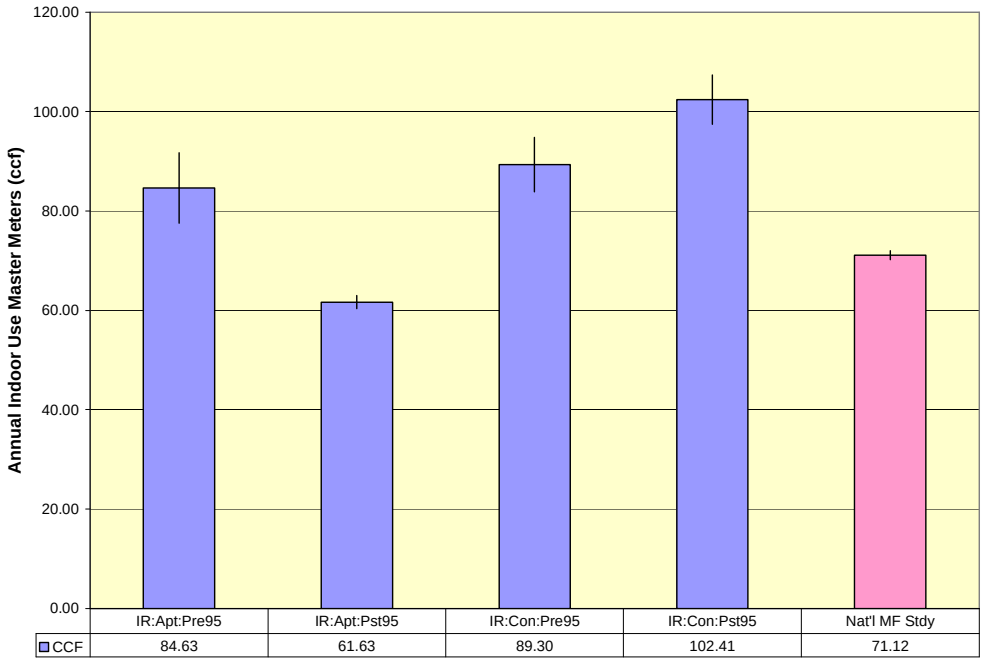


Figure 7: Comparison of average annual per-unit (master-metered only)

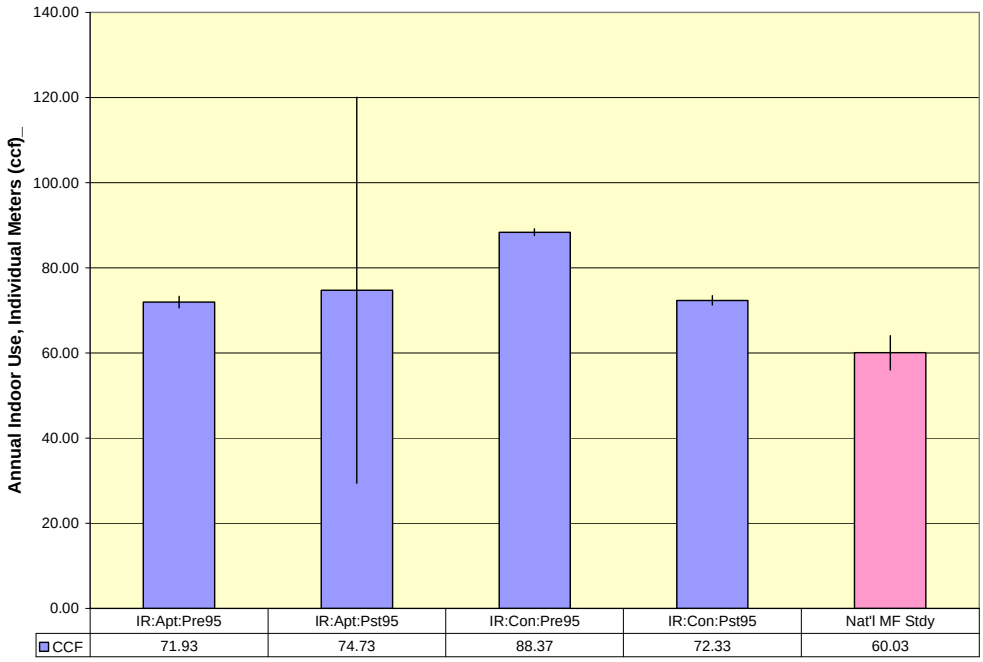


Figure 8: Comparison of individually metered units

Ranking and Percentiles

Table 6 shows the percentiles of annual indoor water use for the seven groups with enough members to allow percentiles to be calculated. It is not clear why, but very few individually metered apartments have been built in the District after 1995. Only 3 of these appear in the database, which makes it impossible to draw any statistically reliable conclusions from their billing information. The seven other groups show clear patterns.

In this context the percentiles represent the percentage of all customers in the group who use less than the amount of water indicated in the table. For example, 90% of all of the master-metered apartments built before 1995 use less than 140 CCF per year for indoor purposes, as shown in row 1 column 1 of the body of the table. At the other extreme for this group, only 10% of the master-metered apartments built prior to 1995 use less than 44 ccf of water. The variability in the water use for each percentile also decreases in the smaller percentiles, i.e. there is a lot more variability in the 90 percentile water use than in the 10 percentile use. In this table the 50 percentile values represent the middle, or median, values.

Table 6: Percentiles of annual indoor water use for MF Categories (CCF)

MF Categories	Percentiles of Annual Use (CCF)								
	90	80	70	60	50	40	30	20	10
Apts:MM:Pre 95	140	95	82	75	70	63	57	51	44
Apts:MM:Post 95	87	74	67	63	57	53	51	47	43
Apts:IM:Pre 95	122	98	83	74	64	56	49	41	31
Cond:MM:Pre 95	148	120	96	84	75	67	60	53	47
Cond:MM:Pst95	163	136	119	108	99	87	80	70	60
Cond:IM:Pre 95	151	123	106	91	79	70	59	49	36
Cond:IM:Pst95	124	102	86	74	64	56	48	41	31

When the percentile values are plotted on a graph, as shown in Figure 9 additional patterns can be identified. In this graph the categories have been plotted according to the rank of their 50^{th} percentile values. The top three water using categories are all condos: the two master-metered groups and the individually metered group built before 1995. The individually metered condos built after 1995, however, are the lowest of the condos in each percentile. These condos are very similar to the individually metered apartments built prior to 1995. The group that is consistently the lowest in indoor use is the apartments built after 1995.

The fact that the biggest water users of the multi-family group are the master-metered condos built after 1995, while the individually metered condos built during the same period are among the lowest water users, could be an indication of the impacts of sub-metering on water use if all other factors such as size and number of residents are similar between the groups. It could also reflect common area water usage in the master metered systems. There is nowhere near so striking a difference between the master-metered and individually metered apartments built prior to 1995. These two lines are relatively close to each other on the graph. Note that the three main categories have been highlighted for emphasis.

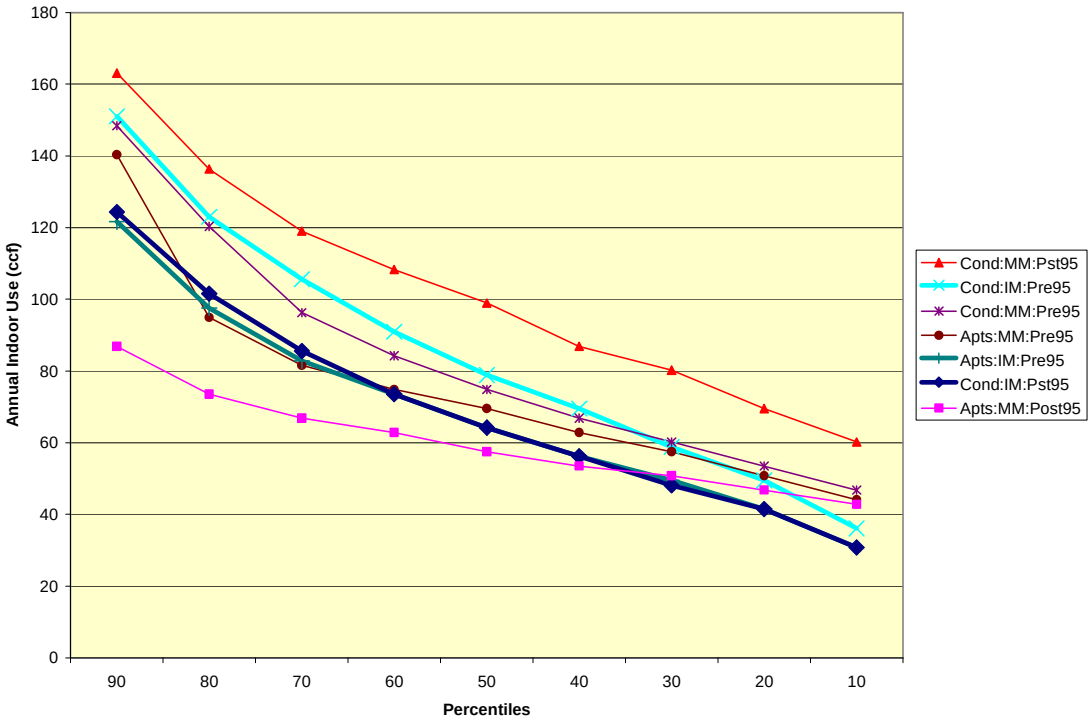


Figure 9: Percentiles of annual water use (CCF)

Distributions of Annual Use

The annual use data were plotted as histograms so that the types of distributions for the data could be examined for both the entire group and for the major categories. The shape of the distributions can be useful for understanding the underlying probabilities governing annual water use.

Distributions for Multi-family Customers

Figure 10 shows the relative frequencies for the annual water use per unit for all of the multi-family customer categories in the billing database with the exception of the individually metered apartments built after 1995, which contained only three records. In general, all of the distributions follow a similar pattern, which is that of a log normal distribution. These distributions show the range of actual values for the annual per unit water use for the seven types of multi-family units in the billing data base, and for the combined results for all multi-family units. These distributions highlight the uncertainty in predictions of water use by the multi-family customers.

Distributions for the Major Customer Categories

In order to further explore the annual water use in the three major multi-family categories we have prepared histograms of their annual use (CCF) and shown these in Figure 11 through Figure 13. All of these are similar in that the 50 to 75 CCF bin contains the largest percentage of the customers (25% to 30%). The difference arises in how much the data spread out in the other bins. The pre 95 apartments and the post 95 condos are

virtually identical, which can also be seen in Figure 9. The pre 95 condos contain the biggest spread.

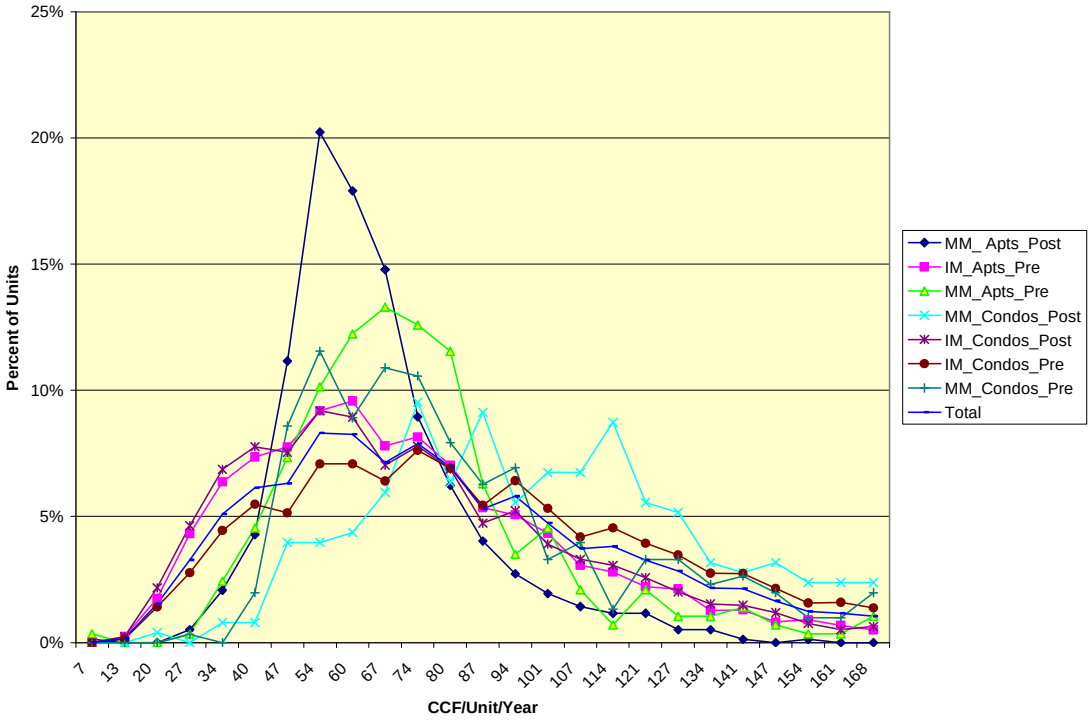


Figure 10: Distributions of annual use per unit for multi-family categories

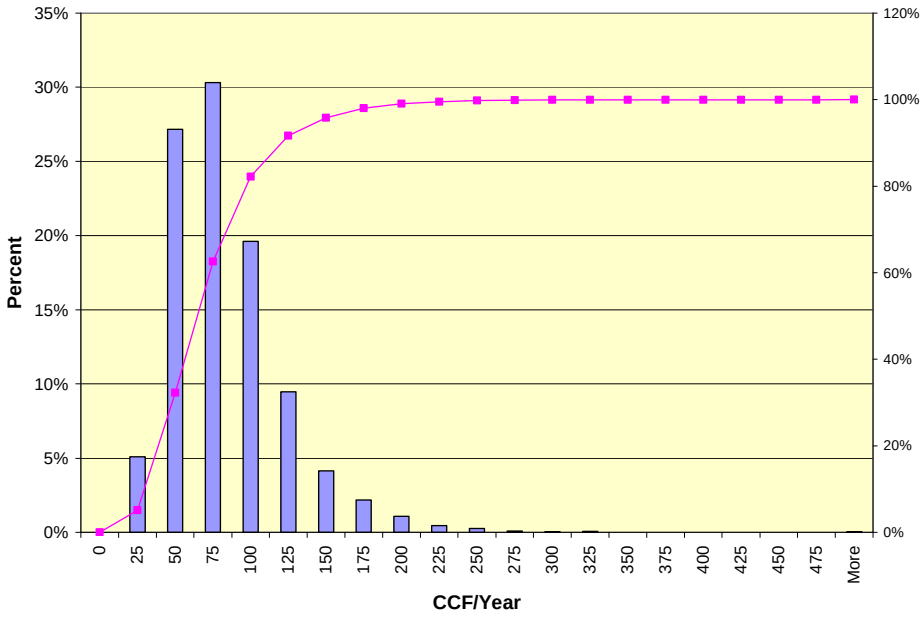


Figure 11: Histogram of annual use by individually metered apartments (Pre 95)

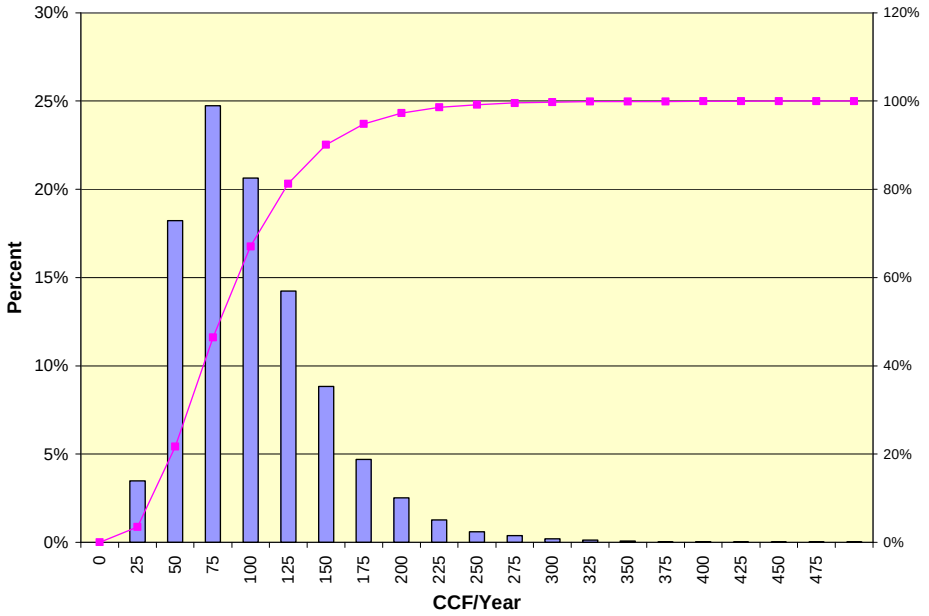


Figure 12: Histogram of annual water use by individually metered condos (Pre 95)

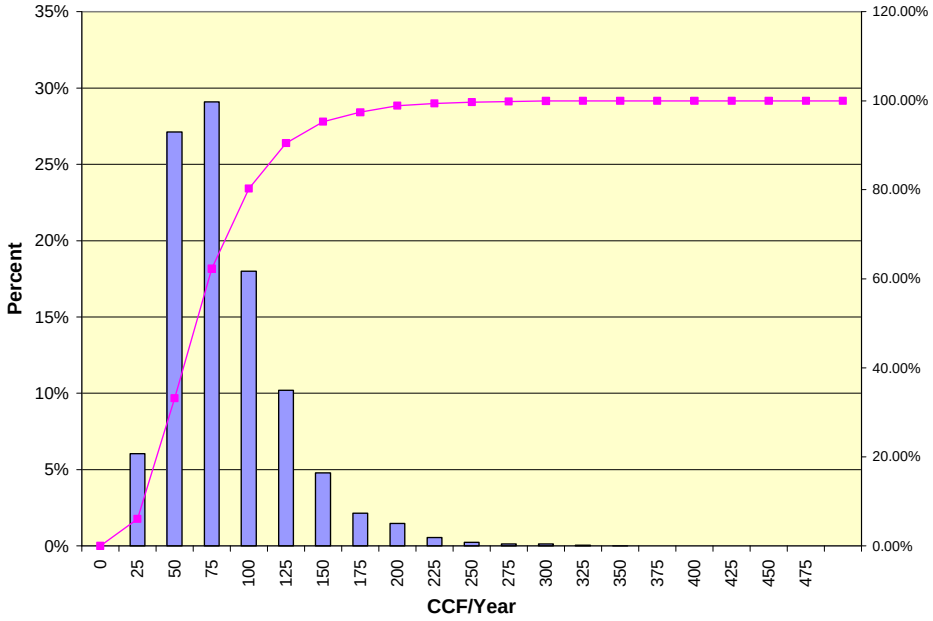


Figure 13: Histogram of annual water use in individually metered condos (Post 95)

Monthly Use Patterns

Seasonal data were calculated for each group of multi-family properties using the available billing data. The winter use was calculated as the average of the median use for the group from December through February. The summer use was calculated as the average of the median use during June through August. The use of the median values

reduced the variability caused by a few outliers and increases the validity of the results. The ratio of the summer to winter water use provides a direct measure of the seasonality of water use in the group. These data are provided in Table 7. They are also provided graphically in Figure 14 through Figure 16.

In general, the water use for the groups is not very seasonal at all. There are only three groups where the ratio of summer to winter use is significantly different from 1.0. The first is the individually metered apartments built after 1995, but there are only three of these, so the results are not reliable for drawing conclusions. The other two groups are both of the master-metered condos. It is very possible that there are hose bibs in the condos or near them that are used for irrigation of small private areas by the owners which, if true, would explain the higher summer use. The master meters may also be delivering water for common area usage. The summer water use for the rest of the groups was effectively the same in the summer as it was in the winter.

Table 7: Seasonal water use patterns in multi-family groups

Category	Ave Winter Month (CCF)	Ave Summer Month (CCF)	Ratio S/W
Apartments:MM:Pre 95	5.66	5.57	0.98
Apartments:MM:Post 95	4.73	4.78	1.01
Apartments:IM:Pre 95	5.00	5.00	1.00
Apartments:IM:Post 95 [a]	5.33	8.67	1.63
Condos:MM:Pre 95	5.81	6.51	1.12
Condos:MM:Post 95	7.16	9.02	1.26
Condos:IM:Pre 95	6.33	6.67	1.05
Condos:IM:Post 95	5.00	5.00	1.00

[a] There are only 3 of these so these data are not reliable

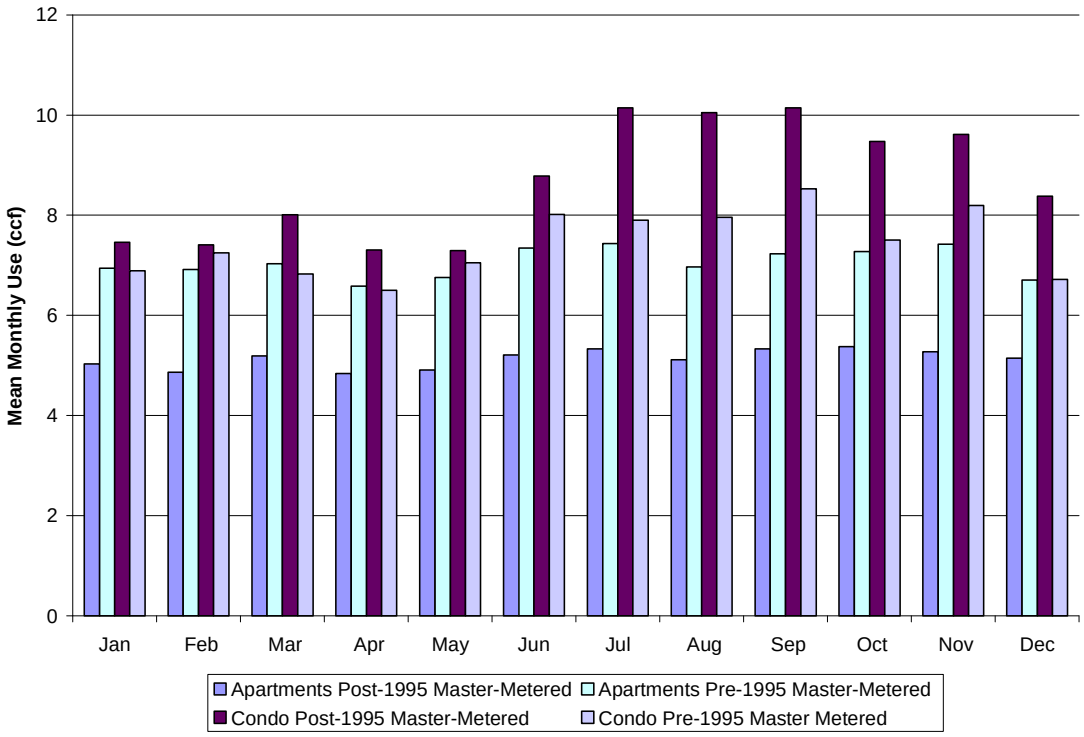


Figure 14: Monthly use in master-metered units

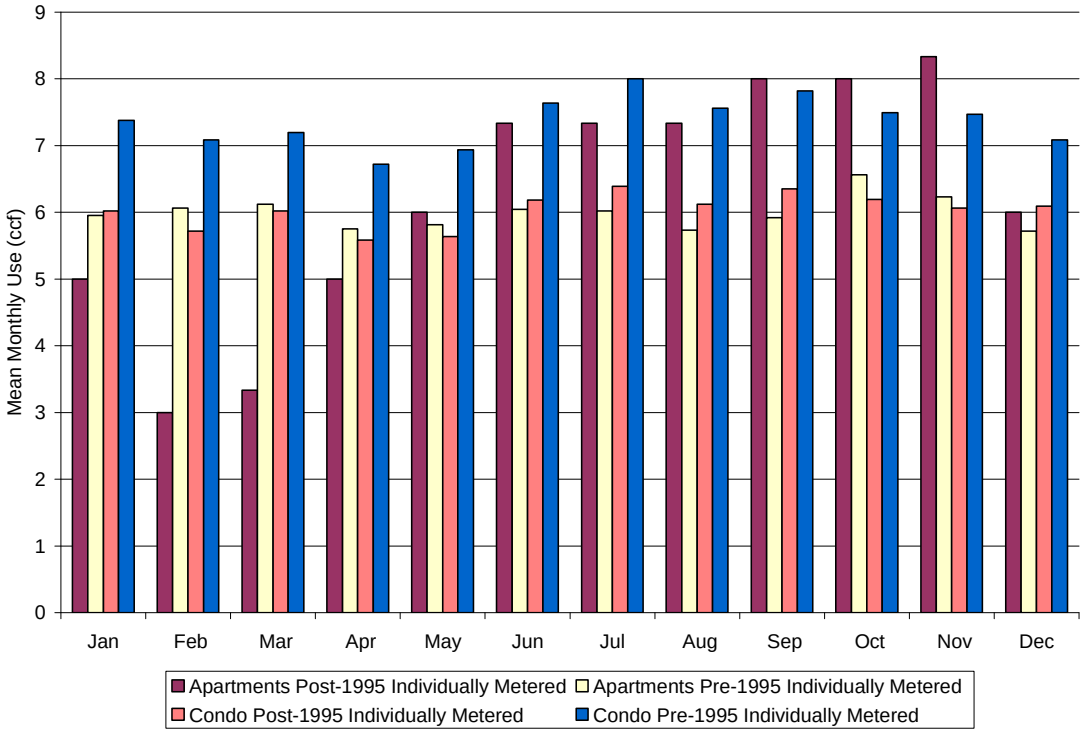


Figure 15: Monthly use in individually metered units

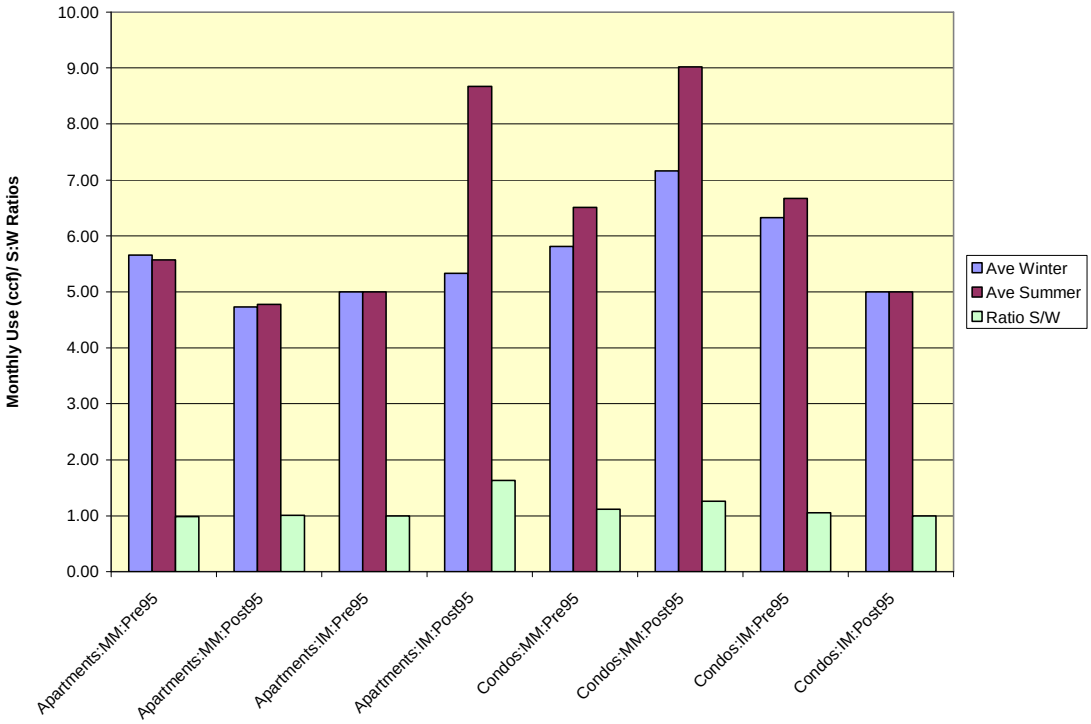


Figure 16: Seasonal use in multi-family categories (CCF)

CUSTOMER SURVEY

Surveys were sent to samples of the individually metered customers in order to provide information needed for modeling their demands. A total of 1500 surveys were sent to apartment residents and 3000 surveys were sent to the larger group of condo residents: 1500 to the pre-1995 group and 1500 to the post-1995 group. The response rate was less than hoped for, but adequate for statistical purposes. Table 8 shows all responses over a 6-week timeframe. All of these responses were entered into the analysis database:

Table 8: Response rate

	Surveys mailed	Responses	Response rate
Apartments (pre-1995)	1500	114	7.6%
Condominiums (pre and post-1995)	3000	551	18.4%
Total		665	

In addition to fields for handwritten responses, the coded fields on the survey are associated within the database with the questions listed in
Table 9. A complete analysis of the surveys is provided in Appendix B for the survey instrument and Appendix C for response rate details.

The problem with the small response rate will become evident in the discussion of the modeling. In brief, the problem occurred while developing models for sub-sets of the data. There was a natural division in the data among apartments and condos; apartments with clothes washers and apartments without clothes washers; condos with irrigation, and condos without irrigation, but as the data were divided the number of units in each category dropped, and as the numbers drop so does the ability to obtain useful statistical information. This left the model results somewhat thin for some groups and not as conclusive as would have been possible with larger sets to work with.

Table 9: Survey questions

Question		Answer indicates
1	a	Number of toilets (i.e. number of bathrooms)
	b	Number of bathtubs with shower
	c	Number of bathtubs without shower
	d	Number of showers without bathtub
	e	Number of whirlpool bathtubs
	f	Number of bathroom sinks
	g	Number of kitchen faucets
	h	Number of indoor utility sinks
	i	Number of hosebibs
	j	Number of hot tubs
2	a	Potted plants
	b	Irrigation of lawn or garden area
3		Clotheswasher in unit
	n	(If no clotheswasher) Where do you commonly do your wash?
	y	(If clotheswasher) Top-loader or front-loader
	y Brand	Clotheswasher brand, model and year
	y Model	
	y Year	
4 T1 – T3	Year	Year, brand and gpf of three toilets
	Brand	
	gpf	
5 S1 – S3	gpm	Gpm and brand of three showerheads
	Brand	
	Multi	Whether shower has multiple showerheads
6	A	Number of adults including yourself (Age 18+)
	T	Number of teenagers (age 13-17)
	O	Number of older children (age 6-12)
	Y	Number of younger children (age 3-5)
	I	Number of infants or toddlers (under age 3)
7		How many bedrooms are in your residence?
8		How many square feet are in your residence?
9		Do you rent or own your residence?
	Rent	How much is your monthly rent?
10		Which type of residence? (out of Apartment, Condo, Town-home, Duplex, Single Family Home)
11		Residence is part of a senior or retirement community

Processing certain answers to differentiate useful non-numeric responses apart from various synonyms for "don't know" is sometimes called "cleaning up" the data. In further analysis, the processing key is quite simple: unless otherwise indicated, non-numeric responses are marked as NaN, and non-responses are NA. It's important to note that the survey database expects whole numbers for many of these fields. This impacts very rare cases; for example a 2.5-bedroom apartment is entered as a 2-bedroom, or a survey indicating a range of residents from 2-4 likely fits the same patterns as 3 residents. More detailed survey questions such as questions 4 and 5 tended to have much lower useful response rates, even when the rest of the survey was filled out.

Certain other fields are inferred from the responses above:

- Number of bathrooms is (for the purposes of water use) simply the number of toilets.
- Number of residents is simply the question 6 total.
- Yes/No values for children, hot tubs, whirlpool bathtubs, and multi-showerheads.

Comparison of Survey Respondents to Population

Even though the number of respondents was small, there did appear to be a good correlation between their water use patterns and those of the populations from which they were drawn as shown by the following figures. The comparison between the survey respondents and the population is shown in Figure 17 and Figure 18.

Histograms for 2006 water consumption for the three study groups show strong similarity between survey respondents and their populations. Table 10 includes the vital statistics while more exhaustive statistics are prepared as Appendices A1 – A3. It is important to note that one outlier was removed from this data set and subsequent analysis because its water use was so far outside the envelope of responses to make it suspect.

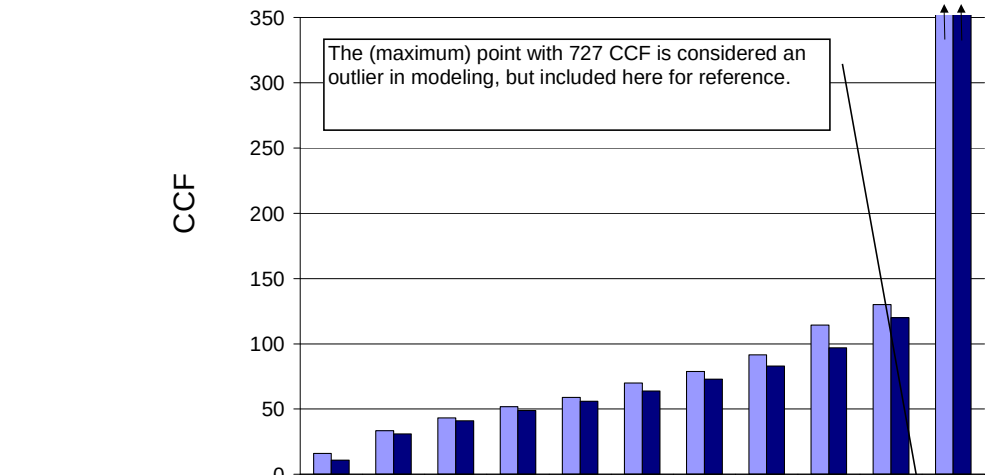
The comparison of the survey respondents to the population is important because to the degree that the 665 respondents are representative of the population it is possible to generalize from the results of this study to the population. This means that the relationships found for water use in the sample should also be useful in predicting water use for all of the other multi-family customers in the system, and that rules for establishing water budgets would also be generally applicable.

The information presented so far show that aside from a slight difference in the mean water use for some of the groups the overall water use patterns of the sample matches that of the population quite closely, and we would expect the results from the sample to be applicable to the population.

Descriptive statistics comparing these two groups imply two broad observations:

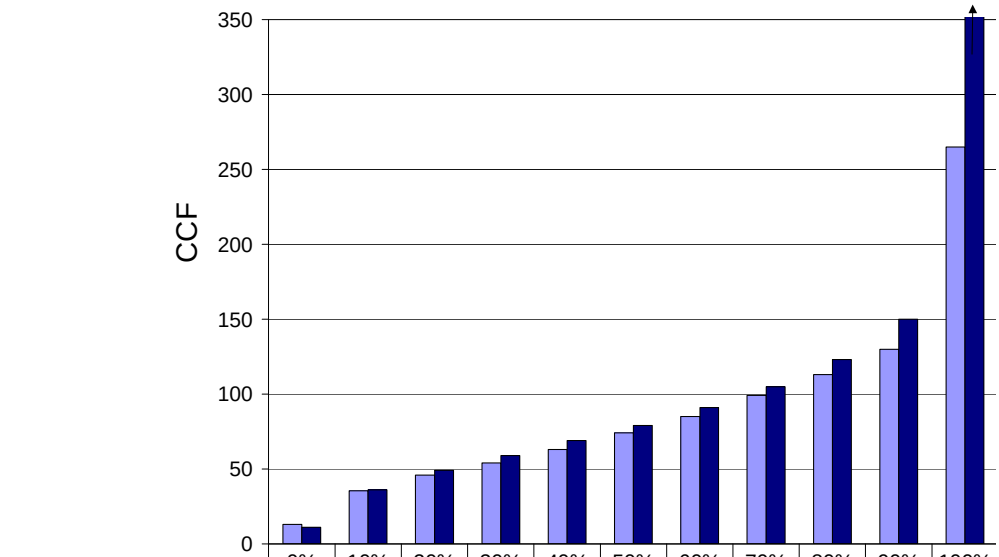
- The survey is representative of most IRWD individually-metered accounts: 2006 use patterns between survey respondents and the population are practically identical for all but the very top accounts.

- The survey is not necessarily representative of the extreme cases having inexplicable use patterns. Among the population, these cases correspond to unreasonable amount of indoor use[3].
-



	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Pre-95 Apartment responses	16	34	43	52	59	70	79	92	114	130	727
Pre-95 Apartment Population	11	31	41	49	56	64	73	83	97	120	1674

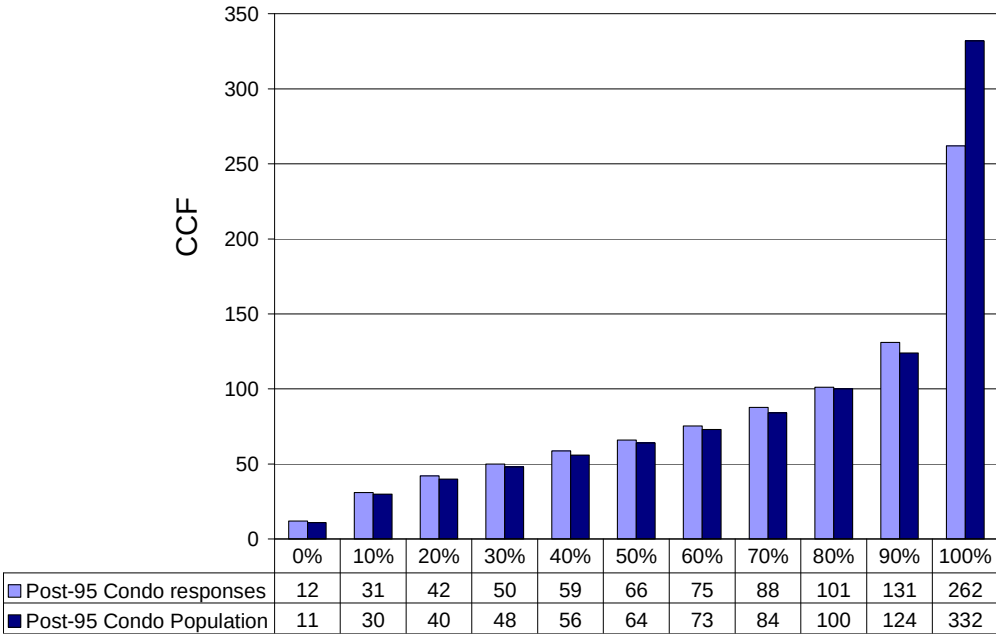
Figure 17: Pre-1995 Apartment 2006 CCF



	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Pre-95 Condo responses	13	36	46	54	63	74	85	99	113	130	265
Pre-95 Condo Population	11	36	49	59	69	79	91	105	123	150	861

Figure 18: Pre-1995 Condominium 2006 CCF

[3] In this case, these accounts could be master-metered buildings that happen to be miscategorized as individually-metered units.



	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Post-95 Condo responses	12	31	42	50	59	66	75	88	101	131	262
Post-95 Condo Population	11	30	40	48	56	64	73	84	100	124	332

Figure 19: 1995-on Condominium 2006 CCF

Comparing distributions above gave a fairly clear indication how the survey adheres to the same central tendency as the population. Median values are quite useful for this in a large distribution that happens to include a few extreme values. Alternatively comparing mean values from the survey and the population showed a slight bias in the sample (see Table 11 below).

Table 10: Annual median water use of survey respondents versus population (ccf)

hcf	Pre-95 Apartment responses [a]	Pre-95 Condo responses	Post-95 Condo responses
min	16	13	12
median	70	74	66
max	203	265	262
N	**114 accounts**	**336 accounts**	**215 accounts**

[a] Excluding 727 CCF outlier. See Appendix D1 for analysis of extreme values.

hcf	Pre-95 Apartment Population	Pre-95 Condo Population	Post-95 Condo Population
min	11	11	11
median	64	79	64
max	1674	861	332
N	**4657 accounts**	**16043 accounts**	**5654 accounts**

Table 11: Mean and standard error of survey respondents versus population

CCF	Pre-95 Apartment Respondents	Pre-95 Condo Respondents	Post-95 Condo Respondents	All Individually Metered Respondents
N	114	336	215	665
Mean	77.1	81.2	74.5	78.3
StDev	39.1	43.0	40.8	41.7
StError	2.7	1.8	2.1	1.2
95% CB	**70.0 - 84.3**	**76.6 - 85.8**	**69.0 - 79.9**	**75.2 - 81.5**

CCF	Pre-95 Apartment Population	Pre-95 Condo Population	Post-95 Condo Population	All Individually Metered Population
N	4657	16043	5654	26354
Mean	71.9	88.4	72.4	82.0
StDev	45.5	48.4	40.2	46.9
StError	0.7	0.4	0.5	0.3
95% CB	**70.6 - 73.2**	**87.6 - 89.1**	**71.3 - 73.4**	**81.5 - 82.6**

We see that the mean for apartments is statistically slightly *higher* than its population. Pre-95 condominiums surveyed were statistically *lower* than the corresponding population group, while the post-95 condos are only slightly higher than their population. One likely explanation is that the number of survey respondents is small, and presence of a few outliers in each group influenced the means. This is supported by the distributions in Figure 17 through Figure 19. Again, refer to the treatment of extreme values appendix or the effect on these statistics.

Nominal Group Statistics

Interpreting the distribution of nominal responses can in fact draw some important basic distinctions between respondents. Table 12 shows descriptive groups of survey responses treating the characteristics number of bedrooms, billing section, and irrigation as nominal values.

With respect to budgeting, certain observations can be generalized to apply to the population:

- Condominium accounts almost certainly have a clothes washer.
- Apartments are very unlikely to irrigate
- There is a good balance in apartments with and without clothes washers: 30% to 40% of apartments have a clothes washer.
- Apartments tend to have more occupants than bedrooms while condos tend to have fewer occupants than bedrooms (See Figure 20).
- The data suggest that units with more than one bathroom tend to use more water than units with just one, but this is not statistically strong enough to be conclusive.

Table 12: Major groups of survey respondents

Bedrooms	Section	Irrigation	Percentage of respondents	Residents range	Resident Average	Bathrooms range	Mean	Percent with clotheswasher in unit	Mean 2006 kgal	Mean 2006 CCF
2	Condo	Not irrigating	23%	0 - 5	2.0	1 - 3	2.2	99%	44.5 +/- 3.5	58.7 +/- 4.7
3	Condo	Irrigating	23%	1 - 7	2.7	2 - 4	2.8	99%	72.6 +/- 5.3	95.8 +/- 7.1
2	Condo	Irrigating	15%	0 - 5	1.9	1 - 3	2.4	100%	55.5 +/- 5.7	73.3 +/- 7.6
3	Condo	Not irrigating	13%	1 - 7	2.9	1 - 4	2.7	96%	65.1 +/- 7.0	85.9 +/- 9.4
2	Apartment	Not irrigating	11%	1 - 6	2.6	1 - 3	2.0	36%	59.0 +/- 6.6	77.8 +/- 8.8
1	Condo	Not irrigating	3%	1 - 3	1.5	1 - 2	1.2	100%	39.1 +/- 9.7	51.6 +/- 12.9
1	Apartment	Not irrigating	3%	0 - 3	1.4	1 - 1	1.0	41%	40.1 +/- 8.1	52.9 +/- 10.9
4	Condo	Irrigating	2%	2 - 6	3.2	3 - 4	3.1	100%	74.5 +/- 19.1	98.3 +/- 25.5
3	Apartment	Not irrigating	2%	2 - 5	3.7	2 - 3	2.6	15%	111.7 +/- 72.6	147.3 +/- 97.0
Other [a]			4%	0 - 5	1.9		2.2	75%	59.3	78.3

[a] More obscure combinations of characteristics accounting for less than 1% of respondents are left uncategorized.

Relationship Between Bedrooms and Occupancy

Figure 20 shows the relationship between the number of bedrooms and the number of occupants for apartments and condos. This information is useful for budget setting when all that is known is the number of bedrooms in a given unit. These data show that apartments tend to have more occupants than bedrooms while condos tends to have fewer occupants than bedrooms.

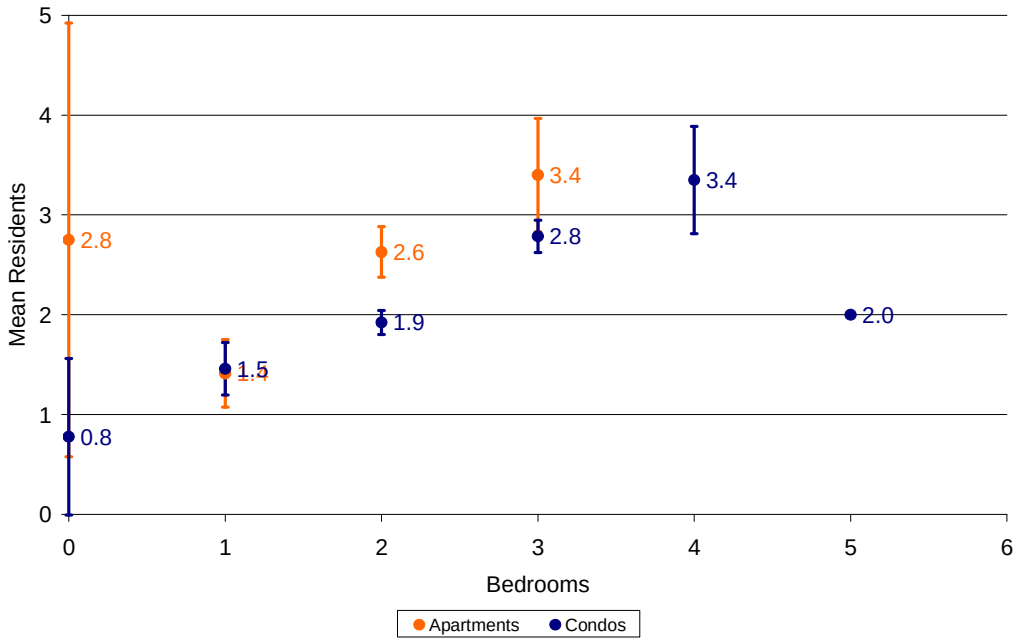


Figure 20: Mean Number Of Residents By Number Of Bedrooms

ANALYSIS OF FACTORS INFLUENCING WATER USE IN MULTI-FAMILY HOUSING UNITS

Having both water use data from the billing system and information on the accounts from the surveys allows us to look for relationships between annual water use in the multi-family customers and a range of independent variables describing their housing and demographics.

ANOVA

The previous sections indicate that the group of responses is indeed representative of the population, and certain distinctions like apartment/condo, irrigator/non-irrigator, clothes washer-no clothes washer, and pre/post-1995 *correlate with* observed water use in specific groups. Yet, other factors may be influential, and a familiar test for establishing confidence in a difference between means is the t-test. More generally, the t-test is extended to apply to multiple nominal responses[4] and this model is called analysis of variance, or ANOVA.

The statistical results from ANOVA can be interpreted as the effect of one nominal variable on differences in water use, irrespective of competing effects by others. For Boolean or categorical indicators (such as the Yes or No value for irrigation or clothes

[4] In this case, the number of bedrooms is nominal: ANOVA produces results suggesting whether annual usage by 2 bedroom housing is different than that of other numbers of bedrooms. Further modeling unrelated to ANOVA indicates the nature of that difference.

washers) the results are equivalent to the t-test. Prior to the task of drawing conclusions based on numeric (continuous) values (which is covered in the next section) this analysis will establish factors that are the foundation for groups in Table 12 being useful for modeling.

Non-numeric responses along with annual billed use (averaged from 2005 and 2006 data) were loaded into the statistical program, SPSS. Characteristics that are statistically significant will show an association with a difference in mean annual use, while non-influential characteristics will show greater than 5% confidence that the difference in means is due to chance. This confidence is conventionally called the p-statistic, but is reported as a decimal rather than a percentage. Perhaps the most familiar algorithm for this analysis, One-Way ANOVA, is used to produce the results in Table 13 and a p-statistic of 0.05 indicates the 95% confidence level.

Table 13: Results from one-way ANOVA

Apartment Responses	p-statistic	F-statistic [a]	Affirmatives
One bathroom or more than one	.000	22.586	22%
One or more children	.043	4.189	29%
2B (Irrigation)	.086	3.010	4%
3 (Clotheswasher in unit)	.145	2.160	34%
11 (Retirement community)	.171	1.896	3%
Hot tub	.217	1.550	2%
Village Name	.237	1.345	N/A
10 (Description of housing as condo or apartment)	.272	1.293	N/A
3N (If no clotheswasher in unit, clotheswasher on site)	.283	1.284	60%
2A (Potted plants)	.591	0.290	47%
Whirlpool	.820	0.199	2%
Multi-showerhead	.948	0.004	11%

Condo Responses	p-statistic	F-statistic	Affirmatives [b]
One or more children	.000	37.124	20% -35%
2B (Irrigation)	.000	28.450	45% - 55%
3N (If no clotheswasher in unit, clotheswasher on site)	.000	16.875	1% - 2%
One bathroom or more than one	.000	12.492	10.1% (pre1995) - 3.7% (post-1995)
Village Name	.000	2.583	N/A
3 (Clotheswasher in unit)	.001	10.220	98% - 100%
Whirlpool	.001	6.774	3% - 8%
10 (Description of housing as condo or apartment)	.008	2.207	N/A
Condo account established 1995 or later	.027	4.921	39%
Hot tub	.039	3.252	2 % - 4%
Multi-showerhead	.115	2.497	8% - 12%
2A (Potted plants)	.258	1.282	68% - 75%
11 (Retirement community)	.538	0.379	0% - 1%

[a] The Fisher test statistic is interpreted as a ratio of variances (kgal). ANOVA on binary values (yes/no or true/false) is effectively the same as the t-test since only two groups are compared.

[b] Two values indicated are for condos pre-1995 and 1995-on. See Appendix A1 for details.

ANOVA and methods like it are very sensitive to the number of samples distinguishing one group from another. It's true that the number of condo responses is significantly larger than the number of apartment responses, and for this reason ANOVA offers better performance for condos. Interpreting Table 13 based on the p-statistic, some expected and unexpected associations emerge as influential factors. The presence of children in the household among both apartment and condo accounts, and irrigation among condos are evidently influential. In these groups whirlpool bathtubs are related to higher water use while multi-showerhead showers are not.

Chi-square

For continuous variables, such as the number of persons per dwelling the Chi-square test is appropriate for determining statistical significance. The confidence in a measure being proportional to water use is the familiar R^2, which is derived by squaring the Pearson r-statistic shown in Table 14.

Table 14: Results From Pearson's Chi-Square Test

Factors for Apartment Accounts	Pearson r	R^2
Residents	0.49	0.24
1a (Number of toilets)	0.41	0.17
6a (Number of adults)	0.37	0.13
6o (Number of older children)	0.32	0.11
1f (Number of bathroom sinks)	0.26	0.07
1b (Number of bathtubs with showers)	0.26	0.07
7 (Number of bedrooms)	0.21	0.04
1d (Number of showers without bathtubs)	0.19	0.04
1j (Number of hot tubs)	-0.16	0.03
6y (Number of younger children)	0.10	0.01
Year account established	0.06	0.00
Account sequence	0.06	0.00
1e (Number of whirlpool bathtubs)	0.05	0.00
6t (Number of teenagers)	0.04	0.00
1i (Number of hosebibs)	-0.03	0.00
6i (Number of infants or toddlers)	0.02	0.00
1h (Number of utility sinks)	-0.02	0.00
8 (square footage, if answered)	-0.01	0.00
1c (Number of bathtubs without a shower)	-0.01	0.00
1g (Number of kitchen faucets)	0.00	0.00

Factors for Condominium Accounts	Pearson r	R^2
Residents	0.51	0.26
6a (Number of adults)	0.46	0.21
7 (Number of bedrooms)	0.30	0.09
6t (Number of teenagers)	0.25	0.06
6o (Number of older children)	0.24	0.06
1a (Number of toilets, ie bathrooms)	0.22	0.05
8 (square footage, if answered)	0.19	0.04
Account sequence	-0.18	0.03

Year account established	-0.17	0.03
1e (Number of whirlpool bathtubs)	0.14	0.02
1i (Number of hosebibs)	0.13	0.02
1h (Number of utility sinks)	0.12	0.01
6y (Number of younger children)	0.11	0.01
1f (Number of bathroom sinks)	0.10	0.01
1d (Number of showers without bathtubs)	0.10	0.01
1c (Number of bathtubs without a shower)	0.09	0.01
1j (Number of hot tubs)	0.07	0.00
1b (Number of bathtubs with showers)	-0.05	0.00
1g (Number of kitchen faucets)	-0.02	0.00
6i (Number of infants or toddlers)	0.00	0.00

The Pearson r-statistic, which theoretically ranges from 1 to –1, is also involved with linear regression modeling. The R^2 statistic gauges the strength of best-fit linear regression. When interpreting this statistic, it's important to recognize that correlation does not imply causation. Artificial associations like Account Sequence may appear to have a better fit compared to actual variables, like year established. Missing values for question 1 were included as 0 if any part of question 1 was answered. For example, if the survey indicated a positive number of toilets but nothing for hot tubs, this analysis would assume 0 hot tubs. Non-numeric or unexpected answers on other questions were treated as equivalent to a missing value.

Discussion of Variables For Modeling Multi-Family Water Use

Potentially all of the information included in the survey questions could be used for modeling water use, but that would be cumbersome and duplicative. In addition, many of the variables are not independent of each other (for example bedrooms and number of residents), so adding them may actually confuse the relationships. The analyses on the strength of correlation of the variables suggest that the following variables should be included in regression models for multi-family water use.

- Residents and/or Number of Bedrooms. The number of residents shows the strongest correlation to water use, but normally it is likely that the District will know the number of bedrooms more than the number of residents. Given that we knew the number of residents for the survey group we used this for modeling, but we also developed relationships (see Figure 20 below) between the number of bedrooms and the number of residents that should be useful for budgeting. As can be seen from the figure the tendency is for apartments to have more people than bedrooms and for condos to have fewer people than bedrooms.
- One or more children, Question 6a (Number of adults), Question 6o (Number of older children). The number of children may also simply be another way of saying that having more residents increases water use. These specific measures of household demographics are probably impossible to collect on a per-account basis and in fact number of residents is indicated as a more influential number. WE do not recommend that modeling consider age demographics.

- Number of bathrooms from Question 1a (Number of toilets), Question 1b (Number of bathtub-showers) and Question 1f (Number of bathroom sinks) It's likely each of these responses is practically equivalent to the number of bathrooms. There is a definite correlation between having more than one bathroom and increased water use in both apartments and condos. The relationship drops off as the numbers exceed 2 bathrooms. Adding the first additional bathroom has a larger effect than adding a third or fourth.
- Irrigation. It's quite clear irrigation influences water use among condo accounts, but the presence of irrigation is almost nonexistent across apartment accounts. Modeling should consider irrigation only for condo accounts.
- Clothes washer in unit. Even though a t-test on apartment respondents indicates this factor is less influential than the confidence standard (it's p-statistic is .145, meaning a 15% probability that the relationship is due to chance) there is a good balance between apartments with and without clothes washers and the mean water use is significantly higher for the units with washers. Therefore, among single factors influencing a difference in mean annual use between apartments and condos, the presence of a clothes washer in-unit is the likeliest to be useful.
- Account activated before or after 1995. Even though the year in which each account was established was not found to fit a linear relationship with water use, whether a condo account was established before or after 1995 is in fact influential. 1995 was chosen as a kick-in year for improved 1992 efficiency guidelines. Modeling condominium usage will include this factor. It is doubtful, however, that the District will want to develop water budgets based on pre-1995 use patterns, since these reflect outmoded technology.
- One or more whirlpool tubs. On further inspection, the distribution of respondents indicating between 1 and 3 whirlpool bathtubs is apparently evenly distributed across subdivisions, but demonstrably higher in recently activated accounts, especially condos. The inclusion of these fixtures in condo building plans appears to be a newer phenomenon. And yet, for the purpose of modeling a water budget it's convincing *not* to include this fixture in the model: should the model grant special dispensation for this feature over other characteristics, such as (for example) whether the unit has a dishwasher?

After analysis of the data and intermediate results the most likely parameters to be of use for modeling water use in the IRWD sample were: whether the units were apartments or condos, the number of residents in the units, the presence of clothes washers (in the apartments), the presence of irrigation (in the condos), and whether the units were pre or post-1995 (for the condos). These were the parameters that were chosen for more detailed analysis in modeling effort.

MODELING MULTI-FAMILY WATER USE

Before attempting to define relationships between annual water use and specific characteristics of the multi-family units we first plotted the annual use for the survey respondents according to simply whether they are condos or apartments, which is shown in Figure 21. In this figure the X-axis is simply the sequential account number sequence

for the account and has no bearing on water use. The Y-axis shows the annual water use for the units according to whether they are apartments or condos. Three things stand out in this diagram: there are more condos than apartments in the sample, there is more variability in the condo use than the apartments, and there is no major difference in the average annual water use between the two groups that can be discerned by simple visual inspection. The two groups appear to be centered somewhere around the 75 ccf/year (56 kgal/yr) level of water use.

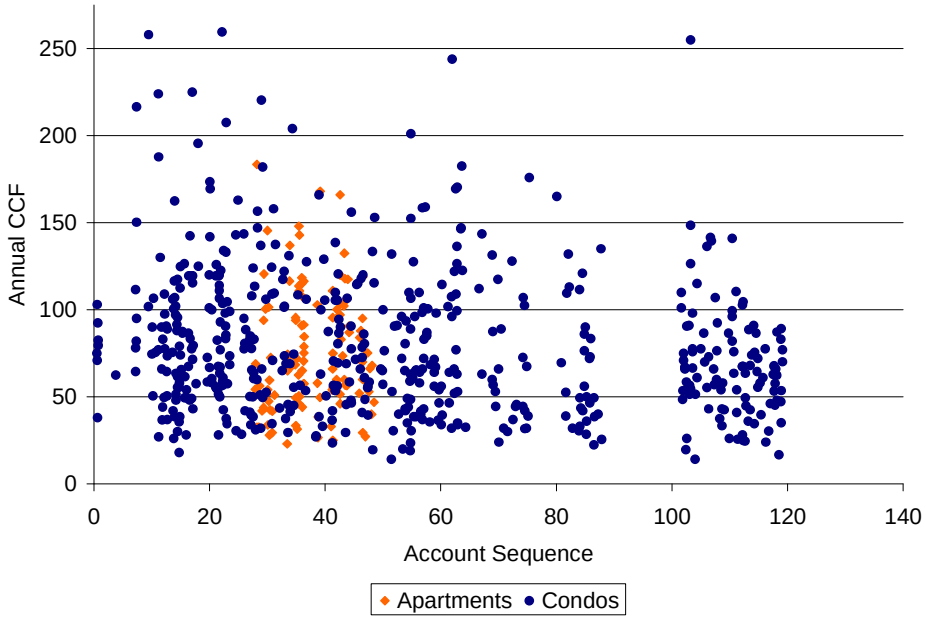


Figure 21: Scatter diagram of annual water use for apartments and condos

Figure 22 and Figure 23 explore the relationship between annual water use, the number of bedrooms and the number of residents for apartments with and without clothes washers, and condos with and without irrigation. In Figure 22 we see that there is definitely a relationship between more persons, more bedrooms and more water use for apartments. We also see that apartments with clothes washers consistently use more water than apartments without clothes washers, but that the difference becomes less pronounced in larger units or units with more persons.

In Figure 23 we see that there is also a clear relationship between the persons, bedrooms and water use for condos, and that condos with irrigation use consistently more water than those without. This relationship stays constant as the units become larger.

These figures demonstrate the types of relationships between water use and readily available information on the multi-family units that show promise for establishing mathematical formula to describe and predict water use for these groups. They also remind us of the amount of scatter in the data, which stresses the importance of using any mathematical relationships with discretion.

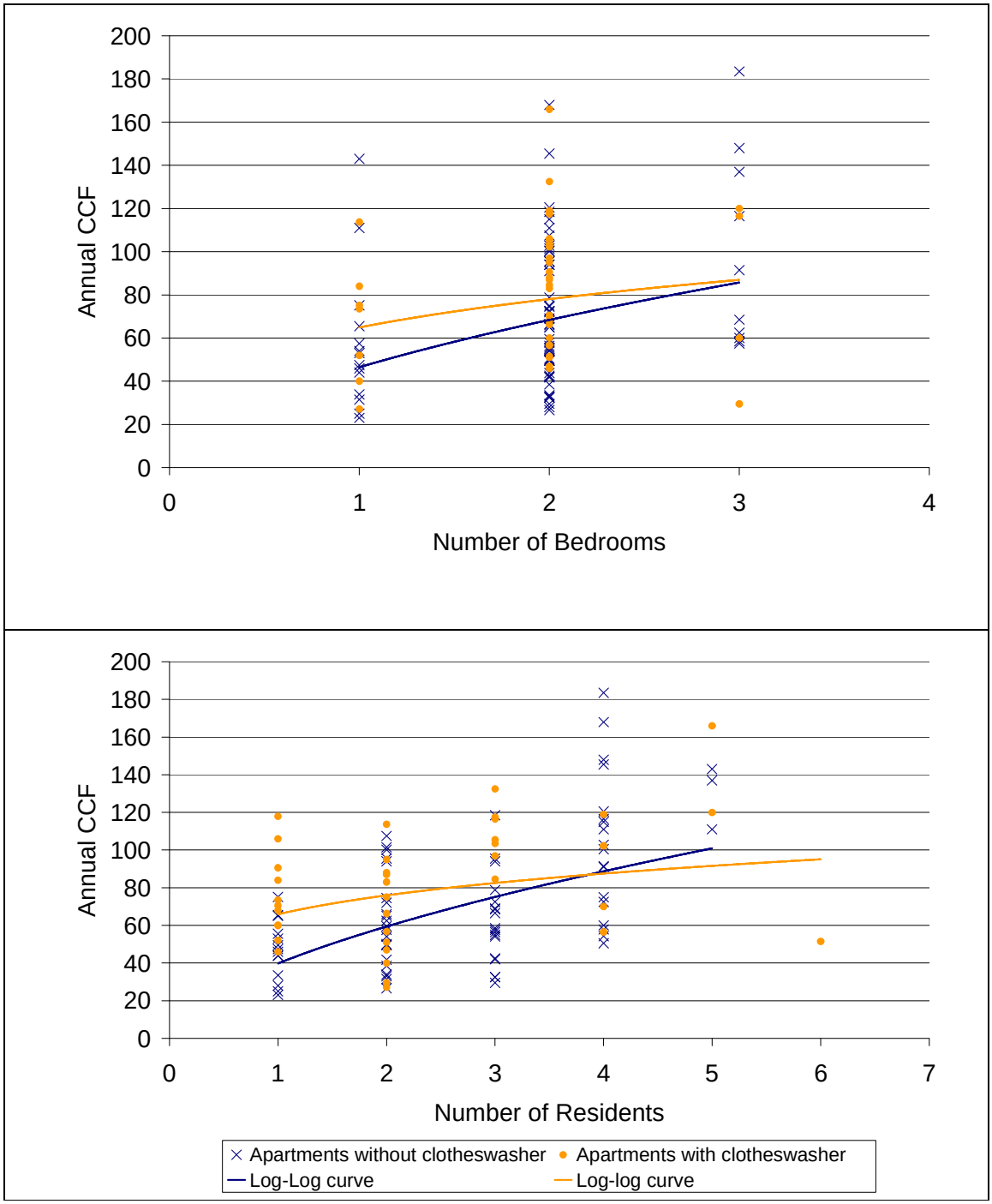


Figure 22: Apartment respondent's use against number of bedrooms and number of residents

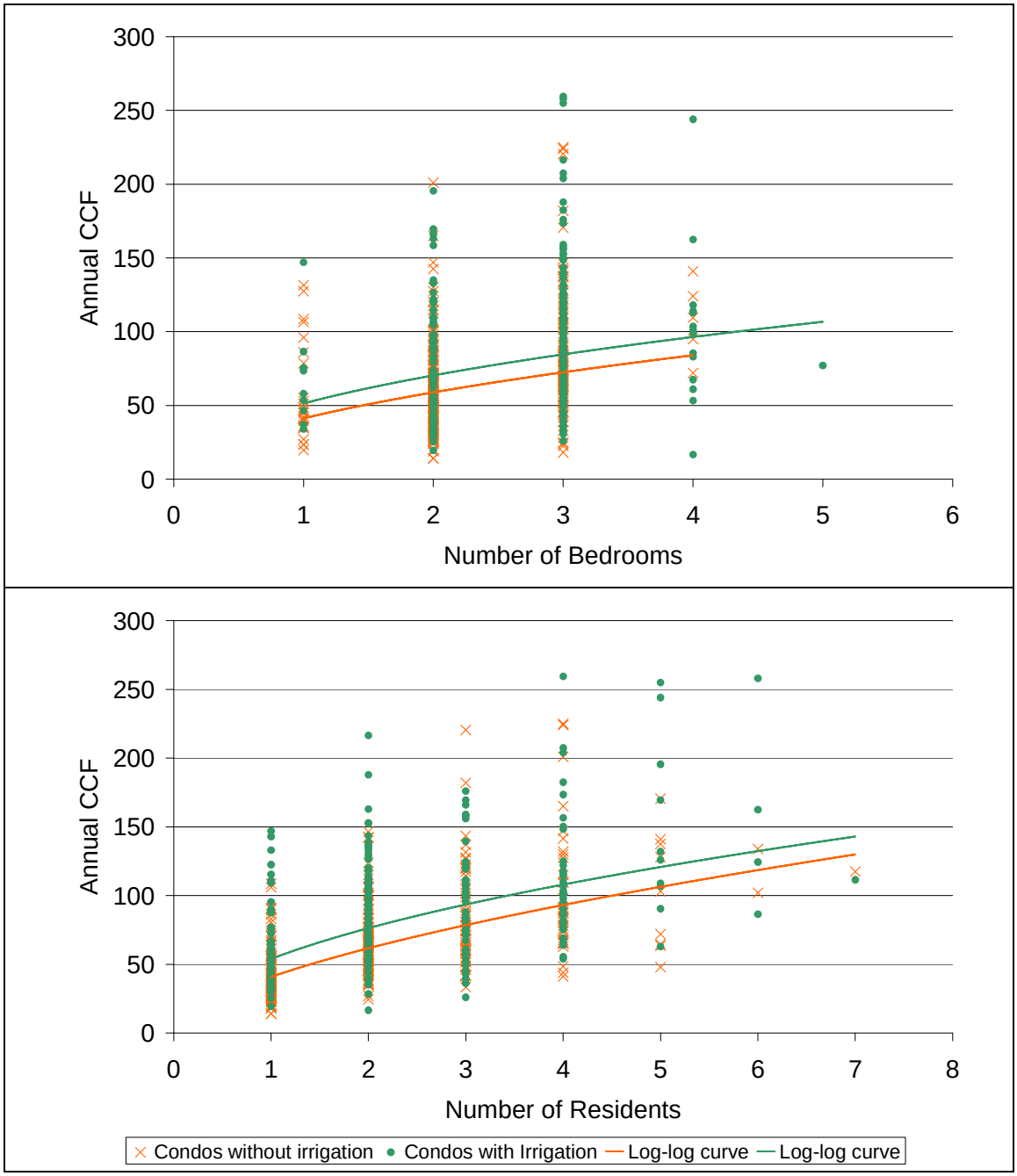


Figure 23: Condo respondent's use against number of bedrooms and number of residents

In Figure 24 the number of residents, the number of bathrooms and the presence of clothes washers and irrigation verses annual water use are combined. In this figure the values are reduced to points with bars to show the variation. This shows a strong degree of correlation between number of residents and water use. Error bars show the 95% confidence bound within these groups, and appreciable overlap implies that neighboring

groups may in fact be statistically indistinguishable. However, the data show a clear indication of the relationships.

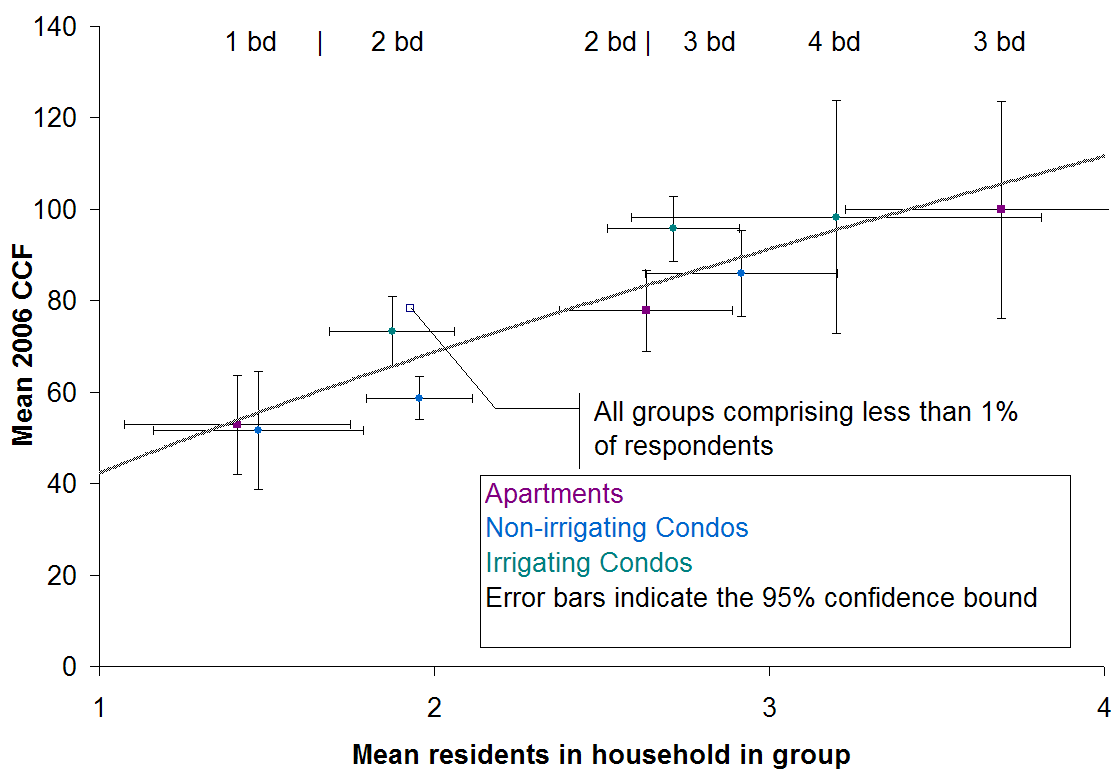


Figure 24: Trend of water use for groups of survey respondents

Regression Models for Apartment and Condo accounts

The following mathematical models were developed to show the relationships between annual water use in 665 multi-family customers who returned surveys and the following variables:

- Whether they were apartments or condos
- How many residents live in the units
- How many bathrooms are present
- If apartments, do they have a clothes washer
- If condos do they irrigate more than just potted plants
- If condos were they built before or after 1995.

These were the factors that the ANOVA analysis showed to be the most significant in predicting water use for this set of respondents. Examination of the data showed that it would be misleading to attempt to use a single model for all of the units. Such a model could have been developed, but it would have distorted the effects of the variables. For example, since virtually no apartments irrigated, including the apartments in the model that included the irrigation variable would under-weight the effect of irrigation and show an artificially low irrigation factor for the condos, where it is actually a factor. Similarly,

since all of the apartments were built before 1995 it would not make sense to include the apartment data in models of the effect of post-1995 construction. Finally, since virtually all condos were equipped with clothes washers it made sense to use the better balanced apartment data to model the impact of clothes washers.

As shown in Figure 25 the data clearly suggest that there are differences in annual water use among the six groups into which the data appear to naturally fall. In apartments, the presence of a clothes washer relates to an average increase in water use of around 5.5 ccf per year. In condos the presence of irrigation increases water use for both the pre and post-1995 groups, and in both cases the post-1995 condos use less water per unit than do their pre-1995 counterparts. Of all groups, the lowest annual water use is found in the post-1995 condos without irrigation, which use approximately 5.6 ccf/month (4.1 kgal). All of these condo units also have clothes washers.

The other thing to notice about the annual water use in these groups is that the degree to which their 95% confidence intervals overlap. This means that while the data may be suggestive of differences in the mean water use associated with the groups in many cases these differences are not statistically significant at the 95% confidence level. Consequently, one should not expect a high degree of correlation in the models. This is born out by the relatively low R^2 values obtained from the regression analyses.

Figure 26 shows the average number of occupants for the same six groups of customers. It is interesting to note that the water use in the groups does not follow the number of occupants in a strict manner. For example apartments without clothes washers use less water than those with clothes washers, but at the same time they have more occupants. The presence of a clothes washer outweighed the lower number of occupants in these units. The pre-1995 condos with irrigation were the highest water users of the group, but their average number of residents was in the middle of the pack. The group with the lowest water use, the post-1995 condos without irrigation, had the second highest occupancy rate of all. This shows that there are other factors beside simply the number of occupants that are important in explaining water use in the multi-family accounts.

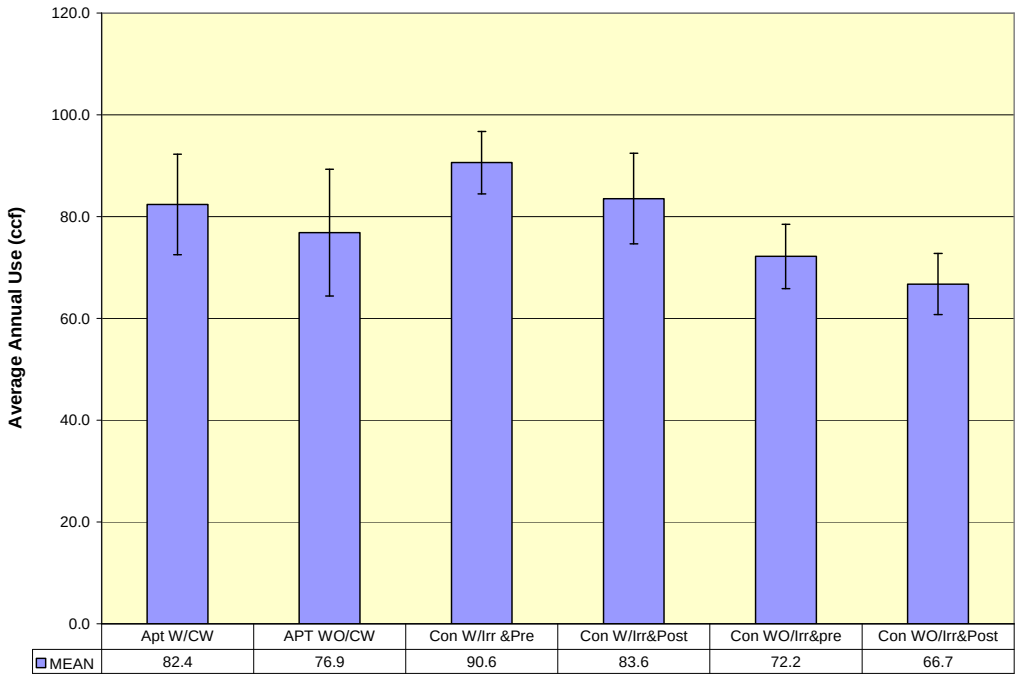


Figure 25: Average Annual Use by Group

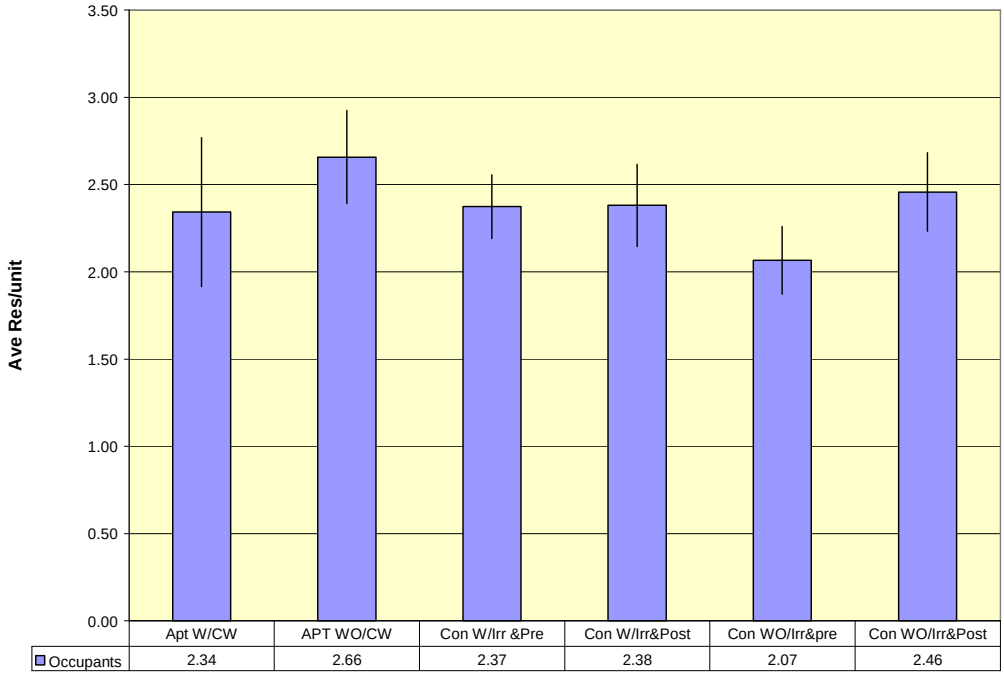


Figure 26: Average Occupancy by group

The results of the regression analysis consist of a set of models developed for the six sub-sets of the 665 unit sample. In the end it was decided not to include the number of bathrooms in the models because including the bathrooms did not improve the correlation coefficients of the models (R^2), and in some it led to illogical situations where units with more residents were predicted to use less water than smaller units with more bathrooms. The strongest determinant of water use for all multi-family units within each group was the number of residents, so this was used as the primary continuous variable for the water use models.

The other variables in the models were all categorical in nature. That is, they identified sub-groups into which the multi-family units were divided. They include the variables about the presence of irrigation, clothes washers or whether the units were built before or after 1995.

All of the models were based on log-log regression analysis. In other words, the data were all transformed to their log values and these were then used for the regression models. The resulting equations had the form:

$$Y = C \cdot Res^{x} \cdot F_{cw(0,1)} \cdot F_{irr(0,1)} \cdot F_{pre/post}$$

Where :

- Y= Annual water use (ccf)
- C= coefficient of best fit line
- Res = number of residents in unit
- X= exponent of log-log relationship
- F_{cw} = factor for presence of clothes washer, or 1 if none is present
- F_{irr} = factor for presence of irrigation, or 1 if not present
- $F_{pre/post}$ = factor for pre or post-1995 construction

Table 15 shows the values for the coefficients in the equations, including the bias corrections. Gauging the performance of one model versus another is often done using statistics like r-squared (which measures the correlation between predicted values and observed values) and absolute error (the expected margin of error of predicting the dependent variable). The R^2 values for the two models generated from the available data equal 0.23 for apartments and 0.38 for condos. These are fairly typical of the kinds of results normally obtained from behavioral research. The interpretation of the results is that the models explain between one quarter and one third of the variation in water use for the sample groups. The predicted water use for each of the 6 groups verses the number of residents per unit is shown in Figure 27. Notice that none of these relationships are linear in form, so that the increment of water per resident becomes smaller as each new resident is added.

Table 15: Coefficients for Selected Multi-family Models

	Constant (CCF)	Residents coefficient	After 1995 coefficient	Clotheswasher coefficient	Irrigation Coefficient	R-squared	Mean Abs Error (CCF)	Median Abs Error (CCF)
Apartments	39.59	0.44		124%		0.23	26.29	19.69
Condos	45.41	0.56	79%		122%	0.38	24.93	16.94

$$\text{Apartment Annual CCF} = 39.59 \cdot \text{Residents}^{0.44} \cdot (124\% \text{ if clotheswasher in unit})$$

$$\text{Condominium Annual CCF} = 45.41 \cdot \text{Residents}^{0.56} \cdot (79\% \text{ if 1995 or newer}) \cdot (122\% \text{ if irrigating})$$

Table 16: Models for predicting annual water use (ccf) in multi-family units

Group No.	Group Name	Model
1	Apartments w/CW	$39.59 * Res^{0.44} * 1.24 = 49.09 * Res^{0.44}$
2	Apartments wo/CW	$39.59 * Res^{0.44}$
3	Condos w/Irr and Pre 95	$45.41 * Res^{0.56} * 1.22 = 55.4 * Res^{0.56}$
4	Condos w/Irr and Post 95	$45.41 * Res^{0.56} * 1.22 * 0.79 = 43.76 * Rex^{0.56}$
5	Condos wo/Irr and Pre 95	$45.41 * Res^{0.56}$
6	Condos wo/Irr and Post 95	$45.41 * Res^{0.56} * 0.79 = 35.9 * Res^{0.56}$

It is worth noting that all of the residential demand models shown in Table 16 and Figure 27 are non-linear. That is, the water demand does not rise in direct proportion to the number of residents in the unit. This is why water budget models that assign a uniform allowance (like 75 gpcd) to each occupant will tend to overestimate the demand for larger units. In Irvine's case the exponent range from 0.44 for apartments to 0.56 for condos. As an example of the impact of this phenomenon consider the water use model #6, for post 1995 condos without irrigation. That model predicts that a single occupant will demand 36 gpd (or 17.6 ccf/year). The demand for 2 occupants will be 1.47 times this amount, or 53 gpd. The demand for three occupants will be 1.85 time the single occupant demand.[5] Other studies have confirmed the non-linear nature of indoor residential water demands.

[5] $2^{0.56} = 1.47$ and $3^{0.56} = 1.85$

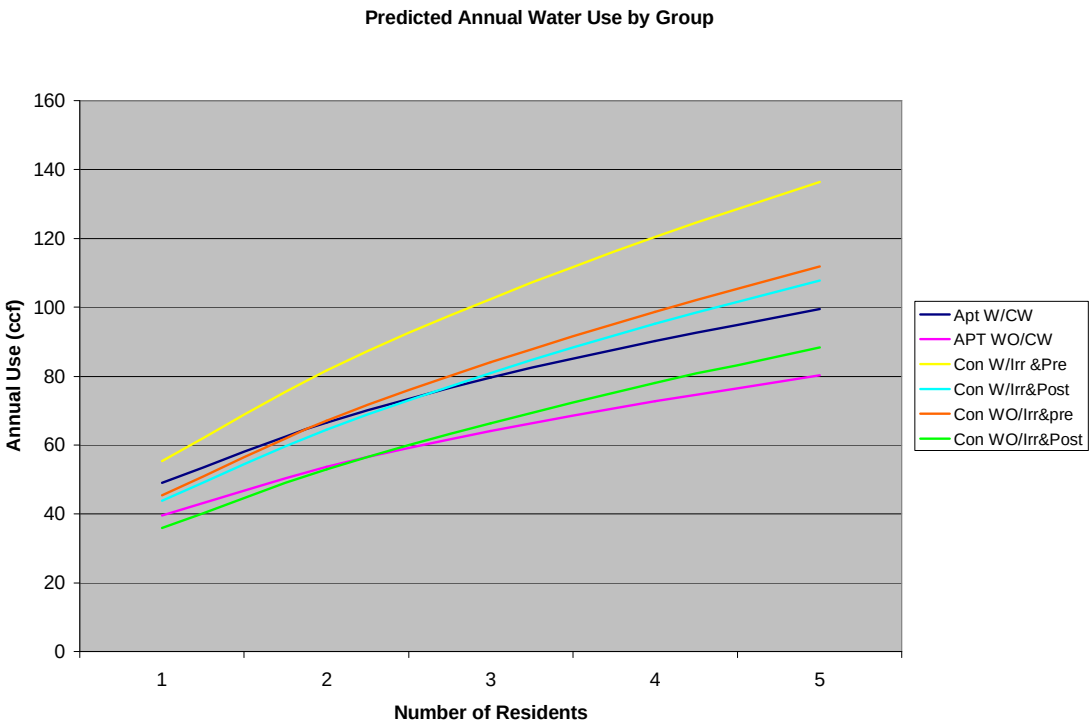


Figure 27: Predicted annual water use for six groups

DISCUSSION OF BUDGET APPROACHES

If the only data that were available to establish budgets for the multi-family customers were the billing data it would be possible to set budgets, but it would be difficult for the budgets to be tailored to the specific characteristics of the customers. Limiting the information to just the raw billing data would also not insure that the budgets reflect water efficiency or that other factors that affect indoor water use by the multi-family customers are taken into account properly.

The combination of the billing data with the survey responses allowed a series of mathematical models to be developed, shown in
Table 16, that predict annual water use in six multi-family groups. These groups are based on the number of residents per unit and the categories into which the units fall (condos, apartments, with or without irrigation, or clothes washers, and before or after 1995). These models predict the existing patterns of water use in the customer base. We can see from Figure 27 that there is a range of predicted water use for the same number of residents based on the group to which the unit belongs. Condos with irrigation and built prior to 1995 have the highest water use pattern, while condos built after 1995 with no irrigation as well as apartments built prior to 1995 without clothes washers use the least water per occupant.

Using the information gathered during this study a mathematical model was created for the 665 households that allowed their actual water use to be compared against the current IRWD water budget approach and a range of possible budget setting approaches. The current budget approach is based on the parameters shown in Table 1. Alternative approaches were developed from the model information and from alternatives being considered by the District. Using the models, the percentages of customers that are expected to fall into each of the five billing tiers used by IRWD could be determined for each budget approach analyzed. Water savings could also be estimated.

The goal of the water budget process is to set budgets that put an appropriate amount of pressure on the high consumption customers to reduce their use, and to limit the number of customers that fall into the two penalty tier to just those that are actually using water inefficiently or wastefully.

Figure 28 shows the results of analysis of the 665 units in the survey respondents which were use used to create the water use models. For each of these accounts the number of residents dwelling in the units, their actual annual water use [6] and the group to which they belong were all known. The annual water budget for each account was then calculated using the current budget approach, and the figure shows the percent of the group falling into each budget category based on their actual annual use.

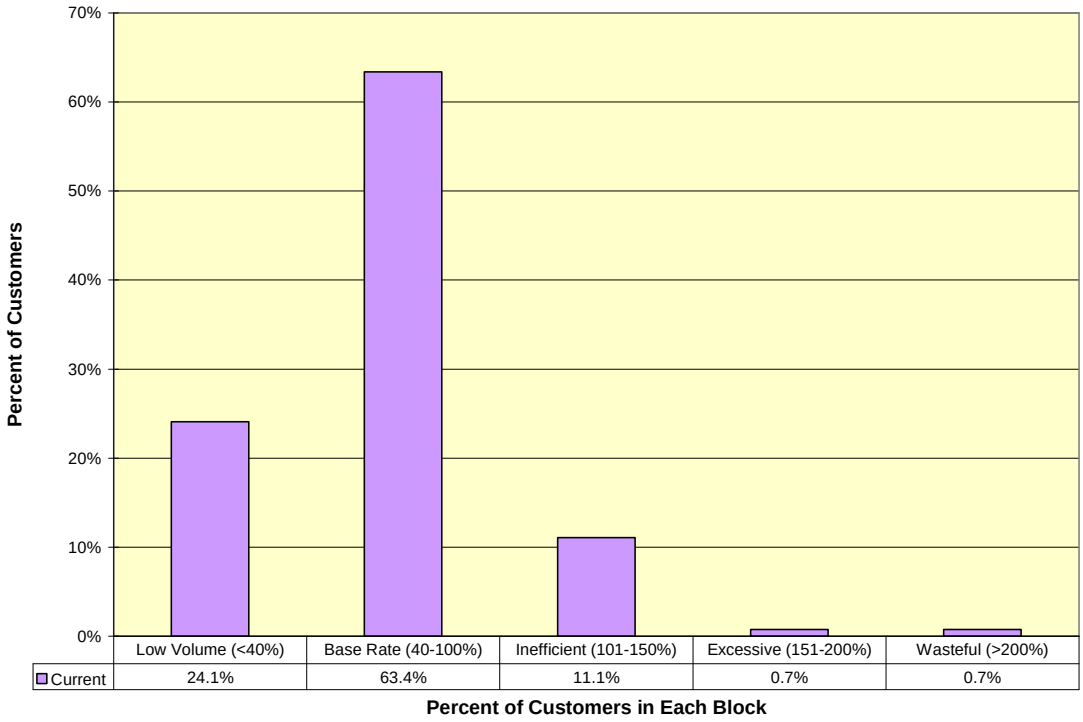


Figure 28: Customer distribution based on current budget system

[6] The annual use data were corrected to eliminate the effects of the small differences in the annual water use between the survey respondents and the populations.

Figure 28 shows that under the existing budget system the majority of customers fall into the first two tiers. These budgets were calculated by allowing 75 gallons per person per day using 2 occupants as the default for apartments, and 3 occupants as the default for condos. For the condos an outdoor allocation was provided based on 450 sf of irrigated area and 47" of ET (~29 gal/sf) was provided. This amounted to an annual allocation of 17 ccf per account. Each condo account water given a budget of 17 ccf for outdoor use whether or not they reported irrigation use.

In order to determine the percent of the budgets used by each customer the annual use for each account was compared to the calculated water budget and the percent of the budget used was tabulated for each. The percent of customers that fell into each tier was determined and graphed in the Figure 28. Approximately 12% of the sample fell into the top three tiers using the current IRWD system. If the survey sample is representative of the overall population of multi-family customers, which the data indicate to be the case, then this analysis indicates that the existing water budget system is probably overly generous, and that the budgets impact relatively few customers.

Next, an analysis was done on the impact of using the six models derived from the regression analysis of the data shown in Table 16. This approach uses the actual demand patterns to set the budgets, and includes irrigation allotments only for the groups who irrigate. So, not all of the condos get irrigation allocations. These results are shown in Figure 29. The equations were used to calculate the budgets for each of the accounts according to their individual characteristics and their group. The actual water use was then compared to the budgets and the percentages falling into each tier were determined. In this case the use of models derived from the actual water use tends to provide less generous budgets.

Using the six models would result in 46% of the sample being at or below the budgets. The remaining 54% would exceed the budgets: 34% would be in the inefficient tier, and 20% would be in the top two "penalty" tiers. This would be a significant increase from the 1.4% of the sample that fall into these tiers using the current budget calculation procedures. Use of the modeled water demands would result in a much more aggressive multi-family water conservation program.

In another approach, shown in Figure 30, the water use model for the most efficient group of customers: the post-1995 condos without irrigation, was used to generate water budgets for all of the account indoor uses, and outdoor allocations for condos were based on 80% of ET for all condos. The default number of residents was set at 3 for both apartments and condos. The results of this approach are less aggressive than those based on the 6 models.

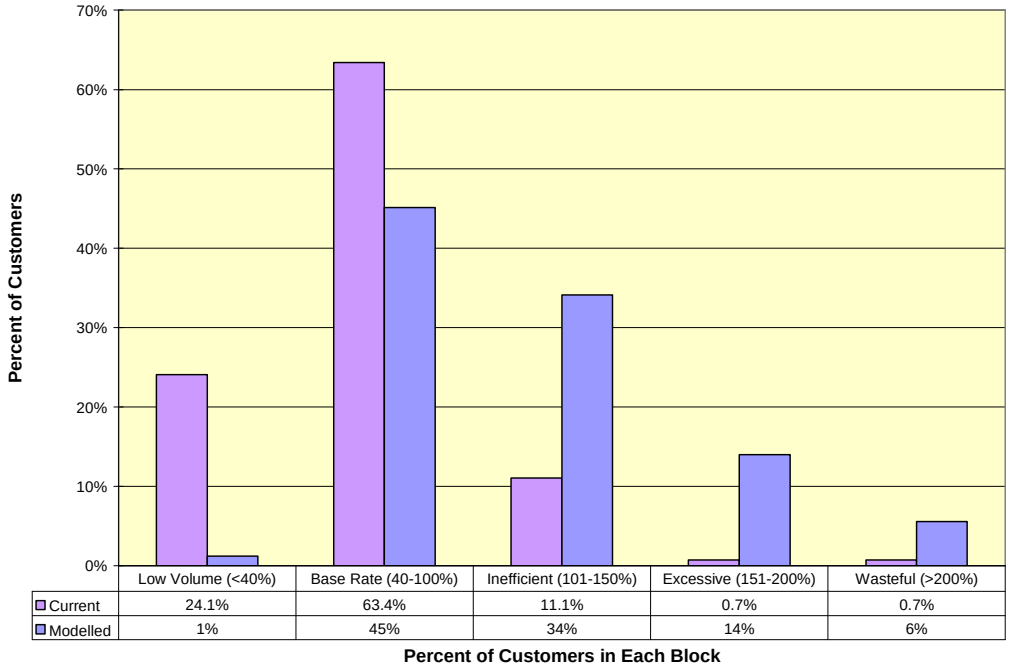


Figure 29: Current budgets vs 6 models (from Table 18)

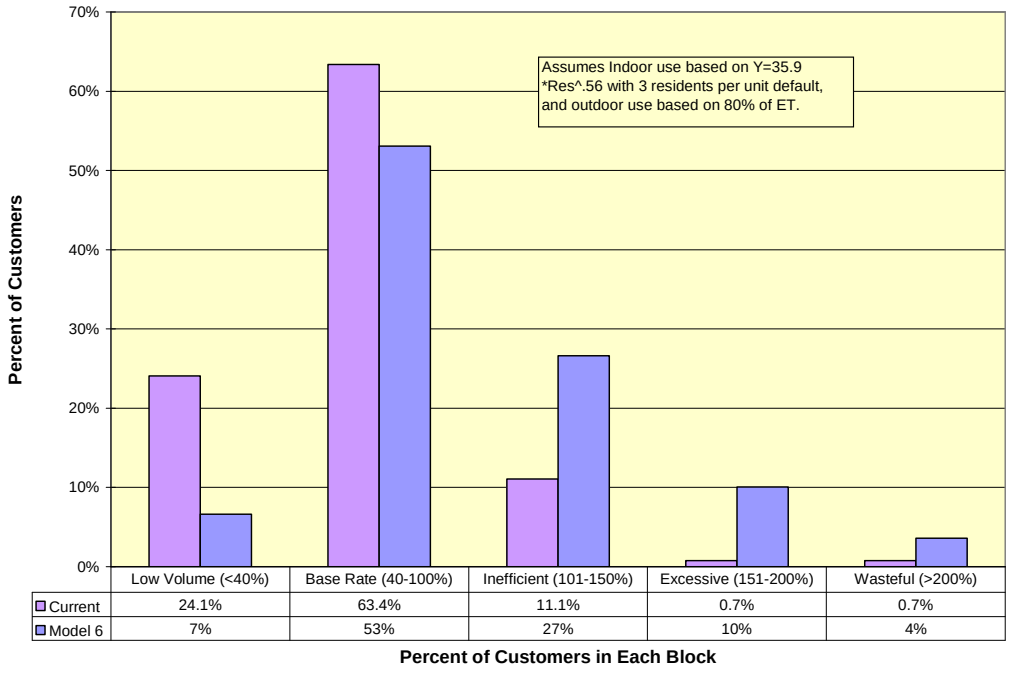


Figure 30: High efficiency indoor use (model 6) and 80% of ET for outdoor

The IRWD is currently considering modifying the water budget approach for the multi-family customers by dropping the per capita allowance from 75 gpcd to 55 gpcd and reducing the outdoor allocation to 90% of ET. (This would still be a linear allocation, and the allocation would be increased by 55 gpd for all occupants.) When these parameters were used to analyze the impacts on the sample group the results shown in Figure 31. This approach results in a less dramatic impact on the customers, but would still send a conservation signal. A total of 28% of the customers would exceed their budgets in this scenario and 6% would be in the top two tiers.

Table 17 shows a comparison of the various water budget scenarios evaluated as part of this study. The table shows the average budget per account derived by each method, the average percent of the budgets used by the customers and the percent of customers falling into each of the budget tiers under the scenario using 2005-06 billing data.

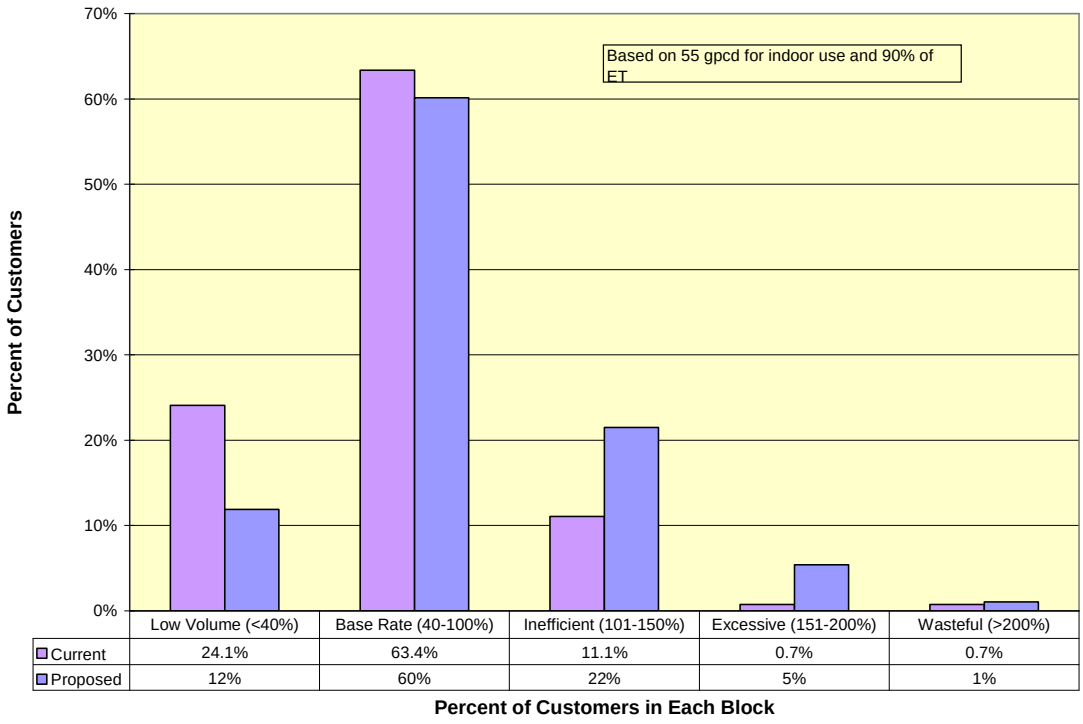


Figure 31: Proposal for 55 gpcd plus 90% of ET

Table 17: Comparison of Budget Approaches

Budget Approach	Ave MF budget (ccf/yr)	Ave % of Budget Used	Percent of Sample in Each Budget Tier (Based on 2005-2006 consumption)				
			1	2	3	4	*5*
Current	130	62	24	63	11	0.7	*0.7*
Models	70.9	113	1	45	34	14	*6*
Model 6	80.8	98	7	53	24	10	*4*
Proposed	97.92	82	12	60	22	5	1

Note: Ave historical use was 80 ccf/account in 2005-2006

CONCLUSIONS

Based on the analyses performed on the multi-family customer information, billing data and survey responses the following conclusions can be drawn about the multi-family water use patterns and the way that the IRWD water budget system is affecting the multi-family customers.

- The IRWD water system served a total of 48,080 multi-family households in 2006. These were split 55% individually metered and 45% master metered.
- The presence of such a large number of individually metered, multi-family accounts provides an excellent opportunity for studying water use in this important group of customers with far more precision than can be provided by master meter data, which obscures the differences among customers.
- There are 8 categories of multi-family accounts that emerge naturally from the IRWD billing data, as shown in Table 3.
- The data show a lot of variability in annual water use among the groups. Figure 9 shows that there is an 80% difference between the median annual water use of the lowest group (the post-1995 master metered apartments) and the largest use group (the post-1995 master metered condos).
- The reasons for these differences become clearer when information provided by customer surveys is included in the analysis.
- The most important factor in explaining water use among multi-family customers was found to be the number of residents occupying each dwelling unit.
- The relationship between water use and the number of residents is not linear, which means that use of a uniform allocation per resident must be done with care.
- The data suggested that units with more than one bathroom used more water than similar units with only one bathroom, but the relationship is not strong enough to be statistically conclusive.
- Table 16 shows the mathematical models that were derived from the ANOVA and multiple regression modeling done with the data. There were 6 relationships that proved significant. These relationships are shown graphically in Figure 27.
- All of the apartments included in this group were built prior to 1995. In that group the most important factor, after the number of residents, was whether or not the unit was equipped with a clothes washer. The presence of a clothes washer

was associated with a 24% increase in the water use within the apartment. (This does not mean that the overall water use of the property increases, but only that the water use in the apartments with clothes washers is higher, while the water use in the laundry rooms would be correspondingly lower).

- For condos, there were two categorical factors for explaining water use: whether they were built before or after 1995 and whether they had irrigation use associated with the unit.
- Condos with irrigation of significant outdoor areas were found to use 122% of the water used by condos with no outdoor irrigation.
- Condos built after 1995 used only 79% of the water used by condos built prior to 1995.
- If we exclude condos with irrigation from the discussion then we see from Figure 27 that there are really two salient water use patterns: the higher use relationship including apartments with clothes washers and condos built prior to 1995, and the lower use group including condos built after 1995 and apartments without clothes washers.
- The most efficient water use group consists of the post-1995 condos without irrigation. These might represent a reasonable and achievable standard for the entire group of multi-family customers over time.
- The current water budget system affects very few of the multi-family customers. As shown in Figure 28 and Table 17, only 1.4% of the sample fell into either of the two high use tiers, while almost 90% of the group fell within the bottom two tiers. This is not sending a conservation message to the customers.
- The use of the model relationships developed from the data was explored as alternate methods of setting budgets. Use of the six individual models resulted in approximately 20% of the sample falling into the top two tiers, and use of the most aggressive indoor model plus an outdoor allowance based on 80% of ET resulted in 14% of the sample falling into the top two tiers.
- If the approach being considered by the District (a 55 gpcd indoor allocation plus 90% of ET) were adopted approximately 6% of the sample would fall into the top two tiers and 72% would fall into the bottom two tiers.

RECOMMENDATIONS

In the draft report a series of questions were raised for consideration. Based on the results of the analysis the following recommendations can be made.

Is it the intention of IRWD to develop separate budgets for individual categories of multi-family customers?

One thing that appears certain is that the existing budgets are larger than necessary. They assume a linear relationship between the number of residents and water use equal to 75 gallons per person per day, which is not supported by the data. The data show that the actual coefficients are between 36 and 49 gpd for the first occupant, and that the water use increases non-linearly, as a power between 0.44 and 0.46. This means as more people are added, the impact on water use decreases.

In a water budget system there will always be some customers whose use exceeds the budgets. If not, the budgets are set so high as to be meaningless. Ideally, the budgets should be set so that only customers with genuine water use problems are falling into the top two tiers. These customers will be likely to contact the agency to ask questions and obtain assistance in reducing their water use, which is precisely the intent of the system. If too many customers are falling into these tiers the response is likely to be discordant and poorly organized. While there is not a lot of data on this, it would seem that having around 10% of the customers in the top tiers is about right. The district, however, needs to have the ability to respond to these customers in the form of telephone and audit personel.

The use of the individual models derived in this study for setting budgets is probably neither a good idea, nor necessary. If the modeled data are used to set the budgets approximately 20% of the customers would fall into the top two tiers. This would include customers who may not be wasting water, and would also be likely to be too many customers for the district to deal with effectively. Therefore we would not recommend the use of the 6 models for developing budgets for the multi-family customers.

On the other hand, it doesn't make sense to be developing budgets based on outmoded devices. So, a reasonable approach might be to use the model for the post-1995 condos as the goal for indoor water budgets in all the multi-family accounts. We know that virtually all of these units have clothes washers so that factor is taken into account. The one area where an adjustment seems warranted is in the number of persons present in the units. The survey showed that the apartments tended to have more residents than did the condos. The apartments had between 2.4 and 2.7 persons per unit on average, and the post-1995 condos had 2.5. Given that the average number of residents is greater than 2 for all multi-family units it would make sense to give everyone a default of 3 residents, but then to use the relationship: $35.9 * Res^{0.56}$ to calculate the annual water use.[7] This gives everyone a minimum default budget of 66.4 ccf per year for indoor uses. In

[7] In this case the coefficient 35.9 equals the model coefficient of 45.41 times 0.79, the post 95 factor.

addition, condos would get a default of 14 ccf per year for irrigation, based on 450 sf of irrigated area and 80% of ET. Use of this approach would result in approximately 14% of the customers falling into the top two tiers.

The proposal being considered by the District based on 50 gpcd and 80% of ET would not result in as many customers falling into the top tiers as would either of the scenarios derived from the models. This proposal would, however, create a much stronger conservation incentive than the current system, but with less of a shock. This approach was evaluated assuming a default of 3 residents per unit for all accounts plus an irrigation allotment of 14 ccf for all condos. If the proposed approach were adopted approximately 10% of the customers would fall into the top two tiers, which is in the recommended range.

Will the budgets be based on individually metered accounts or master metered accounts?
Since the only data we have to work with comes from individually metered accounts the budgets need to be based on the individually metered customers. This is far more accurate way to set them since the data from the individual units can be linked with the survey data to obtain much larger samples and correspondingly higher accuracies.

Are budgets to be based on high efficiency fixtures and appliances, or on older, less efficient devices? If the goal of the budgets is to encourage conservation then it would be most reasonable to set the budgets on the basis of high efficiency fixtures in order to encourage customers to retrofit. This, however, is a policy decision for the District. The budgets derived from Model 6 are based on the efficiency levels found in post-1995 condos. These are somewhere in between the efficiencies found in the older units and those built using best available technology.

How will water use in common areas, such as laundries and pools, be accounted for?
Use of either Model 6 or the Proposed budget approaches will provide for in-unit clothes washers using high efficiency standards. Therefore it should not be necessary to increase budgets for new projects in order to accommodate in-unit clothes washer. If new projects are being built that do not include in-unit washers the budgets for the individual units should be reduced by around 10 ccf[8]. An equivalent budget should then be provided to the common are laundry. Budgets for other common area uses such as clubhouses and pools should be set using the best estimate of their actual water requirements.

Should budgets be set on the basis of the number of occupants in the units or the number of bedrooms? This study has used the number of occupants for modeling purposes since we know this is the best variable data on which to model residential water demands, and we know the number of residents from the survey information. The recommended budget approach assumed 3 persons per unit as the default value, which is based on the actual occupancy rates rounded up. For future developments the District can use information on the number of bedrooms planned for the projects along with

[8] The data showed that standard clothes washers increase in-unit demands by 15 ccf. High efficiency machines would require approximately 30% of this, so

relationships between bedrooms and occupants (See Figure 20) to get an estimate of the number of residents upon which to base water budgets. It would also be reasonable to use an occupancy rule to assign budgets. For example, the first bedroom could be assumed to have 2 occupants and each succeeding bedroom to hold 1 occupant. This would match the most common case of 2 bedroom units, with 3 occupants.

Impacts on water use from adopting recommended budgets

The adjusted historical annual water use for the 665 home sample was 80 ccf (59 kgal), and the average water budget using the IRWD proposed approach will be 98 ccf (73.3 kgal). This implies that the proposed budgets will not impact the average water user since the average budget is greater than the average water use. Table 17 shows that in 2005 28% of the sample exceeded the budget derived using this approach. If these 28% of customers that are using more than their budget drops back to the budget allocation then the average water use for the group would drop to 71 ccf (53 kgal). This represents a reduction of 9 ccf per year, or 11% reduction in overall use by the multi-family sector. This would equate to annual savings of 913 acre feet, which would be a very significant conservation effort from a single customer group, without being overly aggressive.

Based on the results of the analysis the overall recommendation is made to adopt either the budget process based on Model 6 or the proposal based on 55 gpcd for indoor budgets, and use of 90% of ET for outdoor budgets. The advantage of use of the Model 6 approach is that it is based on observed data so it is easier to justify. It gives a lower average budget, and results in more customers falling into the top tiers. It also prevents excessive budgets being set for units with more than three occupants. The use of the 55 gpcd approach is not as accurate as the use of Model 6, but it is simpler to apply, and will be adequate for the vast majority of customers. While it is not as aggressive as Model 6 it still represents a step forward from the current system.

APPENDICES

Appendix A: Distribution of survey responses among multi-family groups
Appendix B & C: Survey questions and response.
Appendix D: Extreme values

Appendix A1: Distributions of survey respondents versus population

CCF		Pre-95 Apartment responses	Pre-95 Condo responses	Post-95 Condo responses
min	0%	16	13	12
	10%	34	36	31
	20%	43	46	42
	30%	52	54	50
	40%	59	63	59
median	50%	70	74	66
	60%	79	85	75
	70%	92	99	88
	80%	114	113	101
	90%	130	130	131
max	100%	727	265	262
N		**114**	**336**	**215**

Table 18: Percentiles (including min, max, and median) of survey responses

CCF		Pre-95 Apartment Population	Pre-95 Condo Population	Post-95 Condo Population
min	0%	11	11	11
	10%	31	36	30
	20%	41	49	40
	30%	49	59	48
	40%	56	69	56
median	50%	64	79	64
	60%	73	91	73
	70%	83	105	84
	80%	97	123	100
	90%	120	150	124
max	100%	1674	861	332
N		**4657**	**16043**	**5654**

Table 19: Percentiles (including min, max, and median) of survey population

Appendix A2: Standard error of mean annual and mean seasonal

Average Annual from 2005-2006 (CCF)

	Pre-95 Apartment Population	Pre-95 Condo Population	Post-95 Condo Population	Individually Metered
N	4657	16043	5654	26354
Mean	71.9	88.4	72.4	82.0
StDev	45.5	48.4	40.2	46.9
SE	0.7	0.4	0.5	0.3
95% CB	**70.6 - 73.2**	**87.6 - 89.1**	**71.3 - 73.4**	**81.5 - 82.6**

Seasonal from 2005-2006 (CCF)

Non-seasonal SE (CCF)	Apartment	Condo	Individually metered
Not surveyed	0.50	0.29	0.25
Survey indicates irrigating	6.05	2.38	2.37
Survey indicates non-irrigating	3.18	2.11	1.76
Individually Metered	0.50	0.28	0.25

Seasonal SE (CCF)	Apartment	Condo	Individually metered
Not surveyed	0.22	0.09	0.08
Survey indicates irrigating	7.91	0.77	0.77
Survey indicates non-irrigating	2.75	0.47	0.87
Individually metered	0.22	0.08	0.08

Appendix A3: Response rate and vital characteristics of individually metered population by geographical orientation

Respondents	Total Units	Representation	Percent of Respondents	Village	Section	Established	Mean residents in household	Mean bd	Mean bath	Percent Irrigating	Percent with clotheswasher in unit
108	4403	2.5%	16%	WOODBRIDGE	Condo	1977-1986	2.4	2.5	2.3	60%	98%
32	2293	1.4%	5%	LAKE FOREST	Condo	1987-1990	1.9	2.4	2.1	50%	97%
28	1340	2.1%	4%	TUSTIN RANCH	Condo	1988-1993	2.1	2.1	2.3	39%	100%
46	1293	3.6%	7%	WESTPARK	Apartment	1986-1989	2.5	2.0	2.0	2%	26%
23	1198	1.9%	3%	TURTLE ROCK	Condo	1977-1987	2.0	2.6	2.7	70%	100%
27	1082	2.5%	4%	UNIVERSITY PARK	Condo	1967-1980	2.1	2.9	2.7	89%	96%
19	940	2.0%	3%	TUSTIN RANCH	Apartment	1987-1992	2.7	1.9	1.9	0%	68%
39	923	4.2%	6%	NORTHPARK	Condo	2000-2005	2.5	2.5	2.6	41%	97%
14	913	1.5%	2%	NORTHWOOD	Condo	1981-1989	2.1	2.3	2.4	29%	92%
13	813	1.6%	2%	UNIV TOWN CTR	Condo	1981-1988	2.2	2.2	2.1	38%	100%
13	799	1.6%	2%	NORTHWOOD	Apartment	1984-1986	3.2	1.9	2.2	8%	8%
26	774	3.4%	4%	WESTPARK	Condo	1987-1994	2.1	2.0	2.4	46%	96%
24	684	3.5%	4%	SAH	Condo	1997-1997	2.3	2.5	2.9	75%	100%
15	569	2.6%	2%	UNIV TOWN CTR	Apartment	1984-1986	2.3	1.8	1.7	7%	0%
12	535	2.2%	2%	PORTOLA HILLS	Condo	1987-1994	2.1	2.2	2.3	58%	100%
19	502	3.8%	3%	QUAIL HILL	Condo	2003-2005	2.3	2.6	2.8	21%	100%
11	493	2.2%	2%	THE TERRACE	Condo	1974-1980	2.0	2.4	2.0	64%	100%
15	482	3.1%	2%	NORTHWOOD	Condo	1998-2004	2.7	2.7	2.9	40%	100%
17	473	3.6%	3%	WEST IRVINE	Condo	1999-2002	3.0	2.9	2.9	82%	100%
5	448	1.1%	1%	WOODBRIDGE	Apartment	1984-1985	2.6	2.0	1.2	0%	25%
13	403	3.2%	2%	OAK CREEK	Condo	1998-2001	2.1	1.8	2.4	15%	100%
11	368	3.0%	2%	NEWPORT COAST	Condo	1995-2004	2.3	2.9	3.5	73%	100%
5	340	1.5%	1%	DEERFIELD	Condo	1975-1979	2.6	2.6	2.8	40%	100%
12	334	3.6%	2%	WESTPARK	Condo	1995-1997	2.4	2.0	1.9	42%	100%
2	298	0.7%	0%	HERITAGE PARK	Condo	1977-1978	4.0	2.5	3.0	50%	100%
9	281	3.2%	1%	TURTLE RIDGE	Condo	2003-2005	1.7	2.1	2.1	0%	100%
7	265	2.6%	1%	LAURELWOOD	Condo	1974-1978	2.9	2.6	2.0	43%	100%
100	3111	3.2%	15%	Other		1976-2005	2.4	2.3	2.4	37%	95%

Appendix B&C: Survey instrument and response rate, and database dictionary

Database field names are indicated next to each question. These fields fit the pattern A1a through A11.

Summary of positive responses to question 1

1. Indicate how many of each of the following types of water-using appliances or fixtures you have. Circle the appropriate number.

		none	1	2	3	4 or more
a.	Toilets A1a	0	1	2	3	4+
b.	Bathtub with shower A1b	0	1	2	3	4+
c.	Bathtub only (no shower) A1c	0	1	2	3	4+
d.	Shower only (no bathtub) A1d	0	1	2	3	4+
e.	Whirlpool bathtub w/ jets A1e	0	1	2	3	4+
f.	Bathroom sink A1f	0	1	2	3	4+
g.	Kitchen faucet A1g	0	1	2	3	4+
h.	Indoor utility sink A1e	0	1	2	3	4+
i.	Outdoor faucet/hose A1f	0	1	2	3	4+
j.	Hot tub (not common or community) indoor or outdoor A1g	0	1	2	3	4+

Toilets				
A1a	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
1	4%	22%	10%	10%
2	28%	66%	45%	43%
3	65%	12%	44%	45%
4	3%	0%	1%	1%

Bathtub with shower				
A1b	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
NA	4%	3%	5%	4%
1	40%	25%	54%	44%
2	48%	72%	40%	48%
3	8%	1%	1%	3%
4	0%	0%	0%	0%

Bathtub no shower				

A1c	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
NA	74%	98%	90%	86%
1	24%	2%	10%	13%
2	2%	0%	1%	1%

Shower only no bathtub				
A1d	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
NA	54%	96%	57%	63%
1	40%	4%	39%	33%
2	4%	1%	4%	3%
3	1%	0%	0%	0%
4	0%	0%	0%	0%

Whirlpool				
A1e	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
NA	92%	98%	97%	95%
1	6%	2%	1%	3%
2	2%	0%	1%	1%
3	1%	0%	1%	1%

Bathroom sink				
A1f	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
NA	2%	2%	3%	3%
1	3%	17%	10%	9%
2	16%	66%	33%	33%
3	40%	13%	36%	33%
4	39%	3%	18%	22%

Kitchen faucet				
A1g	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
NA	2%	4%	3%	3%
1	95%	92%	94%	94%
2	3%	4%	2%	3%
3	0%	0%	0%	0%
4	0%	0%	0%	0%

Indoor utility sink				
A1h	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
NA	88%	92%	89%	89%
1	10%	7%	8%	9%

2	1%	0%	2%	2%
3	0%	1%	0%	0%
4	0%	0%	0%	0%

Outdoor faucet/hose				
A1i	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
NA	7%	60%	11%	18%
1	43%	38%	32%	36%
2	45%	2%	46%	38%
3	3%	1%	9%	6%
4	1%	0%	1%	1%

Hot tub				
A1j	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
NA	98%	98%	96%	97%
1	2%	0%	4%	2%
2	0%	2%	0%	0%

Summary of positive responses to question 2

2. Do you use water from your residence for any of the following?

	Yes	No
a. Potted plants A2a	❑	❑
b. Outdoor lawn/garden/flower bed that you maintain A2b	❑	❑

Potted Plants				
A2a	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
FALSE	32%	53%	25%	32%
TRUE	68%	47%	75%	68%

Outdoor				
A2b	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
FALSE	55%	96%	45%	57%
TRUE	45%	4%	55%	43%

Summary of positive responses to question 3

3. Do you have a washing machine in your residence? A3

- ❑ No ➔ **Where do you most commonly do your wash?**
  - ❑ A3n=Common area laundry
  - ❑ A3n=Off-site laundry
  - ❑ A3n=Other_A3n_Other_
- ❑ Yes ➔ **Is it a… (please check one)**
  - ❑ A3a=Top-loading washing machine
  - ❑ A3a=Front-loading washing machine

  What is the brand, model, and year of the machine?

  Brand _A3y_Brand_ **Model**_A3y_Model_ **Year**_A3y_Year_

Clotheswasher					
A3	A3a	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
FALSE	(blank)	0%	66%	2%	12%
TRUE	Front-loading	19%	4%	15%	14%
	Top-loading	79%	30%	81%	72%
	(blank)	1%	0%	3%	2%

Summary statistics for question 4

4. Please specify the year, brand name and gallons per flush of your toilet(s). The year of manufacture is typically stamped into the porcelain on the underside of the tank lid or inside on the wall of the tank. (Enter as much information below as you can.)

Toilet 1.....*Year*_A4T1_year_
*Brand*_A4T1_Brand_ *Gallons per Flush*_A4T1_gpf_

Toilet 2.....*Year*_A4T2_year_
*Brand*_A4T2_brand_ *Gallons per Flush*_A4T2_gpf_

Toilet 3.....*Year*_A4T3_year_
*Brand*_A4T3_brand_ *Gallons per Flush*_A4T3_gpf_

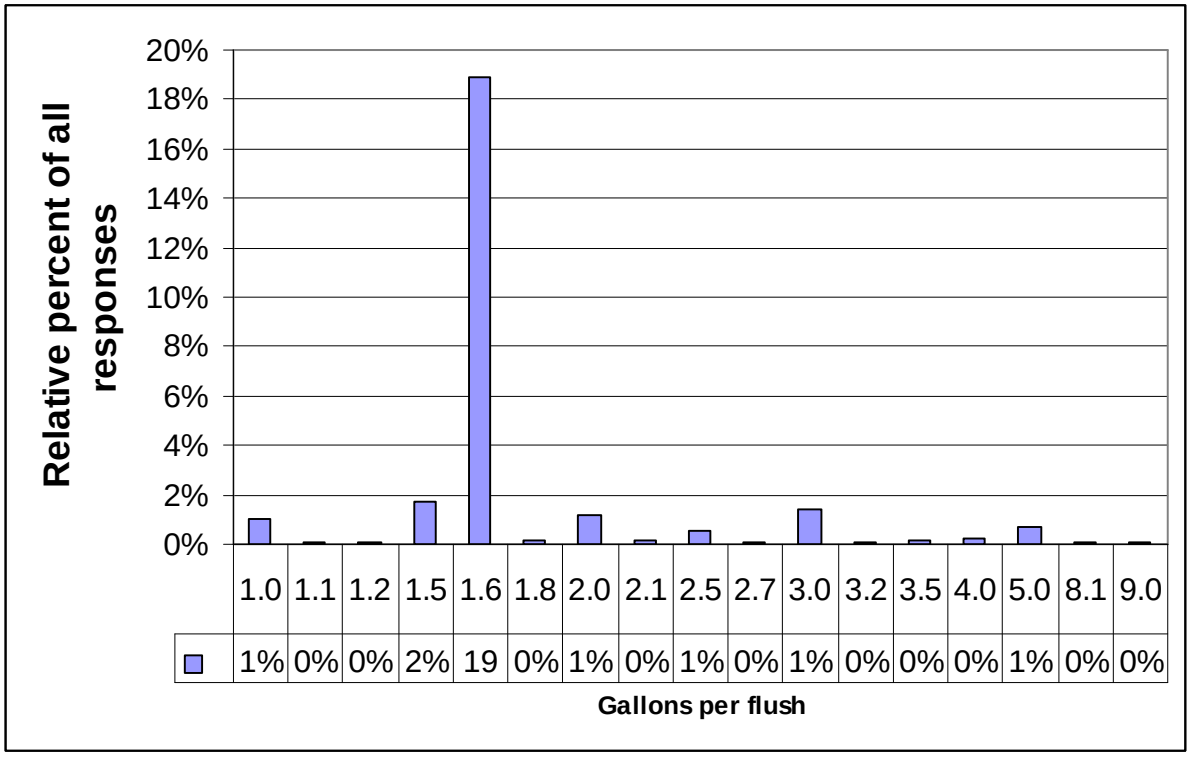


Figure 32: Numeric toilet flush volume indicated by question 4

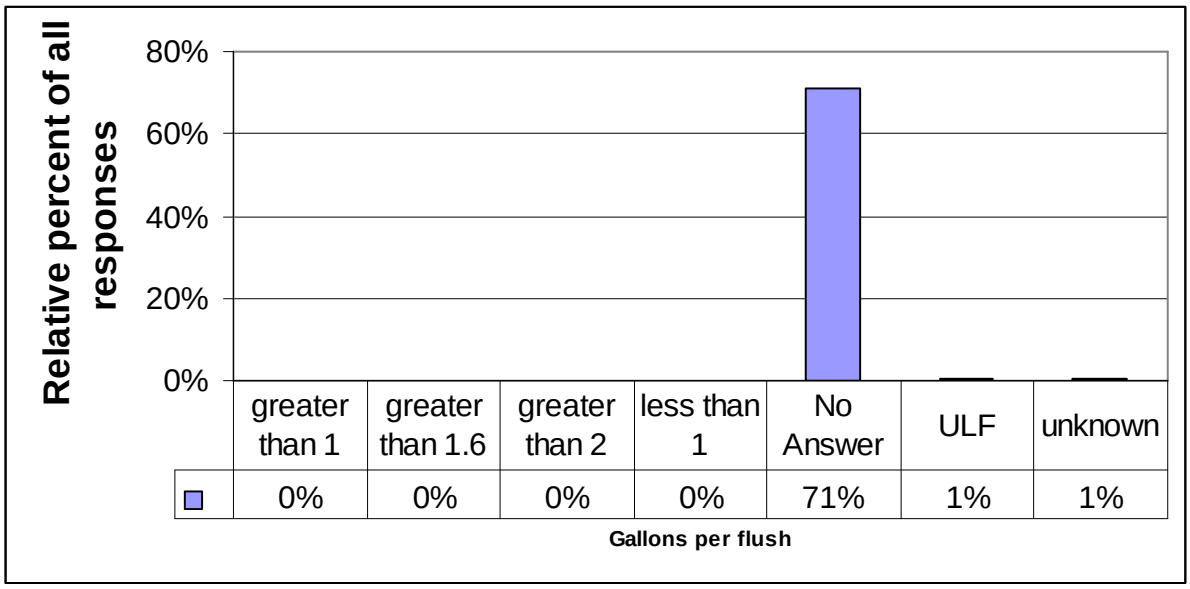


Figure 33: Other answers to question 4

Summary of positive responses to question 5

5. Please specify the flow rate and brand of your showerhead(s). The flow rate is often

stamped onto the fixture. (Enter as much information below as you can.) Please indicate if this showerhead is part of a "multiple showerhead system".

Showerhead 1 *.flow (gpm)*_A5S1_gpm_
*Brand*_A5S1_brand_
Part of multiple head system? A5S1_multi ❑ Yes ❑ No

Showerhead 2 *.flow (gpm)*_A5S2_gpm_
*Brand*_A5S2_brand_
Part of multiple head system? A5S2_multi ❑ Yes ❑ No

Showerhead 3 *.flow (gpm)*_A5S3_gpm_
*Brand*_A5S3_brand_
Part of multiple head system? A5S3_multi ❑ Yes ❑ No

Multiple showerheads in at least one shower				
	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Response Average
TRUE	8%	11%	12%	11%
FALSE or not answered	92%	89%	88%	89%

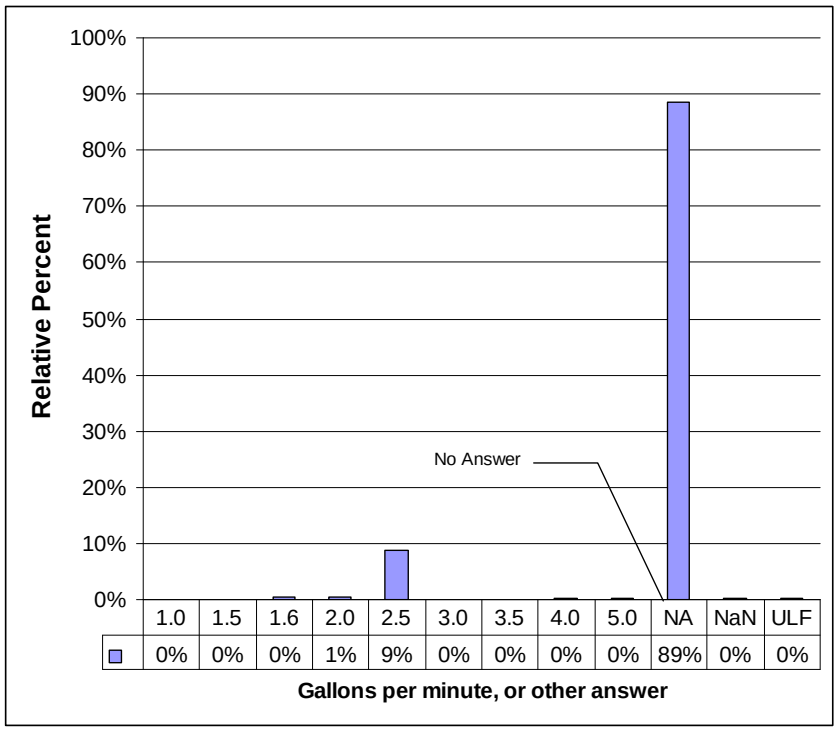


Figure 34: Showerhead flow rates indicated by question 5

Summary of positive responses to question 6

6. How many people, including yourself, reside full-time at this address?

_A6A_ Adults, including yourself (age 18+)

_A6T_ Teenagers (age 13-17)

_A6o_ Older Children (age 6-12)

_A6Y_ Younger Children (age 3-5)

_A6T_ Infants or Toddlers (under age 3)

In the analysis, the number of occupants was used rather than the age range of each occupant.

Occupants				
Total Occupants	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
0	2%	2%	3%	2%
1	21%	20%	28%	24%
2	35%	31%	36%	35%
3	23%	22%	17%	20%
4	13%	20%	13%	14%
5	5%	4%	3%	4%
6	0%	1%	1%	1%
7	0%	0%	0%	0%

Children 0 -18				
	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
Children	35%	29%	20%	26%
No Children	65%	71%	80%	74%

Summary of positive responses to questions 7 and 8

7. How many bedrooms are in your residence? _A7_

Bedrooms				
A7	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
0	0%	4%	2%	2%
1	5%	15%	4%	6%
2	46%	68%	48%	51%
3	45%	13%	42%	38%
4	4%	0%	3%	3%
5	0%	0%	0%	0%

8. How many square feet are in your residence? _A8_

Sq Ft				
A8_bin	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
NA or 0	6%	34%	11%	13%
250	0%	2%	0%	0%
500	0%	8%	2%	2%
750	6%	39%	9%	13%
1000	18%	14%	24%	20%
1250	22%	1%	21%	18%
1500	25%	1%	13%	15%
1750	12%	0%	6%	7%
2000	6%	2%	7%	6%
2250	3%	0%	3%	3%
2500	1%	0%	2%	1%
2750	0%	0%	1%	1%
3000	1%	0%	1%	1%

Summary of positive responses to question 9

9. Do you rent or own your residence?

- ❑ Own A9=Own
- ❑ Rent A9=Rent ➔ **How much is your *monthly* rent?** A9Rent
  - ❑ Less than $500
  - ❑ $500-$600
  - ❑ $600-$899
  - ❑ $900-$1399
  - ❑ $1400-$1799
  - ❑ $1800-$2299
  - ❑ $2300-$2999
  - ❑ $3000 or more

Rent				
A9_Bin	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
Own	87%	4%	82%	71%
Rent, no number given	0%	4%	0%	1%
Rent Less than $500	0%	4%	1%	1%
Rent $600-$899	0%	3%	0%	1%
Rent $900-$1399	1%	10%	2%	3%
Rent $1400-$1799	0%	44%	6%	11%
Rent $1800-$2299	4%	28%	4%	8%
Rent $2300-$2999	4%	4%	4%	4%
Rent $3000 or more	2%	1%	1%	1%

Summary of positive responses to question 10

10. Which best describes your residence? A10

- ❑ Apartment A10=Apartment
- ❑ Condominium A10=Condominium
- ❑ Town-home A10=Town-home
- ❑ Other (please describe) A10=...

Some surveys indicated single-family residences and duplexes, as well as some interesting responses such as "Don't call it an apartment!". This field was regularized to the values below. Unless otherwise noted, further analysis categorized Town-home values into the Condominium category.

A10				
Housing Type	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
Apartment	0%	87%	1%	16%
Condominium	51%	7%	50%	43%
Town-home	44%	5%	44%	38%
Other	5%	0%	5%	4%

Summary of positive responses to question 11

11. Is your residence part of a senior or retirement community? A11

- ❑ Yes
- ❑ No

A11				
Retirement Community	Post-95 Condo	Pre-95 Apartment	Pre-95 Condo	Total
FALSE or no answer	100%	97%	99%	99%
TRUE	0%	3%	1%	1%

Database dictionary

Keycode	Synonym for IRWD Account Sequence
Section	Synonym for IRWD namespace: Apartment or Condo.
Year Established	IRWD account origin date. Some accounts within the population indicated unknown but all responses have valid values. Unknown value: 0
After 1995	Previous field >= 1995
Only 1 bathroom	0: The number of toilets is indicated greater than 1 Non-answer value: Null
SVC VLG NAME	Synonym for subdivision
Label	Apartment, Pre-1995 Condo, Post-1995 Condo
Bool_Children	1: Minors of any age group are indicated 0: Otherwise (including non-answers)
Bool_Whirlpool	1: Whirlpool bathtub indicated 0: Otherwise (including non-answers)
Bool_Hottub	1: Hottub indicated 0: Otherwise (including non-answers)
Bool_Multi_Showerhead	1: Multiple showerheads in a shower indicated 0: Otherwise (including non-answers)

Appendix D1: Modeling details

Extreme Values

Sometimes outliers offer valuable insight into the consequences of applying general analytical techniques. In this case, the billing data and survey data do not yield interesting distinctions between the outlier and the survey groups.

This section applies to all analysis. Each model is neglecting one outlier value: an apartment billed for 727 CCF (543 kgal) in 2006 used 275% of the next high value. The maximum for pre-95 apartments is instead reported in the report to be 203 CCF. The effect of this outlier on confidence intervals is shown in Table 20 and Table 21.

Table 20: Means and confidence intervals with outlier

CCF	Pre-95 Apartment	Pre-95 Condo	Post-95 Condo	Combined groups
N	114	336	215	665
Mean	82.8	81.2	74.5	79.3
StDev	72.2	43.0	40.8	48.7
95% CI	13.3	4.6	5.5	3.7
	69.6 - 96.1	76.6 - 85.8	69.0 - 79.9	75.6 - 83.0

Table 21: Means and confidence intervals as reported

CCF	Pre-95 Apartment	Pre-95 Condo	Post-95 Condo	Combined groups
N	114	336	215	665
Mean	77.1	81.2	74.5	78.3
StDev	39.1	43.0	40.8	41.7
95% CI	7.2	4.6	5.5	3.2
	70.0 - 84.3	76.6 - 85.8	69.0 - 79.9	75.2 - 81.5

The cause for this outlier has been indicated as a leak[9]. While survey information on this data point is used in some analyses the volume was replaced to instead indicate a missing value.

[9] Tim Schaadt confirmed this with the customer.